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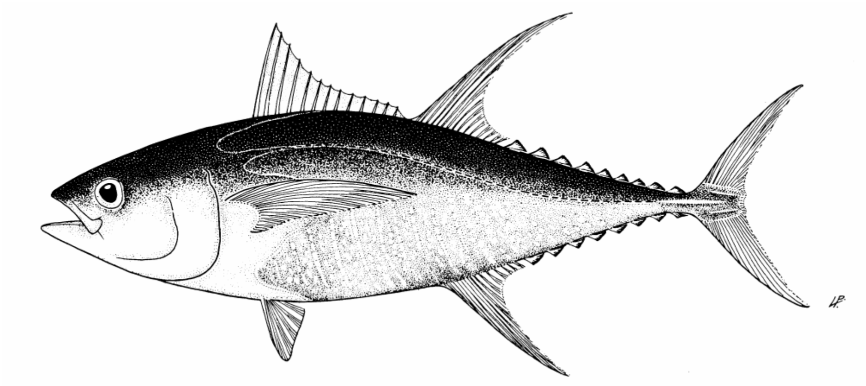
Proceedings of the Second Meeting of the Technical Advisory Committee of the FAO Project "Management of tuna fishing capacity: conservation and socio-economics"



Food and Agriculture Organization of the United Nations (FAO). Rome, Italy.

August 2005

Preparation of this document

Since the FAO Committee on Fisheries adopted the International Plan of Action for the Management of Fishing Capacity in February 1999, FAO has fullfiled a major role in addressing this crucial issue for the conservation and sustainability of fisheries resources. Overcapacity is a problem that contributes substantially to overfishing, the decline of food production and significant economic waste.

In response to the above-mentioned International Plan of Action and at the request made by some countries at the twenty-fourth session of the FAO's Committee on Fisheries for assistance in addressing the problem of tuna fishing overcapacity, FAO formulated the "Management of tuna fishing capacity: conservation and socio-economics" Project. FAO, in its global and multidisciplinary role and involvement and expertise in tuna resources, fishing, processing and trade, was considered an appropriate organization to address the problem. The Government of Japan financed the Project.

The FAO Project established an external Technical Advisory Committee (TAC) to foster the collaboration of tuna fishery bodies and other major intergovernmental and non-governmental organizations involved in tuna fishing, fisheries research and management. The studies included in these Proceedings are a result of the priorities set by the Project in consultation with the TAC in its first meeting (Rome, Italy, 14–16 April 2003). These priorities cover a wide range of subjects, such as tuna fisheries and resources, the estimation of fishing capacity, the tuna fishing industry and the management of tuna fishing capacity. Preliminary versions of papers on these studies were presented and critically reviewed at the second meeting of TAC (Madrid, Spain, 15–18 March 2004). Their final versions presented in this publication benefited from the suggestions for improvements that were received from the TAC and various other fisheries experts.

Abstract

The FAO's Japan-funded Project on the "Management of tuna fishing capacity: conservation and socio-economics" has been formulated by FAO with the objective of improving the management of tuna fisheries on a global scale. Its immediate objectives are to provide technical information necessary for the management of tuna fishing capacity and to identify and resolve the technical problems associated with that management on a global scale, taking into account conservation and socio-economic issues.

This publication presents results of the studies carried out by the Project that were proposed by the Project and considered by its Technical Advisory Committee (TAC) at its first meeting (Rome, Italy, 14-16 April 2003) as being of highest priority. Earlier versions of papers on these studies were presented to the second meeting of the TAC (Madrid, Spain, 15-18 March 2004), where they were critically discussed. These papers were subsequently peer reviewed, revised and edited.

The studies presented in this publication are on the tuna fisheries and resources, the characterization and estimation of fishing capacity, the tuna fishing industry and the management of tuna-fishing capacity. Their results are summarized in the "Overview" of this publication, and detailed information on them is presented in the following four sections associated with these subjects.

The first section describes, on the global scale:

- the development of tuna fisheries since their inception, including (i) the evolution of vessels, fishing gear, navigation and fishing techniques and fishing grounds and (ii) the trends in tuna catches;
- the status of the tuna stocks; and
- the tuna catch data available from the FAO Fisheries Global Information System (FIGIS).

The second section includes three papers on fishing capacity of industrial tuna purse seiners and longliners and on the importance of non-industrial tuna fisheries.

The third section consists of one paper that qualitatively and quantitatively assesses the influence of the tuna market (e.g. prices and imports) on tuna catches.

The fourth section includes two papers that analyse past developments and future options for the management of fishing capacities of the purse-seine and longline fleets.

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Contents

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- Commission for the Conservation of Southern Bluefin Tuna (CCSBT),
- Forum Fisheries Agency (FFA),
- INFOFISH,
- Inter-American Tropical Tuna Commission (IATTC),
- International Commission for the Conservation of Atlantic Tunas (ICCAT),
- Indian Ocean Tuna Commission (IOTC),
- National Research Institute of Far Seas Fisheries - Japan (NRIFSF),
- Organization for Promotion of Responsible Tuna Fisheries (OPRT),
- Secretariat of the Pacific Community (SPC), and
- World Tuna Purse-Seine Organization (WTPO).

We are grateful to these institutions and their scientists for their significant contributions.

In particular, the editors of this publication express their gratitude to the members of the Technical Advisory Committee, i.e. Robin Allen (IATTC), Alejandro Anganuzzi (IOTC), John Annala (Ministry of Fisheries, New Zealand), John Hampton (SPC), James Joseph (Consultant), Victor Restrepo (ICCAT), Peter Miyake (OPRT), Julio Morón (WTPO), Chris Reid (FFA), Suba Subasinghe (INFOFISH) and Ziro Suzuki (NRIFSF) for their cooperation, advice and commitment during the implementation of the Project.

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Preface

Tuna and tuna-like species are targets of important fisheries in both developed and developing countries, and are a significant source of food all over the world. The catch of these species was about six million tonnes in 2002. Albacore, bigeye, Atlantic bluefin, Pacific bluefin, skipjack, southern bluefin and yellowfin, which are frequently referred to as the principal market species of tunas, are the most important species of tunas, in terms of both quantities and market values. They are used mostly for canning and *sashimi* (raw fish regarded as a delicacy in Japan and, increasingly, in other countries). Due to their high economic value and extensive international trade, the principal market species of tunas are a very important global commodity. Their annual catches have increased from less than 500 000 tonnes during the 1950s to more than 4 000 000 tonnes in 2002, having been stable at about the latter level since 1999. The export value of the 2002 catch was about US$5 billion.

Since the 1940s, when the industrial fisheries for tunas began, the numbers of vessels of the traditional tuna-fishing countries have been increasing, and additional countries began participating in tuna fisheries. Also, new developments in fishing technology have dramatically increased fishing capacity worldwide. As a result of these developments, tuna-fishing capacity has become excessive in respect to tuna resources, the demand for tuna products or both. This excess has led to overexploitation, or even depletion, of some tuna stocks.

Research carried out and/or coordinated by regional tuna fishery management organizations and other intergovernmental organizations indicates that most stocks of tuna are fully exploited, and some are overfished, or even depleted. Only a few tuna stocks are underexploited, so there is only a limited potential for sustainable increases in the catches of tunas. In fact, significant increases in fishing effort for tunas would likely lead to a further overexploitation of some stocks, eventually resulting in reductions in overall catches in the long term.

Tuna are fished, traded, processed and consumed almost globally. Vessels registered in coastal countries bordering one ocean frequently fish in other ocean areas. In particular, the industrial fleets often transfer their operations from one ocean to another in response to changing conditions, which makes it difficult to manage fishing capacity on a regional scale. In addition, after capture fish are frequently transported to other parts of the world for processing. Also, substantial illegal, unreported and unregulated (IUU) fishing, which occurs in all oceans, significantly complicates the management of the fisheries for tunas.

In the recent past, due to an excess supply of raw material for tuna canning, the prices paid for the fish were reduced to the point that fishing for some species was no longer profitable. In response, the tuna industry has been trying to overcome this problem independently of governments and intergovernmental organizations. The owners of tuna purse seiners formed a global organization, the World Tuna Purse-Seine Organization, temporarily limiting fishing effort by their vessels. Also, the number of longline vessels supplying the *sashimi* market has been reduced in some countries. However, these actions are not regarded as sufficient in the long term.

Most of the regional tuna fishery management organizations have been attempting to address the issue of tuna-fishing capacity in their areas of competence. However, the problems of managing tuna-fishing capacity are multidisciplinary, involving biological, socio-economic and technological issues, and the conventions of most, if not all, of the tuna fishery management organizations do not encourage their involvement in issues other than biological issues. In addition, the problems are similar in all oceans, so it is more efficient to deal with them on the global scale, eliminating duplication of effort. Also, developing countries need technical support to participate in international discussions on the establishment of international and national regimes for the management of tuna-fishing capacity.

Identification and resolution of the technical problems associated with the management of tuna-fishing capacity on the global scale would:

- make it possible to address the technical problems through intensive, multidisciplinary research into them, preventing the duplication of research;
- enhance the management of tuna-fishing capacity by individual tuna fishery management organizations in the areas of their competence and at national scales; and
- possibly lead to global recommendations and/or decisions being made, making the management of tuna-fishing capacity more effective on global, regional and national scales.

Because of its global and multidisciplinary role and its involvement and expertise in tuna resources, fishing, processing and trade, FAO is an appropriate organization to address the problem of tuna-fishing overcapacity. In response to the request made by several countries at the twenty-fourth session of FAO's Committee on Fisheries for assistance in addressing the problem of tuna-fishing overcapacity, FAO formulated a Project on the "Management of tuna fishing capacity: conservation and socio-economics". The Government of Japan has financed the Project.

The present publication provides information on the technical findings from the studies implemented by the Project.

Acronyms and codes

ACP	African, Caribbean and Pacific Countries
ADB	Asian Development Bank
ADEPALE	Association des entreprises de produits alimentaires élaborés
AIDCP	Agreement on the International Dolphin Conservation Program
ALB	Albacore (*Thunnus alalunga*)
AMSY	Average maximum sustainable yield
ANCIT	Associazione Nazionale Conservieri Ittici e delle Tonnare
ANFACO	Asociación Nacional de Fabricantes de Conservas de Pescados y Mariscos
AO	Atlantic Ocean
ASEAN	Association of Southeast Asian Nations
B_{AMSY}	Biomass at AMSY
BESD	Bigeye statistical document
BET	Bigeye tuna (*Thunnus obesus*)
BFSD	Bluefin statistical document
BFT	Atlantic bluefin tuna (*Thunnus thynnus*)
B_{MSY}	Biomass at MSY
c&f	Cost and freight
CARICOM	Caribbean Community
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CN	Common nomenclature
CPUE	Catch per unit of effort
CU	Capacity utilization
CWP	Coordinating Working Party on Fishery Statistics
DEA	Data envelopment analysis
DFS	Designated fishery licensing scheme
DHA	Docosahexaenoic acid
DOL	Department of Labor
DWFN	Distant-water fishing nation
EAFUS	Everything added to food in the United States
EAO	Eastern Atlantic Ocean
EC	European Community
EEZ	Exclusive economic zone
EII	Earth Island Institute
ENSO	El Niño-southern oscillation
EPA	United States Environmental Protection Agency

EPO	Eastern Pacific Ocean
EPR	GLOBEFISH European price report
EU	European Union
F	Fishing mortality
FAD	Fish-aggregating device
F_{AMSY}	Fishing mortality at AMSY
FAO	Food and Agriculture Organization of the United Nations
FCC	Fish-carrying capacity
FDA	Food and Drug Administration
FFA	Forum Fisheries Agency
FIAC	Fédération française des industries d'aliments conservés
FIDI	FAO Fisheries Department, Fishery Information, Data and Statistics Unit
FIDP	FAO Fisheries Department, Programme Coordination Unit
FIGIS	FAO Fisheries Global Information System
FIIU	FAO Fisheries Department, Fish Utilization and Marketing Service
FIRI	FAO Fisheries Department, Inland Water Resources and Aquaculture Service
FIRM	FAO Fisheries Department, Marine Resources Service
F_{MSY}	Fishing mortality at MSY
FOC	Flag of convenience
FSA	Food Standards Agency
G&G	Gilled and gutted
GATT	General Agreement on Tariffs and Trade
GPS	Global positioning system
GRT	Gross registered tonnage or gross registered tons
GT	Gross tons
H&G	Headed and gutted
HACCP	Hazard analysis and critical control point
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
INC	INFOPESCA noticias comerciales
IO	Indian Ocean
IOTC	Indian Ocean Tuna Commission
IPOA–CAPACITY	International Plan of Action for the management of fishing capacity
IPOA–IUU	International Plan of Action to prevent, deter and eliminate illegal, unreported and unregulated fishing
IQ	Individual catch quota
IREPA	Istituto di Ricerche Economiche per la Pesca e l'Acquacoltura

ISC	Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific
ITN	INFOFISH trade news
ITN–African Edition	INFOPÊCHE trade news–African edition
ITQ	Individual transferable quota
IUU	Illegal, unreported and unregulated
JIMAR	Joint Institute for Marine and Atmospheric Research, University of Hawaii, National Oceanic and Atmospheric Administration
LL	Longline
LOA	Overall length
LOSC	United Nations Convention on the Law of the Sea
LP	Pole-and-line
LSTLV	Large-scale tuna longline fishing vessel
MED	Mediterranean Sea
MEY	Maximum economic yield
MSY	Maximum sustainable yield
NAO	North Atlantic Ocean
nei	Not elsewhere identified
NGO	Non-governmental organization
NMFS	United States National Marine Fisheries Service
NOAA	United States National Oceanic and Atmospheric Administration
NPO	North Pacific Ocean
NRIFSF	National Research Institute of Far Seas Fisheries of Japan
NRT	Net registered tonnage
NSEC	Norwegian Seafood Export Council
OFP	Ocean Fisheries Programme of the SPC
OJ	Official Journal of the European Communities
OPRT	Organization for the Promotion of Responsible Tuna Fisheries
OTH	Other gears
oz	Ounces
PBF	Pacific bluefin tuna (*Thunnus orientalis*)
PL	Pole-and-line
PO	Pacific Ocean
ppm	Parts per million
PS	Purse-seine
RAV	Record of authorized vessels
RDA	Recommended dietary allowance
RFBA	Regional fishery bodies and arrangements
RFMO	Regional fishery management organizations
RVR	Regional vessel register
SAO	South Atlantic Ocean

SBF	Southern bluefin tuna (*Thunnus maccoyii*)
SBR	Spawning biomass ratio
SBR_{AMSY}	Spawning biomass ratio at AMSY
SC	Scientific Committee of the IOTC
SCG	Scientific Coordinating Group of the WCPFC
SCRS	Standing Committee on Research and Statistics of the ICCAT
SCTB	Standing Committee on Tuna and Billfish of SPC
SIDP	Species Identification and Data Programme
SIPAM	FAO information system for the promotion of aquaculture in the Mediterranean
SKJ	Skipjack tuna (*Katsuwonus pelamis*)
SPC	Secretariat of the Pacific Community
SPO	South Pacific Ocean
SSB	Spawning stock biomass
SSB_{AMSY}	Spawning stock biomass at AMSY
SSB_{MSY}	Spawning stock biomass at MSY
SURF	Surface gears
SWO	Swordfish (*Xiphias gladius*)
TAC	Technical Advisory Committee of the FAO Project "Management of tuna fishing capacity: conservation and socio-economics"
TAC	Total allowable catch
TE	Technical efficiency
TIS	Southern bluefin tuna trade information scheme
UN	United Nations
VPA	Virtual population analysis
WAO	Western Atlantic Ocean
WCPFC	Western and Central Pacific Fisheries Commission
WCPO	Western and Central Pacific Ocean
WHO	World Health Organization
WPTT	Working Party on Tropical Tunas of the IOTC
WTO	World Trade Organization
WTPO	World Tuna Purse-seine Organization
YFT	Yellowfin tuna (*Thunnus albacares*)

Overview

1. INTRODUCTION

As mentioned in the Preface, tuna and tuna-like species are an important source of food and are very important economically for many developed and developing countries. Accordingly, FAO has formulated a Project on the "Management of tuna fishing capacity: conservation and socio-economics", which is funded by the Government of Japan.

The ultimate objective of the FAO Project is to improve the management of tuna fisheries on a global scale. Its immediate objectives are to:

- provide technical information necessary for the management of tuna fishing capacity, and
- identify and resolve the technical problems associated with the management of tuna fishing capacity

on a global scale, taking into account conservation and socio-economic issues.

To facilitate the implementation of the Project, FAO created an internal Task Force. Its Members have been nominated by nearly all Services and Units of the FAO Fisheries Department (FI) and a Service of the Technical Cooperation Department that have been involved in the formulation of the Project. The Marine Resources Service of the FI has been leading and coordinating the implementation of the Project.

The Project also created an external Technical Advisory Committee (TAC) to foster the collaboration of the tuna fishery management organizations and other major inter and non-governmental organizations involved in tuna fishing, fisheries research and management. It is composed of technical experts affiliated with these organizations, who are listed in the Acknowledgements. The TAC has been working through correspondence and two meetings, which took place in Rome, Italy, from 14 to 16 April 2003, and Madrid, Spain, from 15 to 18 March 2004.

During the first meeting of the TAC:

- The methods for estimating fishing capacity and its optimal value from the conservation and socio-economic view point and their data requirements were reviewed.
- The applicability of these methods for tuna, particularly in the light of the availability of input data for this estimation, were determined.
- The methods most appropriate for the use by the Project were selected.
- The proposals of the studies to be carried out by the Project were finalized.

The studies implemented by the Project are grouped into the following four subjects:

1. tuna fisheries and resources;
2. characterization and estimation of tuna fishing capacity;
3. tuna fishing industry; and
4. tuna fishing capacity management options and implications.

During the second meeting of the TAC:

- The progress of the research carried out by the Project was critically reviewed.
- Recommendations, particularly on the Project's future activities, were made.
- Research proposals additional to the studies already being completed by the Project at the time of holding the second meeting of the TAC were formulated, recognizing the need for additional funds from the donor to carry them out.

- A statement by the TAC was prepared for use as an information document for the Technical Consultation to Review Progress and Promote the Full Implementation of the International Plan of Action (IPOA) to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing and the IPOA for the Management of Fishing Capacity, which was held in Rome, Italy, on 24-29 June 2004.

The studies completed by the Project are presented in these Proceedings arranged by sections according to the subjects mentioned above.

Thus, under tuna fisheries and resources there are papers on the following topics:

- historical developments in major tuna fisheries (including technological developments);
- tuna catch data available within FAO Fisheries Global Information System (FIGIS); and
- an analysis and classification of the status of the stocks of tuna.

The characterization and estimation of tuna fishing capacity section consists of three papers on:

- an analysis of the fishing capacity of the global tuna purse-seine fleet;
- a review of the fishing capacity of the world longline fleet; and
- a global study on the importance of non-industrial tuna fisheries.

The study of the tuna fishing industry that is presented provides an assessment of the influence of the tuna market (e.g. prices and imports) on tuna catches from qualitative and quantitative point of view.

The final section of the Proceedings, namely, tuna fishing capacity management options and implications, analyses the past developments and future options for managing the tuna fishing capacities of the purse-seine and longline fleets.

This Overview provides a synthesis of the technical findings of the studies implemented by the Project.

2. TUNA FISHERIES AND RESOURCES

2.1 Development of tuna fisheries

Since ancient times, coastal tuna fishing has been carried out in many parts of the world. As a result of increasing demand for tuna for canning, industrial fisheries began during the 1940s and 1950s. During the 1950s, the major industrial fisheries were the Japanese longline fishery and pole-and-line fishery of the United States, both of which operated in the Pacific Ocean. The longline fishery expanded its area of operations, reaching the Atlantic Ocean during the late 1950s. Also, some European pole-and-line vessels, based in local ports, began fishing off the west coast of Africa.

During the 1960s, European pole-and-line and purse-seine vessels, together with Japanese pole-and-line vessels, began fishing for tunas off tropical West Africa. Also, Japanese longliners expanded their fishing operations all over the world, still targeting mostly albacore and yellowfin for canning. During the mid-1960s, vessels of the Republic of Korea and Taiwan Province of China became involved in large-scale longline fishing for tunas. At the end of the decade, extremely cold storage systems were developed for Japanese longliners, which made the fish acceptable for the *sashimi* market, which, in turn, led the vessels to shift their target species from yellowfin and albacore for canning to bluefin and bigeye for *sashimi*. In the eastern Pacific Ocean the pole-and-line vessels of the United States were almost completely replaced by purse-seine vessels. Quotas on the catches of yellowfin in that region were first imposed in 1966.

The European purse-seine fishery in the tropical eastern Atlantic developed quickly during the 1970s. The purse-seine fishery of the tropical eastern Pacific expanded offshore. In this area some vessels of the United States either changed flags to Central and South American countries to avoid strict regulations aimed at reducing the incidental mortality of dolphins, or shifted their fishing effort to the western and central Pacific Ocean, where tunas seldom associate with dolphins.

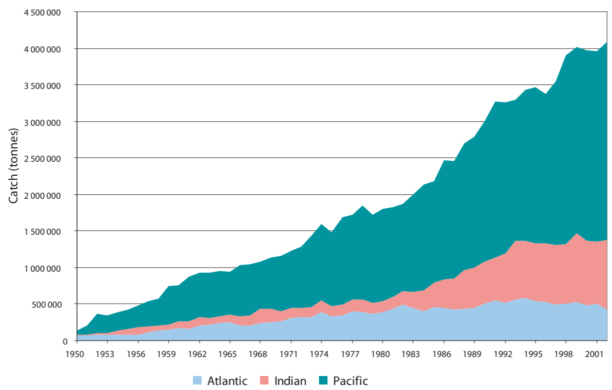
A purse-seine fishery for tunas began in the western Indian Ocean during the 1980s, when European vessels, which normally fished in the Atlantic Ocean, moved to that area. In the Pacific Ocean the purse-seine fishery expanded its fishing area, particularly in the western and central Pacific Ocean. Countries such as Brazil and Venezuela entered purse-seine fisheries for the first time. During the same period, the numbers of Japanese and Korean large-scale longliners began to decrease, whereas the Taiwanese fleet and the numbers of vessels flagged to third countries of open registry increased rapidly. The regional tuna fishery management organizations introduced more management measures for the tuna fisheries.

Tuna fishing increased greatly during the 1990s. Purse seiners began fishing with fish-aggregating devices (FADs) in the Atlantic Ocean during the early 1990s, and this method quickly came into use in the Indian and Pacific Oceans. New management measures were introduced during this decade, and illegal, unreported and unregulated (IUU) fishing increased, becoming a major problem for the sustainability of tuna resources. Many coastal states had begun to get involved in tuna fishing during the 1980s, and this involvement increased during the 1990s. Partially due to the development of new coastal fisheries, the fishing effort by traditional longlining-fishing countries declined. Another important event was the development of bluefin tuna farming.

2.2 Catches

The global catches of the principal market species of tunas from 1950 to 2002 are shown in Figure 1. The total catch increased steadily from about 400 000 tonnes in 1950 to more than 4 000 000 tonnes in 2002. The catches in the Pacific Ocean have exceeded those of the other two oceans throughout the period. The rate of increase in the catches has been greatest in the Pacific Ocean, followed by those of the Indian and Atlantic Oceans in that order. The catches from the Indian Ocean have exceeded those from the Atlantic Ocean since 1989. Currently, the Atlantic, Indian and Pacific Oceans produce about 10, 23 and 66 percent, respectively, of the total catch. It should be noted that the catches of Atlantic bluefin, bigeye and albacore and eastern Pacific yellowfin and bigeye have been restricted in recent years, while there have been no restrictions on any other stocks, except southern bluefin tuna.

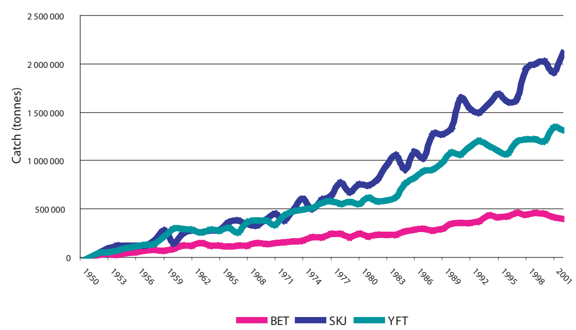
FIGURE 1
Global catches of the principal market species of tunas, by oceans



2.2.1 By species

The global catches of the principal market species of tropical tunas, bigeye, skipjack and yellowfin, and those of the principal market species of temperate tunas, albacore, Atlantic bluefin, Pacific bluefin and southern bluefin, are shown in Figures 2 and 3, respectively.

FIGURE 2
Global catches of the principal market species of tropical tunas



Since the late 1960s the greatest catches, by far, have been skipjack and

FIGURE 3
Global catches of the principal market species of temperate tunas

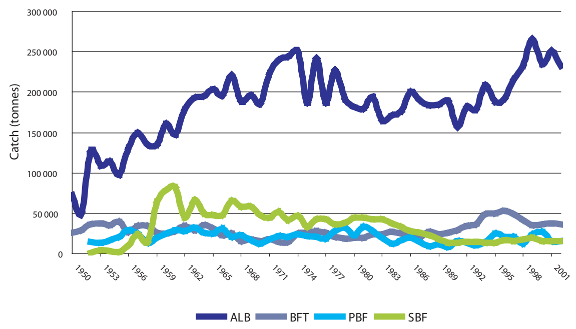
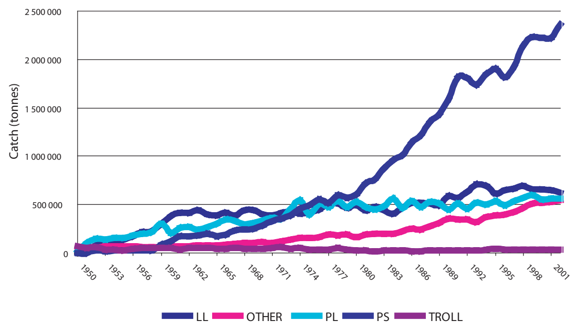


FIGURE 4
Global catches of the principal market species of tunas, by fishing gear



yellowfin (51 and 32 percent of the total catches of the principal market species of tunas respectively, in 2002). The catches of both species have shown rapid increases throughout the period, and their maximum annual catches were taken in 2002. Bigeye (ten percent of the total catch) has also increased nearly continuously, although the catches have been much less than those of skipjack and yellowfin.

The catches of albacore (six percent) have been fluctuating from the mid-1960s to the late 1990s, without a clear trend. The catches of Atlantic bluefin, Pacific bluefin and southern bluefin have been stable or decreasing at much lower levels, accounting for only slightly more than one percent of the total catches of the principal market species in 2002.

2.2.2 By fishing gear

The combined global catches of the principal market species of tunas, by fishing gears, are shown in Figure 4. The purse-seine catches (58 percent of the total catch in 2002) have shown the greatest increase. They became significant only during the late 1950s, and increased at an accelerating rate until 1990, after which the rate of increase began to slow down. The longline catches (15 percent in 2002) increased gradually until 1993, and since then have been declining. The pole-and-line catches (14 percent in 2002) exceeded those of all other gears during the 1950s, but were overtaken by the longline catches during the 1960s. During the 1970s they increased rapidly, exceeding the longline catches again, and have stabilized at about 500 000 tonnes since then.

Recent increases in the catches of “other” gears (13 percent in 2002) are due to the increase in catches by artisanal fisheries (e.g. gillnets, handlines and miscellaneous unclassified gears) in coastal and island areas. The catches by trolling gear (less than one percent in 2002) have declined, stabilizing at about 30 000 to 35 000 tonnes during recent years.

2.2.3 By country

The greatest catches are those of Japan (550 000 tonnes in 2002), the great majority of which comes from the Pacific Ocean. They have been generally decreasing since the mid-1980s.

The catches by Indonesia (500 000 tonnes in 2002), which come from the Pacific and Indian Oceans, have increased rapidly since 1970, and presently are second only to those of Japan.

Vessels of Taiwan Province of China (460 000 tonnes in 2002) entered the tuna fishery during the late 1960s and increased their catches rapidly in all three oceans, but lately those catches have stabilized.

The European catches (mainly those of France and Spain) were limited to the Atlantic Ocean until the early 1980s. The catches have almost doubled (445 000 tonnes in 2002) since the beginning of the purse-seine fisheries for tropical tunas in the western Indian Ocean.

The catches of the Philippines have increased steadily since 1970. Its catches (240 000 tonnes in 2002) come mostly from the Pacific Ocean.

The Republic of Korea (220 000 tonnes in 2002) entered the fishery for tunas during the 1960s, and now its vessels fish in all three oceans. The catches increased rapidly during the 1980s, but stabilized during the 1990s.

The catches of the United States (160 000 tonnes in 2002) are taken mainly in the Pacific Ocean. These catches have been more or less stable since the 1970s.

Mexico (163 000 tonnes in 2002), Venezuela (140 000 tonnes in 2002) and Ecuador (135 000 tonnes in 2002) have participated in traditional fisheries (artisanal and some industrial) for many years, but the catches were low until the early 1980s, when they began to increase rapidly in the eastern Pacific Ocean.

The catches of the Maldives (138 000 tonnes in 2002) have increased greatly since the early 1980s. Pole-and-line fisheries in the Indian Ocean account for almost all of the catch.

2.3 Stock structure

The principal market species of tunas are divided into 23 stocks established by the Inter-American Tropical Tuna Commission (IATTC), the International Commission for the Conservation of Atlantic Tunas (ICCAT), the Indian Ocean Tuna Commission (IOTC), the Interim Scientific Committee (ISC) for Tuna and Tuna-like Species in the North Pacific Ocean and the Secretariat of the Pacific Community (SPC) for stock assessment purposes. As such, the stocks represent effective management units, constituting one, two or three stocks of each species in each ocean. The exceptions are Atlantic bluefin and Pacific bluefin, each of which is restricted to a single ocean, and southern bluefin, which constitutes a single stock in the Atlantic, Indian and Pacific Oceans. The stocks are as follows:

- Atlantic Ocean: Mediterranean albacore, North Atlantic albacore, South Atlantic albacore, eastern Atlantic bluefin, western Atlantic bluefin, bigeye, eastern Atlantic skipjack, western Atlantic skipjack and yellowfin.
- Indian Ocean: albacore, bigeye, skipjack and yellowfin.
- Pacific Ocean: North Pacific albacore, South Pacific albacore, Pacific bluefin, eastern Pacific bigeye, western Pacific bigeye, eastern Pacific skipjack, western Pacific skipjack, eastern Pacific yellowfin and western Pacific yellowfin.
- All oceans: southern bluefin tuna.

2.4 Status of stocks

The maximum annual catches of eight of the 13 tropical tuna stocks have been taken after 1998. All these stocks occur in the Indian and Pacific Oceans. The sizes of these eight stocks are classified by de Leiva and Majkowski (this collection) as either unknown, above their reference points or near their reference points. The maximum annual catches of all four tropical tuna stocks in the Atlantic Ocean were taken before 1995, and their stock sizes are classified as below their reference points, near their reference points or unknown.

The maximum annual catches of only two of the ten temperate tuna stocks have been taken in recent years. The stock sizes and fishing mortalities of these two stocks are unknown. The maximum annual catches of the remaining eight temperate stocks were taken before 1996. For six of these stocks, the stock sizes are below their reference points, near their reference points or unknown and the fishing mortalities are above their reference points, near their reference points or unknown.

For simplicity, the stock sizes and fishing mortalities for the various stocks were assigned to the following categories.

- ***Stock size***: above its reference point, near its reference point, below its reference point, unknown.

- ***Fishing mortality***: below its reference point, near its reference point, above its reference point, unknown.

The numbers of stocks assigned to each category of stock size and fishing mortality are shown in Table 1. The values in Table 1 suggest that the tropical stocks are, in general, in a better condition than the temperate stocks. If we consider only stock size, seven of the 13 tuna tropical stocks are within their safe limits from the conservation perspective (above or near). In contrast, only three of the ten temperate tuna stocks could be considered to be safe. If we consider only fishing mortality, the situation is quite similar. The current fishing mortality is apparently not sustainable for three of the 13 tropical stocks and six of the ten temperate stocks.

There are no estimates of either the stock size or the fishing mortality for about 35 percent of the stocks. This percentage is slightly higher for the tropical stocks than that for the temperate stocks. The status of about 50 percent of the stocks is significantly uncertain.

The status of the tuna stocks across a bivariate system of references related to the stock size and fishing mortality is presented in Figure 5. Seven of the stocks could be considered within safe limits from the conservation perspective (white area). However, the three stocks for which the level of fishing mortality are near the reference points should be closely monitored, so that, if necessary, management actions can be undertaken. Although the stock size and fishing mortality categories assigned to BET-IO (bigeye tuna, Indian Ocean) suggest that the stock is within safe limits, the present level of catches is regarded as not sustainable over the long term.

The remaining eight stocks in the upper row of Figure 5 may be overfished (grey area). Their fishing mortalities should be reduced, their stock sizes should be increased, or both, if these stocks are to be brought up to within safe limits.

3. FISHING CAPACITY

Concepts relating to fish harvesting capacity are not as clearly understood as the biological concept of overfishing. Much of this confusion arises because the terms "overcapacity" and "excess capacity" are frequently used as synonyms even though they are quite different. To make matters even more confusing, the concepts of excess capacity, overcapacity, overfishing and overcapitalization are closely related, yet different.

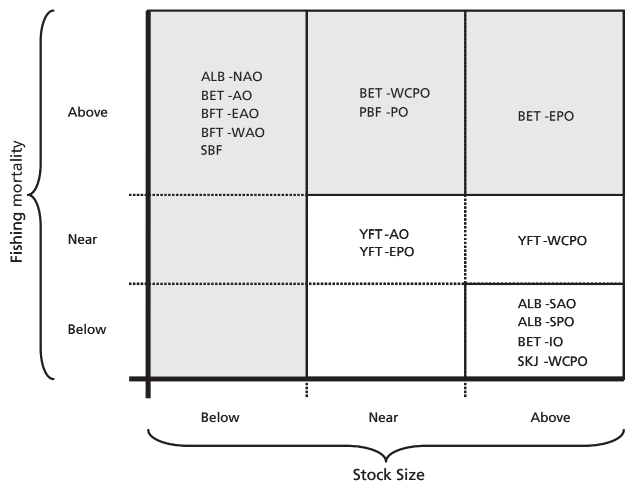
While excess capacity in fisheries remains a short run, self-correcting market phenomenon just as in other commercial activities, it is overcapacity that is a long run, persistent problem that fishery managers need to address through the management process. If fishers have a market incentive to overinvest in capital, i.e. overcapitalization, and other productive inputs used to harvest fish, then the excessive use of capital and labour in a

TABLE 1
Numbers of stocks assigned to the various stock size and fishing mortality categories

	STOCK STATUS					
	Stock size					
	Above	**Above-Near**	**Near**	**Near-Below**	**Below**	**Unknown**
Tropical stocks	4 (1)	-	3 (1)	-	1	5
Temperate stocks	2	-	1 (1)	-	4 (1)	3
Total	6 (1)	-	4 (2)	-	5 (1)	8
	Fishing mortality					
	Below	**Below-Near**	**Near**	**Near-Above**	**Above**	**Unknown**
Tropical stocks	2 (1)	-	3	-	3 (1)	5
Temperate stocks	2	-	0	2 (1)	4 (1)	2
Total	4 (1)	-	3	2 (1)	7 (2)	7

Note: The numbers in parentheses indicate the numbers of stocks for which there is substantial uncertainty (e.g. the stock sizes of four tropical stocks are considered to be above the reference points, but there is substantial uncertainty about one of them).

FIGURE 5
State of tuna stocks across a bivariate system of references. The abbreviations are listed by de Leiva and Majkowski (this collection)



fishery causes biological overfishing to occur. With the appearance of overfishing and resulting declines in stock abundance, overcapacity develops in a fishery when the net benefits to the fishing fleet begin to decline.

In *technological* terms the word "capacity" is used when describing physical measures of the vessel (e.g. hull capacity and the ability to hold fish) as well as the operational or technical efficiency of a fishing vessel and its gear. Thus, in these Proceedings the carrying (hold) capacity is sometimes used as a rough proxy for the fishing capacity of a vessel or a fleet and is assumed to be related to the ability of a vessel to catch fish under normal fishing conditions. Fish-carrying capacity (a statistic that is compiled by the IATTC and other organizations) is measured for most tuna fishing vessels as the tonnage of fish that can be stored on the vessel when it is fully loaded or the storage area, measured in cubic metres.

Understanding these technical distinctions – and their implications for successful fisheries management – is critical for the sustainable development of living marine resources.

3.1 Analysis of the fishing capacity of the global tuna purse-seine fleet

Regional analyses, using Data Envelopment Analysis (DEA), were conducted to measure tuna purse-seine fishing capacity.[1] Due to differing levels of availability of data, the level of aggregation and the period over which the DEA was conducted varied among the different regional tuna purse-seine fisheries, i.e. eastern Pacific, western and central Pacific, Indian Ocean and Atlantic Ocean.

DEA was used to calculate fishing capacity output and capacity utilization. DEA calculates a frontier or maximum landings curve, as determined by the best-practice vessels, given the states of technology, the environment and the resource stocks (fixed inputs), provided that fishing effort (variable input) is fully utilized under normal operating conditions. This frontier represents fishing capacity output. Landings directly on the best-practice production frontier represent full capacity utilization (CU), which is defined as observed output divided by capacity output. CU ranges between 0 and 1, where 0 indicates no observed output (no catches) and 1 indicates that the observed output equals the capacity output. When a vessel produces at less than full capacity, the capacity utilization is less than one, i.e. CU <1.

3.1.1 Eastern Pacific Ocean

The results of the analysis indicate that substantial excess fishing capacity – defined as fishing capacity output minus observed output (landings) – when measured as: (1) potential catch minus actual catch, or (2) potential catch purged of technical efficiency minus actual catch, exists for:

- Skipjack – for all vessel classes and set types utilized by the respective vessel class; and

[1] The Proceedings paper describes "fishing capacity" as the capability of catching fish, sometimes referred to as "fishing power." It is not to be confused with fish-carrying capacity.

- Yellowfin and bigeye combined – for all vessel classes and set types utilized by the respective vessel class.

In short, tuna purse-seine vessels had the ability to catch substantially more of all species during 1998-2002 than they actually caught, a result of both technical inefficiency (or skipper skill) and underutilization of variable inputs (for instance number of days spent fishing).

The greatest contributor, by far, to this excess was Class-6 vessels (more than 363 tonnes of carrying capacity), although there was excess in Classes 2 and 3 (46 -91 tonnes and 92-181 tonnes, respectively) and Classes 4 and 5 vessels (182-272 tonnes and 273-363 tonnes, respectively). Across all vessels it is estimated, after accounting for technical efficiency, that during 1998-2002 the combined catches of yellowfin and bigeye could have been 33 percent greater, while those of skipjack could have been 29 percent greater.

For yellowfin and bigeye it was also estimated that excess capacity – defined as capacity output purged for technical efficiency, minus combined maximum sustainable yield (MSY) – climbed from an excess of about 11 percent in 1998 to an excess of almost 70 percent by 2002. In 2002, therefore, tuna purse-seine vessels had the ability to harvest almost 70 percent more than MSY for yellowfin and bigeye combined.

Technical change was estimated to have increased by about 60 percent during 1998-2002 for the fishery as a whole.

3.1.2 Western and Central Pacific Ocean

The analysis conducted for the WCPO suggests that excess fishing capacity exists for all of the major fleets, i.e. those of Japan, the Republic of Korea, the Philippines, Papua New Guinea, Taiwan Province of China and the United States, and for the other fleets combined.

It is estimated that, on average, during 1998-2002 purse-seine skipjack fishing capacity was around 306 000 tonnes (35 percent) per annum greater than the actual catches (only 137 000 tonnes or 16 percent greater after purging for technical efficiency). Estimated excess fishing capacity, purged for technical efficiency, was at its highest level in 2000. It was hypothesized that this may have been caused by low skipjack prices during the second half of 1999 and throughout 2000, resulting in vessels reducing the number of days spent searching and fishing.

For yellowfin and bigeye combined it was estimated that during 1998-2002 excess purse-seine fishing capacity was around 72 000 tonnes (29 percent) per annum greater than the actual catch (only 12 percent or 31 000 tonnes after purging for technical efficiency). It was also estimated that during 1998-2002, on average, fishing capacity purged for technical efficiency for yellowfin and bigeye combined was in excess of the average catches between 2000-2002 by 47 666 tonnes or 20 percent, but that no excess capacity existed in the fishery in 2002 when measured against average 2000-2002 catch levels.

3.1.3 Indian Ocean and Atlantic Ocean

Overall, it appears that there is excess capacity in the Atlantic and Indian Ocean purse-seine fisheries for tuna. It was estimated that, on an annual basis, there was approximately 61 000 tonnes of excess capacity in the Indian Ocean and 29 500 tonnes of excess capacity in the Atlantic Ocean. If these vessels operated at full efficiency, fully utilized their variable inputs and harvested at levels corresponding to the average annual landings, the fleet size in the Indian Ocean could be reduced from 40 to 31 vessels (22.5 percent) and that in the Atlantic Ocean from 53 to 46 vessels (13.2 percent). These estimates are considered extreme lower-bound estimates due to the limited number of observations and inadequate information for considering different modes of fishing and the fishing activities of individual nations.

3.2 A review of the longline fleet capacity of the world

The regional tuna fishery management organizations maintain lists of vessels more than 24 metres in overall length (LOA) that are licensed to fish for tunas and tuna-like species in their areas of concern. These lists are commonly known as “positive lists”.

Some longliners more than 24 metres in LOA can not be considered to be large-scale because they do not fulfil all the requirements needed for consideration as such. It is not possible to decide, on the basis of LOA or gross registered tonnage (GRT) alone whether a vessel should be considered to be a large scale longliner. Additional information, such as target species, freezing facilities, etc., is required, and most positive lists do not provide this type of information. Therefore, for the purpose of this review, large-scale longliners were defined as longliners equal to or greater than 200 GRT or 35 metres in LOA, with freezing facilities (often super-freezers capable of freezing fish below 45°C), licensed to fish in distant waters and targeting primarily fish for the *sashimi* market. However, some flexibility, based on knowledge of the characteristics of the vessels, was incorporated into the final decisions.

It is acknowledged that some of the vessels between 24 and 35 metres in LOA could be considered to be large-scale longliners. In addition, vessels less than 24 metres in LOA, but satisfying the other requirements to be considered large-scale longliners, are proliferating. Unfortunately, since these vessels are not included in the positive lists, they could not be included in this study. Such being the case, the size of the world’s large-scale longline fleet given in this review is almost certainly underestimated.

The results of the above processing, by fleets and oceans, are summarized in Table 2. Only the data in the public domain have been used. Duplication of vessels, due to the fact that some of them fish in more than one ocean, was eliminated by comparing the names and characteristics of the vessels in the various positive lists. Vessels engaged in IUU fishing, estimated about 30, are not included in this table. The large-scale longliners were further classified into tuna and swordfish longliners. Only vessels that target swordfish most of the time are considered to be swordfish longliners. Extensive guesswork was involved in many of the decisions, as the target species are not specified in any of these vessel lists used.

In summary, it is estimated, based on the positive lists, that there is a total of 1 484 large-scale tuna longliners. Considering that data obtained from the Organization for the Promotion of Responsible Tuna Fishing (OPRT) are more recent, and include previous IUU vessels, and that there is no positive list for the western and central Pacific Ocean, it is likely that this is an underestimate. Accordingly, this estimate (1 484 vessels) was modified, using the data from OPRT for those fleets for which the data are available (101 additional vessels). Also, the current estimate of 39 IUU vessels was added, bringing the total number of large-scale longliners to 1 615.

Approximately 390 000 tonnes of tunas (albacore, bigeye, Atlantic bluefin, Pacific bluefin, southern bluefin and yellowfin) were caught by large-scale longliners, and 200 000 tonnes of these were caught by other longliners (small-scale longliners and/or longliners targeting swordfish) during 2001. As the *sashimi* market consumes about 600 000 tonnes per year, this estimate appears to be realistic. Division of the catch by large-scale longliners by the number of large-scale longliners indicates that the average catch of these vessels is about 240 tonnes per year. The current economic break-even point for catch per boat is roughly 250 tonnes per year, so a vessel that caught 240 tonnes of tunas per year would have to catch at least 10 tonnes of billfishes to break even.

It is unlikely that all the large-scale longliners are currently fishing at their full capacities, due to economic, social and management restrictions. If all these restrictions were removed, their potential catches, even at the current resource abundance levels, would be much greater than what they are producing. Indeed, the same levels of catches could most likely be made with a smaller fleet size, particularly if similar reductions were made in the sizes of the fleets of purse-seiners and small-scale longliners.

3.3 Global study of non-industrial tuna fisheries

In this subsection non-industrial fisheries are considered to be those carried out by vessels less than 24 metres in LOA, that do not have mechanical freezing facilities and are not capable of remaining at sea for more than about one month. Non-industrial fisheries are divided into two categories, small-scale vessels and medium-scale vessels. Small-scale vessels are undecked vessels that use outboard engines or sails and fish with handlines, rod-and-reel gear, etc. Medium-scale vessels are decked vessels with internal combustion engines that are usually less than 24 metres in LOA and do not have mechanical freezing facilities.

Estimates of regional and global tuna catches by small-scale fisheries are presented in Table 2. (Similar data are not available for the medium-scale fisheries because the data are often combined with data for large-scale fisheries.) Unfortunately, not all of the data are reliable. Since the main objective was to estimate the portion of the catch taken by small-scale fisheries, reliable and crude data are combined in this table. The world-wide catch of tunas by small-scale fisheries is about 320 200 tonnes, or about eight percent of the total world catch.

Some notable features of the results of the study are given below:

- There is a great deal of variation among regions. Small-scale tuna fishing is least important in the Oceania portion of the Pacific, where only about two percent of the tuna catch is from small-scale fisheries, and most prominent in the southeast and east Asia portion of the Pacific, where the small-scale catches are about 20 percent of the total.
- There is also a considerable variation among the regional tuna fishery management organizations in effort devoted to collecting catch information for the non-industrial fisheries.
- In some areas (e.g. Oceania) the catch of tuna by small-scale fisheries is largely the result of effort directed at tunas, whereas in other areas (e.g. the Indian Ocean) much of the catch of tuna by small-scale fisheries is taken by vessels directing their effort at other species.
- Fish-aggregating devices (FADs) seem to have a large effect on the catches of tunas by small-scale gear.
- Recreational fisheries can produce substantial amounts of tunas, but information on these operations is not readily available, except in some cases for the catches by commercial sport-fishing vessels.

4. THE WORLD TUNA INDUSTRY: AN ANALYSIS OF IMPORTS AND PRICES, AND OF THEIR COMBINED IMPACT ON CATCHES AND TUNA FISHING CAPACITY

4.1 The tuna industry

Tuna catches are affected by a wide variety of factors, both human and non-human induced. Human-induced factors include trends in the demand for tuna commodities, operating costs for tuna fishing, development of fishing capacity and technology, the set up of a regulatory framework governing tuna fisheries, and the availability and cost of transport of tuna products. The principal non-human induced factors influencing the availability of tuna resources are climatic and meteorological conditions. Other factors include the balance of the ecosystem, as well as the availability and abundance of bait and predation.

The major species utilized for canning are skipjack, yellowfin and albacore. The main species utilized in the Japanese *sashimi* market are: bigeye; yellowfin; skipjack (which is not strictly considered as tuna in Japan, but is still used to prepare a kind of *sashimi* called *takami*); the three species of bluefin; and, more recently, albacore.

The world imports of fresh, chilled and frozen tuna (net weight) increased from 435 000 tonnes (US$406 million) in 1976 to 1.6 million tonnes in 1998, declined slightly

TABLE 2
Catches of tunas by small-scale fisheries

Region	Catches by small-scale fisheries (tonnes)	Total catches (tonnes)	Catches by small-scale fisheries (percentages of totals)
Oceania	19 000	900 000	2.1
Eastern Pacific Ocean	40 500	750 000	5.4
Western Atlantic Ocean	11 000	112 000	9.8
Eastern Atlantic Ocean	11 000	347 600	3.2
Mediterranean Sea	1 700	28 500	6.0
Indian Ocean	52 000	880 000	5.9
East and Southeast Asia	185 000	928 000	19.9
Total	320 200	3 946 100	8.1

to 1.4 million tonnes in 2000 and then increased to 1.5 million tonnes (US$3 billion) in 2001. The principal imported tuna commodities, in terms of quantity, are frozen skipjack and yellowfin, and, in terms of value, are frozen bigeye and yellowfin. The principal importers of fresh, chilled and frozen tuna are Thailand and Japan, and the main exporters of these are the Taiwan Province of China, Spain, France and the Republic of Korea.

The production of canned tuna (including frozen, pre-cooked loins) increased from 499 000 tonnes in 1976 to 1.4 million tonnes in 2001 (net weight). The main producing countries are Thailand, the United States and Spain. The imports of canned tuna (net weight) increased from 89 000 tonnes (US$191 million) in 1976 to 836 000 tonnes (US$2.0 billion) in 2001. The principal importers of canned tuna are the United States, the United Kingdom and France, and the principal exporter is Thailand, followed by Spain and Ecuador.

4.2 The market for *sashimi*-grade tuna

The imports of bluefin tunas increased from 1986 to 1991 (Figure 6). At the same time the catches of bluefin tuna decreased. As a result of heavy demand and low catches, the prices increased from ¥5 279/kg in 1986 to ¥7 299/kg in 1991. From 1992 to 1995 the imports increased rapidly to almost 25 000 tonnes in 1995 and then declined slightly in 1996. In order to supply the demand for bluefin tunas, catches were increased to a record of almost 84 000 tonnes in 1996. Increasing imports, and hence international demand, during 1991-1996 did not generate a parallel increase in prices due to the increasing catches of fish. In fact, the prices decreased from ¥7 299/kg in 1991 to ¥5 246/kg in 1995 and ¥5 885/kg in 1996.

In the years that followed, the imports of bluefin tunas reached a historical maximum of 33 003 tonnes in 1999, declined slightly in 2000 and then increased to 31 709 tonnes in 2001. As a result of stringent quotas imposed by the ICCAT and CCSBT, the catches declined from 1996 to 1998. In 1999 the catches of bluefin tuna increased slightly, but then declined to 60 368 tonnes in 2001. The prices declined in Japan over the entire 1997-2001 period, reaching ¥4 046/kg in 2001.

The development of tuna farming in the Mediterranean Sea and elsewhere since 1997 has made increasing quantities of cheaper bluefin available in the world market, hence lowering the average bluefin tuna prices. In 2003 the average price of bluefin tuna reached a low of ¥3 936/kg.

The world market for bigeye tuna for *sashimi* is shown in Figure 7. The world imports of bigeye tuna increased from 96 484 tonnes in 1990 to 146 404 tonnes in 2000. The longline catches of bigeye remained quite stable during the same period, fluctuating between 260 000 and 290 000 tonnes. The prices of bigeye in the Japanese market increased from ¥2 947/kg in 1989 to ¥3 324/kg in 1994, and then declined during the years that followed, reaching a low of ¥1 757/kg in 2000.

It is interesting to note that the catches and prices both peaked in 1994. The decline of bigeye prices during the second half of the 1990s was the result of increased availability of cheaper bigeye from imports (and of cheaper bluefin tuna from farming).

4.3 The market for canned tuna

From 1992 to 1998 increasing international demand for canned tuna generated an increase in catches and imports of raw material. However, as the increase in catches was not enough to create a continuous oversupply, the prices also increased. The price declines during 1990-1992 and 1998-2000 were both caused by excess supplies, as the increased catches were not matched by increases in the demand for tuna commodities (both raw material and canned tuna). The price decreased to its lowest level of the 1989-2001 period in late 2000 (Figure 8). The supply-restricting measures implemented by the World Tuna Purse-seine Organization (WTPO) reduced the catches during late 2000 and early 2001, increasing prices, but, as far as skipjack was concerned, it proved to be only a temporary measure.

In a situation for which natural resources are regarded as inexhaustible and for which oversupply conditions do not exist, growing demand for canned tuna would generate an increase in imports of raw material, catches and prices. At the same time, increasing prices of raw material and canned tuna would stimulate the construction of fishing vessels, which would, of course, increase the catches. At the same time, variations in catches (supply) and imports (demand) of raw material have opposite impacts on canned tuna and raw material prices (which have been demonstrated to follow the same trend). If the increase in catches exceeds the increase in imports (creating an oversupply) the prices decline; if the increase in imports exceeds the increase in catches the prices increase.

The amount of canned tuna processed is determined by the supply of raw material available to feed a constantly growing demand, rather than by variations in raw material or canned tuna prices. Catches of tuna and production of canned tuna followed an almost parallel trend in the period under examination. However, the processing of canned tuna has been growing more slowly than the catches, mainly because tuna-processing capacity has been growing more slowly than tuna-fishing capacity. In fact, tuna processing capacity is linked more to state of technology than to the abundance of natural resources and the ability to concentrate on the most productive fishing grounds.

When the market is oversupplied, the positive correlations between catches, imports, processing and prices break down, and prices decline. The decreases in price that

FIGURE 6
World market for Atlantic, Pacific and southern bluefin tunas for *sashimi*

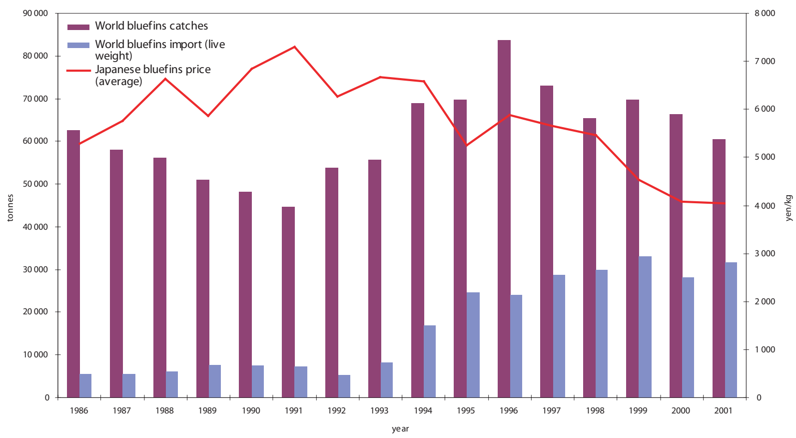
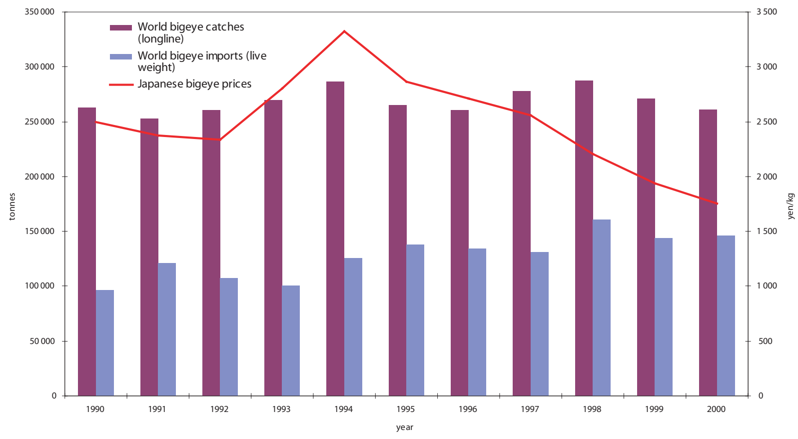


FIGURE 7
World market for bigeye tuna for *sashimi*



occurred between late 1998 and late 2000 were, ultimately, the result of oversupplies caused by the increased capability to catch tuna. The prices of raw material and canned tuna had been elevated since 1992, and had increased since 1996 (Figure 8).

The commercial response was to maximize the catches by maximizing the numbers of days spent at sea and to construct more vessels. In late 1998, however, the abundance of resources, combined with increased fishing capacity, generated large increases in the catches. These continued in the following years until, in late 2000, the WTPO had to implement measures to limit the supply in order to increase the prices of raw material. Had the WTPO not intervened, the continuing excess of supply of catches might have had adverse effects on one or more of the target or non-target species.

5. CURRENT MANAGEMENT MEASURES THAT IMPACT THE CAPACITY OF TUNA FISHING FLEETS

5.1 Inter-American Tropical Tuna Commission (IATTC)

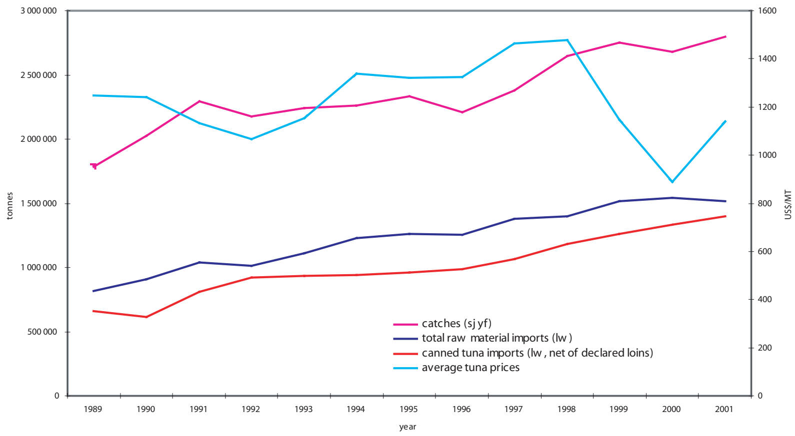
In 1999, for the first time, the IATTC placed limits on the carrying capacity of the purse-seine fleet that operates in the eastern Pacific Ocean. Individual limits were assigned to each of the 13 nations participating in the purse-seine fishery. However, it was not possible to extend the limitation beyond 1999.

In 2000, a resolution was approved to establish and maintain a Regional Vessel Register (RVR) of the vessels authorized by their governments to fish in the eastern Pacific Ocean. In 2002 the Resolution on the Capacity of the Tuna Fleet Operating in the eastern Pacific Ocean, establishing the RVR as the definitive list of purse-seine vessels authorized by the participants to fish for tunas in the eastern Pacific Ocean, was approved. The concept involved in the RVR is that the capacity quotas apply to vessels, rather than to governments. It is also the intent of the program to allow the transfer of vessels on the list to other flags, creating a sort of market for trading carrying capacity.

5.2 International Commission for the Conservation of Atlantic Tunas (ICCAT)

Limits on catches set by ICCAT and allocated to fishing countries and entities provide opportunities for those nations to limit the numbers of vessels authorized to fish, but not many countries have introduced such vessel limits. ICCAT has approved several recommendations calling on fishing nations to limit the numbers of their vessels fishing for bigeye and northern albacore. These vessel limits have been coupled with limits on the catches of those species.

FIGURE 8
Relationship between the canned tuna market (raw material and products), catches and average canned tuna/raw material prices



5.3 Indian Ocean Tuna Commission (IOTC)

The IOTC has established a Record of Authorized Vessels (RAV), which includes vessels greater than 24 metres in overall length (LOA) that are authorized to fish in the Indian Ocean, but the RAV does not impose a limit on the number of vessels. However, the IOTC considers any vessel that is not on the RAV and fishes in the Indian Ocean to be engaged in IUU fishing.

In 2003 a resolution was approved that requires Parties and Co-operating Non-Parties that have more than 50 vessels on the RAV to limit, with some exceptions, the number of their fishing vessels larger than 24 metres in LOA to the numbers registered on the RAV in 2003.

5.4 Commission for the Conservation of Southern Bluefin Tuna (CCSBT)

The CCSBT has created a record of the vessels greater than 24 metres in LOA that are authorized to fish for southern bluefin tuna, and considers any vessel that is not on the list and fishes for southern bluefin to be engaged in IUU fishing.

5.5 Forum Fisheries Agency (FFA)

The FFA maintains a register of vessels that are eligible to apply for fishing licences in the Exclusive Economic Zones (EEZs) of FFA members. Any unregistered vessel found to be engaged in fishing in the EEZ of any FFA member country is not permitted to obtain licences to fish in the EEZ of any FFA member country.

The Palau Arrangement of 1992 for the western Pacific purse-seine fishery limits the levels of purse-seine fishing in the EEZs of eight of the 16 member countries of the FFA, where most of the tuna catch is taken. The arrangement provides an overall limit of 205 purse-seine vessels that will be licensed by the parties for fishing in their waters. Working to ameliorate capacity-related problems, the countries participating in the Palau Arrangement are in the process of considering the introduction of a long-term management system based on national limits on the number of days of purse-seine fishing allowed.

5.6 Other organizations

The Japanese government and the OPRT, an international industry organization, have reduced the number of large-scale tuna longline vessels. So far, about 43 Japanese and Taiwanese longline vessels that were flagged to third countries of open registry have been transferred to the countries corresponding to the citizenships of their owners and either legalized, converted to other uses or scrapped. At present, there are only about 30 such vessels flagged to third countries of open registry, and some of these are inactive.

Industry organizations representing purse-seine vessels from about ten countries have joined the World Tuna Purse-seine Organization (WTPO), an organization that seeks to maintain the prices of purse-seine caught tunas at profitable levels by limiting supply. The members of the WTPO have agreed to reduce the level of fishing effort by requiring that vessels spend more time in port between trips. They also have called for limits on fleet growth. Specifically, the WTPO has proposed the establishment of a world purse-seine and longline vessel register, which would include only vessels authorized by their governments to fish. A new vessel could enter the register only by replacing a vessel of equal or greater size that had been removed from the register.

However, there are large fleets that do not belong to industry organizations that are members of the WTPO. Additionally, a world register of purse seiners and longliners has not yet been created. Nevertheless, the idea of an industry initiative to address capacity concerns relating to overcapacity in the world tuna fleet provides a number of possibilities for helping to resolve these problems.

6. OPTIONS FOR MANAGING TUNA FISHING CAPACITY

The final section of the Proceedings, namely, tuna fishing capacity management options and implications, includes a discussion of potential future options for managing the tuna fishing capacities of the purse-seine and longline fleets, and some points of these are summarised in the sections below.

6.1 Limited entry registers

Limited entry registers of vessels that define the vessels that are authorized to fish in an area can be used to control and curtail the number of vessels allowed to operate in a particular area.

Limited entry registers, used in conjunction with some additional mechanisms, thus offer a potentially effective option for managing tuna fleet capacity. The establishment of such a register, in essence, creates a limited-entry program and a right of access, although such a right would be incomplete because of the lack of definition of exclusive rights to the catch through the setting of individual quotas. In the absence of associated limits on catches for the fishery (total allowable catches) and for the individual operators (IQs), increases in the carrying capacity or efficiency of the registered vessels may be expected to limit the effectiveness of such schemes in managing fishing capacity.

Used in conjunction with limited entry registers, vessel replacement strategies requiring that vessels can be replaced only by vessels of equivalent size could be used to redirect, if not slow, vessel-related technological changes (input substitutions) such as increases in the carrying capacity or efficiency of the licensed vessels. Alternatively, the numbers of vessels allowed in the register could be adjusted downward from time to time to compensate for increases in fishing efficiency. Fishing capacity in a particular fishery could be further reduced through buy-backs of vessels in the register, after which they would be converted to other uses or scrapped.

6.2 Licensing

Another approach to managing fishing capacity is limiting the entry of vessels into a fishery by requiring licences. Similar to a limited entry registry, a licensing system alone does not remove the incentive for fishers to increase fishing capacity or fishing mortality. In fact, without associated limits on total allowable catches for the fishery and for the individual operators (IQs), increases in the carrying capacity or efficiency of the licensed vessels will render a licensing scheme ineffective in managing fishing capacity.

An efficient approach might be to vest the management of the licensing system authority in a regional fishery management organization (RFMO) that would determine the appropriate number of vessels and the catching capacity needed to harvest the allowable catch. A solution of this nature would, however, imply a delegation of rights to the RFMO by flag States and coastal States and would probably face, in many if not most cases, considerable difficulties, particularly with respect to fishing in the EEZs, but also on the high seas. Licensing would be at the vessel level, and the licences would include the gear type and capacity in the licensing unit to avert some undesirable elements of "capital stuffing". Licences could be issued for a limited period of time, they could be held in perpetuity, or they could be held until they were transferred.

As in the case of a limited entry register, the numbers of vessel licences could be adjusted downward from time to time to compensate for increases in fishing efficiency. Fishing capacity in a particular fishery could be further reduced through vessel replacement consolidation schemes or buy-backs of vessels in the register, after which they would be converted to other uses or scrapped.

6.3 Catch quotas

An alternative means of addressing the capacity problem is through the assignment of catch quotas either to nations participating in an international tuna fishery, or to individual participants in that fishery. The use of catch quotas involves determining what the total allowable catch for a fishery should be and the allocation of that total allowable catch among the participants in the fishery.

If individual quotas (IQs) are assigned to operators, the self-regulating or incentive adjusting measure would be particularly effective, as there would be no advantage to the operators to race to take their quotas. On the other hand, if quotas are assigned to countries, then it is necessary to limit the numbers of vessels from different nations allowed by those nations to participate in the fishery to avoid wasteful overcapacity within the respective national fleets.

7. DISCUSSION

The Project has undertaken substantial research into the subjects considered as having high priority for fulfilling its objectives (i.e. tuna fisheries and resources, characterization and estimation of tuna fishing capacity, the tuna fishing industry and tuna fishing capacity management options and implications). Some of these subjects have been addressed comprehensively by the Project, but some of the others could, with more funds and time, be improved or refined.

7.1 Status of tuna stocks

A comprehensive evaluation of the status of stocks of the principal market species of tunas is difficult for several reasons. A uniform and consistent classification of tuna stocks in accordance with some simple, pre-determined criteria is particularly difficult on a global scale. Reference points regarding stock sizes and fishing mortality are the most appropriate, but, due to lack of information, it has not been possible to estimate the reference points for some of the tuna stocks. In spite of these problems, substantial information has been obtained on the status of many of the tuna stocks.

Comparison of the status of the various tuna stocks is difficult, since different methods have been used to estimate the reference points. Consultations among the organizations that conduct the assessments might reduce or eliminate this problem. However, even if the types of reference points and the methods for their estimation were standardized, comparisons of the different stocks would be difficult because estimates of the reference points are based on the age compositions of the catches, and these may differ for different stocks of the same species. According to the

United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, both target and limit reference points should be established and estimated for each stock. At present, this has not been done.

A quantitative determination of the implications of the stock status for the management of fishing capacity is difficult, as was recognized at the second meeting of the Technical Advisory Committee (TAC). Considerable additional research in this area is needed. Nevertheless, these difficulties in quantitatively determining reductions or increases in fishing capacity should not prevent fisheries managers from using the information on the status of tuna stocks as qualitative indicators of overcapacity. Overfished condition of a stock is usually an indicator of overcapacity.

7.2 Measuring capacity

In accordance with a recommendation of the first meeting of the TAC, Data Envelopment Analysis (DEA) was chosen by the Project to measure the capacity to catch fish in the purse-seine fisheries of the eastern Pacific Ocean, the western and central Pacific Ocean, the Atlantic Ocean and the Indian Ocean. The results were promising, and they could be considerably improved if more detailed data were available, especially for the Atlantic and Indian Oceans.

It was intended that DEAs would also be carried out for the longline and pole-and-line fisheries. The participants at the first meeting of the TAC were optimistic with regard to securing longline data for the DEA, but it was impossible to compile the data before the second meeting of the TAC. At the second meeting of the TAC it was concluded that, at least, aggregated data for the large-scale longliners similar to those for the purse seiners could be obtained. Later, however, it was determined that obtaining such data would be extremely difficult, if not impossible. Furthermore, it was concluded at the second meeting of the TAC that, despite the fact that pole-and-line fishing accounted for 14 percent of the total catches of the principal market species of tunas in 2002, there are not enough data to permit the conducting of a DEA that would provide reasonable estimates of global pole-and-line fishing capacity.

The global study on the importance of the non-industrial tuna fisheries makes it possible to estimate the catches of the small-scale fisheries. This is not possible for the medium-scale fisheries, however, due to lack of information on the activities and catches of the vessels. Some of these vessels have recently incorporated mechanical freezing facilities, so they are able to make longer trips and land fish acceptable for the *sashimi* market. Since presently the registry of tuna vessels is mandatory only for vessels more than 24 metres in LOA, these vessels are not included in the positive vessel lists of the regional tuna fishery management organizations, making it difficult even to estimate their numbers. This could pose a threat to the sustainability of the tuna fisheries, because it is expected that the numbers of medium-scale vessels will increase in the near future.

7.3 Data for analysing tuna imports and prices

The data used for the analysis of the tuna imports and prices, and of their combined impact on catches and tuna fishing capacity, were obtained from various sources, such as the FISH INFOnetwork data, Japanese customs data, FISHSTAT Plus, EUROSTAT and other national and regional organizations.

The data for tunas are more reliable than those for most other fish resources, which is due partly to the introduction of statistical documents on catches and trade and the implementation of measures against IUU fishing. However, there are still problems with vessels (numbers of vessels of various sizes, their equipment, and the species toward which their effort is directed), processing (the amounts of fish of each species that are used to produce various products such as *sashimi,* steaks, canned tuna, pouches, etc.). Some of this information is, in theory, in the public domain, but other information, particularly that on processing is proprietary, and not easily obtainable.

In the future, the results of economic analyses could be substantially improved if:

- The amounts of each species of tuna (and billfish) used for canning, *sashimi* and other purposes could be determined.
- The amounts of each species of tuna that are used for the various canned products could be determined.
- The large amounts of unreported tuna loins (for canning) entering international trade could be identified.
- Industry data were more easily available.

7.4 Management measures

It is evident that, in general, fisheries management measures adopted so far have not prevented the growth of tuna fleets. It is likely that if the *status quo* regarding the management of tunas is maintained, the fleets will continue to grow, placing any measures for the rational management and conservation of the tunas in jeopardy.

It is clear, therefore, that maintaining the *status quo* is not a desirable option for managing fishing capacity or for the conservation of tunas. Based on the analyses carried out by the Project, it can be concluded that the common-property and open-access nature of tuna fisheries has been the major cause of the decline in many of the world's tuna stocks. Consequently, moving away from these concepts toward rights-based management schemes is worthy of consideration. The principal problem is the allocation of these rights, which is a sensitive political issue.

Of the various options presented for the management of fishing capacity, those directed at the vessel level would be the easiest to design and administer. Another important issue is the management of non-industrial fisheries. Presently, most management measures are directed at large-scale vessels, and the non-industrial tuna fisheries have been unregulated, or nearly so. However, the magnitude of the non-industrial tuna catches is increasing, and management plans will eventually have to include this component if they are to be effective.

8. TECHNICAL ADVISORY COMMITTEE RECOMMENDATIONS

Several recommendations based on the technical findings reported in this publication were made at the second meeting of the Technical Advisory Committee (Madrid, Spain, 15–18 March 2004). These are listed below. In addition to the general recommendations of the Technical Advisory Committee (TAC), most of the papers in this publication include specific recommendations on how to overcome problems encountered during the implementation of the studies.

Regarding the collection of data, the TAC recommended that the FAO should:

- Promote efforts to provide external support for the collection of better information on tuna fishing in countries where small-scale fisheries account for a large part of tuna fishing activities.
- Encourage countries to collect information on the characteristics and operation of tuna fishing vessels and/or fleets.
- Promote the development of a global record of tuna fishing vessels.

Regarding the management of tuna fishing capacity, the TAC recommended that FAO promote the following actions:

- A moratorium should be imposed on the entry of additional large-scale tuna vessels into the fisheries until an efficient, equitable and transparent management system of fishing capacity is achieved.
- Within the constraints of capacity limits, the regional tuna fishery management organizations should have a system for allowing the transfer of fishing capacity.

- Any country or fishing entity that has expanded or is expanding its tuna fishing capacity should strengthen its management of fishing capacity as recommended above.
- The regional tuna fishery management organizations should collect information on the numbers, capacities and vessel characteristics for tuna vessels other than purse seiners and longliners (such as pole-and-line vessels and trollers) to determine if excess[2] capacity exists for these fleets.
- Rights-based management of tuna fisheries should be considered, where appropriate, as a long-term solution for the management of excess fishing capacity.
- Mechanisms for managing tuna fishing capacity should include monitoring, surveillance and control systems.

[2] Again, excess capacity is a short-run, self-correcting market phenomenon of commercial activities. It is overcapacity that is a long-run, persistent problem that fishery managers need to address through the management process. If fishers have a market incentive to overinvest in capital and other productive inputs used to harvest fish, then the excessive use of capital and labour causes biological overfishing to occur, stocks to decline and overcapacity to develop.

SECTION 1

Tuna fisheries and resources

A brief history of the tuna fisheries of the world

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ABSTRACT

The total world catch of tunas increased steadily from a half million tonnes in 1950 to a peak of almost 4 million tonnes in 1999. The catches in the Pacific Ocean have exceeded those of the Atlantic and Indian Oceans throughout this period, exceeding 2.5 million tonnes in 1998. The catches in the Atlantic Ocean increased more slowly that those in the other two oceans, and have stabilized since 1991. The catches in the Indian Ocean increased rapidly during the 1980s and 1990s, reaching a peak in 1999. The catches in the Indian Ocean have exceeded those of the Atlantic Ocean since 1987.

The greatest catches are those of skipjack tuna (2 million tonnes; 50 percent of the world catch), and the next-greatest catches are those of yellowfin (1 to 1.2 million tonnes; 25 percent of the world catch). The catches of these two species are taken mostly by surface gear, while greater portions of the catches of bigeye and southern bluefin are taken by longline gear. The catches of purse-seine vessels have increased steadily during the last five decades to 2.2 million tonnes, while those of longline and pole-and-line vessels have been stabilized in recent years at about 0.5 to 0.6 million tonnes.

During the 1950s and 1960s the catches of Japan and the United States exceeded those of any other country, but they have been stable since the 1970s, while those of other countries (the Taiwan Province of China, Spain, Indonesia, the Philippines, the Republic of Korea, France, Mexico and Venezuela) have increased greatly since the 1980s.

Technological developments in vessels, gear, navigation equipment and fishing procedures are described. The most important developments are freezers that freeze the fish very rapidly, making them acceptable for the *sashimi* market, longline fishing at greater depths, the invention of the hydraulic power block, increased carrying capacities of the vessels, use of fish-aggregating devices (FADs) for purse-seine fishing; and development of closed, refrigerated circulation of the bait tank for pole-and-line fishing. Other improvements, such as the use of satellite navigation systems, radar and sonar, are also discussed.

1. INTRODUCTION

This paper provides general background information on important developments in the world tuna fisheries for a study of management of tuna fishing capacity. Quantifying the effects of these developments is not possible, so only qualitative descriptions are provided.

Fishing capacity cannot be evaluated without considering the catches of the various stocks of tunas, as well as the development of the fisheries, so summaries of catches appear in this report. More detailed information on the catches can be found in Miyake, Miyabe and Nakano (2004).

In this report the borders between the oceans follow the decisions by the Coordinating Working Party on Fishery Statistics (CWP). Each ocean includes all the adjacent seas (e.g. the Atlantic Ocean includes the Mediterranean Sea). Also, the data on the tuna catches include only the principal market species of tunas, albacore, bluefin, southern bluefin, bigeye, yellowfin and skipjack. Swordfish are discussed in a separate section.

The review of the fisheries is limited to the large-scale longline, purse-seine and pole-and-line fisheries, as these take the overwhelming majority of the catches of tunas. Nevertheless, the longline catch data used in this study include both large-scale and artisanal and/or coastal longliners, as the catches of these are combined in the catch data.

The CWP has recently decided that the Pacific and Atlantic bluefin tuna are different species (*Thunnus orientalis* and *T. thynnus*, respectively). It is impossible to distinguish these two by their appearance, however, and they are sold and bought without specification as to whether they are Atlantic or Pacific bluefin. Also, since they have been treated as a single species for many years, they are combined as “bluefin tuna” in this report.

There is only one stock of southern bluefin tuna, which occurs in all three oceans. Data on the catches of southern bluefin, by oceans, gear and countries, were not available at the time that this paper was written. Therefore, data on the catches of southern bluefin catch are not included in the analyses of catches of the principal market species of tunas by ocean and fishing gears, (e.g. Appendix 1, Tables 1 and 3), but they are included in those of the catches by species (e.g. Appendix 1, Table 2).

2. DEVELOPMENTS IN VESSELS, GEAR AND FISHING METHODS

2.1 General developments

Developments in vessels, gear and fishing methods are discussed in this section. It is not possible to quantify the changes that have taken place over the last 50 years, but it is important to understand these developments when evaluating fishing capacity, since those directly affect fishing efficiencies.

There are three types, in general, of technological development; 1) to increase fishing efficiency; 2) to increase economic gain, though not increasing fishing efficiency; and 3) to make the fishing easier, safer and less labor-intensive. Even though 2) and 3) above do not directly increase fishing efficiency, they affect it indirectly.

Some of the developments are common throughout the fishing gears and/or type of fishing vessel, and some are specific to certain fisheries. Most of these developments increased fishing efficiencies, and hence increased the effect of fishing on the stocks, even if the capacities of the vessels did not increase.

2.1.1 Fishing vessels

- There have been changes in construction materials. For the large industrial vessels, this occurred mostly during the 1940s. For the small coastal fishing vessels, light modern materials, such as fiberglass and plastic, have often been used since the 1960s.
- Replacement of sails with engines began during the late 19th century, and by the 1940s most of the large vessels in the world had engines. The replacement of sails with engines has been expanding to the coastal artisanal fisheries as well.
- The fishing vessels have continuously been increasing in size, which increases their fishing power and the safety of the crew.
- Increases in engine power and efficiency of propellers (e.g. use of variable-pitch and large-diameter propellers) and reduction of resistance (such as bulbous bows) are always taking place. This increases fishing efficiency, and possibly saves labor.

- When there are national or international regulations on fishing vessel size (e.g. carrying capacity or gross registered tons (GRT), vessels have been modified to conform with those restrictions.

2.1.2 Navigation

- Many types of equipment for determining vessel positions, such as Loran and Decca, have been developed.
- During the 1960s non-military use of satellite systems became possible, and by the mid-1970s these became widely used by fishing vessels for positioning and for getting weather and fishing ground information.

2.1.3 Others

- The development, since the 1960s, of radio buoys has been beneficial to all fisheries. The improvements include "select call radio buoys" during the 1980s and "global positioning system (GPS) tracking radio buoys" during the late 1990s. These are useful for locating longlines drifting at sea and flotsam and artificial fish-aggregating devices (FADs) for purse seiners and pole-and-line vessels.
- There have been continuous improvements in sonar and other equipment to measure oceanographic conditions.

2.2 The longline fishery

- In 1914 the first powered longliners (30-70 GRT) began fishing in the western Pacific Ocean.
- In 1953 the conversion from ice cooling systems to air blast freezers began, which enabled longliners to operate without restrictions as to their distance from the landing ports. The fish were frozen at about -25°C, which made them acceptable for canning, but not for the *sashimi* market.
- More efficient freezers were developed during the 1960s, and by the end of that decade fish could be frozen at -55°C, which made them acceptable, for the first time, to the *sashimi* market.
- By the mid-1960s the costs of labor and fuel in Japan had increased so much that longline fishing was no longer profitable. During the late 1960s the Japanese government and industry began a project to reduce the costs of labor, and the following changes were introduced: a line-casting device; a new method to attach and detach the branch lines; a line-hauling drum; a line winder; and, somewhat later, an automatic bait-attaching device. (However, the line-hauling drum and automatic bait-attaching device have not come into wide usage due to their bulk and technical complexity.) These innovations were soon adopted by longliners of other countries.
- In 1967 double-deck longliners, which are more efficient for operations in the rough seas of higher latitudes, came into usage by vessels targeting bluefin and southern bluefin tuna.
- During 1972-1973, slow-speed, large-diameter propellers, which made vessel handling easier and reduced costs, came into usage.
- Beginning during the late 1960s, the vessels began to modify their gear by using fewer buoys, which had the effect of making most of the hooks fish at greater depths. This resulted in greater catches of bigeye, which brings higher prices than the other species of tunas (other than bluefin and southern bluefin, which are relatively rare).

2.3 The purse-seine fishery

- The following events during the 1950s contributed to the development of the modern purse-seine fishery for tunas: invention of the hydraulic power block, which facilitated handling of the net; availability of synthetic netting, which did not deteriorate even in the tropics; and better facilities for freezing the fish (Orange and Broadhead, 1959; McNeely, 1961).

- After the introduction of the power block, the sizes of blocks and the power of the winches have increased to further facilitate the fishing operations.
- The use of auxiliary boats has increased. These may include: speed boats for herding dolphin-associated tuna schools prior to setting the net around them; use of pole-and-line vessels to attract fish schools, after which they can be surrounded by a purse seine; scouting and transport vessels for two-boat purse seining; and, auxiliary vessels for FAD fishing, mostly to keep good fishing grounds occupied and to assist in fishing operations.
- Improvements in fish loading (removing fish from the seine, transferring them from the upper deck to the wells, etc.) have been made.
- There have been changes in the structure of the nets in accordance with oceanographic conditions and behavior of the fish. Deeper nets are used in the western Pacific Ocean, where the thermocline is relatively deep, than in the eastern Pacific Ocean, where it is relatively shallow. Also, the nets now sink more rapidly. Accordingly to Delgado Molina *et al*. (1999) the average set in the Atlantic Ocean took 2.43 hours during the 1970s, but only 1.8 hours during the 1990s.
- The use of bird radar, which is very effective in finding flocks of birds (which are frequently associated with schools of tuna), was introduced in 1987 (Delgado Molina *et al*., 1999). By 1991 the range of bird radar had been extended considerably.
- Fishing on the schools associated with flotsam has been practiced by surface fisheries in all oceans, but particularly in the western and central Pacific Ocean. The use of FADs began during the late 1980s and early 1990s. FAD fishing is much different from other surface fisheries, as searching for fish schools is no longer necessary. This also changed the species and size compositions of the catches, most notably increasing the portion of small bigeye in the catches.

2.4 The pole-and-line fishery

- Equipment for aeration of the bait wells and for freezing the catch was introduced in 1953, which resulted in significant expansion of the fishing grounds.
- Use of forced circulation of seawater in the bait tanks began in 1963.
- The first large pole-and-line vessel with forced circulation and brine freezer was built in 1965. Until the mid-1960s many Japanese pole-and-line vessels (whose catches exceeded those of pole-and-line vessels of all other countries) were engaged in longline fishing for tunas during the off-season. These developments made it possible for a vessel to engage in pole-and-line fishing throughout the year.
- An automatic (robot) pole-and-line fishing device and fiberglass poles were introduced in 1965. The automatic fishing device made it possible to reduce the number of crew members, but it never came into wide usage because the catch rates were not as high as those of boats without this device.
- After several years of experimentation, a complete closed cooling and circulation system was established for the bait wells in 1980. This released the vessels somewhat from restrictions on fishing grounds imposed by lack of baitfish.

3. REVIEW OF THE WORLD TUNA CATCHES

Historical trends in the catches of tunas throughout the world are summarized in this section. Further details can be found in Miyake, Miyabe and Nakano (2004).

3.1 Data sources

3.1.1 Catch data

The data bases prepared by the following regional fishery management organizations (RFMOs) were used in this study.

- International Commission for the Conservation of Atlantic tunas (ICCAT) for the Atlantic Ocean,
- Indian Ocean Tuna Commission (IOTC) for the Indian Ocean,
- Inter-American Tropical Tuna Commission (IATTC) for the eastern Pacific Ocean (east of 150°W),
- Secretariat for the Pacific Community (SPC) for the western and central Pacific Ocean, excluding Pacific bluefin and North Pacific albacore,
- Interim Scientific Committee (ISC) for Pacific bluefin and North Pacific albacore and
- Commission for the Conservation of Southern Bluefin Tuna (CCSBT) for southern bluefin tuna in all oceans.

These data bases include data through 200l or 2002. The data are frequently updated, and sometimes major revisions to historical data series are introduced. Data downloaded on 30 September 2003 were used in this study. As they are more recent, the data used in this report differ from these used in the previous studies (Miyake, Miyabe and Nakano, 2004). The important changes for the historical data series are as follows:

- Japanese longline catch data in the Indian and Pacific Oceans for the 1950s and 1960s have been considerably changed, due to the revision in conversion procedures for numbers of fish to round weights of fish.
- New data for the Taiwan Province of China became available for the 1950s for the Indian Ocean.
- Data for the catches of the Taiwan Province of China in the Pacific Ocean since 1992 were revised, based on new compilations of logbook data.
- The purse-seine catches reported as mixed tunas in the Pacific Ocean have been disaggregated into bigeye, yellowfin and skipjack, using species-sampling data.

Almost all the above data bases (with exception of those for the Atlantic Ocean) include data for 1952 through 2001. The data for 1950 and 1951 are the author's estimates, and most of the data for 2000 and 2001 are preliminary.

3.1.2 Geographical distributions of the catches

The distributional maps were provided by the FAO Fisheries Department (published on a compact disk as Tuna Atlas and available on the FAO web site). The data base does not include data for the 1950s. These data are summarized in Appendix2, Figs 1-4. Appendix 2, Figures 1-3 show the catches of all species combined by longline, purse-seine and pole-and-line gear during four periods, 1964-1966, 1974-1976, 1984-1986 and 1996-1998. Appendix 2, Figure 4 shows the distributions of the catches of 1998, by species and gear. Additional details are available in the Tuna Atlas.

The Appendix figures include data only for the fisheries for which the catches are reported by 5-degree areas. Therefore many components of the catch distributions are missing, although the coverage rate has increased in recent years. The data for the Atlantic Ocean are raised to the total annual catches, while those for the other oceans are not raised. Therefore the densities of the catches are not strictly comparable among oceans.

3.2 Global overview of tuna catches

The combined reported total world catches of the principal market species of tunas (not including southern bluefin tuna) in the three oceans are shown in Figures 1 and 2 and in Appendix 1, Table 1. The total world catches increased steadily from a half million tonnes in 1950 to almost 4 million tonnes in 1999.

The catches of the Pacific Ocean dominated throughout the period, exceeding 2.5 million tonnes in 1998 and every year thereafter. The rate of increase in the catch of the Atlantic Ocean has been much less than those of the other two oceans, the catches having been nearly stable since 1991 and having reached their highest level in 1994. The

FIGURE 1
Combined total world catches of the principal market species of tunas in the three oceans

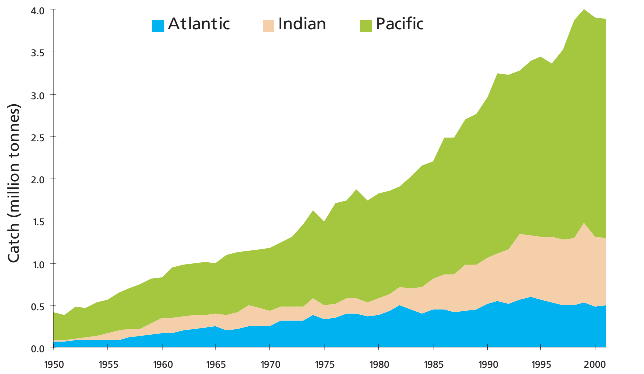


FIGURE 2
Total world catches of the principal market species of tunas in the three oceans

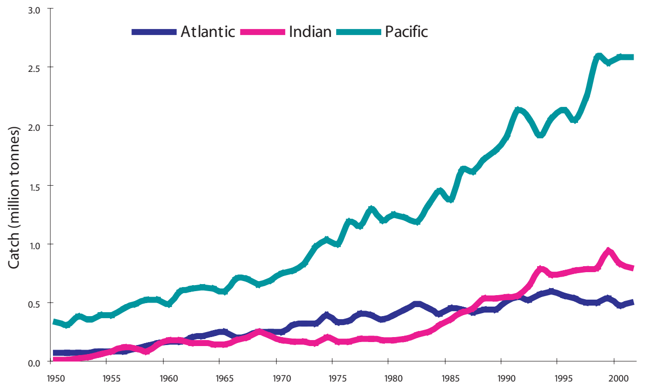
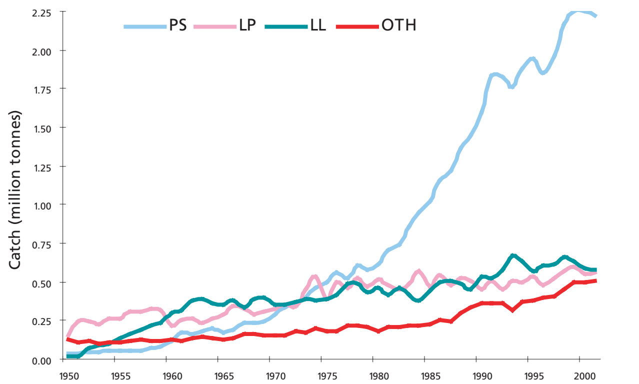


FIGURE 3
Total world catches of the principal market species of tunas, by fishing gears



catches in the Indian Ocean were low until 1981, but thereafter increased until 1999, and have exceeded the catches of the Atlantic Ocean since 1987.

Currently the proportions of the catches among the oceans are about 15, 20 and 65 percent for the Atlantic, Indian and Pacific Oceans, respectively. It should be noted that bluefin, bigeye and albacore have been subject to more severe catch restrictions in the Atlantic Ocean than in the other two oceans.

The distributions of the average annual catches of the principal market species of tunas combined, by 5-degree areas and by fishing gears (longline, purse-seine and pole-and-line) are shown in Appendix 2, Figures 1-3.

The combined total world catches of the principal market species of tunas (not including southern bluefin tuna), by major fishing gears, are shown in Figure 3 and Appendix 1, Table 3. Additional information is given in Section 4 of this report and in Miyake, Miyabe and Nakano (2004).

The total world catches of the principal market species of tunas (including southern bluefin tuna), by species, are shown in Figure 4 and Appendix 1, Table 2 (all oceans combined) and in Figure 5 (not including southern bluefin tuna). It should be noted that the scales on y-axis (catch) differ among oceans in Figure 5.

The relative importance of the various species and the trends in catches by species are very different among oceans. The Atlantic catches are more evenly distributed among species, the bigeye catches being almost as great as those of yellowfin and skipjack. Although swordfish are not included in this report, it is worthy of note that it is relatively more important in the Atlantic Ocean than in the other oceans. Albacore and bluefin were formerly the most important species. The albacore catches have been more-or-less stable since the early 1960s. The bluefin catches increased until 1996 and thereafter slightly decreased, most likely due to the catch quotas introduced by ICCAT.

In the Indian Ocean the catches of skipjack and yellowfin have been increasing since 1982, as a result of rapid development of the purse-seine fishery in the western Indian Ocean (Section 4.4). Since then the catches of those two species have been much greater than those of the other species. During the 1990s, however, the catches of yellowfin have been stable, or have even declined slightly, while those of bigeye have increased rapidly.

In the Pacific Ocean the catches of skipjack and yellowfin began to increase during early 1970s, much earlier than in the Indian Ocean. The catches of skipjack have exceeded those of yellowfin since the mid-1970s, and the dominance has become more pronounced in recent years. The relative importance of the catches of bigeye and albacore are less than in the other two oceans.

The world catches of the principal market species of tunas, by species and gear, are shown in Figure 6. The longline contribution to the albacore catch increased during the 1950s and early 1960s, and in recent years it has accounted for more than half of the total catch. Albacore is also harvested by pole-and-line gear, mostly in the Pacific Ocean, with peak catches during the mid-1970s.

The greatest share of the catch of bluefin has been made, by purse seiners, mainly in the northeastern Atlantic Ocean during earlier years and in the Mediterranean Sea and near Japan during recent years. The longline catch has been less important, with two peaks, one during the 1960s (mostly of fish caught off Brazil) and one in the mid-1990s. Other gears include traps, gillnets and handlines. The catch by traps was very important in the Atlantic Ocean during earlier years.

Bigeye catches were taken almost exclusively by longline gear prior to the mid-1970s. The longline catches increased until early 1990s, and then stabilized. While longline catch has been stable in recent years, the purse-seine catch has been increasing since the early 1990s, so the total catch continued to increase during the 1990s. The increased catch of bigeye by purse seiners is due mainly to increased use of FADs.

FIGURE 4
Total world catches of the principal market species of tunas, by species

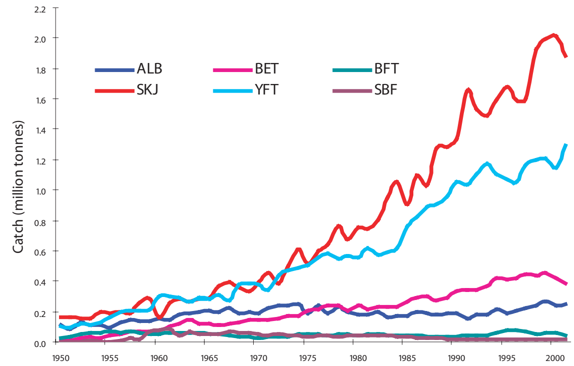


FIGURE 5
Total catches of the principal market species of tunas, by ocean and species

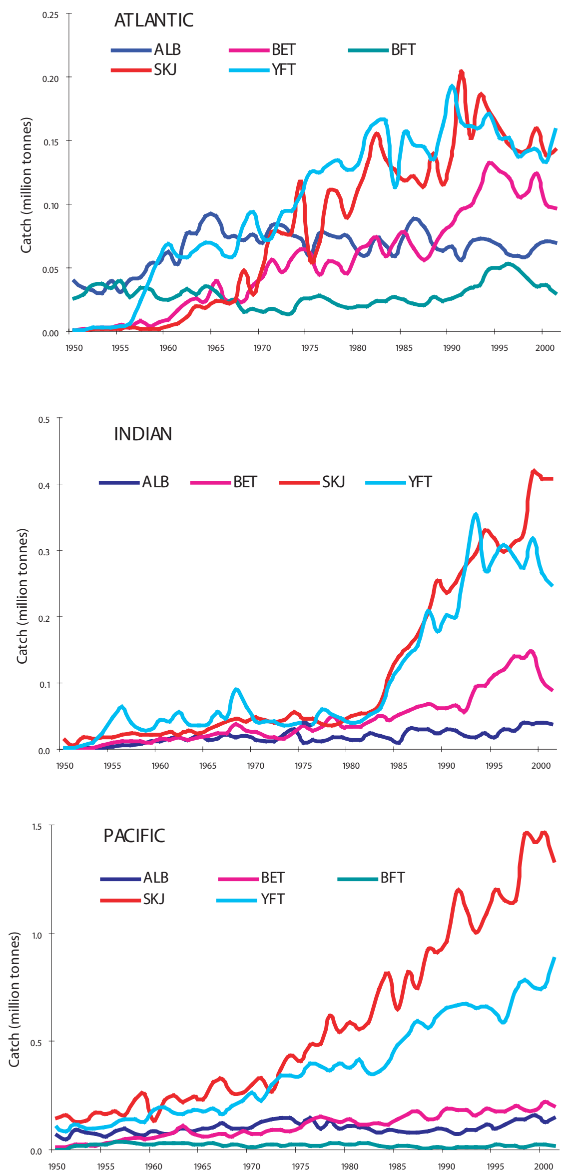
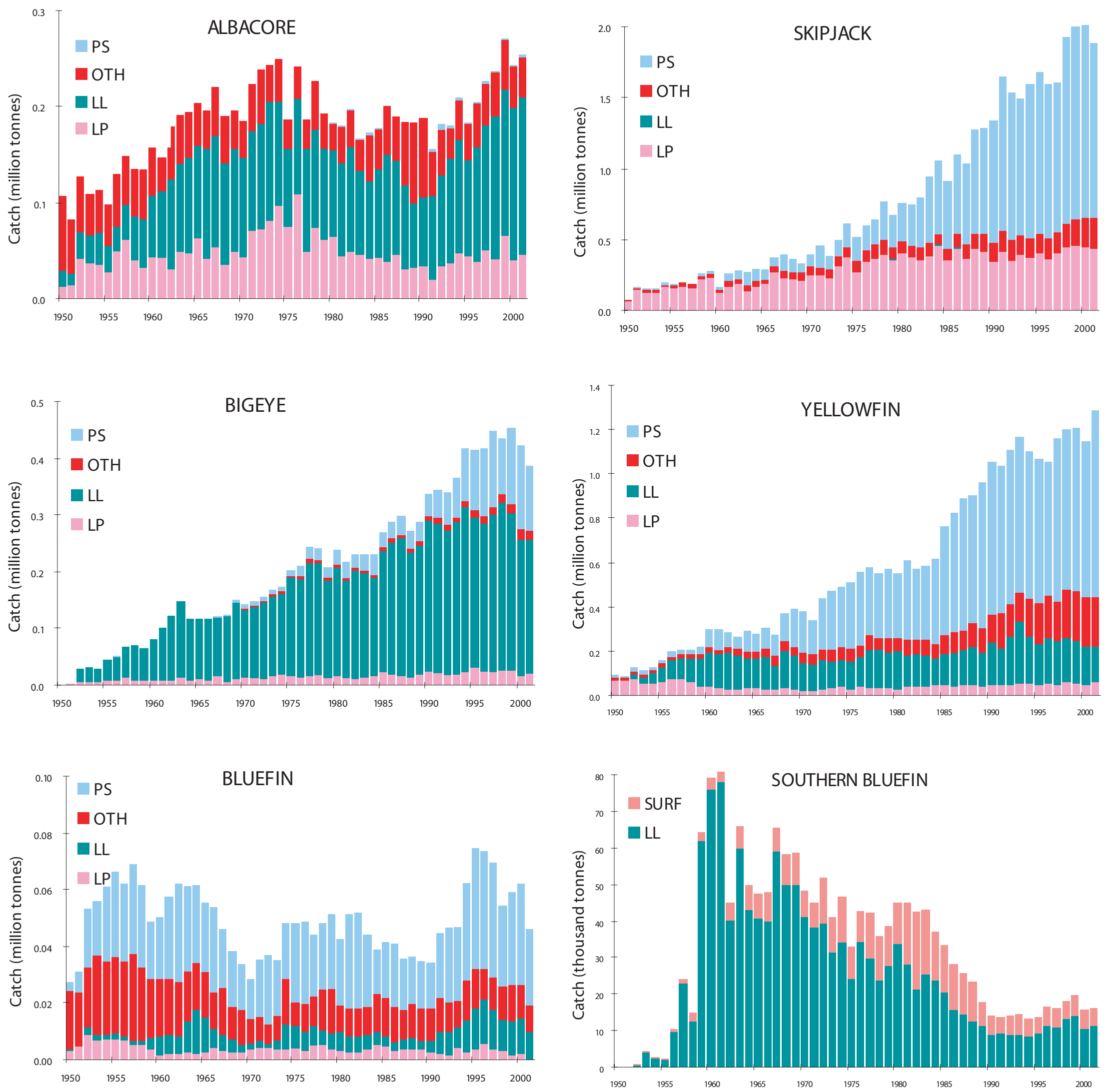


FIGURE 6
Total catches of the principal market species of tunas, by species and gear. It should be noted that scales are different and that the scale for southern bluefin tuna is in thousands of tonnes



In general, the catches of skipjack and, to a lesser extent, yellowfin have dominated the world catches of tunas. Purse seines have increased their share of the catch to more than 60 percent of each of the two species. The catches of both species increased rapidly during the period (Figure 6). The increase in the catch of yellowfin slowed during the 1990s to a level of about 1 to 1.2 million tonnes (over 25 percent of the total), while the skipjack catch is still increasing, reaching its highest level of 2 million tonnes in 1999 (50 percent of the total). It should be noted that in 1999, when the world market price of skipjack declined due to oversupply, the purse-seine industry created the World Tuna Purse-seine Organization (WTPO) to limit the catch of skipjack.

The catch of southern bluefin increased rapidly until 1961 but after that it declined until 1990, after which it stabilized. The downward trend during the 1970s was due to voluntary catch restrictions by Japan, Australia and New Zealand, and, after that, during the 1980s, to regulations adopted by the CCSBT. During the earlier years the catches were made almost exclusively by longlines, but more recently the catches by surface gear, including gillnets, pole-and-line gear, and purse seines, have increased.

4. REVIEW OF HISTORICAL DEVELOPMENT OF TUNA FISHERIES

This section gives a brief overview of the development of the most important fisheries during the last 50 years. Some developments were the result of the technological improvements discussed in Section 2; some were more related to national and international policies for management of fish stocks and/or fishing fleets or to socio-economic elements. All these elements interact with one another and are often specific to countries, fisheries or fishing gears. The proportions of the world catches of the principal market species of tunas (not including southern bluefin tuna) taken by various fishing gears are shown in Figure 7. The proportions of the catches taken by purse-seine and other gears have increased, and that taken by pole-and-line gear has decreased. The proportion of the catches taken by longline gear increased to the mid-1960s, and decreased after that.

4.1 Overview by decades

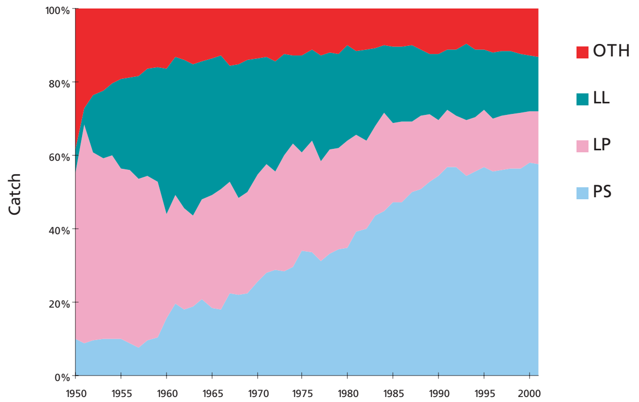
Pre-1950s: Tuna fishing has been carried out in various parts of the world for many years. Those fisheries take place near coasts and islands. In the Atlantic Ocean these include purse seining for bluefin off Norway, trolling for albacore in the Bay of Biscay, trap fishing at the Strait of Gibraltar and along the coast of North Africa, bigeye and skipjack fishing near islands and artisanal fishing along the coast of West Africa. In the Pacific Ocean these include various artisanal fisheries near islands in tropical waters, albacore trolling off the west coast of the United States, pole-and-line and purse-seine fishing for yellowfin and skipjack by vessels based in California, pole-and-line, gillnet and purse-seine fishing by vessels based in South America, fishing for various species of tunas with various types of gear near Japan and fishing for skipjack and yellowfin in tropical waters of the western and central Pacific. In the Indian Ocean these include fishing for skipjack off Sri Lanka, India and the Maldives. Longline fishing for southern bluefin tuna took place off Australia.

1950s: Most of the fisheries that took place before 1950 continued during the 1950s. As a result of the increasing demand for tuna as a substitute for salmon in the canning industry, industrialized tuna fisheries began during the 1940s and 1950s. The Japanese longline fishery expanded, reaching the western Atlantic Ocean in 1957. Pole-and-line fishing continued in the eastern and in the western and central Pacific Ocean, and, during the late 1950s, European pole-and-line vessels fished in coastal waters off West Africa. A purse-seine fishery for bluefin tuna existed in the northeastern Atlantic Ocean, and toward the end of this decade purse-seine fishing for tropical tunas increased in the eastern Pacific Ocean.

1960s: European purse seiners began fishing for tropical tunas off West Africa in 1964. In the tropical eastern Pacific Ocean, off Central and South America, pole-and-line fishing was almost completely replaced by purse seining. A large portion of the yellowfin caught in this region is taken in association with dolphins. In accordance with a recommendation by the IATTC, a quota on the catch of yellowfin was adopted in 1965 (which would first take effect in 1966).

In the western and central Pacific Ocean the number of pole-and-line vessels increased, and the area of operation expanded (Suisanshinchosha, 1970). The catch reached a level of 250 000 tonnes. Due to the lack of data, the pole-and-line catches in the

FIGURE 7
Proportions of the world catches of the principal market species of tunas taken by various fishing gears



western and central Pacific Ocean are not shown in Appendix 2, Figure 3. Longline fishing further expanded into the Atlantic and Indian Oceans, covering most of the world oceans between 40°N and 35°S. The target species were still yellowfin and albacore (Figure 8). Again due to the lack of data, the longline catches in the Indian Ocean are not shown in Appendix 2, Figure 1.

1970s: The fishery in the tropical eastern Atlantic Ocean by purse seiners of European nations developed rapidly, with the primary catches being yellowfin and skipjack. Although strict regulations for the reduction of mortality of dolphins associated with tuna were implemented in the eastern Pacific Ocean, the fishery continued to develop there. However, some effort was diverted from the eastern Pacific to the western and central Pacific, where tunas do not associate with dolphins.

Pole-and-line fishing in the tropical eastern Atlantic and the western and central Pacific expanded in both fleet size and areas in which fishing took place. In contrast, the pole-and-line fishery in the eastern Pacific declined after the middle of the decade.

With the development of facilities for extremely cold storage and deep longline gear (Section 2), the longline fishery gradually changed its target species from albacore and yellowfin to bigeye (Figure 8). The changes affected the fishing areas and seasons, in addition to the species compositions of the catches.

1980s: More regulatory measures were introduced by the IATTC and ICCAT, which affected the fishing patterns, species compositions of the catches and the shares of the catches taken by vessels of various countries.

The purse-seine fishery that begun experimentally in 1974 in the western Indian Ocean expanded rapidly, as vessels that fished in the eastern Atlantic Ocean transferred their operations to the Indian Ocean. The fishing effort in the western and central Pacific and the eastern Pacific increased, and the effort expanded further offshore.

Pole-and-line fishing in the western and central Pacific and eastern Atlantic continued, and new pole-and-line fisheries began in the Atlantic off Brazil and off southern Africa

Deep-longline fishing, targeting bigeye, which was first carried out by Japanese vessels, was adopted by vessels of other nations. There were large changes in the distributions of ownership of longline vessels among the various nations. Small-scale longline fishing operations began in various areas by vessels registered in, among others, several Mediterranean countries, the Philippines and Indonesia.

1990 to present: More and more management measures have been introduced, and these have been circumvented by registration of vessels in countries that do not require their vessels to abide by the restrictions adopted by the international organizations responsible for the management of the fisheries. This illegal, unreported and unregulated (IUU) fishing jeopardizes the management of the fisheries, and has contributed to the increase of total tuna fishing capacity over most of the world.

The most important change for surface fishing is the introduction of FADs. The use of FADs has increased the catches of skipjack and small yellowfin, and especially bigeye, which were seldom taken by surface gear prior to the 1990s. Additional information on FADs is included in Section 4.4.

Pole-and-line fishing continued in the eastern and western Atlantic and in the western and central Pacific. The actual situation is not well represented in Appendix 2, Figure 3, as an important part of the data is missing.

Coastal states had begun chartering vessels registered in other countries during the 1980s, and this trend accelerated during the 1990s. Some of these chartered vessels changed flags to those of the coastal states, and this practice may be intensified in the near future. Partially due to the development of these new coastal fisheries, the fishing effort by traditional longline-fishing countries began to decline.

Tuna farming (keeping tuna in enclosed areas for several months to increase their fatness and have them ready for sale when the prices are higher) began during the 1990s, and nearly 20 000 tonnes of these were sold in 2000. The relatively small tunas taken by purse seiners that were formerly sold for canning can now be converted to products for the *sashimi* market. Until now, tuna farming has been pursued almost entirely with bluefin tuna, but the practice is spreading to bigeye and yellowfin tuna.

Small-scale longline fishing increased extensively, while the numbers of longline vessels that fish legally have decreased due to industry initiatives to limit fishing capacity.

The catches of artisanal fisheries (e.g. trolling, gillnets, handlines and miscellaneous unclassified gears) increased in the coastal and island countries.

4.2 The large-scale longline fisheries

The world catches of tunas by large-scale longline vessels are shown in Figure 8. As the catches by coastal small scale longliners have increased significantly during recent years, the catches by large-scale longliners are actually declining. The distributions of the catches of all species combined during representative years of the last four decades are shown in Appendix 2, Figure 1, and the distributions of the catches of four species during 1998 are shown in Appendix 2, Figure 4.

4.2.1 Summary

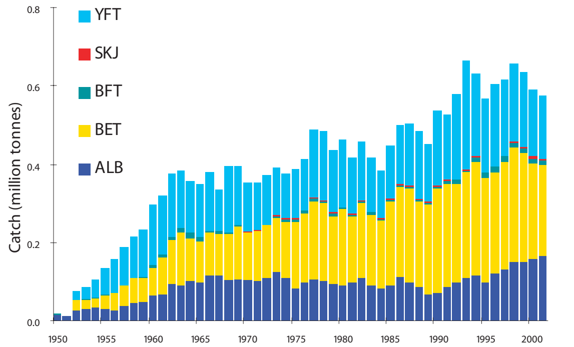
The longline catches of the principal market species of tuna increased rapidly during the 1950s, and during the 1960s more than 40 percent of the world catch was made by longline gear (Figure 7). The rate of increase was less from 1960 to 1990, and then somewhat greater from 1990 to 1993. After 1993 the longline catches have been declining. Due to the increased catches by purse-seine gear, longline gear now takes less than 20 percent of the total catch (Figure 7). During the earlier years the catch was taken almost exclusively by offshore longliners of Asian countries, which targeted yellowfin and albacore. During more recent years, with the entry of more coastal longliners into the fishery, the offshore longliners have directed their efforts more toward bigeye, bluefin, and southern bluefin, whereas the coastal longliners are mostly targeting yellowfin and bigeye.

4.2.2 Initial developments

Japanese vessels have always dominated the longline fishery for tunas, and all the technological developments discussed in Section 2 originated in Japan before being adopted by vessels of other nations. The only exceptions are some of the North American and European longline fisheries, which direct their effort mostly at swordfish.

The Japanese tuna fleet existed at the end of the 19th century, and 48 615 tonnes of tunas were caught in 1894 (Matsuda and Ouchi, 1984). The fishery expanded rapidly to the offshore waters of the western Pacific Ocean, with the boats using longline and pole-and-line gear alternatively, depending on the season. When Japan obtained the ex-Trustee Territories (0°-22°N, 130°-170°E) after World War I, facilities for producing dried skipjack sticks (*katsuobushi*) were constructed in Saipan and the Marshall Islands, and engine-powered vessels began fishing in those waters. This was probably the first industrialized tuna fishery in the world. The Japanese catch of tunas reached 202 439 tonnes in 1940, just before World War II.

FIGURE 8
World catches of the principal market species of tunas by large-scale longline vessels



4.2.3 The world-wide longline fishery

After World War II, which ended in 1945, the Japanese fishery was restricted to the nearshore areas. This restriction was lifted in 1952, and the fishery expanded rapidly. The expansion was assisted by the development of air-blast freezing to replace ice wells (Gyosen Kyokai, 1986). The fishing grounds expanded to the western and central Pacific Ocean, the eastern Pacific Ocean, the western Indian Ocean and the western tropical Atlantic Ocean during the 1950s. In 1958 the total longline catch reached 200 000 tonnes. During the initial post-war stage, the catches were frozen and maintained at about -20°C. The color of the flesh changed to brownish when the fish were thawed. These fish were not acceptable for consumption as *sashimi*, so the catch was mostly exported for canning. The vessels looked for the fishing grounds with high catch rates, regardless the species. The catches in tropical waters were mostly yellowfin, with some bigeye, and those in temperate waters were mostly albacore (which drew higher prices than yellowfin). At this stage, motherships of more than 3 000 GRT were widely used. There were two types of mothership, ones that accompany several independent longliners and ones that carry several small longliners on the deck. Foreign fishing bases were established in 1952. These had facilities for providing supplies to the vessels, receiving the catches for transshipment, and exchanging crew members. This contributed to the expansion of the fishing areas.

By the mid-1960s Japanese longliners were operating all over the world (Appendix 2, Figure 1). The Taiwan Province of China and the Republic of Korea began longline fishing during the early 1960s, mostly with used Japanese longliners with Japanese captains. At the same time vessels owned by residents of Japan, but registered in other countries ("flags of convenience"; FOC), entered the longline fishery. The Japanese government's policy of limiting entries to the tuna fishery was partially responsible for the growth of the Taiwan Province of China, Korean and FOC fleets.

Vessels of the Taiwan Province of China, Republic of Korea and FOCs had no domestic market for their catches, so they were sold in foreign markets for canning and later to the Japanese market for *sashimi*. Their fishing patterns were quite similar to those of the Japanese vessels, although the Taiwan Province of China and Korean vessels directed more effort toward albacore and yellowfin, respectively. This tradition has been maintained even to the current time. Since most of the Japanese foreign bases were operated by fishing or trade companies, the business of Taiwan Province of China, Korean and FOC vessels were accepted. Some bases were even maintained by a Japanese firm solely for non-Japanese vessels.

4.2.4 The sashimi fleet

A new era for the longline fishery began with the development of the extreme cold freezing and storage facilities (-40°C) in 1965. The use of such facilities had become common by 1969, with the fish frozen at -55°C (Gyosen Kyokai, 1986). The fish are frozen, and kept at temperatures that are low enough to prevent them from losing their fresh colour and flavour, and hence can be sold to the *sashimi* market. Consequently the longliners shifted their effort from fish used by the canning industry (yellowfin and albacore) to fish bringing the highest prices from the *sashimi* market, (bluefin and bigeye). The changes affected the fishing areas and seasons, in addition to the species compositions of the catches.

Adoption of extreme cold storage facilities changed the entire operating system, as most of the foreign-based cold storage facilities, except for those built in recent years, could not keep the fish at such low temperatures. The catches had to be taken back to Japan, either by the fishing vessels or by special freezer ships to which the fish were transferred in foreign ports or at sea. Also, mothership operations were terminated by 1975, due to their economic inefficiency.

At about the same time (the latter half of the 1960s), the Japanese industry developed several labor-saving devices, including: a line-casting device; a new method to attach and detach the branch lines; a line-hauling drum; a line winder; and, somewhat later, an automatic bait-attaching device. (The line-hauling drum and automatic bait-attaching device have not come into wide usage due to their bulk and technical complexity, but the others have been useful to the industry.)

Following the development of the extreme cold freezing facilities and the change in target species, the next important change, adoption of deep longlining gear, began during the late 1960s. The only change to the gear was decreasing the numbers of floats and attaching more branch lines between floats. Conventional line gear has four to six branch lines between floats, and fishes at 30 to 100 metres, while deep longline gear has up to 18 branch lines between floats and fishes at depths of more than 200 metres. Deep longlining gear, which has proven to be more efficient at catching bigeye, is now being used by almost all the Japanese longliners.

In 1967 double-deck longliners, which are more efficient for operations in the rough seas of higher latitudes, came into usage by vessels targeting bluefin and southern bluefin tuna.

Taiwan Province of China, Korean and FOC vessels adopted extreme cold freezing facilities and deep longlining about six to eight years after the Japanese vessels had done so. However, lesser portions of the Taiwan Province of China, Korean and FOC vessels have adopted these systems because the non-Japanese vessels tend to be older, and installation of new freezing facilities would not be economically feasible.

4.2.5 Initiatives in reducing fleet size and IUU fleet

During the 1980s the size of the Japanese longline began to decline, due to competition in the domestic market with the catches of Taiwan Province of China, Korean and FOC vessels, soaring labor and fuel costs, declining catch rates and a shortage of labor due to competition with other domestic industries. The growth of the Korean fleet began to slow down, but not that of the Taiwan Province of China fleet. Vessels of China entered the longline fishery during the 1990s. Their patterns of development have been almost identical with those shown by Taiwan Province of China and Korean vessels during the 1980s.

The FOC fleet changed its nature completely after the mid-1980s. During the 1980s, and increasingly during the 1990s, regulatory measures were adopted by the CCSBT, the IATTC, ICCAT, and the IOTC, henceforth referred to as Regional Fishery Management Organizations (RFMOs). As the measures were mandatory only to the contracting parties, some boat owners changed the registrations of their vessels to other nations that were not members of the RFMOs, and thus not subject of the regulations. The catches of old-type FOC vessels were generally reported by the countries in which their owners resided. However, data for the new-type FOC vessels are not available. Collectively, these vessels are known as Illegal, Unreported and Unregulated (IUU) fleet. Solutions for this problem were sought by the RFMOs, FAO and at the national level, and some effective measures, including trade restrictions, have been taken, so the size of IUU fleet is becoming reduced. At that time, the Taiwan Province of China and the Republic of Korea adopted limited-entry licensing system, but China continued to increase its fleet size. Finally, in 2001, China adopted a limited-license system.

FAO adopted its International Plan of Action (IPOA) for the Management of Fishing Capacity in 1999. In accordance with the spirit of the IPOA, Japan reduced its total fleet size by 20 percent in 2001. In 2002 the Organization for the Promotion of Responsible Tuna Fisheries (OPRT), an international organization of tuna industries of the major longline countries, was founded to reduce the amount of IUU fishing by changing the registrations of the FOC vessels to the countries in which their owners reside and then to scrap the excess vessels or convert them to some other use.

4.2.6 Other longline fleets, including swordfish longliners

The major large-scale longline fleets are discussed above. However, there are many longline fisheries in various parts of the world that are descendants of the Japanese longline fishery. These were introduced by the Japanese immigrants (Hawaii, Brazil, Mexico), created by transference of technology through establishing a fishing base (Venezuela, Brazil), or the result of charter arrangements through joint-ventures (Brazil, Uruguay, Canada, Iceland, Panama and Honduras). The vessels of those fleets are using gear and operating systems similar to those used by Japanese vessels, but sometimes at earlier stages in their development.

The only tuna longline fisheries that are not the direct descendants of the Japanese fishery are North American and European (Spain and Portugal) swordfish fisheries. These fisheries began during the 1970s, when restrictions on the mercury content of the fish were lifted in the United States. The swordfish longline fishery uses steel leaders and fluorescent light sticks to attract the fish. The gear is set at night, and the hooks are much closer to the surface than are hooks set for tunas. Monofilament main lines have been used since the late 1990s. The lines are installed into a drum. Normal tuna longline vessels (particularly those of the Taiwan Province of China) occasionally direct their effort at swordfish, depending on the area and season of operation. Those vessels use the same gear as for tuna, but add floats so that the hooks will fish closer to the surface, and set the gear at night.

4.3 The small-scale longline fishery

The small-scale longline fishery has also had a long history. Much of the technology was inherited from that used by Japanese large-scale longliners. During 1928-1929, Japan established a tuna base at Kaosiung, Taiwan Province of China, which was under its jurisdiction at that time. In 1937 200 vessels of about 14-15 gross tons based in Kaosiung were fishing at distances of up to 1000 miles from this base. Japan also established fishing bases in what are currently Indonesia and the Philippines. In 1940 139 033 tonnes of tunas were caught by these vessels (Matsuda and Ouchi, 1984).

After World War II these vessels resumed fishing in these areas and became coastal small-scale tuna fleets. The small-scale fleet in the Taiwan Province of China was the basis for the development of the large-scale longline fleet of the Taiwan Province of China during the 1960s, but at the same time the small-scale longliners based in the Taiwan Province of China continued to fish, and the numbers of such vessels increased. Their fishing grounds are mostly in the western Indian Ocean, the East China Sea and the tropical western Pacific Ocean. Except for bluefin tuna in the East China Sea in the summer, the target species are yellowfin and bigeye tunas. During the late 1980s these small-scale longliners expanded their fishing grounds toward the west and south and began landing their catches at foreign ports, mostly in Indonesia and Thailand. During the 1990s the catches increased rapidly, in respond to an increase in demand and better transshipment of the catches by air. These catches might have amounted to well over 100 000 tonnes by the early 2000s. The most of these vessels preserve their catches with ice. The fish of best quality are shipped by air to Japan for the *sashimi* market, while most of the rest are shipped to the United States for the fresh fish market. There is also some local consumption in the Taiwan Province of China and the Republic of Korea.

The author has tried to separate the catches by small-scale longliners from the total longline catch. This is difficult, however, as most of the catches of small longliners are not reported separately, or are reported as the catches of "unclassified" gears.

Small-scale longline fishing for tunas began on the east and west coasts of the United States during the 1980s. The techniques were not derived from those of Japanese longliners, but are more similar to salmon longline gear, which uses a drum reel for the main line. Small-scale longline fisheries, using similar systems, is beginning in many other parts of the world, e.g. Australia and Reunion.

4.4 The purse-seine fishery

4.4.1 Summary

The proportions of the world catches of the principal market species of tuna, by fishing gear, are shown in Figure 7, and the world purse-seine catches of the principal market species of tuna by species, are shown in Figure 9. It is apparent from these two figures that during the 1950s only about 10 percent of the catch was taken by purse seiners and that most of that catch was bluefin tuna. However, the purse-seine catches increased greatly during the second half of the 20th century, from almost nothing during the early 1950s to about 2.2 million tonnes in 2000 (Figure 9). By the mid-1970s the purse-seine catch exceeded that of any other gear, and by the mid 1980s the purse-seine catch exceeded those of all other gears combined (Figure 7). The major species caught since 1960 have been skipjack and yellowfin. The catches of bigeye began to increase during the early 1990s, but the catches of this species are still far less than those of skipjack and yellowfin. The leveling off of the catches of skipjack during the late 1990s and early 2000s is at least partly the result of catch controls adopted by the purse-seine fishing industry.

The distributions of the catches of all species combined by purse seiners during representative years of the 1960s, 1970s, 1980s and 1990s are shown in Appendix 2, Figure 2, and those for the individual species for 1998 are shown in Appendix 2, Figure 4. Bluefin were first caught by purse seiners off California in 1915 (Scofield, 1951), and yellowfin and skipjack were being caught by purse seiners in the eastern Pacific Ocean "since immediately after World War I" (Shimada and Schaefer, 1956). During the early years most of these vessels also fished for sardines and mackerel, but later some of them fished exclusively for tropical tunas. Bluefin were being caught by Norwegian purse seiners in the northeastern Atlantic Ocean during the 1950s.

4.4.2 Old-type seiners

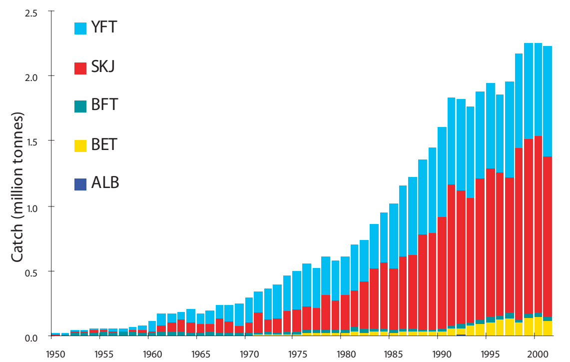
Historically, there are two major types of purse-seining for tunas, single-boat seining and double-boat seining. Double-boat seining started much earlier than single-boat seining, but single-boat seining is now predominant.

4.4.3 Modern seiners

The following events during the 1950s contributed to the development of the modern purse-seine fishery for tunas: invention of the hydraulic power block, which facilitated handling of the net; availability of synthetic netting, which did not deteriorate even in the tropics; and, better facilities for freezing the fish (Orange and Broadhead, 1959; McNeely, 1961). The power block made it possible to retrieve larger nets in less time and reduced significantly the possibility of fish escaping from the bottom of the net. As the catch rates of purse seiners were greater than those of pole-and-line vessels, purse seining rapidly replaced pole-and-line fishing in the eastern Pacific Ocean during the late 1950s and early 1960s (although small numbers of pole-and-line vessels continued to fish in that area through the rest of the 20th century). In the Atlantic Ocean the purse-seine fishery for tropical tunas began in the Gulf of Guinea area in 1964, using vessels similar to those of the eastern Pacific Ocean. However, purse seining did not supplant pole-and-line fishing as much as it had in the eastern Pacific Ocean.

FIGURE 9

World catches of the principal market species of tunas by purse-seine vessels



Schools of medium to large yellowfin are frequently associated with dolphins in the tropical eastern Pacific Ocean, and fishers took advantage of this relationship by herding the dolphins, with the tuna, into the net, after which they released the dolphins and retained the tuna (Perrin, 1969). The catch rates were high, and, since the market prices of yellowfin were greater than those for skipjack, this type of fishing was attractive to vessels large enough to use the equipment necessary for fishing for yellowfin associated with dolphins.

4.4.4 Growth of the purse-seine fleet

In 1966 the Inter-American Tropical Tuna Commission (IATTC) adopted a TAC for yellowfin tuna. The regulation allowed a vessel that left port before the TAC took effect to fish freely until the end of that trip. This triggered an increase in carrying capacity of the vessels, resulting in a significant increase in the total capacity of the purse-seine fleet.

Unfortunately, fishing for tunas associated with dolphins resulted in mortality of dolphins that were not able to escape from the nets. The United States adopted the Marine Mammal Protection Act (MMPA), the objective of which was to eliminate or minimize the mortality of marine mammals caused by the fishery for tunas (Joseph, 1994). Consequently, some United States vessels were sold to owners in other countries, and some transferred their operations to other areas, mainly the western and central Pacific Ocean. Also, new vessels were constructed for owners in other countries.

In the western and central Pacific Ocean Japanese two-boat purse seiners, using deeper and longer nets, had been fishing for tunas since the 1960s. Since the thermocline is deeper in the western Pacific than in the eastern Pacific, the United States vessels that transferred their operations there had to use deeper, faster-sinking nets.

Purse-seine fishing developed rapidly in the Atlantic Ocean during the 1970s, mostly by Spanish and French vessels; but also by vessels of the United States, Canada and the Soviet Union. Also, there were some FOC vessels with French or Spanish captains and crews.

Purse-seine fishing by European vessels based in the Seychelles began in the western Indian Ocean during the 1980s, and developed rapidly.

During the mid-1980s (particularly in 1984), the catch rates in the eastern Atlantic Ocean declined sharply, while those in the western Indian Ocean remained high. As a result, many European purse seiners transferred their operations from the Atlantic to the Indian Ocean. By that time, United States purse seiners were no longer fishing in the eastern Atlantic. Development of the Indian Ocean fishery and a subsidy program for construction of fishing vessels adopted by the European Community (EC), led to expansion of the European purse-seine fleet. Although a licensing system was in effect for the EC, when a new vessel entered the fishery, the registration of the one that it replaced was changed, but the vessel remained in the fishery. At the same time, introduction of various equipment (e.g. bird radar and select-call radio buoys in the 1980s and radio buoys and GPS tracking in the 1990s; see Section 2), increase in the size of the vessels and accumulated experience have led to greater fishing efficiency.

Many newcomers entered the purse-seine fisheries for tunas during the 1990s. Vessels of the Republic of Korea and the Taiwan Province of China began fishing in the western and central Pacific Ocean, and these fleets are still growing. Many other Central and South American countries began fishing for tunas in the eastern Pacific Ocean. Some of these were bought from owners in the United States, some were constructed for owners in Latin America, and some fly FOCs. FOC vessels are also very common in the Atlantic and Indian Oceans. To some extent, this reflects the desire of island nations in the western and central Pacific Ocean and coastal developing states in the Indian Ocean to participate in purse seining for tunas. At the time this is written, no purse-seine fleets have been identified as IUU fleets.

4.4.5 Fish-aggregating devices

Schools of tuna frequently associate with flotsam, such as tree parts and lumber lost or discarded at sea (Le Gall, Cayré and Taquet, 2000). Purse-seine fishers have taken advantage of this association by searching for flotsam and making sets around or near the flotsam when there are sufficient amounts of associated fish. This method of fishing was originated in the eastern Pacific Ocean during the 1960s, and has been a major part of the fishing operations in the western and central Pacific Ocean since the 1970s. When fishers found a piece of flotsam they sometimes attached a reflector or a radio buoy to it to assist them in locating it later.

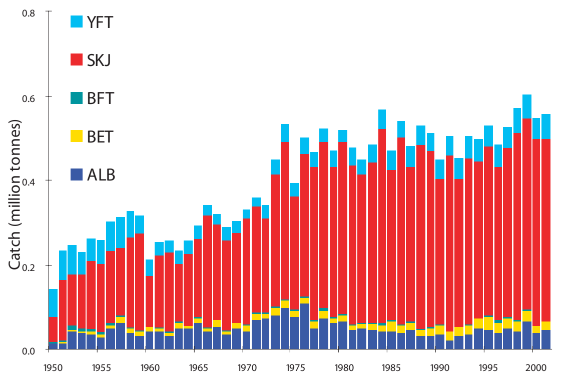
Fishers then began to construct artificial fish-aggregating devices (FADs). Anchored FADs have been used in the western Pacific Ocean for many years by Philippine and Japanese fishers, and further experiments were conducted in the Pacific and Indian Oceans during the 1980s. Drifting FADs were used on a larger scale in the Atlantic Ocean during the early 1990s and shortly thereafter in the Pacific and Indian Oceans. Sophisticated methods of fishing and the use of ancillary vessels began during the 1990s. In the Atlantic about 60 percent of operations are on FADS in recent years, 89 percent (1999) in the East Central Pacific, and 79 percent (1999) in the Indian. In the eastern Pacific Ocean in 2003 19 percent of the sets were made on floating objects, and 86 percent of those sets were made on FADs. The vast majority of the FAD sets in the eastern Pacific Ocean are made between 10°N and 15°S.

Fishing on floating objects, including FADs, is often more profitable than other types of fishing, as the catch rates are higher and the expenditures for fuel and vessel maintenance are less. The sizes of individual yellowfin and bigeye tend to be less than those of yellowfin and bigeye caught by other types of purse-seine sets and much less that those of yellowfin and bigeye caught by longliners. Also, the bycatches of species other than tunas, such as sharks, dorado and wahoo, many of which are of commercial value to other fishers, are greater in floating-object sets than in other types of sets. The recent increases in the catches of bigeye by purse-seine gear are almost entirely the result of fishing for tunas associated with floating objects. In order to reduce the catches of these small fish, voluntary and mandatory restrictions on FAD fishing have been in force in the eastern Atlantic Ocean (since 1997), in the Indian Ocean (in 1998 only) and in the eastern Pacific Ocean (in 2001 only).

4.5 The pole-and-line fishery

The proportion of the catch of the principal market species of tunas by pole-and-line gear decreased from about 50 percent in 1950 to about 10 percent in 2000 (Figure 7). However, the total catches increased from the early 1950s to the mid-1970s, and then leveled off (Figure 10). The distributions of the catches of all species combined by pole-and-line vessels during representative years of the 1960s, 1970s, 1980s and 1990s are shown in Appendix 2, Figure 3, and those for the individual species for 1998 are shown in Appendix 2, Figure 4.

FIGURE 10
World catches of the principal market species of tunas by pole-and-line vessels



4.5.1 Summary

The catches of the principal market species of tunas by pole-and-line gear exceeded those of any other gear during the 1950s, but have been about equal to those of longliners since about 1960 and less than those of purse seiners since the late 1970s (Figure 3). The pole-and-line catches increased sharply during the early

1970s, and then stabilized at about a half million tonnes after 1975. Pole-and-line vessels now take only about 10 percent of the catch. Skipjack is, by far, the most important species in the pole-and-line fishery (Figure 10). However, pole-and-line vessels take a considerable portion of the total catch of albacore.

4.5.2 Traditional fisheries

Pole-and-line fishing has been conducted, at least since the 19th century. There are two types of fishing, the Portuguese style, which originated in the Madeira Islands, and the Japanese style, which originated in southern Japan. Each keeps live bait aboard the vessel to attract the fish and uses pole-and-line gear to catch them. In the Portuguese style the fishers stand in racks outside the stern of the vessel, while in the Japanese style the fishers stand on the deck on the port side of the vessel. Pole-and-line fishing has spread all over the world. The Portuguese style of fishing still takes place in Angola, Senegal, the west coast of Americas and northern Brazil, while Japanese style of fishing is practiced in Ghana, southern Brazil and the Taiwan Province of China.

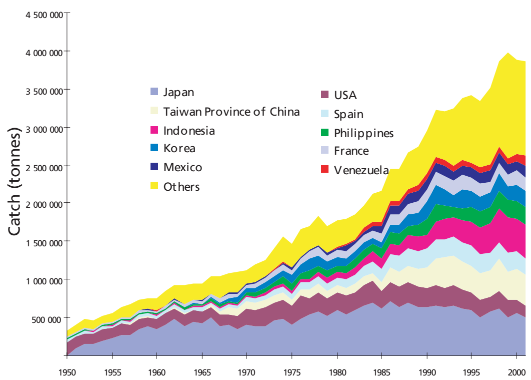
4.5.3 Historical developments

During the 1950s pole-and-line fishing was the predominant method of fishing for tunas. There were important fisheries in the Bay of Biscay (for albacore and bluefin), near various islands in the eastern Atlantic Ocean (e.g. Madeira, where bigeye were caught), the northwestern Pacific Ocean (for albacore) and the tropical eastern Pacific Ocean (for yellowfin and skipjack). During the late 1950s pole-and-line vessels that had been fishing in the Bay of Biscay moved their operations to Senegal and the Congo. As mentioned previously, purse-seine vessels almost entirely replaced pole-and-line vessels in the eastern Pacific Ocean during the late 1950s and early 1960s. In the western Pacific Ocean, due to the greater depth of the thermocline, the initial attempts at purse seining were not very successful. Accordingly, the pole-and-line fishery continued, and the numbers of vessels and the catches even increased. Most of the technological innovations described in Section 2 originated in this western Pacific fishery during the 1960s, the 1970s and even the 1980s. In particular, perfection of systems of closed circulation of refrigerated sea water for the bait tanks made further expansion of the fishing grounds possible.

During the late 1960s Japan began foreign-based pole-and-line operations in the central South Pacific (for skipjack and albacore) and in Gulf of Guinea (for skipjack and yellowfin). In addition, vessels based in Japan participated in these fisheries. During the 1970s Japanese pole-and-line vessels began to withdraw from the Gulf of Guinea fishery, but they were replaced by Korean, and later by Ghanaian, pole-and-line vessels. The Japanese vessels that were withdrawn from the Gulf of Guinea fishery started a new fishery off the southern Brazil. A few years later, during the mid-1970s, Portuguese fishermen started a pole-and-line fishery based in Rio de Janeiro, Brazil. More recently, local pole-and-line fisheries have developed in many places, including Indonesia, the Philippines, Namibia and South Africa.

A new fishing method, which uses a non-fishing vessel carrying live bait as a floating object to attract and maintain fish schools and two pole-and-line vessels to catch the fish, was developed in Senegal during the late 1980s (Fonteneau and Diouf, 1994). This method was introduced to the Canary Island pole-and-line fishery during the mid-1990s.

FIGURE 11
World catches of the principal market species of tunas (other than southern bluefin) by country



5. CATCHES BY COUNTRY

The world catches of the principal market species of tunas (other than southern bluefin) are shown in Figure 11. The catches of Japan have exceeded those of any other country throughout the second half of the 20th century, although they have leveled off since the mid-1980s. The catches of the United States were second to those of Japan until the mid-1980s, but after that its catches have been exceeded by those of the Taiwan Province of China and Indonesia. The catches of the Philippines and Mexico also increased considerably after the mid-1980s.

The catches by the top ten tuna producers are individually plotted by oceans in Figure 12. Japan, the Taiwan Province of China and the Republic of Korea have

FIGURE 12
World catches (tonnes) of the principal market species of tunas (other than southern bluefin) by ocean by the top ten producers of tuna

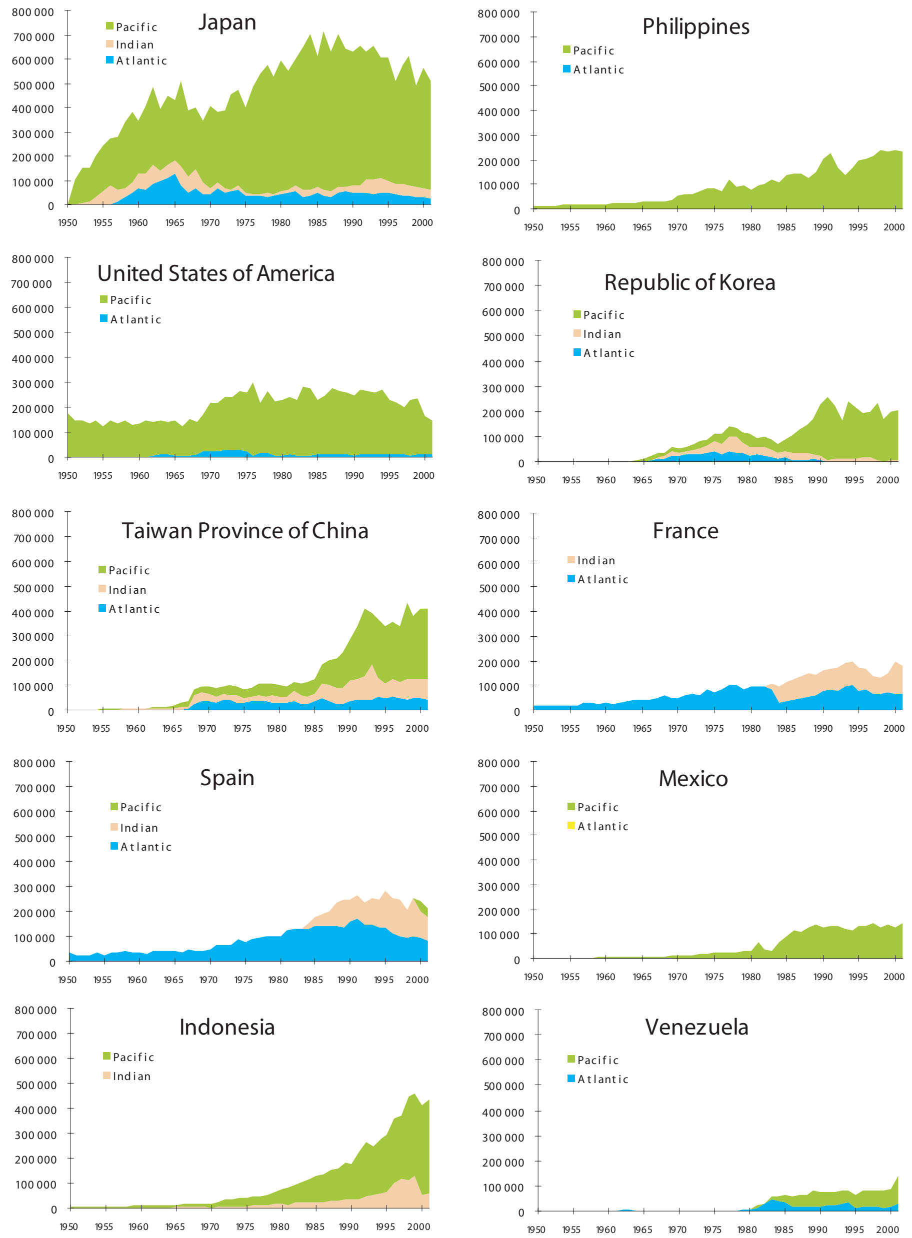
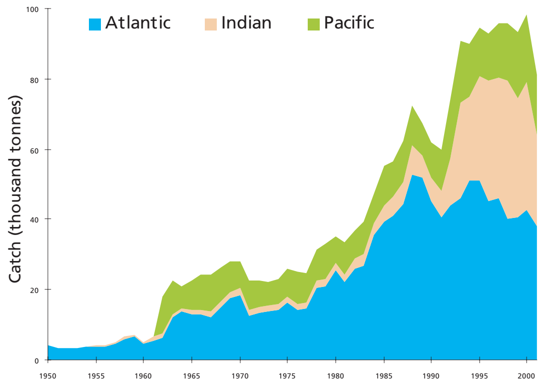


FIGURE 13
World catches of swordfish, by ocean



tuna fisheries in all three oceans. The fisheries of the Taiwan Province of China and the Republic of Korea developed later than those of Japan, but in recent years the catches of the Taiwan Province of China have exceeded those of Japan in the Indian and Atlantic Oceans. Spain and France are major participants in the purse-seine fisheries of the Atlantic and Indian Oceans, and in recent years Spanish purse seiners have fished in the eastern Pacific Ocean. Vessels of Indonesia fish in both the Pacific and Indian Oceans. Vessels of the other countries, the United States, the Philippines, Mexico and Venezuela have fished mostly in the Pacific Ocean. During most of this period the catches of the United States were made mostly in the eastern Pacific Ocean, but more recently they have been made mostly in the western and central Pacific Ocean.

6. SWORDFISH FISHERIES

Swordfish is not one of the principal market species of tunas, so it is not included in most parts of this study. However, swordfish is one of the most important non-target species caught by most of the longliners that target tunas. Also, there are longliners that direct their effort at swordfish, either seasonally or throughout the year, by deploying longline gear specifically designed for the capture of swordfish.

The swordfish catches of the world, by oceans, are shown in Figure 13. The total annual catches increased from 1960 to the early 1990s. Since 1993, however, the catches have been stable at about 90 000 tonnes per year. The catches in the Atlantic Ocean exceeded those in the other two oceans combined until 1994. Even during the most recent years, the Atlantic catch has constituted about half of the world catch of swordfish. On the other hand, the catches of swordfish in the Pacific have been less than those in the other two oceans. The fishery for swordfish in the Atlantic Ocean has been subject to management measures, with quotas since 1991, adopted by the members of ICCAT, which is one of the major reasons that the catches have decreased during the last ten years.

Almost all the catch of swordfish is taken by longlines. Much lesser quantities are taken by harpoons, gillnets and unknown gears.

7. CONCLUSIONS

It is hoped that the effects of the changes in fishing technology and procedures that have taken place and will continue to take place can be quantified. However, it is difficult to evaluate the contribution of each element of the many factors that affect fishing efficiency. Regulatory measures taken by the RFMOs for management of tuna stocks also affect the fishing procedures. Even if these developments cannot be quantified, they must be kept in mind when considering the management of fishing capacity.

There are also many factors that affect fishing capacity. International and national management policy of fleet size and restrictions on operation of fishing vessels are major elements. Those are very complicated and interactive. A policy taken by one country affects the actions of other countries in regard to fleet size and methods of operation, as already seen for the longline and purse-seine fleets. These management policies are related not only to the available tuna resources, but also to socio-economic factors, such as to protecting existing industries. The above factors are not discussed in this paper, as they are covered in other papers in this volume.

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APPENDIX 1

TABLE 1

Total annual nominal catches, in tonnes, of the principal market species of tunas (other than southern bluefin), by ocean

Year	Atlantic	Indian	Pacific	Total
1950	68 223	15 230	250 176	333 629
1951	66 939	9 130	327 156	403 225
1952	75 501	24 254	383 506	483 261
1953	76 405	28 368	358 638	463 411
1954	83 222	52 154	387 512	522 888
1955	82 275	79 570	393 770	555 615
1956	80 313	104 888	453 978	639 179
1957	111 802	80 965	485 957	678 724
1958	134 273	71 018	525 179	730 470
1959	148 403	74 085	525 726	748 214
1960	170 085	93 607	488 363	752 055
1961	163 215	99 457	594 376	857 047
1962	203 520	114 429	615 222	933 171
1963	217 712	92 835	623 151	933 698
1964	237 200	97 190	616 117	950 507
1965	253 201	100 043	592 141	945 385
1966	204 523	132 263	703 971	1 040 756
1967	210 136	137 496	704 291	1 051 923
1968	243 756	192 129	650 160	1 086 044
1969	254 080	155 984	690 470	1 100 534
1970	253 115	127 476	748 736	1 129 326
1971	308 421	119 639	773 782	1 201 843
1972	316 571	113 163	824 916	1 254 651
1973	320 788	118 661	971 088	1 410 537
1974	385 512	150 049	1 034 802	1 570 364
1975	327 928	131 800	1 001 683	1 461 410
1976	345 121	126 901	1 188 857	1 660 879
1977	398 037	144 286	1 149 294	1 691 617
1978	389 066	154 295	1 288 462	1 831 823
1979	356 492	138 441	1 200 639	1 695 571
1980	387 956	137 827	1 243 214	1 768 997
1981	434 319	143 624	1 226 399	1 804 342
1982	490 840	176 815	1 187 982	1 855 638
1983	451 642	201 346	1 322 963	1 975 951
1984	398 377	273 858	1 443 271	2 115 506
1985	454 175	324 518	1 380 937	2 159 629
1986	444 031	383 880	1 621 055	2 448 966
1987	418 497	421 368	1 610 209	2 450 073
1988	436 154	510 610	1 724 164	2 670 928
1989	442 670	517 953	1 785 987	2 746 610
1990	508 664	529 632	1 911 852	2 950 148
1991	551 115	544 327	2 132 763	3 228 205
1992	516 131	628 701	2 064 969	3 209 801
1993	567 681	762 453	1 921 397	3 251 531
1994	596 088	719 802	2 064 817	3 380 706
1995	554 943	736 854	2 129 240	3 421 037
1996	533 136	757 262	2 052 827	3 343 226
1997	493 569	770 197	2 244 525	3 508 291
1998	494 851	777 394	2 581 215	3 853 460
1999	528 383	921 528	2 538 174	3 988 085
2000	478 358	818 301	2 590 535	3 887 194
2001	497 476	781 569	2 584 701	3 863 746

TABLE 2
Total annual nominal catches, in tonnes, of the principal market species of tunas, by species

Year	Albacore	Bigeye	Bluefin	Skipjack	Yellowfin	Southern bluefin	Total
1950	107 813	10 808	27 340	162 108	106 456	829	415 354
1951	82 269	11 651	31 274	166 445	91 435	829	383 903
1952	126 770	29 792	53 350	150 441	122 862	829	484 044
1953	108 798	30 648	55 812	154 800	113 330	4 399	467 787
1954	113 868	29 374	60 900	194 059	124 674	2 871	525 746
1955	97 799	44 624	66 481	187 492	159 122	2 286	557 804
1956	129 974	50 652	62 049	199 663	196 538	10 567	649 443
1957	148 517	67 011	68 931	187 953	205 633	24 172	702 217
1958	133 174	70 685	61 499	255 038	208 112	14 784	743 292
1959	132 883	65 759	48 559	281 175	217 282	64 378	810 036
1960	158 187	79 118	50 121	162 967	299 057	79 371	828 821
1961	143 476	100 386	57 271	257 345	295 794	81 605	935 876
1962	178 700	121 661	61 970	282 900	287 940	45 033	978 204
1963	191 632	147 491	61 063	266 687	266 825	65 923	999 621
1964	195 057	117 548	61 412	286 004	290 486	49 670	1 000 177
1965	202 872	117 223	55 448	288 094	281 748	47 565	992 950
1966	196 001	115 460	54 072	369 224	306 000	47 652	1 088 408
1967	220 564	120 924	46 177	392 614	271 644	65 638	1 117 561
1968	189 211	124 352	38 164	360 436	373 882	58 394	1 144 438
1969	196 678	149 019	33 559	332 896	388 382	58 528	1 159 062
1970	185 932	141 327	28 519	395 819	377 730	48 156	1 177 482
1971	223 160	148 458	35 249	454 499	340 476	45 148	1 246 991
1972	239 200	155 255	36 655	386 559	436 982	51 925	1 306 576
1973	243 706	167 651	35 307	492 730	471 142	41 205	1 451 742
1974	249 869	174 726	48 428	607 241	490 099	46 777	1 617 141
1975	187 338	203 106	48 160	513 917	508 889	32 982	1 494 392
1976	241 884	210 536	48 518	599 997	559 945	42 509	1 703 388
1977	186 615	242 823	44 271	639 317	578 590	42 178	1 733 795
1978	227 112	241 543	48 139	764 880	550 148	35 908	1 867 731
1979	192 798	208 045	51 129	675 070	568 152	38 673	1 733 868
1980	182 805	239 474	42 385	751 354	552 430	45 054	1 813 501
1981	179 537	218 013	51 299	742 027	612 523	45 104	1 848 503
1982	196 453	231 837	52 000	801 454	573 191	42 788	1 897 723
1983	166 332	230 913	44 172	947 257	586 582	42 881	2 018 138
1984	169 754	229 969	38 944	1 056 098	618 281	37 090	2 150 136
1985	174 540	268 631	41 322	908 105	764 320	33 325	2 190 243
1986	199 765	287 490	41 115	1 096 820	823 144	28 319	2 476 654
1987	190 196	297 484	35 778	1 034 407	892 000	25 575	2 475 439
1988	182 999	273 302	36 062	1 273 241	904 637	23 145	2 693 386
1989	184 198	287 637	34 708	1 280 346	959 479	17 843	2 764 212
1990	188 219	337 289	33 939	1 338 020	1 052 509	13 870	2 963 846
1991	156 153	344 871	44 301	1 649 386	1 033 400	13 692	3 241 804
1992	181 671	338 770	46 460	1 535 531	1 107 294	14 217	3 223 944
1993	180 872	366 273	46 411	1 488 300	1 169 651	14 345	3 265 851
1994	210 032	416 136	62 258	1 591 307	1 100 616	13 246	3 393 594
1995	184 081	413 244	74 499	1 677 992	1 070 985	13 680	3 434 481
1996	204 850	416 491	73 652	1 594 855	1 053 208	16 501	3 359 556
1997	225 035	447 373	69 632	1 601 219	1 163 953	16 101	3 523 313
1998	236 249	434 370	54 390	1 927 868	1 199 295	17 981	3 870 152
1999	266 698	453 230	59 138	1 996 061	1 209 164	19 803	4 004 092
2000	241 284	422 317	62 304	2 008 414	1 150 920	15 712	3 900 951
2001	252 465	386 362	46 080	1 886 654	1 290 439	16 002	3 878 003

TABLE 3
Total annual nominal catches, in tonnes, of the principal market species of tunas (other than southern bluefin) by fishing gear

Year	Purse-seine	Pole-and-line	Longline	Other	Total
1950	33 654	150 258	20 957	128 760	333 629
1951	34 942	241 498	16 728	110 057	403 225
1952	46 404	247 198	75 361	114 298	483 261
1953	45 768	228 325	86 271	103 047	463 411
1954	51 261	262 115	103 481	106 031	522 888
1955	55 867	257 720	134 355	107 673	555 615
1956	55 569	303 553	159 173	120 884	639 179
1957	52 593	311 427	188 667	126 037	678 724
1958	68 806	327 593	213 420	120 650	730 470
1959	79 113	315 106	234 370	119 625	748 214
1960	118 434	213 422	296 627	123 572	752 055
1961	168 775	253 908	319 931	114 434	857 047
1962	166 208	258 937	376 954	131 071	933 171
1963	177 080	231 734	384 062	140 822	933 698
1964	198 451	258 441	357 838	135 777	950 507
1965	173 915	292 116	350 858	128 495	945 385
1966	188 433	341 097	379 765	131 462	1 040 756
1967	234 115	320 812	333 838	163 157	1 051 923
1968	239 427	288 254	392 910	165 453	1 086 044
1969	246 989	302 877	394 779	155 889	1 100 534
1970	290 463	329 715	353 580	155 568	1 129 326
1971	336 103	356 670	352 137	156 933	1 201 843
1972	359 692	340 198	373 293	181 467	1 254 651
1973	397 868	447 485	390 002	175 181	1 410 537
1974	462 577	532 220	376 768	198 800	1 570 364
1975	497 726	391 620	387 019	185 045	1 461 410
1976	559 686	501 445	414 679	185 068	1 660 879
1977	525 299	464 632	486 711	214 975	1 691 617
1978	605 477	521 969	484 208	220 170	1 831 823
1979	582 567	467 855	435 049	210 100	1 695 571
1980	612 968	517 139	462 336	176 553	1 768 997
1981	706 583	474 834	415 865	207 060	1 804 342
1982	739 690	450 128	456 526	209 294	1 855 638
1983	859 510	483 593	418 154	214 694	1 975 951
1984	951 382	565 844	383 986	214 293	2 115 506
1985	1 016 742	470 745	446 031	226 111	2 159 629
1986	1 153 290	539 590	500 463	255 622	2 448 966
1987	1 221 030	479 260	503 719	246 064	2 450 073
1988	1 361 788	527 091	485 397	296 652	2 670 928
1989	1 445 205	510 510	452 278	338 617	2 746 610
1990	1 603 774	448 484	535 842	362 048	2 950 148
1991	1 831 658	504 629	526 671	365 247	3 228 205
1992	1 821 133	452 508	578 575	357 585	3 209 801
1993	1 765 780	503 756	665 996	315 999	3 251 531
1994	1 878 469	498 028	631 134	373 074	3 380 706
1995	1 947 029	528 771	567 883	377 354	3 421 037
1996	1 855 485	482 910	606 115	398 716	3 343 226
1997	1 961 857	525 532	617 023	403 879	3 508 291
1998	2 171 184	569 723	659 037	453 517	3 853 460
1999	2 254 203	600 545	634 238	499 099	3 988 085
2000	2 249 460	547 158	591 141	499 435	3 887 194
2001	2 223 457	556 170	576 326	507 793	3 863 746

APPENDIX 2

FIGURE 1
Average annual catches, by 5-degree areas, by longline gear. The denser colours represent greater catches.

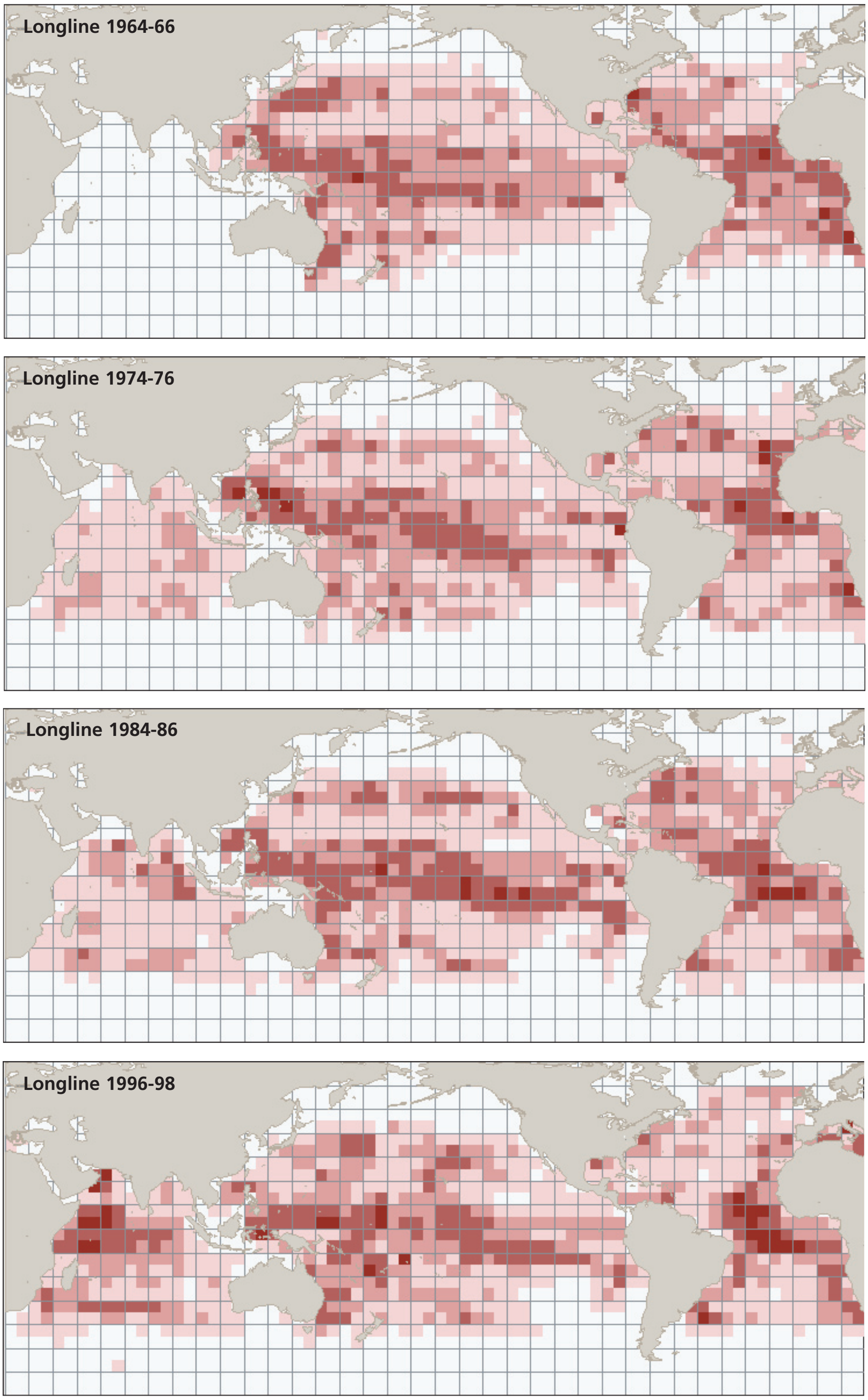


FIGURE 2
Average annual catches, by 5-degree areas, by purse-seine gear. The denser colours represent greater catches

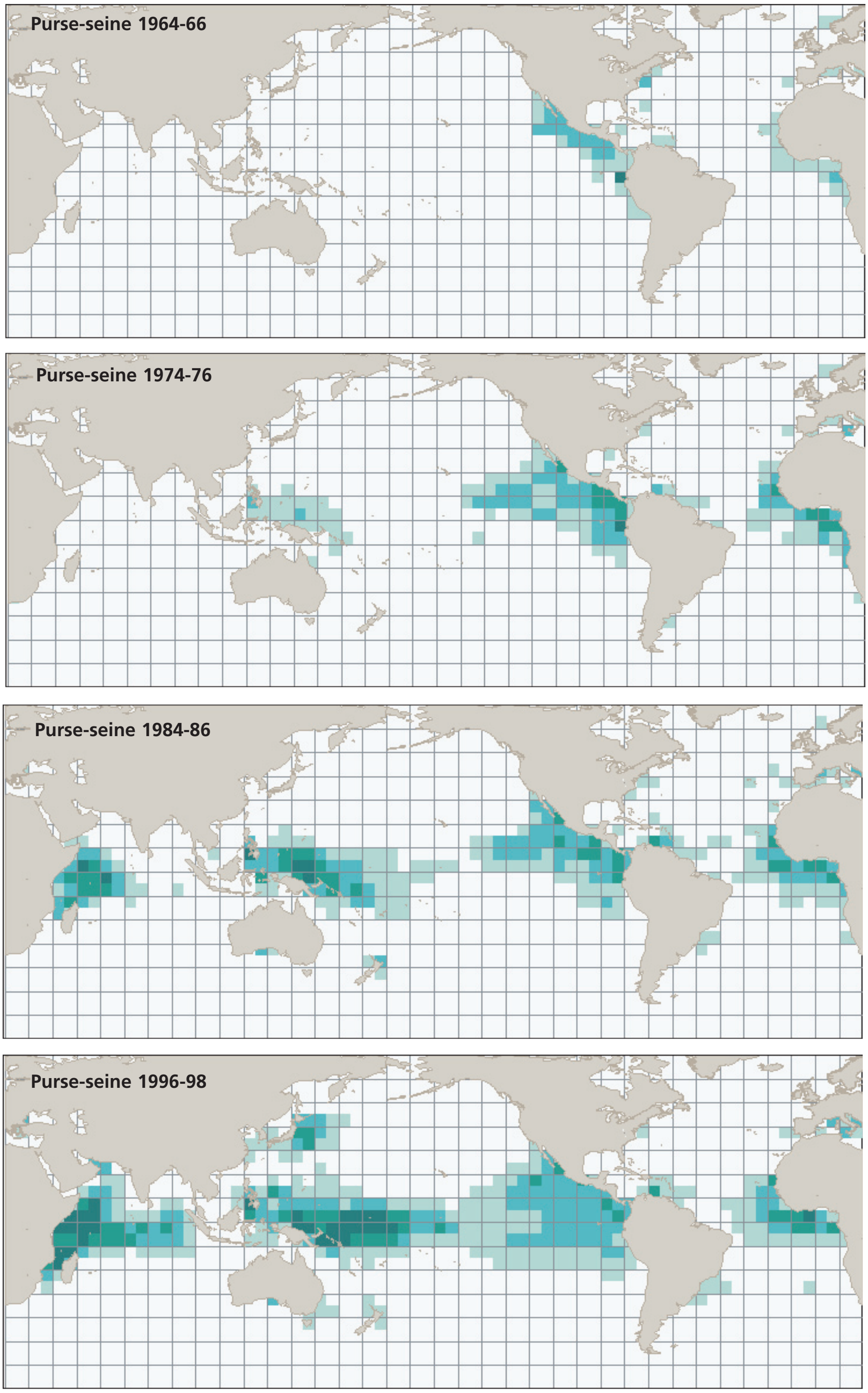


FIGURE 3
Average annual catches, by 5-degree areas, by pole-and-line gear. The denser colours represent greater catche

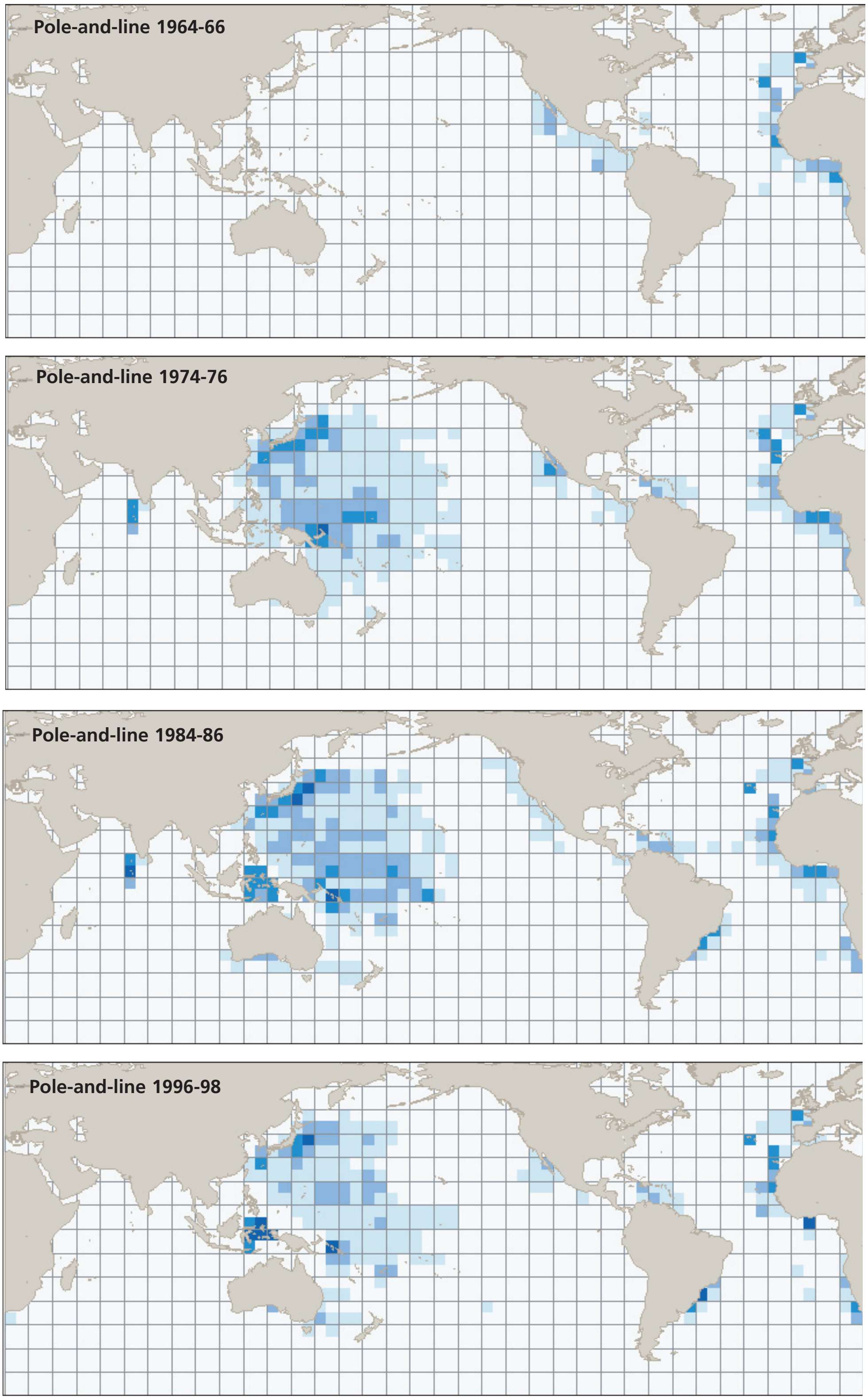
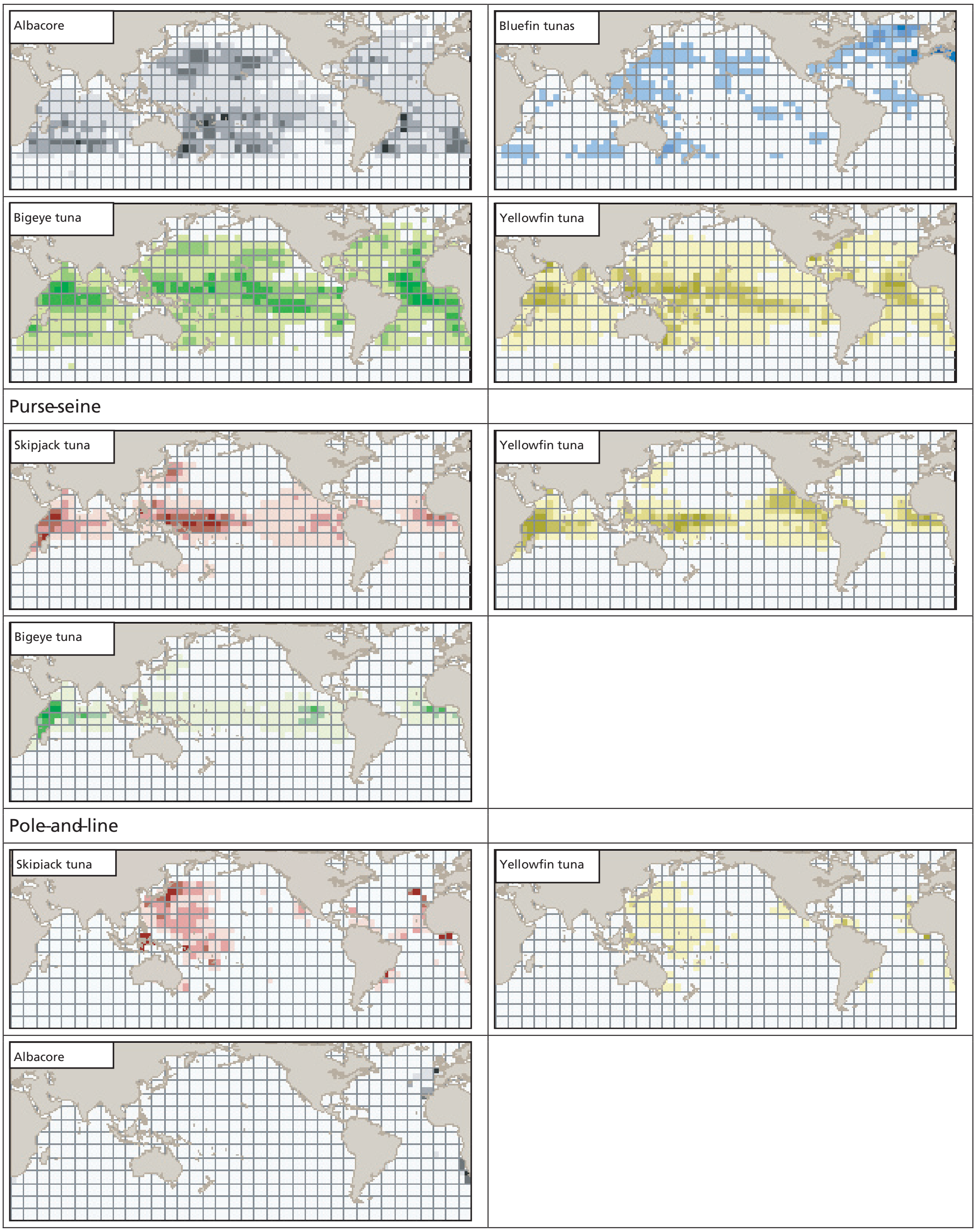


FIGURE 4
Distributions of the catches, by species and major gears, during 1998. The denser colours represent greater catches



Tuna catch data in FAO's Fisheries Global Information System (FIGIS)

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ABSTRACT

Since 1952 FAO has been collecting annual catch data for all marine and freshwater species including tuna and tuna-like species. These data, grouped by fishing country and FAO statistical area, are mostly being obtained directly from fishing countries.

The Marine Resources Service (FIRM) of the FAO Fisheries Department has independently been collating from the tuna fishery bodies and other regional and national institutions:

- annual catch data for principal market tunas by stock and fishing gear (since 2001), and
- catch data for principal market tunas and some billfishes by fishing gear, 5° x 5° square and quarter of year (since 1997).

These statistics are not necessarily official, but are regarded by these institutions as the most representative.

All the above mentioned data are available from FAO´s Fisheries Global Information System (FIGIS) in the form of individual values, their plots and maps. In general, the two data sets of tuna nominal catches are very similar. The discrepancies between them and the 5° x 5° catch data are the result of: (i) the latter data only accounting for longline, pole-and-line and purse-seine fishing; (ii) not including catches of unknown or poorly known locations in the latter data (e.g. many artisanal and some commercial fisheries), and (iii) from the exclusion, in the latter data, of those catches that were available not by weight but by number of fish.

1. INTRODUCTION

Tuna and tuna-like species are very important economically, and a significant source of food. There are approximately 40 species at item or higher taxonomic level for which commercial catches are reported in the Atlantic, Indian and Pacific Oceans and in the Mediterranean and Black Seas. Their global production has increased continuously from less than 0.6 million tonnes in 1950 to nearly 6.1 million tonnes in 2002. In 2001 the estimated value of tuna and tuna-like species at the landing site (US$8.3 billion) accounted for more than 10 percent of the total capture fisheries production. Tunas and tuna-like species are also among the most important commodities in fisheries trade, especially as exports by developing countries. In 2001 exports of tunas and tuna-like species (US$4.9 billion, f.o.b.) represented nearly 9 percent of the total value of fishery exports.

The so-called principal market tuna species are albacore (ALB, *Thunnus alalunga*), bigeye tuna (BET, *T. obesus*), Atlantic bluefin tuna (BFT, *T. thynnus)*, Pacific bluefin tuna (PBF, *T. orientalis)*, southern bluefin tuna (SBF, *T. maccoyii*), skipjack tuna (SKJ, *Katsuwonus pelamis*) and yellowfin tuna (YFT, *Thunnus albacares*). These seven species are the most important among the tuna and tuna-like species from the standpoints of both weight and market value. They are landed at numerous locations around the world, traded on a global scale and processed and consumed in many locations worldwide. In 2002, the combined catch of these seven species was approximately 4 million tonnes, which accounted for about two thirds of the total catch of all the tunas and tuna-like species. During 2002 most of the catches of the principal market tuna species were taken from the Pacific (66 percent), followed by the Indian (24 percent) and the Atlantic, Mediterranean and Black Sea combined (10 percent).

More than 80 percent of the nominal global catches of tunas and tuna-like species consists of skipjack and yellowfin, which account for 50 percent and 32 percent of those catches, respectively. Bigeye and albacore represent 10 percent and 6 percent, respectively, while the three remaining species, Atlantic bluefin tuna, Pacific bluefin tuna and southern bluefin tuna, comprise only 2 percent of global catches.

2. FAO'S TUNA CATCH DATA SETS

Presently, FAO is the repository of three data sets, accessible by internet, with data on the catches of tunas and tuna-like species:

1) Tunas and tuna-like species in the Capture Production (Fishstat Plus) and Global Capture Production (FIGIS) databases;
2) Global Tuna Nominal Catches; and
3) Atlas of Tuna and Billfish Catches.

The main characteristics of these data sets, their sources and the differences among them are described in the following sections.

2.1 Tunas and tuna-like species in the capture production (Fishstat Plus) and global capture production (FIGIS) databases

Information on world capture fishery production is collected by the FAO Fishery Information, Data and Statistics Unit (FIDI) from national offices that collect fishery statistics, by means of a system of standardized, but country-tailored, forms, which list for each country the species items and the fishing areas. ("Capture fishery production" is the volume of fish catches landed by country or territory of capture, by species or higher taxonomic level, by FAO major fishing areas, and year for all commercial, industrial, recreational and subsistence purposes.) As part of the general inquiry, annual commercial tuna nominal catches, by species and area of capture, are provided by the reporting countries. The data are validated, processed and stored in a database. The data for tunas and tuna-like species can be retrieved by accessing ISSCAAP Group 36, "Tunas, bonitos and billfishes", in the data set "Capture production 1950-2002", downloadable together with Fishstat Plus, a universal software for users' customized retrieval and time series analyses, including graphical tools and tabulations developed by FIDI (http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp).

The link http://www.fao.org/fi/statist/statist.asp provides on-line access to the same world capture production data through the Fisheries Global Information System (FIGIS) "Global Capture Production (1950 to 2002)" data set. Users can consult the tuna catches time-series online, using the FIGIS Query Panel, which allows them to define complex multicriteria queries and customize the results table. Results can be viewed as a graph, or exported in a standard format.

Data concerning the nominal catches of tunas and tuna-like species are reviewed in collaboration with organizations involved in research on these species. When data reported to FAO/FIDI are not in agreement with those reported to those organizations, the data provided by the national correspondents are, in most cases, replaced by "the best scientific estimates" produced by organizations collecting tuna catch statistics (i.e.

ICCAT, IOTC, IATTC and SPC).[1] This approach was adopted in accordance with a recommendation of the Coordinating Working Party on Fishery Statistics. On the other hand, FAO/FIDI is provided by its network of national correspondents with data for some countries (that are not reporting regularly to the Commissions), species (mostly small tunas) and segments of the fishing industry (artisanal fisheries) that are not collected by the respective regional organizations. In recent years, some of these regional organizations collecting tuna catch statistics have relied upon data compiled by FAO to complement the information included in their databases.

2.2 Global tuna nominal catches

The Global Tuna Nominal Catches Database[2] presents the nominal catches (in tonnes) for the principal market tuna species by flag fishing nation, fishing gear, stock and species. These data are available through the Fisheries Global Information System (FIGIS).

The collection of catch statistics for tuna species has been carried out by various organizations involved in research on tunas and tuna-like species for specific species and areas. Such statistics were provided to the Fishery Resources Division (FIR) of FAO's Fisheries Department (FI) for the specific purpose of preparing the Global Tuna Nominal Catches database. The organizations that provided data on nominal catches of tunas and tuna-like species are listed in the Acknowledgements section.

The main difference between these data and those collated by the FAO's Fishery Information, Data and Statistics Unit (FIDI) is that the Capture Production database provides the nominal catches, without distinguishing among different fishing gears and tuna stocks. The main reason for FIR to undertake the task of integrating all collated statistics into one data set was the need for data on nominal catches by stock and fishing gear for management and stock assessment purposes. The classification of the nominal catches by stocks was accomplished in consultation with scientists of other organizations involved in research on tunas and tuna-like species.

Presently, several organizations listed in the Acknowledgement section are providing the nominal catch data in Fishstat Plus format, thus simplifying the collation, compilation and processing of the data received.

These organizations have different coding systems with respect, to fishing gears, species, flag fishing nations, etc., and therefore adjustments were needed in order to standardize the data.

The fishing gears considered in this database were:
- longline;
- pole-and-line;
- purse-seine;
- trolling line;
- other: other types of gear.

Seven species, including a total of 22 stocks, were considered,
- albacore: Indian, Mediterranean, North Atlantic, North Pacific, South Atlantic, South Pacific;
- Atlantic bluefin tuna: eastern Atlantic, western Atlantic;
- bigeye tuna: Atlantic, Indian, Pacific;
- Pacific bluefin tuna: Pacific;
- skipjack tuna: eastern Atlantic, Indian, eastern Pacific, western Atlantic, western and central Pacific;
- southern bluefin tuna: all three oceans;
- yellowfin tuna: Atlantic, Indian, eastern Pacific, western and central Pacific.

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1 See acknowledgements for explanations of abbreviations.

2 http://figis01:8282/figis/servlet/FiRefServlet?ds=staticXML&xml=webapps/figis/wwwroot/fi/figis/tseries/index.xml& xsl=webapps/figis/staticXML/format/webpage.xsl

The data set includes catches from 1950 to 2002, and for the first time world nominal catches of tuna species can be extracted by flag fishing nation, fishing gear, stock and species.

2.3 Atlas of tuna and billfish catches

The organizations involved in research on tunas and tuna-like species that provide data on nominal catches also collect catch data on spatial distribution.

Such data, with a geographical resolution of rectangles of 5° latitude by 5° longitude ("5x5 rectangles") or higher resolution were provided to the FAO Fishery Resources Division (FIR) for the specific purpose of preparing the interactive Atlas of Tuna and Billfish Catches[3], which is accessible through FIGIS.

The statistics were collated and integrated into one data set and displayed through the Atlas, which presents the global distribution of 1950 to 2001 catches, by 5x5 rectangles, for those tuna and tuna-like species for which this distribution is generally well known on a global scale. These species consist, as noted above, of the so-called principal market tunas and some billfishes.

In detail, the Atlas shows spatial catches from 1950 to 2001 by:

12 tuna and billfish species,

- albacore (*Thunnus alalunga*);
- Atlantic bluefin tuna (*Thunnus thynnus*);
- white marlin (*Tetrapturus albidus*);
- bigeye tuna (*Thunnus obesus*);
- black marlin (*Makaira indica*);
- blue marlin (*Makaira nigricans*);
- Pacific bluefin tuna (*Thunnus orientalis*);
- skipjack tuna (*Katsuwonus pelamis*);
- southern bluefin tuna (*Thunnus maccoyii*);
- striped marlin (*Tetrapturus audax*);
- swordfish (*Xiphias gladius*);
- yellowfin tuna (*Thunnus albacares*).

3 gear types,

- longline;
- pole-and-line;
- purse-seine.

Spatial resolution by 5x5 rectangles.

Temporal resolution by quarters.

In some cases, the following adjustments were introduced to the individual data sets before combining them into one data set before showing them in the Atlas:

- the catches, in numbers of fish, were converted to units of weight for fisheries for which the conversion factors were given by the data providers; otherwise, the catches in numbers of fish were not included,
- catches from 1x1 rectangles were aggregated into those associated with 5x5 rectangles,
- catches erroneously assigned to land locations were not included (data providers were notified of these discrepancies, and error investigations are in progress),
- for catches reported without quarterly resolution (e.g. Korean longline catches for 1988-1989), catches were included only on charts of annual catches, and the lack of quarterly resolution is clearly indicated in the downloadable data sets,
- for each 5x5 rectangle, catches were assigned to the center of the rectangle, if this had not already been done by the providers of the data,

[3] http://www.fao.org/figis/servlet/TabSelector?tb_ds=TunaAtlas&tb_act=ACTION&tb_grp=RESET&tb_mode=MAP

- overlaps among data sets were eliminated, and
- national data from Japan, the Republic of Korea and Taiwan Province of China were used to supplement spatial catches for bluefin tunas in the Pacific prior to 1970 and for the eastern Pacific Ocean from 1970 to 1997 (the last year for which these data were provided).

For the species included in the Atlas, the catches by area are shown when locations of catch, by 5x5 rectangles, are known or could be assumed as fractions of the nominal catches for all oceans.

3. COMPARISONS BETWEEN CATCH DATA SETS (1950-2000)

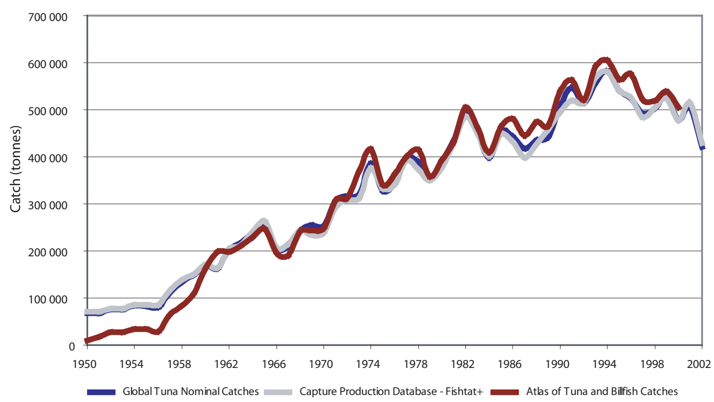
The different data sets for the principal market species, with the exception of southern bluefin tuna, have been compared by oceans, and the results are shown in the charts below. The comparison includes data up to 2002, except for the 5x5 rectangle data set, for which only data up to 2000 were available at the time the document was produced.

3.1 Atlantic Ocean

The three data sets are very similar throughout the time series, except for some differences between the 5x5 rectangle data set and the other two data sets during the 1950s.

For the Atlantic industrial fisheries, ICCAT combined data by 5x5 rectangle and quarter and raised the data to the level of its nominal catches. For most small-scale fisheries in the Atlantic, catches that are not reported by 5x5 rectangle and quarter are also assigned to specific rectangles. For this reason, there are only small differences between spatial data and nominal catches.

FIGURE 1
Data sets comparison in the Atlantic Ocean



3.2 Indian Ocean

The trend of the catches of both the Capture Production data set (retrieved through Fishstat Plus) and the Global Tuna Nominal Catches data sets are almost identical. The greatest differences occur during the 1988-1994 period. The differences may be due partially to the different levels of species identification in reporting.

The difference between the Global Tuna Nominal Catches and the 5x5 rectangle data set is much greater, but the trends are very similar. Part of this difference is explained by the fact that the 5x5 rectangle data set includes only catches by LL, PL and PS, whereas the Global Tuna Nominal Catches data set includes also trolling lines and other gears.

FIGURE 2
Data sets comparison in the Indian Ocean

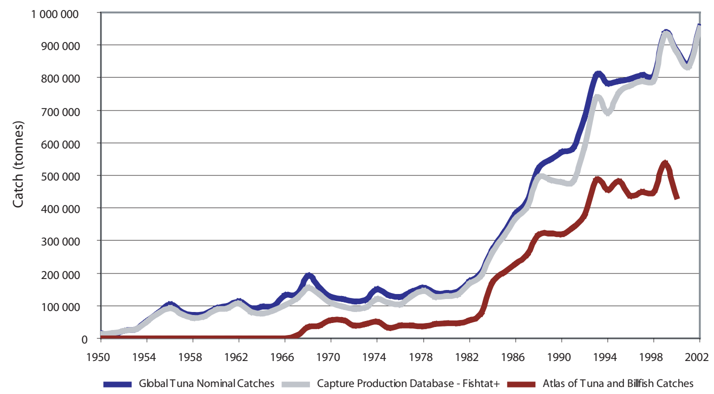
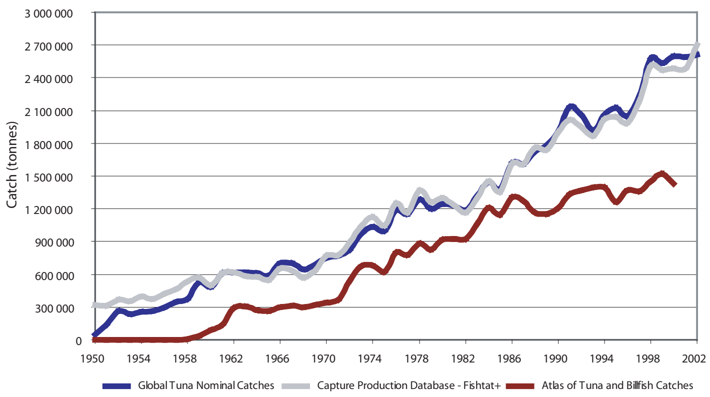


FIGURE 3
Data sets comparison in the Pacific Ocean



However, there are additional important discrepancies between the longline catches of the two data sets. One possible explanation regarding these discrepancies between longline data may be that nominal catch data also include catches of unknown or poorly-known locations, and of many artisanal and some commercial fisheries that are not accounted for in the charts of the Atlas. Such discrepancies also could result from the exclusion, in the Atlas, of catch data that were provided only in numbers of fish (i.e. Japanese longline catches in the Indian Ocean). The latter catches may represent a significant portion of catches in some regions. Effort is underway to convert the data from numbers to weights so they can be included in the Atlas.

3.3 Pacific Ocean

The catches in both the Capture Production data set (retrieved through Fishstat Plus) and the Global Tuna Nominal Catches are practically identical, even though the data sources of the two time series are different. The greatest differences occurred during the early years of the time series (1950-1958), and in 1991, 1992, 2000 and 2001.

The difference between nominal catches and the 5x5 rectangle catches is much greater, mainly because: (1) the coverage of the tuna fleet by observers is not complete; (2) lack of geographical information of illegal, unreported and unregulated fishing (IUU) tuna catches; (3) lack of reports for some of the tuna fleets; (4) exclusion in the Atlas of catch data provided only as numbers of fish; and (5) nominal catch data, including catches with unknown or poorly-known locations, which are not accounted for on the charts of the Atlas. The artisanal component is quite important in the Indian and Pacific Oceans, resulting in the large discrepancies between spatial and nominal catch data. In the eastern Pacific Ocean, for example, catches of vessels of less than 100 gross registered tons (GRT) are not necessarily reported.

4. FUTURE DEVELOPMENTS

With the help of users, several possible improvements and added functionalities have been identified regarding the collections of data sets presently stored and delivered to the public through FIGIS. The following suggestions regarding data content have been made:

- inclusion of monthly data for all gears concerned for the catches by area (Atlas of Tunas and Billfishes);
- possible inclusion of purse-seine catch data disaggregated by modes of fishing for the catch-by-area data set.

The following suggestions regarding functionalities have been made:

- averaging functions through years and quarters (or months);
- downloading of selected records from main data sets;
- enhancement of the quality control, and linking the reference tables to the FIGIS code system to facilitate integration with other FIGIS collections;
- discontinuing the use of the present Java-based query panel for Nominal Catches to a more user-friendly HTML query panel.

ACKNOWLEDGEMENTS

The following organizations provided data on catches of tunas and billfishes to the Global Tuna Nominal Catches and the Atlas of Tuna and Billfish Catches: Australian Fisheries Management Authority (AFMA), Indian Ocean Tuna Commission (IOTC), International Commission for the Conservation of Atlantic Tunas (ICCAT), Inter-American Tropical Tuna Commission (IATTC), Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC), National Institute of Water and Atmospheric Research (NIWA), National Marine Fisheries Service (NMFS) and the Secretariat of the Pacific Community (SPC). The Food and Agriculture Organization of the United Nations (FAO) and its Fisheries Department are grateful for their collaboration.

Nevertheless, the authors assume full responsibility for any potential problems and mistakes in their compilation and its presentation in the figures.

Status of the tuna stocks of the world

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ABSTRACT

Tuna and tuna-like species are very important economically, and a significant source of food. Albacore, bigeye, Atlantic bluefin, Pacific bluefin, skipjack, southern bluefin and yellowfin are frequently referred to as the principal market tuna species. In 2002 their catch was approximately 4 million tonnes, which represents almost 65 percent of the total catch of all the tunas and tuna-like species.

The objective of this paper is to provide information on the status of 23 stocks of the principal market tuna species. This information was obtained mostly from publications and web sites, but also from direct communications with the tuna fishery bodies and other organizations significantly involved in research on tunas.

The maximum annual catches of 13 of the 23 stocks were taken before 1998. This may suggest that these stocks are deteriorating unless the reductions of catches in recent years are the result of economic or environmental conditions or restrictions on the fisheries.

Mostly on the basis of reference points, the sizes and the fishing mortalities of the tuna stocks were classified into the following categories to summarize their status on a global scale in a simple way:

- stock size: above its reference point, near its reference point, below its reference point, unknown;
- fishing mortality: below its reference point, near its reference point, above its reference point, unknown.

If we consider only stock size, seven of the 13 stocks of tropical tunas (bigeye in the Indian Ocean (BET-IO), bigeye in the eastern Pacific (BET-EPO), bigeye in the western and central Pacific (BET-WCPO), yellowfin in the Atlantic (YFT-AO), skipjack in the western and central Pacific (SKJ-WCPO), yellowfin in the eastern Pacific (YFT-EPO) and yellowfin in the western and central Pacific (YFT-WCPO) are considered to be within their safe limits (above or near their reference points). Only three out of ten stocks of temperate tunas (albacore in the South Atlantic (ALB-SAO), albacore in the South Pacific (ALB-SPO) and Pacific bluefin (PBF-PO) are considered to be safe.

If we consider only fishing mortality, the situation is quite similar. The present fishing mortality of only three of the tropical stocks (bigeye in the Atlantic (BET-AO), bigeye in the eastern Pacific (BET-EPO) and bigeye in the western and central Pacific (BET-WCPO) cannot be regarded as sustainable. For temperate stocks the corresponding number is six (albacore in the North Atlantic (ALB-NAO), albacore in the North Pacific (ALB-NPO), Atlantic bluefin in the eastern Atlantic (BFT-EAO), Atlantic bluefin in the western Atlantic (BFT-WAO), Pacific bluefin (PBF-PO) and southern bluefin (SBF).

Little, if anything, is known about the stock sizes and fishing mortalities of eight of the 23 stocks (albacore in the Mediterranean Sea (ALB-MED), albacore in the Indian Ocean (ALB-IO), albacore in the North Pacific (ALB-NPO), skipjack in the eastern

Atlantic (SKJ-EAO), skipjack in the eastern Pacific (SKJ-EPO), skipjack in the Indian Ocean (SKJ-IO), skipjack in the western Atlantic (SKJ-WAO) and yellowfin in the Indian Ocean (YFT-IO). This proportion is slightly higher for the tropical stocks than for the temperate stocks. There is significant uncertainty for four other stocks (albacore in the North Atlantic (ALB-NAO), bigeye in the Indian Ocean (BET-IO), bigeye in the western and central Pacific (BET-WCPO) and Pacific bluefin (PBF-PO), and if these are combined with the first eight stocks it can be said that information for more than half the stocks is considerably less than adequate. The least information on stock status is available for ALB and SKJ.

The status of the tuna stocks was presented across a bivariate system of references related to the stock size and fishing mortality. Seven stocks (ALB-SAO, ALB-SPO, BET-IO, SKJ-WCPO, YFT-AO, YFT-EPO and YFT-WCPO) could be considered to be within safe limits from the conservation perspective. For another eight stocks (ALB-NAO, BET-AO, BET-EPO, BET-WCPO, BFT-EAO, BFT-WAO, PBF-PO and SBF), the fishing mortality should be reduced, the stock size increased, or both, if they are to be brought to within safe limits. Only the stocks for which both reference points were available have been included in this analysis. However, other general information for SKJ-EPO and SKJ-IO indicates that they are within safe limits, while YFT-IO is fully exploited.

The case of the BET-IO deserves clarification. Despite the stock size and fishing mortality reference points suggesting that the stock is within safe limits, the present level of catches is regarded as not sustainable over the long-term, due to the fact that the stock is not in equilibrium.

Future large increases in the catches of the principal market tunas are neither expected nor recommended. In fact, the catches of the stocks that are fully exploited or overexploited may decline in a long-term unless they are properly managed. SKJ-EPO, SKJ-IO, SKJ-WCPO and ALB-SPO are the only stocks for which there are indications that there is still potential for increases in their catches. For SKJ, these increases should be accomplished in a way that would not lead to increases in the catches of stocks of other species, such as BET and YFT, which are currently fully exploited or overexploited. That would require development of methods to catch SKJ, but avoid small BET and YFT. Only gradual increases in the catches of ALB-SPO should be allowed, as it is not known whether large increases would be sustainable.

Presently, a quantitative determination of implications of stock status for the management of fishing capacity is difficult because of:

- the lack adequate information on the status of some stocks;
- the multi-species and multi-gear nature of most tuna fisheries; and
- the mobility of fishing vessels.

Even with the limited information on the status of tuna stocks on the global scale, some actions could be undertaken to prevent further increases in the present fishing capacity and, in some cases, reducing it gradually, while simultaneously carrying out further research to determine more precisely the desired extent of this reduction.

1. INTRODUCTION

1.1 Background information on tuna and their fisheries

The subfamily Scombrinae includes the tunas, bonitos, mackerels, seerfishes, and billfishes (Klawe 1977, Collette and Nauen 1983, Nakamura 1985, Collette 1999). These are among the largest and fastest fishes in the sea.

The tribe Thunnini, consisting of the genera *Thunnus*, *Euthynnus*, *Katsuwonus*, *Auxis* and *Allothunnus*, and a total of 15 species, includes the most economically important species, referred to as the principal market tunas because of their global economic importance and the extensive international trade in them for canning and for *sashimi* (raw fish, regarded as a delicacy in Japan and, increasingly, in many other countries). Because a tuna consists mostly of edible muscle tissue, they are relatively easy to process for human consumption.

The principal market tunas are albacore (ALB, *Thunnus alalunga*), bigeye tuna (BET, *T. obesus*), Atlantic bluefin tuna (BFT, *T. thynnus)*, Pacific bluefin tuna (PBF, *T. orientalis)*, southern bluefin tuna (SBF, *T. maccoyii*), yellowfin tuna (YFT, *T. albacares*) and skipjack tuna (SKJ, *Katsuwonus pelamis*). Their superbly efficient metabolic system includes a circulatory system that allows them to retain or dissipate heat as required for peak biological performance and efficiency. They occur in all oceans (see Appendix II), and are capable of long migrations or movements.

The principal market tunas are commonly classified as tropical and temperate species. In this paper, SKJ, YFT and BET are considered to be tropical species, and ALB, BFT, PBF and SBF to be temperate species.

The principal market tunas are divided into 23 stocks, based on their treatment for stock assessment purposes by the CCSBT, IATTC, ICCAT, IOTC, ISC and SPC. There are one, two or three stocks of ALB, BET, SKJ and YFT in each ocean, and these represent effective management units. BFT and PBF are each restricted to a single ocean, and SBF consists of a single stock occurring in the Atlantic, Indian and Pacific Oceans.

Because of the economic situation in Japan in recent years, the prices of BFT, PBF and SBF, the tuna species most valued for *sashimi*, although still high compared to those of other species, have decreased somewhat. For a whole fish, fishers may get between US $ 30 and US $ 40 per kg, with some getting closer to US $ 100 per kg. Not long ago, the price of a fish of exceptional quality was as high as US $ 500 per kg and, more recently, even higher. BET are also in demand for the production of *sashimi*, so the prices are high. Although YFT are also popular in these markets, the prices are much lower. For canning, ALB fetch the best prices due to their white meat, followed by YFT and SKJ. Fishers are paid less than US $ 1 per kg for YFT and SKJ. The relatively low prices for canning-quality fish are compensated for by the very large catches of these, especially SKJ and YFT. Longtail tuna (*Thunnus tonggol*) is becoming increasingly important for canning, and is a subject of substantial international trade. The consumption of tuna and tuna-like species in forms other than canned products or *sashimi* is increasing.

To manage tuna fisheries, the following tuna fishery bodies have been created:

- Commission for the Conservation of Southern Bluefin Tuna (CCSBT), Canberra, Australia (http://www.ccsbt.org),
- Indian Ocean Tuna Commission (IOTC), Victoria, Seychelles (http://www.seychelles.net/iotc),
- Inter-American Tropical Tuna Commission (IATTC), La Jolla, USA (http://www.iattc.org),
- International Commission for the Conservation of Atlantic Tunas (ICCAT), Madrid, Spain (http://www.iccat.es) and
- Western and Central Pacific Fisheries Commission (WCPFC), Ponepei, Federated States of Micronesia (http://www.ocean-affairs.com).

In addition the following organizations:

- Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC, Shimizu, Japan, http://isc.ac.affrc.go.jp/home.html) and
- Secretariat of the Pacific Community (SPC, Noumea, New Caledonia, http://www.spc.int)

also carry out or facilitate the assessment of tuna stocks in the North Pacific and South Pacific respectively, but they do not manage them. The WCPFC will soon undertake management responsibility for the tuna stocks in the area west of 150°W in the North Pacific and the area west of 120°W in the South Pacific.

Further information on tunas and their fisheries, trade and management on the global scale can be found in Allen (2002); Catarci (this collection); Joseph (2003 and this collection); Majkowski (1997 and this collection); Miyake, Miyabe and Nakano (2004); Miyake (this collection); and Reid *et al.* (this collection).

1.2 Objective of this paper

The objective of this paper is to provide information on the status of tuna stocks on a global scale that is of relevance to the management of tuna fishing capacity.

The information in this paper was collated for FAO's Project on the management of tuna fishing capacity, particularly for consideration at the 2nd Meeting of its Technical Advisory Committee (TAC), which was held in Madrid on 15-18 March 2004.

1.3 Background information on the related FAO project

The present tuna fishing capacity is excessive in respect to at least some tuna resources and the demand for some tuna products. This excess has led to overexploitation, and even depletion, of some tuna stocks. Also, in the recent past, excess capacity produced catches of some species, especially SKJ, which reduced the prices so much that fishing became unprofitable.

The ultimate objective of the FAO Project entitled "Management of tuna fishing capacity: conservation and socio-economics", which is funded by the Japanese government, is to improve the management of tuna fisheries on the global scale. Its immediate objectives are:

- to provide technical information necessary for the management of tuna fishing capacity and
- to identify, consider and resolve technical problems associated with the management of tuna fishing capacity.

This is to be done on the global scale, taking into account conservation and socio-economic issues.

The Project's activities consist of:

- technical work preparatory to the Expert Consultation on Management of Tuna Fishing Capacity and
- reviewing, integrating and disseminating the results of the preparatory work and formulating conclusions and recommendations.

The preparatory work includes:

- collation of data and other information of relevance to the management of tuna fishing capacity,
- analyses of these and other relevant studies and
- identification of needs for additional technical work required for better management of tuna fishing capacity.

The analyses and other studies consist of:

- reviews of the tuna resources and fisheries,
- quantification of tuna fishing capacity,
- determination of demand for tuna raw materials and products,
- review of the socio-economic importance and profitability of the tuna industry and
- determination of options for the fisheries management, particularly of tuna fishing capacity.

The Project is being implemented in close collaboration with tuna fishery bodies and other international organizations significantly involved in tuna fisheries research and management. Some further information on the Project can be found in Majkowski (2003).

1.4 Structure of the paper

The main body of the paper summarizes the information for tropical and temperate tunas, broken down by ocean, on:

- combined historical catches,
- status of the stocks (separately for each stock) and
- outlook (separately for each stock).

These summaries are followed by a global summary, providing the numbers of stocks assigned by us into five categories, according to their status. The summaries were prepared on the basis of more detailed information on the same subjects, which is presented for each stock in Appendix I.

The abbreviations used in this paper are listed and explained at the beginning of the paper. References to papers and other sources of information cited in the main body of the paper are listed at its end. Additional sources of information cited in Appendix I are given there.

Appendix II provides some information on the structure of each stock and global maps showing the boundaries of the stocks and the distributions of the catches by the principal fishing gears.

2. SOURCES OF INFORMATION AND METHODS

2.1 Catches

Information on the annual tuna catches in this paper is taken from the data base constructed for its public release through FAO's Fisheries Global Information System (FIGIS).[1] 2002 was the last year for which the data were available at the time of preparing this paper. Particularly, for this year the data may be reviewed in the future. The institutions from which these data were obtained are the CCSBT (December 2003), IATTC (November 2003), ICCAT (February 2004), IOTC (December 2003), ISC (December 2003) and SPC (November 2003). The dates in brackets indicate when the data were obtained. We provide data on the catches by longline, trolling, pole-and–line, purse-seine and "other" gears. Catches for which the gears are unknown are also included into the "other" category.

The maps in this paper were generated from another data base constructed for its public release through FAO's Fisheries Global Information System (FIGIS).[2] The organizations from which these data have been obtained are the Australian Fisheries Management Authority (AFMA, http://www.afma.gov.au, June 2003), IATTC (August 2002), ICCAT (February 2003), IOTC (May 2003), the U.S. National Marine Fisheries Service (NMFS, http://www.nmfs.noaa.gov, October 2002) and SPC (June 2003). Further information on the data available from FIGIS at the time of preparing this paper can be obtained from Carocci *et al*. (this collection).

Further information on tuna fisheries and their catches can be found in Miyake, Miyabe and Nakano (2004) and Miyake (this collection).

2.2 Stock structure, status and outlook for the catches

The information on the structure and status of the stocks and the outlook for future catches was obtained mostly from publications and the web sites of the tuna fishery bodies, ISC and SPC, and from direct communications with some of them. The exception is the classification of stock size of and fishing mortality for each stock into categories defined later in this section. All this information applies to the beginning of 2004. It is given in Appendix I, and summarized in the main body of the paper.

We recognize that the information compiled by us on the structure and status of the stocks and the outlook for the catches is uncertain and that this uncertainty varies

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[1] These data or their updates can be obtained presently from: http://www.fao.org/figis/servlet//FiRefServlet?ds=staticXML&xml=webapps/figis/wwwroot/fi/figis/tseries/index.xml&xsl=webapps/figis/staticXML/format/webpage.xs

[2] These data or their updates and information about their collation and processing can be obtained presently from: http://www.fao.org/figis/servlet/TabSelector?tb_ds=TunaAtlas&tb_act=ACTION&tb_grp=RESET&tb_mode=MAP

among the stocks. These uncertainties are the result of deficiencies in the data and the methods applied to analyze the data, but it is very difficult to realistically evaluate these uncertainties. This is addressed further later in this paper.

Various reference points for the fishing mortality and the stock size are used by tuna fishery bodies, ISC and SPC. They include F_{MSY}, F_{AMSY}, F_{max}, $F_{30\%}$, $F_{40\%}$, SSB_{MSY}, B_{MSY}, SBR, ratio of exploited to unexploited total biomass and slight modifications of the last reference point. In some cases, however, only qualitative information on the fishing mortality and the stock size is available (for example "the fishing mortality is low to moderate").

To summarize the status of stocks on a global scale in a simple way, on the basis of the information mentioned in the previous paragraphs, particularly the reference points, the sizes of and the fishing mortality for each tuna stock were classified into the following categories:

- *stock size*: above its reference point, near its reference point, below its reference point, unknown.
- *fishing mortality*: below its reference point, near its reference point, above its reference point, unknown.

In cases for which the information on the stock status that we obtained from the tuna fishery bodies, ISC and SPC has been considered as substantially uncertain, we add "possibly" in front of categories (e.g. possibly above its reference point). The stock size and fishing mortality "near its reference point", depends on the age-composition of the catches, which is determined by the current combination of fishing gears and their current patterns of fishing.

When only qualitative information is available (i.e. BFT-EAO, BFT-WAO, ALB-SPO, PBF-PO, SKJ-WCPO, YFT-WCPO and SBF), the assignment of categories to the stock size and fishing mortality requires intuitive and subjective judgment. If the current fishing mortality or stock size is close to a reference point, also some subjectivity is involved into classifying them as "near its reference point". Due to significant uncertainties associated with the fishing mortality for ALB-NAO and SBF, we have created an "in-between" category ("near to above its reference point").

3. TROPICAL TUNAS

3.1 Atlantic Ocean

Stocks – The following stocks of tropical tunas are recognized in the Atlantic Ocean (AO):

- bigeye in the Atlantic Ocean (BET-AO),
- skipjack in the eastern Atlantic Ocean (SKJ-EAO),
- skipjack in the western Atlantic Ocean (SKJ-WAO) and
- yellowfin in the Atlantic Ocean (YFT-AO).

Historical catches – The maximum combined annual catch of tropical tunas in the AO, 462 109 tonnes, was taken in 1994 (Figure 1). Since then, with some fluctuations, the catches have been decreasing, and in 2002 the catch was 324 923 (70 percent of that obtained in 1994). In 2002 most of the catches of tropical tunas in the AO were taken by purse-seine (56 percent), pole-and-line (23 percent) and longline (19 percent) gear.

In 2002 the principal countries or entities fishing for tropical tunas in the AO were as follows: purse seining, Spain, France and Ghana; pole-and-line fishing, Ghana and Brazil; longlining, Taiwan Province of China and Japan.

The maximum annual catches of tropical tunas (Figure 2) were as follows: BET, 129 506 tonnes (in 1994); SKJ, 203 173 tonnes (in 1991); YFT, 192 456 tonnes (in 1990). In 2002 the catches of BET, SKJ and YFT were 73 110 tonnes (56 percent of the maximum catch), 114 373 tonnes (56 percent of the maximum catch) and 137 440 tonnes (71 percent of the maximum catch), respectively.

FIGURE 1
Catches of the tropical species, by gear, in the AO

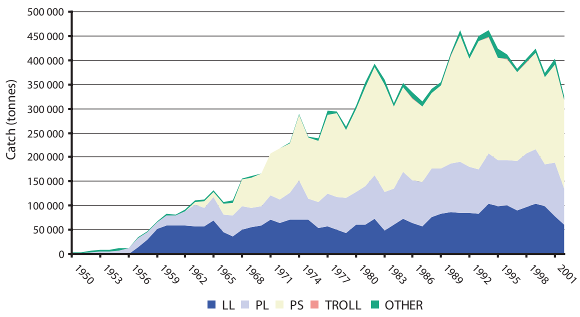


FIGURE 2
Catches of the tropical species in the AO

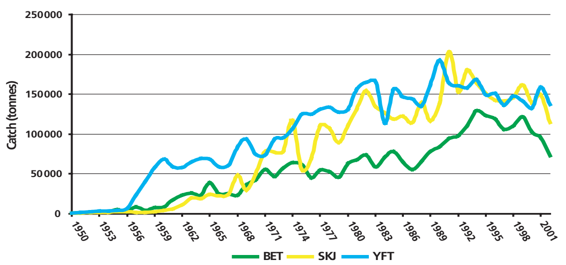
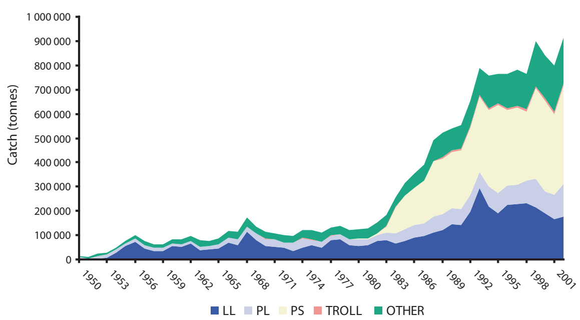


FIGURE 3
Catches of the tropical species, by gear, in the IO



Stock status – Reliable information on the stock size and fishing mortality is missing for two of the four stocks (SKJ-EAO and SKJ-WAO). For BET-AO, the stock size is below its reference point and the fishing mortality is above its reference point. For YFT-AO, both the stock size and fishing mortality are near their reference points.

Outlook – BET-AO is overexploited and YFT-AO is fully exploited, so sustained increases in their catches with the present pattern of exploitation (or, more specifically, the size-compositions of the catches) are not possible. However, if the catches of small BET and YFT could be reduced, sustained increases in their catches would be possible. The status of both SKJ-EAO and SKJ-WAO are unknown, so it is not known whether increases in their catches could be sustainable. However, in the light of the precautionary approach, such increases should not be considered until more reliable information on the status of these stocks is obtained.

3.2 Indian Ocean

Stocks – The following stocks of tropical tunas are recognized in the Indian Ocean (IO):

- bigeye in the Indian Ocean (BET-IO,
- skipjack in the Indian Ocean (SKJ-IO)
- yellowfin in the Indian Ocean (YFT-IO).

Historical catches – The combined annual catches of tropical tunas in the IO have been increasing since the 1980s (Figure 3). The maximum combined annual catch of these species, 913 564 tonnes, was taken in 2002. Of this, 43 percent was taken by purse seiners, 20 percent by longliners, 15 percent by pole-and-line gear, and 20 percent by other gears.

In 2002 the principal countries or entities fishing for tropical tunas in the IO were as follows: purse seining, France, Spain and the Seychelles; longlining, the Taiwan Province of China, Indonesia and Japan; pole-and-line fishing, the Maldives; other gears, Sri Lanka, Indonesia and Iran.

The maximum annual BET catch of 150 122 tonnes was taken in 1999 (Figure 4). Since then the BET catches have decreased, and the catch of 2002 was 122 842 tonnes (82 percent of the maximum catch). The SKJ catches have been increasing relatively steadily, reaching a maximum of 482 245 tonnes in 2002. The maximum annual YFT catch of 386 056 tonnes was taken in 1993. Since then the YFT catches have decreased, and the catch of 2002 was 308 477 tonnes (80 percent of the 1993 catch).

Stock status – The stock size of BET-IO is possibly above its reference point and the fishing mortality is possibly below its reference point. It has not been possible to estimate reference points for the stock sizes and fishing mortalities of SKJ-IO and YFT-IO. However, information presented at the 2003 meeting of the Working Party on Tropical Tunas (WPTT) of the IOTC indicates that there should be no immediate concern about the status of SKJ-IO. On the other hand, it appears that the catches of YFT are close to or above the MSY level, so the stock is considered to be fully exploited.

Outlook – For the present pattern of fishing (or, more specifically, the size-compositions of the catches), BET-IO and YFT-IO catches have possibly reached the upper limits of their sustainable catches and, consequently, attempts to further increase the catches are not advisable. However, if the catches of small BET and YFT could be reduced, sustained increases in their catches might be possible. Sustainable increases in the catches of SKJ may be possible, but their extent is unknown. However, because SKJ is caught with juvenile BET and YFT, increasing the catches of SKJ catches should not be attempted unless ways to reduce the accompanying catches of juvenile BET and YFT can be found.

FIGURE 4
Catches of the tropical species in the IO

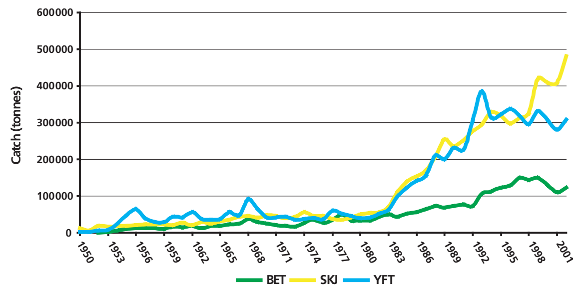
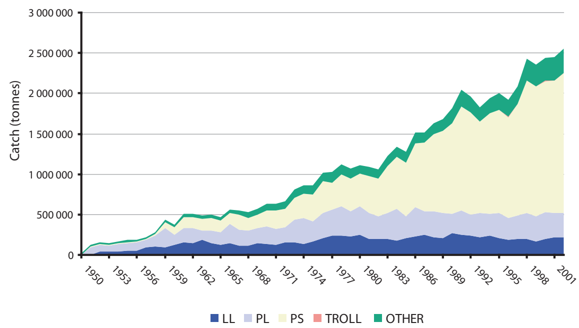


FIGURE 5
Catches of the tropical species, by gear, in the PO



3.3 Pacific Ocean

Stocks – The following stocks of tropical tunas are recognized in the Pacific Ocean (PO):[3]

- bigeye in the eastern Pacific Ocean (BET-EPO),
- bigeye in the western and central Pacific Ocean (BET-WCPO),
- skipjack in the eastern Pacific Ocean (SKJ-EPO),
- skipjack in the western and central Pacific Ocean (SKJ-WCPO),
- yellowfin in the eastern Pacific Ocean (YFT-EPO) and
- yellowfin in the western and central Pacific Ocean (YFT-WCPO).

Historical catches – With some fluctuations, the combined annual catches of tropical tunas in the PO have been increasing since the 1950s (Figure 5). The maximum annual combined catch of these species in the PO, 2 552 547 tonnes, was taken in 2002. Of this, 68 percent was taken by purse seiners, 12 percent by pole-and-line gear, 8 percent by longliners, and 12 percent by other gears.

In 2002 the principal countries or entities fishing for tropical tunas in the PO were as follows: purse seining, the Taiwan Province of China, Japan, the Republic of Korea, Mexico, Ecuador, the United States, Venezuela, Papua New Guinea and the Philippines; longlining, Japan, the Taiwan Province of China, the Republic of Korea, China and Indonesia; pole-and-line fishing, Indonesia and Japan; other gears, Indonesia and the Philippines.

Recently, the BET catches have been quite stable (Figure 6). The maximum annual BET catch, 222 732 tonnes, was taken in 2000. The 2002 BET catch, 197 523 tonnes,

[3] Even if there is no clear evidence of two stocks existing in PO (see the Stock Structure section of BET-PO in Appendix 1), stock assessments of BET for EPO and WCPO are currently undertaken separately. In this paper, therefore it has been considered appropriate to differentiate between BET-EPO and BET-WCPO.

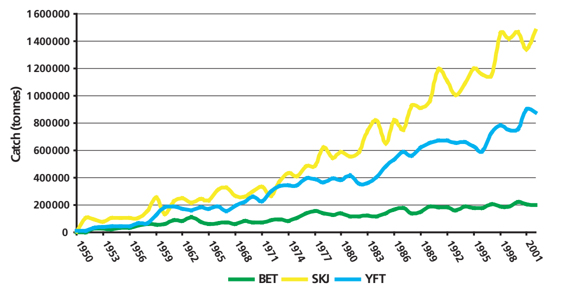
TABLE 1
2002 and maximum annual catches for tropical tuna stocks and their status

OCEAN		Atlantic (AO)				Indian (IO)			Pacific (PO)					
STOCKS		**BET-AO**	**SKJ-EAO**	**SKJ-WAO**	**YFT-AO**	**BET-IO**	**SKJ-IO**	**YFT-IO**	**BET-EPO**	**BET-WCPO**	**SKJ-EPO**	**SKJ-WCPO**	**YFT-EPO**	**YFT-WCPO**
2002 catch (tonnes)	Total	73 110	92 945	21 428	13 440	122 842	482 245	308 477	73 416	124 107	158 911	1 320 692	429 299	446 122
	%[1]	56%	55%	53%	71%	82%	100%	80%	67%	100%	60%	100%	100%	89%
	LL	43 774	26	61	17 202	94 283	75	82 119	37 786	81 701	39	4 200	10 091	80 039
	PL	11 640	24 074	18 737	20 172	958	113 658	20 544	-	2 927	592	280 377	928	17 815
	PS	16 193	68 634	2 116	95 436	27 542	235 609	142 271	35 630	21 072	158 280	931 105	418 280	170 492
	TROLL	-	-	58	13	12	4 208	4 524	-	277	-	217	-	595
	OTHER	1 503	211	456	4 617	47	128 695	59 019	-	18 130	-	104 793	-	177 181
Maximum annual catch (tonnes)	Total	129 506	169 771	40 272	192 456	150 122	482 245	386 056	109 596	124 107	265 598	1 320 692	429 299	501 438
	Year[2]	1994	1991	1985	1990	1999	2002	1993	2000	2002	1999	2002	2002	1998
	LL	78 296	5	24	29 104	111 015	-	203 104	39 443	-	96	-	-	65 967
	PL	20 285	41 612	28 490	24 278	604	-	9 275	-	-	2 109	-	-	17 256
	PS	29 952	126 264	11 191	134 473	38 319	-	128 634	70 153	-	262 040	-	-	266 148
	TROLL	34	19	-	330	39	-	3 898	-	-	-	-	-	1 173
	OTHER	939	1 871	567	4 271	145	-	4 145	-	-	1 353	-	-	150 894
Catch-related reference point (tonnes)		79 000 to 105 000	Unknown	Unknown	137 500 to 161 300	102 000	Unknown	280 000 to 350 000	77 000 (PS = 48 000 LL = 29 000)	40 000 to 80 000	Unknown	1 600 000	250 000	381 000 to 554 000
Stock size		Below its reference point	Unknown	Unknown	Near its reference point	Possibly above its reference point	Unknown	Unknown	Above its reference point	Possibly near its reference point	Unknown	Above its reference point	Near its reference point	Above its reference point
Fishing mortality		Above its reference point	Unknown	Unknown	Near its reference point	Possibly below its reference point	Unknown	Unknown	Above its reference point	Possibly above its reference point	Unknown	Below its reference point	Near its reference point	Near its reference point

[1] Ratio between the 2002 catch and the maximum historical annual catch.
[2] Year in which the total maximum historical annual catch was taken for the stock.

was 89 percent of its maximum catch. The SKJ catches have been increasing steadily, reaching the maximum annual catch of 1 479 603 tonnes in 2002. The maximum annual catch of YFT, 901 037 tonnes, was taken in 2001. In 2002 the catch of YFT decreased slightly to 875 421 tonnes (97 percent of the 2001 catch).

FIGURE 6
Catches of the tropical species in the PO



Stock status – The stock size of BET-EPO and its fishing mortality are above their reference points. However, it was forecast that its size will decrease to below its reference point. The stock size of BET-WCPO is possibly near its reference point and the fishing mortality is possibly above its reference point. No reference points were estimated for the stock size and fishing mortality of the SKJ-EPO stock, but other general information suggests that the stock is well within its safe limits. The stock size of SKJ-WCPO is above its reference point and its fishing mortality is below its reference point. The stock size of YFT-EPO and its fishing mortality are both near their reference points. The stock size of YFT-WCPO is above its reference point, and the fishing mortality is near its reference point.

Outlook – With the present pattern of fishing (or, more specifically, the size-compositions of the catches) for BET-EPO, BET-WCPO and YFT-EPO, the catches should not be increased. Increases in the sustainable catches of these stocks might be possible if the catches of juvenile fish could be reduced.

Increases in the sustainable catches of SKJ-EPO could be possible. However, since the purse seiners that target SKJ catch also juvenile BET, the catches of SKJ-EPO should not be increased unless methods can be found to reduce the amounts of juvenile BET in the catches.

Increases in the sustainable catches of SKJ-WCPO could be possible.

4. TEMPERATE TUNAS

4.1 Atlantic Ocean

Stocks – The following stocks of temperate tunas are recognized in the Atlantic Ocean (AO):

- albacore in the Mediterranean Sea (ALB-MED),
- albacore in the North Atlantic Ocean (ALB-NAO),
- albacore in the South Atlantic Ocean (ALB-SAO),
- Atlantic bluefin in the eastern Atlantic Ocean (BFT-EAO) and
- Atlantic bluefin in the western Atlantic Ocean (BFT-WAO).

Historical catches – Since 1964, when the maximum annual catch of 125 566 tonnes was taken, the catch of temperate tunas in the AO has been fluctuating without a clear trend (Figure 7). The third-largest catch, 119 693 tonnes, was taken in 1994, and since then the catches have been decreasing. The 2002 catch, 95 823 tonnes, was 76 percent of the 1964 catch.

In 2002 approximately 39 percent of combined catches of temperate tunas in the AO were taken by longlining, 21 percent by purse seining, 20 percent by pole-and-line fishing, 4 percent by trolling, and 16 percent by other gears (Figure 7).

In 2002 the principal countries or entities fishing for temperate tunas in the AO were as follows: longlining, the Taiwan Province of China; purse seining, France and Italy; pole-and-line fishing, Spain and South Africa; trolling, Spain; other gears, France (mid-water trawling) and Morocco (traps).

FIGURE 7
Catches of the temperate species, by gear, in the AO

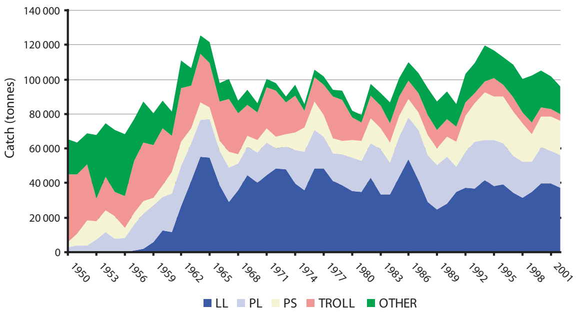
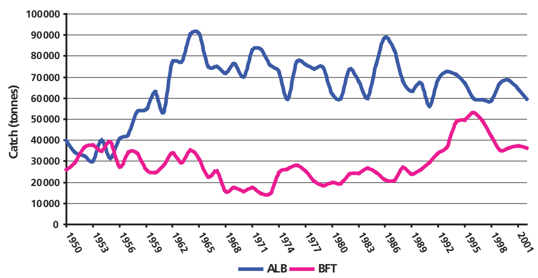


FIGURE 8
Catches of the temperate species in the AO



The maximum annual catch of ALB, 90 732 tonnes, was taken in 1965; since then the catches have fluctuated, with a decreasing trend (Figure 8). In 2002 the catch was 59 510 tonnes (66 percent of the 1965 catch). The maximum annual catch of BFT (53 163 tonnes) was taken in 1996. Since then the catches have decreased, and the 2002 catch was 36 313 tonnes (68 percent of the 1996 catch). The catches of ALB and BFT are currently limited by TACs.

Stock status – No information on the stock size and fishing mortality is available for ALB-MED. Stock size of ALB-NAO is below its reference point, and fishing mortality is near or above its reference point, but there are significant uncertainties in regard to these conclusions. Stock size of ALB-SAO is above its reference point, and its fishing mortality is below its reference point. For both BFT-EAO and BFT-WAO, the stock sizes are below their reference points, and the fishing mortalities are above their reference points.

Outlook – Insufficient information is available to predict the future catches of ALB-MED. TACs of 34 500 tonnes for ALB-NAO, 29 200 tonnes for ALB-SAO, 32 000 tonnes for BFT-EAO and 2 700 tonnes for BFT-WAO are currently in effect.

4.2 Indian Ocean

Stocks – Only one stock of temperate tuna, ALB-IO, is recognized in the Indian Ocean (IO).

Historical catches – The ALB catches fluctuated between 11 000 and 31 000 tonnes between 1962 and 1997, without showing a clear trend (Figures 9 and 10). Since then the catches have been increasing. The maximum annual catch, 42 749 tonnes, was taken in 2002. In that year 98 percent of the catch was taken by longliners.

The longline catches of ALB in the IO were taken principally by vessels of the Taiwan Province of China, Japan, Indonesia and Belize.

Stock status – There is no information about the status of ALB-IO.

Outlook – Because of the lack of information on ALB-IO, the outlook for future catches is unknown.

4.3 Pacific Ocean

Stocks – The following stocks of temperate tunas are recognized in the Pacific Ocean (PO):

- albacore in the North Pacific Ocean (ALB-NPO),
- albacore in the South Pacific Ocean (ALB-SPO) and
- Pacific bluefin in the Pacific Ocean (PBF-PO).

Historical catches – The combined annual catch of temperate tunas in the PO increased greatly during the 1991-1999 period (Figure 11), and the maximum annual catch of 183 397 tonnes was taken in 1999. The annual catches have decreased since then, and

148 712 tonnes (81 percent of the 1999 catch) were caught in 2002. The estimates of the 2001 and 2002 catches are still preliminary.

In 2002 the catches of temperate tunas in the PO were taken by longlining (58 percent), pole-and–line fishing 21 percent), trolling (11 percent), purse seining (8 percent) and other gears (3 percent). In 2002 the principal countries or entities fishing for tropical tunas in the PO were as follows: longlining, Japan and the Taiwan Province of China; pole-and-line fishing and purse seining, Japan; trolling, the United States, Canada, New Zealand and Japan.

The catches of ALB have increased in recent years (Figure 12). The maximum annual catch, 159 057 tonnes, was taken in 1999. In 2002 the ALB catch was 133 094 tonnes (84 percent of 1999 catch). The catch of BFT has declined since the early 1980s. The maximum annual catch, 32 769 tonnes, was taken in 1981. The 2002 catch, 15 618 tonnes, was 48 percent of the maximum catch. (As mentioned above, the data for 2001 and 2002 are preliminary.)

Stock status – It was not possible to estimate reference points for the stock size and fishing mortality of ALB-NPO, but information compiled by the Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) suggests that the stock is fully to overexploited. The stock size of ALB-SPO is above its reference point, and its fishing mortality is below its reference point. The stock size of PBF-PO is possibly near its reference point, but its fishing mortality is above its reference point.

Outlook – The catches of ALB-NPO should not be increased, and it may be necessary to reduce them to ensure that the stock size is at the level corresponding to MSY. ALB-SPO catches are likely to increase with further increases in the fishing effort, but the extent to which the fishing effort and catches can be increased is unknown. PBF-PO is considered to be overexploited by the ISC, so the catches should be reduced. However, if the catches of age-0 and age-1 fish are reduced, it is likely that increased sustainable overall catches are possible.

FIGURE 9
Catches of the temperate species, by gear, in the IO

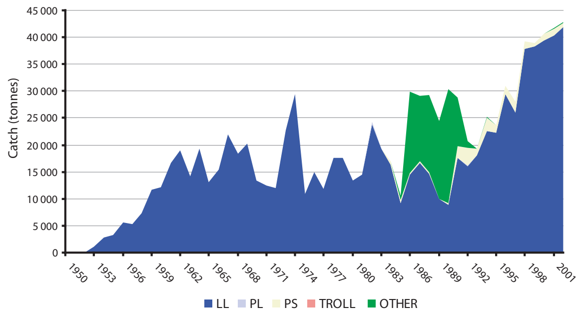


FIGURE 10
Catches of the temperate species in the IO

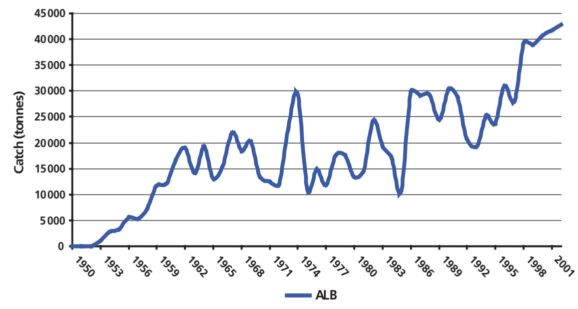


FIGURE 11
Catches of the temperate species, by gear, in the PO

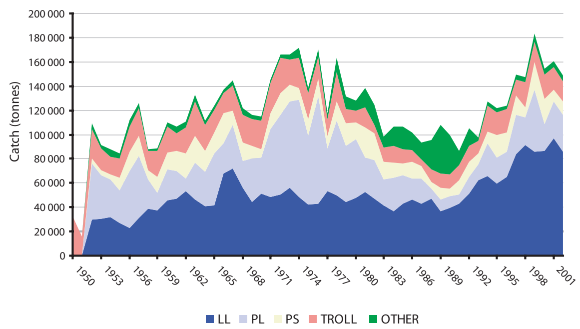


FIGURE 12
Catches of the temperate species in the PO

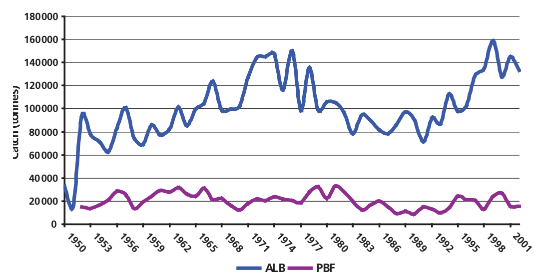


TABLE 2
2002 and maximum annual catches for temperate tuna stocks and their status

OCEAN		Atlantic (AO)					Indian (IO)	Pacific (PO)			All
STOCKS		**ALB-MED**	**ALB-NAO**	**ALB-SAO**	**BFT-EAO**	**BFT-WAO**	**ALB-IO**	**ALB-NPO**	**ALB-SPO**	**PBF-PO**	**SBF**
2002 catch (tonnes)	Total	5 608	22 496	31 406	33 093	3 220	42 749	82 236	50 858	15 618	16 096
	%[1]	100%	35%	77%	68%	17%	100%	65%	97%	48%	20%
	LL	3 706	6 006	21 506	5 160	802	41 948	37 476	45 969	2 138	-
	PL	29	6 639	9 539	2 569	-	-	29 987	262	518	-
	PS	1 305	118	38	18 341	208	735	856	-	10 446	-
	TROLL	117	4 007	-	12	-	4	10 663	4 477	982	-
	OTHER	451	5 726	323	7 011	2 210	62	3 254	150	1 534	-
Maximum annual catch (tonnes)	Total	5 608	64 354	40 630	50 762	18 679	42 749	125 622	52 576	32 769	81 605
	Year[2]	2002	1964	1987	1996	1964	2002	1976	1989	1981	1961
	LL	-	15 868	30 964	12 959	12 410	-	17 958	22 238	977	-
	PL	-	20 428	8 181	5 362	-	-	88 041	-	754	-
	PS	-	-	948	26 344	5 158	-	1 381	-	24 304	-
	TROLL	-	28 058	-	-	-	-	16 183	8 370	2 456	-
	OTHER	-	-	537	6 097	1 111	-	2 059	2 968	4 278	-
Catch-related reference point (tonnes)		Unknown	32 600	30 915	Unknown	3 500 and 7 200	Unknown	Unknown	Unknown	Unknown	Unknown
Stock size		Unknown	Possibly below its reference point	Above its reference point	Below its reference point	Below its reference point	Unknown	Unknown	Above its reference point	Possibly near its reference point	Below its reference point
Fishing mortality		Unknown	Possibly near to above its reference point	Below its reference point	Above its reference point	Above its reference point	Unknown	Possibly above its reference point	Below its reference point	Above its reference point	Near to above its reference point

[1] Ratio between the last year catch and the maximum historical annual catch.
[2] Year in which the total maximum historical annual catch was taken for the stock.

4.4 Southern bluefin (SBF)

Stocks – SBF consists of a single stock distributed throughout all the oceans of the Southern Hemisphere, mainly in waters between 30°S and 50°S, but only rarely in the AO and the EPO.

Historical catches – After a rapid increase in the catches during the 1950s, a maximum catch, 81 605 tonnes, was taken in 1961 (Figures 13 and 14). After that the catches declined precipitously until 1990. During the 1990-2001 period the catches fluctuated between 13 500 and 19 500 tonnes.

Stock status – The stock size of SBF is below its reference point and the fishing mortality is near to above its reference point.

Outlook – The catches of SBF should be decreased to allow the heavily-exploited stock to rebuild. The members of the CCSBT agreed to TAC of 14 030 tonnes for its members, plus an additional global allocation of 900 tonnes for cooperating non-members during the 2003-2004 season.

FIGURE 13
Catches of SBF by gear

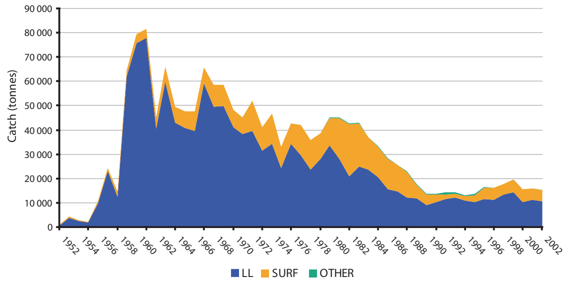
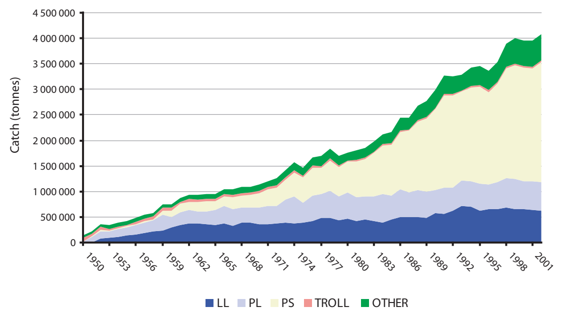


FIGURE 14
Catches of SBF

FIGURE 15
Global tuna catches by gear



5. GLOBAL SUMMARY

Historical catches – Generally, the combined global catch of the principal market tunas has been increasing (Figure 15). The maximum annual catch of approximately 4 078 000 tonnes was taken in 2002.

In 2002 66 percent of the catches of the principal market species came from the Pacific Ocean, 24 percent from the Indian Ocean, and 10 percent from the Atlantic Ocean and Mediterranean Sea.

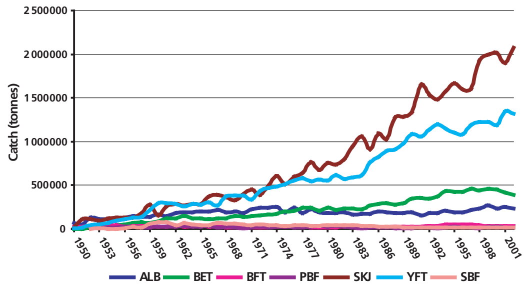
In 2002 58 percent of catch was taken by purse seiners, 15 percent by longliners, 14 percent by pole-and-line gear, 1 percent by trolling gear, and 13 percent by other gears.

The principal countries or entities fishing for tunas in 2002 were Japan, Indonesia, the Taiwan Province of China, the European Union (chiefly France and Spain), the Philippines, the Republic of Korea, the United States, Mexico, Venezuela, Ecuador, the Maldives and Papua New Guinea.

The global annual catches, by species, are shown in Figure 16. The catches of both SKJ and YFT have been increasing, and their maximum annual catches were both taken in 2002. In 2002 the catch of SKJ was 2 076 000 tonnes (51 percent of the total catch) and that of YFT was 1 321 000 tonnes (32 percent of the total catch).

In 2002 BET accounted for 10 percent of total catch. The catches of BET increased until 1997, when the maximum annual catch, 462 000 tonnes, was taken. After that the catches declined, and the BET catch in 2002 was 393 000 tonnes, about 85 percent of the maximum catch.

FIGURE 16
Global tuna catches by species



In 2002 ALB accounted for 6 percent of total catch. ALB catches were approximately constant from the mid-1960s to the late 1990s, without large fluctuations. The maximum annual catch of ALB, 265 000 tonnes, was taken in 1999. In 2002 235 000 tonnes of ALB were caught (89 percent of the 1999 catch). The estimate for the 2002 catch of ALB should be interpreted with caution, however, since the catch data for the NPO are still preliminary.

The catches of Atlantic bluefin, Pacific bluefin and southern bluefin have been stable or decreasing, at much lower levels than those of the other principal tunas.

The maximum annual catch of BFT, 53 200 tonnes, was taken in 1996. The 2002 catch, 36 300 tonnes, was 68 percent of 1996 catch.

The maximum annual catch of PBF, 32 700 tonnes, was taken in 1981. The 2002 catch, 15 600 tonnes, was 48 percent of the 1981 catch. However, as is the case for ALB, the 2002 catch data are preliminary.

The maximum annual catch of SBF, 81 600 tonnes, was taken in 1961. After that the catches declined precipitously until 1990. During the 1990-2001 period the catches fluctuated between 13 500 and 19 500 tonnes. The 2002 catch, 16 000 tonnes, was approximately 20 percent of the maximum annual catch.

The combined catches of BFT, PBF and SBF account for only slightly more than 1 percent of the total catches of the principal market species.

Analysis of the catches – For eight out of the 13 tropical tuna stocks (BET-IO, SKJ-IO, BET-EPO, BET-WCPO, SKJ-EPO, SKJ-WCPO, YFT-EPO and YFT-WCPO), the maximum annual catch has been taken after 1998. All these stocks occur in the IO and the PO. The sizes of these eight stocks are classified by us as either above their reference points (four stocks), near their reference points (two stocks) or unknown (two stocks). The only stock in these oceans for which the maximum annual catch was taken before 1998 (in 1993) is YFT-IO. The maximum annual catches for the four tropical tuna stocks in the AO (BET-AO, SKJ-EAO, SKJ-WAO and YFT-AO) were taken before 1995, and the sizes of these stocks are classified by us as either below their reference points (one stock), near their reference points (one stock) or unknown (two stocks).

The maximum annual catches of only two of the ten temperate tuna stocks, ALB-MED and ALB-IO, have been taken in recent years (after 1997). The stock sizes and fishing mortalities of these two stocks are unknown. For the remaining eight temperate stocks, ALB-NAO, ALB-SAO, BFT-EAO, BFT-WAO, ALB-NPO, ALB-SPO, PBF-PO and SBF, the maximum annual catches were taken before 1996. With the exception of ALB-SAO and ALB-SPO, the sizes of these temperate stocks are classified by us as below their reference points (four stocks), near their reference points (one stock) or unknown (one stock), and their fishing mortalities as above their reference points (three stocks), near to above their reference points (two stocks) or unknown (one stock).

These observations should be interpreted with caution, however, because the catches depend not only on the status of the stocks, but also on socio-economic factors, management measures and environmental conditions.

Stock status – The numbers of stocks assigned to various stock size and fishing mortality categories are shown in Table 3.

The information in Table 3 suggests that the tropical stocks are, in general, in a better condition than the temperate stocks. If we consider only the stock size, seven of

TABLE 3
Numbers of stocks assigned to the various stock size and fishing mortality categories

	STOCK STATUS					
	Stock size					
	Above	**Above-Near**	**Near**	**Near-Below**	**Below**	**Unknown**
Tropical stocks	4 (1)	-	3 (1)	-	1	5
Temperate stocks	2	-	1 (1)	-	4 (1)	3
Total	**6 (1)**	**-**	**4 (2)**	**-**	**5 (1)**	**8**
	Fishing mortality					
	Below	**Below-Near**	**Near**	**Near-Above**	**Above**	**Unknown**
Tropical stocks	2 (1)	-	3	-	3 (1)	5
Temperate stocks	2	-	0	2 (1)	4 (1)	2
Total	**4 (1)**	**-**	**3**	**2 (1)**	**7 (2)**	**7**

Note: The numbers in brackets indicate the numbers of stocks for which there is substantial uncertainty (e.g. the stock sizes of four tropical stocks are considered to be above the reference points, but there is substantial uncertainty about one of them).

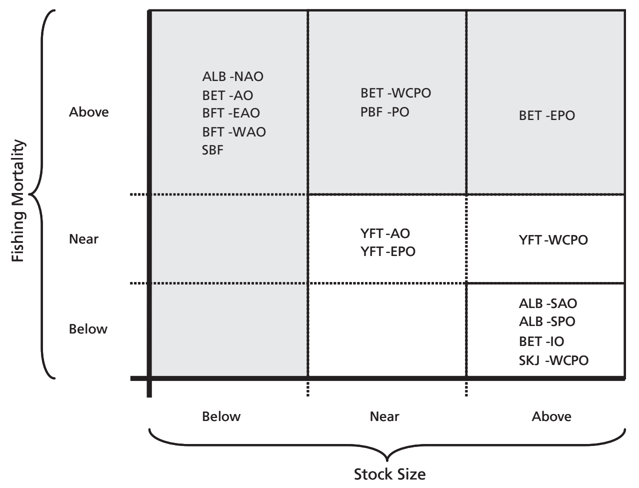
the 13 tuna tropical stocks (BET-IO, BET-EPO, BET-WCPO, YFT-AO, SKJ-WCPO, YFT-EPO and YFT-WCPO) are within their safe limits (above or near their reference points), and only one of them (BET-AO) is below its safe limit. However, only three of the ten temperate tuna stocks (ALB-SAO, ALB-SPO and PBF-PO) are within their safe limits, and four of them (ALB-NAO, BFT-EAO, BFT-WAO and SBF) are below their safe limits. For the fishing mortality, the situation is similar. Five of the 13 tropical stocks (YFT-AO, BET-IO, SKJ-WCPO, YFT-EPO and YFT-WCPO) are within their safe limits, and only three of them (BET-AO, BET-EPO and BET-WCPO) are above their safe limits. Only two of the ten temperate stocks (ALB-SAO and ALB-SPO) are within their safe limits, and six of them (ALB-NAO, ALB-NPO, BFT-EAO, BFT-WAO, PBF-PO and SBF) above those limits.

No estimates of either the stock size or fishing mortality have been obtained for five of the 13 tropical stocks (SKJ-EAO, SKJ-EPO, SKJ-IO, SKJ-WAO and YFT-IO) and three of the ten temperate stocks (ALB-IO, ALB-MED, ALB-NPO). This proportion of the stocks for which this information is lacking is slightly higher for the tropical stocks than for the temperate stocks. If the number of stocks for which their status is significantly uncertain is added (ALB-NAO, BET-IO, BET-WCPO and PBF-PO), information is lacking for seven of the 13 tropical stocks and five of the ten temperate stocks. ALB and SKJ are the species for which the stock status is least known.

The status of the tuna stocks across a bivariate system of references related to the stock size and fishing mortality is presented in Figure 17. The representation is qualitative, since not enough information is available for a quantitative presentation. In accordance with the precautionary approach (FAO 1995), when the stock size or fishing mortality category assigned by us in Tables 1 and 2 was uncertain the more conservative category has been adopted in the figure.

Seven of the stocks (ALB-SAO, ALB-SPO, BET-IO, SKJ-WCPO, YFT-AO, YFT-EPO and YFT-WCPO) could be considered within safe limits from the conservation perspective (white area). However, the three stocks

FIGURE 17
Status of tuna stocks across a bivariate system of references



for which the levels of fishing mortality are near the reference points (YFT-AO, YFT-EPO and YFT-WCPO) should be and are closely monitored, so that, if necessary, management action can be undertaken. For instance, the IATTC has closely monitored YFT-EPO for many years, and there have been restrictions on the fishery since 1998.

The case of the BET-IO requires a further clarification. Despite the stock size and fishing mortality categories suggesting that the stock is within safe limits, the present level of catches is regarded as not sustainable in the long-term. This is a consequence of the stock not being in equilibrium. In addition, the estimates for both B_{MSY} and F_{MSY} were considered to be substantially uncertain by the WPTT of the IOTC.

The remaining eight stocks (ALB-NAO, BET-AO, BET-EPO, BET-WCPO, BFT-EAO, BFT-WAO, PBF-PO and SBF) in the upper row of Figure 17 may be overfished (grey area). Their fishing mortalities should be reduced and their stock sizes should be increased, or both, if these stocks are to be brought to within safe limits. Of these stocks, the stock size of only one, BET-EPO, was above its reference point in 2002 (the last year for which stock size estimates were available at the time that this paper was prepared). However, assessments by the IATTC staff indicate that its stock size will decrease below its reference point.

The eight principal market tuna stocks for which the stock size and fishing mortality categories were not assigned (ALB-IO, ALB-MED, ALB-NPO, SKJ-EAO, SKJ-EPO, SKJ-IO, SKJ-WAO and YFT-IO) are not included in Figure 17.

Outlook – Future large increases in the catches of the principal market tunas are neither expected nor recommended. Several stocks are already fully exploited, overexploited (or depleted), and their catches should be limited to their current levels, or even decreased to permit the stock sizes to increase toward the levels corresponding to their MSYs. If this is not done, the catches may, in fact, decrease over the long-term. The information for several stocks is very limited and/or uncertain, so, in accordance with the precautionary approach, further research should be carried out before increases in catches are allowed.

SKJ-EPO, SKJ-IO, SKJ-WCPO and ALB-SPO are the only stocks for which there are indications that there is still potential for some increase in their catches. SKJ are caught mostly by purse seining, and sets that include SKJ usually also include small BET and YFT. Accordingly, increased fishing effort for SKJ should not be encouraged unless methods can be found for reducing the incidental catches of BET and YFT. Increases in the catches of ALB-SPO should be allowed only in small increments, as there is insufficient knowledge of the status of this stock to know to what extent they can be allowed.

It appears, from the information in Figure 17, that increases in the catches for BET-IO and ALB-SAO could be also be sustainable. This is not the case with BET-IO, however, for reasons stated in the previous subsection. For ALB-SAO, the stock size is currently above its reference point, and the fishing mortality is currently below its reference point. However, the catches have been above or close to those corresponding to the MSY since 1988, so ICCAT has adopted TACs to prevent overfishing.

The catches of some stocks other than SKJ-EPO, SKJ-IO, SKJ-WCPO and ALB-SPO could be increased if the catches of small fish could be reduced. This applies particularly to all stocks of BET, all stocks of YFT, BFT and PBF. The increased catches of some of these stocks might not be significant, but their SSBs would definitely increase. Also, the total market value of the fish would increase, because the market value per kilogram is greater for larger fish.

6. DISCUSSION

The tuna fishery bodies, ISC and SPC and their member countries carry out substantial research to evaluate the status of stocks of principal market species of tunas. These evaluations are difficult for many reasons. In some cases the stock structure is uncertain. For example, the degree of independence of the BFT of the EAO from those in the WAO has been under investigation for many years. Each stock, especially PBF and SBF, has a very wide geographical distribution, so different individuals from the same stock are affected differently by oceanographic conditions in different parts of these areas. Fishing is carried out by vessels of many nations, with many different types of gear, and different species of fish are caught by the same gear. This makes collection of catch and fishing effort data, sampling of the catches, and analysis of the data very difficult. In some cases, data that are needed are not available or not made available to scientists. Surveys by research vessels are, for the most part, impractical because of the wide distributions of even single stocks.

Regardless of the difficulties and uncertainties described in the previous paragraph, substantial information has been obtained on the status of the tuna stocks. However, a uniform and consistent classification of tuna stocks in accordance with some simple, pre-determined criteria is quite difficult on a global scale because reference points for many of the stocks have not been determined. For some stocks for which reference points have not been determined, only qualitative information on the stock sizes and fishing mortality exists. Regardless of the problems with such information, we believe that it should be included in a review such as this one, as it indicates what further research should be conducted.

Different methods have been used to estimate the reference points for the different stocks, which makes it difficult to compare their statuses, particularly when the assessments have been carried out by different organizations. Consultations among these organizations might reduce or eliminate this problem. According to the United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (1995), both target and limit reference points should be established and estimated for each stock. At presently, there is no distinction between these two types of reference points.

Even if the types of reference points were standardized, comparisons of the different stocks would be difficult because estimates of the reference points are based on the age compositions of the catches, and these may differ for different stocks of the same species. Nevertheless, we regard the classification presented in this paper as a useful summary of the status of the tuna stocks of the world on a global scale.

There is insufficient information to evaluate the status of some tuna stocks, and other evaluations are highly uncertain. For these stocks, further research is required. For some other stocks, the uncertainties as to their status may appear to be less serious, but nevertheless it is important that additional data be collected and further analyses be made.

Presently, a quantitative determination of implications of stock status for the management of fishing capacity is difficult because of:

- the lack of information on the status of some stocks,
- the multi-species, multi-national and multi-gear nature of the tuna fisheries and
- the mobility of the larger fishing vessels.

For the same reasons, combining the information on the desired reductions or possible increases in the fishing capacity on a global scale is even more complex. The Technical Advisory Committee (TAC) of the FAO Project “Management of tuna fishing capacity: conservation and socio-Economics”, at its second meeting in Madrid, Spain, on 15-18 March 2004, was of the opinion that significant additional research is needed to address it. It was recommended that a multi-disciplinary working group for resolving the problem be created (FAO 2004).

Even with the limited information on the status of tuna stocks on a global scale presently available, some fisheries management actions could be undertaken to prevent further increases in the present fishing capacity and, subsequently, reducing it gradually, while simultaneously carrying out further research to determine more precisely the desired extent of this reduction. In fact, on the basis of all the information presented to the second meeting of TAC (including that from this paper), in its Statement (FAO 2004), it was recommended "that a moratorium on the entry of additional large scale tuna vessels be implemented, until an efficient, equitable and transparent management system of fishing capacity is achieved".

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- Commission for the Conservation of Southern Bluefin Tuna (CCSBT),
- Indian Ocean Tuna Commission (IOTC),
- Inter-American Tropical Tuna Commission (IATTC),
- Interim Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC),
- International Commission for the Conservation of Atlantic Tunas (ICCAT) and
- Secretariat of the Pacific Community (SPC).

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APPENDIX I

Status of individual stocks

ATLANTIC OCEAN AND MEDITERRANEAN SEA

Albacore (ALB) in the Mediterranean Sea (MED)

Historical catches – The catches of ALB in the MED were stable from the beginning of the fishery until 1980 (Figure AI.1). From 1980 to 1985, the catches increased by almost eight-fold, and in 1985, for the first time, they exceeded 4 000 tonnes. From 1985 to 1989 the catches oscillated around that level. After that the catches began to decrease, reaching a very low level (1 350 tonnes) in 1994. Then the catches again increased, and in 2002 a maximum catch of 5 608 tonnes was taken. The longline catches of ALB in the MED are taken mainly by Italy (3 600 tonnes in 2002) and the purse-seine catches almost exclusively by Greece (1 300 tonnes in 2002).

FIGURE AI.1
Cumulative catches of ALB, by gear, in the MED

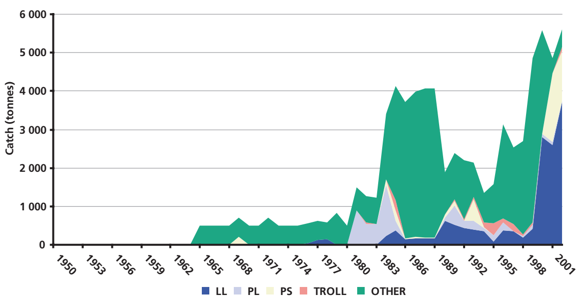
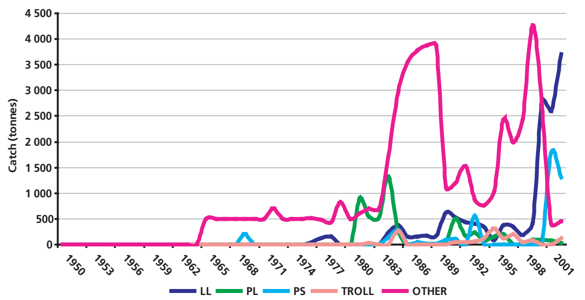


FIGURE AI.2
ALB catches, by gear, in the MED



Stock status – Due to the lack of adequate data, an assessment of ALB in the MED has not been carried out.

2002 catch (tonnes) – Total = 5 608 (LL = 3 706; PS = 1 305; TROLL = 117; PL = 29; OTHER[1] = 451).

Maximum annual catch (tonnes) – Taken in 2002 (see above).

Catch-related reference point (tonnes) – Unknown.

Stock size – Unknown.

Fishing mortality – Unknown.

Management recommendations/regulations – There are no ICCAT regulations aimed directly at managing ALB in the MED. The SCRS recommended to ICCAT that reliable data be provided in the future, and that effort be made to recover historical data.

Stock status summary – *Stock size*: unknown. *Fishing mortality*: unknown.

[1] Mainly gillnets and handlines.

Outlook – Unknown.

Albacore (ALB) in the North Atlantic Ocean (NAO)

Historical catches – The total catches of ALB in the NAO tended to increase, although with major fluctuations, from 1950 to 1964, when the maximum catch of 64 354 tonnes was taken (Figure AI.3). Since then the catches have decreased, with large fluctuations. The 2002 catch of approximately 22 500 tonnes is the lowest on record. This catch represents only about 35 percent of the maximum catch, taken in 1964. The principal fishing countries and entities employed the following methods of fishing in 2002: pole-and-line fishing, Spain (4 700 tonnes) and Portugal (1 900 tonnes); mid-water paired trawling, France (4 300 tonnes) and Ireland (1 100 tonnes); longlining, the Taiwan Province of China (4 300 tonnes); trolling, Spain (3 900 tonnes).

FIGURE AI.3
Cumulative catches of ALB, by gear, in the NAO

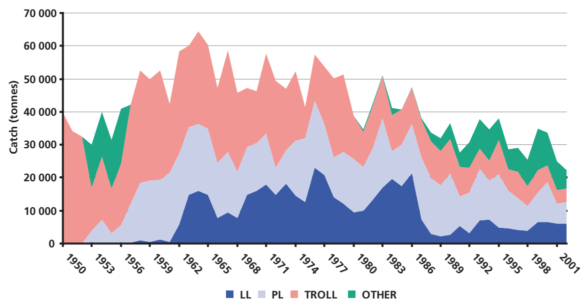
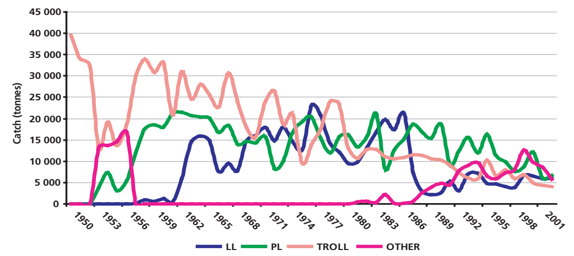


FIGURE AI.4
ALB catches, by gear, in the NAO



Stock status – The SCRS of ICCAT decided that it would not be appropriate to conduct a virtual population analysis (VPA) based on 2003 catch-at-age data until the catch-at-size to catch-at-age transformation was reviewed and validated. Consequently, information on the present status of the stock is based on an assessment conducted in 2000 and CPUE and catch data provided to the SCRS since then.

2002 catch (tonnes) – Total = 22 496 (PL = 6 639; LL = 6 006; TROLL = 4 007; PS = 118; OTHER[1] = 5 726).
Maximum annual catch (tonnes) – Total = 64 354 (TROLL = 28 058; PL = 20 428; LL = 15 868) in 1964.
Catch-related reference point (tonnes) – 32 600 (MSY).
Stock size – The present spawning stock biomass (SSB) is probably about 30 percent below that corresponding to MSY (SSB_{MSY} = 42 300 tonnes). However, due to the uncertainty in these estimates, it is possible that the stock is greater than the B_{MSY}.
Fishing mortality – The equilibrium yield-per-recruit analysis conducted in 2000 indicates that the stock is not being growth-overfished ($F<F_{max}$). However, estimates of F_{MSY} indicate that the F in 2000 was about 10 percent greater than F_{MSY}.
Management recommendations/regulations – In 2001 ICCAT established a total allowable catch (TAC) of 34 500 tonnes for ALB in the NAO. In 2003 the 34 500-tonne TAC was extended to 2004, 2005 and 2006. The 1998 recommendation to limit fishing capacity to the average capacity of 1993 to 1995 also remains in force.
Stock status summary – *Stock size*: possibly below its reference point. *Fishing mortality*: possibly near or above its reference point.

[1] Mainly drift gillnets and mid-water trawls.

Outlook – In 2000 the SCRS recommended that, to maintain a stable SSB in the near future, the catch should not be permitted to exceed 34 500 tonnes (as in 1999) in 2001 and 2002. The SCRS further noted that, to increase the SSB toward the level estimated to correspond to MSY, the catches in 2001 and 2002 should not exceed 31 000 tonnes. According to ICCAT catch statistics, the 2001 and 2002 catches were less than 31 000 tonnes, but it is still too soon to assess whether these level of catches have had a positive effect on the SSB. The ALB-NAO catches are currently restricted to a TAC of 34 500 tonnes.

Albacore (ALB) in the South Atlantic Ocean (SAO)

Historical catches – The total catches of ALB in the SAO increased sharply during the first years of the fishery, reaching 30 000 tonnes in 1965 (Figure AI.5). Since then the ALB catches have fluctuated widely, with a minimum of 14 600 tonnes in 1984 and a maximum of 40 000 tonnes in 1987, without a clear trend. The 2002 catch of 31 406 tonnes, the greatest since 1981, was about 77 percent of the maximum catch, taken in 1987. The principal fishing countries and entities employed the following methods of fishing in 2002: longlining, the Taiwan Province of China (17 700 tonnes); pole-and-line fishing, South Africa (6 199 tonnes) and Namibia (2 900 tonnes).

FIGURE AI.5
Cumulative catches of ALB, by gear, in the SAO

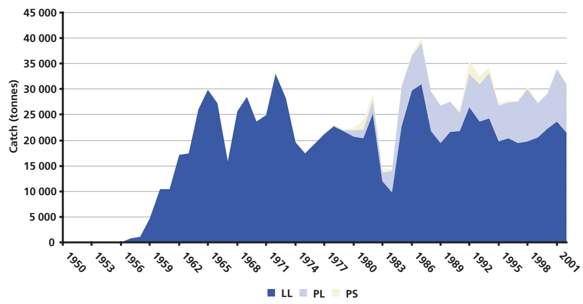
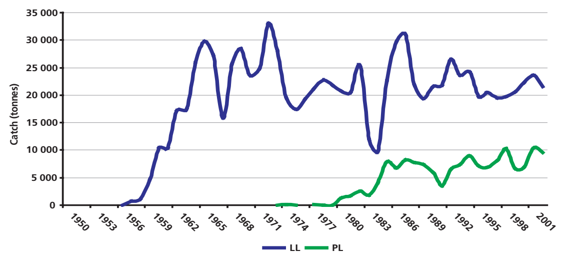


FIGURE AI.6
ALB catches, by gear, in the SAO



Stock status – A stock assessment for ALB in the SAO was conducted by the SCRS of ICCAT in 2003. The results were similar to those obtained in 2000.

2002 catch (tonnes) – Total = 31 406 (LL = 21 506; PL = 9 539; PS = 38; OTHER = 323).
Maximum annual catch (tonnes) – Total = 40 630 (LL = 30 964; PL = 8 181; PS = 948; OTHER = 537) in 1987.
Catch-related reference point (tonnes) – 30 915 (MSY).
Stock size – The SSB declined substantially after the mid-1980s, but has leveled off in recent years, and in 2002 it was well above the SSB corresponding to MSY.
Fishing mortality – F was estimated to be about 60 percent of F_{MSY} in both 2001 and 2003.
Management recommendations/regulations – In 1999 ICCAT established a TAC for ALB in the SAO. The TAC for 2004 was set at 29 200 tonnes, slightly less than the catch-related reference point.
Stock status summary – *Stock size*: above its reference point. *Fishing mortality*: below its reference point.

Outlook – The SCRS recommended that the catch not exceed 31 000 tonnes (MSY) for the next three to five years. The catches of ALB in the SAO have been above or close to MSY since 1988. Catches of this level would probably reduce the stock toward the B_{MSY}. The ALB-SAO catches are currently restricted by a TAC of 29 200 tonnes.

Atlantic Bluefin (BFT) in the Eastern Atlantic Ocean (EAO)

Historical catches – The catches of BFT in the EAO (including the Mediterranean Sea) increased from 1950 to 1955, reaching almost 40 000 tonnes in 1955 (Figure AI.7). After that the catches declined to a minimum of approximately 10 000 tonnes in 1970. The catches then increased until 1996, when the maximum catch of approximately 50 000 tonnes was taken. After that the catches decreased to 33 093 tonnes in 2002. The 2002 catch was about 65 percent of the maximum catch, taken in 1996.

The principal fishing countries and entities employed the following methods of fishing in 2002: purse seining, France (5 800 tonnes), Italy (3 200 tonnes), Tunisia (2 500 tonnes), Turkey (2 300 tonnes) and Spain (1 700 tonnes); longlining, Japan (2 900 tonnes); pole-and-line fishing, Spain (2 400 tonnes); trap fishing, Morocco (1 700 tonnes) and Spain (1 500 tonnes).

FIGURE AI.7
Cumulative catches of BFT, by gear, in the EAO

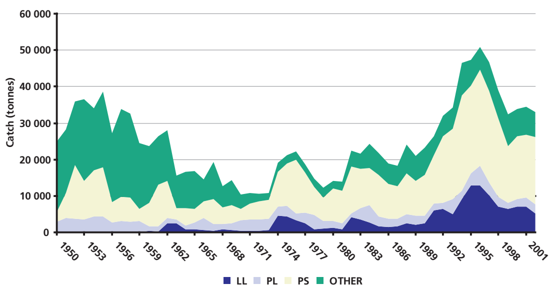
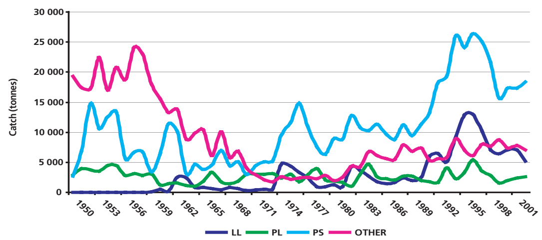


FIGURE AI.8
BFT catches, by gear, in the EAO



Stock status – A stock assessment for BFT was conducted in 2002 and reviewed in 2003 by the SCRS of ICCAT. There is considerable concern regarding the quality of the catch, fishing effort and catch-at-size data especially for the Mediterranean Sea, so the assessment was regarded as uncertain.

2002 catch (tonnes) – Total = 33 093 (PS = 18 341; LL = 5 160; PL = 2 569; TROLL = 12; OTHER[1] = 7 011).

Maximum annual catch (tonnes) – Total = 50 762 (PS = 26 344; LL = 12 959; PL = 5 362; OTHER = 6 097) in 1996.

Catch-related reference point (tonnes) – Unknown.

Stock size – The SSB in 2000 was about 86 percent of its level in 1970 (the first year for which an estimate is available). The recruitment has fluctuated, without showing a clear trend, in recent years.

Fishing mortality – An increase in F, especially for older fish after 1993, has been observed. In 2000 F was almost 2.5 times greater than that corresponding to the maximum yield per recruit.

Management recommendations/regulations – In spite of serious concerns regarding the status of the stock, no definite fisheries management recommendations were made by the SCRS in 2003, due to the poor quality of the catch, fishing effort and catch-at-size data and, consequently, the uncertainty of the stock assessment. Beginning in 1998, the BFT catches in the EAO have been restricted by TACs; these were fixed at 32 000 tonnes for 2003 through 2006. Closed areas and/or seasons limiting the use of specific gears have been adopted by ICCAT to protect juveniles and to restrict the catches during the spawning season. The minimum catch size is 6.4 kg (with 15-percent tolerance in number of fish) and 3.2 kg (with no tolerance).

Stock status summary – *Stock size*: below its reference point. *Fishing mortality*: above its reference point.

[1] Mainly mid-water trawls, traps, handlines, gillnets and recreational gear.

Outlook – The present catch level is not sustainable. If the total fishing mortality is reduced substantially, especially for immature fish, the catches would decrease and the stock biomass would increase. After the recovery of the biomass to a higher level (e.g. to the level of the early 1970s), catches greater than the present ones (possibly more than 50 000 tonnes per year, depending on the selectivity pattern) could be sustained. The catches are currently restricted by TACs of 32 000 tonnes.

Atlantic Bluefin (BFT) in the Western Atlantic Ocean (WAO)

Historical catches – The catches of BFT in the WAO increased almost by 20-fold from 1960 to 1964, when the maximum catch of 18 679 tonnes was taken (Figure AI.9). The catches subsequently decreased sharply, and oscillated between 3 200 and 6 700 tonnes between 1968 and 1981. The catch decreased to 1 400 tonnes in 1982 as a result of a catch limit imposed by ICCAT. The 2002 catch (3 220 tonnes), the greatest since 1981, was about 17 percent of the maximum catch, taken in 1964. The greatest catches of BFT in the WAO were taken by the United States (1 900 tonnes), Canada (640 tonnes) and Japan (575 tonnes).

FIGURE AI.9

Cumulative catches of BFT, by gear, in the WAO

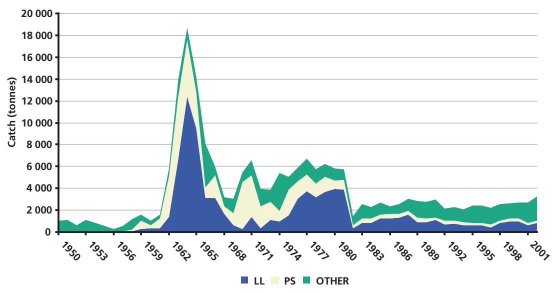
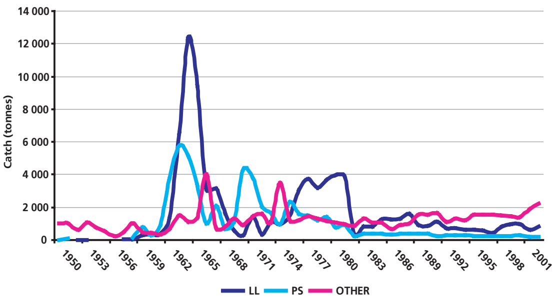


FIGURE AI.10

BFT catches, by gear, in the WAO



Stock status – A stock assessment for BFT was conducted in 2002 by the SCRS of ICCAT and reviewed in 2003. There are two hypotheses regarding the relationship between SSB and recruitment. One states that the recruitment has been poor because of low SSB levels, while the other assumes that environmental conditions are now less favorable for recruitment. The SCRS conducted projections for two scenarios, the so-called low-and high-recruitment scenarios, which reflect the two hypotheses. The high-recruitment scenario reflects the first hypothesis, i.e. that the recruitment will increase with increased SSB, while the low-recruitment scenario reflects the second hypothesis.

2002 catch (tonnes) – Total = 3 220 (LL = 802; PS = 208; OTHER = 2 210).
Maximum annual catch (tonnes) – Total = 18 679 (LL = 12 410; PS = 5 158; OTHER[1] = 1 111) in 1964.
Catch-related reference point (tonnes) – 3 500 (MSY for the low-recruitment scenario); 7 200 (MSY for the high-recruitment scenario).
Stock size – The SSB declined steadily from 1970 through the late 1980s, before leveling off at about 20 percent of its level in 1975 (the reference year used in previous assessments). After 1997 the SSB steadily declined again, and in 2001 it was at 13 percent of its 1975 level (the lowest level since 1970). The recruitment has been low since 1976, except for 1995 and 1998.
Fishing mortality – F for adults was at its highest level since 1970 in 2001.
Management recommendations/regulations – Regulatory measures for BFT in the WAO have been in place since 1981. In 2002 ICCAT set the annual TAC at 2 700 tonnes (effective in 2003). ICCAT adopted a programme in 1998 to rebuild the BFT stock to SSB_{MSY} in the WAO by 2018. A minimum size limit was set at 6.4 kg (with 15-percent tolerance, in number of fish).
Stock status summary – *Stock size*: below its reference point. *Fishing mortality*: above its reference point.

[1] Mainly rod-and-reel.

Outlook – As it was mentioned earlier, projections of the SSB for two scenarios were conducted by the SCRS. The low-recruitment scenario included the assumption that the future average recruitment will be approximately equal to the average estimated recruitment since 1976, when the recruitment was low. The high-recruitment scenario allowed the average recruitment to increase with spawning stock size up to a maximum level no greater than the average estimated recruitment for 1970-1974, when recruitment was high. These scenarios implied that the SSB_{MSY} is 42 percent and 183 percent of the SSB_{1975}, respectively.

It is unlikely that SSB_{MSY} for the high-recruitment scenario will be reached by 2018 if the recent level of catch (and the TAC) is maintained. For the low-recruitment scenario, assuming that the relatively large recruitment estimates for some recent year-classes are realistic, the SSB_{MSY} could be reached even with an increase of the present catch (and the TAC).

In addition, the projections for the low-recruitment scenario suggest that a catch of 2 500 tonnes per year has a 97-percent probability of allowing the SSB to rebuild to SSB_{MSY} by 2018. A catch of 3 000 tonnes per year has an 83-percent probability of this. The projections for the high-recruitment scenario indicate that a catch of 2 500 tonnes per year has a 20-percent probability of allowing rebuild the SSB to rebuild to SSB_{MSY} by 2018.

It is unclear which of the two hypotheses is more probable.

The BFT-WAO catches are currently restricted by a TAC of 2 700 tonnes.

Bigeye (BET) in the Atlantic Ocean (AO)

Historical catches – The catches of BET in the AO increased, with some fluctuations, from 1950 to 1994, when the maximum catch of 129 506 tonnes was taken (Figure AI.11). During the 1994-1999 period the catches fluctuated between 100 000 and 120 000 tonnes. Since then the catches of BET have sharply decreased. The 2002 catch, 73 110 tonnes, was approximately 56 percent of the maximum catch. The principal fishing countries and entities employed the following methods of fishing in 2002: longlining, the Taiwan Province of China (16 500 tonnes) and Japan (14 700 tonnes); pole-and-line fishing, Ghana (4 300 tonnes), Spain (2 700 tonnes) and Portugal (2 400 tonnes); purse seining, Spain (7 000 tonnes).

FIGURE AI.11
Cumulative catches of BET, by gear, in the AO

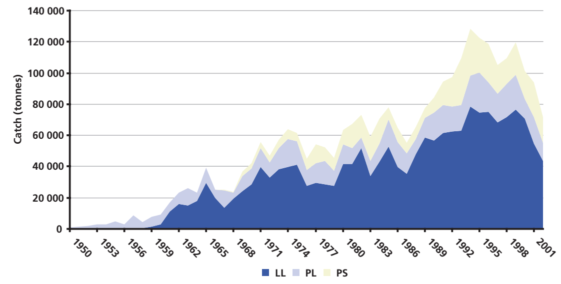
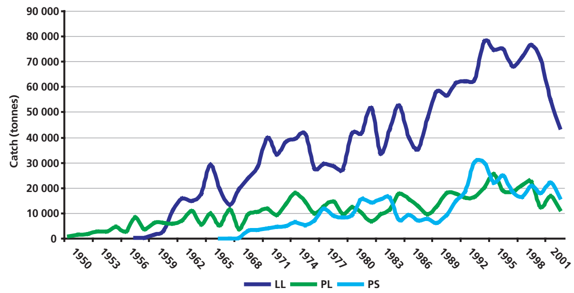


FIGURE AI.12
BET catches, by gear, in the AO



Stock status – A full stock assessment for BET was conducted by the SCRS of ICCAT in 2002. The lack of reasonable estimates of some biological parameters considerably hindered it and led to some unrealistic results.

2002 catch (tonnes) – Total = 73 110 (LL = 43 774; PL = 11 640; PS = 16 193; OTHER[1] = 1 503).

Maximum annual catch (tonnes) – Total = 129 506 (LL = 78 296; PL = 20 285; PS = 29 952; TROLL = 34; OTHER = 939) in 1994.

Catch-related reference point (tonnes) – MSY between 79 000 and 105 000 (range of estimates based on various production models).

Stock size – The biomass declined considerably between 1993 and 1999 due to the catches greater than the MSY, followed by a leveling off as a consequence of the subsequent decreased catches. The present biomass is about 10 to 20 percent below the level corresponding to the MSY.

Fishing mortality – Production modeling indicates that the present F is about 15 percent greater than that corresponding to the MSY. A yield-per-recruit analysis also supports this conclusion.

Management recommendations/regulations – ICCAT in 2003 recommended limiting the 2004 catch to the average catch of BET taken in 1991 and 1992 (approximately 96 000 tonnes). A moratorium on FAD fishing in the Gulf of Guinea has been implemented by ICCAT since 1999, and the SCRS considers that full compliance with this regulation is crucial for the sustainability of BET. The minimum size limit is 3.2 kg.

Stock status summary – *Stock size*: below its reference point. *Fishing mortality*: above its reference point.

[1] Mainly trawls and handlines.

Outlook – Stock projections based on the results of a production model were conducted, assuming a catch of 100 000 tonnes in 2002 (very close to the reported catch for 2001) and various levels of constant catch thereafter. They suggested that the biomass of BET will not decline further with constant annual catches of 100 000 tonnes. It is expected that the biomass will increase with catches of 95 000 tonnes or less, and that further declines in the biomass would result with catches of 105 000 tonnes or more. According to a yield-per-recruit analysis, a reduction of fishing effort by the fisheries catching small fish could result in an increase in the yield per recruit by as much as 20 percent.

Skipjack (SKJ) in the Eastern Atlantic Ocean (EAO)

Historical catches – The catches of SKJ in the EAO (including the Mediterranean Sea) increased until 1974 when, for the first time, they exceeded 100 000 tonnes (Figure AI.13). From 1974 to 1990 the catches fluctuated widely, without any clear trend. In 1991, with the introduction of fish-aggregating devices (FADs), the catches increased sharply, attaining a maximum of 169 771 tonnes in 1991. Since then the catches have declined, and the recent catches are comparable to those taken prior to the introduction of FADs. The 2002 catch, 92 945 tonnes, was about 55 percent of the maximum catch. The principal fishing countries and entities employed the following methods of fishing in 2002: purse seining, Spain (21 600 tonnes) and Ghana (20 600 tonnes); pole-and-line fishing, Ghana (11 300 tonnes).

FIGURE AI.13
Cumulative catches of SKJ, by gear, in the EAO

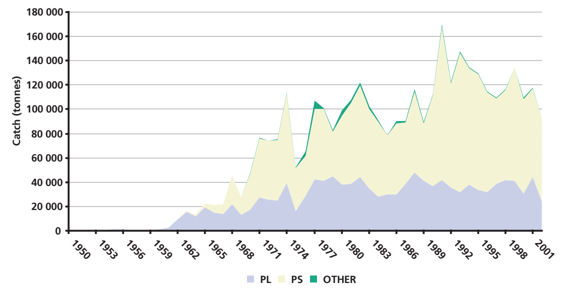
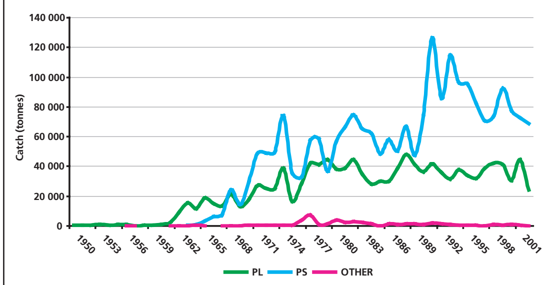


FIGURE AI.14
SKJ catches, by gear, in the EAO



Stock status – The most recent assessment of SKJ in the AO was conducted in 1999 by the SCRS of ICCAT. According to the SCRS, "characteristics such as continuous recruitment but heterogeneous in time and area, variable growth between areas, exploitation by diverse fishing fleets having different and changing catchabilities, make it very difficult to conduct a standard assessment".

2002 catch (tonnes) – Total = 92 945 (PS = 68 634; PL = 24 074; LL = 26; OTHER = 211).

Maximum annual catch (tonnes) – Total = 169 771 (PS = 126 264; PL = 41 612; TROLL = 19; LL = 5; OTHER = 1 871) in 1991.

Catch-related reference point (tonnes) – Unknown.

Stock size – Unknown.

Fishing mortality – Unknown.

Management recommendations/regulations – The owners of French and Spanish vessels voluntarily introduced moratoria on fishing from November 1997 through January 1998, and November 1998 through January 1999. The moratoria, which were implemented to protect juvenile BET, have influenced the catches of SKJ around FADs. Similar moratoria have been recommended by ICCAT since 1999, and these are still in effect.

Stock status summary – *Stock size*: unknown. *Fishing mortality*: unknown.

Outlook – Unknown.

Skipjack (SKJ) in the Western Atlantic Ocean (WAO)

Historical catches – The catches of SKJ in the WAO were at low levels until 1979 (Figure AI.15). From 1979 to 1985, the year in which the maximum catch of 40 272 tonnes was taken, the catches increased by six-fold. Then they decreased sharply, and since 1988 the catches have fluctuated between 24 000 and 33 000 tonnes. The 2002 catch, 21 428 tonnes, the lowest catch since 1981, was about 53 percent of the maximum catch. The principal fishing countries employed the following methods of fishing in 2002: pole-and-line fishing, Brazil (18 185 tonnes); purse-seine fishing, Venezuela (2 000 tonnes).

FIGURE AI.15
Cumulative catches of SKJ, by gear, in the WAO

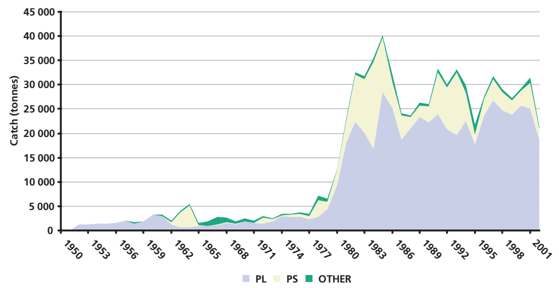
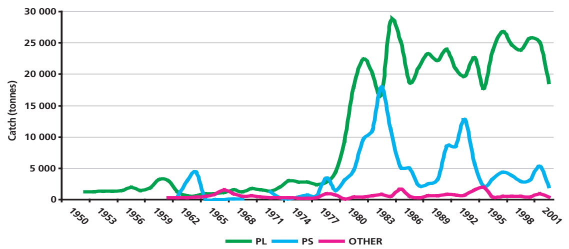


FIGURE AI.16
SKJ catches, by gear, in the WAO



Stock status – The last assessment on SKJ in the AO was conducted in 1999 by the SCRS of ICCAT. That assessment has been considered inconclusive, however. As was already mentioned in the previous section, there are some characteristics of SKJ that make it very difficult to conduct a standard assessment.

2002 catch (tonnes) – Total = 21 428 (PL = 18 737; PS = 2 116; LL = 61; TROLL = 58; OTHER = 456).
Maximum annual catch (tonnes) – Total = 40 272 (PL = 28 490; PS = 11 191; LL = 24; OTHER = 567) in 1985.
Catch-related reference point (tonnes) – Unknown.
Stock size – Standardized abundance indices up to 1998 were available from the Brazilian pole-and-line fishery and the Venezuelan purse-seine fishery, and both indices were stable.
Fishing mortality – Unknown.
Management recommendations/regulations – The owners of French and Spanish vessels voluntarily introduced moratoria for November 1997 through January 1998, and November 1998 through January 1999. The moratoria, which were implemented to protect juvenile BET, have influenced the SKJ catches around FADs. Similar moratoria have been recommended by ICCAT since 1999, and these are still in effect.
Stock status summary – *Stock size*: unknown. *Fishing mortality*: unknown.

Outlook – Unknown.

Yellowfin (YFT) in the Atlantic Ocean (AO)

Historical catches – The catches of YFT in the AO increased steadily from 1950 to 1984 (Figure AI.17). After that the catches fluctuated, without a clear trend, until 1990, when the maximum catch of 192 456 tonnes was taken. The catches have decreased since 1990. The 2002 catch was approximately 140 000 tonnes, about 71 percent of the maximum catch. The principal fishing countries or entities employed the following methods of fishing in 2002: purse seining, France (31 300 tonnes), and Spain (30 300 tonnes); longlining, the Taiwan Province of China (4 500 tonnes), Brazil (3 300 tonnes), the United States (2 500 tonnes) and Japan (1 800 tonnes); pole-and-line fishing, Ghana (10 200 tonnes).

FIGURE AI.17
Cumulative catches of YFT, by gear, in the AO

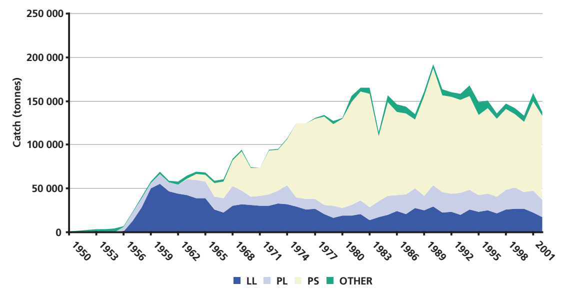
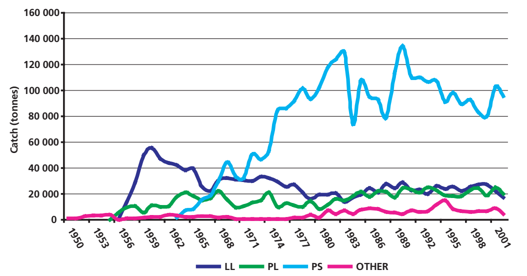


FIGURE AI.18
YFT catches, by gear, in the AO



Stock status – A stock assessment for YFT was conducted by the SCRS of ICCAT in 2003. Various age-structured and production models were applied.

2002 catch (tonnes) – Total = 137 440 (PS = 95 436; PL = 20 172; LL = 17 202; TROLL = 13; OTHER[1] = 4 617).

Maximum annual catch (tonnes) – Total = 192 456 (PS = 134 473; LL = 29 104; PL = 24 278; TROLL = 330; OTHER = 4 271) in 1990.

Catch-related reference point (tonnes) – The MSY is estimated to be between 137 500 and 161 300 tonnes (based on results of age-structured and non-equilibrium production models).

Stock size – The SSB has been steadily decreasing since 1970. Estimates of the current biomass differ, depending on the models used. One model suggests that the current biomass is greater than that corresponding to the MSY, while another suggests that it is less than that biomass (B_{2001}/B_{MSY} = 0.73-1.10).

Fishing mortality – The declining trend in F since the early 1990s seems to have been reversed, and in 2001 F approached the highest level ever. Depending on the methods used, the current value of F was estimated to be either below or above the level corresponding to the MSY (F_{2001}/F_{MSY} = 0.87-1.46).

Management recommendations/regulations – In 2003 the SCRS reaffirmed its support for the ICCAT's 1993 recommendation "that there be no increase in the level of effective fishing effort exerted on Atlantic YFT, over the level observed in 1992". It also recommended that effective measures be found to reduce fishing mortality of small YFT. Moratoria on FAD fishing in the Gulf of Guinea have been implemented by ICCAT since 1999. The minimum size limit for YFT is 3.2 kg.

Stock status summary – *Stock size*: near its reference point. *Fishing mortality*: near its reference point.

[1] Mainly trawls and handlines.

Outlook – Projections indicate that an increase in the fishing effort is likely to decrease the yield per recruit, while reductions in the fishing mortality on fish less than 3.2 kg could result in substantial gains in the yield per recruit and modest gains in the spawning biomass per recruit. They also suggest that the biomass is likely to decrease if the fishing mortality increases to the 1992 level, which is currently being approached or exceeded.

INDIAN OCEAN

Albacore (ALB) in the Indian Ocean (IO)

Historical catches – The catches of ALB in the IO increased during the 1950s, reaching 19 000 tonnes in 1962 (Figure AI.19). Between 1962 and 1997 they fluctuated between 11 000 and 31 000 tonnes, without showing a clear trend. Since 1997 the catches of ALB have increased, and in 2002 the maximum catch of 42 749 tonnes was taken. From 1985 to 1992 large quantities of ALB were taken by drift gillnets[1]. Drift gillnetting ceased on the high seas in 1992, following United Nations General Assembly Resolution 46/215 (Large-scale pelagic drift-net fishing and its impact on the living marine resources of the world's oceans and seas). ALB are caught almost entirely by longlining in the IO. The principal fishing countries or entities in 2002 were the Taiwan Province of China (27 300 tonnes), Japan (3 200 tonnes), Indonesia (2 900 tonnes) and Belize (2 600 tonnes).

FIGURE AI.19
Cumulative catches of ALB, by gear, in the IO

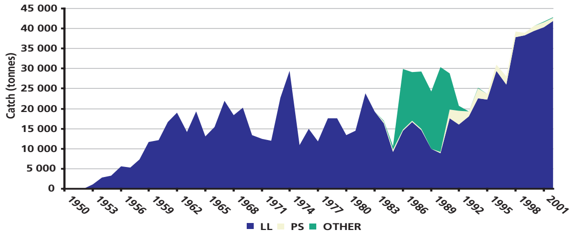
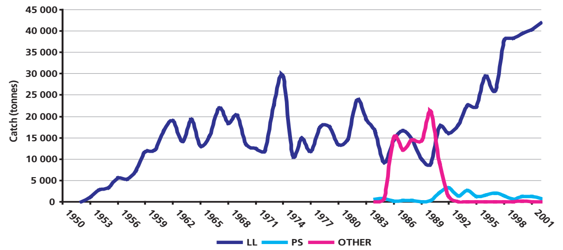


FIGURE AI.20
ALB catches, by gear, in the IO



Stock status – No assessment has been conducted for ALB by the IOTC. Due to increasing catches of ALB in recent years, during the 7th Session of the IOTC in 2002 its secretariat was asked to prepare a document on the status of ALB. The IOTC convened a Working Party on Temperate Tunas in 2004.

2002 catch (tonnes) – Total = 42 749 (LL = 41 948; PS = 735; TROLL = 4; OTHER = 62).
Maximum annual catch (tonnes) – Taken in 2002 (see above).
Catch-related reference point (tonnes) – Unknown.
Stock size – Unknown.
Fishing mortality – Unknown.
Management recommendations/regulations – No management recommendations or regulations have been adopted.
Stock status summary – *Stock size*: unknown. *Fishing mortality*: unknown.

Outlook – Unknown.

[1] Driftnets are classified in Figs. AI.19 and AI.20 as "other".

Bigeye (BET) in the Indian Ocean (IO)

FIGURE AI.21
Cumulative catches of BET, by gear, in the IO

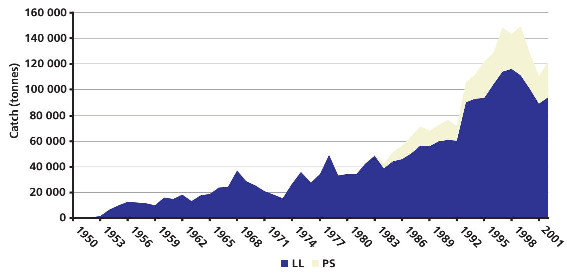
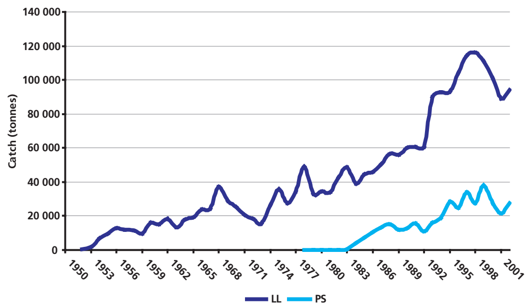


FIGURE AI.22
BET catches, by gear, in the IO



Historical catches – The catches of BET in the IO have increased steadily, except during the 1969-1973 period, when they declined by almost 50 percent from the 1968 level of 37 000 tonnes (Figure AI.21). In 1992 the catch (72 000 tonnes) was almost double that of the previous year, and after that, until 1999, the catches increased more rapidly, mainly as a consequence of the introduction of FADs. After 1999, when the maximum catch of 150 000 tonnes was taken, the catches decreased precipitously. The 2002 catch, 122 842 tonnes, was about 81 percent of the maximum catch. The principal fishing countries or entities employed the following methods of fishing in 2002: longlining, the Taiwan Province of China (42 300 tonnes), Indonesia (21 300 tonnes) and Japan (14 000 tonnes); purse seining, the European Union (France and Spain) (19 000 tonnes). Most BET catches by purse seiners are made around FADs and are composed of juveniles.

Stock status – In 2001 the third session of the WPTT of the IOTC conducted a stock assessment, using age-structured production models. In 2002 and 2003 the stock indicators were updated in accordance with new information that had been obtained after 2001. Various uncertainties in the assessments conducted were identified.

2002 catch (tonnes) – Total = 122 842 (LL = 94 283; PS = 27 542; PL = 958; TROLL = 12; OTHER = 47).
Maximum annual catch (tonnes) – Total = 150 122 (LL = 111 015; PS = 38 319; PL = 604; TROLL = 39; OTHER = 145) in 1999.
Catch-related reference point (tonnes) – 102 000 (MSY).
Stock size – The stock size is estimated to be significantly greater than that corresponding to the MSY. This estimation is substantially uncertain, however. The recruitment has increased in recent years, but there is also significant uncertainty in its estimation.
Fishing mortality – F is currently below $F_{MSY,}$ but the catches in recent years have exceeded MSY because the stock size is greater than $B_{MSY,}$ and is not in equilibrium with present F. However, there are large uncertainties associated with the estimates of F_{MSY} and the current F.
Management recommendations/regulations – Despite WPTT's fifth session recommendation that the catches of BET by all gears, particularly those that take juvenile BET around floating objects, be reduced, no management resolutions to reduce the catches of BET have been adopted.
Stock status summary – *Stock size*: possibly above its reference point. *Fishing mortality*: possibly below its reference point.

Outlook – The latest assessments suggest that reductions in purse-seine fishing mortality on juveniles could lead to increases in long-term yield and SSB, while decreases in longline fishing mortality could lead to an increase in SSB. The present catches are regarded as not sustainable in the long-term. It is foreseen that when the stock size reaches equilibrium (in 4 to 5 years) with a lower level of abundance, the catches will decrease below MSY, because the current F is below $F_{MSY.}$

Skipjack (SKJ) in the Indian Ocean (IO)

Historical catches – The catches of SKJ in the IO increased steadily until 1968 (Figure AI.23). Between 1968 and the early 1980s they remained at about 50 000 tonnes per year. After that they increased sharply, mainly because of the rapid expansion of purse-seine fishing and the introduction of FADs. About 80 percent of purse-seine catches are currently taken in association with FADs. The maximum catch, 482 245 tonnes, was taken in 2002. The principal fishing countries or entities employed the following methods of fishing in 2002: purse seining, the European Union (France and Spain) (149 200 tonnes); pole-and-line fishing, the Maldives (113 650 tonnes); gillnetting, Sri Lanka (42 900 tonnes) and Iran (23 100 tonnes); other gear, Indonesia (43 500 tonnes) and the Seychelles (29 900 tonnes).

FIGURE AI.23
Cumulative catches of SKJ, by gear, in the IO

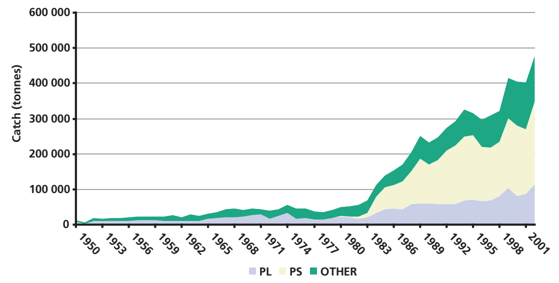
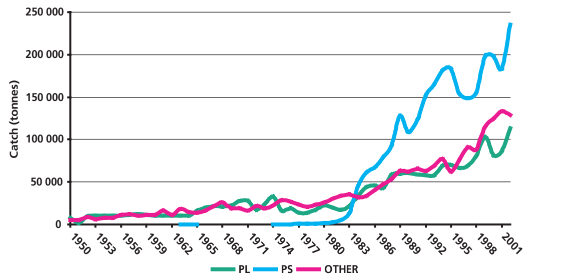


FIGURE A1.24
SKJ catches, by gear, in the IO



Stock status – In 2003, as in earlier years, the fifth session of the WPTT of the IOTC was unable to conduct a full stock assessment for SKJ in the IO due to the lack of sufficient data.

2002 catch (tonnes) – Total = 482 245 (PS = 235 609; PL = 113 658; TROLL = 4 208; LL = 75; OTHER[1] = 128 695).
Maximum annual catch (tonnes) – Taken in 2002 (see above).
Catch-related reference point (tonnes) – Unknown.
Stock size – Unknown.
Fishing mortality – Unknown.
Management recommendations/regulations – The WPTT has not made any specific management recommendations for SKJ. The information presented suggests that there is no need for concern about the status of SKJ.
Stock status summary – *Stock size*: unknown. *Fishing mortality*: unknown.

[1] Mainly gillnets and unclassified gears.

Outlook – SKJ is generally considered to be very resistant to overfishing. In spite of the rate of increase in catches (Figure AI.23), there is no evidence of overexploitation. It is possible that even greater catches are sustainable. However, because SKJ are caught with juvenile BET and YFT, the effects on these two species should be considered when contemplating increasing the fishing effort in order to catch more SKJ.

Yellowfin (YFT) in the Indian Ocean (IO)

Historical catches – The catches of YFT in the IO averaged about 45 000 tonnes per year from 1955 to 1983, with a peak of 90 000 tonnes in 1968 (Figure AI.25). The catch increased sharply from 1983 to 1993, when the maximum catch of more than 350 000 tonnes was taken, which was due mainly to exceptionally high catches in the northern Arabian Sea by longliners of the Taiwan Province of China. The upward trend of 1983-1993 was the consequence of the introduction of purse seiners, mainly of the European Union, to the IO. About half of the YFT caught by purse seiners in the IO is taken around FADs. The catches decreased after 1993, with some fluctuations, and the catch of 2002 was about 80 percent of the maximum catch. The principal fishing countries or entities employed the following methods of fishing in 2002: purse seining, the European Union (France and Spain) (91 900 tonnes); longlining, Taiwan Province of China (28 900 tonnes), Indonesia (28 700 tonnes) and Japan (15 200 tonnes); gillnetting, Iran (19 000 tonnes), Sri Lanka (17 400 tonnes) and Oman (11 000 tonnes); pole-and-line fishing, the Maldives (16 300 tonnes).

FIGURE AI.25
Cumulative catches of YFT, by gear, in the IO

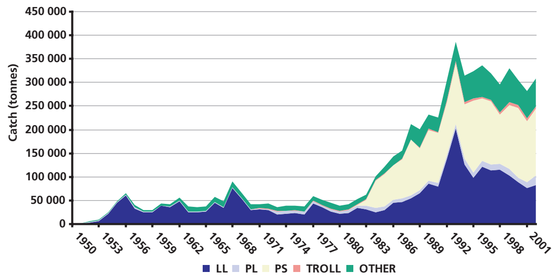
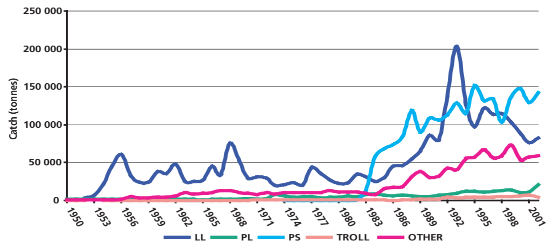


FIGURE AI.26
YFT catches, by gear, in the IO



Stock status – In 2002 a comprehensive assessment of YFT was conducted by the fourth session of the WPTT of the IOTC. The results obtained with the various methods differed, but the overall conclusions were consistent. In 2003 the stock indicators were updated in accordance with new information that had been obtained after 2002.

2002 catch (tonnes) – Total = 308 477 (PS = 142 271; OTHER[1] = 59 019; LL = 82 119; PL = 20 544; TROLL = 4 524).
Maximum annual catch (tonnes) – Total = 386 056 (LL = 203 104; PS = 128 634; OTHER = 41 145; PL = 9 275; TROLL = 3 898) in 1993.
Catch-related reference point (tonnes) – MSY between 280 000 and 350 000.
Stock size – The YFT biomass has been substantially declining since at least the mid-1980s.
Fishing mortality – Since the early 1980s, there has been a continuous increase in F, but no reliable estimate of F_{MSY} has been obtained.
Management recommendations/regulations – New information presented during the fifth session of the WPTT in 2003 confirmed the previous finding that YFT are heavily exploited. The WPTT recommended that the level fishing effort directed at juvenile YFT associated with floating objects be reduced and that the effort directed at YFT not associated with floating objects not be further increased.
Stock status summary – *Stock size*: unknown. *Fishing mortality*: unknown.

[1] Mainly handlines and gillnets.

Outlook – The current catches of YFT in the IO are sustainable, provided that the fishing effort, especially that directed toward juvenile fish associated with FADs, is not further increased.

PACIFIC OCEAN

Albacore (ALB) in the North Pacific Ocean (NPO)

FIGURE AI.27
Cumulative catches of ALB, by gear, in the NPO

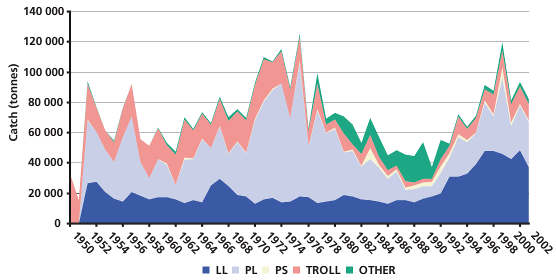
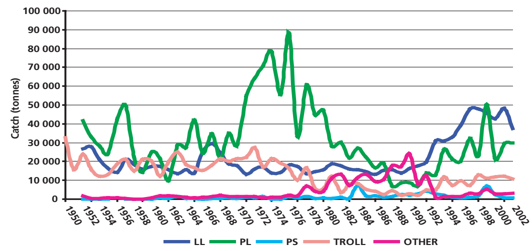


FIGURE AI.28
ALB catches, by gear, in the NPO



Historical catches – Catches of ALB in the NPO peaked in 1976 at 125 000 tonnes, and then declined to 38 000 tonnes in 1991 (Figure AI.27). The catches increased later in the 1990s, and reached 120 000 tonnes in 1999. Since then catches have oscillated between about 80 000 and 90 000 tonnes. The 2002 catch was about 65 percent of the maximum catch. Catches by drift gillnets were very high during the late 1980s and early 1990s. In 1992 the General Assembly of the United Nations imposed a global moratorium on fishing with drift gillnets on the high seas, and since then the catches by this gear have been almost negligible. The principal fishing countries or entities employed the following methods of fishing in 2002: longlining, Japan (29 500 tonnes) and Taiwan Province of China (7 200 tonnes); pole-and-line fishing, Japan (29 600 tonnes); troll fishing, United States (7 400 tonnes) and Canada (3 200 tonnes).

Stock status – A virtual population analysis for ALB in the NPO was conducted in 2002 by the 18th North Pacific Albacore Workshop. Growing concern about the uncertainties in the stock assessment was expressed during the workshop.

2002 catch (tonnes) – Total = 82 236 (LL = 37 476; PL = 29 987; TROLL = 10 663; PS = 856; OTHER[1] = 3 254).
Maximum annual catch (tonnes) – Total = 125 622 (PL = 88 041; LL = 17 958; TROLL = 16 183; PS = 1 381; OTHER = 2 059) in 1976.
Catch-related reference point (tonnes) – Unknown.
Stock size – The present biomass (510 000 tonnes) is almost 40 percent greater than that estimated for 1975, the first year for which such estimates are available. However, it is uncertain whether this biomass is above or below that corresponding to the MSY.
Fishing mortality – The estimates of the current F exceed some commonly used indicators of overfishing, e.g. $F_{30\%}$ and $F_{40\%}$[2].
Management recommendations/regulations – No recommendations have been made.
Stock status summary – *Stock size*: unknown. *Fishing mortality*: possibly above its reference point.

[1] Mainly gillnets (driftnets) and sport fishing gears.

[2] The fishing mortality that will reduce the equilibrium spawning potential per recruit to $X_{\%}$ of what it would be without any fishing. $F_{35\%}$ has been recommended as a proxy for F_{MSY}.

Outlook – It has been suggested that the biological productivity of ALB in the NPO has increased. Biomass projections were conducted, assuming constant annual fishing mortalities equal to those estimated for 2000. The biomass projections were computed under two scenarios involving: (1) high recruitment (sampled randomly from the recruitments estimated for 1990 to 1997) and (2) low recruitment (sampled from the recruitment series estimated for 1975 to 1989). Under the high-recruitment scenario, the biomass is expected to remain essentially at its 2001 level. Under the low–recruitment scenario, the biomass is expected to decline. In either case, the uncertainty is high; the biomass may deviate considerably from the predicted trend.

Albacore (ALB) in the South Pacific Ocean (SPO)

FIGURE AI.29

Cumulative catches of ALB, by gear, in the SPO

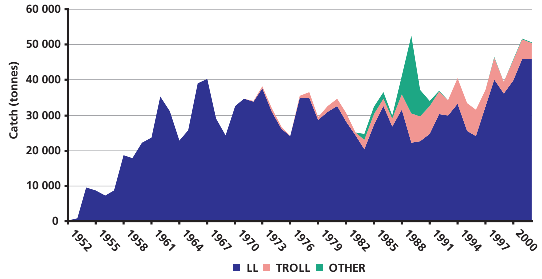
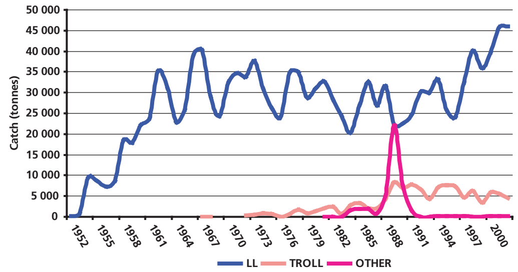


FIGURE AI.30

ALB catches, by gear, in the SPO



Historical catches – After an increase during the 1950s, the catches of ALB in the SPO have been relatively constant since early 1960s (Figure AI.29). The maximum catch, 53 000 tonnes, was taken in 1989, mainly due to a sharp increase in catches by drift gillnets. In 1992 the General Assembly of the United Nations imposed a global moratorium on fishing with drift gillnets on the high seas, and since then the catches by this gear have been almost negligible. The catches of ALB have been increasing since 1996. The 2002 catch, 51 000 tonnes, was 97 percent of 1989 maximum catch. The principal fishing countries or entities employed the following methods of fishing in 2002: longlining, Fiji and the Taiwan Province of China (8 000 tonnes each), American Samoa (6 000 tonnes), Japan (4 800 tonnes), French Polynesia (4 600 tonnes) and Samoa (4 400 tonnes); trolling, New Zealand (3 000 tonnes) and the United States (1 000 tonnes).

Stock status – A stock assessment for ALB in the SPO was conducted in 2003 and presented to the 16th meeting of the SCTB of the SPC. The results were similar to those of 2002.

2002 catch (tonnes) – Total = 50 858 (LL = 45 969; TROLL = 4 477; PL = 262; OTHER = 150).
Maximum annual catch (tonnes) – Total = 52 576 (LL = 22 238; TROLL = 8 370; OTHER[1] = 21 968) in 1989.
Catch-related reference point (tonnes) – Unknown.
Stock size – The biomass has been declining since the late 1970s, reaching historic low levels during recent years. This is largely the result of declining recruitment since the mid-1970s. Its negative correlation with El Niño events may explain the low recruitment rates during the 1980s and 1990s. The current biomass is about 60 percent of that during the early 1950s.
Fishing mortality – As longlining is the predominant method of fishing, F is greater for adult than for juvenile ALB. F has increased strongly, especially during recent years, but it is still probably low to moderate.
Management resolutions – In spite of the fact that ALB in the SPO is only moderately exploited, there is some evidence of localized depletion around some small island states. The SCG of the WCPFC has drawn attention to this issue, which could be an important one for the small island states dependent on these resources. No management resolutions have been adopted for ALB in the SPO.
Stock status summary – *Stock size*: above its reference point. *Fishing mortality*: below its reference point.

[1] Mainly gillnets (driftnets).

Outlook – The current catch levels appear to be sustainable. The exploitation rates, particularly for juvenile fish, appear to be low, but data for the fishery provide little information on the MSY. The catches are likely to continue to increase with further increases in fishing effort, although the extent to which the effort and catches could be increased is unknown. The recruitment and vulnerability to longlining appear to be strongly affected by environmental conditions. It is possible that the stock is now entering a more productive (La Niña-dominated) phase with respect to recruitment.

Bigeye (BET) in the Eastern Pacific Ocean (EPO)

Historical catches – The catches of BET in the EPO increased from 1954 to 1978, showing quite wide fluctuations (Figure AI.31). After a period of decreasing catches from 1978 to 1984, the catches almost doubled during the next two years, exceeding 100 000 tonnes for the first time in 1986. Since then the catches have fluctuated widely, without a clear trend. The 2002 catch, 73 000 tonnes, was about 67 percent of the maximum catch of 110 000 tonnes in 2000. The principal fishing countries employed the following methods of fishing in 2002: longlining, Japan (29 800 tonnes); purse-seining, Ecuador (18 500 tonnes), Spain (4 700 tonnes), Vanuatu (1 900 tonnes), the United States (1 700 tonnes) and Panama (1 300 tonnes).

FIGURE AI.31
Cumulative catches of BET, by gear, in the EPO

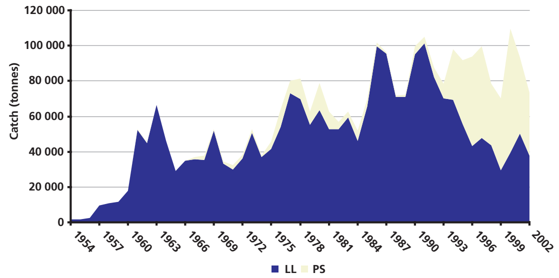
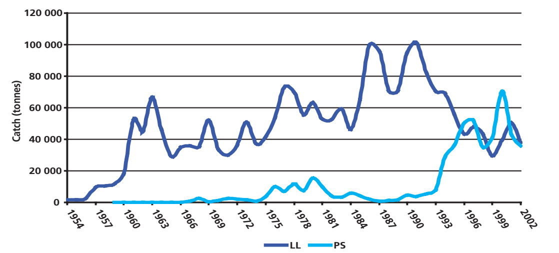


FIGURE AI.32
BET catches, by gear, in the EPO



Stock status – The most recent stock assessment for BET in the EPO was conducted by the IATTC in 2003. At the time of the assessment, data for recent longline catches for important parts of the fleet were not available, so the results of the assessment should be interpreted with caution.

2002 catch (tonnes) – Total = 73 416 (LL = 37 786; PS = 35 630).

Maximum annual catch (tonnes) – Total = 109 596 (PS = 70 153; LL = 39 443) in 2000.

Catch-related reference point (tonnes) – Total AMSY = 77 000 (PS = 48 000; LL = 29 000). This is based on the recent fishing mortality patterns and mix of gears.

Stock size – In January 2003 the SSB of BET was greater than that corresponding to the AMSY, but it was forecast that it would be below that level by the end of 2003. The biomass of 1+-year-old BET has been reduced by fishing, and it was predicted that it would reach its lowest observed level (185 000 tonnes) by the end of 2003. This decrease in biomass has been most rapid since 2000, due to a series of weak year classes. The SSB has followed a similar trend, but with a lag of 2 to 3 years, and it is predicted that it will continue to decline over the next few years to below the level corresponding to the AMSY. The abundance of BET recruits does not seem to be related to the SSB. The recruitment is variable, and the mechanisms that explain this variation have not been identified.

Fishing mortality – On average, F for BET less than about 5 years old has increased substantially since 1993, due to the expansion of the purse-seine fisheries that catch BET in association with floating objects. F for fish more than about 6 years old has remained relatively constant.

Management recommendations/regulations – Considering that the studies of YFT and BET show that the current fishing effort exceeds that corresponding to the AMSY for both species, if recruitment is moderately dependent on the amount of spawning, it was decided at the 71st meeting of the IATTC (October 2003) to:

i) close the purse-seine fishery in a part of the EPO[1] from 1 December 2003 to 31 December 2003, and in the entire EPO from 1 August 2004 to 11 September 2004 and
ii) ensure that the longline catch of BET in the EPO in 2004 would not exceed that of 2001.

Stock status summary – *Stock size*: above its reference point. *Fishing mortality*: above its reference point.

[1] From the intersection of longitude 95°W with the west coast of the Americas south to latitude 10°N, then west to longitude 120°W, then south to latitude 5°S, then east to longitude 100°W, then north to latitude 5°N, then east to longitude 85°W, and finally north to the intersection with the west coast of the Americas.

Outlook – If the fishing mortality is proportional to the fishing effort, and the current patterns of age-specific selectivity are maintained, the level of fishing effort corresponding to the AMSY is estimated to be about 80 percent of the 2000-2001 effort. Such a reduction in the effort would increase the long-term average yield slightly, but it would significantly increase the spawning potential[1] of the stock.

A simulation study was conducted to estimate how various fishing scenarios would affect the stock of BET in the EPO. Several scenarios were defined by changing the present average fishing effort exerted by the purse seiners and assuming that the longline fishing effort would be constant. The increase of the purse-seine effort to 125 percent of the present one would decrease the spawning biomass ratios[2] (SBR) by about 28 percent by 2006, while the purse-seine catches would decrease by about 3 percent. Decreasing the purse-seine effort to 75 percent of the current level would increase the SBR by about 57 percent, while the purse-seine catches would decrease by about 7 percent. With the current effort level, provided that discards are avoided, it is predicted that by 2006 the catches would increase by about 5 percent.

The results from the simulation study suggest that future changes in the effort exerted by purse seiners would affect the catches by longliners. The longline catch would increase by about 18 percent by 2006 if the purse-seine effort were reduced to 75 percent of the current level. Similarly, the longline catch in 2006 would decrease by about 27 percent if the purse-seine fishing effort were increased to 125 percent of its current level.

It is predicted that changes in the fishing effort would have moderate effects on the average weight of individual BET caught in EPO. The critical weight[3] of BET is about 55 kg, while the current average weight of purse-seine caught BET is about 12 kg.

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[1] The spawning potential is based on the biomass of mature fish. The age at 50-percent maturity is approximately five years.

[2] The ratio of spawning biomass during a period of harvest to that that might accumulate in the absence of fishing.

[3] The weight of individual fish corresponding to the age at which the gains due to growth exactly balance the losses due to natural mortality.

Bigeye (BET) in the Western and Central Pacific Ocean (WCPO)

Historical catches – The catches of BET in the WCPO averaged 35 000 tonnes until 1974, after which they increased considerably, reaching a maximum of more than 124 000 tonnes in 2002 (Figure AI.33). The principal fishing countries or entities employed the following methods of fishing in 2002: longlining, Japan (25 400 tonnes), the Republic of Korea (25 000 tonnes) and the Taiwan Province of China (18 500 tonnes); purse seining, Japan (5 800 tonnes), the United States (3 500 tonnes), Papua New Guinea (3 300 tonnes), the Philippines (3 100 tonnes) and the Taiwan Province of China (2 600 tonnes); handlines, ring nets and unclassified gears, Indonesia (11 400 tonnes) and the Philippines (6 500 tonnes).

FIGURE AI.33
Cumulative catches of BET, by gear, in the WCPO

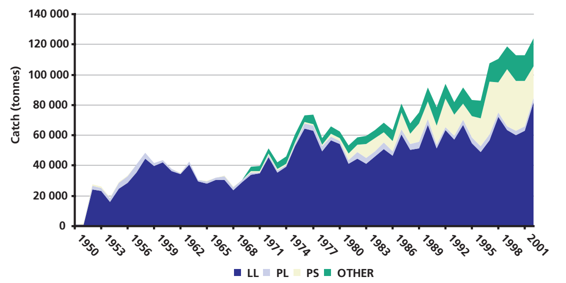
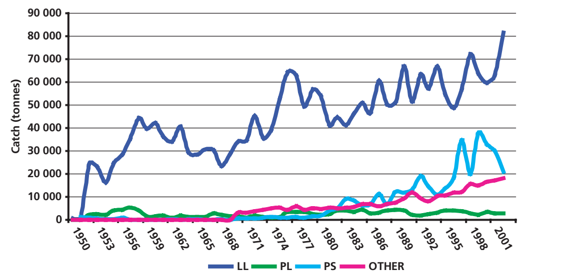


FIGURE AI.34
BET catches, by gear, in the WCPO



Stock status – A stock assessment for BET in the WCPO was conducted in 2003 and presented at the 16th meeting of the SCTB of the SPC. The results of the 2003 assessment were very different from those of 2002, due to the incorporation of new data and different standardization of longline effort.

2002 catch (tonnes) – Total = 124 107 (LL = 81 701; PS = 21 072; PL = 2 927; TROLL = 277; OTHER[1] = 18 130).
Maximum annual catch (tonnes) – Taken in 2002 (see above).
Catch-related reference point (tonnes) – MSY[2] is estimated to be between 40 000 and 80 000, depending on recruitment regime, at the current age-specific selectivity.
Stock size – The present biomass level is above B_{MSY}. The ratio of exploited to unexploited total biomass has been decreasing since 1950, and has approached 0.3 in recent years. The equilibrium biomass at MSY is estimated to be approximately 35 percent of the equilibrium unexploited biomass. The estimated recruitment has been increasing, with some fluctuations, since the early 1980s, reaching the greatest level in 1999[3].
Fishing mortality – F for both juveniles and adults has increased since the beginning of the fishery. F was formerly greater for adults than for juveniles, but during recent years they have been at about the same level. F appears to be greater than F_{MSY} although the assessment is uncertain.
Management recommendations/regulations – The SCG of the WCPFC has recommended that there be no further increase in F, at least until the uncertainty in the stock assessment is reduced to acceptable levels.
Stock status summary – *Stock size*: possibly near its reference point. *Fishing mortality*: possibly above its reference point.

[1] Mainly handline, ring nets and unclassified gears.
[2] The estimates of MSY are based on equilibrium recruitment obtained from a Beverton and Holt stock-recruitment relationship. Recent recruitment has been much greater than the equilibrium levels, and MSY would be greater if based on the greater recent recruitment.
[3] This pattern may be an artefact related to the surface fishery development and/or the lack of length-frequency data for the early years.

Outlook – The present fishing mortality rates for both juveniles and adults may not be sustainable in the long-term, particularly if the recent increase in the recruitment is not permanent. Yield and biomass projections were conducted for a range of scenarios of fishing effort. The equilibrium biomass was most sensitive to modifications of the fishing mortality by the purse-seine fishery. If the purse-seine fishing mortality were doubled the equilibrium total biomass and equilibrium adult biomass would decrease to 63 and 56 percent, respectively, of their current levels, while the catches would be reduced by 22 percent. Conversely, if the purse-seine fishing mortality were halved, the equilibrium total biomass and equilibrium adult biomass would increase by 5 percent and 32 percent, respectively, while the catches would increase by 12 percent. Modifications of the longline fishing mortality would have smaller, but significant, impacts on the equilibrium biomass levels.

Pacific Bluefin (PBF) in the Pacific Ocean (PO)

Historical catches – Catches of PBF in the PO have fluctuated, without a clear trend, since the early 1950s (Figure AI.35). Catches of more than 30 000 tonnes were taken during the early and mid 1960s, and during the late 1970s and early 1980s. After a period of low catches during the late 1980s and early 1990s, attaining the minimum catch of around 8 000 tonnes in 1990, the catches have recovered to a certain extent, but in 2001 and 2002, the catches have decreased again. The 2002 catch was about 48 percent of the 1981 maximum catch. The principal fishing countries or entities employed the following methods of fishing in 2002: purse seining, Japan (8 000 tonnes); longlining, Taiwan Province of China (1 500 tonnes) and Japan (600 tonnes); trolling, Japan (1 000 tonnes).

FIGURE AI.35
Cumulative catches of PBF, by gear, in the PO

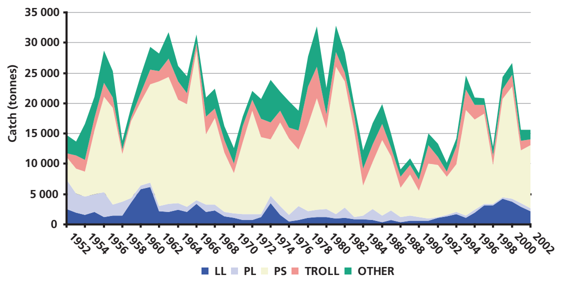
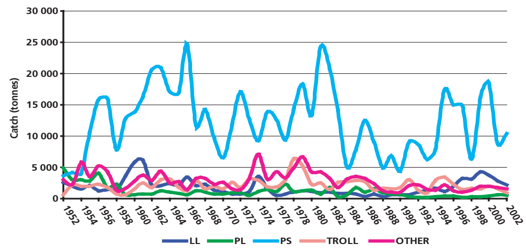


FIGURE AI.36
PBF catches, by gear, in the PO



Stock status – A stock assessment was conducted during the third meeting of the Pacific Bluefin Tuna Working Group (2004) of the ISC. The results were uncertain, and it was possible to discuss only general trends and broad conclusions with a reasonable degree of certainty.

2002 catch (tonnes) – Total = 15 618 (PS = 10 446; LL = 2 138; TROLL = 982; PL = 518; OTHER[1] = 1 534).
Maximum annual catch (tonnes) – Total = 32 769 (PS = 24 304; TROLL = 2 456; PL = 754; LL = 977; OTHER = 4 278) in 1981.
Catch-related reference point (tonnes) – Unknown.
Stock size – The biomass and SSB of PBF have fluctuated widely over the 51 years for which the stock assessment was carried out (1952-2002). These fluctuations are mainly the result of fluctuations in recruitment during that period. The biomass appears to have recovered from a record low level during the late 1980s to an intermediate level during recent years, largely as a result of better-than-average recruitment during the 1990s (particularly the strong 1994 year class).
Fishing mortality – The recent F is greater than F_{max}. In particular, the high F for young fish (ages 0-2) and older fish (ages 6+) may be of concern with respect to maintaining a sustainable fishery in the future.
Management recommendations/regulations – The ISC recommended no further increases in F for any of the fisheries taking PBF.
Stock status summary – *Stock size*: possibly near its reference point. *Fishing mortality*: above its reference point.

[1] Mainly gillnets and traps.

Outlook – The SSB has been declining since 1995 and if the estimated recent fishing mortality rates continue, the SSB is likely to continue to decline, at least from 2003 to 2005. The results of yield-per-recruit and cohort analyses indicate that greater catches could be obtained if age-0 and age-1 fish were not caught, or their catches significantly reduced. Age-0 fish occur only in the WCPO, and these are caught there by trolling gear. Age-1 fish are caught in both the WCPO and the EPO. The extent to which each fishery should reduce its fishing effort to maximize the catches, while achieving a sustainable exploitation of the stock, is not known.

Skipjack (SKJ) in the Eastern Pacific Ocean (EPO)

Historical catches – SKJ catches had been fluctuating without a clear trend until 1994, when they increased with some fluctuations (Figure AI.37). Since 1999, catches of SKJ have decreased, and the 2002 catch is about 60 percent of its maximum of 265 598 tonnes, taken in 1999. SKJ are caught almost entirely by purse seining in the EPO. In 2002 the principal fishing countries were Ecuador (77 600 tonnes) and Spain (22 000 tonnes).

FIGURE AI.37
Cumulative catches of SKJ, by gear, in the EPO

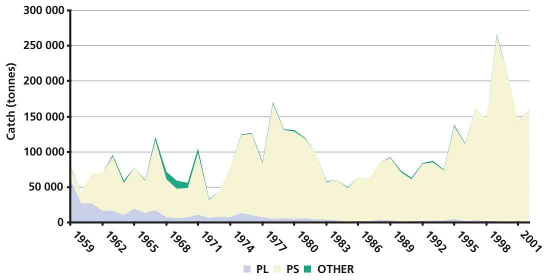
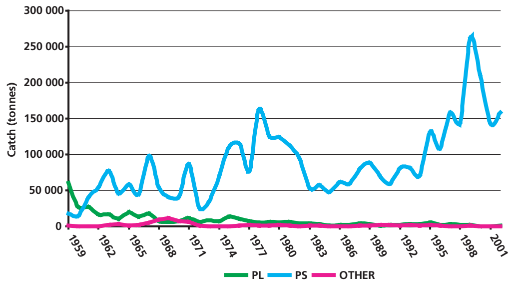


FIGURE AI.38
SKJ catches, by gear, in the EPO



Stock status – A stock assessment for SKJ in the EPO was conducted by the IATTC in 2002, but not in 2003. The assessment is still considered preliminary because (1) it is not known whether the catch per day is proportional to the abundance of the population accessible to the purse-seine fisheries, (2) it is possible that there is a population of large SKJ that is invulnerable to the fisheries, (3) the stock structure is uncertain and (4) the estimates of the biomass from the 2002 assessment are very different from those of the 2001 assessment.

2002 catch (tonnes) – Total = 158 911 (PS = 158 280; PL = 592; LL = 39).
Maximum annual catch (tonnes) – Total = 265 598 (PS = 262 040; PL = 2 109; LL=96; OTHER = 1353) in 1999.
Catch-related reference point (tonnes) – AMSY and yield-per-recruit calculations suggest that maximum yields would be achievable with infinite fishing mortality, given the current selectivity patterns of the fleet.
Stock size – The biomass of SKJ has been highly variable between 1975 and 2001. A rapid increase was observed late in 1998 and in 1999, but since then it has declined to much lower levels. The SSB was considerably reduced at the beginning of 2002. The variation in the biomass is attributable mostly to changes in recruitment. The absolute biomass and the spawning biomass ratio (SBR[1]) of SKJ are unknown.
Fishing mortality – The current levels of F are unknown. According to a yield-per-recruit analysis, F_{MSY} would be infinite.
Management recommendations/regulations – At the 71st meeting of the IATTC (October 2003) it was decided to close the purse-seine fishery in a part of the EPO[2] from 1 December 2003 to 31 December 2003, and in the entire EPO from 1 August 2004 to 11 September 2004 (see the section on BET in the EPO). This resolution was adopted to avoid increases in fishing effort for YFT and BET, but these species are taken together with SKJ.
Stock status summary – *Stock size*: unknown. *Fishing mortality*: unknown.

[1] The ratio of spawning biomass during a period of harvest to that which might accumulate in the absence of fishing.
[2] From the intersection of longitude 95°W with the west coast of the Americas south to latitude 10°N, then west to longitude 120°W, then south to latitude 5°S, then east to longitude 100°W, then north to latitude 5°N, then east to longitude 85°W, and finally north to the intersection with the west coast of the Americas.

Outlook – Regardless of the reduction of SSB in 2002, there is no evidence of overexploitation of SKJ. The critical weight[1] is less than the average weight at recruitment to the main fisheries. Further increases in the catches of SKJ in the EPO could be sustainable, provided that further increases in the catches of BET and YFT are avoided. The historical biomass of SKJ was driven by fluctuations in the recruitment, and, because of this, no projections of future biomass have been provided by the IATTC.

[1] The weight of individual fish corresponding to the age at which the gains due to growth exactly balance the losses due to natural mortality.

Skipjack (SKJ) in the Western and Central Pacific Ocean (WCPO)

FIGURE AI.39

Cumulative catches of SKJ, by gear, in the WCPO

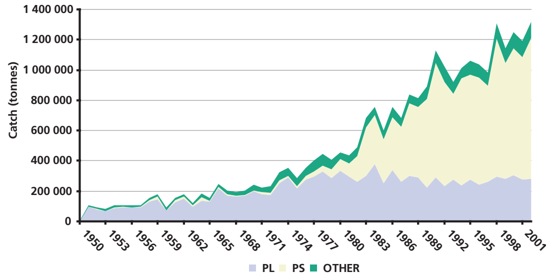
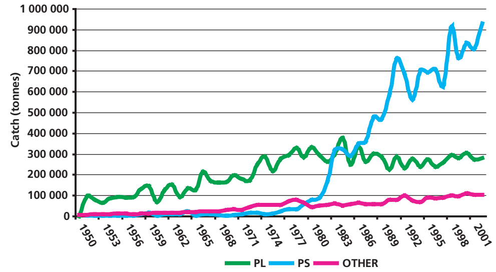


FIGURE AI.40

SKJ catches, by gear, in the WCPO



Historical catches – Catches of SKJ in the WCPO increased greatly from 1950 to 2002 (Figure AI.39). The upward trend became much more pronounced during the early 1980s, when the expansion of the purse-seine fleet began. Average annual catch during the last decade has been more than 1 000 000 tonnes. Maximum catch to date was taken in 2002. The principal fishing countries or entities employed the following methods of fishing in 2002: purse seining, Taiwan Province of China (229 400 tonnes), Japan (184 900 tonnes) and the Republic of Korea (162 000 tonnes); pole-and-line fishing, Indonesia (167 000 tonnes) and Japan (103 000 tonnes); handline, ring nets and unclassified gears, Indonesia and the Philippines (45 000 tonnes each).

Stock status – A stock assessment for SKJ in WCPO was conducted in 2003 and presented to the 16th meeting of the SCTB of the SPC. Some concern has been expressed about the model's ability to produce accurate estimates for some population parameters, particularly their absolute values. Due this concern, the Skipjack Research Group (SRG) of the SCTB has relied largely on trends and ratios, rather than absolute estimates from the model, in making conclusions about the stock status.

2002 catch (tonnes) – Total = 1 320 692 (PS = 931 105; PL = 280 377; LL = 4 200; TROLL = 217; OTHER[1] = 104 793).
Maximum annual catch (tonnes) – Taken in 2002 (see above).
Catch-related reference point (tonnes) – 1 600 000 (MSY[2]).
Stock size – The level of the biomass of SKJ is closely related to the recruitment. The biomass has increased since 1972, with maximum levels in the mid-1980s and the late 1990s, as a result of increases in recruitment. The present biomass is well above B_{MSY}. The difference between fished and unfished biomass has generally been in the range of 20 to 25 percent in recent years. The current recruitment is high, probably due to recent El Niño events.
Fishing mortality – F is less for juveniles than for adults. F for both juveniles and adults increased from 1972 to 1997, after which they both decreased, which is attributed to an increase in biomass. F is currently about 0.20 to 0.25 per year.
Management recommendations/regulations – In 2003 the SCG of the WCPFC has expressed a concern that further increases in SKJ purse-seine catches may result in increased catches of juvenile BET and YFT, which should be avoided (see the sections on BET and YFT in the WCPO). No management resolutions have been adopted for SKJ.
Stock status summary – *Stock size*: above its reference point. *Fishing mortality*: below its reference point.

[1] Mainly handlines, ring nets and unclassified gears.

[2] MSY estimates are based on equilibrium recruitment obtained from a Beverton and Holt stock-recruitment relationship. Recent recruitment has been much higher than the equilibrium levels, and MSY would be higher if based on the higher recent recruitment.

Outlook – Analyses of the stock suggest that SKJ in the WCPO is in a healthy state. Increases in fishing mortality would likely result in increases in the catches. Due to the extremely high productivity of this stock and its high resilience to fishing, the catches may be much more dependent on economic factors than on biological constraints. However, because SKJ is being fished together with YFT and BET, fisheries management measures for these species may have an impact on the future catches of SKJ.

Yellowfin (YFT) in the Eastern Pacific Ocean (EPO)

Historical catches – The catches of YFT in the EPO increased from the early 1960s to 1976 (Figure AI.41). The catch rates were low during 1978-1983, due to concentration of fishing effort on small fish, and a major El Niño episode, from mid-1982 to the late 1983, which made the fish less vulnerable to capture. The catches increased from 1983 to 1988, decreased from 1988 to 1994, and then increased again to a maximum of 420 000 tonnes in 2002. The catches are made mostly by purse seining. The principal purse-seine fishing countries catching YFT in the EPO in 2002 were Mexico (149 900 tonnes), Venezuela (120 300 tonnes), Ecuador (39 400 tonnes), Colombia (30 000 tonnes) and Panama (20 400 tonnes).

FIGURE AI.41
YFT cumulative catches, by gear, in EPO

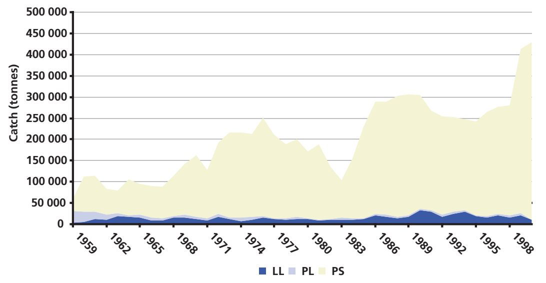
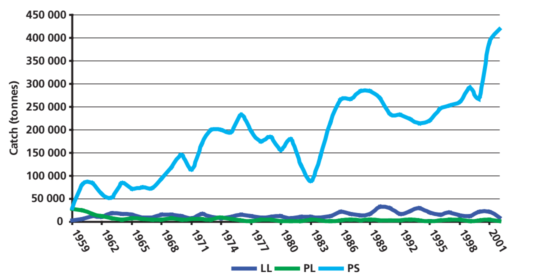


FIGURE AI.42
YFT catches, by gear, in the EPO



Stock status – A stock assessment for YFT was carried out by IATTC in 2003. Its results are similar to those of previous assessments.

2002 catch (t) – Total = 429 299 (PS = 418 280; LL = 10 091; PL = 928).
Maximum annual catch (t) – Taken in 2002 (see above).
Catch-related reference point (t) – 250 000. This AMSY is based on average recruitment, the recent fishing mortality patterns and mix of gears.
Stock size – The YFT stock has experienced two different productivity regimes (greater recruitment during 1984-2001 than during 1975-1983). Particularly strong cohorts entered the fishery in 1998, 1999 and 2000, which increased the biomass in 1999 and 2000. However, these cohorts have now moved through the fishery, so the biomass decreased in 2001 and 2002. Currently the spawning biomass ratio[1] (SBR) appears to be slightly less than the SBR corresponding to the AMSY, but this conclusion should be taken with caution, due to uncertainties in the estimation of the actual SBRs and SBR_{AMSY}.
Fishing mortality – F has been stable in recent years (slightly below F_{AMSY}), and is greatest for age-3 and age-4 fish.
Management recommendations/regulations – At the 71st meeting of the IATTC (October 2003) it was decided to close the purse-seine fishery in a part of the EPO[2] from 1 December 2003 to 31 December 2003, and in the entire EPO from 1 August 2004 to 11 September 2004 (see the section on BET in the EPO).
Stock status summary – *Stock size*: near its reference point. *Fishing mortality*: near its reference point.

[1] The ratio of spawning biomass during a period of harvest to that which might accumulate in the absence of fishing.
[2] From the intersection of longitude 95°W with the west coast of the Americas south to latitude 10°N, then west to longitude 120°W, then south to latitude 5°S, then east to longitude 100°W, then north to latitude 5°N, then east to longitude 85°W, and finally north to the intersection with the west coast of the Americas.

Outlook – The average weight of the YFT in the catch is much less than the critical weight (36 kg).

The present fishing effort is estimated to be less than that corresponding to AMSY, but increasing the effort would probably not produce noticeable increases in the catches. Due to the large recruitment of 1998-2000, the current catches are greater than the AMSY.

The SBR is at about the level corresponding to the AMSY. Projections with the current fishing effort and average recruitment indicate that the stock will increase to a SBR level above that corresponding to the AMSY. However, because the biomass is declining from the relatively high level associated with the strong recruitments during the late 1990s, and because there is some uncertainty about recent and future recruitment and biomass levels, the present fishing mortality should not increase.

A simulation study was conducted to gain further understanding of how several scenarios would affect the stock of YFT in the EPO. These scenarios were defined by changing the average recent effort exerted by the purse-seine fleet and assuming that the longline effort would be constant. An increase of the surface effort by 25 percent would decrease the SBR by about 16 percent by the end of 2007, while the catches would increase by only 3 percent. A decrease in the purse-seine effort by 25 percent would increase the SBR by about 21 percent, while the catches would decrease by 7 percent. With the present effort, it is predicted that at the end of 2007, the SBR would remain, on average, greater than SBR_{AMSY}. Changes in the amount of effort exerted by the surface fleet would substantially affect the longline catches. The longline catch in 2007 would increase by about 31 percent, if the surface effort were reduced by 25 percent. Similarly, the catch during 2007 would decrease by about 22 percent, if the surface effort were increased by 25 percent. Not catching unmarketable YFT around floating objects (or ensuring that the discarded fish would survive) would not significantly increase the spawning stock. Changes in the fishing effort would have moderate effects on the average weight of the fish caught.

Yellowfin (YFT) in the Western and Central Pacific Ocean (WCPO)

FIGURE AI.43
Cumulative catches of YFT, by gear, in the WCPO

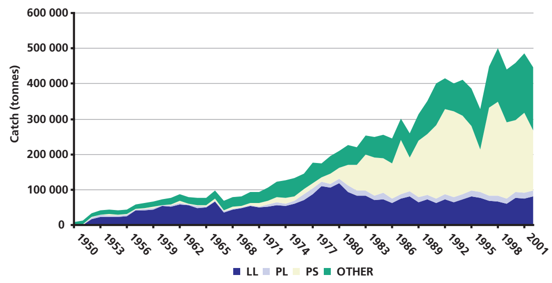
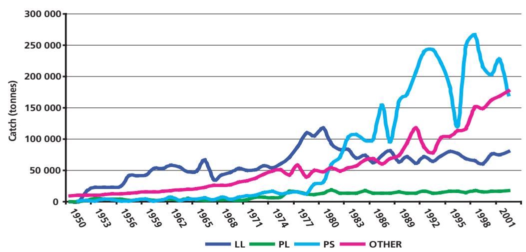


FIGURE AI.44
YFT catches, by gear, in the WCPO



Historical catches – The catches of YFT in the WCPO clearly increased from 1950 to 2002 (Figure AI.43). Due to the expansion of the purse-seine fleet, this upward trend accelerated during the late 1970s, with the exception of 1996, when the catches dropped to a relatively low level (325 000 tonnes). The 2002 catch, 446 000 tonnes, is about 89 percent of the maximum catch, 501 000 tonnes, taken in 1998. The principal fishing countries or entities employed the following methods of fishing in 2002: purse seining, the Philippines (29 000 tonnes), the United States (28 600 tonnes), Papua New Guinea (26 200 tonnes), the Taiwan Province of China (26 100 tonnes), Japan (21 300 tonnes) and the Republic of Korea (17 500 tonnes); longlining, the Taiwan Province of China (24 000 tonnes), Japan (17 000 tonnes), the Republic of Korea (13 800 tonnes) and Indonesia (11 200 tonnes); pole-and-line fishing, Indonesia (14 000 tonnes); handlining, the Philippines (67 000 tonnes); unclassified gears, mostly Indonesia (105 000 tonnes).

Stock status – A stock assessment for YFT in WCPO was conducted in 2003 and presented at the 16th meeting of the SCTB of the SPC. Its results are consistent with those obtained in 2002. However, the SCTB and the SCG of the WCPFC identified important gaps in the data from Indonesia and the Philippines. This lack of data has contributed substantially to the uncertainty of the assessments of YFT in the WCPO.

2002 catch (tonnes) – Total = 446 122 (PS = 170 492; LL = 80 039; PL = 17 815; TROLL = 595; OTHER[1] = 177 181).
Maximum annual catch (tonnes) – Total = 501 438 (PS = 266 148; LL = 65 967; PL = 17 256; TROLL = 1 173; OTHER = 150 894) in 1998.
Catch-related reference point (tonnes) – MSY between 381 000 and 554 000.
Stock size – The biomass has been declining over time, but remains above B_{MSY}. The present biomass is 20 to 35 percent less than that in the absence of fishing. However, the depletion is greater in equatorial regions (nearly 50 percent). The recruitment has been fluctuating since the 1960s. The trends in recruitment are sensitive to the type of standardization procedure used to standardize the longline effort for the stock assessment analysis.
Fishing mortality – The average F for both juveniles and adults increased strongly over the period of exploitation. However, F/F_{MSY} is still below 1, indicating that the YFT stock in the WCPO is not overfished.
Management resolutions – The SCG recommended in 2003 that further increases in fishing mortality be avoided to reduce the risk of the YFT stock becoming overfished. No management resolutions have been adopted.
Stock status summary – *Stock size*: above its reference point. *Fishing mortality*: near its reference point.

[1] Mainly handline and unclassified gears.

Outlook – The present fishing pattern is sustainable. The biomass should remain above that corresponding to the MSY. This situation is due mainly to the low levels of exploitation in the sub-equatorial regions of the WCPO.

Yield projections indicate that increases in the fishing mortality would not result in long-term increases in the catches, and might result in overexploitation. These projections show that the equilibrium biomass is most sensitive to changes in the fishing mortality of the Indonesian fishery. The doubling of the Indonesian fishing mortality would decrease the equilibrium total biomass and adult biomass by 22 percent and 26 percent, respectively, from the current levels. Reducing the Indonesian fishing mortality by half would increase the equilibrium total and adult biomass by 13 percent and 16 percent, respectively, from the current levels. The third most important impact on the equilibrium biomass levels would be in response to changes to the purse-seine fishery. Changes to the longline fishery would have the least impact on the equilibrium biomass levels. Doubling the present longline effort would reduce the total and adult equilibrium biomass levels by only 2 percent and 4 percent, respectively.

The use of FADs increased during the late 1990s, and the mortality rates of juvenile YFT increased accordingly. In addition, deployment of FADs increases the difficulties of assessing the trends in CPUE (causing abrupt changes in catchability), adding uncertainty to the stock assessment. The extent to which this problem could affect the sustainability of the stock in the long-term should be studied further.

ALL OCEANS

Southern bluefin (SBF)

FIGURE AI.45
Cumulative catches of SBT, by gear

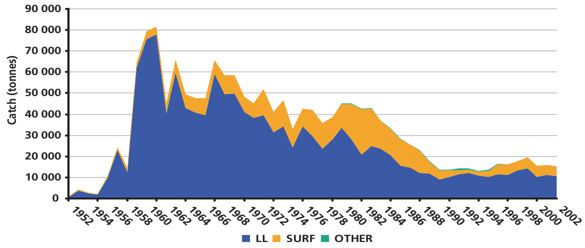
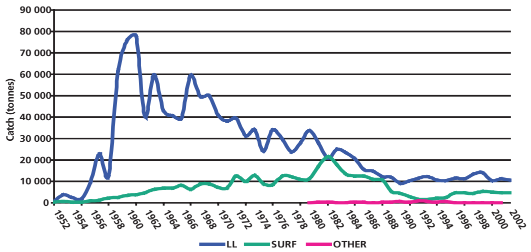


FIGURE AI.46
SBF catches, by gear



Historical catches – After a rapid increase in the catches during the 1950s, a maximum catch of 81 605 tonnes was taken in 1961 (Figure AI.45). After that the SBF catches declined significantly, with some fluctuations, until 1990. From 1990 to 2001 the catches fluctuated between 13 500 and 19 500 tonnes. The decline was mainly due to the introduction of a total allowable catch (TAC) in 1989 by the three original members of the CCSBT, Australia, Japan and New Zealand, that reduced the fishing mortality. The growth in this latter period was due to increasing fishing effort by non-members, two of which, the Republic of Korea and the Taiwan Province of China, have since joined CCSBT and stabilized their catches at reduced levels. The 2002 catch (15 193 tonnes) was approximately 20 percent of the 1961 maximum catch. In 2002 the principal fishing countries or entities fishing SBF with longlines were Japan (6 192 tonnes), Indonesia (1 691 tonnes), the Taiwan Province of China (1 137 tonnes), the Republic of Korea (746 tonnes) and New Zealand (450 tonnes). Of these, only Indonesia is not a member of the CCSBT. Australia accounted for most of purse-seine catch, 4 683 tonnes, in 2002.

Stock status – The last full stock assessment of SBT was conducted in 2001. After that a range of stock status indicators were reviewed each year, and the results indicated that there had been no significant changes in the state of the stock since 2001. A new full stock assessment was to be undertaken in 2004.

2002 catch (tonnes) – Total = 15 193 (SURF[1] = 4 683; LL = 10 510).

Maximum annual catch (tonnes) – Total = 81 605 (SURF = 3 678; LL =77 927) in 1961.

Catch-related reference point (tonnes) – Unknown.

Stock size – The SSB in 1999 was estimated to be between 5 and 12 percent of the 1960 level. National scientists are not certain of the significance of this level, which appears to have stabilized, with a possible upturn in recent years. The recruitment appears to have declined during the 1990s, especially during 1999 and 2000. Acoustic surveys (2001 and 2002), CPUE data for the Australian surface fishery (2002 and 2003) and aerial surveys (2003) suggest that this decline may have continued during 2001, 2002 and 2003. However, there are some doubts about the validity of these surveys as indices of the global recruitment.

Fishing mortality – F has been reduced since 1988, largely due to decisions by the CCSBT on TACs and national allocations. Recent Fs have not been unduly high, given that the catches since 1990 appear to have stabilized the SSB. It appears that the current removals are close to surplus production. However, the recent Fs may not be low enough to allow the spawning stock to increase.

Management recommendations/regulations – The members of the CCSBT agreed to a TAC of 14 030 tonnes for members, and an additional global allocation for cooperating non-members, of 900 tonnes for the 2003-2004 fishing season. In addition, Australia has introduced individual transferable quotas (ITQs) for SBF, and New Zealand plans to do so as well, beginning in October 2004. Other members of the CCSBT manage their fisheries through a mixture of vessel limits, limits on days fished and area closures.

Stock status summary – Stock size: below its reference point. Fishing mortality: near to above its reference point.

[1] Surface gear refers mainly to PS and PL, with a progressive increase in PS catching from 1992 to almost exclusively PS from 1999.

Outlook – According to projections conducted in 2001, with the global catch of about 15 500 tonnes, there is an equal probability that the stock could decline or increase. It was also estimated that there is little chance that the spawning stock can be rebuilt to the 1980 level by 2020 without substantial quota reductions.

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APPENDIX II

Stock structure

The maps of distributions of the catches by the principal fishing gears presented in this appendix were produced from the Global Database of Catches of Tunas and Billfishes (described by Carocci *et al.* in this collection). It contains the data that FAO regularly receives from international organizations and national institutions and published, after standardization and integration, as they are. Therefore, it does not contain data for which FAO has not received proper geo-referencing or data reported in number of fishes instead of tonnes caught.

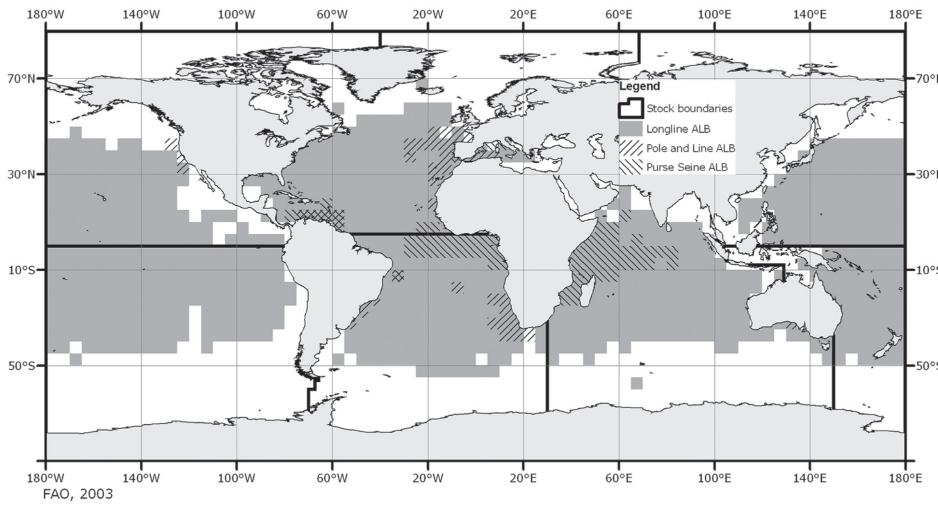
ALBACORE (ALB)

Atlantic Ocean – ALB is a temperate species widely distributed in the AO and MED. For the stock assessment purposes, the existence of three stocks is assumed: North and South Atlantic stocks, separated at 5°N, and a Mediterranean stock.

Indian Ocean – A single stock of ALB is assumed to occur in the IO. It is distributed in waters between 20°N and 40°S.

Pacific Ocean – There are two ALB stocks in the PO, one in the northern hemisphere and the other in the southern hemisphere. The SPO stock appears to be homogeneous, but there seem to be two subgroups of the NPO stock.

FIGURE AII.1
Albacore stocks, and distributions of the catches by the principal fishing gears in 1991 to 2001



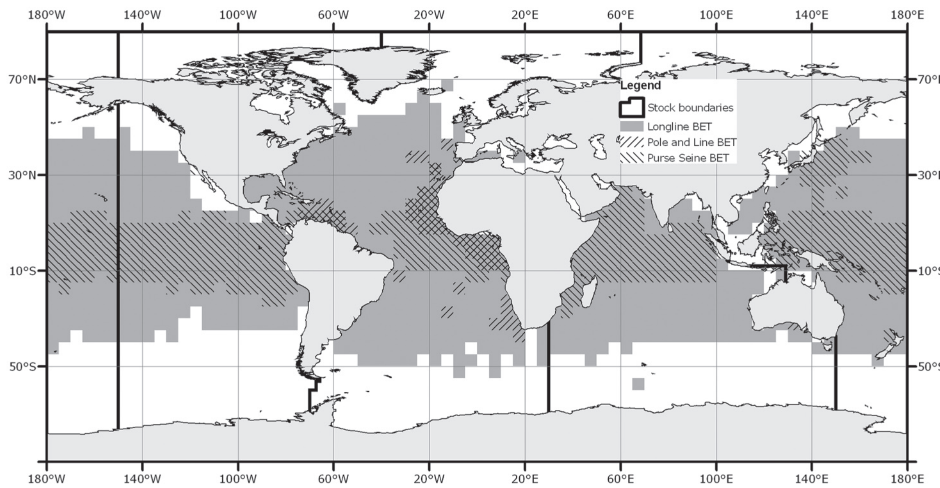
BIGEYE (BET)

Atlantic Ocean – BET are distributed over almost the entire AO between 50°N and 45°S. It is assumed that there is a single stock in the AO, but the possibility of other scenarios, such as northern and southern stocks, should not be disregarded.

Indian Ocean – A single stock of BET is assumed to occur in the IO. The distribution of the catches suggests that the range of the stock includes tropical waters, where reproductively active individuals are found, and temperate waters, usually considered to be feeding grounds.

Pacific Ocean – BET are distributed continuously from the Americas to Asia between 40°N and 40°S. In the absence of adequate information on the stock structure of BET in the PO, it has been assumed that there are two stocks, one in the EPO and the other in the WCPO. However, scientists of the IATTC and the SPC have also performed assessments based on the assumption that there is a single stock of BET in the PO.

FIGURE AII.2
Bigeye stocks, and distributions of the catches by the principal fishing gears in 1991 to 2001



FAO, 2003

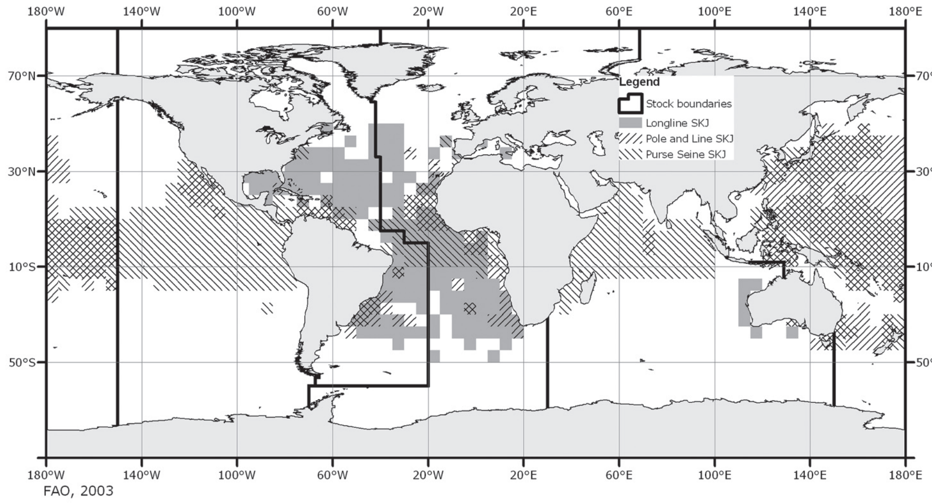
SKIPJACK (SKJ)

Atlantic Ocean – Two stocks of SKJ, one east of 30°W and the other west of 30°W, are recognized in the AO. The boundary at 30°W was established when the SKJ fisheries were mostly coastal, but in recent years the fishery of the EAO has extended to the west of 30°W, which might imply that there is some mixing between the presently defined stocks. However, taking into account the large distances, various oceanographic features restricting such mixing, the existence of spawning areas in both the EAO and the WAO and the lack of tagging data indicating trans-Atlantic migrations, the two-stock hypothesis has been retained.

Indian Ocean – A single stock of SKJ is assumed to occur in the IO. Tagging studies indicate that there is little exchange of SKJ between the Maldives and the rest of the IO, but these results are not conclusive. Due to the need for a better understanding of the stock structure of SKJ in the IO, a genetic study is being carried out.

Pacific Ocean – There are two hypotheses for the stock structure of SKJ in the PO, a single stock with isolated subgroups or two or more separate stocks. For stock assessment purposes, it is assumed that there are two stocks of SKJ in the PO, a WCPO stock occurring west of 150°W and an EPO stock occurring east of 150°W. The WCPO has been divided into six sub-areas, thus allowing for the possibility of sub-stocks in this region.

FIGURE AII.3
Skipjack stocks, and distributions of the catches by the principal fishing gears in 1991 to 2001.



YELLOWFIN (YFT)

Atlantic Ocean – It is assumed that there is a single stock of YFT in the AO. This assumption is supported by trans-Atlantic movements evident from tagging data, a 40-year time series of longline catch data that indicates that YFT are distributed continuously throughout the tropical AO and time-area size-frequency data.

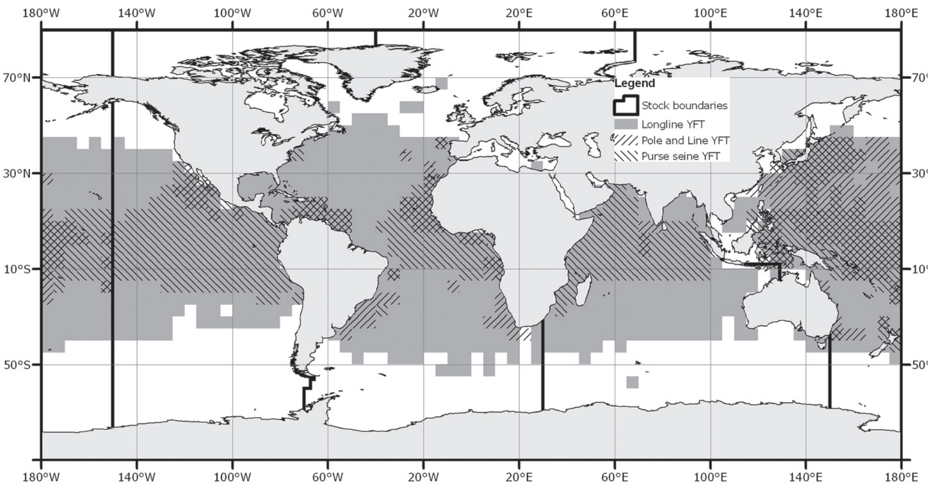
Indian Ocean – The stock structure of YFT in the IO is uncertain, but it is assumed for stock assessment purposes that there is a single stock. Longline catch data indicate that YFT are distributed continuously throughout the tropical IO, but there are indications, from more detailed analyses of fisheries data, that the stock structure is more complex. A study of stock structure, using DNA analyses, produced inconclusive results.

Pacific Ocean – The exchange of YFT between the EPO and the WCPO has been studied by examination of data from tagging, morphometric characteristics of the fish, catch-per-unit-of-effort (CPUE) data, sizes of fish caught, etc. The mixing of fish between the EPO and WCPO is not extensive, so, for purposes of stock assessment, it has been assumed that there are two stocks, separated at 150° W longitude. The WCPO has been divided into five-areas, thus allowing for the possibility of sub-stocks in this region.

ATLANTIC BLUEFIN (BFT)

Atlantic Ocean – ICCAT established two management units for BFT in 1982. This decision was based on discontinuities in the distributions of the catches at that time and on the assumption that mixing of western and eastern BFT was limited. The two management units are separated at 45° W north of 10° N and at 25° W south of the equator, with an eastward shift in the boundary between those parallels. Later, however, it appeared that the distribution of catches across the NAO is nearly continuous. Also, evidence has accumulated that there is more mixing between the two units than previously thought, so research on the stock structure (including modeling) has continued.

FIGURE AII.4
Yellowfin stocks, and distributions of the catches by the principal fishing gears in 1991 to 2001

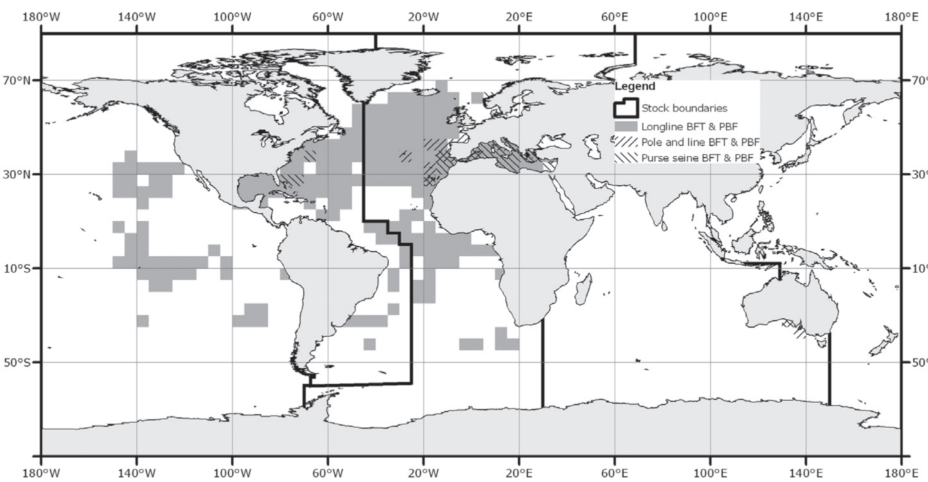


FAO, 2003

PACIFIC BLUEFIN (PBF)

Pacific Ocean – It has been assumed that there is a single stock of PBF in the PO. Tagging studies have shown that there is considerable exchange of fish between the EPO and the WCPO. It appears that spawning occurs only in the WCPO, since larval, post-larval, and early juvenile PBF have been caught only in the WPO.

FIGURE AII.5
Atlantic and Pacific bluefin stocks, and distributions of the catches by the principal fishing gears in 1991 to 2001

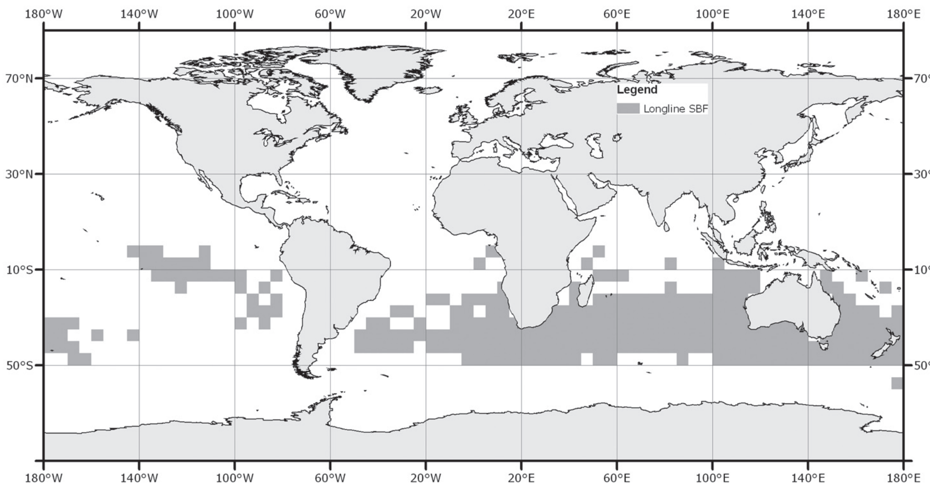


FAO, 2003

SOUTHERN BLUEFIN (SBF)

All Oceans – SBF are found throughout the southern hemisphere, mainly in waters between 30° and 50°S, but only rarely in the AO and the EPO. As SBF spawn in only one area (south of Java, Indonesia), they are managed as a single stock.

FIGURE AII.6
Southern bluefin stocks, and distributions of the catches by the principal fishing gears in 1991 to 2001



FAO, 2003

SECTION 2

Characterization and estimation of tuna fishing capacity

An analysis of the fishing capacity of the global tuna purse-seine fleet[1]

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ABSTRACT

This paper presents the results of analyses conducted to measure tuna purse-seine fishing capacity in the eastern Pacific Ocean (EPO), western and central Pacific (WCPO), Indian and Atlantic oceans as part of FAO Project GCP/INT/851/JPN Management of tuna fishing capacity: conservation and socio-economics. The regional analyses were conducted using Data Envelopment Analysis (DEA), as recommended by the project's Technical Advisory Committee (TAC). The results of the regional analyses are then drawn together in an overview discussion of tuna purse-seine fishing capacity at a global level.

The level of aggregation and the period over which the DEA was conducted varied among the different regional purse-seine fisheries due to differing levels of data that were available for each of the fisheries. The DEA of the EPO and WCPO purse-seine fisheries were conducted at the vessel level during 1998-2002. The period over which the analysis was conducted was limited to 1998-2002, as limiting the number of years of analysis to the five most recent ones captures more recent fleet configurations, cost conditions and fishing patterns, and also helps to control for the potential shifts in capacity output due to technical change. Further, capacity for these fisheries was estimated under two measures: (1) under full variable input utilisation and maximum technical efficiency (TE) and (2)

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[1] The views expressed in this paper are those of the authors, and do not necessarily reflect the views of the U.S. National Marine Fisheries Service or the Forum Fisheries Agency or its member countries.

under full variable input utilisation, but with current levels of TE. The latter was done to try to account for variations in skipper skill levels in deriving estimated capacity output levels. In effect, it measures capacity utilisation purged for the effects of TE. The DEA of the Indian and Atlantic purse-seine fisheries were conducted at the fishery level during the 1981-2002 and 1991-2002 periods, respectively. This was done as the data available were extremely limited, and consequently the DEA could be conducted only at the fishery level as opposed to the vessel level. In order to ensure that sufficient observations were obtained it was therefore necessary to conduct the analysis over the whole period for which data were available.

The results of the DEA for the EPO purse-seine fishery indicated that there was considerable excess capacity in the fishery, and that the largest contributor, by far, to excess capacity was Class-6 vessels, although there was excess capacity for Classes 2-3 and 4-5 vessels as well. It was estimated that across the fishery excess capacity, defined as capacity output, purged for TE, minus observed catch, increased from about 120 000 tonnes in 1998 to close to 200 000 tonnes in 2002, an increase approaching 63 percent in five years. For yellowfin and bigeye it was also estimated that excess capacity, defined as capacity output, purged for TE, minus combined maximum sustainable yield, climbed from an excess of about 11 percent in 1998 to an excess of almost 70 percent by 2002. Technical change was estimated on a cumulative basis to have increased by about 60 percent during 1998-2002 for the fishery as a whole. Thus "fishing power" or the state of technology increased considerably, and was an important factor in the exhibited increase in fishing capacity and excess capacity over this period.

For the western and central Pacific purse-seine fishery it was estimated that, on average, during 1998-2002 the purse-seine skipjack fishing capacity was around 306 000 tonnes (35 percent) per annum greater than the actual catch levels. However, it noted that when purging for TE excess skipjack fishing capacity was only 137 000 tonnes (16 percent) per annum greater than the actual catch levels. In other words, only around 40 percent of the potential increase in catches could be realised through increases in variable input usage, given the biomass, environmental conditions and state of technology that prevailed over this period. Estimated excess fishing capacity, purged for TE, was at its highest level in 2000. It was hypothesised that this may have been caused by low skipjack prices in the second half of 1999 and throughout 2000, resulting in vessels reducing the number of days spent searching and fishing.

For yellowfin and bigeye combined in the WCPO purse-seine fishery it was estimated that during 1998-2002 excess purse-seine fishing capacity was around 72 000 tonnes (29 percent) per annum greater than the actual catch. However, it noted that when purging for TE excess yellowfin and bigeye fishing capacity was only 31 000 tonnes (12 percent) per annum greater than the actual catch levels. In other words, only around 40 percent of the potential increase in catches could be realised through increases in variable input usage, given the biomass, environmental conditions and state of technology that prevailed over this period. It was also estimated that during 1998-2002, on average, fishing capacity, purged for TE, for yellowfin and bigeye combined was in excess of the average catches between 2000 and 2002 by 47 666 tonnes, or 20 percent, but that no excess capacity existed in the fishery in 2002 when measured against the average 2000-2002 catch levels.

From the DEA for the Indian and Atlantic purse-seine fisheries it appears that there is excess capacity in both oceans. The more serious level of excess capacity exists for the Indian Ocean fishery. It was estimated that, on an annual basis, there was approximately 61 000 tonnes of excess capacity in the Indian Ocean fishery. In comparison, the Atlantic Ocean fishery had approximately 29 500 tonnes of excess harvesting capacity. Alternatively, if Indian and Atlantic Ocean vessels operated efficiently, fully utilized their variable inputs and harvested the average annual reported level of landings, fleet sizes could be reduced, respectively, from 40 to 31 (22.5 percent) in the Indian Ocean fishery and from 53 to 46 (13.2 percent) in the Atlantic Ocean fishery. These estimates are considered extreme lower-bound estimates of capacity due to the limited number of observations and inadequate information for considering different modes and nations' fishing activities.

At a global level for skipjack it appears that fishing capacity peaked in 1999, then declined in 2000 and 2001 and then returned to 2000 levels in 2002. Excess capacity followed a similar pattern, with a significant rise in 1999, followed by a decline of more than 50 percent in 2000 and 2001 and then by a small increase in 2002. Excess capacity as a percentage of catch also peaked in 1999; however, from then until 2002 it was in continuous decline. From the estimates it appears that global purse-seine fishing capacity for yellowfin and bigeye was on a downward trend between 1998 and 2000, even though observed catch levels were rising, before increasing back to 1998 levels in 2001 as observed catch levels rose sharply and then declined again in 2002. Excess fishing capacity between 1998 and 2000 fell by over 40 percent, while excess capacity in 2001 was at levels similar to that seen in 1999. In 2002 excess capacity was less than those in 1998, 1999 and 2001, but greater than that in 2000.

Excess fishing capacity is a result of both technical inefficiency (or skipper skill) and under-utilisation of variable inputs. In other words, catches can be increased through either an increase in the efficiency of inefficient purse-seine vessels or through an increase in the utilisation of variable inputs such as increases in the numbers of days spent fishing and searching. In the analysis of the purse-seine fisheries of the EPO and the WCPO, fishing capacity, purged for TE, was also estimated. In both analyses under this measure, there was a significant reduction in the estimated level of fishing capacity. For the EPO, the estimated average excess capacity level, purged for TE, measured against the observed catches of skipjack and of yellowfin and bigeye combined during 1998-2002 were around half the level of the estimated excess capacity levels measured against observed catches. For the WCPO, average excess capacity level, purged for TE, measured against observed catches for skipjack and for yellowfin and bigeye combined during 1998-2002 were around 60 percent lower than the levels of the estimated excess capacity measured against observed catches. These results indicate that TE improvements (or increases in skipper skill levels) of inefficient vessels are required if capacity output levels are to be fully achieved.

1. INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) is implementing a project on the management of tuna fishing capacity, FAO Project GCP/INT/851/JPN Management of tuna fishing capacity: conservation and socio-economics. The main objectives of the project are to identify, consider and resolve technical problems associated with the management of tuna-fishing capacity on a global scale, taking into account conservation and socio-economic issues.

The project's Technical Advisory Committee (TAC) met in April 2003. The TAC recommended that a data envelopment analysis (DEA) be undertaken to estimate the fishing capacity of industrial tuna fleets, including the purse-seine, pole-and-line and longline fleets. Subsequent to this it was decided that the analysis would be undertaken in a phased manner, with the analysis of purse-seine fishing capacity undertaken at the first stage and then, depending on the availability of appropriate data, the pole-and-line and longline fisheries at a later stage. This paper presents the results of the DEA of global purse-seine fishing capacity conducted at the regional level.

This paper is structured as follows. Section 2 provides an overview of the definition of capacity and capacity utilisation (CU), as used in this report, and analytical methods used for measuring fishing capacity and excess (over-) capacity. In Sections 3 to 5 the methodology, data employed and results of the analyses conducted for the tuna purse-seine fisheries of eastern Pacific Ocean (EPO), western and central Pacific Ocean (WCPO), Indian Ocean and Atlantic Ocean are presented. Details of the analyses of the EPO conducted by Dale Squires and Jun Ye, the WCPO conducted by Chris Reid and the Atlantic and Indian Oceans conducted by James Kirkley are given in Sections 3, 4, and 5, respectively. Finally, in Section 6 the results of the regional analyses are combined in an overview discussion of tuna purse-seine fishing capacity at a global level.

2. OVERVIEW OF THE ANALYTICAL APPROACH

2.1 Capacity and capacity utilisation

Capacity is a short-run concept, where firms and industry face short-run constraints, such as the stock of capital or other fixed inputs, existing regulations, the state of technology and other technological constraints (Morrison, 1985). Capacity is defined in terms of potential output. This potential output can be further defined and measured, following either a technological-economic approach or an economic optimisation approach based directly on microeconomic theory (Morrison, 1985).[2] The two notions of capacity are distinguished by how the underlying economic aspects are included to determine the capacity output.

In either approach, CU is simply actual output divided by capacity output (Morrison, 1985). In the technological-economic approach, a CU value less than one implies that firms have the potential for greater production without having to incur major expenditures for new capital or equipment (Klein and Summers, 1966).

This paper, and those of FAO (1998), Kirkley and Squires (1999), FAO (2000) and Squires *et al.* (2003), focus upon the technological-economic measures of capacity, because the paucity of cost data in most fisheries mitigates against estimation of cost or profit functions to derive economic measures of capacity and CU. Similarly, the technological-economic approach is used by the United States (Corrado and Mattey, 1998) and most other countries to monitor CU throughout the economy.

The technological-economic capacity of a firm can be defined following Johansen's (1968, p. 52) definition of plant capacity as, "... the maximum amount that can be produced per unit of time with existing plant and equipment, provided the availability of variable factors of production is not restricted". Färe (1984) provides a formal proof and discussion of plant capacity.

Capacity output thus represents the maximum production that the fixed inputs are capable of supporting. This concept of capacity conforms to that of a full-input point on a production function, with the qualification that capacity represents a realistically-sustainable maximum level of output, rather than some higher unsustainable short-term maximum (Klein and Long, 1973). In practice, this approach gives maximum potential output, given full utilisation of the variable inputs under normal operating conditions, since the data used reflect normal operating conditions and existing market, resource stock and environmental conditions.[3] This approach gives an endogenous output, and incorporates the firm's *ex ante* short-run optimisation behaviour for

[2] In the economics approach, capacity can be defined as that output pertaining to one of two economic optimums: (1) the tangency of the short- and long-run average cost curves (Chenery, 1952; Klein, 1960; Friedman, 1963), so that the firm is in long-run equilibrium with respect to its use of capital, or (2), the tangency of the long-run average cost curve with minimum short-run average total cost curve (Cassels, 1937; Hickman, 1964).

[3] Klein and Long (1973, p. 744) state that, "Full capacity should be defined as an attainable level of output that can be reached under normal input conditions – without lengthening accepted working weeks, and allowing for usual vacations and for normal maintenance". The U.S. Bureau of the Census survey uses the concept of practical capacity, defined as "the maximum level of production that this establishment could reasonably expect to obtain using a realistic employee work schedule with the machinery and equipment in place" and assuming a normal product mix and down-time for maintenance, repair, and cleanup.

the production technology, given full utilisation of the variable inputs under normal operating conditions.

The definition and measurement of capacity in fishing and other natural resource industries face a unique problem because of the stock-flow production technology, in which inputs are applied to the renewable natural resource stock to produce a flow of output. For renewable resources, capacity measures are contingent on the level of the resource stock. Capacity is, therefore, the maximum yield in a given period that can be produced, given the capital stock, regulations, current technology and state of the resource (FAO, 1998; Kirkley and Squires, 1999). Nonetheless, annual climate-driven ocean variability is clearly a key factor affecting fisheries. The monsoon and El Nino-Southern Oscillation events provide clear examples, since the distribution and catchability of fish varies. As a consequence, and due to annual changes in the size and species mix of the resource stocks, the target level and capacity output from the stock-flow production process can vary annually, and even seasonally.

An additional factor that is important to consider is the source of variations in the level of technical efficiency (TE) at which a vessel operates. Pascoe and Coglan (2002) found that differences in vessel characteristics explained around one third of the variation in TE of English Channel trawlers, and attributed the remainder to unmeasurable characteristics, such as skipper skill and differences in technology that could not be quantified. Other studies (e.g. Kirkley, Squires and Strand, 1998; Squires and Kirkley, 1999) have also suggested that much of the difference in efficiency among vessels may be due to differences in skipper skill. As such, in this study, where data permits, fishing capacity is estimated under two different measures. First, as discussed previously, it is estimated under full-variable input utilisation and maximum TE. Second, it is estimated under full-variable input utilisation, but with current levels of TE. The latter was done to try to account for variations in skipper skill levels in deriving estimated capacity output levels; in effect, it measures capacity utilization (CU) purged for the effects of TE.

In fisheries and other renewable resource industries, excess capacity is often defined relative to some biological or bio-socio-economic reference point that accounts for sustainable resource use and a target resource stock size. Excess capacity, in a technological-economic approach, can be defined as the difference between capacity output and the target level of capacity output, such as maximum sustainable yield (MSY) or the catch rate corresponding to the fishing mortality of an alternative harvest (FAO, 1998). The target level of capacity output was defined by FAO (1998, p. 11), "Target fishing capacity is the maximum amount of fish over a period of time (year, season) that can be produced by a fishing fleet if fully utilized while satisfying fishery management objectives designed to ensure sustainable fisheries…"[4]. A similar conclusion was reached by FAO (2000). The target fishing capacity catch can be specified as, for example, MSY or maximum economic yield (MEY).

In this paper, however, we apply a different approach. Capacity and excess capacity are addressed primarily in terms of observed catch against capacity, or potential, catch,

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[4] Fishing capacity is generally defined by FAO (1998, 2000) as follows:

> Fishing capacity is the maximum amount of fish over a period of time (year, season) that can be produced by a fishing fleet if fully utilized, given the biomass and age structure of the fish stock and the present state of the technology. Fishing capacity is the ability of a vessel or fleet of vessels to catch fish, *i.e.* $Y_C = Y(E_C, S)$.

In this general definition, Y_C denotes current yield/catch, E_C denotes current effort, and S denotes stock size (biomass). Fishing capacity thus represents the maximum amount of fish caught by a fleet fully utilizing its variable economic inputs under normal operating conditions, given the fleet's capital stock (vessels, gear, and equipment, including FADs), biomass, and harvesting technology. Normal operating conditions refers to those operating conditions faced by fishing vessels in the normal conditions of the time period in which they operate.

assuming that the potential catch is sustainable. In addition, however, in the analysis of the EPO an examination of excess capacity with regard to the AMSY[5] for yellowfin and bigeye is presented, and in the WCPO analysis excess capacity is examined in the context of recent scientific advice that there be no further increases in fishing mortality on yellowfin and bigeye stocks.

2.2 Measuring capacity using data envelopment analysis

DEA is a mathematical programming approach introduced by Charnes, Cooper and Rhodes (1978). The DEA approach seeks to derive the most technically-efficient production frontier, from either an input or an output orientation, by constructing a piece-wise linear technology. Although capacity may be estimated by numerous methods (e.g. a stochastic production frontier, peak-to-peak or surveys), we use DEA to estimate harvesting capacity for the EPO, WCPO, Indian Ocean and Atlantic Ocean. The estimation is restricted to a technological-economic approach in that the data are restricted to the physical quantity of inputs used in the production process and the physical quantity of output produced. The output-orientated approach of Färe (1984) is used in this study for estimating capacity. The output orientation seeks to determine the maximum expansion in outputs, given fixed input levels for some factors (fixed factors) and unrestricted levels for other factors (i.e. the variable factors). The fixed factors limit total production. Although the variable factors are unrestricted, DEA permits the determination of variable input usage consistent with the levels determined by the fixed factors.

The original approaches of Charnes, Cooper and Rhodes (1978) and Färe (1984) provided estimates of TE consistent with the notion of TE offered by Farrell (1957) (i.e. maximum expansion of output, given no change in inputs, or maximum reduction in inputs, given no change in outputs). The method of Färe (1984), later modified by Färe, Grosskopf and Kokkelenberg (1989), separates the factors of production into fixed and variable inputs, and subsequently solves a mathematical programming problem that permits the determination of a piece-wise production technology or frontier, which represents the efficient levels of output, given the fixed factors of production. The mathematical programming problem is the following:

$$
\begin{aligned}
& TE = MAX\ \theta \\
& \text{Subject to } \theta u_{jm} = \sum_{j=1}^{J} z_j u_{jm},\ m = 1, \ldots, M \\
& \sum_{j=1}^{J} z_j x_{jn} \leq x_{jn},\ n = F_x \qquad [1] \\
& \sum_{j=1}^{J} z_j x_{jn} = \lambda_{jn} x_{jn},\ n = V_x \\
& z_j \geq 0,\ j = 1, \ldots, N
\end{aligned}
$$

where TE_{CAP} equals a measure of the potential expansion in outputs; 2 (2 ∃1.0) is the inverse of an output distance function; u_{jm} is the m^{th} output of the j^{th} producer or observation; x_{jn} is the nth input for the j^{th} producer; F_x and V_x, respectively, indicate vectors of fixed and variable factors; 8 is a measure of the optimum utilization of the variable inputs; and z is a vector of intensity variables that define the reference technology. If the value of 2 is 1.0, production is efficient and output cannot be expanded, and if [1]> 1.0, the potential output may be expanded by 2 - 1.0. Problem [1] imposes constant returns to scale; in our analysis we allow for variable returns to scale by imposing the constraint 3 z_j = 1.0.

[5] AMSY is the Average Maximum Sustainable Yield and is an average over a number of years to account for fluctuations that may occur over time.

One limitation of problem [1] or the Färe, Grosskopf and Kokkelenberg (1989) model is that it imposes a radial expansion of outputs (i.e. all outputs expand by the same proportion, 2 - 1.0). This limitation, however, can be easily resolved through the use of directional distance vectors, the Russell (1985) measure, or the slack-based approach of Cooper, Seiford and Tone (2000), all of which permit non-radial expansions of outputs. We consider the Russell measure because of its ease of estimation. The use of either directional vectors or the approach of Cooper, Seiford and Tone require considerably complicated estimation algorithms. The Russell measure (*RM*) is as follows:

$$RM_{CAP} = \frac{1}{M} MAX \sum_{m=1}^{M} \theta_m$$

$$\text{Subject to } \theta u_{jm} = \sum_{j=1}^{J} z_j u_{jm}, \; m = 1,\ldots, M$$

$$\sum_{j=1}^{J} z_j x_{jn} \le x_{jn}, \; n = F_x \qquad [2]$$

$$\sum_{j=1}^{J} z_j x_{jn} = \lambda_{jn} x_{jn}, \; n = V_x$$

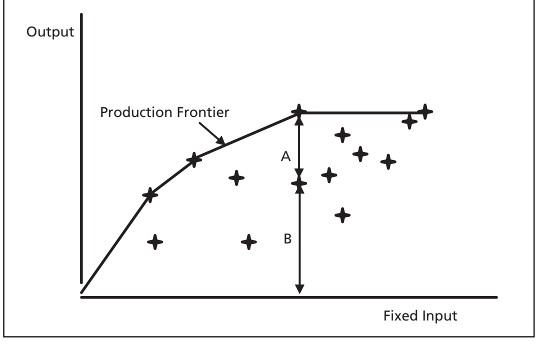
$$z_j \ge 0, \; j = 1,\ldots, N$$

where M is the number of outputs, and the variables are the same as those previously discussed. The division by M ensures an overall efficiency score of 1.0 or greater. We also impose variable returns to scale.

The use of DEA to calculate fishing capacity output and CU is illustrated in Figure 2.1. DEA, using the observed landings for different-sized vessels and a measure of the capital stock or fixed inputs, such as gross registered tons (GRT), determines the output or landings that are the greatest for any given vessel size, assuming that the variable inputs are fully utilized (variable inputs are thereby unconstrained) under normal operating conditions, where normal operating conditions are reflected in the data. DEA calculates a frontier or maximum landings curve, as determined by the best-practice vessels, which represents fishing capacity output. Landings directly on the best-practice production frontier represent full capacity CU or CU = 1. When a vessel produces at less than full capacity, as represented by an output lying below the frontier in Figure 2.1, the CU is less than one, i.e. CU < 1. Thus, in Figure 2.1 B represents the size of the landings, A denotes the excess capacity (*vis-à-vis* observed production), A + B denotes capacity output, and the ratio A/(A + B) represents CU, so that CU < 1 in this case.

The production frontier, established by the best-practice vessels (the ones on the frontier) and estimated by DEA, gives capacity output, given the fixed inputs or capacity base, the states of technology, the environment and the resource stocks, provided that the variable inputs (fishing effort) are fully utilized under normal operating conditions. The production frontier (also called the reference technology), established by the best-practice vessels, and also estimated by DEA, gives technically-efficient output, given the fixed inputs, states of technology and the environment and resource stocks when the variable inputs are utilized at the observed levels. Hence, the difference between capacity output and technically-efficient output is that variable inputs are fully utilized in the former and are utilized at the observed levels (which could be fully utilized) in the latter.

FIGURE 2.1
Data envelopment analysis



Alternative methods for measuring capacity and CU have been proposed in the literature, most notably duality-based measures using cost, profit or revenue functions (Morrison, 1985; Squires, 1987; Segerson and Squires, 1995a and 1995b; Färe *et al.*, 2002). Unlike duality-based econometric estimates of cost, profit or revenue functions, DEA does not impose an underlying functional form, so that estimation is not conditional upon the functional specification. Unlike the cost, profit or revenue function approach, DEA can estimate primal measures of capacity in a multiple-product environment without imposing separability assumptions on the outputs (Segerson and Squires, 1990). DEA can be used when prices are difficult to define, or behavioural assumptions, such as cost minimisation, are difficult to justify or cost data are unavailable.

The DEA approach has limitations. First, it is a non-statistical approach, which makes statistical tests of hypotheses about structure and significance of estimates difficult to perform, although there are several non-parametric tests that can be performed to test the results of DEA. Second, because DEA is non-statistical, all deviations from the frontier are assumed to be due to inefficiency. Third, estimates of capacity and CU may be sensitive to the particular data sample (a feature shared by the dual cost, profit or revenue function approach).

3. THE PURSE-SEINE FISHERY FOR TUNAS IN THE EASTERN PACIFIC OCEAN

In this section we focus attention on the purse-seine fishery for tunas in the EPO. We find that excess capacity exists for the EPO fishery with respect to yellowfin (YFT), skipjack (SKJ) and bigeye (BET) tunas caught in sets on dolphins, sets on floating objects and sets on unassociated schools.

3.1 Data and methodology

Capacity output, capacity output adjusted for TE and CU rates (observed output divided by CU or observed output divided by capacity output adjusted for TE) are estimated by DEA. We attempted to estimate the output-oriented non-radial method of Russell (1985), but the results were unsatisfactory. We instead estimated the output-oriented radial expansion approach, whereby all outputs were kept in fixed proportions as they were expanded, holding fixed factors constant and with full utilization of variable inputs. The CU rates are thus ray measures (Segerson and Squires, 1990).

The set- and vessel-level purse-seine data from the EPO tuna fishery were provided by the Inter-American Tropical Tuna Commission (IATTC) for 1980-2002. These data, by set and vessel, included landings of yellowfin, bigeye and skipjack tunas, vessel GRT and other measures of vessel size (cubic meters, net weight, or length, weight and depth in metres), trip lengths (days, arrival date minus departure date for trip), number of sets. Total is catch in tonnes, and is derived from observer data (or logbook data when observer date not available) raised to unloaded weight. All of these data were differentiated by mode of fishing, i.e. sets on fish associated with dolphins, sets on floating objects and sets on unassociated schools. The data were also differentiated by vessel size class (carrying capacity in tonnes) as follows: (1) 0-45 tonnes; (2) 45-91 tonnes; (3) 92-181 tonnes; (4) 182-272 tonnes; (5) 273-363 tonnes; (6) >363 tonnes. Biomass estimates for yellowfin, bigeye and skipjack tunas were provided by the IATTC (Maunder, 2003 personal communication; also see Maunder, 2002; Harley and Maunder, 2004 and Maunder and Harley, 2004).[6] Monthly sea-surface temperature data were obtained from Rayner *et al.* (2003) for 5°N to 20°N between the coast of the Americas and 120°W to try to capture environmental influences.

[6] The estimates of biomass are for age 1 year and older. The 2003 assessments for which the yellowfin biomass comes from is at http://www.iattc.org/IATTC4thMeetingoftheScientificWorkingGroupENG.htm. The skipjack biomass is from stock assessment report 3. Bigeye is not from the assessment report 4, but from an updated assessment which the results are presented in the IATTC status of the stocks.

Estimates of capacity outputs, allowing for variable returns to scale[7], were made at the set and vessel level by mode of fishing (dolphin, unassociated or floating object). Data for yellowfin and bigeye tunas were combined to reduce the number of zero-valued observations of bigeye (which is troublesome to the operation of the DEA program). Output or retained catches in the analysis was specified by species and method of harvest per set as follows: (1) yellowfin and bigeye tuna caught in sets made on dolphins; (2) yellowfin and bigeye tuna caught in sets made on unassociated schools; (3) yellowfin and bigeye tuna caught in sets made on floating objects; (4) skipjack tuna caught in sets made on dolphins; (5) skipjack caught in sets made on unassociated schools; and (6) skipjack caught in sets made on floating objects. The retained catches of other fish were negligible, and hence not considered in the analysis. The analysis estimated capacity output for all six outputs and three types of fishing, specifying a common harvesting frontier (i.e. the DEA models were run with all six outputs at once, rather than separately for each of the three types of fishing). To be able to accurately estimate capacity output by individual vessel for each of the different types of fishing, each of the six outputs in the DEA model were specified as average landings per vessel per set per year.

Biomass estimates for yellowfin and skipjack were used to specify stock conditions, with sea-surface temperature used to account for environmental conditions. Both of these variables were specified as non-discretionary or fixed (constrained) inputs. The capital stock or capacity base of an individual vessel was captured by the GRT to allow for consistency with specifications for the other tuna purse-seine fisheries.

Although data were provided for 1980-2002, capacity output estimates were made only for 1998-2002. Limiting the analysis to the five most recent years captures more recent fleet configurations, cost conditions and fishing patterns, and also helps to control for the potential shifts in capacity output due to technical change. Limiting the number of years of analysis thus leaves differences in TE and variable input usage as the determinants of differences in observed output from capacity output (Färe, Grosskopf and Kokkelenberg, 1989). In addition, the technological-economic approach to capacity output is predicated on "normal practice" or "normal operating conditions" among the vessels, which is better given when the number of years is limited (*cf*. Corrado and Mattey, 1997).

Capacity output and TE were estimated separately for each of the following vessel size groupings: (i) classes 2 and 3 with 28 vessels; (ii) classes 4 and 5 with 43 vessels and (iii) class 6 with 188 vessels. There were no class-1 vessels in the data set. Classes 2 and 3 and classes 4 and 5 were combined to provide an acceptable minimum level of observations in each grouping.[8] The full five years of data were available for only 50 vessels.

The technological-economic measure of capacity output specifies full utilization of variable inputs. However, estimates of TE by DEA were made using the number of sets per vessel by each type of fishing by year as the variable input.

Estimates of ray CU, in which deviations from full CU are due to either low variable input usage or technical inefficiency, are given by θ in problem [1]. Estimates of ray CU purged for the effects of TE were given by the ratio θ_2/θ_1, where θ_2 is derived from problem [1], allowing for variable inputs that are not necessarily fully utilized and θ_1 is the θ in problem [1] when variable inputs are fully utilized (Färe, Grosskopf and Kokkelenberg, 1989). Thus, estimates of ray CU purged for the effects of TE are due to low variable input usage. As noted above, we have attempted to control for

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7 Variable returns to scale were allowed by imposing the constraint $3\ z_j = 1.0$ in problem [1].

8 An "insufficient" number of observations gives an estimated piece-wise linear frontier with more and/or longer linear segments and a less accurate measure of capacity output. Without enough "kinks" (from shorter and a larger number of segments) in the piece-wise linear frontier, the distance from an observed output to the frontier, where the observed frontier gives the capacity output, is reduced.

TABLE 3.1
Data used to estimate capacity for Class-2 and -3 vessels in the tuna purse-seine fishery of the EPO

Year	Set type	GRT	No. of vessels	Trip length (days)	Total no. of sets	Total landing (tonnes)		
						Yellowfin and bigeye	Skipjack	Total
By year								
1998	All	148	68	10 608	2 907	8 260	6 663	14 923
1999	All	152	63	10 397	2 655	17 678	10 796	28 474
2000	All	146	64	11 939	3 233	10 028	13 564	23 591
2001	All	161	51	10 410	2 481	13 759	7 500	21 258
2002	All	167	53	7 918	1 625	5 920	6 325	12 245
By year and set type								
2000	Dolphin	68	1	250	1	0	18	18
1998	Unassociated	153	25	5 539	2 370	6 839	4 271	11 110
1999	Unassociated	150	32	5 667	2 405	15 548	8 269	23 817
2000	Unassociated	153	32	6 336	2 946	9 115	10 590	19 705
2001	Unassociated	168	26	5 537	1 880	8 376	3 778	12 154
2002	Unassociated	172	25	4 178	1 248	4 853	5 045	9 898
1998	Floating object	158	19	4 323	537	1 421	2 392	3 813
1999	Floating object	161	23	4 259	250	2 131	2 527	4 658
2000	Floating object	148	25	5 134	286	913	2 955	3 868
2001	Floating object	154	21	4 724	601	5 383	3 722	9 104
2002	Floating object	169	22	3 527	377	1 067	1 279	2 347

Source: Inter-American Tropical Tuna Commission.
Note: There were no reported dolphin sets by Class-2 and -3 vessels in 1998, 1999, 2001 or 2002.

TABLE 3.2
Data used to estimate capacity for Class-4 and -5 vessels in the tuna purse-seine fishery of the EPO

Year	Set type	GRT	No. of vessels	Trip length (days)	Total no. of sets	Total landing (tonnes)		
						Yellowfin and bigeye	Skipjack	Total
By year								
1998	All	374	47	9 869	2 742	11 686	12 100	23 786
1999	All	350	50	8 560	2 655	22 858	17 153	40 011
2000	All	319	53	10 059	3 162	13 780	21 089	34 869
2001	All	377	63	11 749	3 100	26 301	10 722	37 022
2002	All	406	73	13 805	4 450	30 295	16 764	47 058
By year and set type								
2002	Dolphin	454	1	217	11	0	160	160
1998	Unassociated	366	23	5 075	2 269	7 659	9 588	17 248
1999	Unassociated	343	27	4 995	2 433	13 464	20 395	33 859
2000	Unassociated	318	27	5 739	2 867	16 824	12 015	28 839
2001	Unassociated	383	33	6 557	2 629	7 724	20 862	28 587
2002	Unassociated	410	38	7 633	3 850	12 363	26 513	38 876
1998	Floating object	401	20	4 369	473	4 440	2 098	6 538
1999	Floating object	387	18	3 237	222	3 689	2 463	6 152
2000	Floating object	334	21	4 287	295	4 265	1 765	6 030
2001	Floating object	388	25	5 081	471	2 997	5 439	8 436
2002	Floating object	429	30	5 913	589	4 400	3 622	8 023

Source: Inter-American Tropical Tuna Commission.
Note: There were no reported dolphin sets by Class-4 or -5 vessels between 1998 and 2001.

deviations from full ray CU due to technical change in the later years by limiting the analysis to the last five years. We also attempted to control for deviations from full ray CU due to fluctuations in resource abundance and environmental conditions (which

TABLE 3.3
Data used to estimate capacity for Class-6 vessels in the tuna purse-seine fishery of the EPO

Year	Set type	GRT	No. of vessels	Trip length (days)	Total no. of sets	Total landing (tonnes)		
						Yellowfin and bigeye	Skipjack	Total
By year								
1998	All	1 036	362	88 984	21 211	279 749	119 093	398 842
1999	All	1 081	366	78 845	19 722	296 782	231 517	528 299
2000	All	1 116	366	80 958	18 198	320 733	169 121	489 854
2001	All	1 119	323	71 755	17 477	376 226	116 751	492 977
2002	All	1 179	333	77 196	20 379	395 408	134 087	529 495
By year and set type								
1998	Dolphin	1 025	81	10 942	19 863	158 868	5 044	163 912
1999	Dolphin	1 060	91	8 709	20 456	143 775	1 758	145 533
2000	Dolphin	1 136	91	8 876	20 033	150 934	387	151 321
2001	Dolphin	1 018	73	9 130	14 438	221 481	1 668	223 149
2002	Dolphin	1 073	77	11 169	15 761	278 318	2 841	281 159
1998	Unassociated	1 053	127	4 742	30 789	60 188	13 596	73 784
1999	Unassociated	1 087	133	6 063	28 039	60 794	52 819	113 613
2000	Unassociated	1 113	134	5 597	29 294	49 656	54 908	104 564
2001	Unassociated	1 141	127	3 041	28 904	49 476	7 834	57 310
2002	Unassociated	1 182	130	3 235	30 747	41 343	16 658	58 002
1998	Floating object	1 054	122	5 476	30 098	60 005	100 277	160 282
1999	Floating object	1 102	128	4 934	27 230	91 898	176 791	268 689
2000	Floating object	1 127	125	3 703	28 207	119 971	113 076	233 047
2001	Floating object	1 178	112	5 296	26 268	104 908	107 224	212 132
2002	Floating object	1 202	110	5 960	27 497	75 410	114 491	189 901

Source: Inter-American Tropical Tuna Commission.

shift the capacity output frontier in or out) by specifying biomass and sea-surface temperature.

Annual capacity output on a per-set and per-vessel basis was estimated and subsequently converted to total annual fleet activity for each vessel size class by multiplying the per-vessel and per-set estimates of capacity output by the number of vessels and sets in each year for each vessel size class.

Technological change can also increase fishing capacity. To begin to evaluate the effects of technical change, we estimate a Malmquist index of technological change for the Class-6 vessels, which gives us balanced panel data set of nine years with total number of data for 128 vessels for all three set types. We estimate the Malmquist index DEA model with constant-returns-to-scale, which basically uses the same output-oriented DEA model as that in our capacity estimation, with number of sets as variable input and the interaction term of number of sets and gross weight of the vessel added as another input. This gives a flow measure of capital services for the vessel, engine and gear. Four CU rates (also called output distance in this methodology) are calculated. We provide annual year-to-year estimates and chain or cumulative indices over the nine years.

3.2 Results

3.2.1 Overall levels of capacity in the tuna purse-seine fishery of the eastern Pacific Ocean

The results of the analysis indicates that substantial excess fishing capacity, defined as fishing capacity output minus observed output (retained catches), when measured as: (1) potential catch minus actual catch or (2) potential catch, purged for TE, minus actual catch exists for:

FIGURE 3.1
Excess fishing capacity and excess fishing capacity purged for technical efficiency for the purse-seine fishery for skipjack in the EPO

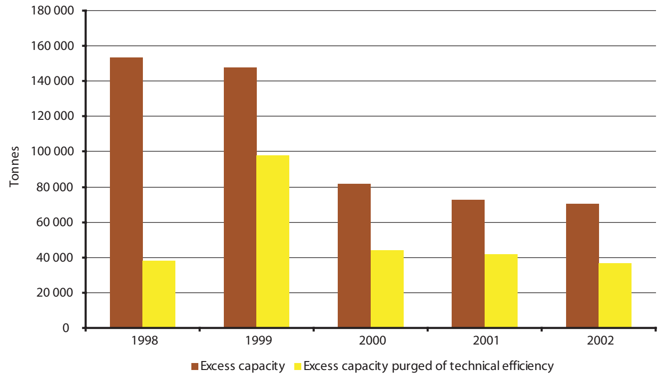


FIGURE 3.2
Observed catch, fishing capacity and fishing capacity purged for technical efficiency for the purse-seine fishery for skipjack in the EPO

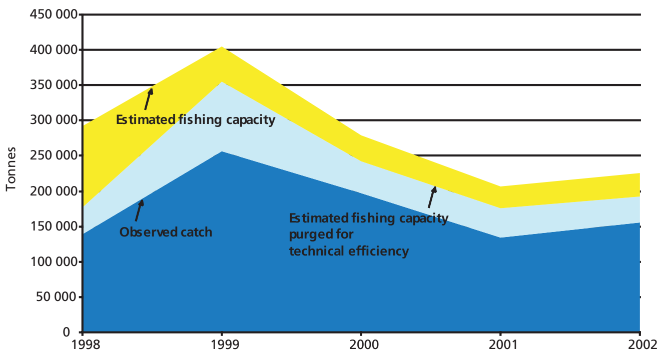
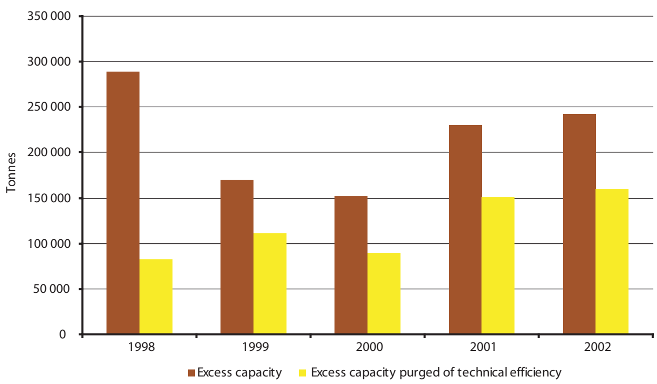


FIGURE 3.3
Excess fishing capacity and excess fishing capacity purged for technical efficiency for the purse-seine fishery for yellowfin and bigeye combined in the EPO



- Skipjack for all vessel classes and set types utilised by the respective vessel class;
- Yellowfin and bigeye combined for all vessel classes and set types utilised by the respective vessel class.

In short, tuna purse-seine vessels had the capacity to catch substantially more of all species during 1998-2002 than they actually caught. The greatest contributor, by far, to excess capacity was Class-6 vessels, although there was excess capacity for Classes 2-3 and 4-5 vessels as well (Table 3.5). Excess capacity for all species combined, purged for TE, fluctuated from a minimum of 120 420 tonnes in 1998 to a maximum of 208 162 tonnes in 1999, dipping in 2000 and steadily rising to 193 199 tonnes in 2001 and to 196 178 tonnes in 2002 (Figures 3.5 and 3.6). Across all vessels it is estimated, after accounting for TE, that during 1998-2002 the combined catches of yellowfin and bigeye could have been 33 percent greater (Table 3.5, Figures 3.3 and 3.4) while those of skipjack could have been be 29 percent greater (Table 3.5, Figures 3.1 and 3.2).

The CU rates for all species combined also indicate substantial excess capacity, defined as capacity output minus observed output, regardless of whether TE is purged (Table 3.7). (CU is defined as observed output divided by capacity output. CU ranges from 0 to 1, where 0 indicates no observed output and 1 indicates that observed output equals capacity output.) The CU for Class 2-3 vessels, purging TE from capacity output, averaged 67 percent, i.e. on average a vessel caught about two-thirds of its potential catch. Across all Class 2-3 vessels it is estimated, after accounting for TE, that the combined catches of yellowfin and bigeye could have been 51 percent greater, while those of skipjack could have been 39 percent greater (Table 3.5). The CU for Class 4-5 vessels, purging TE from capacity output, averaged 72 percent; i.e. on average a vessel caught slightly less than three-quarters of its potential catch. Across all Class 4-5 vessels it is estimated, after accounting for TE combined, that the combined catches of yellowfin and bigeye could have been 10 percent greater, while those of skipjack could have been 28 percent greater (Table 3.5). The CU for Class-6 vessels, purging TE from capacity output, averaged 75 percent, i.e. on average a vessel caught about three-quarters of its potential catch. Across all Class-6 vessels it is estimated, after accounting for TE, that the combined catches of yellowfin and bigeye could have been 34 percent greater, while those of skipjack could have been 29 percent greater (Table 3.5).

Excess capacity exists for all vessel size classes combined for all set types for yellowfin and bigeye tuna when measured as either: (1) potential catch, purged for TE, minus actual catch (Table 3.5, Figure 3.3), or as (2) potential catch, purged for TE, minus the combined AMSYs for both yellowfin and bigeye (Tables 3.6, Figure 3.7). Excess capacity for yellowfin and bigeye tuna *vis-à-vis* their combined AMSY was relatively small in 1998 at 37 167 tonnes, i.e. capacity output, purged for TE, was 37 167 tonnes, or almost 11 percent more than the combined AMSYs. Capacity output, purged for TE, rose to 92 518 tonnes, or almost 27 percent more than the combined AMSY in 1999. In 2000, capacity output, purged for TE, decreased slightly to 89 704 tonnes, or almost 26 percent more than the combined AMSYs. By 2001, however, capacity output, purged for TE, rose to 210 915 tonnes, or almost 61 percent more than the combined AMSYs. In 2002, capacity output, purged for TE, rose to 241 835 tonnes, or almost 70 percent more than the combined AMSYs. In all cases, Class-6 vessels contributed the lion’s share of the excess capacity.

In summary, by 2002 tuna purse-seine vessels had the capacity to harvest almost 70 percent more than the AMSYs for yellowfin and bigeye combined.

FIGURE 3.4
Observed catch, fishing capacity and fishing capacity purged for technical efficiency for the purse-seine fishery for yellowfin and bigeye combined in the EPO

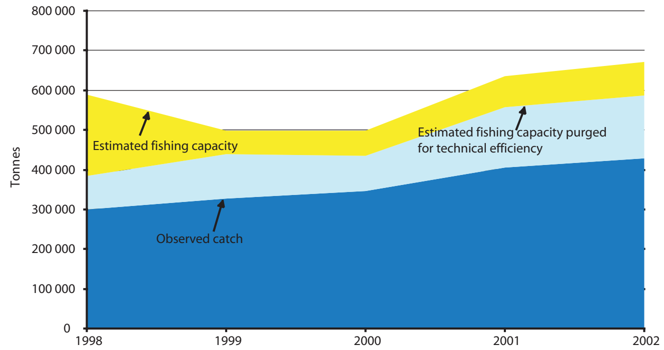


FIGURE 3.5
Excess fishing capacity and excess fishing capacity purged for technical efficiency for the purse-seine fishery for all species combined in the EPO

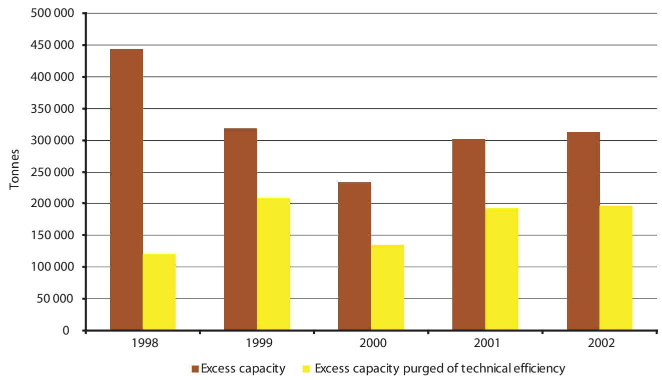


FIGURE 3.6
Observed catch, fishing capacity and fishing capacity purged for technical efficiency for the purse-seine fishery for all species combined in the EPO

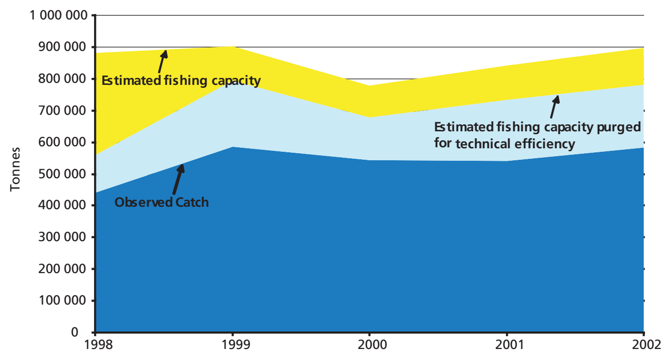


TABLE 3.4
Reported catch, estimated capacity and capacity purged for technical efficiency for the purse-seine fishery in the EPO.

Vessel class	Year	Reported catch (tonnes)						Fishing capacity (tonnes)						Fishing capacity purged for technical efficiency (tonnes)					
		Skipjack			Yellowfin and bigeye			Skipjack			Yellowfin and bigeye			Skipjack			Yellowfin and bigeye		
		Dolphin	Unasso-ciated	Floating objects	Dolphin	Unasso-ciated	Floating objects	Dolphin	Unasso-ciated	Floating objects	Dolphin	Unasso-ciated	Floating objects	Dolphin	Unasso-ciated	Floating objects	Dolphin	Unasso-ciated	Floating objects
Classes	1998	----	6 012	2 201	----	7 663	2 126	----	11 801	4 977	----	21 322	5 394	----	8 348	4 266	----	15 749	7 465
2 and 3	1999	----	6 444	1 992	----	7 303	1 361	----	14 715	4 360	----	18 065	4 948	----	9 768	2 470	----	11 580	5 096
	2000	18	5 817	2 317	0	9 664	2 041	18	13 347	4 725	0	22 024	4 638	18	8 475	2 674	0	13 150	5 652
	2001	----	6 467	1 696	----	10 230	779	----	11 200	4 100	----	16 981	2 471	----	7 759	1 615	----	12 494	4 356
	2002	----	5 934	1 415	----	8 306	1 567	----	12 619	3 959	----	16 493	4 507	----	7 756	2 168	----	10 682	4 538
	Av.	**18**	**6 135**	**1 924**	**0**	**8 633**	**1 575**	**18**	**12 736**	**4 424**	**0**	**18 977**	**4 392**	**18**	**8 421**	**2 638**	**0**	**12 731**	**5 421**
Classes	1998	----	7 659	4 440	----	9 588	2 098	----	16 858	8 167	----	20 140	4 395	----	9 915	6 159	----	11 682	2 886
4 and 5	1999	----	13 464	5 172	----	20 395	3 076	----	18 775	6 334	----	26 523	3 517	----	17 945	6 125	----	23 937	3 366
	2000	----	16 824	4 265	----	12 015	1 765	----	23 603	5 690	----	13 006	2 017	----	21 242	5 380	----	11 768	1 878
	2001	----	7 724	2 997	----	20 862	5 439	----	11 933	4 578	----	27 631	7 499	----	10 448	4 023	----	24 616	6 373
	2002	0	12 330	4 272	160	26 431	3 622	0	15 861	6 168	160	28 525	4 406	0	14 622	5 467	160	25 242	4 059
	Av.	**0**	**11 600**	**4 229**	**160**	**17 858**	**3 200**	**0**	**17 406**	**6 188**	**160**	**23 165**	**4 367**	**0**	**14 834**	**5 431**	**160**	**19 449**	**3 713**
Class 6	1998	5 044	13 596	100 277	158 868	60 188	60 005	8 341	27 241	215 115	300 663	110 248	127 811	6 287	17 281	125 844	200 974	73 840	73 756
	1999	1 758	52 819	175 308	143 775	60 794	91 285	2 364	75 097	283 217	207 942	86 925	149 876	2 205	66 485	249 450	187 020	76 618	133 513
	2000	387	54 908	113 076	150 934	49 656	119 971	525	79 842	151 329	222 651	75 926	158 323	499	71 140	132 170	200 407	66 451	139 363
	2001	1 585	7 673	105 875	216 583	48 180	103 634	2 593	10 843	161 598	347 537	72 673	160 706	2 255	9 674	139 122	307 197	64 133	140 473
	2002	2 763	15 893	113 021	272 926	40 211	74 840	4 241	22 619	160 512	451 035	61 137	104 007	3 796	19 520	138 517	399 297	53 821	92 393
	Av.	**2 307**	**28 978**	**121 511**	**188 617**	**51 806**	**89 947**	**3 613**	**43 128**	**194 354**	**305 965**	**81 382**	**140 145**	**3 008**	**36 820**	**157 020**	**258 979**	**66 973**	**115 900**

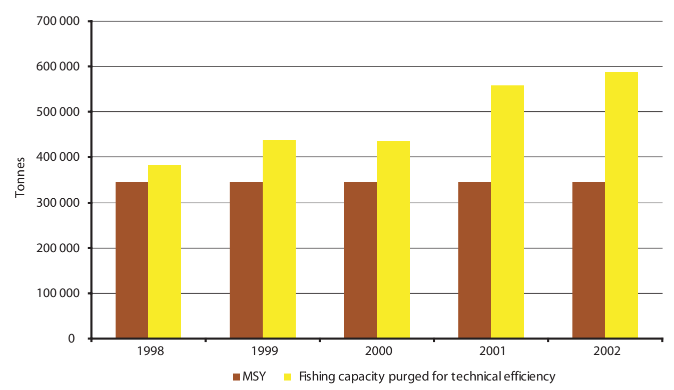
Note: Actual output (retained catches in tonnes) from Inter-American Tropical Tuna Commission.

TABLE 3.5
Reported catch, estimated excess capacity and excess capacity purged for technical efficiency for the purse-seine fishery of the EPO

Vessel class	Year	Reported catch		Excess fishing capacity				Excess fishing capacity purged for technical efficiency			
		Skipjack	Yellowfin and bigeye	Skipjack		Yellowfin and bigeye		Skipjack		Yellowfin and bigeye	
		tonnes	tonnes	tonnes	%	tonnes	%	tonnes	%	tonnes	%
Classes 2 and 3	1998	8 213	9 789	8 565	(104)	16 927	(173)	3 335	(41)	10 225	(104)
	1999	8 436	8 664	10 639	(126)	14 350	(166)	3 957	(47)	5 386	(62)
	2000	8 152	11 705	9 938	(122)	14 958	(128)	3 318	(41)	4 120	(35)
	2001	8 163	11 009	7 137	(87)	8 443	(77)	2 337	(29)	3 101	(28)
	2002	7 349	9 873	9 229	(126)	11 127	(113)	2 778	(38)	2 976	(30)
	Average	**8 077**	**10 208**	**9 102**	**(113)**	**13 161**	**(129)**	**3 145**	**(39)**	**5 161**	**(51)**
Classes 4 and 5	1998	12 099	11 686	12 926	(107)	12 849	(110)	3 974	(33)	2 882	(25)
	1999	18 636	23 471	6 473	(35)	6 569	(28)	5 434	(29)	3 833	(16)
	2000	21 089	13 780	8 204	(39)	1 244	(9)	5 532	(26)	-134	-(1)
	2001	10 721	26 301	5 789	(54)	8 829	(34)	3 749	(35)	4 688	(18)
	2002	16 602	30 213	5 427	(33)	2 878	(10)	3 487	(21)	-752	-(2)
	Average	**15 829**	**21 218**	**7 764**	**(49)**	**6 474**	**(31)**	**4 435**	**(28)**	**2 103**	**(10)**
Class 6	1998	118 917	279 061	131 781	(111)	259 661	(93)	30 495	(26)	69 509	(25)
	1999	229 885	295 854	130 793	(57)	148 890	(50)	88 255	(38)	101 298	(34)
	2000	168 371	320 561	63 325	(38)	136 339	(43)	35 438	(21)	85 659	(27)
	2001	115 133	368 397	59 900	(52)	212 519	(58)	35 918	(31)	143 406	(39)
	2002	131 677	387 977	55 695	(42)	228 201	(59)	30 155	(23)	157 534	(41)
	Average	**152 796**	**330 370**	**88 299**	**(58)**	**197 122**	**(60)**	**44 052**	**(29)**	**111 481**	**(34)**
All vessels[a]	1998	139 229	300 536	153 272	(110)	289 437	(96)	37 804	(27)	82 616	(27)
	1999	256 957	327 989	147 905	(58)	169 809	(52)	97 646	(38)	110 517	(34)
	2000	197 612	346 046	81 467	(41)	152 541	(44)	44 288	(22)	89 645	(26)
	2001	134 017	405 707	72 826	(54)	229 791	(57)	42 004	(31)	151 195	(37)
	2002	155 628	428 063	70 351	(45)	242 206	(57)	36 420	(23)	159 758	(37)
	Average	**176 702**	**361 796**	**105 165**	**(60)**	**216 757**	**(60)**	**51 632**	**(29)**	**118 745**	**(33)**

Notes: Excess capacity output is defined as capacity output less observed output (landings) in tonnes.
Actual output (landings in tonnes) from Inter-American Tropical Tuna Commission.

FIGURE 3.7
Combined AMSYs vs. fishing capacity purged for technical efficiency for the purse-seine fishery for yellowfin and bigeye in the EPO



3.2.2 The fishery by class-2 and -3 vessels

Potential catch exceeds actual catch for sets on unassociated schools and on floating objects for Class-2 and -3 vessels, i.e. there is excess capacity, regardless of whether capacity output is purged for TE (Table 3.4). (There were no dolphin sets for Class-2 or -3 vessels.) When TE is purged from capacity output for yellowfin and bigeye, this excess capacity is comparatively greater for sets on unassociated schools than for sets on floating objects, with an annual average about four times greater. Excess capacity for all set types for Class-2 and -3 vessels has been declined steadily during 1998-2002.

FIGURE 3.8
Annual year-to-year technical change class 6 vessels, all set types and species, 1994-2002

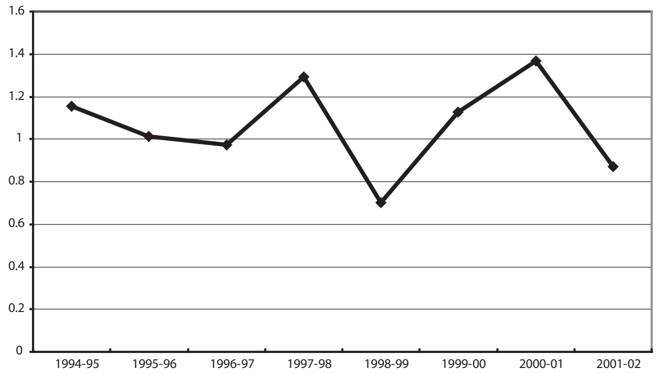
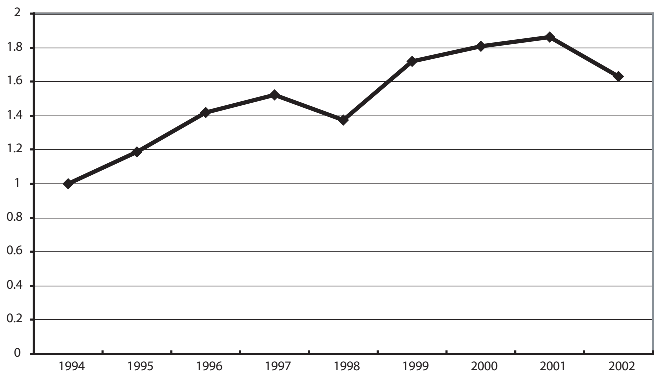


FIGURE 3.9
Cumulative (chained) technical change class 6 vessels, all set types and species, 1994-2002



3.2.3 The fishery by class-4 and -5 vessels

Potential catch exceeds actual catch for sets on unassociated schools and on floating objects for Class-4 and -5 vessels, i.e. there is excess capacity, regardless of whether capacity output is purged for TE (Table 3.4). (There was a negligible number of dolphin sets for this size category.) When capacity output is purged for TE for yellowfin and bigeye, this excess capacity is comparatively greater for sets on unassociated schools than for sets on floating objects, with an annual average about three times greater. For skipjack, this excess capacity also averages three times greater for sets on unassociated schools than for sets on floating objects. Excess capacity over all set types averages about three times greater for sets on unassociated schools than for sets on floating objects. The trend for excess capacity for all set types has been roughly downward during 1998-2002, but with considerable variability.

3.2.4 The fishery by class-6 vessels

Potential catch exceeds actual catch for sets on unassociated schools and on floating objects for Class-6 vessels, i.e. there is excess capacity, regardless of whether capacity output is purged for TE (Table 3.4). When capacity output is purged for TE for yellowfin and bigeye, this excess capacity can be ranked by set type, from most to least excess capacity as: dolphin sets, sets on floating objects and unassociated school sets. For skipjack, this excess capacity is greatest for floating-object sets, intermediate for sets on unassociated schools sets and least for dolphin sets. Average excess capacity, purged for TE, is greatest for dolphin sets at 71 063 tonnes per year, intermediate for sets on floating objects at 61 462 tonnes per year and least for sets on unassociated schools at 23 009 tonnes per year. Excess capacity for all set types has been roughly upward over 1998-2002, but with considerable variability.

3.2.5 Technical change

Technical change on a cumulative basis for Class 6 vessels increased by about 60 percent for all set types, species during 1998-2002 (Figure 3.9). Thus "fishing power" or the state of technology increased considerably, and was an important factor in the exhibited increase in fishing capacity and excess capacity over this time period.

3.3 Summary and conclusions

Excess capacity for all species combined, defined as capacity output minus observed output (retained catches), exists for all vessel size classes individually and combined for all set types (dolphin, unassociated, floating objects) for yellowfin and bigeye tuna

TABLE 3.6
Excess capacity for yellowfin and bigeye: capacity output purged for technical efficiency minus combined average maximum sustainable yield of yellowfin and bigeye for all vessels in the EPO

Year	Capacity output purged for technical efficiency *(tonnes)*				AMSY (YFT + BET) (2) (tonnes)	Excess capacity (1-2) *(tonnes)*	Ratio (1/2)
	Classes 2-3	Classes 4-5	Class 6	All vessels (1)			
1998	20 014	14 568	348 570	383 153	345 986	37 167	1.107
1999	14 049	27 303	397 151	438 504	345 986	92 518	1.267
2000	15 824	13 646	406 220	435 690	345 986	89 704	1.259
2001	14 109	30 989	511 802	556 901	345 986	210 915	1.610
2002	12 849	29 461	545 510	587 821	345 986	241 835	1.699
Annual average	**15 369**	**23 194**	**441 851**	**480 414**	**345 986**	**134 428**	**1.389**

Notes: Excess capacity output is defined as capacity output, purged for technical efficiency, less combined AMSY for yellowfin and bigeye in tonnes. AMSYs from Inter-American Tropical Tuna Commission.

TABLE 3.7
Average vessel capacity utilisation and technical efficiency by vessel class

Vessel Class	Year	Capacity utilisation	Technical efficiency[a]	Capital utilisation without technical efficiency
Classes 2 and 3	1998	0.40	0.70	0.59
	1999	0.41	0.62	0.63
	2000	0.49	0.65	0.74
	2001	0.50	0.70	0.68
	2002	0.46	0.63	0.69
	All years	**0.45**	**0.66**	**0.67**
Classes 4 and 5	1998	0.46	0.61	0.76
	1999	0.71	0.92	0.71
	2000	0.72	0.92	0.73
	2001	0.60	0.89	0.65
	2002	0.72	0.91	0.74
	All years	**0.64**	**0.85**	**0.72**
Class 6	1998	0.52	0.65	0.78
	1999	0.67	0.89	0.75
	2000	0.68	0.89	0.76
	2001	0.63	0.88	0.71
	2002	0.65	0.88	0.72
	All years	**0.63**	**0.84**	**0.75**

Notes: a. Output-oriented technical efficiency for a vessel size class is measured relative to that vessel size class's own vessels' best-practice production frontier. Vessel size, biomass and sea-surface temperature are held fixed.

when measured as: (1) potential catch minus actual catch or (2) potential catch, purged for TE, minus actual catch. Excess capacity, purged for TE, for all vessel size classes has increased from about 120 000 tonnes in 1998 to close to 200 000 tonnes in 2002, an increase approaching 63 percent in five years. The largest contributor, by far, to excess capacity was Class-6 vessels, although there was excess capacity for Classes 2-3 and 4-5 vessels.

Excess capacity exists for all vessel size classes combined for all set types for yellowfin and bigeye tuna when measured as either: (1) potential catch, purged for TE, minus actual catch, or as (2) potential catch, purged for TE, minus the combined AMSYs for both yellowfin and bigeye.

For yellowfin and bigeye, combining over all set types and vessel size classes, excess capacity (defined as capacity output, purged for TE, minus combined AMSY) climbed from an excess of about 11 percent in 1998 to an excess of almost 70 percent by 2002. In all cases, Class-6 vessels contributed the lion's share of the excess capacity.

Technical change on a cumulative basis increased by about 60 percent for all set types, species and vessel size classes during 1998-2002. Thus "fishing power" or the state of technology increased considerably, and was an important factor in the exhibited increase in fishing capacity and excess capacity over this period.

In short, there is considerable excess capacity, whether measured relative to existing catches or AMSY. There is also considerable technical inefficiency and considerable increases in "fishing power" or the state of technology due to technical change, which, in turn, is an important factor in increases in fishing capacity.

4. THE PURSE-SEINE FISHERY FOR TUNAS IN THE WESTERN AND CENTRAL PACIFIC OCEAN

In this section, we focus attention on the purse-seine fishery for tunas in the WCPO. We find that fishing capacity exceeds observed catches for all major fleets, i.e. the purse-seine fleets of Japan, the Republic of Korea, the Philippines, Papua New Guinea, the Taiwan Province of China and the United States, and for the other fleets combined. We estimate that, on average, during 1998-2002 purse-seine skipjack-fishing capacity, purged for TE, was around 138 000 tonnes per annum greater than the actual catch levels. For yellowfin and bigeye combined we estimate that, on average, during 1998-2002 purse-seine fishing capacity, purged for TE, was around 29 000 tonnes per annum greater than actual catch levels.

4.1 Data

Vessel level purse-seine catch (by species and set type) and effort (by days fished and searched[9] and number of sets made by set type) data by vessel flag for the WCPO tuna fishery were obtained from the Secretariat of the Pacific Community (SPC) for 1980-2002.[10] These data, which covered the operations of the purse-seine fleets of China, the Federated States of Micronesia, Kiribati, the Republic of Korea, the Marshall Islands, New Zealand, Papua New Guinea, the Philippines, the Solomon Islands, the Taiwan Province of China, the United States and Vanuatu throughout the WCPO, were obtained from vessel logbooks.

Data were also provided by the SPC for the purse-seine fleet of Japan; however, these data include only fishing activity in the Exclusive Economic Zones of countries other than Japan, which is only a portion of Japanese purse-seine operations. Data covering the fishing activities of the Japanese purse-seine fleet throughout the WCPO for 2000-2002 was obtained from the National Research Institute of Far Seas Fisheries (NRIFSF) of Japan. These data included catches by set type, the combined number days spent fishing and searching, and carrying capacities of the vessels, provided in ranges of 800 to 900 tonnes, 900 to 1000 tonnes, 1000 to 1100 tonnes, 1100 to 1200 tonnes, 1200 to 1300 tonnes, and 1300 to 1400 tonnes.[11]

Data on the activities of the Spanish and Australian purse-seine fleets were not available at the time that the analyses were undertaken.

While, for confidentiality purposes, the data provide by the SPC could not be attributed to individual vessels the SPC matched vessel characteristics taken from the Regional Register of the Forum Fisheries Agency (FFA) to the logbook data to allow for a data set for each vessel that included both catch and effort data and data relating to the characteristics of the vessel. The vessel characteristics provided were: GRT, storage capacity, length overall (LOA) and power of main engine. These data pertain to

[9] The number of days spent fishing and searching is provided as an aggregated total.
[10] Pers. com. Colin Miller, Fisheries IT Specialist, Secretariat of the Pacific Community.
[11] Pers. com. Naozumi Miyabe, Chief, Tropical Tuna Section, NRIFSF.

TABLE 4.1
Exploitable biomass and sea-surface temperatures

Year	Exploitable biomass (tonnes)			Sea-surface temperature
	Skipjack	Yellowfin	Bigeye	°F (°C)
1998	2 096 661	431 885	46 021	84.30 (29.1)
1999	2 663 134	323 635	45 113	83.80 (28.8)
2000	2 095 842	297 930	46 155	83.60 (28.7)
2001	2 054 939	297 187	47 710	84.90 (29.4)
2002	2 210 299	292 977	30 148	83.68 (28.7)

the characteristics of the vessel at the time that they were obtained from the Regional Register, and thus do not capture changes in these characteristics of the period for which the analysis was conducted. Finally, in some cases the vessel characteristics for a vessel were not available[12] or were incomplete. The data set used in the analysis is based on the sample of vessels for which complete data sets were available. The number of vessels that formed the data set for each fleet grouping used in the analysis is provided in Table 4.2.

Exploitable biomass estimates for the purse-seine fishery for yellowfin, bigeye and skipjack tunas, which were provided on a quarterly basis by the SPC[13], are based on stock assessments undertaken for the 16th meeting of the Standing Committee on Tuna and Billfish of the SPC. The quarterly estimates were converted to annual estimates by averaging over a given year. Sea-surface temperatures taken at the time of each set of each vessel, in degrees Fahrenheit, are taken from the logbooks of United States purse-seine vessels. These data are collected jointly by the U.S. National Marine Fisheries Service and the Forum Fishery Agency. These temperatures are averaged (a simple or unweighted arithmetic average) over all sets, vessels and areas to provide a mean annual sea-surface temperature for the area fished in the WCPO. These temperatures are used for all fleets in the analysis, rather than just the United States vessels. The exploitable biomass and sea-surface temperature data used in the analysis are shown in Table 4.1.

For the analysis the data were grouped by fishing nations for the fleets of Japan, the Republic of Korea, Papua New Guinea, the Philippines, the United States, and the Taiwan Province of China. The remaining fleets were combined in a single group, as there were insufficient observations to allow the analysis to be undertaken at the individual fleet level.[14]

Average vessel data across groups for each of the variables used in the analysis are reported in Table 4.2.

4.2 Methodology

Capacity output, capacity output adjusted for TE and CU rates (observed output divided by capacity output or observed output divided by capacity output adjusted for TE) are estimated by DEA. We estimate fishing capacity using the output-oriented non-radial method of Russell (1985), assuming variable returns to scale.

For the reasons outlined in the EPO analysis, capacity output estimates, with the exception of those for the Japanese fleet, were made for the five-year period of 1998-2002.[15] For the Japanese fleet estimates were made for the three-year period of 2000-2002, as these were the only years for which data were obtained from the NRIFSF.

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[12] Not all vessel operating in the WCPO appear on the FFA regional register, for example, a portion of the New Zealand purse-seine fleet operates exclusive within New Zealand waters and are not on the register.

[13] Pers. com. John Hampton, Oceanic Fisheries Programme Manager, Secretariat of the Pacific Community.

[14] See footnote 7.

[15] See Section 3.

TABLE 4.2
Averages for vessel data used to estimate capacity in the purse-seine fishery of the WCPO

Flag	Year	Number of vessels	GRT	LOA (metres)	Engine size (horsepower)	Storage capacity (cubic metres)	Combined days fished and search	Reported catch per vessel by set type					
								Skipjack			Yellowfin and bigeye		
								Unasso-ciated	Floating objects	Other	Unasso-ciated	Floating objects	Other
Japan	2000	34	na	na	na	1 135	241	886	3 202	na	505	595	na
	2001	34	na	na	na	1 135	230	1 475	3 075	na	409	591	na
	2002	34	na	na	na	1 135	244	2 283	2 483	na	307	383	na
Republic of Korea	1998	27	1 027	62.64	3 645	1 301	257	3 499	1 789	131	1 824	341	24
	1999	25	1 025	62.79	3 633	1 318	281	2 929	1 163	264	867	328	96
	2000	26	1 024	62.69	3 632	1 312	233	3 784	930	81	908	161	10
	2001	26	1 024	62.69	3 632	1 312	251	3 898	835	159	1 251	68	99
	2002	26	1 024	62.69	3 632	1 312	255	4 023	1 848	290	551	139	28
Papua New Guinea	1998	11	952	58.28	2 905	673	161	374	401	1 762	160	133	645
	1999	12	920	61.08	2 902	692	151	176	956	1 221	93	151	447
	2000	17	959	60.43	2 887	737	166	1 050	919	1 116	338	180	357
	2001	18	879	59.06	2 748	684	250	1 579	985	828	475	347	456
	2002	22	912	59.19	2 735	764	210	1 121	1 105	1 479	218	200	825
Philippines	1998	9	955	56.34	2 816	718	203	119	1 280	1 529	72	401	408
	1999	9	955	56.34	2 816	718	226	162	1 547	1 352	12	386	372
	2000	9	978	57.27	2 894	737	225	170	1 277	1 317	45	473	404
	2001	9	945	57.79	2 994	782	242	270	1 158	747	208	734	414
	2002	12	949	59.19	3 145	853	173	124	749	489	60	263	133
Taiwan Province of China	1998	43	1 071	64.68	3 064	1 282	266	2 371	1 962	283	1 292	136	52
	1999	43	1 071	64.68	3 060	1 282	278	1 084	2 533	134	462	559	32
	2000	43	1 100	65.05	3 098	1 298	231	2 336	1 787	207	749	134	13
	2001	44	1 126	65.48	3 128	1 310	245	2 702	1 625	225	875	156	50
	2002	42	1 128	65.69	3 135	1 322	267	2 530	2 725	386	440	208	24
United States	1998	34	1 229	66.25	3 724	1 480	191	974	2 485	33	687	341	11
	1999	35	1 248	66.45	3 729	1 409	163	83	3 466	11	24	978	3
	2000	30	1 187	66.04	3 698	1 310	163	807	1 798	16	162	611	8
	2001	34	1 191	65.84	3 736	1 518	183	1 199	1 517	28	355	480	8
	2002	29	1 207	66.63	3 788	1 536	209	1 723	1 261	10	627	259	4
Others	1998	12	938	58.65	2 878	873	274	1 613	1 988	1 143	762	440	425
	1999	16	1 069	61.60	3 084	1 031	248	653	1 936	1 262	360	566	476
	2000	22	1 090	62.28	3 099	1 048	143	484	1 933	553	279	234	67
	2001	15	1 124	60.85	3 016	1 003	196	919	2 339	535	369	405	250
	2002	19	1 168	62.61	3 119	1 124	178	1 093	2 319	224	273	245	125

Note: For Japan catches reported by the NRIFSF as “free” sets are listed under “unassociated” sets in the table and those reported as “associated” sets are listed as “floating objects” sets.

Estimates of capacity outputs, allowing for variable returns to scale[16], were made at the set and vessel level by mode of fishing. Reports of yellowfin often include bigeye, as the two species are difficult to distinguish during the juvenile stages of their life cycle, so the data on the catches of the two species were aggregated. For all fleets, with the exception of the Japanese purse-seine fleet, output or catches in the analysis was specified by species and method of harvest as follows: (1) yellowfin and bigeye tuna caught in sets on unassociated schools; (2) yellowfin and bigeye tuna caught in sets on floating objects (FADS or flotsam); (3) yellowfin and bigeye tuna caught in other set types such as anchored FADs; (4) skipjack caught in sets on unassociated schools; (5) skipjack caught in sets made on floating objects and (6) skipjack caught in other set types. For the Japanese fleet the catches were specified as (1) yellowfin and bigeye tuna caught in free sets; (2) yellowfin and bigeye tuna caught in associated sets; (3) skipjack caught in free sets; (4) skipjack caught in associated sets. Free sets are the same as unassociated sets and associated sets are the same as floating-object sets as used previously. The reported catches of other fish were negligible, and hence not considered in the analysis. The analysis estimated capacity output for all six (four for the Japanese fleet) outputs and three (two) types of fishing specifying a common harvesting frontier (i.e. the DEA models were run with all six (four) outputs at once, rather than separately for each of the three (two) types of fishing). To be able to accurately estimate capacity output by individual vessel for each of the different types of fishing, each of the six (four) outputs in the DEA model was specified as catches per vessel per year.

The capital stock or capacity base of an individual vessel was specified by its GRT, storage capacity, LOA and engine power, except for vessels of the Japanese fleet, for which it was specified by the mid-point of the carrying capacity band in which it fell.

Biomass estimates for yellowfin and skipjack were used to specify stock conditions with sea-surface temperature used to account for environmental conditions. Both of these variables were specified as non-discretionary or fixed (constrained) inputs.

The technological-economic measure of capacity output specifies full utilization of variable inputs. However, estimates of TE by DEA were made by using the annual numbers of days fished and searched as the variable inputs.

Annual capacity output on a per-vessel basis was estimated and subsequently converted to total annual fleet activity for each fleet group by summing over the individual vessels.

Finally, it should be noted that the catch estimates obtained from the logbook data and the data for the Japanese fleet provided by the NRIFSF differ from the SPC estimates of catches published in its Tuna Fishery Yearbook, as the logbook data are only one of many sources that are used to derive the published estimates. Given this, in Section 4.3.2 we combine the estimates derived from the DEA analysis and the SPC Tuna Fishery Yearbook catch estimates to obtain estimates of excess fishing capacity in the WCPO tuna purse-seine fishery.

4.3 Results

4.3.1 DEA estimates

The results of the analysis indicate that substantial excess fishing capacity, defined as fishing capacity output minus observed output (landings), when measured as: (1) potential catch minus actual catch or (2) potential catch, purged for TE, minus actual catch exists for:

- Skipjack for all of the major fishing nations and for other fishing nations as a group for all set types; and
- Yellowfin and bigeye combined for all of the major fishing nations and for other fishing nations as a group for all set types.

[16] Variable returns to scale were allowed by imposing the constraint 3 z_j = 1.0 in problem [1].

TABLE 4.3

Reported catches, estimated capacities and capacity purged for technical efficiency for the purse-seine fishing of the WCPO

Flag	Year	Reported catch (tonnes)						Fishing capacity (tonnes)						Fishing capacity purged for technical efficiency (tonnes)					
		Skipjack			Yellowfin and bigeye			Skipjack			Yellowfin and bigeye			Skipjack			Yellowfin and bigeye		
		Unasso-ciated	Floating objects	Other	Unasso-ciated	Floating objects	Other	Unasso-ciated	Floating objects	Other	Unasso-ciated	Floating objects	Other	Unasso-ciated	Floating objects	Other	Unasso-ciated	Floating objects	Other
Japan	2000	30 127	108 871	-	17 154	20 245	-	34 787	121 990	-	21 527	25 691	-	32 002	113 231	-	18 803	21 583	-
	2001	50 150	104 534	-	13 903	20 080	-	70 663	116 244	-	16 837	22 623	-	53 364	106 340	-	13 688	21 359	-
	2002	77 618	84 425	-	10 433	13 025	-	99 311	106 966	-	11 582	18 986	-	76 893	99 132	-	9 102	15 758	-
Republic of Korea	1998	94 483	48 308	3 530	49 235	9 201	635	113 580	66 135	3 795	59 765	13 649	809	111 050	64 635	3 644	59 091	13 034	737
	1999	73 214	29 069	6 605	21 682	8 206	2 400	131 708	50 417	7 279	24 381	8 595	2 624	86 623	33 873	6 798	23 490	8 417	2 469
	2000	98 372	24 187	2 105	23 601	4 188	270	136 581	35 759	4 169	26 998	6 645	683	132 587	34 437	3 233	25 957	6 224	481
	2001	101 349	21 719	4 140	32 535	1 761	2 570	124 056	24 233	4 447	35 958	2 028	2 829	117 230	23 199	4 380	34 784	1 914	2 755
	2002	104 588	48 040	7 535	14 327	3 610	740	133 744	56 250	8 288	17 360	4 214	919	113 385	51 801	8 058	15 396	3 858	788
Papua New Guinea	1998	4 116	4 406	19 378	1 756	1 458	7 096	17 490	9 679	22 242	2 873	2 862	8 550	17 080	8 091	22 140	2 777	2 275	8 443
	1999	2 108	11 477	14 656	1 110	1 815	5 367	16 805	29 959	19 549	1 978	2 273	8 795	7 658	23 378	18 302	1 400	2 187	8 185
	2000	17 852	15 625	18 969	5 740	3 063	6 067	27 756	18 462	22 353	8 019	3 482	7 091	26 861	18 415	22 353	7 319	3 415	7 036
	2001	28 416	17 735	14 899	8 555	6 240	8 215	32 807	22 803	15 826	9 757	6 722	8 491	31 928	19 370	14 987	8 905	6 612	8 391
	2002	24 664	24 320	32 546	4 787	4 396	18 156	30 973	41 291	39 909	5 401	4 762	20 778	29 712	38 962	38 603	4 698	4 703	20 188
Philippines	1998	1 072	11 521	13 765	645	3 611	3 673	1 994	14 355	17 369	1 159	5 011	5 346	1 702	14 099	15 411	885	4 649	4 506
	1999	1 458	13 924	12 167	112	3 470	3 350	2 101	15 621	13 605	315	4 706	4 684	1 458	13 970	12 250	119	3 480	3 367
	2000	1 531	11 495	11 853	408	4 257	3 639	2 595	13 692	13 396	757	5 893	5 341	2 145	13 546	13 008	594	5 762	4 919
	2001	2 433	10 418	6 721	1 870	6 606	3 729	2 563	12 352	7 175	1 891	9 041	4 879	2 478	10 687	6 455	1 871	6 900	3 763
	2002	1 488	8 984	5 872	717	3 157	1 598	1 499	9 570	6 727	859	3 702	1 790	1 488	8 984	5 872	717	3 157	1 598
Taiwan Province of China	1998	101 938	84 368	12 166	55 543	5 862	2 248	158 106	97 094	14 156	74 961	6 961	3 043	113 932	81 826	12 248	59 781	4 989	2 254
	1999	46 592	108 918	5 756	19 875	24 055	1 388	86 932	186 135	16 755	36 279	35 115	1 862	55 502	108 891	10 867	23 261	23 092	1 678
	2000	100 468	76 828	8 909	32 222	5 743	550	159 043	99 192	9 730	49 327	6 490	595	132 356	85 605	9 138	41 872	5 277	587
	2001	118 878	71 511	9 895	38 519	6 879	2 183	147 419	76 573	10 746	51 094	10 843	2 599	133 122	73 924	9 972	44 367	7 008	2 331
	2002	106 254	114 437	16 210	18 485	8 744	995	124 720	128 044	30 554	23 354	9 495	2 102	113 961	121 756	19 468	20 126	9 290	1 274
United States	1998	33 110	84 504	1 131	23 365	11 608	375	48 187	95 199	1 380	24 019	15 573	681	42 135	92 813	1 193	23 259	13 354	619
	1999	2 890	121 314	393	853	34 220	95	16 553	160 099	1 017	6 874	52 285	226	7 828	149 677	498	2 139	46 720	181
	2000	24 197	53 938	481	4 871	18 333	230	34 209	67 808	601	6 495	20 911	355	28 795	60 204	527	5 112	19 752	290
	2001	40 749	51 572	942	12 068	16 322	268	53 176	71 386	1 663	13 229	21 218	342	47 074	67 433	1 470	12 625	19 567	301
	2002	49 973	36 583	276	18 169	7 522	124	70 316	44 068	300	21 545	9 671	183	64 632	39 884	295	20 610	8 830	153
Others	1998	19 351	23 851	13 711	9 143	5 279	5 099	23 704	26 598	18 192	10 249	6 145	5 916	21 594	23 988	15 218	9 784	5 360	5 553
	1999	10 445	30 980	20 192	5 765	9 061	7 611	14 224	38 805	33 976	7 391	9 457	11 760	10 586	30 732	27 597	6 198	9 128	10 545
	2000	10 659	42 520	12 176	6 144	5 138	1 475	12 927	70 687	25 471	7 594	6 072	2 332	12 262	58 607	17 721	6 672	4 951	1 466
	2001	12 863	32 746	7 495	5 168	5 676	3 501	15 407	39 932	9 573	6 655	5 676	3 629	14 523	37 485	8 757	6 211	5 676	3 601
	2002	18 587	39 420	3 805	4 646	4 172	2 122	19 826	51 548	4 049	4 891	5 319	2 254	18 923	48 435	3 888	4 588	5 017	2 176

Note: For Japan catches reported by the NRIFSF as "free" sets are listed under "unassociated" sets in the table and those reported as "associated" sets are listed as "floating-object" sets.

During 1998-2002 excess capacity for skipjack, purged for TE, ranged from eight percent of the observed catch for the Philippines' fleet to 35 percent of the observed catch for the Papua New Guinea fleet (Table 4.4). Excess capacity for skipjack, purged for TE, for the Korean, Taiwanese and United States fleets during 1998-2002 averaged 19, 10 and 20 percent of the observed catches, respectively. The estimates for the United States fleet are likely to be biased upward because some vessels of this fleet also operate in the EPO, and this is not accounted for in the analysis. For the other vessels as a group, it was estimated that excess capacity for skipjack, purged for TE, averaged 17 percent of their observed catch. For the Japanese fleet it was estimated that during 2000-2002 the excess capacity for skipjack, purged for TE, averaged six percent of the observed catch.

During 1998-2002 the excess capacity for yellowfin and bigeye combined, purged for TE, ranged from nine to 17 percent, a significantly narrower range than that for skipjack (Table 4.4). The group of other vessels was estimated to have the lowest relative excess capacity for yellowfin and bigeye combined, purged for TE, at nine percent of the observed catch, while the United States fleet was estimated to have the greatest, at 17 percent of the observed catch. Once again, the estimates for the United States fleet are likely to be biased upward for the reason given above. Excess capacity for yellowfin and bigeye combined, purged for TE, for the Taiwanese, Philippine, Korean and Papua New Guinea fleets during 1998-2002 averaged 11, 13, 14 and 15 percent of their observed catches, respectively. For the Japanese fleet it was estimated that during 2000-2002 the excess capacity for yellowfin and bigeye combined, purged for TE, averaged six percent of the observed catch.

The CU rates for all species combined also indicate significant excess capacity, defined as capacity output minus observed output, regardless of whether TE is purged (Table 4.5). (CU is defined as observed output divided by capacity output.) CU ranges between 0 and 1, where 0 indicates no observed output and 1 indicates that observed output equals capacity output. CU, purging TE from capacity output, during 1998-2002 averaged across all vessels in the respective fleets ranged from 0.81 for the Papua New Guinea fleet to 0.95 for the Philippines fleet. CU for all species combined, purged for TE, for the Korean, Taiwanese and United States fleets during 1998-2002 averaged 0.86, 0.91 and 0.86 percent respectively. For the reason previously mentioned, the estimates for the US fleet are likely to be biased downward. For the other vessels as a group it was estimated that CU for all species combined, purged for TE, averaged 0.88. For the Japanese fleet it was estimated that during 2000-2002 that CU, purged for TE, for all species combined averaged 0.95.

4.3.2 Using the DEA results and SPC catch estimates to estimate total excess fishing capacity in the WCPO

In this section the results of the DEA analysis are combined with the catch estimates in the SPC *Tuna Fishery Yearbook* to provide estimates of purse-seine fishing capacity and purse-seine fishing capacity, purged for TE, for all species combined and individually for skipjack and for yellowfin and bigeye combined. This is done because the DEA estimates derived in the previous section are based on logbook data, rather than raised catch data.

These estimates were derived as follows. For each fleet and species grouping covered in the analysis the estimated catches from the SPC Tuna Fishery Yearbook were multiplied by the estimated excess capacity, expressed as percentages, obtained from the DEA analysis for the given fleet and species grouping. This was done for both fishing capacity and fishing capacity purged for TE. The resulting excess capacity estimates were then divided by the SPC **Tuna Fishery Yearbook** total catch for the fleets covered in the analysis and this percentage multiplied by the total WCPO purse-seine catch.

TABLE 4.4
Reported catch, estimated excess capacity and excess capacity purged for technical efficiency for the purse-seine fishery of the WCPO

Flag	Year	Reported catch		Excess fishing capacity				Excess fishing capacity purged for technical efficiency			
		Skipjack	Yellowfin and bigeye	Skipjack		Yellowfin and bigeye		Skipjack		Yellowfin and bigeye	
		tonnes	tonnes	tonnes	%	tonnes	%	tonnes	%	tonnes	%
Japan	2000	138 997	37 399	17 780	(13)	9 820	(26)	6 236	(4)	2 988	(8)
	2001	154 684	33 983	32 222	(21)	5 478	(16)	5 019	(3)	1 064	(3)
	2002	162 043	23 458	44 234	(27)	7 110	(30)	13 982	(9)	1 401	(6)
	Average	**151 908**	**31 613**	**31 412**	**(21)**	**7 469**	**(24)**	**8 412**	**(6)**	**1 817**	**(6)**
Republic of Korea	1998	146 321	59 104	37 188	(25)	15 119	(26)	33 009	(23)	13 758	(23)
	1999	108 888	32 376	80 516	(74)	3 224	(10)	18 406	(17)	1 999	(6)
	2000	124 664	28 139	51 844	(42)	6 186	(22)	45 593	(37)	4 522	(16)
	2001	127 208	36 945	25 529	(20)	3 869	(10)	17 600	(14)	2 508	(7)
	2002	160 163	18 765	38 119	(24)	3 728	(20)	13 082	(8)	1 277	(7)
	Average	**112 844**	**34 992**	**46 639**	**(35)**	**6 425**	**(18)**	**25 538**	**(19)**	**4 813**	**(14)**
Papus New Guinea	1998	27 899	10 309	21 511	(77)	3 975	(39)	19 412	(70)	3 185	(31)
	1999	28 242	8 293	38 071	(135)	4 754	(57)	21 095	(75)	3 479	(42)
	2000	52 445	14 870	16 125	(31)	3 722	(25)	15 184	(29)	2 900	(20)
	2001	61 050	23 010	10 386	(17)	1 961	(9)	5 235	(9)	899	(4)
	2002	81 531	27 339	30 642	(38)	3 603	(13)	25 746	(32)	2 250	(8)
	Average	**50 234**	**16 764**	**23 347**	**(46)**	**3 603**	**(21)**	**17 334**	**(35)**	**2 543**	**(15)**
Philippines	1998	26 358	7 928	7 361	(28)	3 588	(45)	4 855	(18)	2 111	(27)
	1999	27 549	6 932	3 778	(14)	2 773	(40)	129	(0)	35	(1)
	2000	24 880	8 305	4 804	(19)	3 687	(44)	3 820	(15)	2 970	(36)
	2001	19 573	12 204	2 518	(13)	3 607	(30)	47	(0)	330	(3)
	2002	16 343	5 471	1 453	(9)	878	(16)	0	(0)	0	(0)
	Average	**22 940**	**8 168**	**3 983**	**(17)**	**2 907**	**(36)**	**1 770**	**(8)**	**1 089**	**(13)**
Taiwan Province of China	1998	198 472	63 653	70 883	(36)	21 312	(33)	9 533	(5)	3 371	(5)
	1999	161 266	45 318	128 556	(80)	27 939	(62)	13 993	(9)	2 713	(6)
	2000	186 205	38 515	81 760	(44)	17 896	(46)	40 894	(22)	9 220	(24)
	2001	200 284	47 581	34 454	(17)	16 955	(36)	16 733	(8)	6 125	(13)
	2002	236 901	28 224	46 416	(20)	6 727	(24)	18 284	(8)	2 466	(9)
	Average	**196 626**	**44 658**	**72 414**	**(37)**	**18 166**	**(41)**	**19 888**	**(10)**	**4 779**	**(11)**
United States	1998	118 745	35 348	26 022	(22)	4 925	(14)	17 396	(15)	1 884	(5)
	1999	124 596	35 168	53 073	(43)	24 217	(69)	33 406	(27)	13 872	(39)
	2000	78 616	23 434	24 002	(31)	4 326	(18)	10 910	(14)	1 720	(7)
	2001	93 263	28 659	32 963	(35)	6 130	(21)	22 715	(24)	3 834	(13)
	2002	86 832	25 815	27 852	(32)	5 585	(22)	17 979	(21)	3 779	(15)
	Average	**100 410**	**29 685**	**32 782**	**(33)**	**9 037**	**(30)**	**20 481**	**(20)**	**5 018**	**(17)**
Others	1998	56 913	19 521	11 582	(20)	2 790	(14)	3 887	(7)	1 177	(6)
	1999	61 617	22 437	25 388	(41)	6 172	(28)	7 298	(12)	3 435	(15)
	2000	65 354	12 757	43 732	(67)	3 241	(25)	23 236	(36)	332	(3)
	2001	53 105	14 345	11 807	(22)	1 615	(11)	7 659	(14)	1 143	(8)
	2002	61 813	10 941	13 610	(22)	1 523	(14)	9 433	(15)	840	(8)
	Average	**59 760**	**16 000**	**21 224**	**(36)**	**3 068**	**(19)**	**10 303**	**(17)**	**1 385**	**(9)**
All vessels[a]	1998	574 708	195 863	188 427	(36)	45 265	(23)	82 891	(16)	15 800	(8)
	1999	512 158	150 524	333 572	(67)	70 586	(47)	86 464	(17)	24 901	(17)
	2000	671 161	163 419	240 019	(36)	46 222	(28)	143 289	(22)	22 491	(14)
	2001	709 167	196 727	162 333	(23)	45 522	(23)	71 298	(10)	18 052	(9)
	2002	805 626	140 013	214 540	(27)	29 272	(21)	94 020	(12)	11 352	(8)
	Average	714 718	181 623	240 343	(35)	50 361	(28)	98 957	(14)	19 246	(11)

Notes. As no estimates for the Japanese fleet are available for 1998 and 1999 all vessel figures for these years are exclusive of this fleet.

The derived estimates indicate that on average during 1998-2002 excess capacity for skipjack, purged for TE, was 137 452 tonnes, and was at its highest in 2000 at 188 991 tonnes and was at its lowest in 2001 at 89 088 tonnes. As indicated in Figure 4.1, excess capacity for skipjack, purged for TE, trended upward during 1998-2000, before declining significantly in 2001 and then increasing again in 2002. A possible driving force behind this pattern is the skipjack price fluctuations experienced over the period, with Bangkok skipjack prices plummeting to record lows in the second half of 1999 and remaining at these depressed levels throughout 2000 (Catarci, this collection). This price decline resulted in revenues below operating costs for some fleets, which led to some vessels tying up for prolonged periods and fishing fewer days than they would normally, particularly in 2000, as reflected in the number of days vessels in most fleets spent searching and fishing in total (Table 4.2) In other words, there was a reduction in the level of utilisation of variable inputs. In early 2001 the prices recovered to some degree, and prices throughout 2001 and 2002 remained significantly above the levels of the second half of 1999 and throughout 2000, and the average time vessels spent fishing and searching in total increased for all fleets except that of Japan, that was higher in 2001 than in 2000.

The derived estimates also indicate that on average during 1998-2002 excess capacity for yellowfin and bigeye combined, purged for TE, was 31 278 tonnes, and at its highest in 1999 at 43 873 tonnes and lowest in 2002 at 16 977 tonnes. As indicated in Figure 4.3, excess capacity for yellowfin and bigeye combined, purged for TE, rose in 1999, before declining continuously to its 2002 level.

TABLE 4.5

Average vessel capacity utilisation and technical efficiency

Flag	Year	Capacity utilisation	Technical efficiency	Capital utilisation without technical efficiency
Japan	2000	0.87	0.92	0.95
	2001	0.85	0.88	0.97
	2002	0.80	0.85	0.93
	All years	**0.84**	**0.88**	**0.95**
Republic of Korea	1998	0.80	0.96	0.82
	1999	0.66	0.76	0.88
	2000	0.74	0.97	0.77
	2001	0.85	0.95	0.89
	2002	0.82	0.89	0.93
	All years	**0.78**	**0.91**	**0.86**
Papua New Guinea	1998	0.67	0.96	0.70
	1999	0.55	0.85	0.65
	2000	0.82	0.99	0.82
	2001	0.89	0.95	0.94
	2002	0.80	0.96	0.83
	All years	**0.77**	**0.95**	**0.81**
Philippines	1998	0.80	0.93	0.86
	1999	0.88	0.88	1.00
	2000	0.85	0.98	0.88
	2001	0.88	0.88	0.99
	2002	0.95	0.95	1.00
	All years	**0.88**	**0.93**	**0.95**
Taiwan Province of China	1998	0.77	0.81	0.96
	1999	0.62	0.68	0.93
	2000	0.73	0.87	0.83
	2001	0.83	0.91	0.92
	2002	0.84	0.91	0.93
	All years	**0.76**	**0.83**	**0.91**
United States	1998	0.85	0.94	0.90
	1999	0.71	0.91	0.78
	2000	0.81	0.90	0.89
	2001	0.80	0.93	0.86
	2002	0.82	0.94	0.87
	All years	**0.80**	**0.92**	**0.86**
Others	1998	0.86	0.91	0.94
	1999	0.78	0.81	0.92
	2000	0.69	0.83	0.79
	2001	0.88	0.96	0.92
	2002	0.87	0.96	0.91
	All years	**0.80**	**0.89**	**0.88**

4.3.3 Estimated fishing capacity in the WCPO and sustainable fishing mortality on yellowfin and bigeye stocks

The Scientific Co-ordinating Group of the Preparatory Conference for the Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific recommended that there be no further increases in fishing mortality rates on yellowfin (particularly juveniles) and bigeye. Based on this recommendation, we compare estimated fishing capacity and fishing capacity, purged for TE. Against a target catch level set at the average yellowfin catch by purse seiners during 2000-2002.

Fishing capacity and fishing capacity purged for TE, for yellowfin and bigeye combined with average purse-seine catches during 2000-2002 are compared in Figure

FIGURE 4.1
Skipjack in the WCPO purse-seine fishery – Excess fishing capacity and excess fishing capacity purged for technical efficiency

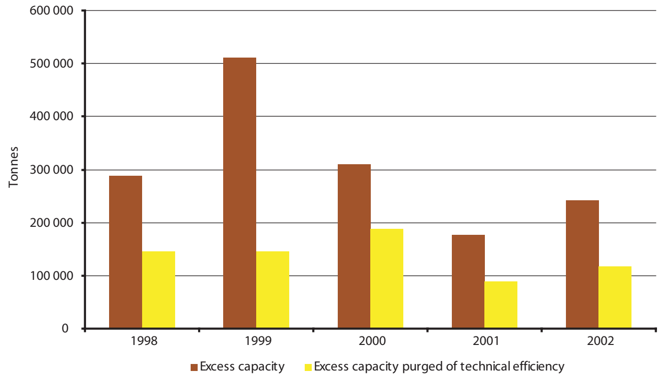


FIGURE 4.2
Skipjack in the WCPO purse-seine fishery – Observed catch, fishing capacity and fishing capacity purged for technical efficiency

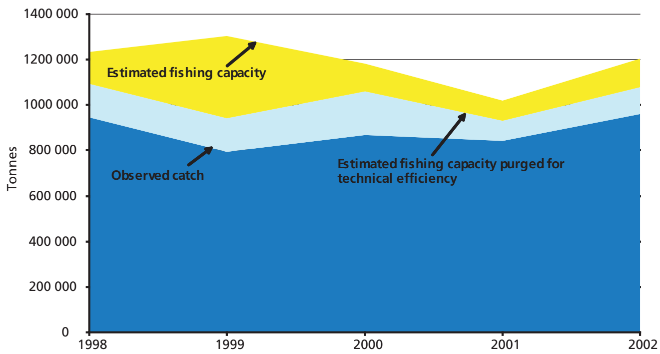
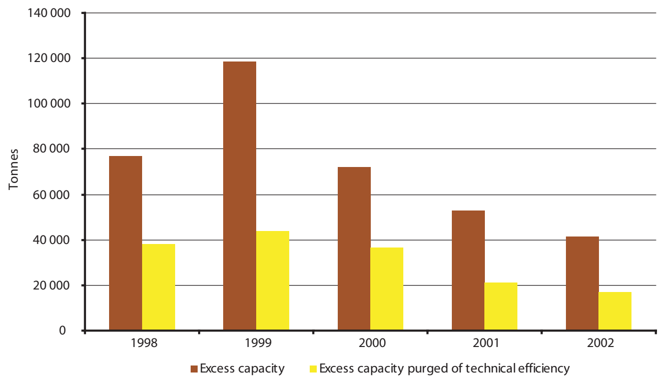


FIGURE 4.3
Yellowfin and bigeye combined in the WCPO purse-seine fishery – Excess fishing capacity and excess fishing capacity purged for technical efficiency



4.5. From this it can be seen that there was significant excess fishing capacity for yellowfin and bigeye when measured as fishing capacity minus average catches from 2000-2002 in the fishery from 1998 to 2002, although this excess capacity existed primarily in 1998 and 1999 and was very low in 2002. During 1998-2002 the average fishing capacity for yellowfin and bigeye combined was in excess of average catches between 2000 and 2002 by 88 762 tonnes or 38 percent.

It can be seen in Figure 4.5 that excess capacity for yellowfin and bigeye, when measured as fishing capacity, purged for TE, minus average catches from 2000-2002 existed in the fishery from 1998 to 2001, but in 2002 there was no excess capacity in the fishery. During 1998-2002 the average fishing capacity, purged for TE, for yellowfin and bigeye combined was in excess of average catches between 2000 and 2002 by 47 666 tonnes or 24 percent.

4.4 Summary and conclusions

The analysis conducted for the WCPO suggests that excess fishing capacity exists for all major fleets, i.e. the purse-seine fleets of Japan, the Republic of Korea, the Philippines, Papua New Guinea, the Taiwan Province of China and the United States, and for the other fleets as a group.

It was estimated that on average during 1998-2002 purse-seine skipjack fishing capacity was around 240 000 tonnes (35 percent) per annum greater than actual catch levels. However, it noted that when purging for TE excess skipjack fishing capacity was only 99 000 tonnes (14 percent) per annum greater than the actual catch levels. In other words, only around 40 percent of the potential increase in catches could be realised through increases in variable input usage, given the biomass, environmental conditions and the state of technology that prevailed over this period. Estimated excess fishing capacity, purged for TE, was at its highest level in 2000. It was hypothesised that this may have been caused by low skipjack prices in the second half of 1999 and throughout 2000, resulting in vessels reducing the number of days spent searching and fishing (Catarci, this collection).

For yellowfin and bigeye combined it was estimated that during 1998-2002 excess purse-seine fishing capacity was around 50 000 tonnes (28 percent) per annum greater than the actual catches. However, it noted that when purging for TE excess yellowfin and bigeye fishing capacity was only 19 000 tonnes (11 percent) per annum greater than the actual catches. In other words, only around 40 percent of the potential increase in catches could be realised through increases in variable input usage, given the biomass, environmental conditions and the state of technology that prevailed over this period. It was also estimated that on average during 1998-2002 fishing capacity, purged for TE, for yellowfin and bigeye combined was in excess of the average catches between 2000-2002 by 47 666 tonnes or 24 percent, but that no excess capacity existed in the fishery in 2002, when measured against average 2000-2002 catch levels.

FIGURE 4.4
Yellowfin and bigeye combined in the WCPO purse-seine fishery – Observed catch, fishing capacity and fishing capacity purged for technical efficiency

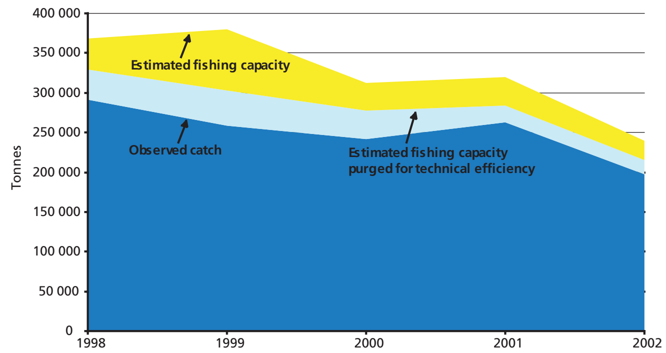
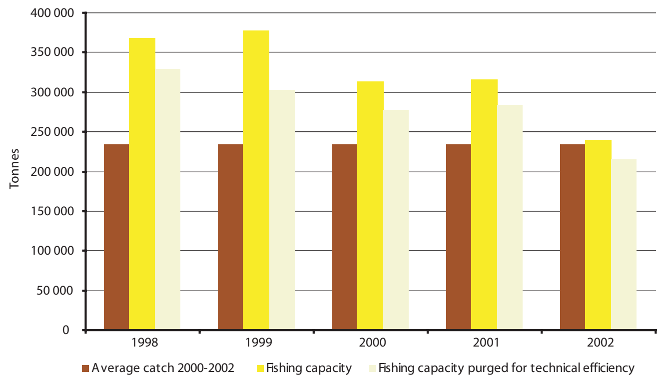


FIGURE 4.5
Yellowfin and bigeye combined in the WCPO purse-seine fishery – Average catch 2000-2002 vs. fishing capacity purged for technical efficiency



5. THE PURSE-SEINE FISHERIES FOR TUNAS IN THE INDIAN OCEAN AND THE ATLANTIC OCEAN

For the Indian and Atlantic Oceans we consider the Russell (1985) measure because of its ease of estimation, and impose variable returns to scale.

5.1 Data and methodology

Data was sought from around the world on fishing activity for the Atlantic and Indian Ocean purse-seine fisheries for tuna. Contacts were also made with ICCAT and the IOTC to obtain data. The data were determined to be inadequate for estimating capacity. Subsequently, data were obtained from Pallares *et al.* (2003) and Pianet *et al.* (2003) on the Indian and Atlantic Ocean fisheries, respectively. These data, however, were highly aggregated and inadequate for estimating capacity on a nation-by-nation basis or by fishing mode (e.g. sets on floating objects vs. sets on unassociated schools). It was subsequently decided to estimate capacity using aggregate annual data on the catches of yellowfin, skipjack, bigeye, albacore and all other species combined, numbers of vessels, fishing days, searching days, carrying capacity, a weighted mean of GRT, using the mid-point of vessel tonnage classes, and number of sets. Data were then converted to a per-vessel basis by dividing by the number of vessels in each year. Data on the Atlantic fishery and Indian Ocean fisheries were available for 1991-2002 and 1981-2002, respectively (Tables 5.1 and 5.2).

Unfortunately, the data were extremely limited in number of observations and detail, which might be important variables for estimating capacity (e.g. fishing days and

TABLE 5.1
Data used to estimate capacity in the Atlantic tuna fishery

Year	Average GRT	Number of vessels	Days of fishing	Days of searching	Carrying capacity	Number of sets	Landings (tonnes)					
							YFT	SKJ	BET	ALB	Others	Total
1991	783	71	15 633	13 709	41 978	8 195	92 475	125 536	14 188	416	1 735	234 350
1992	804	65	17 454	15 886	44 091	6 975	96 705	87 243	18 230	2 518	1 254	205 950
1993	829	64	16 425	14 674	41 119	7 877	90 101	124 875	30 857	1 450	1 246	248 529
1994	800	59	15 904	14 231	40 833	7 663	88 062	105 633	32 378	1 079	2 239	229 391
1995	784	55	14 786	13 086	38 149	8 129	84 684	99 208	25 095	412	2 302	211 701
1996	775	54	14 671	13 116	35 641	7 705	82 476	83 928	25 006	258	3 799	195 467
1997	770	52	12 781	11 551	30 832	5 614	68 311	60 204	15 918	118	2 733	147 284
1998	1 005	44	12 585	11 215	29 784	5 898	73 338	56 438	12 622	434	3 065	145 897
1999	762	41	11 731	10 578	25 877	4 861	58 289	76 852	15 545	264	2 004	152 954
2000	730	41	10 576	9 394	27 385	5 122	64 047	64 625	13 752	32	1 741	144 197
2001	812	44	11 344	10 121	30 714	5 198	77 097	60 891	14 002	24	2 460	154 474
2002	801	41	9 823	8 816	25 036	4 324	74 094	47 900	14 230	39	1 008	137 271
Annual average	**805**	**53**	**13 643**	**12 198**	**34 287**	**6 463**	**79 140**	**82 778**	**19 319**	**587**	**2 132**	**183 955**

Source: Pianet *et al.* (2003)

TABLE 5.2
Data used to estimate capacity in the Indian Ocean tuna fishery

Year	Average GRT	Number of vessels	Days of fishing	Days of searching	Carrying capacity	Number of sets	Landings (tonnes)					
							YFT	SKJ	BET	ALB	Others	Total
1981	613	2	84	0	129	33	199	163	10	0	0	372
1982	681	4	256	221	820	105	1 028	1 027	8	0	0	2 063
1983	685	12	1 461	1 142	3 729	766	10 505	9 366	218	0	0	20 089
1984	847	47	8 041	6 502	23 642	3 491	56 456	41 884	3 561	558	0	102 459
1985	886	48	9 929	8 302	29 209	4 289	65 772	55 266	6 160	726	0	127 924
1986	863	35	8 597	6 907	25 562	3 904	68 610	60 483	9 951	179	0	139 223
1987	935	35	8 246	6 484	25 942	4 940	78 335	68 292	12 682	239	0	159 548
1988	973	40	9 135	7 244	31 550	5 638	112 780	82 822	13 812	266	0	209 680
1989	982	44	10 880	9 030	37 204	5 590	84 058	115 181	9 997	6	0	209 242
1990	1 015	46	10 628	8 880	34 525	5 911	101 070	87 932	10 489	317	0	199 808
1991	1 041	39	9 767	7 985	33 781	5 493	94 087	91 983	12 994	2 243	40	201 347
1992	1 095	39	9 944	8 162	35 061	6 227	91 172	102 569	8 326	3 256	0	205 323
1993	1 140	42	11 109	9 342	39 521	6 350	102 814	116 850	12 365	1 289	0	233 318
1994	1 133	42	11 061	9 228	40 113	7 051	98 623	144 492	13 767	2 574	1	259 457
1995	1 133	42	11 848	10 004	42 153	7 343	124 098	140 546	22 916	1 254	0	288 814
1996	1 174	47	12 380	10 510	45 384	7 733	112 501	124 998	21 755	1 526	1 286	262 066
1997	1 250	58	14 883	12 930	56 796	8 509	116 875	123 418	30 744	1 961	208	273 206
1998	1 226	53	14 648	12 667	54 669	8 300	89 193	132 073	24 945	1 376	0	247 587
1999	1 240	52	13 339	11 363	51 875	8 062	120 179	168 950	35 587	542	829	326 087
2000	1 267	50	12 635	10 657	52 740	8 132	130 717	170 793	25 519	1 162	2 779	330 970
2001	1 261	50	12 911	10 978	53 519	7 845	114 439	156 929	19 482	1 230	525	292 605
2002	1 284	49	12 864	10 851	55 410	8 356	130 187	212 173	26 943	703	5 379	375 385
Annual average	**1 033**	**40**	**9 757**	**8 154**	**35 152**	**5 639**	**86 532**	**100 372**	**14 647**	**973**	**502**	**203 026**

Source: Pallares *et al*. (2003)

TABLE 5.3
Reported and estimated capacity output (tonnes) for the Atlantic Ocean purse-seine fishery

Year	Observed						Capacity					
	YFT	SKJ	BET	ALB	Others	Total	YFT	SKJ	BET	ALB	Others	Total
1991	92 475	125 536	14 188	416	1 735	**234 350**	96 705	125 536	32 378	2 518	3 799	**260 936**
1992	96 705	87 243	18 230	2 518	1 254	**205 950**	96 705	124 969	32 378	2 518	3 799	**260 369**
1993	90 101	124 875	30 857	1 450	1 246	**248 529**	95 771	124 875	32 378	2 424	3 799	**259 247**
1994	88 062	105 633	32 378	1 079	2 239	**229 391**	91 103	114 435	32 378	1 955	3 799	**243 669**
1995	84 684	99 208	25 095	412	2 302	**211 701**	87 368	106 083	28 637	1 579	3 799	**227 466**
1996	82 476	83 928	25 006	258	3 799	**195 467**	86 434	103 995	27 702	1 485	3 799	**223 416**
1997	68 311	60 204	15 918	118	2 733	**147 284**	84 567	99 820	25 832	1 297	3 652	**215 167**
1998	73 338	56 438	12 622	434	3 065	**145 897**	77 097	83 116	18 351	546	3 065	**182 174**
1999	58 289	76 852	15 545	264	2 004	**152 954**	74 094	76 852	15 545	264	2 004	**168 759**
2000	64 047	64 625	13 752	32	1 741	**144 197**	74 094	76 852	15 545	264	2 004	**168 759**
2001	77 097	60 891	14 002	24	2 460	**154 474**	77 097	83 116	18 351	546	3 065	**182 174**
2002	74 094	47 900	14 230	39	1 008	**137 271**	74 094	76 852	15 545	264	2 004	**168 759**
Annual average	**79 140**	**82 778**	**19 319**	**587**	**2 132**	**183 955**	**84 594**	**99 708**	**24 585**	**1 305**	**3 216**	**213 408**

searching days on schools associated with floating objects and unassociated schools, or activities and summary statistics by nation). The number of observations was, in fact, too few to consider all inputs. Unlike statistics in which the required degrees of freedom are well established, there are no specific required degrees of freedom. It has been well established, however, that too few observations leads to problems in DEA because of its orientation to relative efficiency. A rough rule of thumb offered by Cooper, Seiford and Tone (2000) is that the degrees of freedom (n) for DEA should be as follows: $n \exists \max \{m \text{ x } s, 3(m + s)\}$, where n is the number of observations; m is the number of outputs; and s is the number of inputs. For the two data sets on the Atlantic and Indian Ocean purse-seine fisheries, we have five outputs and up to five inputs (average GRT, fishing days, searching days, carrying capacity and number of sets). We should, thus, have a minimum of 30 observations ($m \text{ x } s = 25$, and $3(5+5) = 30$). It was subsequently decided to use only average GRT per vessel per year and fishing and searching days per vessel per year. The GRT was considered as a fixed factor (i.e. could not be easily changed), and fishing and searching days were considered to be variable factors.

In actuality, the DEA problem used to estimate capacity has only one factor of production (GRT). This is because capacity can be estimated without including the variable factors. The constraint introduced by 8 ensures unrestricted use of the variable factors, which is equivalent to excluding the variable factors from Problems [1] or [2]. We, nevertheless, have a potential problem with degrees of freedom relative to estimating capacity for the Atlantic Ocean purse-seine fishery.

Capacity on a per-vessel basis was estimated for both the Atlantic and Indian Ocean fleets and subsequently converted to total fleet activity by multiplying the per-vessel estimates of capacity by the number of vessels in each year. We stress that because of the limited degrees of freedom and the paucity of the data relative to detailed activities of the various nations and the modes of fishing, our estimates represent extreme lower-bound estimates of capacity for the Atlantic and Indian Ocean purse-seine fisheries.

5.2 Results

5.2.1 Overall levels of capacity in the tuna purse-seine fisheries of the Atlantic and Indian Oceans

Estimates of capacity output on a per vessel basis for the Atlantic and Indian Ocean purse-seine fisheries suggest that both fisheries have some degree of excess capacity for all species (Tables 5.3 and 5.4). The highest degree of excess capacity (i.e. capacity output minus observed output per vessel) occurred for skipjack and yellowfin for both fisheries, which also had the greatest landings of all four of the tuna species.

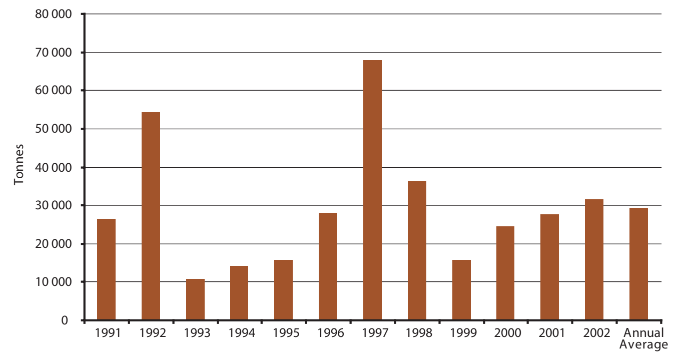
TABLE 5.4

Reported and estimated capacity output (tonnes) for the Indian Ocean purse-seine fishery

Year	Reported						Capacity					
	YFT	SKJ	BET	ALB	Others	Total	YFT	SKJ	BET	ALB	Others	Total
1981	199	163	10	0	0	**372**	199	163	10	0	0	**372**
1982	1 028	1 027	8	0	0	**2 063**	3 324	2 962	327	0	0	**6 613**
1983	10 505	9 366	218	0	0	**20 089**	10 505	9 366	1 036	0	0	**20 907**
1984	56 456	41 884	3 561	558	0	**102 459**	92 568	83 765	12 549	1 911	0	**190 793**
1985	65 772	55 266	6 160	726	0	**127 924**	107 057	97 010	14 845	2 272	0	**221 184**
1986	68 610	60 483	9 951	179	0	**139 223**	72 604	65 739	9 951	1 517	0	**149 811**
1987	78 335	68 292	12 682	239	0	**159 548**	89 665	81 360	12 682	1 954	0	**185 660**
1988	112 780	82 822	13 812	266	0	**209 680**	112 780	102 418	16 102	2 497	0	**233 797**
1989	84 058	115 181	9 997	6	0	**209 242**	124 402	115 181	18 142	2 817	0	**260 542**
1990	101 070	87 932	10 489	317	0	**199 808**	131 331	129 000	20 559	3 206	0	**284 096**
1991	94 087	91 983	12 994	2 243	40	**201 347**	112 196	115 090	18 492	2 893	2 734	**251 404**
1992	91 172	102 569	8 326	3 256	0	**205 323**	113 968	127 024	20 706	3 256	0	**264 954**
1993	102 814	116 850	12 365	1 289	0	**233 318**	124 098	147 683	24 319	3 507	0	**299 606**
1994	98 623	144 492	13 767	2 574	1	**259 457**	124 098	145 976	24 002	3 507	3 578	**301 160**
1995	124 098	140 546	22 916	1 254	0	**288 814**	124 098	145 976	24 002	3 507	0	**297 582**
1996	112 501	124 998	21 755	1 526	1 286	**262 066**	138 871	174 343	28 899	3 924	4 320	**350 358**
1997	116 875	123 418	30 744	1 961	208	**273 206**	171 373	240 045	39 693	4 842	6 048	**462 001**
1998	89 193	132 073	24 945	1 376	0	**247 587**	156 600	212 248	35 491	4 425	0	**408 764**
1999	120 179	168 950	35 587	542	829	**326 087**	153 645	212 369	35 587	4 341	5 340	**411 283**
2000	130 717	170 793	25 519	1 162	2 779	**330 970**	147 736	211 624	34 219	4 175	5 349	**403 101**
2001	114 439	156 929	19 482	1 230	525	**292 605**	147 736	209 919	34 219	4 175	5 300	**401 347**
2002	130 187	212 173	26 943	703	5 379	**375 385**	144 781	212 173	33 534	4 091	5 379	**399 958**
Annual average	**86 532**	**100 372**	**14 647**	**973**	**502**	**203 026**	**109 256**	**129 156**	**20 880**	**2 855**	**1 729**	**263 877**

FIGURE 5.1

Annual and average annual excess capacity relative to all species caught in the Atlantic Ocean purse-seine fishery



For the Atlantic Ocean fishery during 1991-2002 the highest level of excess capacity relative to all species occurred in 1997 (Figure 5.1); the highest level of excess capacity for the Indian Ocean fishery also occurred in 1997 (Figure 5.2). The reason for this is unknown, but it may be a result of management or environmental conditions.

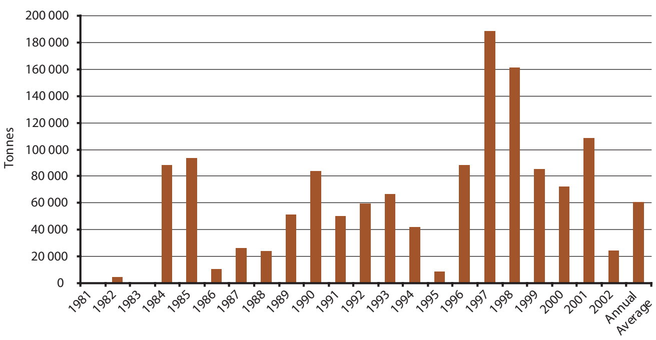
The Atlantic Ocean purse-seine fishery had the capability of harvesting 84 596 tonnes of yellowfin, 99 708 tonnes of skipjack, 24 585 tonnes of bigeye, 1 305 tonnes of albacore and 3 216 tonnes of other species per year (Table 5.3). Alternatively, the fleet had the capability to harvest 213 408 tonnes of all species combined. In comparison, the fleet had a reported average annual harvest of 79 140 tonnes of yellowfin, 82 778 tonnes of skipjack, 19 319 tonnes of bigeye, 587 tonnes of albacore and 2 132 tonnes of other species; the reported average annual harvest between 1991 and 2002 was 183 955 tonnes of all species combined. There was not, however, excess capacity for all species in all years. There was no excess capacity for yellowfin in 1992, 2001 and 2002; none for skipjack in 1991, 1993 and 1999; none for bigeye in 1994 and 1999; none for albacore in 1992 and 1999; and none for other species in 1996, 1998 and 1999.

The overall greatest level of excess capacity occurred in the Indian Ocean purse-seine fishery (Table 5.4). The estimated average annual capacity output between 1981 and 2002 for the Indian Ocean fishery was 109 256 tonnes of yellowfin, 129 156 tonnes of skipjack, 20 880 tonnes of bigeye, 2 855 tonnes of albacore and 1 729 tonnes of

TABLE 5.5
Excess capacity and full-utilization levels of variable inputs per vessel in the Atlantic Ocean purse-seine fishery

Year	Number of vessels	Observed		Full-utilization		Excess Capacity (tonnes)					
		Fishing days	Searching days	Fishing days	Searching days	YFT	SKJ	BET	ALB	Others	Total
1991	71	220	193	246	224	60	0	256	30	29	374
1992	65	269	244	269	244	0	580	218	0	39	837
1993	64	257	229	269	245	89	0	24	15	40	167
1994	59	270	241	272	247	52	149	0	15	26	242
1995	55	269	238	274	249	49	125	64	21	27	287
1996	54	272	243	275	249	73	372	50	23	0	518
1997	52	246	222	276	250	313	762	191	23	18	1305
1998	44	286	255	286	255	85	606	130	3	0	824
1999	41	286	258	286	258	385	0	0	0	0	385
2000	41	258	229	286	258	245	298	44	6	6	599
2001	44	258	230	286	255	0	505	99	12	14	630
2002	41	240	215	286	258	0	706	32	5	24	768
Annual average	**53**	**259**	**232**	**274**	**248**	**104**	**322**	**100**	**14**	**21**	**560**

FIGURE 5.2
Annual and average annual excess capacity relative to all species caught in the Indian Ocean purse-seine fishery



other species; the reported average annual landings were, respectively, 86 532 tonnes of yellowfin, 100 372 tonnes of skipjack, 14 647 tonnes of bigeye, 973 tonnes of albacore and 502 tonnes of other species. The average annual capacity output for all species was estimated to equal 263 877 tonnes, whereas the reported average annual total output was 203 026 tonnes. There was no excess capacity for yellowfin in 1981, 1983, 1988 and 1995; none for skipjack in 1981, 1983, 1989 and 2002; none for bigeye in 1981, 1986, 1987 and 1999; none for albacore for 1981-1983 and 1992; and none for other species in all years except 1991, 1994, 1996-1997 and 1999-2001.

5.2.2 The Atlantic Ocean fishery

In the Atlantic Ocean fishery, a vessel had, on average, the capability to harvest an additional 322 tonnes of skipjack and 104 tonnes of yellowfin per year (Table 5.5). The total average annual excess capacity per vessel between 1991 and 2002 was 560 tonnes. They could do this by operating efficiently and making small increases in their fishing and searching days (the average annual number of fishing and searching days per vessel for the Atlantic fleet between 1991 and 2002 were, respectively, 259 and 232 days; the average annual level of fishing and searching days per vessel required to produce the capacity output were, respectively, 274 and 248 days). In general, the Atlantic Ocean purse-seine fleet could realize capacity output mostly by improving its efficiency (Table 5.6). The measure of CU adjusted for TE is quite close to one for most species and years, which indicates that gains in output could come mostly from operating more efficiently. The non-parametric Kruskal-Wallis test was conducted to determine the equality of observed and full-utilization levels of fishing and searching days; the equality was rejected at the 5-percent level of significance for both fishing and searching days, which implies that producing the capacity output would require an increase in fishing and searching days. The CU values were quite low for other

TABLE 5.6
Capacity utilization in terms of ratio of observed and technically-efficient output levels to capacity output levels in the Atlantic Ocean purse-seine fishery

Year	Capacity utilization—Observed/Reported output					Capacity utilization—Technically-efficient output				
	YFT	SKJ	BET	ALB	Others	YFT	SKJ	BET	ALB	Others
1991	0.96	1.00	0.44	0.17	0.46	0.96	1.00	0.95	0.70	1.00
1992	1.00	0.70	0.56	1.00	0.33	1.00	1.00	1.00	1.00	1.00
1993	0.94	1.00	0.95	0.60	0.33	0.98	1.00	1.00	0.86	1.00
1994	0.97	0.92	1.00	0.55	0.59	1.00	1.00	1.00	0.98	1.00
1995	0.97	0.94	0.88	0.26	0.61	1.00	1.00	0.99	0.95	1.00
1996	0.95	0.81	0.90	0.17	1.00	1.00	1.00	1.00	0.97	1.00
1997	0.81	0.60	0.62	0.09	0.75	0.98	0.91	0.89	0.77	0.86
1998	0.95	0.68	0.69	0.80	1.00	1.00	1.00	1.00	0.99	1.00
1999	0.79	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2000	0.86	0.84	0.88	0.12	0.87	1.00	0.84	0.94	0.43	0.87
2001	1.00	0.73	0.76	0.04	0.80	1.00	0.88	0.96	0.74	0.80
2002	1.00	0.62	0.92	0.15	0.50	1.00	0.62	0.92	0.15	0.50
Annual average	**0.93**	**0.82**	**0.80**	**0.41**	**0.69**	**0.99**	**0.94**	**0.97**	**0.80**	**0.92**

TABLE 5.7
Observed and full utilization fishing and searching days required to produce the capacity output in the Atlantic Ocean purse-seine fishery

Year	Number of vessels	Observed Levels		Full-utilization levels	
		Fishing days	Searching days	Fishing days	Searching days
1991	71	15 633	13 709	17 454	15 886
1992	65	17 454	15 886	17 454	15 886
1993	64	16 425	14 674	17 216	15 665
1994	59	15 904	14 231	16 023	14 559
1995	55	14 786	13 086	15 069	13 674
1996	54	14 671	13 116	14 831	13 453
1997	52	12 781	11 551	14 354	13 011
1998	44	12 585	11 215	12 585	11 242
1999	41	11 731	10 578	11 731	10 578
2000	41	10 576	9 394	11 731	10 578
2001	44	11 344	10 121	12 585	11 242
2002	41	9 823	8 816	11 731	10 578
Annual average	**53**	**13 643**	**12 198**	**14 397**	**13 029**

species and albacore, which is the likely reason why the observed number of fishing and searching days were not equivalent to the levels required to produce the capacity output.

In addition to improved efficiency in operations, the average annual capacity output for the fleet could be realized with only a very modest increase in fishing and searching days (Table 5.7). The analysis suggests that fishing days should be increased by a meagre 5.5 percent to realize the capacity output, and the number of days spent searching by the fleet should be increased by only 6.8 percent.

5.2.3 The Indian Ocean fishery

In the Indian Ocean fishery, a vessel had, on average, the capability to harvest an additional 504 tonnes of skipjack and 616 tonnes of yellowfin per year (Table 5.8), both of which are considerably greater than the levels of excess capacity for these two species in the Atlantic Ocean fishery. The total average annual excess capacity per vessel for 1981-2002 was 1 327 tonnes. Vessels could realize the capacity output mostly by operating efficiently and making small increases in their fishing and searching days (the average annual numbers of fishing and searching days per vessel for the Indian Ocean fleet for 1981-2002 were, respectively, 224 and 185 days; the average annual level of fishing and searching days per vessel required to produce the capacity output

TABLE 5.8

Excess capacity and full-utilization levels of variable inputs per vessel in the Indian Ocean purse-seine fishery

Year	Number of vessels	Observed levels		Full-utilization levels		Excess capacity (tonnes)					
		Fishing days	Searching days	Fishing days	Searching days	YFT	SKJ	BET	ALB	Others	Total
1981	2	42	0	42	0	0	0	NA	0	NA	0
1982	4	64	55	117	90	574	484	80	0	0	1 138
1983	12	122	95	122	95	0	0	68	0	0	68
1984	47	171	138	233	185	768	891	191	29	0	1 879
1985	48	207	173	242	193	860	870	181	32	0	1 943
1986	35	246	197	246	197	114	150	0	38	0	303
1987	35	236	185	236	188	324	373	0	49	0	746
1988	40	228	181	243	202	0	490	57	56	0	603
1989	44	247	205	247	205	917	0	185	64	0	1 166
1990	46	231	193	249	207	658	893	219	63	0	1 832
1991	39	250	205	251	208	464	592	141	17	69	1 284
1992	39	255	209	269	224	585	627	317	0	0	1 529
1993	42	265	222	282	238	507	734	285	53	0	1 578
1994	42	263	220	282	238	607	35	244	22	85	993
1995	42	282	238	282	238	0	129	26	54	0	209
1996	47	263	224	282	238	561	1 050	152	51	65	1 879
1997	58	257	223	282	238	940	2 011	154	50	101	3 255
1998	53	276	239	282	238	1 272	1 513	199	58	0	3 041
1999	52	257	219	282	238	644	835	0	73	87	1 638
2000	50	253	213	282	238	340	817	174	60	51	1 443
2001	50	258	220	282	238	666	1 060	295	59	95	2 175
2002	49	263	221	282	238	298	0	135	69	0	501
Annual average	**40**	**224**	**185**	**242**	**199**	**504**	**616**	**141**	**41**	**25**	**1 327**

TABLE 5.9

Capacity utilization in terms of ratio of observed and technically-efficient output levels to capacity output levels in the Indian Ocean purse-seine fishery

Year	Capacity utilization—Observed/Report output					Capacity utilization—Technically-efficient output				
	YFT	SKJ	BET	ALB	Others	YFT	SKJ	BET	ALB	Others
1981	1.00	1.00	1.00	NA	NA	1.00	1.00	1.00	NA	NA
1982	0.31	0.35	0.02	NA	NA	0.51	0.68	0.91	NA	NA
1983	1.00	1.00	0.21	NA	NA	1.00	1.00	1.00	NA	NA
1984	0.61	0.50	0.28	0.29	NA	0.97	0.98	0.99	1.00	NA
1985	0.61	0.57	0.41	0.32	NA	1.00	1.00	1.00	1.00	NA
1986	0.94	0.92	1.00	0.12	NA	1.00	1.00	1.00	1.00	NA
1987	0.87	0.84	1.00	0.12	NA	1.00	1.00	1.00	1.00	NA
1988	1.00	0.81	0.86	0.11	NA	1.00	0.99	1.00	1.00	NA
1989	0.68	1.00	0.55	0.00	NA	1.00	1.00	1.00	1.00	NA
1990	0.77	0.68	0.51	0.10	NA	0.99	0.99	1.00	1.00	NA
1991	0.84	0.80	0.70	0.78	0.01	1.00	1.00	1.00	1.00	1.00
1992	0.80	0.81	0.40	1.00	NA	0.99	1.00	1.00	1.00	NA
1993	0.83	0.79	0.51	0.37	NA	0.99	1.00	1.00	1.00	NA
1994	0.79	0.99	0.57	0.73	0.00	0.98	1.00	1.00	1.00	1.00
1995	1.00	0.96	0.95	0.36	NA	1.00	1.00	1.00	1.00	NA
1996	0.81	0.72	0.75	0.39	0.30	0.98	1.00	1.00	1.00	1.00
1997	0.68	0.51	0.77	0.40	0.03	0.98	1.00	1.00	1.00	1.00
1998	0.57	0.62	0.70	0.31	NA	1.00	1.00	1.00	1.00	NA
1999	0.78	0.80	1.00	0.12	0.16	0.98	1.00	1.00	1.00	1.00
2000	0.88	0.81	0.75	0.28	0.52	0.97	0.98	0.98	0.99	0.98
2001	0.77	0.75	0.57	0.29	0.10	0.98	1.00	1.00	1.00	1.00
2002	0.90	1.00	0.80	0.17	1.00	0.98	1.00	1.00	1.00	1.00
Annual average	**0.79**	**0.78**	**0.65**	**0.28**	**0.10**	**0.97**	**0.98**	**0.99**	**1.00**	**1.00**

TABLE 5.10
Observed and full-utilization fishing and searching days required to produce the capacity output in the Indian Ocean purse-seine fishery

Year	Number of vessels	Observed levels		Full-utilization levels	
		Fishing days	Searching days	Fishing days	Searching days
1981	2	84	0	84	0
1982	4	256	221	469	359
1983	12	1 461	1 142	1 461	1 142
1984	47	8 041	6 502	10 951	8 700
1985	48	9 929	8 302	11 636	9 287
1986	35	8 597	6 907	8 597	6 907
1987	35	8 246	6 484	8 246	6 568
1988	40	9 135	7 244	9 734	8 072
1989	44	10 880	9 030	10 880	9 030
1990	46	10 628	8 880	11 451	9 522
1991	39	9 767	7 985	9 795	8 127
1992	39	9 944	8 162	10 499	8 755
1993	42	11 109	9 342	11 848	10 004
1994	42	11 061	9 228	11 848	10 004
1995	42	11 848	10 004	11 848	10 004
1996	47	12 380	10 510	13 259	11 195
1997	58	14 883	12 930	16 362	13 815
1998	53	14 648	12 667	14 951	12 624
1999	52	13 339	11 363	14 669	12 386
2000	50	12 635	10 657	14 105	11 910
2001	50	12 911	10 978	14 105	11 910
2002	49	12 864	10 851	13 823	11 671
Annual average	**40**	**9 757**	**8 154**	**10 483**	**8 727**

were, respectively, 242 and 199 days). In general, the Indian Ocean purse-seine fleet could realize capacity output mostly by improving its efficiency (Table 5.9). The measure of CU adjusted for TE is quite close to one for most species and years, which indicates that gains in output could come mostly from operating more efficiently. The Kruskal-Wallis test was again conducted to determine the equality of observed and full-utilization levels of fishing and search days in the Indian Ocean fishery; results of the test could not reject the equality of reported and full utilization fishing and searching days. In other words, based on the non-parametric analysis, we conclude that the number of fishing and searching days required to produce the capacity output is equal to the reported or actual number of fishing and searching days. The exception is 1982, when the CU values were extremely low for yellowfin (0.51) and skipjack (0.68). The number of fishing and searching days would have had to increase 83.2 and 62.4 percent, respectively. Alternatively, we conclude that the capacity output could be realized mostly by improvements in TE only. In contrast to the Atlantic Ocean fishery, the CU values were quite high for other species and albacore.

Although results from the Kruskal-Wallis test suggest that realizing the capacity output requires only improvements in TE, there is still the possibility that gains could be realized by very small increases in fishing and searching days (Table 5.10). The analyses suggest that fishing days should be increased by a meagre 7.4 percent to realize the capacity output, and the number of days spent searching by the fleet should be increased by only seven percent.

5.3 Summary and conclusions

Overall, it appears that there is excess capacity in the Atlantic and Indian Ocean purse-seine fisheries for tuna. The more serious level of excess capacity exists for the Indian Ocean fishery. It was determined that, on an annual basis, there was approximately 61 000 tonnes of excess capacity in the Indian Ocean fishery. In comparison, the Atlantic Ocean fishery had approximately 29 500 tonnes of excess harvesting capacity. Alternatively, if Indian and Atlantic Ocean vessels operated efficiently, fully utilized their variable inputs and harvested the average annual reported level of landings, fleet

FIGURE 6.1
Skipjack in the global purse-seine fishery – Excess fishing capacity

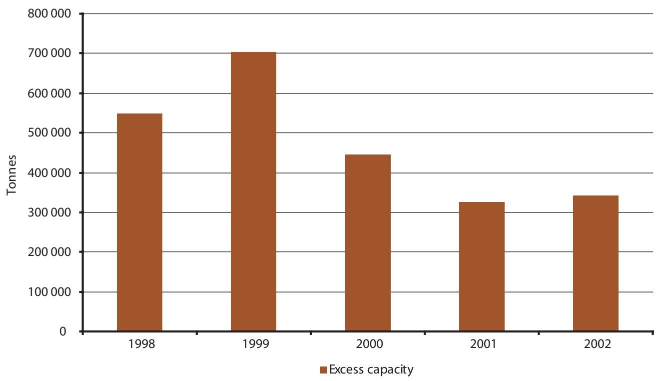


FIGURE 6.2
Skipjack in the global purse-seine fishery – Observed catch, fishing capacity and fishing capacity purged for technical efficiency

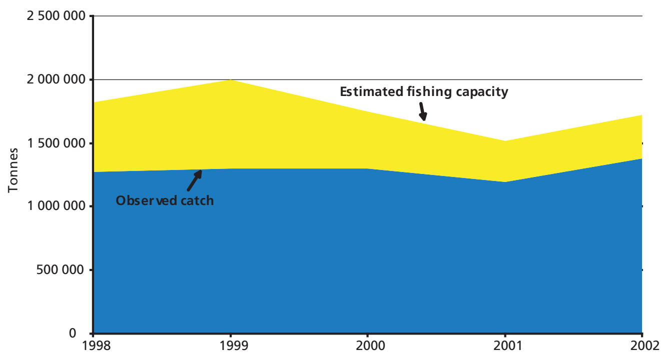
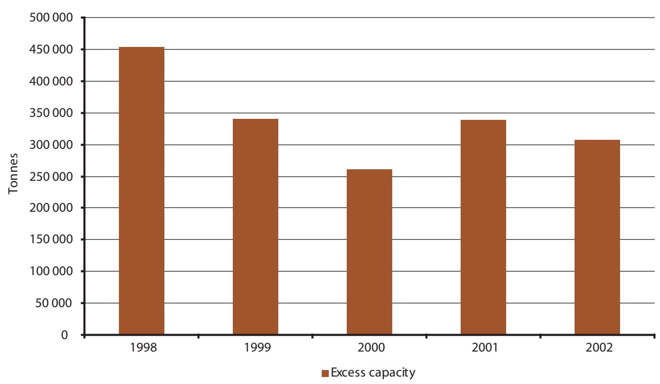


FIGURE 6.3
Yellowfin and bigeye combined in the global purse-seine fishery – Excess fishing capacity



sizes could be reduced, respectively, from 40 to 31 (22.5 percent) in the Indian Ocean fishery and from 53 to 46 (13.2 percent) in the Atlantic Ocean fishery.

We stress that the estimates presented in this paper are extreme lower-bound estimates of capacity. The limited number of observations and inadequate information for considering different modes and nations' fishing activities limits the estimation of the frontier or piece-wise technology. Alternatively, if there are few observations for estimating the frontier, DEA will tend to recognize each firm as being technically efficient and operating at full capacity. In this case, the observed or reported output will equal the technically-efficient output level and the capacity output level.

6. GLOBAL TUNA PURSE-SEINE FISHING CAPACITY

The analyses presented in this paper provide estimates of fishing capacity for the tuna purse-seine fisheries of the EPO, WCPO, Atlantic Ocean and Indian Ocean.

Estimated total purse-seine catch, fishing capacity and excess capacity in the four regional fisheries for skipjack and for yellowfin and bigeye combined are provided in Figures 6.1-6.4 and Table 6.1. In examining these figures, it should be borne in mind that different analyses were applied in different regions due to data considerations and the fact that the estimates for the Indian and Atlantic Oceans are extreme lower-bound estimates of capacity. From the estimated global purse-seine fishing capacity for skipjack it appears that fishing capacity peaked in 1999, declined in 2000 and 2001 and then returned to 2000 levels in 2002. Excess capacity followed a similar pattern, with a significant increase in 1999, followed by declines in 2000 and 2001 of more than 50 percent and then a small increase in 2002. Excess capacity, as a percentage of the catch, also peaked in 1999, and from then until 2002 it was in continuous decline.

TABLE 6.1
Observed global purse-seine catch and estimated purse-seine fishing capacity by ocean area

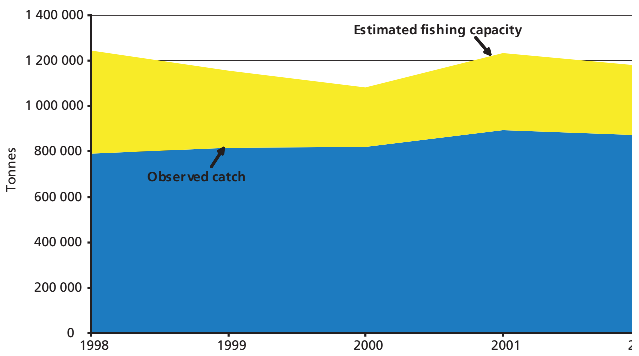
	1998	1999	2000	2001	2002
Eastern Pacific Ocean					
Skipjack					
Observed catch	139 229	256 957	197 612	134 017	155 628
Fishing capacity	292 501	404 862	279 079	206 843	225 979
Excess capacity	**153 272 (110)**	**147 905 (58)**	**81 467 (41)**	**72 826 (54)**	**70 351 (45)**
Yellowfin and bigeye					
Observed catch	300 536	327 989	346 046	405 707	428 063
Fishing capacity	589 973	497 798	498 587	635 498	670 269
Excess capacity	**289 437 (96)**	**169 809 (52)**	**152 541 (44)**	**229 791 (57)**	**242 206 (57)**
Western and Central Pacific Ocean					
Skipjack					
Observed catch	947 149	794 606	869 547	842 287	962 233
Fishing capacity	1 285 674	1 328 337	1 185 505	1 037 121	1 226 691
Excess capacity	**338 525 (36)**	**533 731 (67)**	**315 958 (36)**	**194 834 (23)**	**264 458 (27)**
Yellowfin and bigeye					
Observed catch	291 240	258 642	241 314	262 725	197 871
Fishing capacity	359 879	385 844	306 977	320 610	239 510
Excess capacity	**68 639 (24)**	**127 202 (49)**	**65 663 (27)**	**57 885 (22)**	**41 639 (21)**
Atlantic Ocean					
Skipjack					
Observed catch	56 438	76 852	64 625	60 891	47 900
Fishing capacity	83 116	76 852	76 852	83 116	76 852
Excess capacity	**26 678 (47)**	**0 (0)**	**12 227 (19)**	**22 225 (36)**	**28 952 (60)**
Yellowfin and bigeye					
Observed catch	85 960	73 834	77 799	91 099	88 324
Fishing capacity	95 448	89 639	89 639	95 448	89 639
Excess capacity	**9 488 (11)**	**15 805 (21)**	**11 840 (15)**	**4 349 (5)**	**1 315 (1)**
Indian Ocean					
Skipjack					
Observed catch	132 073	168 950	170 793	156 929	212 173
Fishing capacity	212 248	212 369	211 624	209 919	212 173
Excess capacity	**80 175 (61)**	**43 419 (26)**	**40 831 (24)**	**52 990 (34)**	**0 (0)**
Yellowfin and bigeye					
Observed catch	114 138	155 766	156 236	133 921	157 130
Fishing capacity	192 091	189 232	181 955	181 955	178 315
Excess capacity	**77 953 (68)**	**33 466 (21)**	**25 719 (16)**	**48 034 (36)**	**21 185 (13)**
All Oceans					
Skipjack					
Observed catch	1 274 889	1 297 365	1 302 577	1 194 124	1 377 934
Fishing capacity	1 873 539	2 022 420	1 753 060	1 536 999	1 741 695
Excess capacity	**598 650 (47)**	**725 055 (56)**	**450 483 (35)**	**342 875 (29)**	**363 761 (26)**
Yellowfin and bigeye					
Observed catch	791 874	816 231	821 395	893 452	871 388
Fishing capacity	1 237 391	1 162 513	1 077 158	1 233 511	1 177 733
Excess capacity	**445 517 (56)**	**346 282 (42)**	**255 763 (31)**	**340 059 (38)**	**306 345 (35)**

Note: Figures in brackets provide excess capacity as a percentage of observed catch.

It appears that global purse-seine fishing capacity for yellowfin and bigeye was on a downward trend between 1998 and 2000, even though observed catch levels were slowly increasing. In 2001 global purse-seine fishing capacity for yellowfin and bigeye, returned to 1998 levels and then declined again in 2002. Excess fishing capacity decreased by more than 40 percent between 1998 and 2000, and its level in 2001 was similar to that in 1999. In 2002 excess capacity was less than in 1998, 1999 and 2001, but greater than in 2000.

As stated previously, excess fishing capacity is a result of both technical inefficiency (or skipper skill) and under-utilisation of variable inputs. In other words, the catches

FIGURE 6.4
Yellowfin and bigeye in the global purse-seine fishery – Observed catch, fishing capacity and fishing capacity purged for technical efficiency



can be increased either through an increase in the efficiency of purse-seine vessels or through an increase in the utilisation of variable inputs, such as increases in the numbers of days spent fishing and searching. In the analysis of the EPO and WCPO purse-seine fisheries, fishing capacity, purged for TE, was also estimated. In other words, it was assumed that TE (or skipper skill) remained constant and that fishing capacity could be increased only by increasing the levels of variable inputs employed. In both analyses under this assumption, there was a significant reduction in the estimated level of fishing capacity. For the EPO the estimated average excess capacity level, purged for TE, measured against observed catches for skipjack and for yellowfin and bigeye combined during 1998-2002 were around half the levels of the estimated excess capacity measured against observed catches. For the WCPO, average excess capacity level, purged for TE, measured against observed catches for skipjack and for yellowfin and bigeye combined during 1998-2002 were around 60 percent less than the levels of the estimated excess capacity measured against observed catches. These results indicate that increases in TE (or increases in skipper skill) of inefficient vessels are required if capacity output levels are to be fully achieved.

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A review of the fishing capacity of the longline fleets of the world

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ABSTRACT

This paper provides estimates of the size of the large-scale tuna longline fleet of the world, and discusses it in terms of the tuna resources available to it. Large-scale longliners are defined as those with gross registered tonnages greater than 200 or overall lengths greater than 35 metres, equipped with freezers making it possible for them to market their catches as "*sashimi*-grade" fish. Lists of the vessels authorized to fish in the areas of responsibility of the various regional fishery management organizations ("positive lists") were used to make the basic estimates of fleet sizes. Duplication of vessels in the positive lists, because they fished in more than one ocean, was eliminated in estimating the total number of vessels of the world fleet.

Logbook data from Japanese longliners were used to estimate the numbers of Japanese longliners actively engaged in fishing in the three oceans, and this estimate was compared with the official list of licensed longliners. It is obvious that vessels frequently fish in more than one ocean during the same year and that not all the longliners licensed for a particular ocean fish in that ocean.

Activities of illegal, unreported and unregulated (IUU) vessels and the work by the Organization for the Promotion of Responsible Tuna Fisheries (OPRT) were reviewed. The fleet size publicized by the OPRT, rather than the numbers of vessels in the positive lists, was used for its members. This resulted in the addition of 30 IUU vessels, assumed to be still in existence, and the total number of large-scale longliners was estimated to be 1 622.

The catches of commercially-important species of tunas by large-scale longliners were estimated to be roughly 400 000 tonnes in 2001. Therefore, the average catch per vessel per year was 240 tonnes, which is close to the current economic break-even point. It appears that almost all the tuna stocks in the world are now harvested at levels close to those corresponding to the maximum sustainable yields, if not in excess of those levels. If the fishing patterns and fishing behavior of longliners remain at the present levels, any increase in longline fishing capacity would have a negative impact on tuna stocks. On the other hand, the same levels of catches could most likely be achieved even with a smaller fleet size. A reduction of the fleet size would make the longline fishery more competitive with the other fisheries, provided the sizes of the other fleets were also reduced. Some elements that may affect this situation are:

- status of the resources;
- regulatory measures;
- species compositions of the catches;
- competition with other fishing gears;
- competition with small-scale longliners;
- recent developments in tuna farming (catching juvenile fish and fattening them in pens for later sale).

1. INTRODUCTION

This paper reviews the current fishing capacity of the large-scale tuna longline fleets of the world. Fishing capacity, or simply "capacity", is difficult to define, but is essentially the mechanical and economical ability of a vessel or a fleet to catch fish. Fishing capacity is not to be confused with fish-carrying capacity, which is useful in studies of purse-seine and pole-and-line fisheries, but not in studies of longline fisheries. It is even more difficult to estimate the total fishing capacity of the longline fleets of the world. Nevertheless, it is important, for purposes of management, to have estimates of the fishing capacities of the various fishing fleets.

Compilation of a list of large-scale longline vessels is not straightforward, due to the following difficulties:

- Data were not provided by the governments of most of the countries in which longline vessels are registered.
- The definition of a large-scale longline vessel is not clear, creating difficulties in separating these from other vessels from the available fleet statistics.
- There is much duplication of vessels in the lists obtained from various sources. Also, the names of vessels are frequently misspelled or different phonetic transcriptions are made.
- When a vessel changes its name, especially when the registration is also changed, the previous name is not often recorded.
- Registered vessels are not necessarily operational.
- Many small vessels are multi-purpose vessels.
- Specifications (particularly sizes and registration numbers) of the vessels are often not available in the fleet statistics.

Those difficulties are discussed in the following sections, and some solutions are offered. While estimating fleet size, it is imperative to consider illegal, unreported and unregulated (IUU) vessels and the management policies adopted by the various countries for their longline fleets. Although management is to be covered by other contributors to this collection in this paper past national and international management of fleet sizes is briefly discussed, in respect to the estimation of the total fleet size.

2. LONGLINE FLEETS OF THE WORLD

2.1 Distribution of fisheries and size of fishing vessels

Longlining for tunas and tuna-like species takes place in tropical and temperate ocean waters all over the world. In general, longline fisheries exist wherever tunas and billfishes occur. Historical developments in longline fishing and processing longline-caught fish are discussed by Miyake (this collection) and by Miyake, Miyabe and Nakano (2004). The fleet has consisted of various-sized vessels, from canoes to motherships of more than 1 000 gross registered tons (GRT). Two categories, large-scale and small-scale[1], are defined.

2.1.1 Small-scale longliners

Small-scale longliners are further divided into the following groups:

- Artisanal longliners (small, according to the TAC definition). These vessels, which are powered with sails or outboard engines, fish near the coast or islands. A trip lasts one day. Those vessels are found most often in the Indian Ocean and the

[1] During the meeting of the Technical Advisory Committee (TAC) it was recommended that the fleet be classified into the following categories: small – uncovered; medium – covered, but with no freezing capacity; and large – covered, and with freezing capacity. The "small" category in this report includes some vessels that would be classified as small and some that would be classified as medium in the new TAC classification. However, there are many factors to be considered in the classification of vessels, so, due to the complexity of the matter, the two categories, "small" and large, are retained in this report. The readers of this report should understand that "small" in this report consists mostly of vessels that are "medium", but also some that are "small", according to the TAC definitions.

western Pacific Ocean, but they are also found along the west coast of Africa and both coasts of South America. Most of the catch is consumed locally.

- Near-shore longliners (medium, according to the TAC definition). These vessels have generally GRTs of less than 20, and fish almost exclusively within the Exclusive Economic Zones (EEZs) of the countries in which they are registered, except in the Mediterranean Sea, where the EEZs are not well defined. A trip lasts from one-day to one week, and the catches are landed at ports near the waters in which fishing takes place. These vessels could be multi-purpose vessels.
- Offshore longliners (medium, according to the TAC definition). Those are vessels of about 5 to 200 GRT. The fishing grounds are mostly within, but not limited to, the EEZs. A trip lasts from a few days to two weeks and, in some cases, as long as one month. The vessels are not equipped with freezers, and the catches are preserved with ice. This type of vessel is particularly abundant in the Indian and western Pacific Oceans. Possibly the largest fleets of this type are owned by citizens of the Taiwan Province of China or Indonesia. The catches, if of superior quality, are marketed as *sashimi*-quality fish; otherwise they are marketed as steaks.

2.1.2 Large-scale longliners

These vessels are equipped with freezers (often super- freezers that freeze and maintain the fish at temperatures below -45°C). Generally, the vessels are more than 200 GRT (i.e. definitely more than 24 metres in overall length (LOA)—see later section). However, after the positive list system (Section 2.4) was adopted, some boats less than 24 metres in LOA, but equipped with super-freezers, have been constructed. These vessels are not considered to be large-scale longliners in this report, however, as information on the activities of these vessels is not available. A trip of a large-scale longliner lasts from several weeks to more than one year. Often fishing takes place far from the vessels home ports, and crew members are rotated by air. This fleet targets *sashimi*-quality fish.

Most of the vessels of this type that target tunas are owned by interests in Japan, China, the Republic of Korea, the Taiwan Province of China and, to a lesser extent, the Philippines. This category also includes vessels engaged in illegal, unreported or unregulated (IUU) fishing, and vessels flying “flags of convenience” (FOC).

There are also longliners that target swordfish. These vessels do not need to have super-freezers, and many of them, even those of more than 250 GRTs, use ice to preserve their catches. Swordfish longliners are most often registered in Spain, Portugal, Italy, the United States or Canada.

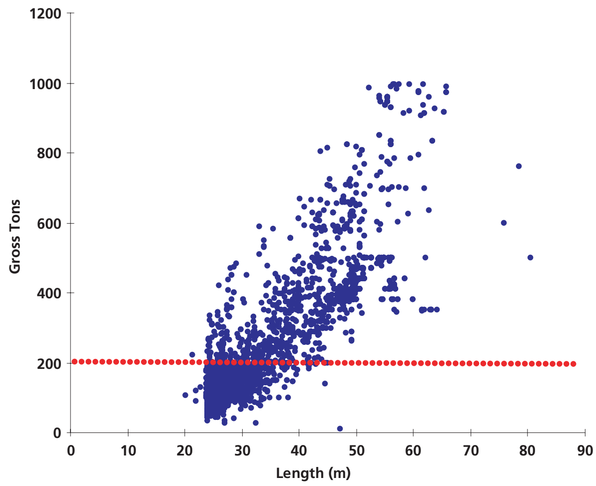
Unfortunately, not all vessels can be easily assigned to one of these categories, as some of them have characteristics of more than one category. This is discussed further in Section 2.2.

2.2 Criteria for classifying sizes of fishing vessels

In this study, the fleet statistics are composed basically from lists of registered vessels (Section 3.1). Most such lists do not contain essential information, such as the target species, method of preservation of the catch, etc. In order to identify the large-scale tuna longliners, a single criterion would be most useful. The parameters that are available for most of the longliners are GRT and/or LOA

The LOA is the perpendicular distance between the bow and stern of the vessel at the main deck. The GRT is the volume of space within the hull and enclosed spaces above the deck of a vessel that are available for cargo, stores, fuel, passengers and crew. One ton is equivalent to 100 cubic feet (2.83 cubic metres). The International Maritime Organization set the international standard for GRT, but the interpretation of enclosed space can vary from one country to the other. Therefore, when specification is given in GRT, it is not clear how this is measured.

FIGURE 1
Relationship between LOA and GRT reported for tuna longline vessels in three oceans



The relationship between LOA and GRT for the tuna longliners for which information on both parameters is available in the positive lists (see later sections) is shown in Figure 1. The positive lists include only vessels more than 24 metres in LOA, and hence most of the points in the figures are greater than 24 metres. Also those of 1 000 or more GRT were excluded, as they are mostly mothership-type vessels or cargo vessels (possibly exclusively for tuna). The wide variation observed in this relationship is due mostly to the different measurement standards applied by the various countries.

Considering all these complex elements, the following criteria were adopted to separate out large-scale longliners:

- The vessels of 200 GRT or larger (which corresponds to about 35 metres LOA) were considered to be large-scale longliners.
- When the GRT is not available, vessels of 35 metres LOA or greater were considered to be large-scale longliners.
- When no information on either GRT or LOA was available, or the information appeared to be erroneous, other information was used. For example, longline vessels based in Asia, but fishing in the Atlantic Ocean, were considered to be large-scale longliners, regardless of the reported size, since small vessels cannot fish that far away from the home ports.

However, some flexibility was adopted in the final decision. For example, a higher GRT criterion was used for the longliners of the Taiwan Province of China that are fishing in the eastern Indian Ocean or the western Pacific Ocean. All the longliners of the Republic of Korea were considered to be large-scale longliners, in accordance with a suggestion by government officials.

2.3 Regulation of fishing fleets

The management of fleet size has developed more for large-scale longliners than for any other type of tuna-fishing vessel. When Japan initiated a licensing system for tuna longliners during late 1940s, a limited-entry system, based on the total GRT of the fleet, was already established. During the period of development of the fishery the total allowable GRT was increased from time to time, and the fishing fleet expanded until the 1970s. Thereafter, no increase has been allowed and, for the first time, a reduction in the total licensed GRT was introduced in 1982. It was reduced again in 1999, to conform to the FAO International Plan of Action for the management of fishing capacity.

A licensing system similar to that of Japan, with limited entry and restrictions based on total GRT, has been adopted by other countries with large-scale longliners, e.g. the Republic of Korea, the Taiwan Province of China, the Philippines and China. However, the conditions and procedures have differed among nations. For example, the Republic of Korea began limiting its total licences during the 1980s, while China and the Taiwan Province of China increased their total licences (in numbers of vessels and GRT) until 2003. Both of these, however, declared that no more increases would be allowed.

Many other countries (e.g. Panama, Honduras, Belize, Vanuatu and Cambodia), on the other hand, continued to issue licences without any restrictions. A detailed discussion of this can be found in Section 2.4.

In the case of Japan, all the vessels of more than 80 GRT were formerly considered to be large-scale longliners. This limit was changed to 120 GRT in 2002. Further restrictions were placed on vessels in accordance with upper limits (e.g. 500, 440, 380, 260 and 200 GRT) and areas of operation.

All longliners of the Republic of Korea are considered to be large-scale vessels.

For the Taiwan Province of China, 50 GRT is the criterion adopted by the governing authorities to separate the coastal and distant-water longliners. However, the vessels of less than 200 GRT are mostly fresh-fish vessels, even though they may fish in distant waters, so, for that reason, 200 GRT was used as the criterion for separating small- and large-scale longliners.

Most of the Japanese large-scale longliners are equipped with super-freezers, whereas super-freezers are not often found on vessels of the Taiwan Province of China, with GRTs less than 500. However, a 500-GRT vessel of the Taiwan Province of China is equivalent to a Japanese longliner of a much lesser GRT, as the standards for measuring GRT are different for the two fleets.

2.4 Flag of Convenience and IUU fleets, and international regulations

When a vessel is registered in a country of open registry it is said to fly a "flag of convenience" (FOC). FOC vessels, owned mostly by residents of Asia, existed as early as the 1960s. As there were already limited-entry systems in some countries, when an owner acquired a new fishing vessel, he would lose the licence for the one that it replaced. Often, however, such vessels were "reflagged" to countries with open registry. Also, FOC registration was used to avoid domestic regulations on nationality of crew members, safety requirements, periodic inspections, etc.

During the late 1980s, when regulatory measures such as catch quotas were adopted by the various regional fishery management organizations (RFMOs), some vessel owners, reflagged their vessels to non-contracting countries whose vessels were not subject to the regulations adopted by the RFMOs. This is called "illegal, unreported and unregulated" (IUU) fishing, and the vessels are called IUU vessels. More details are given by Miyake (this collection).

IUU fishing has increased during the 1990s, and various measures have been taken by the FAO and the RFMOs to address this problem. In 2001 FAO adopted the International Plan of Action to prevent, deter and eliminate illegal, unreported and unregulated fishing (IPOA-IUU). ICCAT was the first of the RFMOs to take such measures. It developed a Plan of Action for bluefin tuna, which was later applied to other species, which prescribed the steps to be taken against IUU fishing. The most stringent actions that the ICCAT can take are trade measures, and, indeed, the Commission recommended to the contracting parties that there be a ban on the importation of certain species of tunas from IUU countries.

At the same time, ICCAT identified IUU vessels operating in the Atlantic Ocean, and a list of these was posted on its web site in 1998. Buyers were encouraged to refrain from purchasing fish from these vessels. At that time, it was estimated that there were about 300 IUU vessels. It was not possible to ascertain the precise number of such vessels, as some of them were listed more than once, due to differences in specifications and changes in flags that were constantly taking place.

Shortly thereafter, similar actions were taken by the IOTC, and a list of IUU vessels was developed for the Indian Ocean. Most of the vessels in the Indian Ocean list were also listed in ICCAT's Atlantic Ocean list, but, again, the precise number of duplicated IUU vessels could not be ascertained.

In 2002, ICCAT adopted a new policy, listing the "legal" vessels (positive list), rather than the IUU vessels (negative list). Soon thereafter, positive lists of longliners were adopted by the IOTC for the Indian Ocean and by the IATTC for the eastern Pacific Ocean. The Contracting Parties are responsible for providing lists of legal vessels with

LOAs of 24 metres or more that are licensed for fishing in the respective oceans. At the same time, the three RFMOs recommended that all the Contracting Parties prohibit trade with vessels that are not included in the positive lists. The three lists were made available to the public during August 2003. The adoption of the positive list system on a global basis was generally affirmed at the twent-fifth session of the FAO Committee on Fisheries in 2003.

Unfortunately, as soon as the positive-list system was introduced, construction of longline vessels less than 24 metres in LOA, but equipped with super-freezers, began, and some were operating in 2004. Since they are less than 24 metres in LOA, there is no requirement that these vessels be included in the positive lists, and the restrictions regarding vessels not included in the positive lists do not apply to them. Therefore, they are now a new type of IUU vessel. These vessels operate in the same way as do longliners with LOAs greater than 24 metres, and should be subject to the same restrictions as the large-scale longliners.

2.5 Activities of the Organization for the Promotion of Responsible Tuna Fisheries

In accordance with the IPOA-IUU, Japan began to reduce the size of its longline fleet. In 1999, it reduced the total number of licences given to large-scale tuna longliners by 20 percent. At the same time, because of concern about IUU fishing, the Japanese fishing industry created a non-governmental organization, the Organization for the Promotion of Responsible Tuna Fisheries (OPRT), with a membership consisting of tuna producers, tuna marketers and consumer groups. Currently its membership includes ten groups in Japan and one longline-fishing association each from the Taiwan Province of China, the Republic of Korea, the Philippines, Indonesia, China and Ecuador. In addition, Vanuatu and Seychelles longliners are subject to the requirements of the IPOA-IUU through their association with the Japan Federation of Tuna Fisheries Associations.

The initial objective of the OPRT was to persuade the owners of IUU vessels (1) to register them in the countries corresponding to the nationalities of the true owners and to fish legally, observing the regulatory measures and reporting their catches or (2) to scrap them, with some government and/or industry compensation. Since the countries corresponding to the owners' nationalities have limited-entry systems, not all the boats that had been called back could be licensed. Also, when catch quota had been established, the increased numbers of vessels reduced the individual shares, which caused hardship on the owners and fishers. The numbers of large-scale longliners owned by the members of the OPRT are given in Table 1. Between 2001 and 2003, there was an increase of more than 400 longliners. These were the ex-IUU vessels that were called back to the countries corresponding to the owners' nationalities. Therefore, at least these many longliners were removed from the IUU fleet and came, at least in principle, under the control of the RFMOs.

The OPRT estimates that as of June 2004 there are still about 30 IUU longliners. It should be noted that the process of reflagging did not change the total number of large-scale longliners much, except for the loss of an unknown number of vessels that were scrapped. However, it is important that almost all of the longliners are now under the control of responsible governments that are either contracting parties or cooperating parties, entities or fishing entities to one or more RFMOs. It should be noted that the data on fleet size in Table 1 are not current, as older vessels are being scrapped and new vessels are being constructed.

3. SIZE OF THE CURRENT FLEET

3.1 Sources of data

The author of this report repeatedly asked the governments of the countries with major tuna longline fleets to provide him with information on the past and current fleet sizes,

TABLE 1
Numbers of large-scale tuna longliners owned by members of OPRT (as the end of each year)

Country	Group	2001	2002	2003
Japan	Japan Tuna Federation	432	428	420
	Distant Waters Association	34	34	39
	Near Coast Water Tuna Fishing Association	28	28	25
	Subtotal	494	490	484
Taiwan Province of China		567	562	610
Republic of Korea		-	183	170
Philippines		-	6	17
Indonesia		-	-	14
China		98	100	105
Vanuatu		-	-	48
Seychelles		-	-	21
Ecuador		-	-	5
Total		1 159	1 341	1 474

numbers of licences issued for each ocean and numbers of longliners actively fishing. Unfortunately, no information was provided by most of these countries, the exceptions being Japan, which provided information on the current status of its fleet, including data to estimate the numbers of active vessels, and China and the Philippines, which provided the total numbers of large-scale longliners currently licensed. Accordingly, the positive lists were used to make a basic estimate of the size of the fleet.

3.1.1 Pacific Ocean

The following sources of information were used:

- the IATTC vessel list, as of October 2003, for the eastern Pacific Ocean;
- the Forum Fisheries Agency (FFA) list of vessels (non-public) licensed to fish in the FFA waters;
- a list provided by the Secretariat of the Pacific Community (SPC);
- a list of registered longliners of most of the countries that fish in the western and central Pacific Ocean obtained from the Japanese government.

There was no active RFMO in the western and central Pacific at the time that this report was written, so there is no official list of licensed vessels. (However, the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean (WCPFC) will soon enter into force.) Therefore, the FFA and SPC kindly provided its non-public list of vessels licensed to fish in its waters, which was used for cross-checking the data from other sources. The largest missing component is the fleet of the Taiwan Province of China, as many of these vessels fish in the northwestern Pacific Ocean, which is not covered by any of these lists. The IATTC list often provides the carrying capacities of the vessels, rather than the GRTs.

3.1.2 Indian Ocean

The following sources of information were used:

- the IOTC positive list, as of September 2003;
- a list of registered longliners of the Taiwan Province of China provided by the Japanese government.

The vessels of the Taiwan Province of China were not included in the positive list of the IOTC at the time of this study. However, these vessels are listed in the web site of the Indian Ocean Tuna Commission, http://www.iotc.org/, which maintains the list for the purpose of carrying out its own regulations, which allow the purchase of fish only from registered vessels.

3.1.3 Atlantic Ocean

The following source of information was used:

- the ICCAT positive list, http://www.iccat.es/, as of September 2003.

The ICCAT list combines longline and pole-and-line gear in the category "Line and hooks". Among those, Ghanaian vessels were excluded, as they are probably pole-and-line vessels, but the Portuguese fleet, which may include some pole-and-line vessels, is not excluded.

3.2 Data processing

The information from the above vessel lists was combined, and the duplicate entries, to the extent that was possible, were eliminated. The duplications were mostly the result of vessels being licensed to fish in more than one ocean area. In addition, duplications are sometimes the result of obtaining information for the same ocean area from different sources. When vessel names, registration numbers, radio call signs and/or sizes (LOA and/or GRT) matched, they were considered to be the same vessels. When two vessels had the same name, but the sizes and/or registration numbers differed, they were considered to be different vessels, particularly when the names were transcribed from the original languages. In some cases, however, an older boat may have been replaced by a new and larger one with the same name. Therefore, such cases were considered as duplications, if they occurred for a country with limited entries.

On the other hand, if the names of Asian longliners were slightly different, and the other specifications matched, these vessels were considered to be the same. This happens most often when a vessel change its registration from one fleet to another, as the transcription of Chinese characters might differ among fleets.

When the description of a vessel in a list was inadequate, some informed guesswork was necessary. After vessels other than longliners and duplicate records were eliminated, an attempt was made to separate the large-scale longliners from the others. As stated previously, large-scale longliners are those with GRTs greater than 200 tonnes or LOAs greater than 35 metres (Section 2.2), whereas the positive lists include all the longliners with LOAs greater than 24 metres (Section 2.4). Vessels with LOAs between 24 and 35 metres are classified as small-scale longliners. It should be born in mind that there are also many longliners with LOAs less than 24 metres.

The vessels were further classified as tuna or swordfish longliners. Only the vessels that target swordfish most of the time are classified as swordfish longliners; most of these are registered in Spain or the United States. Some of the Asian longliners target swordfish part of the time, depending on the area and/or season; these vessels were classified as tuna longliners. Considerable guesswork, with many assumptions, was involved, as the target species are not specified in any of the vessel lists used.

3.3 Size of the current fleet estimated from the positive lists

The results of the above processing are summarized in Table 2. Only data in the public domain were used in this table. As stated above, there are uncertainties in the estimates. It is more likely that the size of the fleet is underestimated than overestimated, as not all of the positive lists are complete. Also, the data for the western and central Pacific lacks information on vessels of the Taiwan Province of China.

Some of the small-scale vessels have freezing facilities that make them capable of marketing their catches as *sashimi*-grade fish. In addition, there are several thousand small-scale longliners (Gillett, this collection) and about 30 IUU vessels (Section 2.5) that are not included in this table.

3.4 Licensed vessels vs. active vessels

As explained earlier, the estimated size of the fleet is based on the numbers of licensed longliners. However, not all these vessels are actively engaged in fishing. At any given

TABLE 2
Numbers of longliners greater than 24 metres in LOA licensed to fish in the Indian, Atlantic and Pacific Oceans (as of September 2003)

Country	Small-scale vessels (between 24 and 35 m LOA)					Large-scale vessels (over 35 m LOA)				
	Indian	Atlantic	Pacific	Duplicate	Total	Indian	Atlantic	Pacific	Duplicate	Total
Australia	14	-	-	-	14	14	-	2	-	16
Belize	-	-	-	-	-	-	1	20	2	19
Bolivia	-	-	-	-	-	1	-	-	-	1
Brazil	-	11	-	-	11	-	-	-	-	-
Cambodia	-	-	-	-	-	-	-	3	-	3
Canada	-	5	-	-	5	-	-	-	-	-
China	72	-	149	-	221	21	60	78	39	120
Cook Islands	-	-	2	-	2	-	-	-	-	-
France	3	-	14	-	17	-	-	-	-	-
Ireland	-	8	-	-	8	-	-	-	-	-
Portugal	-	32	-	-	32	12	12	-	6	18
Spain	75	351	73	142	357	57	43	54	80	74
Ecuador	-	-	6	-	6	-	-	20	-	20
Micronesia	-	-	4	-	4	-	-	-	-	-
Fiji	-	-	37	-	37	-	-	-	-	-
Georgia	-	-	-	-	-	-	-	1	-	1
Honduras	-	-	-	-	-	-	4	-	-	4
Iceland	-	-	-	-	-	-	1	-	-	1
Indonesia	722	1	-	1	722	17	-	1	-	18
Iran	-	-	-	-	-	1	-	-	-	1
Japan	83	35	171	94	195	477	482	480	951	488
Republic of Korea	-	-	-	-	-	175	1	176	163	189
Madagascar	1	-	-	-	1	-	-	-	-	-
Mexico	-	-	6	-	6	-	-	3	-	3
Namibia	-	-	-	-	-	-	1	-	-	1
New Caledonia	-	-	3	-	3	-	-	-	-	
Panama	-	10	38	1	47	-	2	15	-	17
Peru	-	-	-	-	-	-	-	1	-	1
Philippines	-	-	-	-	-	39	8	2	9	40
Seychelles	9	2	4	1	14	-	-	-	-	-
South Africa	-	7	-	-	7	-	10	-	-	10
St. Vincent	-	5	-	-	5	-	3	-	-	3
Taiwan Province of China	-	-	14	3	11	173	163	164	50	450
Thailand	-	-	-	-	-	2	-	-	-	2
USA	-	162	28	2	188	-	18	-	-	18
Uruguay	-	1	-	-	1	-	6	-	-	6
Vanuatu	-	1	-	-	1	-	-	48	-	48
Venezuela	-	13	-	-	13	-	18	-	-	18
Total	979	644	549	244	1 928	989	833	1 068	1 300	1 590
Swordfish Longline	75	483	87	142	503	69	69	54	86	106
Tuna Longline	904	161	462	102	1 425	920	764	1 014	1 214	1 484

"Duplicate" indicates the numbers of vessels counted more than once because they were licensed to fish in more than one ocean. Criteria for classifying small- and large-scale longliners are explained in Section 2.2.

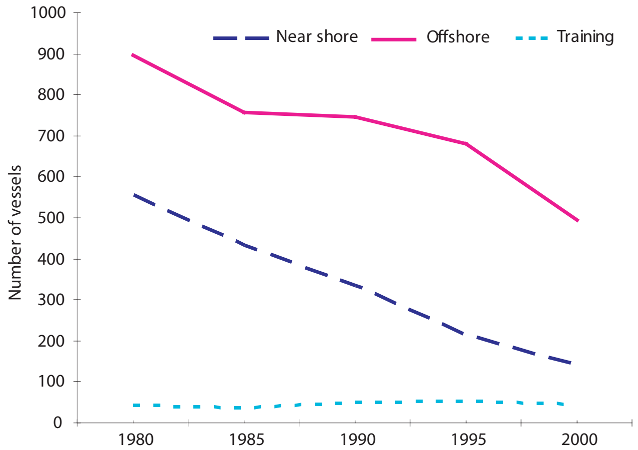
time, some vessels are undergoing repairs and others have ceased fishing prior to being sold or scrapped. Also, many governments issue licences to vessels to fish in more than one ocean area, and the vessels may or may not fish in all of these ocean areas. Duplication can be eliminated, as explained in Section 3.1, but the number of vessels that actually fished in each ocean area cannot be determined, or even estimated, from these data.

Unfortunately, no governments other than that of Japan responded to questions regarding the numbers of vessels actively fishing in each ocean. Since the difference between numbers of vessels registered and the numbers actively fishing is important,

TABLE 3
Numbers of Japanese longliners engaged in fishing in each ocean

Year	Coastal				Offshore				Government			
	Indian	Atlantic	Pacific	Total	Indian	Atlantic	Pacific	Total	Indian	Atlantic	Pacific	Total
1979	-	-	-		289	237	685	864	-	-	-	-
1980	1	-	553	554	310	284	696	897	17	-	36	42
1981	-	-	-	-	316	289	679	892	-	-	-	-
1982	-	-	-	-	287	255	571	861	-	-	-	-
1983	-	-	-	-	274	183	517	792	-	-	-	-
1984	-	-	-	-	291	213	467	748	-	-	-	-
1985	-	-	433	432	298	232	464	757	17	-	33	35
1986	-	-	-	-	267	187	509	757	-	-	-	-
1987	-	-	-	-	258	171	585	864	-	-	-	-
1988	-	-	-	-	219	194	518	739	-	-	-	-
1989	-	-	-	-	213	235	503	740	-	-	-	-
1990	-	-	332	332	193	238	535	745	12	-	37	49
1991	-	-	-	-	176	241	514	724	-	-	-	-
1992	-	-	-	-	160	238	442	653	-	-	-	-
1993	-	-	-	-	274	183	517	792	-	-	-	-
1994	-	-	-		204	195	409	788	-	-	-	-
1995	2	-	211	213	233	243	377	680	4	-	47	51
1996	-	-	-	-	240	279	309	651	-	-	-	-
1997	-	-	-	-	238	255	289	629	-	-	-	-
1998	-	-	-	-	227	240	290	578	-	-	-	-
1999	-	-	-	-	221	217	263	547	-	-	-	-
2000	-	-	139	139	189	203	236	495	3	-	41	44
2001	-	-	134	134	195	370	178	503	2	-	37	39

FIGURE 2
Total numbers of Japanese coastal, offshore and government tuna longliners that have fished anywhere in the world, by five-year intervals



logbook data for the Japanese fleet were analysed, using data on the names of the vessels and their registration numbers. The logbook coverage is nearly complete. The estimated total numbers of Japanese vessels that fished in each ocean are shown in Table 3.

The criterion for separation of coastal and offshore vessels is GRT (80 GRT during 1979-2001 and 120 GRT after that). Therefore the offshore category includes vessels that would have been classified as small-scale longliners during the processing of the positive lists. The government vessels are mostly training or research vessels, belonging to the central or local governments. These vessels were not included in the fishing capacity analysis, as their activities are not commercial fishing, even though they operate under the normal licensing system.

Since many vessels fish in more than one ocean, the sum of the number of vessels in the three oceans is far greater than the total fleet size. The total numbers of Japanese coastal, offshore and government tuna longliners that actively fished anywhere in the world are shown in Figure 2. The total numbers of Japanese offshore longliners that fished in any of the three oceans and the total numbers (eliminating the duplications between oceans) are shown in Figure 3. It is obvious that the numbers of active offshore longliners have been declining continuously. The numbers of the Japanese active offshore vessels for each ocean are compared with the total number of Japanese

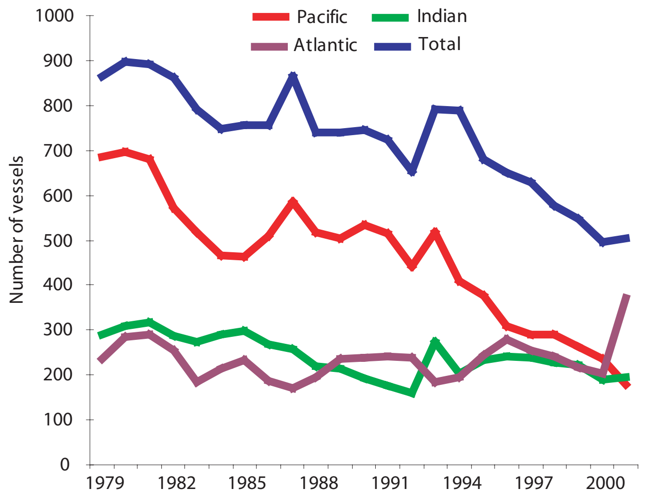
TABLE 4
Comparison of Japanese large-scale tuna longliners in the positive lists and actively-fishing offshore longliners extracted from the logbooks (for 2001)

	Indian	Atlantic	Pacific	Duplicate	Total
Positive lists	477	482	480	951	488
Actively fishing	195	370	178	240	503

large-scale vessels estimated from the positive lists in Table 4.

The total number of Japanese large-scale longliners from the positive list is 488, whereas the total number of such vessels obtained from the logbook data is 503. In addition, there are 39 government vessels (Table 3), so the total number of active Japanese longliners is 542. As explained in Section 3.2, the criteria adopted for defining large-scale longliners in this report is different from that used for defining offshore longliners in the logbook data, which accounts for most of the discrepancy.

FIGURE 3
Total numbers of Japanese offshore tuna longliners fishing in the three oceans and the three oceans combined



It is obvious that not all the vessels that were licensed to fish in a given ocean actively fished in that ocean. This applies to other fleets, as well as that of Japan. Therefore, the analysis of the world-wide fishing capacity of any fleet cannot be achieved unless information on active fishing is available. It is regrettable that more information of this type was not available.

4. ESTIMATES OF THE SIZE OF THE FISHING FLEET

4.1 Estimates of the total number of large-scale longliners

Unfortunately, there is only fragmentary information with which to estimate the size of the large-scale longline fleet for past years. Also, it is clear that it is impossible, at least at present, to estimate the numbers of vessels actively fishing. Therefore, an estimate, as current as possible, was made for the entire world longline fleet, regardless of ocean.

In Table 5 the numbers of large-scale tuna longliners, estimated from the positive lists (Section 3.3), are compared with the estimates from the OPRT data (Section 2.5), for those countries for which data are available from both sources. For Japan, the number of active vessels estimated from the logbook is also included.

Most of the discrepancies are explained by the time lag between the two sources. The OPRT numbers are as of December 2003, while the positive list data are almost a year older. The positive lists were publicized on the RFMOs web sites in about August 2003, but the data had been submitted a few months prior to that by the respective governments (i.e. early 2003). Many activities took place during 2003. Many IUU vessels were re-registered to the Taiwan Province of China and to the Seychelles, which explains the discrepancies for those two countries.

Some minor discrepancies are due to real changes in fleet sizes during 2003 and to the misclassification of large-scale longliners. However, considering the quality of the original data, the similarity between data from two sources is encouraging.

In summary, analysis of the positive lists produced an estimate of 1 484 large-scale tuna longliners. Considering the fact that the OPRT data are more recent, and include vessels that were previously IUU vessels, and the fact that positive lists do not exist for western and central Pacific Ocean, it is likely that this is an underestimate. For this

TABLE 5
Comparisons of estimates of the sizes of the fleets of large tuna longliners from different sources. The active Japanese vessels are those classified as licensed to fish offshore, and hence may include some small-scale vessels

	OPRT report (end of 2003)	Positive lists (publicized in September 2003)	Active vessels (2001)
Japan	484	488	503
Taiwan Province of China	610	450	-
Republic of Korea	170	189	-
Philippines	17	40	-
Indonesia	14	18	-
China	105	120	-
Vanuatu	48	48	-
Seychelles	21	0	-
Ecuador	5	20	-
Others	0	111	-
Total	1 474	1 484	-

reason, this estimate (1 484) was modified, using the data from the OPRT for the fleets for which data are available (+101 vessels). In addition, there are currently about 30 IUU vessels. The addition of these produces an estimate of 1 615 for the total number of large-scale longliners in the world.

4.2 Current catch of large-scale longliners

The determination of the current fishing capacity of the large longliners requires information that is not available or difficult to quantify (e.g. vessel specifications, operational patterns, increases in gear efficiency and socio-economic factors). Also, there are other things that should be considered, such as the portion of time actually spent fishing for tunas. Under these circumstances, the fishing effort that may be derived from this fleet was considered in terms of tuna resources.

The problem is to define the resources (bigeye, yellowfin, albacore, and the three species of bluefin) available to the longliners and to the other types of gear. In this study, it was assumed that the shares of the stocks of these species among the fishing gears remain the same as in 2001-2002, and that the fishing patterns (i.e. age-specific fishing mortality by various gears) also remain the same.

According to the stock assessments carried out by the various RFMOs, almost all tuna stocks in the three oceans are at or below levels corresponding to the maximum sustainable yields (MSYs) (i.e. either the fishing effort is about equal to or greater than that corresponding to the MSY or the spawning biomass is about equal to or below the level corresponding to the MSY) (de Leiva and Majkowski, this collection). Many of these stocks are regulated, or there have been recommendations “not to increase the fishing mortality” for them.

Therefore, comparison of the fleet size with the catch by that fleet should be of interest. Miyake, Miyabe and Nakano, (2004) estimated the longline catches of the species mentioned above by species, area and country. However, the catches by longline cannot be classified by vessel categories.

In this report, these catches were separated into those made by large-scale longliners, small-scale longliners and by swordfish longliners (as bycatches), using the author’s knowledge of the longline fisheries. However, the catches by small-scale longliners are often reported as having been taken by unclassified gears (artisanal). Because the numbers of small-scale longline fleet are unknown, it was difficult to determine whether the catches were made by longliners or some other gear, so the results should be considered as rough estimates.

The data indicate that during 2001 approximately 390 000 tonnes of tunas were caught by large-scale longliners, and 200 000 tonnes were caught by other longliners (small-scale longliners and/or longliners targeting swordfish). As the *sashimi* market consumes about 600 000 tonnes per year, this estimate appears to be realistic.

5. CONCLUSIONS

The longline fleet size, by large- and small-scale longliners is compared with the estimated tuna catches, by small and large-scale longliners, in Table 6. The data are segregated by ocean, but only the totals are of interest, as many of the longliners operate in more than one ocean during the same year. It should be noted that the catch corresponds to those made by small longliners while numbers of "small-scale" longliners refer to those included in the positive list, thus being greater than 24 metres in LOA. Therefore, the catches per vessel are not calculated for that category.

It should be noted that no data for small-scale longliners (vessels with LOAs less than 24 metres) are included in the table. Only the data for large-scale longliners are considered below.

The last row contains the best estimate for total number of large-scale longliners. The annual average catch of the registered vessels was 241 tonnes in 2002. The catch discussed here does not include bycatches of tunas by swordfish longliners nor bycatches of billfishes by longliners targeting tunas. Therefore, the catches of the marketable species would be somewhat greater than 389 251 tonnes. On the other hand, as explained in Section 5.1, the fleet size may be underestimated, in which case the catch per vessel could be less than 240 tonnes.

It is unlikely that all of the large-scale longliners are currently fishing at their full capacities, due to economic, social and management restrictions. If all these restrictions are removed, their potential catches, even at the current levels of abundance of the resources, would be greater than 240 tonnes per vessel.

However, if the fishing patterns, in terms of gear share, age composition and species composition, were to stay the same, any increases in the size of the longline fleet would not increase the catches much above the current levels because most of the stocks are currently harvested near or beyond the MSY levels. On the other hand, the same levels of catches can most likely be achieved with a smaller fleet size. In fact, if the sizes of the fleets that utilize the other gear types (purse-seine, pole-and-line, troll and small-scale longliners) were reduced by the same proportion as the large-scale longline fleet, the large-scale longline fleet would probably increase its share of the catch.

The market price of fish varies considerably by species and area and/or season of capture. The species composition of the catch is important, as the catch rates of lower-priced fish (e.g. yellowfin) are greater than those of the higher-priced fish (e.g. the three species of bluefin). Therefore, the boat owners can decide whether to direct their efforts toward lower- or higher-priced fish (taking into account the constantly

TABLE 6
Estimated fleet size and catches for small- and large-scale longliners, by ocean. The difference between the total and grand total for the large-scale longliners is explained in the text

Type of vessel	Ocean	Number of vessels	Estimated catch (tonnes)	Catch per vessel (tonnes)
Small-scale vessels (incomplete)	Indian	914	54 683	-
	Atlantic	151	29 260	-
	Pacific	458	112 244	-
	Duplicate	102	-	-
	Total	1 421	196 177	-
Large-scale vessels	Indian	920	90 620	98.5
	Atlantic	764	108 028	141.4
	Pacific	1 014	190 603	188.0
	Duplicate	1 214	-	-
	Total (positive list)	1 484	389 251	262.3
	Grand total (adjusted by other information)	1 615	389 251	241.0

fluctuating prices of the fish). In addition, the operating costs vary among fleets, distances from port, etc., so it is difficult to determine, on an economic basis, the most appropriate size for the longline fleet. In spite of the above, the current break-even point appears to be around 250 tonnes, regardless of the fleets. Each vessel tries hard to make a profit, changing the target species and areas of operation in accordance with the captain's judgment.

The tuna resources that are available to large-scale longliners are also variable, since it is not a single-gear fishery. Some of the factors, other than natural fluctuations, that affect the available stocks are:

- Status of resources.
- Regulatory measures adopted by the various RFMOs.
- Species composition of the catches. For example, if a large proportion of the vessels targets a high-priced species, as has been the case, the fleet size that is optimal for all species would be excessive for the afore-mentioned high-priced species.
- Allocation among fishing gears. Currently the fishing capacity of purse seiners is expanding rapidly, which would reduce the amount of fish available for the longliners, particularly since the purse seiners most often catch smaller, younger fish than do the longliners. The recent increase in fishing on tunas associated with fish-aggregating devices has further reduced the average size of the fish captured, and presumably reduces the numbers of large fish available for the longliners.
- Competition with longliners that direct their effort at fish suitable for the fresh-fish market. These can provide fresh fish to the markets, which bring higher prices than do the frozen fish landed by the large-scale longliners. Also, current regulations do not restrict the numbers of medium- and small-scale longliners (less than 24 metres in LOA) in many countries, whereas the numbers of large-scale longliners are well controlled.
- The recent rapid development of tuna farming (Farwell, 2001) has already affected price structure, and further changes are likely in the future.
- Change in age compositions of catches. This may affect the yield per recruitment, and also reduce the MSY level.

This study is preliminary. The results would have been much better if the data had been better. Each country should collect information on the names or registration numbers and the characteristics of each vessel registered in that country, including information on transfers of registration. Logbook data for every vessel should be collected and provided to scientists of the countries in which the vessels are registered or to scientists of the RFMOs, so that they can determine the catches, the oceans in which fishing was taking place, and the species toward which the vessels were directing their effort. Also the past trends in fleet size should be studied to analyse the relationships between fleet fishing capacity and abundance of the various stocks. Data on effort directed at swordfish and the catches of tunas made by swordfish longliners and of billfishes made by tuna longliners were not incorporated into this study, but they should be included in future analyses.

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Global study of non-industrial tuna fisheries

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ABSTRACT

FAO is implementing a project on the management of world tuna fishing capacity. As part of this project, a study was undertaken of non-industrial tuna fisheries to describe these fisheries and their relative importance.

Although fishing-capacity specialists generally believe that it would be impractical to estimate the fishing capacity for the multitude of types of non-industrial tuna fishing, it is necessary to know at least the magnitude of non-industrial tuna catches in order to evaluate how important the lack of estimates of the non-industrial capacity would be to the success of the overall capacity study.

This study is concerned exclusively with the "principal market species of tunas": skipjack tuna, yellowfin tuna, bigeye tuna, albacore, Atlantic bluefin tuna, Pacific bluefin tuna and southern bluefin tuna.

The categories of fishing used in this report are: (1) industrial-scale (mechanized purse seining, conventional-freezer longlining and most pole-and-line fishing); (2) small-scale (all handlining, rod-and-reel fishing, sportfishing, all kinds of tuna fishing from vessels that are undecked, unpowered or use outboard engines or sails and most "unclassified surface gear"); (3) medium-scale (operations that fall between the definitions of industrial- and small-scale given above).

Estimates of the catches of tuna by non-industrial fishing were made in 148 countries, and a closer examination was undertaken of tuna fishing in the Philippines and Indonesia.

The results of this study show that the amount of tuna caught in the world by small-scale fisheries is about 320 200 tonnes, or about 8 percent of the global tuna catch. It was not possible to make a similar compilation for the medium-scale tuna fisheries. In most regions, the readily available information did not permit certain gear types to be assigned to industrial and non-industrial components.

With the benefit of hindsight, it appears that the best option for a "clear division of scales" in the future would be to use the following scheme: (1) small-scale (handlining, rod-and-reel fishing, sportfishing, and all kinds of tuna fishing from vessels, usually less than 12 m long, that are undecked and unpowered, or using outboard engines or sails; (2) medium-scale (fishing from decked vessels, usually between 12 and 24 m long, without mechanical freezing capability); (3) large-scale (fishing from vessels, usually more than 24 m long, that have mechanical freezing capability).

The accuracy of the information in this report could be greatly improved by scrutiny by specialists with knowledge of national tuna fisheries. It is especially important for those experts to resolve the uncertainty associated with whether certain fleets should be assigned to medium-scale or to industrial-scale fisheries.

1. INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO) is implementing a project on the management of tuna-fishing capacity. The main objectives of the project are to identify, consider and resolve technical problems associated with the management of tuna fishing capacity on a global scale, taking into account conservation and socio-economic issues.

The project's first Technical Advisory Committee (TAC) met in April 2003. The TAC discussed a variety of items concerning the project, including issues related to non-industrial tuna fisheries. The Committee noted that it would be useful to have descriptions of these fisheries, with information on their relative importance. The present review has been commissioned to deal with this need.

2. BACKGROUND

Work on the review of non-industrial tuna fishing began in mid-October 2003. Contact was made with authorities on fishing capacity, tuna fishery specialists, staff of tuna management bodies, other consultants to the FAO project, and FAO staff members. A strategy for the work on non-industrial fisheries was formulated, initial requests for information were sent, and arrangements for travel were made in accordance with suggestions received. From 6 November to 15 December 2003, travel was undertaken, which included visits to the Inter-American Tropical Tuna Commission, the FAO Sub-Regional Office for the Caribbean, FAO headquarters, the Indian Ocean Tuna Commission, the FAO Regional Office for Asia and the Pacific, and various offices in the Philippines and Indonesia. Ninety individuals were contacted, either through personal meetings or correspondence. The interviews were structured so as to obtain an understanding of the non-industrial tuna fisheries, available quantitative data and relevant documentation. Certain patterns emerged from the discussions and literature that were useful in establishing appropriate definitions and classifications for the non-industrial fisheries.

From 17 December 2003 to 15 January 2004, the information obtained during the travel was used to make estimates of the catches of tunas by non-industrial fishing in 148 countries.[1] Also, a closer examination of tuna fishing in the Philippines and Indonesia was carried out.

This review, and the larger FAO project on tuna-fishing capacity, are concerned exclusively with the "principal market species of tuna", skipjack tuna, yellowfin tuna, bigeye tuna, albacore, Atlantic bluefin tuna, Pacific bluefin tuna and southern bluefin tuna. Unless otherwise specified in this report, the term "tuna" is used to denote these seven species.

3. WHY STUDY NON-INDUSTRIAL TUNA FISHERIES?

Under FAO auspices, efforts to estimate the global fishing capacity of the large-scale purse-seine and longline fleets are presently underway. Fishing-capacity specialists generally believe that, because of the very large number of fishing operations involved, the great variety of gear types and other factors, it would be impractical, at least at present, to estimate the fishing capacity for non-industrial tuna fishing. It is necessary, however, to estimate the magnitude of non-industrial tuna catches in order to evaluate how important the lack of information on non-industrial capacity estimates would be to the success of the overall capacity study (and any subsequent capacity limitation measures).

In the course of the field work for this study, another important reason for reviewing the catches of small-scale tuna fisheries became apparent. These fisheries are

[1] More precisely, these are country/ocean entities, as for example, Canada with its two coasts is considered as two entities in this report. Overseas territories are considered as separate entities from the governing metropolitan country.

often carried out in isolated locations, are a major component of the diet of the people and the participants frequently are socially disadvantaged. For practical and political reasons, it may be difficult or impossible, or undesirable, to limit capacity in the small-scale tuna fisheries. The quantities of tuna that these "semi-unmanageable" fisheries are able to capture must therefore be taken into consideration in capacity management schemes, at least in areas where small-scale tuna fisheries are relatively important.

4. TERMINOLOGY

It is important to clarify the "scale" terminology used in this study. Terms such as small-scale, artisanal, semi-industrial, non-industrial, industrial, and large-scale are often used rather loosely. This may lead to confusion and problems with consistency, especially in situations involving many countries, regions, gear types and languages.

4.1 Observations made during the review work

During the data-gathering phase of this review several observations were made on the use of these terms in the countries covered. There are many schemes used to delineate the lower end of the fishing spectrum ("small-scale", "artisanal" or other terms). These include:

- Tonnage of vessel used in fishing: "Municipal fisheries" in the Philippines are defined as those operations that use fishing vessels of three gross registered tons (GRT) or less.
- Distance offshore: In the Taiwan Province of China, small-scale or artisanal fisheries refer to the production obtained without any fishing boat or using unpowered fishing boats within three nautical miles of the coast.
- Size of vessel: In the Netherlands Antilles, artisanal fishing is fishing that is carried out on vessels less than seven metres in length. In Chile, artisanal swordfish fishing is fishing that is carried out on vessels of less than 28 m in length.
- Carrying capacity: In Iran, artisanal fishing is fishing carried out on fishing craft with capacities not greater than 100 tonnes (Kaymaram and Talebzadeh, 1998).
- Water depth: In Suriname, fishing operations in depths less than ten metres are considered artisanal.
- Horsepower: Artisanal fishing in Guinea-Bissau is fishing that is carried out on fishing craft of up to 60 horsepower.
- Gear: Small-scale fisheries in Thailand are those that use gillnets (except for Spanish mackerel- and mackerel-encircling nets), cast nets and scoops, and fisheries that collect shellfish.
- Combination of features: In Hong Kong, artisanal production is that from vessels less than 40 feet (12 m) in length that fish in coastal waters 15-25 fathoms (27-48 m) deep.
- Other schemes for partitioning the small-scale and artisanal sector involve how the catch is disposed of, length of voyages, labour intensity and degree of mechanization of fishing gear.

Certain features concerning delineating scales of fishing emerged during this study. Although small-scale tuna fishing is often delineated in legislation by length or tonnage of vessel, the readily-available national statistics and anecdotal information on tuna tend to be categorized by gear type. When statistics from regional management bodies include small-scale tuna fishing, this is often by gear type rather than by size or capacity of vessel. Also, because the definitions of small-scale fishing in many countries are embedded in legislation, efforts to standardize what constitutes small-scale fishing across countries may have limited success, or at least take a very long time.

4.2 Some considerations on defining small-scale and artisanal tuna fishing

There have been numerous attempts at defining small-scale and artisanal fisheries. Typical is that of FAO's World Fisheries and Aquaculture Atlas, which defines "artisanal fisheries" as:

> Traditional fisheries involving fishing households (as opposed to commercial companies), using relatively small amounts of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption. In practice, the definition varies between countries, e.g. from gleaning or a one-man canoe in poor developing countries, to more than 20 m trawlers, seiners, or longliners in developed ones. Artisanal fisheries can be subsistence or commercial fisheries, providing for local consumption or export. Sometimes referred to as small-scale fisheries.

Although this definition (and numerous others) reflects the reality of the situation, it is not especially helpful in separating out the small-scale component of the world's tuna fisheries. In other words, it does not provide guidance in "making clear definitions of the scale of artisanal, small-scale and large-scale components of various fleets", as recommended by the Technical Advisory Committee (TAC).

Specifically with respect to tuna fisheries, the report of the first TAC meeting (FAO, 2003) has suggested that small-scale tuna fisheries are equivalent to "tuna fisheries producing for local markets". It should, however, be noted that some of the most important small-scale tuna fisheries (in terms of numbers of fishers, quantity of catch and lack of data) are oriented to export markets (e.g. handlining in Indonesia and the Philippines).

The difficulty of defining small-scale fishing is not new, nor is it unique to tuna fisheries. The report of the FAO Technical Consultation on the Measurement of Tuna Fishing Capacity (FAO, 2000) states that "the group also noted that the definitions of artisanal, subsistence, and small-scale were unclear and recommended that consistent definitions be provided by FAO". On the other hand, there appears to have been some recent evolution in thinking concerning the concept of a definition. FAO's Working Party on Small-Scale Fisheries of the Advisory Committee on Fisheries Research indicated that "it would be inappropriate to formulate a universally-applicable definition for a sector as dynamic and diverse as small-scale fisheries" (FAO 2004).

The definition issue can be approached from a different perspective. Rather than attempting to formulate a clever definition of small-scale or artisanal tuna fishing and then apply it globally to tuna fisheries, it may be more appropriate to establish a boundary for information to be collected by this study in accordance with objectives of the FAO tuna fishing capacity work. That is, the boundary should be established in view of the aim of determining the level of catches of all tuna fisheries for which capacity estimation is not possible.

4.3 Some practical considerations

Ideally, this global study should estimate catches from all tuna fisheries of a scale smaller than the industrial longline, purse-seine and pole-and-line fisheries for which fishing capacity estimates are presently being made. In the course of the field work for this review, certain realities became apparent:

- However desirable, in a short study of a few weeks that covers seven regions and 147 countries, it is not possible to determine the catches of all the tuna fisheries for which fishing capacity estimates cannot be made.
- Despite appropriate definitions and/or suitable boundaries of the tuna fishing for which catch levels should be collected, there was little choice but to use the information that was readily available. In many cases the available information was less than ideal, and it was often not available in consistent categories that can be compared across countries.

4.4 Categories of scale used in this report

In order to make catch estimates, some form of working definition of small-scale tuna fishing was required in order to communicate with individuals and organizations in position to supply catch information. In the course of the study, there was a growing realization that, rather than define small-scale or artisanal tuna fishing in terms of what it is, it is more practical to define it in terms of what it is *not*.

In establishing what is *not* included in small-scale tuna fishing, there were some important considerations, such as using established categories of vessel or gear (in databases, as well as in reports and in the minds of individuals supplying anecdotal information), the need to reduce complexity to allow completion of over 100 national catch estimates in a few weeks, and the desire to estimate the catches of fleets of a scale smaller than that for which fishing capacity estimates are being made.

In balancing these various considerations, it was decided that small-scale tuna fishing should exclude mechanized purse seining, conventional freezer longlining, distant-water fishing and (unless information was available to suggest a small-scale character) pole-and-line fishing.

This working definition of small-scale tuna fishing and the practicalities of collecting data resulted in the following categories for this review:

1. Small-scale: includes all handlining, rod-and-reel fishing, sportfishing, and all kinds of tuna fishing from vessels which are undecked, unpowered, or use outboard engines or sails. “Unclassified surface gear” is also included, unless there is some reason not to do so. Regardless of how vague or incomplete the data, an attempt is made to estimate the catches in this category for each country, using the best readily available information.
2. A second category that includes:
   (a) Operations of a larger scale that fall between the definitions of industrial and small-scale given above. In practice, this consists mainly of relatively small mechanized longliners (mainly ice boats), relatively large mechanized gillnetters and the extensive trapping operations.
   (b) Groups of vessels that have a considerable size range, so that it is difficult or impossible to isolate the non-industrial components.

   For convenience, this second category is called simply “medium-scale”, although it is acknowledged that it includes some components of an undetermined scale. In many cases, the information in this category is unclear, incomplete or inconclusive. In this short review, no attempt is made to resolve these data difficulties; rather, summary data are simply presented for use as appropriate. As the information is sometimes vague, no attempts were made to estimate the total catches in this category for many countries.

4.5 Summary of scale terminology

Industrial: The term is considered to be equivalent to “large-scale”, and includes mechanized purse seining, conventional freezer longlining, pole-and-line fishing using inboard-powered decked vessels and all forms of distant-water tuna fishing.

Non-industrial: The term is considered roughly equivalent to both “small-scale” and “artisanal”, and includes the small-scale fisheries and medium-scale fisheries.

As statistics and individual perceptions are often oriented to gear types, rather than vessel length (Section 4.1 above), it was thought that defining scale by gear would therefore be more suitable to the needs of the present study. The appropriateness of this assumption, and others in the above terminology scheme, are re-visited in Section 7.

5. SOURCES OF INFORMATION

Several sources of information were used in this study to make country estimates of non-industrial tuna catches. National, regional and global databases covering tuna provided much of the information. These included:

- FAO's FISHSTAT Plus, version of late 2003. For convenience, this is referred to simply as "FAO database" in the appendix tables.
- International Commission for the Conservation of Atlantic Tuna dataset, version of November 2003. This is referred to as "ICCAT database" in the appendix tables.
- Indian Ocean Tuna Commission (IOTC) dataset version of late 2003. This is referred to as "IOTC database" in the appendix tables.

An important source of information was individuals working at regional fishery organizations, such as tuna management bodies, fisheries projects covering large areas, and FAO regional or sub-regional offices. For countries for which statistics are not available, these individuals, with their broad knowledge of tuna fisheries, in particular regions, were invaluable at providing estimates of tuna catches, or at least educated guesses as to catch magnitudes.

Other information to estimate national catches came from published and unpublished national reports (Section 10 of this report), regional tuna conference proceedings, internet searches, FAO fishery country profiles and correspondence with national authorities.

Indonesia and the Philippines have very important small-scale tuna fisheries, and yet there is considerable uncertainty as to the level of catches. Special attention, including dedicated visits, was therefore focused on those two countries to obtain catch estimates. Background information on the sources of the estimates is given in Appendixes 8 and 9.

6. RESULTS AND DISCUSSION

6.1 General

Using the categorization scheme described in Section 4.5 and the sources of information given in Section 5, estimates of non-industrial tuna catches were made for each country for which non-industrial tuna fisheries are known to occur. These consisted mainly of catch estimates (or, at least, informed guesses) for the small-scale fisheries, and a summary of the readily available information on the "medium-scale".

These estimates, grouped into seven regions, are given in Appendixes 1 to 7. They are summarized in Table 1.

Although many of the country catch estimates are based upon data from sound statistical systems, that was not always possible, so information of lesser quality was used in order to arrive at catch estimates. The "educated guesswork" that was required for some countries, should not be judged too harshly, in view of the intended nature

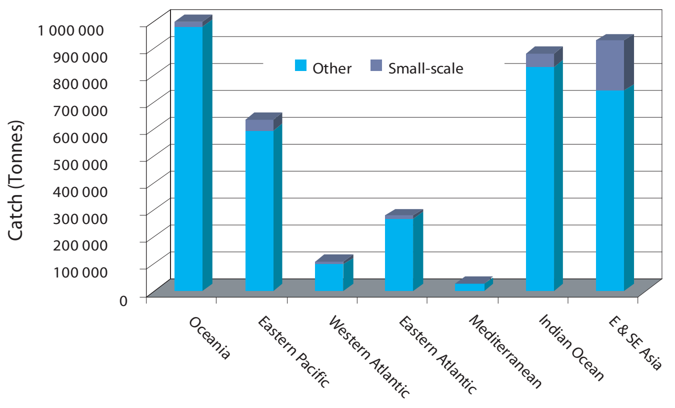
TABLE 1
Regional summaries of tuna catches by small-scale fisheries

	Small-scale catches (tonnes)	Total catches (tonnes)	Small-scale catches as percentages of totals	Sources of regional total catch estimates
Oceania	19 000	900 000	2.1	SPC Tuna Fishery Yearbook information covering SPC fisheries statistical area, less any included Indonesia and Philippines catches.
Eastern Pacific	40 500	750 000	5.4	J. Joseph (per. com. using FAO and IATTC data).
Western Atlantic	11 000	112 000	9.8	ICCAT database.
Eastern Atlantic	11 000	347 600	3.2	ICCAT database.
Mediterranean	1 700	28 500	6.0	ICCAT database.
Indian Ocean	52 000	880 000	5.9	IOTC database.
East and Southeast Asia (Pacific Ocean)	185 000	928 000	19.9	FAO database (NW Pacific); Appendixes 8 and 9 of his report.
Total	**320 200**	**3 946 100**	**8.1**	

of the work, a qualitative study of the relative magnitude of the non-industrial fisheries.

It is stressed that the catches given in the appendix tables are crude estimates. They are put forward to generate discussion in order to encourage future improvement. Most, if not all, of the country estimates could probably be improved by scrutiny by tuna fishery specialists familiar with the concerned countries.

FIGURE 1
Relative importance of small-scale tuna fisheries



It is not possible to make a similar compilation for the "medium-scale" tuna fisheries, the other component of the non-industrial tuna fisheries in the appendix tables. In most regions, the readily available information did not allow certain gear types (mainly longlines and, to a lesser extent, gillnets) to be segregated into industrial and non-industrial components.[2] For example, the catches in the category "longline" in some regions could consist of that from a 12 m vessel with four crew members undertaking short local trips (non-industrial according to the definition in Section 4.5), and the catches from a 30 m vessel involved in long voyages to locations outside the national Exclusive Economic Zone (EEZ) (industrial, according to the definition). Within the study period, the issue of the medium-scale fisheries in most regions could be taken only as far as presentation of relevant summary data for each of the 147 countries and making recommendations as to how the information could be improved in the future (Section 8).

The author's experience and access to information made it possible to estimate the tuna catches by medium-scale fishing in the Oceania region. The 39 000 tonnes of tuna taken by this category of fishing is about twice the catch of that from small-scale tuna fishing, or 4.3 percent of the catch in this region. Together the small-scale and the medium-scale fisheries form the non-industrial component, which accounts for about 6.4 percent of the catch in the region.

The results of this study indicate that the world-wide catch of tunas by small-scale fisheries is about 320 200 tonnes, or about eight percent of the total world catch. Apparently, there have been only a few reviews containing information with which these results can be compared. Joseph (2003) states "About 12 percent of the world catch is taken with gear other than purse-seine, longline, and pole-and-line. About one-half of this remaining 12 percent is taken by trolling vessels that fish for albacore, and the rest by a variety of other fishing gears, such as anchored and drifting gillnets, harpoons, and traps". Allen (2002) shows that the gear category "other or unknown"[3] grew steadily over the last few decades to about 400 000 tonnes in 2002. Considering the quality of the data available, these three estimates are not remarkably different from one another.

Some notable features of the results of the present study are:

- There is a great deal of variation among regions. Small-scale tuna fishing is least important in the Oceania portion of the Pacific, where only 2.1 percent of the tuna catch is from small-scale fisheries, and most prominent in the southeast and east

[2] "Flag of convenience" vessels also complicated the situation for some countries.
[3] The other categories are purse-seine, longline, pole/line and troll.

Asia portion of the Pacific where the relative importance of small-scale catches is far greater.

- There is also a considerable variation among the fishery bodies in interest in collecting catch information on the non-industrial fisheries. The IOTC seems to have the greatest experience in this area.
- In some areas (e.g. Oceania) the catch of tuna by small-scale fisheries is largely by effort directed at tuna, whereas in other areas (e.g. the Indian Ocean) much of the catch of tuna by small-scale fisheries is taken by vessels directing their effort at other species.
- Fish-aggregating devices (FADs) seem to have a large effect on the catch of tunas by small-scale gear. In some regions (e.g. West Africa) there is little mention of their use, whereas in other locations (e.g. Martinique and Guadeloupe) the effect of FADs on tuna catches by small-scale gear is remarkable.
- Recreational fisheries can produce substantial amounts of tunas, but the readily available information on these operations is often limited to the number of commercial sport fishing vessels.
- It also should be noted that, when dealing with regional totals, imprecise statistics or erroneous guesswork for the non-industrial tuna catches for countries with large tuna fisheries (e.g. Brazil) could overwhelm good statistics for countries with small fisheries (e.g. Barbados) to create a misleading regional picture.

6.2 Some regional features

Some miscellaneous observations on small-scale tuna fishing in the seven regions are summarized below.

6.2.1 Oceania

- Most of tuna fishing by small-scale fisheries in the region is by trolling in small open boats a few miles outside reefs, often close to urban markets and, in many countries, in conjunction with FADs.
- Small-scale tuna fishing in the region is relatively more important in small, resource-poor islands than in large, fertile islands. For example, Vanuatu has a population of about 200 000, but virtually no small-scale tuna fishing, while Kiribati, with small islands and less than half the population of Vanuatu, has catches of 7 500 tonnes of tuna by small-scale fishing.
- The Kiribati small-scale tuna catch is about 40 percent of such catches in the entire region.
- Dalzell *et al.* (1994) estimated that "large pelagic fishes" make up about 20 percent of the commercial coastal production of the region (20 percent of 24 610 tonnes = 4 922 tonnes), and about 30 percent of the subsistence catches (30 percent of 80 048 tonnes = 24 014 tonnes). If the principal market species make up 70 percent of large pelagic fishes (as suggested by the report), about 20 255 tonnes of principal market species of tuna are taken annually by coastal fisheries. This is close to the estimate of the present study.
- The very large catches of the industrial tuna fisheries of the region in conjunction with the small population tend to downplay the importance of small-scale fishing to the residents of the area.
- In comparison with other areas (e.g. Indian Ocean), little statistical data on small-scale tuna fishing is collected on a regional basis in the Pacific Islands. Descriptive accounts of national tuna fisheries by national authorities (e.g. those presented at regional meetings) are common, but often make no mention of small-scale tuna fishing. A study of small-scale tuna fishing in the region 18 years ago (Gillett and Toloa, 1987) noted that "there is no quantitative data on small-scale tuna fishing in many Pacific Islands. Where information has been collected, it is often in a

non-published form or difficult to locate". There has not been much change in the situation in the past 18 years.

6.2.2 Eastern Pacific Ocean

- The estimate of the small-scale landings used for Ecuador (25 000 tonnes) is more than half of the small-scale landings of the entire eastern Pacific Ocean, but that estimate should be considered as little more than guesswork.
- Unlike other eastern Pacific countries, most tuna specialists in Mexico focus on individual states, rather than the entire country, and therefore it is difficult to make even a crude estimate of the small-scale tuna catches from the very long Mexican Pacific coast.
- In the eastern Pacific region, there seems to be general recognition of two classifications of tuna fishing: "artisanal" and industrial. Classifying the available tuna catch data into these categories seems to be difficult only for longlining.
- Much of the tuna caught by small-scale fisheries in Central America is as a non-target species.
- Yellowfin makes up a large portion of the tuna caught by small-scale fisheries in the eastern Pacific Ocean. Landings of skipjack by these fisheries are relatively small.

6.2.3 Western Atlantic Ocean

- Brazil and the French Caribbean possessions account for about 36 percent and 21 percent, respectively, of the total small-scale tuna catch in this region.
- In the tropical portion of the western Atlantic, the small-scale catches of tuna represent about 23 percent of all the tuna caught.
- FADs seem to have a remarkable effect on the catch of tuna by small-scale gear, with Martinique and Guadeloupe as prime examples.
- The present annual catch of Atlantic bluefin tuna by small-scale fishing is about 1 570 tonnes, or about 57 percent of the catch of Atlantic bluefin in the western Atlantic Ocean.
- Sportfishing is important in the area. Although the numbers of commercial sportfishing vessels are documented for many countries or groups of countries (Mahon, 2004), the tuna catch by these vessels is, for the most part, unknown.
- The catch rate of tuna by longliners (tonnes per vessel per year) in several countries seems quite low (e.g. 105 tonnes of tuna for 31 longliners of 45 to 55 feet (14 to 17 m) in Barbados). Possible explanations supported by anecdotal information include low abundance of tuna, a small number of hooks per se, or targeting species other than tuna (e.g. sharks or swordfish).

6.2.4 Eastern Atlantic Ocean

- For the tropical African countries, the typical situation is that the artisanal marine fisheries target shallow-water species and small pelagic fish, using large canoes, but catch virtually no tuna.
- It is acknowledged that there was some difficulty in classifying ICCAT gear codes into the two non-industrial categories of fishing used in the tables, and consequently it could be improved with input from the region.
- Only a small amount of tuna, about 1 393 tonnes, is taken by small-scale gear in the tropical eastern Atlantic Ocean. The small offshore island countries produce the vast majority of this. Cape Verde alone is responsible for 94 percent of the 1 393 tonnes.
- Spain and Portugal take about 60 percent of the catch of tuna by small-scale gear in the eastern Atlantic Ocean.
- In the material available for this review, there is virtually no mention of the use of FADs to promote small-scale tuna fishing.

6.2.5 Mediterranean Sea

- Trap fishing is considered to be "medium-scale", because of the magnitude of the operations. In Spain, Jimenez *et al.* (2001) state "In the tuna trap fishing sector, the number of employees is very high during fishing seasons. In particular, the number of employees per tuna trap ranges from 54 to 93. Nowadays the number of employees is more than 300. There are about 60 vessels related to the four tuna traps".
- Tuna harvest statistics are complicated by fattening operations. "Fattening" is defined as collection of fish ranging from less than 10 kg to more than 200 kg, and confining them to cages for periods from a few months up to 2 years. Imports of these fish into Japan were 7 700 tonnes in 2001. Now two-thirds of the Mediterranean Atlantic bluefin imported into Japan originate from fattening operations.
- There appear to be some problems with the quality of the available catch statistics. ICCAT (2003) indicates: (1) estimates of harvest of Atlantic bluefin from trade data are greater for many countries than that from ICCAT catch statistics, and (2) data on albacore are too poor to allow assessment.

6.2.6 Indian Ocean

- Without a good knowledge of the various fisheries, it is difficult to estimate the catches in the category "medium-scale". One of the difficulties is that some gear types (e.g. gillnet and pole-and-line) can be used on vessels that range in size from small to obviously industrial. Nevertheless, the catches in the medium-scale category (excluding that from longlining that is probably industrial in scale) appear to represent about a quarter of all tuna catches in the Indian Ocean.
- Much of the non-industrial catches of tuna in the Indian Ocean is bycatch from fisheries that are not targeting tuna. Gillnetting for seerfish is an example of this.
- IOTC staff members estimate that about half of the landings of large pelagic fish (billfish, seerfish and all species of tuna) in the Indian Ocean (about 1.5 million tonnes annually) are captured by non-industrial fishing.

6.2.7 Southeast and East Asia

- In Indonesia (both Pacific and Indian Ocean areas), the only gear considered to be industrial is the conventional tuna purse seining in the north, pole-and-line fishing, using vessels larger than 15 GRT and mechanized longlining. All other tuna fishing presently undertaken in Indonesia is considered to be non-industrial.
- How Indonesia's small pole-and-line vessels under 15 GRT are categorized has a huge effect on the size of the "small-scale sector" in Indonesia, and also the world.
- Using the categorization scheme described in Section 4.5, Indonesia and the Philippines take about 60 percent of all the tuna captured by small-scale tuna fishing in the world.
- Indonesia (both Pacific and Indian Ocean areas) produces more tuna from its waters than any other country in the world.
- Aside from Indonesia and the Philippines, small-scale fisheries in the other Asian nations seem to take only tiny amounts of tuna.

7. FURTHER THOUGHTS ON SCALE CLASSIFICATION: INDUSTRIAL VS. NON-INDUSTRIAL

The scheme used in the present study was to classify the fisheries into two general categories, industrial and non-industrial. The latter was sub-divided into (1) small-scale, and (2) medium-scale. The industrial and small-scale category are defined by gear and/or vessel attributes, and the medium-scale category includes those fishing operations that fall between small-scale and industrial categories.

With the benefit of hindsight, several observations can be made on the appropriateness of the scheme. Basing the categories on gear and/or vessel types was good from the perspective that much of the available data, national reports, and anecdotal recollections are similarly based. Difficulties were encountered, however, with (1) gear types for which there was a wide range in scales (creating difficulty in separating the industrial from the non-industrial operations) and (2) the inconsistency of this scheme with the practice of the regional tuna bodies to define, for some purposes, large fishing vessels as those being more than 24 m long.

Taking into consideration the various factors, it appears that a favourable solution would be to use a scheme that would have categories that are both oriented to management purposes and determined largely by functional characteristics (rather than mainly by vessel size). In other words, vessels should be grouped as much as possible by fleets and/or fisheries, rather than by vessel size. In addition, terms that have significantly different meanings in different regions (e.g. "artisanal") should be avoided.

The following tuna fishing scheme is suggested:[4]

Small-scale:

- Handlining and trolling from open vessels, rod-and-reel fishing, sportfishing, and all kinds of tuna fishing from vessels that are undecked, un-powered, or use outboard engines or sails.
- Generally, the vessels are less than 12 m in length.
- Fishing trips are usually less than three days, and within a nation's EEZ.

Medium-scale:

- Vessel and/or gear characteristics:
  longline: decked vessel with an ice hold;
  seine: decked vessel without a power block;
  pole-and-line: decked vessel without mechanical freezing;
  gillnet: decked vessel with mechanical net-hauling gear;
  troll: decked vessel;
  trap: multiple vessels;
  other: decked vessel.
- Generally, the vessels are between 12 and 24 m in length.
- Fishing trips are usually less than two weeks, and within a nation's EEZ and those of neighbouring countries.

Large-scale:

- Vessel and/or gear characteristics:
  longline: mechanical freezing;
  purse-seine: use of power block;
  pole-and-line: mechanical freezing capacity.
- Generally, the vessels are greater than 24 m in length.
- The vessels are usually capable of trips to distant locations lasting more than a month.

It should be noted that such a scheme is not without difficulties. It would require catch data partitioned by vessels larger or smaller than 24 m in length, something that is not available for most regions at present. Universally applicable characteristics for the various scales are not possible, which explains the use of "generally" and "usually". As mentioned in Section 4.1, it also may be difficult to alter the classification schemes presently embedded in the legislation of some countries.

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[4] This scheme benefited from input from the second meeting of the FAO project's Technical Advisory Committee (TAC) in March 2004. It was subsequently adopted by the TAC.

8. IMPROVING THE ESTIMATES OF TUNA CATCHES BY NON-INDUSTRIAL FISHERIES

There are several ways to improve the estimates of tuna catches by non-industrial fisheries, in both the short and longer term.

In the short-term, the accuracy of the information in this report could be greatly improved by scrutiny by specialists with knowledge of national tuna fisheries. It is especially important for those experts to resolve the uncertainty associated with whether certain categories (or parts of categories) belong to medium-scale or to industrial-scale fisheries. For example, according to the IOTC database, in the 1997 to 2001 period, 1 862 tonnes of yellowfin (68 percent), skipjack (31 percent), and albacore (1 percent) were caught by handline and troll gear in the Indian Ocean. This could be considered small-scale fishing. If the "unclassified gear" category is added, however, the total increases to 54 421 tonnes and six percent of the total tuna catch. If gillnet gear is added to the three gears, the total increases to 178 892 tonnes and 20 percent of the total Indian Ocean tuna catch.

An intimate knowledge of national tuna fisheries could assist in resolving the issue of what should be allocated to the medium-scale category.

Other short-term actions to improve the non-industrial catch estimates include:

- "Ground truthing" database information by alternate sources of information. In some regions (e.g. the tropical eastern Atlantic) catch data from the regional bodies was often the only information used for estimating small-scale catches. Trade data or specialized reports could be very useful in this situation to either support or refute the database information.
- Special attention to countries for which good catch information is lacking. In the present study, trips were made to Indonesia and the Philippines to clarify the tuna-fishing situation. Similar work seems warranted in other countries for which small-scale tuna fishing could be important, and yet good information is not readily available. Included in this category are Mexico and Yemen.
- Additional attention should be given to the recreational fisheries. Information on such fishing is often not included in national tuna literature and regional databases, yet such fishing can be quite significant, as demonstrated by the case of Mauritius, where sportfishing could be ten times as important as all other forms of non-industrial tuna fishing. Information on sportfishing catches is likely to exist for most regions, but in forms or locations quite different than that for the other tuna fisheries.

In the longer term, the accuracy of the estimates of the tuna catches by the non-industrial fisheries could be improved by consensus on standard classification of fishing scales (such as that proposed in Section 7) and subsequent collection and dissemination of data in a form compatible with those scales.

9. CONCLUDING REMARKS

From the limited perspective obtained during the present review, it appears that the best option for a "clear division of scales", as requested by the FAO Project TAC, would be to use categories that are both oriented to management purposes and determined largely by functional characteristics, rather than strictly by vessel size. In summary, it is suggested that small-scale tuna fishing be defined as handlining, rod-and-reel fishing, sportfishing, and all kinds of tuna fishing from vessels, usually under 12 m, that are undecked and un-powered, or use outboard engines or sails. Medium–scale fishing is largely fishing from decked vessels, usually between 12 and 24 m in length, without mechanical freezing capacity. Large-scale fishing is usually fishing from vessels, usually longer than 24 m, that have mechanical freezing capacity.

The aim of this study was to gain a qualitative appreciation for the non-industrial tuna fisheries. A more ambitious objective was to estimate the catches of the principal market species of tuna from the fisheries for which fishing capacity calculations are impractical. These fisheries fall largely into the categories of non-industrial fisheries used in this review: small-scale and medium-scale. Although it was possible in this study to obtain at least a qualitative appreciation of the importance of the small-scale category, it was more difficult to do so for the medium-scale fisheries. This was due primarily to the problem of dividing the catches from the fleets that include a wide range of vessel sizes into industrial and non-industrial components. Some additional scrutiny by knowledgeable national tuna specialists of the catches provisionally allocated to the medium-scale category could resolve the problem, or at least permit a qualitative appreciation of the importance of the tuna catches by medium-scale tuna fisheries.

There are other reasons for studying the non-industrial catches of tuna, besides those related to calculating tuna fishing capacity. As pointed out in Section 3, for various reasons it may be difficult and/or undesirable to place capacity controls on many of the non-industrial tuna fisheries. These "semi-manageable fisheries" appear to correspond quite closely to the category of "small-scale" used in this study. It could be argued that catches by the small-scale tuna fisheries lie outside that which should be subject to capacity controls. In any case, the magnitude of these small-scale catches has important management implications, and therefore worthy of the attention received in this study.

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APPENDIX 1

NON-INDUSTRIAL TUNA FISHING IN OCEANIA

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
American Samoa	Trolling and handlining (15 vessels) and small alia catamarans (27 vessels) have been reported. Four FADs were reported in late 2003.	Trolling and handlining: SKJ, 5 tonnes; YFT, 5.5 tonnes per year. Alia fishing: SKJ, 13 tonnes; ALB, 131 tonnes; YFT, 86 tonnes; BET, 5 tonnes per year. A total of 246 tonnes of tuna per year.	Longline vessels: 5 vessels <50 feet (15 m); 28 vessels > 50feet (15 m). A total of 33 monohull longline vessels.	SKJ 218 tonnes, ALB 5 825 tonnes, YFT 399 tonnes, BET 191 tonnes per year. A total of 6 633 tonnes of tuna per year.	Sources of information: unpublished data for the 2003 Western Pacific Pelagics Fishery Management Plan Report (2002 data), American Samoa Module.
Australia	The category "minor line fisheries" includes trolling, handlining and droplining. The minor line catches in 2001 were very low, with no YFT being reported by Commonwealth-managed vessels. In 2002, 2.4 tonnes of YFT and 7.7 tonnes of SKJ were taken by minor line gear. Using National Recreational Fishing Survey data, the total recreational catch of tuna and bonito in eastern Australia was estimated to be as high as 1 000 tonnes for the 2000-2001 year. About 32 percent of this was bonitos and tunas other than the principal market species of tuna.	The minor line and recreational fisheries caught about 650 tonnes of tuna during a recent year.	The catches of SKJ by purse-seine and pole-and-line vessels in the eastern Australian fishing zone declined to 84 tonnes in 2002. The 114 longliners range from 15 m in length to industrial-size vessels capable of fishing far offshore. As the average number of hooks set per day is about 500, a significant portion of the longline fleet should probably be considered to be non-industrial.	During 2000-2002, longline vessels caught an annual average of 3 417 tonnes* of YFT, SBF, BET and ALB (63 percent YFT). *dressed weight (rather than round weight).	Sources of information: Bromhead and Findlay (2003).
Cook Islands	The troll and handline tuna catches around the main island of Rarotonga were 35 tonnes in 1998 and 59 tonnes in 1999, but have decreased in recent years because of competition in the market with bycatches of longliners. There is a very active FAD programme throughout the Cook Islands.	About 80 tonnes of tuna are caught per year.	14 local longliners 12 to 20 m in length, plus 7 foreign fishing vessels have been reported. At least some of these vessels should be considered to be industrial.	In 2002, a total of 1 117 tonnes of tuna was caught by the local and foreign fleets.	Sources of information: Mitchell (2003), staff of the Ministry of Marine Resources, SPC web site, Chapman (2004).
Federated States of Micronesia	Trolling for tuna produces about 57 tonnes of tuna per year, which is sold locally. Subsistence catches of tuna, mainly in the outer islands, taken by handlining and trolling with outboard-powered motorboats or by canoe. Subsistence fishing yields about 1 900 tonnes per year.	1 957 tonnes of tuna per year.	The domestic longline fleet has 18 vessels, some of which are industrial in scale.	The entire tuna catch of this fleet in 2002 was 259 tonnes.	Sources of information: Gillett *et al.* (2001), Park (2003).

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
Fiji	Prior to deployments of FADs, mainly around Suva, at the end of 1991, artisanal tuna production was about 150 tonnes per year, after which it increased to about 250 tonnes during the following two years. Judging from the distribution of the population and fishing effort, it can be crudely esti-mated that about 25 percent of Fiji's artisanal tuna production is from the Suva area.	About 1 000 tonnes per year.	101 longliners (from 13 m up in length) in 2001 and 2002. 2 to 3 pole-and-line vessels in 2001-2002.	An average of 10 800 tonnes of tuna (74 percent ALB) has been reported for 2001 and 2002.	Sources of information: Amoe (2003), Anderson and Gates (1996), Gillett (2003).
French Polynesia[1]	The coastal tuna fishery uses two types of boats: (1) the poti marara, 237 vessels in 2002, 6 to 8 m in length, and (2) the bonitier, 55 vessels in 2002, 10 to 12 m in length. In order to support the coastal fishery, the Fisheries Department maintains a permanent network of 30 FADs around the Windward Group (Tahiti, Moorea, Tetiaroa and Maiao) and approximately 10 FADs in the Leeward Group.	In 2002 the bonitiers caught 919 tonnes of SKJ, YFT and ALB, and the poti marara caught 619 tonnes of SKJ, YFT and ALB. 1 538 tonnes of tuna total.	The offshore longline fleet has four kinds of vessels: 1) Longlining *bonitiers*, 6 vessels in 2002, which are SKJ boats converted to longlining; 2) fresh-fish longliners, 30 vessels in 2002, which comprises boats 13 to 20 m in length made of steel or fibre-reinforced plastic; 3) mixed longliners, 2 vessels in 2002, which are 21-m steel boats; 4) freezer longliners, 16 vessels in 2002: 25 to 26 m steel vessels.	The total catch from the fleet in 2002 was 5 713 tonnes of ALB, BET and YFT (80 percent ALB). The two larger categories of longliners are considered industrial, and produced about half of the catch in 2002.	Sources of information: Misselis (2003), Misselis (2002).
Guam	12 to 48 foot (4 to 15 m) trolling, handlining and sport-fishing charter vessels (375 in total).	SKJ, 60.0 tonnes; YFT, 14.3 tonnes; 74.3 tonnes total per year.	None (only Guam-based foreign longline vessels).	None.	Sources of information: NOAA (2003).
Hawaii	Trolling (1 451 CMLs) and hand-lining (164 CMLs). CML is a State of Hawaii commercial fishing license, which may or may not equate to a fishing vessel.	BET, 234 tonnes; YFT, 526 tonnes; SKJ, 80 tonnes per year. A total of 840 tonnes of tuna per year.	Longline, 100 vessels. Pole-and-line, 5 vessels. Pole-and-line vessels range from about 55 to 70 feet (17 to 21 m), and the longliners from about 50 to 100 feet (15 to 30 m).	Longline: BET, 4 395 tonnes; YFT, 571 tonnes; ALB, 26 tonnes; SKJ, 128 tonnes; total, 5 120 tonnes per year. Pole-and-line: SKJ, 241 tonnes; YFT, 1 tonne per year.	Sources of information: 2002 unpublished data, NOAA Fisheries Pacific Islands Fisheries Science Center.
Kiribati	There are approximately 200 to 250 small, motorized skiffs based in South Tarawa, which troll for tuna and other large pelagic species. The weekly landings of tuna in Tarawa by these small-scale vessels are about 33 tonnes. The weekly production for the other 17 islands of Kiribati ranges from 0.5 to 20 tonnes per island, averaging 8 tonnes per island.	About 7 500 tonnes per year.	There is a 33 foot (10 m) catamaran longline vessel and an ex-US longline vessel, but there was very little fishing by these vessels in 2002.	Almost none.	Sources of information: Gillett and Lightfoot (2001), Kirata (2003).

[1] It is recognized that French Polynesia lies in both the WCPO and EPO. All the catches of the territory have, however, been listed on this WCPO table. To keep the Pacific Islands region together, the information for the Pitcairn Islands is also given on this table.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
Marshall Islands	It is estimated that 444 tonnes of fish are taken per year by small-scale commercial vessels. Government fisheries officials believe that tuna make up between 5 percent and 10 percent of these landings.	About 35 tonnes per year.	Although 54 longliners were based in the Marshall Islands in early 2003, these were all foreign-owned industrial vessels.	None.	Sources of information: Joseph (2003), Gillett (2003).
Nauru	The Nauru fisheries newsletter (NFMRA, 1998) gives the following information on monthly catches of "pelagic catches": May 1998, 9.5 tonnes; April 1998, 11.9 tonnes; June 1998, 14.9 tonnes; July 1998, 8.9 tonnes. It is likely that about 75 percent of these fish were tuna.	About 90 tonnes per year.	The Nauru Fisheries Corporation has two catamaran longliners (18 m and 15 m). The tuna catch of the larger vessel in 2001 was "500 kg per week for a few months". There was not much fishing by these vessels in 2002.	About 10 tonnes per year.	Sources of information: Gillett (2003), NFMRA (1998).
New Caledonia	About 10 vessels participate occasionally in trolling. Four or five FADs were reported to be deployed in late 2003. A small amount of recreational fishing occurs.	Not likely to be more than 50 tonnes per year.	There were 25 longliners in 2002, of which 11 were less than 50 GRT and 14 were more than 50 GRT.	In 2002, 272 tonnes of YFT, 189 tonnes of BET and 1 165 tonnes of ALB were reported.	Sources of information: Etaix-Bonnin (2003), SPC staff, Chapman (2004).
New Zealand	"Other gear" caught about 3 tonnes of ALB and SKJ in 2001. It is likely that a significant proportion of the troll catch (given to the right), comes from small-scale fishing activity, but information to enable partitioning it into categories of scale is not readily available.	For the purpose of this report, the annual catch of tuna by small-scale fishing is assumed to be 10 percent of the troll catch, or about 350 tonnes per year.	Over 90 percent of the troll fleet (328 vessels in 2001) is less than 50 GRT, but some are more than 150 GRT. About 65 percent of the longline fleet is less than 50 GRT, but some are more than 500 GRT.	Annual troll catches have averaged 3 472 tonnes of ALB, 24 tonnes of YFT, 16 tonnes of SKJ and 8 tonnes of SBF in the 1990s; a total of 3 520 tonnes of tuna. The annual longline catches have averaged 981 tonnes ALB, 188 tonnes BET, 13 tonnes BFT, 303 tonnes SBF, 2 tonnes SKJ and 76 tonnes YFT; 1 563 tonnes of tuna.	Sources of information: Murray *et al.* (2002).
Niue	The artisanal fleet consists of 100 outrigger canoes and 50 aluminium skiffs. There is currently a FAD programme. Many vessels, and probably all deployed FADs, were destroyed by a cyclone in January 2004.	About 100 tonnes per year.	None.	None.	Sources of information: Pasisi (2003), Chapman (2004).
Northern Marianas	The fleet consists of 12 to 24 foot (4 to 7 m) trolling and hand-lining vessels (142 subsistence and/or recreational plus 121 part- or full-time commercial fishing vessels), plus 27 sport-fishing charter boats. There is currently a FAD programme.	SKJ. 60.9 tonnes; YFT, 6.6 tonnes; other tuna, 1.7 tonnes; total, 69.2 tonnes per year.	None.	None.	Sources of information: NOAA (2003).
Palau	There are about 20 to 30 boats from Koror that occasionally troll outside the reef. In addi-tion, there are about 10 vessels that occasionally participate in commercial sport fishing. Eight Philippine-style handline boats operate near FADs. There are both government and private FAD programmes.	About 75 tonnes per year.	The fleet consists of Asian-owned industrial longliners and one locally-owned industrial pole-and-line vessel.		Sources of information: Sisior (2003), Gillett (1999), Chapman (2004).

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Papua New Guinea	Few data are available on subsistence catches of tuna, but 10 percent of the estimated annual subsistence production of 26 000 tonnes is thought to be comprised of pelagic species, including tuna. There is some commercial catch of tuna.	About 3 000 tonnes per year.	In late 2002 there were 40 locally-based longline vessels, a few of which could be considered to be smaller than industrial in scale.	In 2002 the catches of the entire longline fleet were: 1 832 tonnes of YFT, 368 tonnes of BET, 159 tonnes of ALB; 2 359 tonnes total (70 percent YFT).	Sources of information: Gillett (2003).
Pitcairn Islands	The very small amount of fishing by the 47 residents does not target tuna.	Likely to be less than 3 tonnes per year.	None.	None.	
Samoa	During the mid-1990s, trolling for tuna produced about 100 tonnes of tuna per year. The 116 Class-A longline vessels (less than 10 m) caught 2 376 tonnes of tuna in 2001.	About 2 476 tonnes of tuna in 2001 (mostly ALB).	During 2001 the catches of tuna were as follows: 14 Class B-longline vessels (l0 to 12.5 m), 428 tonnes; 8 Class-C longline vessels (12.5 to 15 m), 992 tonnes; 11 Class D-longline vessels (longer than 15 m), 2 383 tonnes.	About 3 800 tonnes of tuna (mostly ALB) were caught in 2001.	The longline fleet contains vessels from 9 m to 25 m. For the purpose of this report, Class-A longline vessels (less than 10 m) are considered to be “small scale”. Sources of information: Sua *et al.* (2003), Watt and Imo (2003), Gillett (2003), staff of AusAID/ Samoa Fisheries Project.
Solomon Islands	Small-scale commercial landings of tuna have been estimated by a fish-marketing specialist to be about 300 tonnes per year. During the mid-1980s, all small-scale landings of tuna (commercial and subsistence) were estimated to be about 10 percent of the entire small-scale fisheries catch. The small-scale commercial and subsistence fish catch (all species) was estimated to be 16 200 tonnes in 2001. There is a private-sector FAD programme.	About 1 600 tonnes per year in recent years.	Although there were 8 longline and 12 pole-and-line vessels operating in late 2002, these are considered to be industrial in scale.		Sources of information: Oreihaka (2002), Gillett (2003), staff of the EU Fisheries Project, Gillett and Lightfoot (2001), Chapman (2004).
Tokelau	There are many part-time subsistence fishers. A large variety of traditional techniques is used, including catching YFT by noose from un-powered canoes. It can be inferred from a study in the late 1980s that the present annual catch of tuna is about 50 tonnes. This is consistent with the information in an SPC report for the mid-1990s.	About 50 tonnes per year.	None.	None.	Sources of information: Gillett and Toloa (1987), Gillett (1985), Dalzell *et al.* (1996), Gillett (1985), Chapman (2004).

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Tonga	Coastal trolling for tuna and other pelagic species is well-established in some fishing communities throughout Tonga, notably on ‘Eua, ‘Atata, Euaiki, ‘Uiha and Ofolaga, but no catch data are available. There are about 10 commercial sport-fishing vessels.	For the purpose of this report, it is assumed that about 50 tonnes of tuna are taken per year.	Of the 33 longliners, 17 are locally-owned or based. About half of the longliners are more than 20 m long.	The longline tuna catch in 2002 was 1 455 tonnes (72 percent ALB).	Sources of information: Ministry of Fisheries (2003), Gillett *et al.* (1998).
Tuvalu	There is no fisheries statistical system, but various projects and studies have made estimates of the fisheries production. The information suggests that the annual small-scale commercial catch of tuna is about 110 tonnes. The subsistence catch of tuna is perhaps twice that amount. Most of the fish are caught by trolling.	330 tonnes, mostly SKJ, per year.	None, except for inter-island trolling by a large government vessel.	Very little.	Sources of information: Gillett and Lightfoot (2001).
Vanuatu	Only very small tuna catches from sport fishing and bottom fishing vessels.	Likely to be less than 10 tonnes per year.	None.	None.	Sources of information: Naviti (2003).
Wallis and Futuna	There is only sporadic trolling outside the reef in Wallis. One FAD was reported off Futuna in late 2003.	Likely to be less than 10 tonnes per year.	None.	None.	Sources of information: Chapman (2004).

APPENDIX 2:

NON-INDUSTRIAL TUNA FISHING IN THE EASTERN PACIFIC OCEAN

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Canada	Recreational, if any.	Probably quite small.	The 150 to 250 vessels that fish for tuna in the eastern Pacific Ocean are divided into two fleets: (1) the coastal trolling fleet, which consists of vessels of 35 to 60 feet (11 to 18 m) in length; and (2) the offshore fleet, which is made up of vessels mostly greater than 60 feet (18 m).	In 2001, 4 826 tonnes of ALB was landed. In 2002, 4 866 tonnes of ALB was landed.	Sources of information: FAO database (Areas 67 and 77), Stocker and Shaw (2003).
Chile	"Artisanal" swordfish vessels are defined as those less than 28 m in length.	Very small or insignificant.	A small amount of ALB, as bycatch of the swordfish fishery, is taken, but most of the bycatch is shark.	In 2000, 100 tonnes of YFT, BET, SKJ and ALB was landed. In 2001, 130 tonnes of YFT, BET, SKJ and ALB was landed.	Tropical tunas are more prevalent during El Niño conditions. Sources of information: Weidner and Serrano (1997), descriptions by IATTC staff; FAO data.
Colombia	Very little fishing targeting tuna.	Probably less than 10 tonnes per year.	About six shrimp boats do some longlining during the off-season, but there is no domestic Colombian commercial longline fleet.		Sources of information: descriptions by IATTC staff, Weidner and Serrano (1997).
Costa Rica	National statistics indicate there are 1 837 vessels in the "flota artesanal", which target tuna or occasionally catch tuna. Almost all of these vessels are outboard-powered, and about 87 percent are less than 10 m in length. They use a variety of gear, but most of the tuna is caught on small longlines and handlines. In addition to tuna, they catch dorado, sharks and marlins.	The following catches have been recorded: 1999: 1 042 tonnes of YFT and BET; 2000: 1 098 tonnes of YFT and BET; 2001: 1 144 tonnes of YFT and BET; 2002: 773 tonnes of YFT and BET. The annual catch is about 1 000 tonnes of YFT and BET.	There are 73 Costa Rica-flag longliners. These range from 10 to 25 m in length. Many vessels target sharks, rather than tuna.	The following catches have been recorded: 1999: 14 tonnes of YFT and BET; 2000: 12 tonnes of YFT and BET; 2001: 16 tonnes of YFT and BET; 2002: 7 tonnes of YFT and BET.	Relatively good statistics because of linking subsidized fuel with the provision of statistics. The small-scale tuna landings are about 10 times those of the longline fleet. Sources of information: national statistics and reports provided by IATTC.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
Ecuador	Various reports indicate that from 5 000 to 15 000 small outboard-powered fibreglass boats catch YFT and BET, using handlines and small longlines. Some operate from the shore, and others are towed offshore by motherships. Dorado are targeted part of the year.	Some fishery specialists believe that somewhat less than half of the 90 000 tonnes Ecuador tuna catch comes from the small-scale operations. This equates to 45 000 tonnes, or 4.5 tonnes per small boat per year. Alternatively, an industry association reported that in recent years the average yearly YFT and BET landings from artisanal vessels to be 7 560 tonnes. In the absence of better data, in this report the catch of tuna by small-scale fisheries in Ecuador is assumed to be 25 000 tonnes, with the recognition that this estimate is little more than an educated guess.	In total, 181 large longliners and 3 pole-and-line vessels are reported. The number of vessels that would fit into the category of "medium scale" is unknown.	There is not enough information to make an estimate.	Only data for the exported tuna is available, but, according to knowledgeable individuals, it is likely that about 90 000 tonnes of tuna are caught per year. It is difficult to partition the estimated 90 000 tonnes of tuna landings into artisanal and industrial components. Sources of information: descriptions by IATTC staff, tuna fishery consultants, Asociación de Exportadores de Pesca Blanca del Ecuador.
El Salvador	About 4 900 vessels (10–12 m) occasionally catch tuna, mainly by longline and handline, but the main target species are corvina, squid and snapper.	Likely to be less than 10 tonnes per year.	Only two to four longliners have been operational during the last few years. The two in 2000 were 22.85 and 20.42 m in length.	The following catches have been recorded in recent years: 2000: 17.9 tonnes of YFT and 11.3 tonnes of BET; 2001: 8.7 tonnes of YFT and 2.6 tonnes of BET; 2002: 20.8 tonnes of YFT and 7.3 tonnes of BET.	The artisanal fleet that catches tuna appears similar to that of Guatemala. Sources of information: official documentation, descriptions by IATTC staff.
Guatemala	Vessels less than 10 m in length appear to be considered "artisanal". There are about 8 340 such vessels that occasionally catch tuna, but the primary targets are dorado, shark, corvina and pargo. Most of the tuna is caught by small-scale longline and gillnet vessels.	These vessels are likely to catch less than 5 tonnes per year.	There are 65 Guatemala-flag longliners, with carrying capacities ranging from 4 to 105 tonnes.	As these vessels do not target tuna, the catches of these are quite small, probably less than 10 tonnes per year.	National statistics coverage of small-scale tuna fishing, but only for the number of vessels. Sources of information: national vessel registry, descriptions by IATTC staff.
Honduras	There is very little fishing targeting tuna.	Probably less than 10 tonnes per year.	Four longliners are larger than 10 m, but do not target tuna.	Probably less than 10 tonnes per year.	Only a very small Pacific coast. Sources of information: descriptions by IATTC staff.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Mexico	There is no readily available information on catches of tuna by artisanal craft on the Pacific coast. Most tuna catches appear to be bycatches of vessels fishing for shark, pargo and bottom fish; the sport-fishing catches of tuna are probably significant near resort areas.	The small vessel handline fishery in Oaxaca state (one of 11 states which border the Pacific Ocean) caught an annual average of 235 tonnes of tuna during 1997-2002. In the absence of better data, in this report the catch of tuna by small-scale fisheries in Mexico is assumed to be 5 000 tonnes.	There are 127 longline and 8 pole-and-line vessels on the Pacific coast of Mexico, but only 2 of the pole-and-line vessels fished in 2002. The IATTC database shows that during 1991-1995 an annual average of 130 tonnes of tuna was caught by other or unknown gear.	The two active pole-and-line vessels caught about 500 tonnes of SKJ and 300 tonnes of YFT in 2002.	Unlike other eastern Pacific countries, most tuna specialists in Mexico seem to focus on individual states, rather than the entire country, and therefore it is difficult to make even a crude estimation of the small-scale tuna catches all along the Pacific coast of Mexico. According to the IATTC staff, a study of the artisanal tuna fisheries will soon begin. Sources of information: descriptions by IATTC staff, G. Compean (per. com.), J. Joseph (per. com.), Instituto Nacional de la Pesca (2001).
Nicaragua	Official documentation indicates three categories of artisanal craft: lancha (inboard engine, with cabin), panga (intermediate), and bote (dugout). There are approximately 4 900 artisanal craft in these three categories that catch tuna, along with dorado and sharks, mostly by small longlines and handlines.	The following catches, consisting mainly of YFT and SKJ, have been recorded: 1999, about 31 000 pounds (14 tonnes); 2000, about 27 000 pounds (12 tonnes); 2001, about 128 000 pounds (60 tonnes). The annual average is about 29 tonnes of YFT and SKJ.	Although there are a many industrial vessels, there appear to be only 42 of these craft that occasionally catch tuna. The others are shrimpers, which catch tuna only sporadically.	The following catches have been recorded: 1999, 6 848 pounds (3 tonnes); 2000, about 24 000 pounds (10 tonnes); 2001, 649 pounds (0.3 tonnes).	The artisanal fleet that catches tuna appears to be similar to that of Guatemala. Sources of information: official documentation, Rivera (2001), descriptions by IATTC staff.
Panama	There are about 6 000 outboard-powered craft less than 12 m in length that target tuna, dorado and sharks. There are several artisanal ports, but hundreds of artisanal landing points. Longlining is the principal technique for catching tuna from these vessels.	About 3 000 to 4 000 tonnes of tuna (mainly YFT) are caught per year.	There are 337 Panama-flag longline vessels, some of which could be medium scale.	It is difficult to distinguish the catches from those of flag-of-convenience vessels.	There are data on the artisanal fleet, other than approximate vessel numbers. Sources of information: verbal communication from national authorities, US import data, descriptions by IATTC staff.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
Peru		During 2002 2 227 tonnes of YFT and 1 920 tonnes of SKJ was landed by artisanal vessels. However, some fishery specialists believe that small-scale tuna fishing may result in catches as great as those in Ecuador. In the absence of better data, in this report the catch of tuna by small-scale fisheries is assumed to be 4 000 tonnes.	There is some industrial longlining and some purse seining.		During 1997-2000 the official data show an annual average of about 3 500 tonnes of YFT and SKJ was landed by the industrial and small-scale fleets. Sources of information: official documentation, descriptions by IATTC staff.
United States	Mainly recreational.	In 2000 recreational fishing resulted about 86 000 ALB, 6 000 PBF and 115 000 YFT being landed in California, Oregon and Washington. At 10 kg per fish, this represents about 2 000 tonnes.	There are commercial fisheries for tuna, using trolling, gillnet, longline, pole-and-line and hook-and-line gear.	In 2001, 11 078 tonnes of ALB, 45 tonnes of BET, 21 tonnes of PBF, 3 tonnes of SKJ, and 19 tonnes of YFT was landed on the US west coast; 11 166 tonnes total.	Sources of information: NOAA unpublished data, Southwest region PACFIN database; NOAA Marine Recreational Fisheries Statistics Survey database.

APPENDIX 3

NON-INDUSTRIAL TUNA FISHING IN THE WESTERN ATLANTIC OCEAN

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Antigua and Barbuda	Most large pelagic fish are caught by sport-fishing vessels. There are about 35 of these vessels, ranging from 6 to 17.5 m in length; some tuna are taken by gillnetting and trolling.	Probably less than 10 tonnes of tuna per year.	Longliners 7 to 15 m in length have been reported to operate in the past.	Presently none.	Sources of information: Looby 2002, Chakalall and Cochrane (2004), Mahon (2004), descriptions by the staff of FAO Subregional Office for the Caribbean.
Argentina	Because of the width of the Argentinean continental shelf, there is probably little, if any, tuna fishing from small vessels.	Likely to be very small.	Although there are 7 longliners operating in Argentina, they target bottom species. No tuna longlining has been reported in recent years.	Little, if any.	No tuna catch reported to ICCAT during 1998-2002. Sources of information: ICCAT database, FAO fishery country profile.
Bahamas	Fishing effort is directed primarily at demersal resources, but some large pelagic fish are caught by trolling. There is both commercial and private sport fishing.	Probably less than 50 tonnes per year.	Longlining has been banned, because of perceived conflicts.	Probably none.	During 1986-1996 an annual average of 62 tonnes of YFT was caught in the Bahamas zone by all types of fishing. Sources of information: Chakalall and Cochrane (2004), Die (2004), descriptions by staff of FAO Subregional Office for the Caribbean, staff of the CARICOM Fisheries Unit.
Barbados	Three classes of vessels, day boats (decked), ice boats (decked) and longliners, occasionally catch tuna. The first two classes of vessels catch tuna mostly by troll and gillnet gear. There are about eight commercial sport-fishing operations.	Tuna represents about 5 percent of the total fish landings of about 2 500 tonnes in the Barbados. In 2002 the three smaller classes of vessels caught about 20 tonnes of tuna, about 90 percent of which was YFT.	The 31 local longliners are mostly 45 to 55 feet (14 to 17 m) in length, and are responsible for about 85 percent of the Barbados tuna catch.	About 105 tonnes in 2002.	During the 1990s annual averages of 7 tonnes of SKJ and 156 tonnes of YFT were reported to FAO. Locally, "tuna" commonly does not include SKJ, which is often reported as bonito. Sources of information: Barbados Fisheries Division officials; FAO documents.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Belize	The number of undecked boats with outboard engines is unknown. Because of the extensive reef system, there is little offshore fishing by small-scale vessels. There is some gillnetting, but this targets Scomberomorus. There is some sport fishing by both local residents and tourists.	Probably less than 10 tonnes per year.	Although there are a many Belize-registered longliners (reportedly about 900 flag of convenience vessels), only one longliner, less than 15 m in length, was reported to be operating in 2001.	Probably less than 10 tonnes of tuna is landed per year.	Sources of information: Chakalall and Cochrane (2004); Mahon (2004), descriptions by the staff of FAO Subregional Office for the Caribbean.
Brazil	For statistical purposes, "artisanal" is defined to be fishing from boats less than 12 to 15 m in length, and less than 20 GRT.	The tuna landings by artisanal fisheries in 2000 were: YFT, 13 tonnes; ALB, 175.5 tonnes; SKJ, 22 tonnes; Thunnus spp., 1 197.5 tonnes; "bonito" (SKJ, Auxis spp., Euthynnus alleteratus, or Sarda sarda), 1 958.5 tonnes. Depending on the composition of the "bonito" category, the above could perhaps represent about 2 000 tonnes of tuna.	Because "artisanal" includes vessels up to 15 m in length, that category probably encompasses most non-industrial tuna fishing. There is a pole-and-line fishery in Brazil, but the size of the participating vessels is not readily available.	The pole-and-line fishery catches about 25 000 tonnes per year (85 percent SKJ).	Sources of information: Freire (2004), FAO/FIRM tuna database.
Canada	Fishing by harpoon, rod and reel and trapping was reported to ICCAT.	For these gears, an average of 477 tonnes per year during 1998-2002 was reported to ICCAT from the northwest Atlantic, of which about 96 percent was BFT and 3 percent BET.	Gillnetting is considered to be in this category. It was not possible to partition longliners by size. For the purpose of this study, Canadian longliners are all considered to be industrial.	Gillnetting did not produce any catch by Canadian vessels during 1998-2002.	Source of information: ICCAT database.
Colombia	A few small longliners operate, primarily for sharks.	ICCAT data show that "unclassified" gear has taken 46 to 50 tonnes of YFT per year during recent years.	Little, if any.		Although Colombia has tuna resources, these are located predominantly on the Pacific Ocean. Sources of information: ICCAT database, FAO fishery country profile, NMFS web site "World Swordfish Fishery".
Costa Rica	There is very little tuna fishing on the Caribbean coast; but there is some commercial sport fishing.	0.72 tonnes of tuna was landed in 1992.	Little, if any.		Sources of information: government summary of unloading; sport fishing web sites.
Cuba	Three FADs were reported in 2001.	A catch of 15 tonnes of YFT was reported from sport fishing in 1999. "Unclassified gear" caught YFT during most of the 1990s (40 tonnes in both 1996 and 1997).	42 pole-and-line and longline vessels were reported in 2001. The pole-and-line vessels are about 18 m in length. Blackfin tuna makes up about one-third of the pole-and-line catch. Longliners target marlin and shark, but catch few tuna.	During 1998-2000, an annual average of 651 tonnes of SKJ was reported caught by the pole-and-line fleet. No catch was reported in 2001 or 2002. 65 tonnes of YFT was reported caught by longline gear in 2002.	Sources of information: Martin (2002), ICCAT database.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
Dominica	961 artisanal vessel fished for coastal pelagic fish in 2001, One commercial and two private sport fishing vessels were reported in 2002.	367 tonnes of "migratory pelagics" were reported caught in 1998. If one-quarter of these were tuna, and half of that was caught by artisanal vessels, the artisanal tuna catch would be about 45 tonnes per year.	Three longline vessels were reported in 2001.	The catch included in the 367 tonnes of "migratory pelagics" caught in 1998; perhaps 45 tonnes of tuna caught by longliners.	During 1998-2002 an annual average of 150 tonnes of tuna (60 percent YFT and 40 percent SKJ) was reported to ICCAT. Sources of information: Sebastian (2002), FAO database, Chakalall and Cochrane (2004).
Dominican Republic	The "professional artisanal fishery" has vessels that fish in oceanic waters as far offshore as 40 km. The annual catch of these vessels ranges from 2 to 8 tonnes per vessel, of which an unknown percentage is tuna. There is some commercial sport fishing. There is a report of an increase in the use of FADs recently.	For the purpose of this report, the catch from small-scale tuna fishing is assumed to be about 250 tonnes per year.	For the purpose of this report, the catch from this category of tuna fishing is assumed to be about 250 tonnes per year.		According to the ICCAT database, "surface fisheries unclassified" have resulted in annual landings of about 255 tonnes of tuna during 1998-2002. The CARICOM Fisheries Unit reports 446 tonnes and 528 tonnes of tuna. According to a recent survey, large pelagic fish (king mackerel, bluefin tuna, wahoo, dolphin, barracuda, yellow fin tuna) make up 33 percent of the fish catch of the country, which, according to the FAO profile, is 11 579 tonnes per year. Sources of information: FAO country profile, ICCAT database, sport fishing web sites, Brown (2000), Singh-Renton (2002).

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
France (French Guiana, Guadeloupe, Martinique, St. Barthelemy and St. Martin)	In Guadeloupe the following categories of boats were involved in tuna fishing: 758 small boats, 8 coastal boats, and one open ocean boat in 2000. Trolling targets dorado and wahoo, but YFT makes up about 25 percent of the catch around FADs. In Martinique there were 869 small boats, 41 coastal boats, and 32 open-ocean boats in 2000. In 1993 the pelagic trolling catch was about 25 percent YFT and/or SKJ.	In Martinique in 1993 about 3 230 tonnes of fish was caught by trolling. Due to influence of the Amazon River, it is likely that there is very little tuna fishing off French Guiana. A crude estimate of the annual tuna catch by trolling in all these areas is about 1 200 tonnes.	No information available.		A crude estimate was obtained by extrapolating one source of limited information, Martinique, to the other islands. No tuna catches have been reported to FAO/ ICCAT from this area since the 1970s. Source: Diaz *et al.* (2002), Doray *et al.* (2002), descriptions by the staff of the FAO Subregional Office for the Caribbean.
Grenada	About 500 open boats with outboard engines and 30 medium longliners were reported in 2001. The following numbers of boats were involved in tuna fishing: 215 open pirogues (trolling), 75 small open longliners, and 30 medium longliners (less than 32 feet (10 m). The Grenada Fisheries Division reported about 150 small longliners in November 2003. Beach seining, which takes place throughout the year, catches juvenile YFT and SKJ.	The catch is about 4.5 tonnes of tuna per small longliner per year, or about 600 tonnes per year for the small longline fleet. The troll catch is unknown, but assumed for this report to be 1 tonne per pirogue per year, or a fleet total of 200 tonnes per year. A crude annual estimate is 800 tonnes for the small longliners and trolling pirogues.	There are 63 longliners, 34 to 60 feet (10 to 18 m) in length. The Grenada Fisheries Division reports 65 such longliners in November 2003.	About 40 000 to 50 000 pounds (18 to 23 tonnes) per vessel per year. Assuming that not all vessels are fully operational, the catch is about 1 000 tonnes per year for the fleet.	During the 1990s annual averages of 15 tonnes of SKJ, 360 tonnes of YFT, 3 tonnes of ALB and 8 tonnes of BET were reported to FAO (386 tonnes average annual total). During 2000-2002 an annual average of about 600 tonnes is given in the ICCAT database. NMFA reports that 356.6 tonnes of YFT and BET were exported from Grenada to the United States in 2002. Sources of information: Baldeo (2002), Mahon (2004), information from Grenada Fisheries Division staff, the staff of the CARICOM Fisheries Unit, FAO/ICCAT databases, US National Marine Fisheries Service import database.
Guatemala	Little, if any tuna fishing on Caribbean coast No catch is reported in the FAO/ICCAT databases.	Probably none.	Little, if any, such tuna fishing on Caribbean coast.	Probably none.	Sources of information: FAO/ICCAT databases, descriptions by the staff of the FAO Subregional Office for the Caribbean.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Guyana	There is almost no directed tuna fishing, but some could be caught in conjunction with other fishing activities. There are no catch reports in the FAO/ICCAT databases. Large pelagic fisheries are "just now developing" according to a recent report.	Probably less than 5 tonnes per year.	Almost no tuna fishing.	Probably none.	Sources of information: FAO/ICCAT databases, descriptions by the staff of the FAO Subregional Office for the Caribbean, the staff of the CARICOM Fisheries Unit.
Haiti	No information is readily available. 36 percent of fishers in a recent survey claim to do some tuna fishing, but the survey report notes that this may express desire, rather than actuality.	Tuna resources are likely to bear some similarity to those of the Dominican Republic. For the purpose of this report, the small-scale tuna catches are assumed to be the same as those of the Dominican Republic, about 255 tonnes per year.	Due to lack of capital and infrastructure, there is likely to be little, if any, tuna fishing of this scale.		There are no catch reports in FAO/ICCAT databases; no exports to United States recorded; no FAO fishery country profile. There is some information in CRFM (2004).
Honduras	Some sport fishing has been reported.	The catches are likely to be less than 10 tonnes per year.	There is little, if any, such tuna fishing.		No tuna catches are reported to FAO/ICCAT. There are no reports of artisanal or industrial tuna fishing in FAO fishery country profile. Sources of information: FAO/ICCAT databases, sport fishing web sites.
Jamaica	475 open boats with outboard engines were reported in 2001. There is some gillnetting and trolling for pelagic fish. According to the ICCAT database, in 1996 "unclassified fishing gear" caught 62 tonnes of SKJ and 21 tonnes of YFT. Some sport fishing takes place.	For the purpose of this report, small-scale tuna catches are assumed to be 40 tonnes per year.	There is little, if any, such tuna fishing.		An annual average of 13 tonnes of YFT was caught in the Jamaica zone during 1986-1996 by all fishing methods. Sources of information: Die (2004), Mahon (2004), Aiken (1993), descriptions by the staff of the FAO Subregional Office for the Caribbean, the staff of the CARICOM Fisheries Unit, ICCAT database.
Mexico	Although some of the longliners are reported to be small, for the purpose of this report, no longline fishing is considered to be in the category of small-scale.	None.	The typical longliner is greater than 10 GRT and carries from 6 to 18 crew members.	An annual average of 1 224 tonnes of tuna (about 90 percent YFT) was taken by Mexican longline gear in the Gulf of Mexico during 1997-2002.	Sources of information: ICCAT database, G. Compean (per. com.), Instituto Nacional de la Pesca (2001).

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Nicaragua	Little, if any.	No tuna were caught in 2000.	Little, if any.	No tuna were caught in 2000.	Source of information: Rivera (2001).
Panama	According to the FAO fishery country profile, 95 percent of the fishing activity in Panama occurs in the Pacific Ocean. What little artisanal fishing occurs in the Caribbean Sea is directed primarily at lobster, octopus, crab and shrimp.	Probably none.	Probably none.		ICCAT records no tuna catches by Panamanian vessels during the past 20 years. Source of information: FAO fishery country profile.
St. Kitts and Nevis	Large pelagic fish are caught by sport fishing and small-scale commercial fishing, mainly with trolling gear. There are 55 open boats with outboard engines that participate in commercial fishing. There are 13 commercial and 13 private sport-fishing vessels. Recent increases in tuna landings are attributed to increasing use of FADs.	St. Kitts alone recorded an annual average of about 4.8 tonnes of "tuna/mackerel" during 1995-2000. Probably about 5 tonnes are landed per year.	There is no record of any medium-scale fishing. In addition, there is no safe harbour or facilities for larger boats, and there is a cultural aversion to multi-day trips.		Sources of information: Mahon (2004), Die (2004), Heyliger (2002), descriptions by the staff of the FAO Subregional Office for the Caribbean, ICCAT database, Singh-Renton (2002).
St. Pierre and Miquelon	The 1 tonne of BFT reported to ICCAT is likely to be from rod-and-reel fishing. No catches have been reported in any other years.	Probably none at present.	None.		In 1999, 1 tonne of BFT was reported to ICCAT. Source of information: ICCAT database.
St. Lucia	There are about 835 open vessels with outboard engines, plus about 20 to 30 commercial sport-fishing vessels. An annual average of 332 tonnes of SKJ and YFT was landed during 1997-2001 by all gear types (trolling and longlining), of which 53 percent was SKJ and 47 percent was YFT. Beach seining, which catches juvenile YFT and SKJ, takes place throughout the year.	From the amount of SKJ in the catch, it can be estimated that about 300 tonnes of tuna per year comes from trolling.	Four longliners in the size range of 7 to 15 m.	From the amount of SKJ in the catch, it can be estimated that about 30 tonnes of tuna per year comes from longlining.	Sources of information: FAO database, James (2002), Mahon (2004), descriptions by the staff of the FAO Subregional Office for the Caribbean, descriptions by the staff of the CARICOM Fisheries Unit.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
St. Vincent and the Grenadines	There is a total of about 600 fishing vessels in the country. Flat transom boats, pirogues, canoes and launches participate in commercial tuna fishing. There are four commercial sportfishing vessels. Beach seining, which catches juvenile YFT and SKJ, takes place throughout the year.	The proportion of the 181 tonnes of tuna that came from small-scale fishing is unknown. For the purpose of this report, it is assumed to be half, or about 90 tonnes, per year.	There are some longliners, ranging between 34.7 and 42 feet (11 and 13 m).	The proportion of the 181 tonnes of tuna that came from longlining is unknown. For the purpose of this report, it is assumed to be half, or about 90 tonnes, per year.	In the 1990s an annual average of 41 tonnes of SKJ, 38 tonnes of YFT and 1 tonne of BET was reported to FAO (annual average of 181 tonnes of all tuna). Sources of information: James (2002), Die (2004), descriptions by the staff of the FAO Subregional Office for the Caribbean, descriptions by the staff of the CARICOM Fisheries Unit, Singh-Renton (2002).
Suriname	Artisanal fishing is defined as operations that take place in depths less than 10 m, implying there is no artisanal tuna fishing in Suriname.	Probably none.	Two longliners more than 15 m in length.	An annual average of 76 tonnes of YFT was caught around Suriname during 1986-1996 by all fishing methods.	Sources of information: FAO fishery country profile, Die (2004), Mahon (2004), descriptions by the staff of the FAO Subregional Office for the Caribbean.
The Netherlands Antilles (Aruba, Bonaire, Curacao, Saba, St. Eustatius and St. Maarten)	About 100 fishing vessels less than 12 m length operated in 2001.	Judging from the proportion of SKJ in the total tuna catch reported to ICCAT, the annual small-scale troll catch of tuna is likely to be about 60 tonnes.	Six semi-industrial longliners more than 12 m in length were reported in 2001. From the catch composition, it appears that this fleet targets swordfish.	Judging from the proportion of SKJ in the total tuna catch reported to ICCAT, the annual longline catch of tuna is likely to be about 70 tonnes.	During 1996-2000, an annual average of 30 tonnes of SKJ and 130 tonnes of YFT (both from "unclassified fishing gear") was reported to ICCAT. Sources of information: Dilrosun (2002), Die (2004), descriptions by the staff of the FAO Subregional Office for the Caribbean.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
Trinidad and Tobago	There are many open outboard-powered boats. Pelagic fishing targets wahoo, seerfish and sharks, and tuna are not often caught. In addition, the lack of SKJ in the catch statistics suggests that the catch of tuna by trolling is small.	Probably less than 10 tonnes per year.	14 longliners between 7 and 15 m in length and 4 longliners more than 15 m in length.	Judging from past statistics, about 380 tonnes per year in recent years.	During the 1990s annual averages of 161 tonnes of YFT, 155 tonnes of ALB and 62 tonnes of BET were reported to FAO (annual average of 378 tonnes of all tuna). Sources of information: Lalla (2002), Die (2004), descriptions by the staff of the FAO Subregional Office for the Caribbean.
UK -Virgin Islands	A 1991 survey found that there were about 300 artisanal fishermen operating in British Virgin Islands waters. Most artisanal fishing is carried out on the continental shelf, with very little tuna fishing being undertaken. About 60 commercial and private sport-fishing operations were licensed during the mid-1990s. Many of these target inshore and slope species. Much of sport fishing in British Virgin Islands is foreign-based.	During 1997-2001 from 1 to 3 tonnes of YFT were reported to FAO. The present catches are not likely to be greater than about 5 tonnes per year.	Two locally based longliners started operating in the British Virgin Islands in 1985 and 1992. Their present status is unknown, but low catch reports to FAO (less than 5 tonnes of tuna per year) suggest that the longliners are not active in tuna fishing.	Probably none.	Sources of information: Development Planning Unit (1997), FAO database.
UK – Bermuda	Sport fishing is quite important. BFT were occasionally caught in the past, but are rare now. It is likely that the "unclassified" catches are also rod-and-reel catches.	Rod-and-reel and "unclassified" gear types resulted in 37 to 67 tonnes of YFT per year during the past decade. No data are available for 2000.	34 tonnes of YFT longline-caught were reported in 2000, but the catch decreased to 1 tonne in 2001.	Little, if any.	Sources of information: ICCAT database, Bermuda on-line web site.
Other UK possessions in the tropical western Atlantic **(Anguilla, Cayman Islands, Montserrat, Turks and Caicos Islands)**	Fishing is likely to be quite small, and limited to the bycatch of other types of small-scale fishing activities and sport fishing.	Not likely to be greater than 5 tonnes per year.	No information is readily available on such fishing.	Little, if any.	Source of information: descriptions by the staff of the FAO Subregional Office for the Caribbean.
USA **(northwest Atlantic)**	Fishing by handlines, rod-and-reel, trapping and trolling was reported to ICCAT.	An average of 5 077 tonnes per year from the northwestern Atlantic Ocean during 1998-2002 was reported to ICCAT. This consisted of about 71 percent YFT, 22 percent BFT and 6 percent ALB.	Gillnetting is considered to be in this category. As it was not possible to partition the longliners by size, for the purpose of this study, the longliners are all considered to be industrial.	There were no catches of tuna by gillnetting during 1998-2002.	Sources of information: ICCAT database, U.S. National Marine Fisheries Service annual landings web site.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
USA (western tropical Atlantic, Gulf of Mexico)	Fishing by handlines, rod-and-reel, trapping and trolling was reported to ICCAT.	An average of 300 tonnes per year from the western tropical Atlantic Ocean and the Gulf of Mexico during 1998-2002 was reported to ICCAT. This consisted of about 86 percent YFT and 13 percent SKJ.	Gillnetting is considered to be in this category. As it was not possible to partition the longliners by size, for the purpose of this study, the longliners are all considered industrial.	Gillnetting has produced between 1 and 3 tonnes per year during recent years.	Sources of information: ICCAT database, U.S. National Marine Fisheries Service annual landings web site.
Uruguay	No information on any small-scale tuna fishing is available.	Little, if any.	There are 5 to 9 longliners targeting swordfish. 54.6 tonnes of fresh YFT and BET were exported to the United States in 2002.	Catches of 15 to 224 tonnes of YFT, BET and ALB were reported to ICCAT annually during 1998-2002.	Sources of information: Dinara (2000), U.S. National Marine Fisheries Service fish import web site, seafood industry web sites.
Venezuela	About 35 small gillnet vessels (7 to 10 m in length) make daily trips. The 2001 tuna catch consisted 15.4 tonnes of YFT, ALB and SKJ. About 70 to 75 vessels 9 to 14 m in length, which make 5 to 20 day trips, use handlines and pelagic longlines with 400 to 600 hooks. The 2001 tuna catch consisted of 68.5 tonnes of YFT, ALB and blackfin. According to sport fishing web sites, there is some sport fishing for tuna in the Venezuela. A yacht club on the central coast recorded the capture of 651 YFT during 1990-2000.	About 80 tonnes.	The U.S. National Marine Fisheries Service reported that 564 tonnes of fresh YFT and BET was imported into the United States during 2002. No information is readily available on the sizes of the longliners.	During 1998-2002, annual longline catches of 266 to 561 tonnes were reported to ICCAT.	Sources of information: ICCAT database, U.S. National Marine Fisheries Service fish import web site, sport fishing web sites, FAO fishery country profile, Alio *et al.* (1994), Marcano *et al.* (1994), J. Alio (per. com.), F. Arocha (per. com.), Venezuela's National Report to ICCAT in 2002.

APPENDIX 4

NON-INDUSTRIAL TUNA FISHING IN THE EASTERN ATLANTIC OCEAN

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Angola	No small-scale fishing has been reported to ICCAT in recent years. Although the artisanal fisheries are very important in Angola (30 percent of all fish landings, 23 000 registered artisanal fishermen, 4 677 small fishing boats), there is little, if any, fishing effort directed at tuna.	Probably less than 20 tonnes per year.	Trap and unclassified gear were reported to ICCAT in recent years. Although catches by pole-and-line boats are reported, these are not included in the catch details to the right. For the purpose of this report, all pole-and-line fishing is considered to be industrial.	During 1998-2002, these gear types produced an annual average of 3 tonnes of YFT and SKJ (71 percent YFT).	Sources of information: ICCAT database, Hampton *et al.* (2000).
Benin	No small-scale tuna fishing have been reported to ICCAT in recent years.	Assumed to be none.	Gillnet and "haul seine" gear have been reported to ICCAT in recent years. ICCAT's "haul seine" appears to be the "sennes tournante" described by FAO.	During 1998-2002, these gear types produced an annual average of 18 tonnes of YFT, SKJ and BET (60 percent BET).	Sources of information: ICCAT database, FAO fishery country profile.
Cameroon	No small-scale tuna fishing has been reported to ICCAT. Most small-scale marine fishing takes place within 3 nautical miles of estuaries, where catching tuna is unlikely. Shrimp and Sardinella spp. fisheries predominate.	Assumed to be none.	No tuna catch has been reported to ICCAT.	Assumed to be none.	Sources of information: ICCAT database, FAO fishery country profile.
Cape Verde	The only small-scale tuna fishing reported to ICCAT in recent years is by handline gear. The artisanal fleet typically uses 4 to 8 m wooden boats with 8 to 25 horsepower outboard engines. There are about 1 500 boats, each with two or three men aboard. They fish close to the coast, and the main fishing gears are handlines for demersal fish and tuna, and purse-seines for small pelagic fish.	During 1998-2001 (no data are available for 2002), this gear produced an annual average of 1 308 tonnes of YFT and SKJ (97 percent YFT).	Although there is a significant amount of pole-and-line fishing (recently about 950 tonnes of tuna per year), this is considered to be industrial scale, as the vessels are up to 70 GRT, and fish as far away as Angola.		Sources of information: ICCAT database, Fonteneau and Marcille (1993), Fonseca (1999).

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Congo	No small-scale fishing has been reported to ICCAT in recent years. Although there are significant artisanal marine fisheries using large canoes (many fishermen originate from Ghana and Togo). Sardinella spp. and demersal species are targeted.	Assumed to be none.	No catches have been recorded by ICCAT in recent years. From the mid-1960s to the early 1990s some tuna catch, using "unclassified gear" was recorded.	Assumed to be none in recent years.	Sources of information: ICCAT database, FAO fishery country profile.
Democratic Republic of the Congo	The coastline is only about 40 km long (160 km if the mouth of Congo River is included), and the EEZ is very small compared to those of the other African coastal countries. Furthermore, much of the small EEZ is reserved for oil production. The little marine artisanal fishing that occurs, targets near-shore species.	Assumed to be none.	None recorded by ICCAT.	Assumed to be none.	Sources of information: ICCAT database, SADC (1999), FAO fishery country profile.
Denmark	No small-scale tuna fishing has been reported to ICCAT in recent years.	Assumed to be none.	Only catches by "unclassified gear" have been reported to ICCAT in recent years.	Except for 1 tonne of BFT in 1998, no tuna catches in this category have been reported recently. The ICCAT database also gives an estimate of 23 tonnes of YFT in 2001 for unreported catches by longline vessels.	Source of information: ICCAT database.
Equatorial Guinea	No small-scale tuna fishing has been reported to ICCAT in recent years. Small-scale fishers typically fish from canoes within 4 nautical miles of the coast, and target Sardinella spp. and Ethmalosa spp.	Assumed to be none.	Only catches by longline gear have been reported to ICCAT in recent years. The ICCAT database also gives an estimate of unreported catches of 780 tonnes of BET and YFT during 2001.	ICCAT has received reports of longline catches of 1 tonne of BET in 1997 and 16 tonnes of BET in 2002.	Sources of information: ICCAT database, FAO fishery country profile.
Faroe Islands	No small-scale tuna fishing has been reported to ICCAT in recent years.	Assumed to be none.	Tuna catches by longline gear have been reported to ICCAT during recent years.	During 1998-2002 (no catches reported for 2001 or 2002), longline gear produced an annual average of 58 tonnes of YFT and BFT (99 percent BFT).	Source of information: ICCAT database.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
France	Tuna catches by "surface fisheries unclassified" have been reported to ICCAT in recent years.	During 1998-2002, this gear produced an annual average of 17 tonnes of ALB.	Tuna catches by gillnet and unclassified gear have been reported to ICCAT in recent years. Because of EU regulations, drift gillnet fishing has been banned since 2002. Although catches by pole-and-line boats are reported (about 16 000 tonnes of tuna in 2002), this is not included in the catch details to the right. For the purpose of this report, all pole-and-line fishing is considered to be industrial.	During 1998-2002, these gear types produced an annual average of 1 966 tonnes of ALB, BET, BFT and SKJ (92 percent ALB, mostly by gillnet). The ICCAT database gives an estimate of unreported catches of 515 tonnes of BET in 2001 by longline vessels registered in "France OT".	Sources of information: ICCAT database, Miyake *et al.* (2004).
Gabon	Tuna catches by "surface fisheries unclassified" and troll gear have been reported to ICCAT in recent years. It has been estimated that the entire marine artisanal fleet (including those that do not catch tuna) consists of 3 500 fishermen and 1 047 canoes.	During 1998-2002, this gear produced an annual average of 79 tonnes of BET, YFT and SKJ (44 percent YFT, mostly by surface unclassified gear).	Tuna catches by gillnet and unclassified gear have been reported to ICCAT in recent years.	During 1998-2001 (no catch reported for 2002), these gear types produced an annual average of 212 tonnes of YFT, BET and SKJ (61 percent YFT, mostly by unclassified gear).	Source of information: ICCAT database.
Gambia	The ICCAT database does not show any reported tuna catches for Gambia. Gambia is a small country stretching along the banks of the River Gambia, and has only a short coastline. The marine fisheries resources are greatly influenced by the freshwater flow from the river, and hence large tuna catches would not be expected near shore.	During 1998-2001, an annual average of 2 tonnes of YFT was reported to FAO.	Although the ICCAT database does not show any reported tuna catches from Gambia, it gives an estimate for unreported catches of 383 tonnes of BET by longline vessels registered in Gambia in 2002.		Sources of information: ICCAT database, FAO fishery country profile.
Ghana	Fonteneau and Marcille (1993) report a very active artisanal tuna fishery, consisting of "multiple fishing gears: ringnets, gillnets, trollers, beach seines etc.". It is stated that "the artisanal fleets of Ghana are probably among the most ancient to have exploited Atlantic intertropical tuna".	Tuna catches by only "surface fisheries unclassified" have been reported to ICCAT in recent years. ICCAT staff members have stated that this unclassified gear is actually purse-seine gear. Therefore, according to the ICCAT data, there is no catch of tuna by small-scale gear.	Although there is a significant pole-and-line fishery, most vessels are more than 30.5 m long, with engines of 400 horsepower or more. This fleet is therefore considered industrial, for the purpose of this study.		Sources of information: ICCAT database, ICCAT staff, Fonteneau and Marcille (1993), Fonteneau (per. com.), FAO fishery country profile.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
Guinea	The ICCAT database does not list any reported tuna catches from Guinea. The FAO database indicates a catch of 330 tonnes of BFT in 1994; no other tuna catches were recorded for 1950-2001. According to the FAO profile, the tuna resources of Guinea have not been evaluated or economically developed. Although there is an active marine artisanal fishery (2 358 boats), the main target species are Sardinella spp. and Ethmalosa spp.	Probably very little, if any.	The ICCAT database does not list any reported tuna catches from Guinea. The ICCAT database gives an estimate for unreported catches of 1 412 tonnes in 1998 and 1 870 tonnes in 1999 by longline vessels registered in Guinea.		Sources of information: FAO database, FAO fishery country profile.
Guinea Bissau	Neither the ICCAT nor the FAO databases list any tuna catches from Guinea Bissau. According to the FAO profile, there are 107 fishing vessels in the archipelago, 29 of which are motorized. Most of the catch is reported to be "big and small demersals, pelagics and shrimps".	Probably very little, if any.	The ICCAT database gives an estimate of unreported catches of 1 652 tonnes of BET by longline vessels in 2001.		Source of information: FAO fishery country profile.
Iceland	No small-scale tuna fishing has been reported to ICCAT in recent years.	Assumed to be none.	Tuna catches only by longline gear have been reported to ICCAT in recent years.	During 1998-2002, this gear produced an annual average of 6 tonnes of BFT. No other species was reported.	Source of information: ICCAT database.
Ireland	Tuna catches by trolling gear have been reported to ICCAT in recent years.	During 1998-2002, this gear produced an annual average of 22 tonnes of ALB and BET (98 percent ALB).	Tuna catches by gillnet and longline gear have been reported to ICCAT in recent years. Because of EU regulations, drift gillnet fishing has been banned since 2002. The ICCAT database gives an estimate of unreported catches of 39 tonnes of BET by longline vessels in 2001.	During 1998-2001, gillnet gear produced an annual average of 3 243 tonnes of ALB, YFT and BFT (more than 99 percent ALB). Longline gear has not produced any catches since 1999, when it produced 1 tonne of BFT.	Sources of information: ICCAT database, Miyake *et al.* (2004).
Côte d'Ivoire	No small-scale tuna fishing has been reported to ICCAT. Although there is an active marine artisanal fishery (about 30 000 tonnes per year; 3 500 large canoes), tuna are apparently not targeted.	Assumed to be none.	Some tuna catch by "unclassified gear" has been reported.	2 tonnes of YFT was reported for 1997; this is the only record in the ICCAT database of any tuna catches in the Ivory Coast.	Sources of information: ICCAT database, FAO fishery country profile.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
Liberia	The ICCAT database does not show any small-scale tuna catches from Liberia. There is an active marine artisanal fishery by both indigenous Kru fishermen and Fanti fishermen of Ghanaian descent, but tuna are apparently not targeted.	Assumed to be none.	The ICCAT database does not show any tuna catches from the Liberia, but the FAO database gives some catches.	Probably none from non-industrial vessels.	Sources of information: ICCAT database, FAO fishery country profile.
Mauritania	Neither the ICCAT nor the FAO databases list any tuna catches from Mauritania. There is an active marine artisanal fishery (10 000 fishermen; 3 000 canoes), but tuna are apparently not targeted.	Assumed to be none.		Assumed to be none.	Sources of information: ICCAT database; FAO fishery country profile.
Morocco	The ICCAT database does not show any small-scale tuna catches from the Atlantic coast of Morocco. There is an active marine artisanal fishery (18 000 vessels), but tuna are apparently not targeted.	Assumed to be none.	Tuna catches by gillnet, trap and unclassified gear have been reported to ICCAT in recent years. Although catches by pole-and-line vessels are reported, these are not included in the catch details to the right. For the purpose of this report, all pole-and-line fishing is considered to be industrial.	During 1998-2002 the ICCAT database shows an annual average of 2 297 tonnes of BFT, BET, ALB and YFT (70 percent BFT, mostly by trap).	Sources of information: ICCAT database, FAO fishery country profile.
Namibia	The ICCAT database does not show any small-scale tuna catches from Namibia.	Assumed to be none.	Tuna catches by only longline gear have been reported to ICCAT in recent years. Although catches by pole-and-line boats are reported (recently an annual average of 2 600 tonnes), this is not included in the catch details to the right. For the purpose of this report, all pole-and-line fishing is considered to be industrial.	During 1998-2002, this gear produced an annual average of 224 tonnes of YFT, BET and ALB (74 percent ALB).	Source of information: ICCAT database.
Nigeria	Neither the ICCAT nor the FAO databases lists any tuna catches from Nigeria. According to the FAO profile, the artisanal canoe fleet exploits coastal waters up to 5 nautical miles from shore, targeting small pelagic fish (Sardinella spp. and Ethmalosa spp.). Although some shark longlining occurs farther offshore, the catch of tuna is very small, if any.	Assumed to be none.	According to the FAO profile, Nigeria, because of technical constraints, is not actively participating in the exploitation of the offshore tuna resources.	Assumed to be none.	Sources of information: ICCAT database, Ssentongo *et al.* (1986), FAO fishery country profile.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Portugal	Tuna catches by handline, trolling and unspecified surface gear have been reported to ICCAT in recent years.	During 1998-2002, this gear produced an annual average of 1 236 tonnes of BET, BFT, ALB, YFT and SKJ (97 percent BET, mostly by unspecified surface gear).	Tuna catches by longline and trap gear have been reported to ICCAT in recent years. Although catches by pole-and-line gear are reported, this is not included in the catch details to the right. For the purpose of this report, all pole-and-line fishing is considered to be industrial.	During 1998-2002, longline gear produced an annual average of 1 963 tonnes of BET, BFT, ALB, YFT and SKJ (85 percent BET). During 1998-2002, trap gear produced an annual average of 6 060 tonnes of BFT.	Catches by Portugal reported in both north Atlantic, south Atlantic, and Azores areas. Source of information: ICCAT database.
Saint Helena (UK)	Tuna catches by only "rod and reel" have been reported to ICCAT in recent years.	During 2001-2002, this gear produced an annual average of 20 tonnes of BET (no other species reported).	In recent years only longline gear catches have been reported to ICCAT.	During 2001-2002, this gear produced an annual average of 1 tonne of YFT (no other species reported).	Source of information: ICCAT database.
São Tomé et Principe	Tuna catches by "unclassified surface gear" have been reported to ICCAT in recent years. According to the FAO profile, the artisanal fishing fleet is made up of 2 400 canoes based on 19 beaches on São Tomé and 4 beaches on Principe.	During 1998-2002, this gear produced an annual average of 2 tonnes of YFT (no other species recorded). According to the ICCAT database, the reported annual catches were much greater during the 1980s and early 1990s than at present (e.g. 227 tonnes per year during 1983-1992).	In this category, the only tuna catches reported to ICCAT were by "unclassified" gear. According to the FAO profile, the semi-industrial fleet was made up of six seiners (13 to 16 m), 5 longliners (12 m) and 21 "ligneurs" (13 m).	During 1998-2002, the "unclassified" gear produced an annual average of 38 tonnes of BFT (no other species recorded). The ICCAT database also gives an estimate of unreported catches of 1 934 tonnes of BET and YFT by longline vessels in 2001.	Sources of information: ICCAT database, FAO fishery country profile.
Senegal	According to Fonteneau and Marcille (1993), the Senegalese artisanal tuna fishery has been catching tuna for several centuries, and is "currently very active and well-covered by fishing statistics". There are other reports that the artisanal fleet is experiencing "dynamic growth", and that YFT is part of the catch.	Although tuna catches using hand, surface-unspecified and troll gears have been reported to ICCAT in previous years, no catches from these gears were reported during 1998-2002, nor in the national statistics for 1996-2002.	No tuna catches by gear in this category were reported to ICCAT during 1998-2002. The pole-and-line fleet caught an annual average of 1 823 tonnes of tuna during 1998-2002, but this fleet is considered to be industrial for the purpose of this report.		Sources of information: ICCAT database, FAO fishery country profile, Fonteneau and Marcille (1993), Anonymous 1998, Hallier (per. com.).
Sierra Leone	The ICCAT database does not show any small-scale tuna catches from Sierra Leone. There is considerable artisanal fishing activity, with about 7 000 canoes fishing in the 3 to 5 mile Inshore Exclusive Zone, employing some 20 000 to 30 000 fishermen. Most of the catch is Ethmalosa spp., Ilisha spp., Sardinella spp., Pseudotolithus spp., threadfins, barracuda and catfish. The gears used are driftnets, set nets, gillnets, ring nets, beach seines, hook-and-line gear, and cast nets.	Apparently little, if any, tuna is produced by the small-scale fisheries.	Tuna catches by only longline gear have been reported to ICCAT in recent years. The ICCAT database also gives an estimate for unreported catches of 148 tonnes of BET by longline vessels registered in Sierra Leone in 2002.	During 2000-2002 this gear produced an annual average of 155 tonnes of BET, ALB and BFT (45 percent BFT).	Sources of information: ICCAT database, FAO fishery country profile.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
South Africa, Republic of	Tuna catches by sport-fishing gear have been reported to ICCAT in recent years.	During 1998-2002, this gear produced an annual average of 185 tonnes of YFT and ALB (90 percent ALB).	Tuna catches by only longline gear have been reported to ICCAT in recent years.	During 1998-2002, this gear produced an annual average of 295 tonnes of YFT, ALB and BET (48 percent BET).	Source of information: ICCAT database.
Spain	Tuna catches by handline and troll gear have been reported to ICCAT in recent years.	During 1998-2002, these gear types produced an annual average of 8 002 tonnes of BET, ALB and BFT (65 percent ALB, all by trolling).	Tuna catches by longline, trap and unclassified gear have been reported to ICCAT during recent years. Although catches by pole-and-line gear have been reported, these are not included in the catch details to the right. For the purpose of this report, all pole-and-line fishing is considered to be industrial.	During 1998-2002, trap and unclassified gear produced an annual average of 1 626 tonnes of BET, BFT and SKJ (96 percent BET). During 1998-2002, longline gear produced an annual average of 5 805 tonnes of BET (no other species recorded).	Catches by Spain reported in both north and south Atlantic. Source of information: ICCAT database.
Togo	The ICCAT database does not show any small-scale tuna catches from Togo.	Maybe none, but some of the catch placed in the medium-scale category may actually belong to this category.	According to the ICCAT database, in recent years only "unclassified gear" caught tuna. According to the FAO profile, drifting gillnets are used to catch a variety of species, including tuna.	During 1998-2000, "unclassified gear" produced an annual average of 8 tonnes of BET.	Sources of information: ICCAT database, FAO fishery country profile.
United Kingdom	No small-scale tuna fishing has been reported to ICCAT in recent years.	Assumed to be none.	Tuna catches by longline and gillnet gear have been reported to ICCAT in recent years. Because of EU regulations, drift gillnet fishing has been banned since 2002. The ICCAT database also gives an estimate for unreported catches of 36 tonnes of BET by longline vessels registered in "UK OT" in 1998.	In recent years longline gear has produced only 10 tonnes of BFT in 2002. During 1998-2000, gillnet gear produced an annual average of 18 tonnes of ALB (no other species recorded).	Sources of information: ICCAT database, Miyake *et al.* (2004).

APPENDIX 5

NON-INDUSTRIAL TUNA FISHING IN THE MEDITERRANEAN SEA

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Algeria	Fishing with handlines and "tended lines" has been recorded by ICCAT in recent years.	During 1998-2002, these gear types produced an annual average of 239 tonnes of BFT; no other species of tuna were recorded.	Longline, gillnet, trap and unclassified gear have been recorded by ICCAT in recent years.	During 1998-2002, these gear types produced an annual average of 914 tonnes of BFT and SKJ (92 percent BFT).	Sources of information: ICCAT database.
Croatia	Handline and sport fishing have been recorded by ICCAT in recent years.	During 1998-2002, these gear types produced an annual average of about 1 tonne of BFT; no other species of tuna were recorded.	Only longline gear has been recorded by ICCAT in recent years.	During 1998-2002, this gear produced an annual average of about 7 tonnes of BFT. No other species were recorded.	Sources of information: ICCAT database.
Cyprus	Only sport fishing has been recorded by ICCAT in recent years.	During 1998-2002, this gear produced between 0 to 12 tonnes of ALB, with an average of about 4 tonnes.	Only longline gear has been recorded by ICCAT in recent years.	During 1998-2002, this gear produced an annual average of about 58 tonnes of BFT. No other species were recorded.	Sources of information: ICCAT database.
France	Only sport fishing has been recorded by ICCAT in recent years.	During 1998-2002, this gear produced between 0 to 5 tonnes of ALB, with an average of about 1 tonne.	Only unclassified gear has been recorded by ICCAT in recent years.	During 1998-2002, this gear produced an annual average of 114 tonnes of BFT and SKJ (about 96 percent BFT).	Sources of information: ICCAT database.
Greece	No catches by gear in this category have been reported to ICCAT in recent years. The ICCAT database includes some unreported handline catches. A General Fisheries Council for the Mediterranean-ICCAT meeting report states that most of the 200 Greek boats targeting exclusively BFT use handlines.	During 1998-2002, this gear produced an annual average of about 382 tonnes of BFT and ALB (97 percent BFT). The unreported catch for handline gear was estimated by ICCAT to be 64 tonnes in 1998 and 42 tonnes in 1999.	Longline and unclassified gear have been recorded by ICCAT in recent years.	During 1998-2002, these gears produced an annual average of about 1 011 tonnes of BFT and ALB (about 98 percent ALB).	Sources of information: ICCAT database, ICCAT (2003).
Italy	Hand, harpoon, rod-and-reel and sport-fishing gear have been recorded by ICCAT in recent years.	During 1998-2002, these gear types produced an annual average of 377 tonnes (about 99 percent BFT).	Longline, gillnet, trap and unclassified gear have been recorded by ICCAT in recent years.	During 1998-2002, these gear types produced an annual average of 3 656 tonnes of BFT, ALB and SKJ (79 percent ALB).	Sources of information: ICCAT database.
Libya	No small-scale tuna fishing has been recorded by ICCAT.		Longline and trap gear have been recorded by ICCAT in recent years. The catches by Libyan traps have plunged during the last few decades.	During 1998-2002, this gear produced an annual average of about 825 tonnes of BFT. No other species of tuna were recorded.	Sources of information: Tawil (2002), ICCAT database.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
Malta	No small-scale tuna fishing has been recorded by ICCAT.		Longline and unclassified gear have been recorded by ICCAT in recent years. ICCAT (2003) indicates that 58 vessels used drifting surface longlines.	During 1998-2002, these gears produced an annual average of about 291 tonnes of BFT and ALB (about 99 percent BFT).	Sources of information: ICCAT database, ICCAT (2003).
Morocco	Only handline gear has been recorded by ICCAT in recent years.	During 1998-2002, this gear type produced an annual average of 479 tonnes of BFT; no other species of tuna was recorded.	Gillnet and trap gear have been recorded by ICCAT in recent years.	During 1998-2002, these gear types produced an annual average of 89 tonnes of BFT and SKJ (96 percent BFT).	Sources of information: ICCAT database, FAO/FIRM staff.
Spain	Handline, sport, unclassified surface gear and trolling have been recorded by ICCAT in recent years.	During 1998-2002, these gear types produced annual averages of 113 tonnes of BFT, 69 tonnes of ALB and a small amount of SKJ. The annual average for these for the period was 183 tonnes.	Longline, trap and unclassified gear have been recorded by ICCAT in recent years. A non-ICCAT source indicated that trap fishing produced between 942 and 2 742 tonnes of BFT per year during the 1990s. ICCAT (2003) states that the trap catches of BFT have been "almost insignificant for last 7 years".	During 1998-2002, these gear types produced an annual average of 613 tonnes of BFT, ALB and SKJ (about 90 percent BFT).	Sources of information: ICCAT database, Jimenez *et al.* (2001), De La Serna *et al.* (2003), ICCAT (2003).
Tunisia	Only handline gear has been recorded by ICCAT in recent years.	During 1998-2002, this gear type produced an annual average of 37 tonnes of BFT. No other species of tuna were recorded.	Only trap gear has been recorded by ICCAT in recent years. ICCAT (2003) reports some longlining for tuna in 2002, and that trap production of BFT in 2001 did not exceed 3 tonnes.	During 1998-2002, this gear produced an annual average of about 19 tonnes of BFT. No other species of tuna recorded.	Sources of information: ICCAT database, ICCAT (2003).
Turkey	No small-scale tuna fishing has been recorded by ICCAT, but another source indicates that there is some handline fishing in the northern Aegean Sea.		No catch by the gear classification has been reported to ICCAT during 1998-2002.		Purse-seine and handline fishing produced about 2 300 tonnes of BFT in 2001. Sources of information: Oray and Karakulak (2003).
Yugoslavia Federal Republic	No small-scale tuna fishing has been recorded by ICCAT.		Only unclassified gear has been recorded by ICCAT in recent years.	During 1998-2002, this gear produced an annual average of about 1 tonne of BFT. No other species were recorded.	Sources of information: ICCAT database.

APPENDIX 6

NON-INDUSTRIAL TUNA FISHING IN THE INDIAN OCEAN

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Australia (Indian Ocean portion)	Troll and handline gear have been reported to the IOTC. There is a significant recreational component.	During 1997-2001, this gear caught an annual average of 10 tonnes of YFT, SKJ and ALB (71 percent YFT).	Gillnet, baitboat and longline gear have been reported to the IOTC.	During 1999-2001, gillnet gear caught an annual average of 1 tonne of YFT. During 1997-2000, pole-and-line gear caught an annual average of 2 973 tonnes of SKJ and SBF (92 percent SKJ). During 1997-2001, longline gear caught an annual average of 953 tonnes of YFT, BET, ALB, SKJ and SBF (51 percent YFT).	Sources of information: IOTC data, IOTC staff, IOTC (2002), Robins and Caton (1998).
Comoros	Handlining and trolling have been reported to the IOTC. Some "unclassified" fishing, which is probably in the category of small-scale scale fishing, has been reported.	During 1997-2001, this gear caught an annual average of 7 422 tonnes of YFT, BET and SKJ (72 percent YFT).	None.		Sources of information: IOTC data, IOTC staff.
East Timor	Only trolling has been reported.	During 1999-2001, this fishery caught an annual average of 2 tonnes of YFT (no other species of tuna reported).	Probably none.		Sources of information: IOTC data; IOTC staff.
France-Reunion	Only handlining has been reported.	In 2001 this gear caught 459 tonnes of tuna, including 68 tonnes of ALB, 5 tonnes of BET, 310 tonnes of YFT, and 76 tonnes of SKJ.	Longlining is directed at swordfish, and tuna is mostly bycatch. There are three size categories of longline vessels, less than 16 m, 16 to 20 m, and more than 20 m.	During 2001 this gear caught 801 tonnes of tuna, including 405 tonnes of ALB, 106 tonnes of BET, and 290 tonnes of YFT.	It was reported that the catches of swordfish were poor in 2002, so that some vessels subsequently targeted tuna. Sources of information: IOTC data, IOTC staff, Poisson *et al.* (1998).
India	All line fishing (troll and handline) has been reported together. Much of the tuna catch is incidental, as other species are often targeted. "Unclassified" gear is considered to be in this category.	During 1997-2001, this gear caught an annual average of 4 192 tonnes of YFT and SKJ (58 percent SKJ).	Purse seining for small pelagic fish results in some incidental catches of tuna by vessels about 15 m in length. There is some pole-and-line fishing in the Lakshadweep Islands, but data on the catches is currently unavailable to the IOTC.	During 1997-2001, small purse-seine gear caught an annual average of 19 tonnes of YFT and SKJ (57 percent SKJ). During 1997-2001 gillnet gear caught an annual average of 2 951 tonnes of SKJ and YFT (55 percent SKJ).	The longliners are mostly greater than 300 GRT and are considered for this report to be industrial. Sources of information: IOTC data, IOTC staff, Somvanshi *et al.* (1998).

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Indonesia (Indian Ocean portion)	Trolling, small purse seining, Danish seining and drift gillnetting is considered to be small-scale fishing in Indonesia.	The catches of tuna by small-scale gear have been estimated (Herrera 2000, and Appendix 9 of this report) at about 50 000 tonnes per year. The vessels that use these small-scale gear types have a wide size range. For the purpose of this report, half of the 50 000 tonnes is assigned to the "small-scale" category and half to the "medium-scale" category.	For the purpose of this report, half of the 50 000 tonnes of tuna from trolling, small purse seining, Danish seining and drift gillnetting is assigned to this category. Longlining in the Indian Ocean involves mainly vessels from three large ports: Muara Baru, Benoa and Cilacap. Although some vessels are as small as 10 m in length, most of vessels should be considered to be industrial. The annual catch of 54 000 tonnes by these vessels is therefore not considered in this report.	About 25 000 tonnes is allocated to the "medium-scale" category.	Sources of information: IOTC data, IOTC staff, Herrera (2000), Appendix 9 of this report.
Islamic Republic of Iran	Iran has reported 6 790 gillnet vessels of about 1 GRT each. As these vessels are quite small, species other than the tunas are likely to make up much of the catch.	During 1997-2001, an annual average of 31 625 tonnes of YFT and SKJ (59 percent YFT) was caught by all gillnet gear. For the purpose of this report, about 15 percent of the entire annual tuna catch (4 700 tonnes) is considered to have been taken by small-scale gillnet vessels.	Gillnetting is conducted by larger vessels of three size categories: 3 to 20 GRT (1 070 vessels), 21 to 50 GRT (1 165 vessels) and 50 to 100 GRT (859 vessels).	For the purpose of this report, about 85 percent of the entire annual tuna catch (27 000 tonnes) is considered to have been taken by larger gillnet vessels.	The tuna catches are not disaggregated by size of vessel in the IOTC data summary. Gillnet vessels of up to 100 tonnes carrying capacity are considered to be "artisanal". Sources of information: IOTC data, IOTC staff, Kaymaram and Talebzadeh (1998).
Jordan	The gear type has been reported to the IOTC as "other".	During 1998-2001, "other" gear caught an annual average of 48 tonnes of YFT and SKJ (93 percent SKJ).	None.		Sources of information: IOTC data; IOTC staff.
Kenya	Trolling has been reported by 80 vessels of 2.1 to 10 m in length.	During 1997-2001, trolling gear caught an average of 80 tonnes of YFT per year.	None.		Includes some catch by sport-fishing vessels. Sources of information: IOTC data; IOTC staff.
Maldives	Handlining and trolling have been reported.	During 1997-2001, these gear types caught an annual average of 1 980 tonnes of SKJ and YFT (57 percent YFT).	The pole-and-line fleet consists of vessels with a wide size range (up to 30 m in length), but, as most of them are in the range of 10 to 14 m, they are placed in this category. It has been reported that in 1999 there were 1 206 mechanized and 52 sailing pole-and-line vessels.	During 1997-2001, pole-and-line, longline and unclassified gear caught an annual average of 93 486 tonnes of SKJ, YFT and BET (87 percent SKJ). Pole-and-line vessels took 99 percent of the total catch.	Sources of information: IOTC data, IOTC staff, Flewwelling (2000), IOTC (2002).

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
Mauritius	In this category, only trolling is reported in the IOTC database. According to individuals with long experience in the country's fisheries, there are several hundred sport-fishing vessels, each catching at least 10 tonnes of tuna per year.	During 1997-2001, an annual average of 302 tonnes of YFT, SKJ, BET and ALB (53 percent YFT) were caught by trolling. About 200 tonnes could be captured by sport fishing.	It has been reported that the longline vessels are 11 to 30 m in length, but there is a possibility that they are larger than that, and should be in the industrial category.	During 1997-2001, longline gear caught an annual average of 20 tonnes of YFT, BET and ALB (63 percent YFT).	Sources of information: IOTC data; IOTC staff.
Oman	None reported.	None.	Only gillnetting has been reported. Most of the vessels (13 116 in 2000) were in the size range 5 to 23 m in length. Tuna are a non-target species.	During 1997-2001, longline gear caught an annual average of 9 693 tonnes of YFT and SKJ (96 percent YFT).	Sources of information: IOTC data; IOTC staff, IOTC (2002).
Pakistan	None reported.	None.	Only gillnetting has been reported. Most vessels (1 904 in 2000) are in the size range of 35 to 50 GRT. There are reports of small gillnet vessels, but catch data for these are not included in IOTC database.	During 1997-2001, these large gillnet vessels captured an annual average of 9 101 tonnes of YFT and SKJ (54 percent YFT).	No longlining was reported after 2000. Sources of information: IOTC data; IOTC staff, IOTC (2002).
Seychelles	In this category, only trolling is reported.	During 1997-2001, trolling caught an annual average of 10 tonnes of YFT and BET (65 percent YFT).	In this category, only longlining is reported. The fishing in the eastern Indian Ocean is considered to be industrial scale. In addition to the large longliners (25 to 58 m in length), there are six longliners of about 16 m in length.	In 1997 the six small longliners caught 311 tonnes of tuna, of which 79 percent was YFT and BET.	Sources of information: IOTC data; IOTC staff, IOTC (2002), Bargain (1998).
South Africa, Republic of	Only handline has been reported.	During 1997-2001, an annual average of 34 tonnes of YFT, SKJ and ALB (89 percent YFT) was caught by handlining.	There are about 8 to 10 swordfish longliners. These vessels are about 16 to 18 m in length, and operate near the coast.	During 1998-2001, these longliners captured an annual average of 136 tonnes of YFT, BET and ALB (79 percent YFT).	Sources of information: IOTC data; IOTC staff.
Sri Lanka	Trolling, handlining and unclassified gear have been reported. Ring netting probably makes up much of the unclassified category.	During 1997-2001, this gear caught an annual average of 82 tonnes of YFT, SKJ and BET (60 percent SKJ).	Gillnetting, longlining and some pole-and-line fishing have been reported. Most of the 26 longliners reported in 1999 are between 15.2 and 18.3 m in length. Many of the gillnets have longlines attached.	During 1997-2001, this longline and pole-and-line gear caught an annual average of 618 tonnes of YFT, BET and SKJ (51 percent YFT), 99 percent by the longline fleet. During 1997-2001 gillnet gear caught 62 541 tonnes of YFT, SKJ and BET (68 percent SKJ).	With the IOTC summary data it is difficult to segregate the small-scale and medium-scale catches. Although some gillnet vessels are quite small, the gillnet catch has been allocated to the medium-scale category. Sources of information: IOTC data, IOTC staff, Maldeniya and Amarasooriya (1998), IOTC (2002).
Tanzania	Only unclassified fishing has been reported; this is probably small-boat trolling.	During 1999-2001, this fishing caught an annual average of 616 tonnes of YFT (no other species of tuna reported).	None reported.		Sources of information: IOTC data; IOTC staff.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Thailand (Indian Ocean portion)	Small amounts of SKJ are caught in the Andaman Sea area by mackerel drift gillnets, troll lines and sport fishing.	Probably less than 5 tonnes.	Small amounts of YFT are caught by seine gear, but this is in the Gulf of Thailand, which is not considered to be in Indian Ocean area, but rather in FAO area 71.		Source of information: Dhammasak (1998).
Yemen	Handlines are the main artisanal tuna fishing gear, but some tuna is caught by driftnets, set gillnets and small purse-seines. The vessels used are fiberglass, outboard-powered boats of 8 to 10 m in length. Scomberomorus spp., is the main component of the catch, but significant amounts of YFT are also caught.	The IOTC database indicates that during 1997-2001 unclassified gear (probably mostly handlines) caught an annual average of 914 tonnes of YFT and SKJ (90 percent YFT). Reports from individuals with experience in Yemen indicate that the tuna catch is at least an order of magnitude greater than that given above. For the purpose of this report, 5 000 tonnes are allocated to the small-scale category.	For the purpose of this report, half of the estimated 10 000 tonnes of tuna are allocated to the medium-scale category.		Recent reports from FAO staff members traveling to Yemen suggest that the tuna catch by small-scale fishing could be 60 000 tonnes (mostly YFT). New fishery legislation does not permit foreign vessels to operate in national waters any longer, and it is likely that the catches of the local fleet will dramatically increase. Sources of information: IOTC data, Hamba (1998), FAO staff, IOTC staff.
Other Indian Ocean countries	Several Indian Ocean countries do not report tuna catches to the IOTC. Staff members of the IOTC believe that the amount of this unreported catch is about 5 000 tonnes per year.	For the purpose of this report, half of the 5 000 estimated tonnes is assigned to the "small-scale" category and half to the "medium-scale" category.	Several Indian Ocean countries do not report tuna catches to the IOTC. Staff members of the IOTC believe that the amount of this unreported catch is about 5 000 tonnes per year.	For the purpose of this report, half of the 5 000 estimated tonnes is assigned to the "small-scale" category and half to the "medium-scale" category.	Sources of information: IOTC data, IOTC staff.

APPENDIX 7

NON-INDUSTRIAL TUNA FISHING IN SOUTHEAST AND EAST ASIA

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Cambodia	There are no fisheries that target tuna or have tuna as a significant bycatch.	Assumed to be none.	Assumed to be none.	Assumed to be none.	Sources of information: Try (2003), Gillett (2004), FAO database, Collette and Nauen (1983).
China	Tuna species distribution maps show that tuna are not often found close to the coast of mainland China. Significant catches of tunas by small vessels would therefore not be expected. According to INFOYU, there are no fishing vessels specialized in tuna fishing along the coast.	Assumed to be none.	Assumed to be none.	Assumed to be none.	The FAO database does not include any catches of oceanic tunas by China in FAO Area 61. According to Globefish, no major tuna species are caught in the waters of China. Sources of information: Williams and Lawson (2001), Collette and Nauen (1983), staff of INFOYU, Globefish (1996).
Indonesia (FAO area 71 portion)	Of the 370 000 tonnes of tuna caught in the FAO Area 71 portion of Indonesia, pole-and-line fishing from vessels of less than 15 GRT, handlining, and trolling from small vessels produces about 60 percent, or about 222 000 tonnes. Although adequate information is lacking for properly allocating the small-scale catch of 222 000 tonnes to various categories, for the purpose of this report, it is assumed that 30 percent comes from the small-scale techniques of handlining and trolling.	67 000 tonnes (30 percent of 222 000 tonnes).	Although adequate information is lacking for allocating the small- and medium-scale catch of 222 000 tonnes to various categories, for the purpose of this report, it is assumed that 70 percent comes from pole-and-line fishing from vessels less than 15 GRT.	155 000 tonnes (about two-thirds SKJ and one-third YFT).	Sources of information: staff of the Indonesian Research Institute for Marine Fisheries, Appendix 9 of this report.
Japan	Trolling, using small vessels (one crew member, little mechanization) and trapping are the most important gears in this category.	In 2001, the catch by this gear was 18 300 tonnes of Thunnus spp. and SKJ. Of this, the catch of tuna by trap (mainly BFT) has been less than 1 000 tonnes in recent years.	"Coastal" longline and pole-and-line vessels are defined as those of less than 20 GRT in size (Japanese measurement).	During recent years the annual catches by these vessels have been as follows: longline, 5 888 tonnes of YFT and 4 846 tonnes of BET; pole-and-line, 477 tonnes of YFT, 6 845 tonnes of SKJ, and 180 tonnes of BET. In summary, during recent years 18 236 tonnes of tuna have been taken per year by the coastal tuna fleets.	Sources of information: staff of National Research Institute of Far Seas Fisheries (Temperate Tuna Research Group), Miyake *et al.* (2004), Lawson (2002).

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	Information on landings by small-scale fishing	Types of medium-scale fishing	Information on landings by medium-scale fishing	Comments
Korea, Democratic People's Republic of	Assumed to be none.	None.	Assumed to be none.	None.	Maps of the distributions of tunas show that they are not often found near the coast. Source of information: Collette and Nauen (1983).
Korea, Republic of	Assumed to be none.	None.	Assumed to be none. A recent report indicates there are no small-scale tuna longliners operating from the Republic of Korea.	None.	Maps of the distributions of tunas show that they are not often found near the coast. The only catch of BFT in the FAO database is 22 tonnes in 1991. Sources of information: Collette and Nauen (1983), FAO web site, Miyake (this collection).
Malaysia	Assumed to be none.	None.	Assumed to be none.	None.	Some SKJ has been reported from the portion of the South China Sea to the northwest of Borneo, but apparently none has been taken by non-industrial gear. Sources of information: Collette and Nauen (1983), staff of the Indonesian Research Institute for Marine Fisheries, Williams and Lawson (2001), FAO database.
Philippines	Philippine law defines municipal fishing as "fishing within municipal waters using fishing vessels of three GRT or less, or fishing not requiring the use of a fishing vessel". Handlining produces most of the municipal tuna catch, but other important municipal tuna fishing gears are gillnets and small ringnets.	In recent years, production of tuna in the "municipal fisheries" has been about 100 000 tonnes, of which about 60 percent is YFT and BET.	Commercial fishing is usually considered to be fishing from vessels from of more than 3.1 GRT. It has been estimated (Appendix 8) that in recent years the "commercial" production of tuna has been about 190 000 tonnes, of which about 55 percent is SKJ.	Data are not readily available to allow allocation of a portion of this catch to non-industrial fishing.	Sources of information: Appendix 8 of this report, Barut (2003), Staff of the Philippine Bureau of Fisheries and Aquatic Resources.
Russia	Assumed to be none.	None.	Assumed to be none.	None.	Maps of the distributions of tunas show that the principal market species of tuna, except for BFT, are not often found close to the coast. No catch of BFT has ever been recorded in the FAO database. Sources of information: Collette and Nauen (1983), FAO database.

	Small-scale tuna fishing		Medium-scale tuna fishing		
	Types of small-scale fishing	**Information on landings by small-scale fishing**	**Types of medium-scale fishing**	**Information on landings by medium-scale fishing**	**Comments**
Singapore	Assumed to be none.	None.	Assumed to be none.	None.	During 1997-2001, Singapore caught an annual average of 19 tonnes of SKJ in FAO Area 71. As the principal market species of tuna are uncommon near Singapore, it is not likely that this catch (or significant quantities of principal market species of tuna) was taken by non-industrial fisheries. Sources of information: Williams and Lawson (2001), the FAO database.
Taiwan Province of China	Information on small-scale tuna fishing is not readily available.	Assumed to be none.	A large fleet of longliners of less than 100 GRT operates near Taiwan. In recent years these vessels have caught an annual average of between 17 000 and 28 000 tonnes of YFT, BET, ALB and SKJ.	It is not known how much of this catch should be placed in the non-industrial category.	Sources of information: staff of Overseas Fisheries Development Council, staff of SPC.
Thailand (FAO area 71 portion)	Assumed to be none.	None.	Assumed to be none.	None.	Only a very small amount of tuna captured, and this is limited to YFT caught by seining in the Gulf of Thailand. Sources of information: FAO database, Collette and Nauen (1983), Dhammasak (1998).
Vietnam	According to Roberts (2002), Vietnamese fishermen in the central provinces have traditionally caught tuna with weirs, rake nets, drag nets and especially with fishing lines. It should be noted that most of this "tuna" is Auxis spp., Euthynnus spp. and other small tunas. The only principal market species is SKJ, which makes up only 0.59 percent of the "tuna" catch.	There are almost no data with which to make an estimate, but for the purpose of this report it is assumed that the catch of tuna by small-scale gear is 100 tonnes.	What little information is available indicates that tuna are taken mainly by longline and driftnet gear, with some purse-seine and pole-and-line gear. Many longline vessels are 12 to 17 m in length, and use surface gillnets during the day for flyingfish and longlines at night for large pelagic fish.	It is likely that most of the 20 000 tonnes of tuna is taken by longliners and gillnetters less than 17 m in length.	Oceanic tuna fishing has been developed only since the early 1990s. 5 912 tonnes of "frozen tuna" were exported in 2000. The total national catch of tuna has been estimated to have been 20 000 tonnes in 2001, most of which was YFT and BET. Sources of information: Williams and Lawson (2001), Roberts (2002), SPC web site, Munprasit and Prajakjitt (2001), Tri (2002).

APPENDIX 8

NOTES ON TUNA FISHING IN THE PHILIPPINES

Tuna catch data

TABLE 1
Bureau of Agriculture Statistics (BAS) catch data (in tonnes) for the principal market species of tuna (adapted from Barut, 2003)

	Municipal catch of YFT and BET	Municipal catch of SKJ	Total municipal catch YFT, BET and SKJ	Commercial catch of YFT and BET	Commercial catch of SKJ	Total commercial catch of YFT, BET and SKJ	Total catch of YFT, BET and SKJ (municipal and commercial)
1998	40 185	27 987	68 172	39 030	88 686	127 716	195 888
1999	43 997	29 344	73 341	46 356	79 434	125 790	199 131
2000	45 257	29 635	74 892	45 071	83 376	128 447	203 339
2001	47 395	31 472	78 867	49 055	80 766	129 821	208 688
2002	36 743	26 592	63 335	63 051	83 385	146 436	209 771

The average municipal catch from 1998-2002 was 71 721 tonnes. The average commercial catch from 1998-2002 was 131 642 tonnes.

Bureau of Fisheries and Aquatic Resources (BFAR) tuna specialists and private sector sources indicate that the above catches are underestimates of the actual catches. BFAR and industry officials have independently expressed the opinion that the current production of yellowfin, bigeye and skipjack[1] from the municipal fisheries is likely to be about 100 000 tonnes. BFAR officials believe that commercial production of these species is currently likely to be 200 000 tonnes, while industry representatives believe that the figure may be about 180 000 tonnes. For the purpose of this report, the current municipal production of yellowfin, bigeye and skipjack is assumed to be 100 000 tonnes, and the commercial production to be 190 000 tonnes.

According to Pagdilao and Querijero (1993), the major tuna fishing grounds for both the municipal and commercial fisheries are the Moro Gulf, Sulu Sea, Bohol Sea, Batangas Bay, Visayan Sea, Ragay Gu and Tayabas Bay. Unpublished BAS data show the catches by species in both the municipal and commercial fisheries in 15 regions of the country. According to those data, in 2002 Region 4 (near Palawan) and Region 9 (near Zamboanga) produced the greatest municipal and commercial catches, respectively, of yellowfin, bigeye and skipjack. One of the factors that contribute to the south being a productive area is the favourable weather, including the absence of monsoon conditions.

Municipal tuna fishing

The Philippine Fisheries Code of 1998 defines municipal fishing as "fishing within municipal waters using fishing vessels of three GRT or less, or fishing not requiring the use of a fishing vessel".

Handlining produces most of the catch of the principal market species. Barut (2003) estimates that there are around 10 000 municipal tuna handline boats, commonly referred to as "pump boats", many of which have grown out of the municipal size category. Williams (2002) indicates that the handline fleet based in General Santos city, which is the largest such fleet in the Philippines, catches about 10 000 tonnes per year. BFAR and industry officials estimate that about two-thirds of the catches of the principal market species are made by handlining. If it is assumed (as done above) that

[1] These three species are referred to in this report as "principal market species" in the worldwide sense, recognizing that the smaller tuna species have a ready market in the Philippines. In many cases, bigeye is reported as yellowfin in the Philippines.

the municipal catch of principal market species is about 100 000 tonnes per year, then handlining is responsible for some 70 000 tonnes annually.[2] Both industry and BFAR sources agree that about one-third of the handline production of yellowfin and bigeye is exported fresh, with most of the large non-*sashimi* handline tuna for processing into smoke or carbon monoxide-treated "loin" products for export to the United States and the European Union. The Moro Gulf typically produces larger handline-caught tuna than does the Sulu Sea. BFAR sources indicate that many, if not most, of the FADs in the country have handliners working from them.

Other important municipal tuna fishing gears are gillnets and small ringnets. Both of these gears catch many species, especially small tunas, in addition to the principal market species of tuna. According to government officials, these two gear types account for about a quarter of the municipal landings of the principal market species, or about 25 000 tonnes per year. It should be noted that the ringnet fishing vessels in this category are "baby ringnet" vessels, as the regular ringnet vessels are much larger, with an average size of about 35 GRT, and therefore are considered to be in the commercial category.

Much lesser amounts of the principal market species of tuna are caught by "mini-longlining" and trolling. Mini-longlining is confined largely to the Palawan area, while trolling (often by un-motorized vessels) is common around Mindanao and in the Visayan Sea.

Other than the estimate of 10 000 handliners given above, little information is available on the number of vessels participating in municipal tuna fishing. Some data exist from the licensing system, but because there are locations in which most of the vessels are not registered, it is not possible to estimate sizes of the fleets from licensing data. BFAR officials report, however, that an inventory of vessels has recently commenced.

Commercial tuna fishing

The Philippine Fisheries Code of 1998 defines commercial fishing as "fishing for trade, business, or profit beyond subsistence or sport fishing". It has three categories: (1) small-scale commercial fishing, using vessels from 3.1 GRT to 20 GRT; (2) medium-scale commercial fishing, using vessels from 20.1 GRT to 150 GRT; and (3) large-scale commercial fishing, using vessels of more than 150 GRT. Commercial fishing boats are not allowed to fish within 15 km of the shoreline.

As indicated above, the estimated landings of the principal market species given by the BAS system are thought to be too low, with BFAR and industry indicating that the annual total is actually between 180 000 and 200 000 tonnes.

The commercial category encompasses a huge variety of fishing operations, ranging from ring netting from 3.1 GRT vessels to purse seining by large purse seiners with carrying capacities in excess of 1 000 tonnes. Industry representatives indicate that they classify the tuna-fishing operations mainly by carrying capacity. The various types of operations can be grouped for the purpose of this report into two categories: industrial and semi-industrial.

Industrial:

- purse seiners of more than 1 000 tonnes of carrying capacity,
- purse seiners of 600 to1 000 tonnes of carrying capacity,
- purse seiners of 200 to 600 tonnes of carrying capacity,
- group seine operations (no carrying capacity).

[2] This equates to an average of 7 tonnes of tuna per vessel per year.

Semi-industrial:

- purse seiners of less than 200 tonnes of carrying capacity,
- "unay" and larger ring net boats[3] (non-mechanical net hauling).

Industry sources say that the industrial category above is responsible for about 75 percent of the catch of the principal market species, or about 140 000 tonnes of tuna. The fleet is made up of about 150 purse seiners, including "less than ten vessels" with carrying capacities of more than 1 000 tonnes.

In accordance with the above industry information, the semi-industrial category should be responsible for 25 percent of the commercial catch, or about 50 000 tonnes of yellowfin, bigeye and skipjack per year.

Barut (1996) used a different classification. He indicated that for 1993 and 1994 the ratio of purse-seine catches (all vessel sizes) to ring net catches was about 85:15. This is not remarkably different from the above industry information.

Other features of commercial tuna fishing in the Philippines:

- Seven or eight tuna canneries are presently in operation in the Philippines. About 200 000 tonnes are processed annually. A substantial amount of the raw material comes from outside the Philippines, and, according to industry officials, the price paid to the fishermen is often greater than that paid in Bangkok.
- In 2002 there were 22 Philippine purse-seine vessels operating outside of the Philippines in the Pacific Islands area (total carrying capacity 14 521 cubic metres), with only one vessel having a carrying capacity greater than 1 000 cubic metres (Gillett and Lewis, 2003).
- The catch by conventional longlines is very small, and fishing with this gear appears to be limited largely to the area south of Mindanao.
- One of the major changes in the past decade is a steady increase in the size of purse-seine vessels.

Other sources of information

BFAR (2003); Republic of the Philippines (1999); Thomas, F. (1999).

Personal communication:

- officials of the Bureau of Fisheries and Aquatic Resources – R. Ganaden and N. Barut;
- official of Bureau of Agriculture Statistics – S. DeOcampo;
- private sector – Gus Natividad, and Gerry Silvestre.

[3] "Unay" is a Visayan term for all types of surrounding net fishing. Although originally used for small-scale fishing, even some of the large industrial vessels are sometimes called unay.

APPENDIX 9

NOTES ON TUNA FISHING IN INDONESIA

General

Fisheries are important to Indonesia, with its 17 000 islands, 81 000 km of coastline, 5.8 million square km of maritime waters and 4.3 million fishers. Tuna fishing is an especially important activity in Indonesia. In terms of value of the catch, tuna ranks second to shrimp, and exports are in excess of US$200 million. Despite this importance, the last comprehensive review of Indonesia tuna fishing appears to be that of Marcille *et al*. (1984).

Tuna and the various types of tuna fishing are not distributed evenly across Indonesia. In the shallow-sea areas, some tuna species are not abundant (e.g. skipjack in the South China Sea area) or absent (e.g. yellowfin in the Arafua Sea, Java Sea and South China Sea areas).

Tuna catch data

TABLE 1
Official statistics (MMAF 2002) for "tuna"[1] and skipjack (in tonnes) for all of Indonesia

	2000 tuna	2000 skipjack	2000 total (tuna+skipjack)	2001 tuna	2001 skipjack	2001 total (tuna+skipjack)
West Sumatra	10 202	16 180	26 382	12 467	16 423	28 890
South Java	6 037	3 088	9 125	6 025	3 158	9 183
Malaka Strait	1 503	6 185	7 688	1 500	7 286	8 786
East Sumatra	6 602	2 570	9 172	2 263	1 345	3 608
North Java	7 565	5 149	12 714	7 707	3 636	11 343
Bali–Nusatenggara	32 065	15 230	47 295	31 466	20 751	52 217
South and West Kalimantan	0	0	0	0	0	0
East Kalimantan	3	1 061	1 064	22	1 678	1 700
South Sulawesi	19 625	33 854	53 479	15 107	36 903	52 010
North Sulawesi	37 814	68 825	106 639	41 478	65 699	107 177
Maluku–Papua	41 825	84 133	125 958	35 075	57 198	92 273
Total Indonesia	163 241	236 275	399 516	153 110	214 077	367 187

To examine tuna fishing more closely, the above official statistics can be divided into two subsets: (1) the Indian Ocean area (that portion of Indonesia lying within FAO area 57[2]–largely the islands bordering the Indian Ocean) and (2) the archipelagic and Pacific Ocean area (that portion of Indonesia lying within FAO area 71). For convenience, these areas are referred to in this report as the "Indian Ocean area" and the "Archipelagic and Pacific Ocean area".

Although "North Java" does not lie within FAO area 57, it is included in area 57 in Table 3, as virtually all the catch comes from Jakarta-based longliners that fish primarily in the Indian Ocean.

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[1] The category "tuna" in the official statistics is comprised of mainly yellowfin, but also unspecified amounts of bigeye, albacore, southern bluefin tuna, black marlin, white marlin, striped marlin, and swordfish.

[2] IOTC staff points out that there were different FAO and IOTC boundaries for the Area 57 until 2003. FAO changed recently the boundary of Area 57 to match with that of the IOTC and will update the catches accordingly.

TABLE 2
Official statistics (MMAF 2002) for "tuna" and skipjack (in tonnes) in the Indian Ocean (FAO Area 57)

	2000 tuna	2000 skipjack	2000 total (tuna+skipjack)	2001 tuna	2001 skipjack	2001 total (tuna+skipjack)
West Sumatra	10 202	16 180	26 382	12 467	16 423	28 890
South Java	6 037	3 088	9 125	6 025	3 158	9 183
East Sumatra	6 602	2 570	9 172	2 263	1 345	3 608
North Java	7 565	5 149	12 714	7 707	3 636	11 343
Bali–Nusatenggara	32 065	15 230	47 295	31 466	20 751	52 217
Total Indian Ocean	54 906	37 068	91 974	52 221	41 677	105 241

TABLE 3
Official statistics (MMAF 2002) for "tuna" and skipjack (in tonnes) in the Archipelagic and Pacific Ocean (FAO Area 71)

	2000 tuna	2000 skipjack	2000 total (tuna+skipjack)	2001 tuna	2001 skipjack	2001 total (tuna+skipjack)
Malaka Strait	1 503	6 185	7 688	1 500	7 286	8 786
East Kalimantan	3	1 061	1 064	22	1 678	1 700
South Sulawesi	19 625	33 854	53 479	15 107	36 903	52 010
North Sulawesi	37 814	68 825	106 639	41 478	65 699	107 177
Maluku–Papua	41 825	84 133	125 958	35 075	57 198	92 273
Total Arch/Pacific	108 335	199 207	307 542	100 889	172 400	261 946

Considerations on the official tuna statistics

An important issue is the accuracy of the above statistics. The official tuna statistics are from the national fisheries statistical system established with FAO assistance in the mid-1970s. General problems with fisheries statistics in Indonesia are discussed by Tan *et al*. (1996) and Venema (1997). Gillett (1996) indicates that there are many problems with Indonesia's tuna statistics. Although there have been several attempts to improve national fishery statistics in Indonesia in the last two decades, the basic system remains largely unchanged since its inception. Improvements come slowly to one of the world's largest fisheries statistical systems.

Herrera (2002) studied the tuna statistics situation for Indonesia's Indian Ocean area. Using all available information, he made a new estimate of 177 384 tonnes of "tuna and tuna-like species" for the Indian Ocean area for 2000. A more recent review of the Indonesia's Indian Ocean tuna statistics (Proctor *et al*., 2003) did not attempt to update Herrera's estimate.

Lawson (2002) gives the skipjack, yellowfin and bigeye catches in Indonesia's part of area 71 (referred to as Indonesia's part of the Western and Central Pacific Ocean catches) as 361 384 tonnes. It is not clear how this relates to the official 307 542 tonnes given above for the Archipelagic and Pacific Ocean area for 2000.

Because the contention that there may be considerable problems with Indonesia's tuna statistics, attempts were made to obtain additional information on tuna production from individuals familiar with Indonesia's tuna fisheries. Discussions were undertaken during December 2003 with knowledgeable people from government agencies (nine individuals), the tuna fishing and processing industry (seven), and other organizations (four). The information obtained offered considerable insight into the tuna fishing situation (especially when a solid consensus emerged). Nevertheless, the conclusions drawn from such anecdotal sources should be considered as a contribution to the "educated guesswork" given in the following notes. Proctor *et al*. (2003) state that targeted monitoring over 12 to 18 months would be necessary to produce detailed information on the artisanal tuna fisheries in Indonesia's Indian Ocean area.

In the course of discussions with government agencies, the private sector and others, it was the unanimous opinion that the official tuna statistics were underestimates of the actual landings. In general, government researchers believed that actual landings are 30 to 40 percent greater than those given by the statistics, with the underestimate for eastern Indonesia being more serious. Representatives of private sector companies, using their own tuna production, estimates of the production of their competitors and knowledge of the various fisheries, all independently expressed the opinion that the discrepancy is much greater. Most of them believe that the government figures should be doubled. There is no obvious reason why they should exaggerate the difference.

Although the estimate of Herrera (2002) for Indonesia's Indian Ocean area given above is 92 percent greater than that given by the official statistics, it is important to clarify what is being compared. The Herrera estimate (177 384 tonnes for the Indian Ocean area for 2000) is for "tuna and tuna-like species", and includes billfish, small tunas and seerfish. Clarification with IOTC staff members indicates the following landings for 2000 for the principal market species of tuna:[3]

	Albacore	Bigeye	Yellowfin	Southern bluefin	Skipjack	Total
Gillnet	-	-	908	-	7 368	8 276
Longline	2 659	20 926	29 611	1 068	-	54 263
Other	-	-	364	-	36 177	36 540
Small purse-seine	-	-	1 404	-	3 276	4 680
Total	2 659	20 926	32 287	1 068	46 820	103 759

The official tuna statistics given above for the Indian Ocean area (91 974 tonnes) are for skipjack and "tuna", the latter including yellowfin, bigeye, albacore and southern bluefin tuna, plus marlins, sailfish and swordfish.[4] If the billfish comprise 2 percent of the catch, then the official statistics for 2000 suggest that a total of about 90 000 tonnes of skipjack, yellowfin, bigeye, albacore and southern bluefin tuna was landed. For the year 2000, the Herrera (2002) estimate for the Indian Ocean area is therefore about 15 percent greater than that suggested by the official statistics. According to Herrera (per. com.), this difference is entirely the result of a greater estimate of the longline catch; the IOTC estimates for the small-scale tuna fisheries do not differ from the official statistic, as IOTC does not have comprehensive alternative sources of information and lacks resources for an independent assessment.

Catches of tuna in the Archipelagic and Pacific Ocean area of Indonesia are generally acknowledged to be greater than in the Indian Ocean area. Official statistics, researchers and industry representatives seem to agree that catches in the Archipelagic and Pacific Ocean area represent about 75 to 80 percent of the total Indonesian tuna catch.

Some conclusions can be made about total catches of skipjack, yellowfin, bigeye, albacore and bluefin in Indonesia:

- The official statistics for the latest two years (2000 and 2001 average for "tuna" category, less 2 percent for billfish) suggest an annual average of about 376 000 tonnes for the entire country.
- The views of government tuna researchers (30 percent greater than the average of the official landings for 2000 and 2001) suggest an annual average of about 490 000 tonnes for the country.

[3] Skipjack, yellowfin, bigeye, albacore and northern and/or southern bluefin tuna are referred to in this report as "principal market species" in the worldwide sense, recognizing that the smaller tuna species have a ready market in Indonesia.

[4] IOTC staff members indicate that the "tuna" category may also include some longtail tuna, and, to a lesser extent, frigate and bullet tunas and kawakawa. At least some Indonesian researchers believe that in the official statistics these species are categorized as "Tongkol", of which 233 051 tonnes were recorded in 2001.

- Opinions expressed by industry representatives suggest an annual average of about 750 000 tonnes for the entire country.

Even the lowest estimate above represents about ten percent of the entire world production of these tuna species. By comparison, the Japanese domestic tuna fishery, often used as a benchmark for large production has in recent years fluctuated between 150 000 and 300 000 tonnes (Joseph 2003). The 1999 catch in all 15 Pacific Island countries was about 660 000 tonnes. Indonesia produces more tuna from its waters than any other country in the world.

It should be noted that the situation is complicated by:

- Legal, semi-legal[5], and illegal fishing by Philippine tuna fishing vessels in the northern portion of Indonesia.
- An unknown portion of the longline catch originates from locations outside of Indonesia. Some government officials and industry representatives believe that most of the catch (about 54 000 tonnes per year) is from locations outside of Indonesia's EEZ. However, information on the location and extent of the Indonesia longline vessel fishing grounds (Proctor *et al*., 2003) indicates that most fishing by vessels from the three most important longline ports is within Indonesia's Indian Ocean EEZ.

Small-scale tuna fishing in Indonesia

There is no standard definition of "small-scale" fishing in Indonesia. Some information relevant to categorizing scales of fishing in the country are:

- From a legal perspective, the Fisheries Law of Indonesia (Law Number 9 of 1985) grants the authority to license vessels of less than 30 GRT to the governors of provinces. Alternatively, Ministerial Decree No. 392 of 1999 on Fishing Zones stipulates that the zone from three to six nautical miles offshore is reserved for vessels with a maximum length of 12 m or a maximum of 5 GRT.
- Naamin and Gafa (1998) indicate that Indonesian pole-and-line vessels less than 10 GRT are considered artisanal.
- Bailey and Dwiponggo (1987) define small-scale fisheries in Indonesia as all fishing units powered by sails or outboard engines, or those that use gear without a vessel.
- Herrera (2000), who covered tuna fishing in Indonesia's Indian Ocean area, considered that all tuna fishing in that area other than longlining is "artisanal".
- Proctor *et al.* (2003) avoid defining artisanal fishing by using the concept of "artisanal ports", which are locations where fishing vessels are owned primarily by fishing households, but not by fishing companies, and where the majority of vessels are smaller than 25 GRT.
- Government tuna researchers seem to believe that an upper limit of a small-scale tuna fishing vessel is about 15 GRT.
- Several private sector representatives have categorized the fisheries by gear type. Only the conventional tuna purse seining in the north, pole-and-line fishing using vessels larger that 15 GRT and mechanized longlining is considered to be industrial. All other tuna fishing in Indonesia is considered to be small-scale (synonymous with artisanal).

For practical reasons, during the short period of the present review, it was necessary to define small-scale tuna fishing as per the default schemes used by the private sector and Herrera (2002) above.

In the past, it was possible to disaggregate information in the national fisheries statistical system to permit estimation of skipjack and "tuna" catches by gear type

[5] Authorized vessels making unauthorized landings outside Indonesia.

(presented for 1991 by Venema (1997)). Although this would facilitate partitioning the tuna catch data into small- and large-scale categories, according to staff members of the Directorate General of Capture Fisheries, this is not possible at present, as information in this form is now not received from the provinces.

Descriptive information on small-scale tuna fishing is readily available from various sources, including Proctor *et al*. (2003), government agencies, fishing companies and tuna canners.

Some information is available on the relative amounts of the principal market species of tuna taken by the different scales:

- Government tuna researchers believe that about half of the tuna from the Archipelagic and Pacific Ocean area is from small-scale fishing.
- The private sector believes that at least three-quarters of the tuna from the Archipelagic and Pacific Ocean area is from small-scale fishing.
- Naamin and Gafa (1998) indicate that small-scale pole-and-line fishing in eastern Indonesia produces about 80 percent of the skipjack and yellowfin caught by this technique.
- McElroy (1989) indicates that "small- (artisanal) and medium-scale enterprises account for most of the landings (currently about 75 percent)".
- Overall, the tuna canneries that obtain raw material from the Archipelagic and Pacific Ocean area indicate that about half is from small-scale fishing operations.
- The data of Herrera (2002) show that, for the Indian Ocean area, slightly less than half of the tuna catch of 103 000 tonnes of tuna comes from techniques other than longlining, and therefore is considered to be "artisanal".

The above limited information enables at least some speculation about the quantity of catches by small/large scale fishing operations in the two areas.

	Industrial tuna fishing	Small-scale tuna fishing
Indian Ocean area	Longlining, mainly from the three industrial ports of Muara Baru (North Jakarta), Benoa (South Bali) and Cilacap (south coast of Central Java). The best estimate appears to be that of Herrera (2002)–about 54 000 tonnes of the principal market species[6] in 2000.	Trolling, small purse seining (especially in the north of Sumatra) and drift gillnetting. The best estimate appears to be that of Herrera (2002)–about 50 000 tonnes of the principal market species in 2000.
Archipelagic and Pacific Ocean area	Purse seining, and pole-and-line fishing from vessels greater than 15 GRT–about 40 percent of the 370 000 tonnes of tuna from this area (given above), or 148 000 tonnes.	Pole-and-line fishing from vessels less than 15 GRT, handlining–about 60 percent of the 370 000 tonnes of tuna from this area, or 222 000 tonnes.

As indicated above, considering the lack of reliable data, this should be considered "educated guesswork".

Other information

The number of tuna canneries in Indonesia has decreased markedly in recent years. Simorangkir (2002) states there were 27 tuna canning units in Indonesia in mid-2002. A representative of the Indonesia Tuna Canners Association indicated that in December 2003 there were 16 tuna canneries, eight of which are operating full time, while the other eight produce only sporadically.[7] The capacity is about 30 000 tonnes of tuna, but the present utilization is about 100 000 tonnes. The source of the raw material depends on the location of the cannery, but overall about 50 percent of this raw material comes

[6] Principal market species–see previous footnote.

[7] The large decline in number of canneries could be due to the fact that some canneries may have done a limited amount of tuna canning during periods of low catches of sardines (P.Martosubroto, per.com.)

from small-scale fishing operations (defined as being from vessels less than 50 GRT), 30 percent is from mid-size domestic vessels (purse-seine, longline and pole-and-line) and 20 percent is imported.[8] Canneries exist in east Java (five), Bitung (three), Surabaya (two), Sorong (one), and Biak (one). There are no longer any canneries in Bali.

Indonesia's tuna exports have historically consisted of about one-third fresh fish, one-third frozen fish, and one-third canned fish. A recent industry report indicates that in 2002 the amounts of tuna exports were 26 718 tonnes of fresh fish, 27 733 tonnes of frozen fish, and 38 346 tonnes of canned fish. This information, together with the above assumptions, suggests that most of the tuna landed in Indonesia is consumed domestically.

Purse seining in Indonesia requires some additional explanation. Although there are many purse-seine vessels in the country (over 7 000 in the mid-1990s), most are used for fishing for species other than the principal market species of tuna (e.g. small pelagic species). Two types of purse seiners target tuna, the small seiners that fish in the Indian Ocean area and the much larger seiners that operate in the Archipelagic and Pacific Ocean area.

The small and mainly un-mechanized seining operations take place mostly in the north portion of Sumatra, using vessels around 5 to 10 GRT. Herrera (2002) indicates that there about 300 such vessels operating in the Indonesia's Indian Ocean area. Badrudin and Bahar (1997) review the catches of the portion of this fleet operating from Aceh.

Regarding the much larger seiners operating in the north of the country, Simorangkir (2002) indicated that there were 39 licensed purse-seine vessels in that area, mostly of about 300 GRT in size, and three 900- to 1000-GRT seiners based in Biak. Fisheries researchers believe that there are about 50 vessels, each of around 200 GRT, plus some group-seining operations and one or two larger purse seiners based in Biak. Correspondence from a Bitung cannery manager states that 34 catcher boats and 88 purse-seine carrier vessels operate from the Bitung (North Sulawesi) checkpoint. The seining grounds were reported to be around North Sulawesi a few years ago, but have been extended to the east around Papua recently. Some reports indicate that the boats operated as Indonesian vessels when foreign fishing was not allowed in Indonesia, but are now registered as Philippine vessels, which is now permitted under an Indonesia-Philippine agreement. Lawson (2002) gives the 2000 purse-seine catch data in the Archipelagic Pacific Ocean area of Indonesia as 30 387 tonnes.

Other sources of information

Personal communication:

- Government agencies: M. Badrudin, Gede Merta, and Bactiar Gafa, Research Institute for Marine Fisheries; Subhat Nurhakim, Budi Iskandar, Berbudi (observer), Research Centre for Capture Fisheries; Mrs. Elia and M. Anas, Directorate General of Capture Fisheries; Lasma Tambunan, Jakarta Fishing Port.
- Private sector: Didik Priono, Bimo Setiabudi, PT Ocean Mitramas; Wawan Koswara, ASEAN Fisheries Federation; Enni Soetopo, Indonesia Tuna Association; Harini Nalendra, PT Harini; Romeo Lamzon, PT Sinar Pure Foods Cannery; Hendri Sutadata, Indonesia Tuna Canners Association.
- Others: Charles Greenwald, COREMAP; Michi Hotta, consultant; Benni Sormin, FAO; Jos Pet, The Nature Conservancy; Lida Pet, WWF; Purwito Martosubroto, FAO retired.

[8] The manager of a cannery in Bitung stated that 90 percent of his raw material comes from purse seining, with the remainder coming from mostly small pole-and-line fishing and, to a lesser extent, from small-scale surround netting.

SECTION 3

Tuna fishing industry

The world tuna industry – an analysis of imports and prices, and of their combined impact on catches and tuna fishing capacity

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ABSTRACT

Tunas are among the most important fish commodities in the world. The global catches of commercial tuna species increased from 402 000 tonnes in 1976 to 3.7 million tonnes in 2001. World imports of fresh, chilled and frozen tuna increased from 435 000 tonnes in 1976 to 1.5 million tonnes in 2001, and imports of canned tuna (net weight) increased from 89 000 tonnes in 1976 to 836 000 tonnes in 2001.

The ultimate aim of this paper is to demonstrate the relationship between the tuna market (*sashimi* and raw material/canned tuna) and tuna catches by utilizing a practical "bottom-up" approach. The results of the paper will be used in the estimation of tuna fishing capacity, and hence for the estimation of the optimum fishing capacity to achieve proper management of the tuna fisheries, taking into account biological, economic and social considerations.

The analysis of the *sashimi* market focus on Atlantic, Pacific and southern bluefin, and on bigeye, the four species which best represent this market. According to the paper, the decline of prices of bluefins and bigeye as from early to mid-nineties was generated by the changing economic conditions in Japan and increased demand of cheaper bluefins from farming and of cheaper bigeye.

Buoyant international demand for canned tuna generated an increase in catches and imports of raw material from 1992 to 1998. However, as the increase in catches was not sufficient to meet demand, prices increased concurrently. When the market became oversupplied in late 1998, the positive correlation between imports, catches, production and prices broke down, and the prices started to decline. In late 1998, the abundance of resources, combined with maximised capacity inputs, generated a large increase in catches, which continued until late 2000, when the World Tuna Purse-seine Organization (WTPO) had to implement supply limitation measures to prevent the prices of skipjack from descending to unprofitable levels.

Growing demand for tuna products has been stimulating increases in the catches. At the same time, demand for tuna has been keeping prices at levels that have ensured adequate income for all stakeholders. However, in the case of some species (such as skipjack and, to a lesser extent, yellowfin in 1998-2000) continuous high exploitation has created an excess of supply, causing prices, and therefore income of operators, to decline.

In the case of other species, such as the *sashimi* tunas in Japan, external economic conditions affected the market by gearing it towards lower-valued tunas (including farm-raised bluefin tuna), hence generating a decline of average *sashimi* tuna prices.

1. INTRODUCTION

1.1 Purpose of the paper

The present paper has been prepared within the framework of the FAO-implemented project "Management of tuna fishing capacity: conservation and socio-economics" (GCP/INT/851/JPN). The ultimate aim of the project is to improve the management of tuna fisheries on a global scale, while the intermediate aims are:

- to provide technical information necessary for the achievement of the ultimate aim, and
- to identify, analyse and solve the technical problems associated with tuna-fishing capacity at a global level.

The project consists of the following activities:

- A1: tuna fisheries and resources;
- A2: characterization and estimation of tuna fishing capacity;
- A3 and A4: the tuna fishing industry (canning and *sashimi*)[1];
- A5: options and implications for management of tuna-fishing capacity.

The intermediate aim of this paper is to analyse the tuna market and industry on a global, regional and national scale. Its ultimate aim is to assess the influence of the tuna market (e.g. prices and imports) on tuna catches, both qualitatively and quantitatively. Furthermore, the data and information provided by this paper can be used as input for evaluation of the tuna fishing capacity, and for estimation of the optimum tuna fishing capacity from environmental and socio-economic points of view.

Over time, growing demand for tuna products has been stimulating increases in the catches. At the same time, demand for tuna has been keeping prices at levels that have ensured adequate income for all stakeholders. However, in the case of some species[2], continuous high exploitation has created an excess of supply, causing prices, and therefore income of operators, to decline.

1.2 Methodology and shortcomings

The introductory section (*Analysis of the factors affecting tuna catches*) provides a general overview of the tuna industry and an analysis of the human and non human-induced factors affecting tuna catches.

The section *Tuna industry analysis* represents the core of the study. It provides a detailed analysis of the tuna-processing industry, including the processing chain, health and safety issues and the world market for tuna commodities, with a particular focus on imports and prices.

The *Conclusion* section demonstrates the links between tuna fishing capacity, catches, demand for tuna (imports) and prices. The ultimate aim is to provide analysts with a tool for the estimation of the optimal tuna fishing capacity, based on environmental and socio-economic factors.

The main sources utilized for the preparation of this paper were the databases FISHSTAT Plus[3] and EUROSTAT and the data and information provided by the Services of the FISH INFOnetwork (GLOBEFISH, INFOFISH, INFOPÊCHE, INFOPESCA and INFOSAMAK). Other important sources of information were

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[1] Activity A3/A4 results from the merging of ex project activity A3: demand for tuna raw materials and products and their prices, and A4: socio-economic importance of tuna industry: fishing, processing and marketing.

[2] For instance, skipjack and (to a lesser extent) yellowfin by the end of the decade ("the Bangkok bottleneck").

[3] Available http://www.fao.org/fi/statist/FISOFT/fishplus.asp.

national statistics (online and on CD ROM), the internet, articles in trade journals and scientific journals, books, grey literature and personal communications.

The author has strived to provide a balanced analysis of the world tuna market. The approach utilized is a "bottom-up" one, which relies on the analysis of empirical data series as a necessary pre-condition for the elaboration of a theoretical model. The shortcomings encountered in the preparation of the paper relate mainly to the availability and quality of some of the data.

Traditionally, FISHSTAT Plus, EUROSTAT and national data on international trade of fresh, frozen and canned tuna share a high degree of consistency. However, data on imports and exports of tuna loins are not consistent with the true extent of the utilization of loins by the world tuna processing industry. Moreover, data on processing capacity of tuna canneries are generally based on estimates, and historic series are unavailable. Furthermore, the quality of data collection and of reporting varies in accordance with the different countries.

The availability of historical data on the prices for some commodities, such as materials for canning (frozen skipjack, yellowfin and albacore) and canned white and light meat tuna permitted the Services of the FISH INFOnetwork and other agencies to undertake consistent analyses of price series of the world tuna market. Other products, such as *sashimi*-quality frozen or fresh tuna, are very complicated (due to the presence of various degrees of quality according to objective, but also subjective, criteria), so the quality and consistency of the data are often inferior to those for materials for canning.

In general, when reading this paper, it should be borne in mind that, while the trends reflect the available statistics, there is a variable degree of uncertainty in the monthly and annual data.

1.3 Principal findings of the study

The analysis contained in the study covers the period from 1989 to 2003[4], an eventful period for the world tuna industry. During this period the tuna industry was characterized by:

- the tuna-dolphin issue;
- the continued and possibly accelerated internationalization of the European tuna industry, and its integration with the African and Latin American industries;
- the strengthening of the position of Thailand as the top world canned tuna producer (despite the mid-decade crisis);
- the development of bluefin tuna farming, which increased the availability of *sashimi*-quality bluefin to the Japanese market.

The market has been characterised by:

- creation of the World Tuna Purse-seine Organization (WTPO), the principal purpose of which was to reduce the purse-seine fishing effort, which, in turn, would reduce the supply of raw material to levels corresponding to the demand and increase the prices for raw material;
- progressive substitution of pre-cooked, frozen loins for whole frozen raw material by canneries in developed countries;
- introduction of a wide range value-added canned products, such as tuna salads, tuna in sauce, tuna paste "tuna in a pouch";
- increase in the world demand for tuna for *sashimi* and other non-canning purposes;
- growing concerns over tuna resources, especially and bigeye and the three species of bluefin, which are the principal components of the *sashimi* market;

[4] A detailed analysis of the world tuna market before 1989 is available in ADB/INFOFISH (1991).

- increasing trade of non-frozen (fresh) tuna in the international market;
- development of farming of the three species of bluefin, which has increased the supply of *sashimi*-grade fish.

During the 1990-2003 period the *sashimi* tuna market was characterised by good international demand (imports) and supply (ensured by catches of large *sashimi*-grade fish and farm-raised fish). In spite of the strong demand for *sashimi*, the prices of the three species of bluefin and of bigeye for the upper-end *sashimi* market declined due to:

- increasing availability of farm-raised bluefin; and the condition of the Japanese general economy;
- increased catches of bigeye during the 1994-2002 period.

During the 1989-1998 period the demand for raw material for the canned tuna market was generally exceeded by the supply. In some quarters the tuna resources were regarded as inexhaustible, or nearly so. This period was characterized by:

- good supplies of raw material;
- increasing imports of raw material; and
- relatively high prices of both raw material and canned tuna.

This situation led to construction of new vessels, which, in turn, led to greater catches. The market could not absorb the greater catches of fish, and the prices declined between late 2000 and early to mid-2003. This decline, known as "the Bangkok bottleneck", was the result of excess fishing capacity. In late 2000 the WTPO implemented measures to restrict fishing effort in order to eliminate the oversupply of fish and increase the prices for the raw material. The prices increased in 2001, but between 2002 and 2003 the market became oversupplied again, and the prices declined, so the WTPO measures were re-introduced[5]. According to King (1987), cited by Gillett, McCoy and Itano (2002), when prices decline, the productivity and efficiency of vessel operations become more critical. A typical vessel might increase its efficiency in order to increase its catches sufficiently to compensate for the reduced prices of fish. When a large numbers of vessels do this the prices are pushed even lower. At best, this is a waste of capital. At worst, in addition to the waste of capital, overfishing of some target or non-target species of fish could occur.

2. ANALYSIS OF THE FACTORS AFFECTING TUNA CATCHES

Tuna captures are affected by a wide variety of factors, both human and non-human induced.

Human-induced factors include:

- trends in the demand of tuna commodities;
- operating costs of tuna fishing;
- developments in fishing capacity and technology;
- regulations governing tuna fisheries; and
- availability and cost of transport of tuna products.

The increase in tuna catches after World War II was propelled by the growing demand for this protein-rich food[6]. Over time, the growth of the tuna industry fostered the growth of the fleet, both in numbers of vessels and in the sizes of the individual vessels. Also, there were numerous technological developments, which increased the efficiencies of the individual vessels.

The bulk of tuna catches is taken by purse-seine vessels, longliners and pole-and-line vessels. Other fishing methods include gillnets, traps, handlines, ring nets and

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[5] Further information is available in (1) the section *Analysis of the factors affecting tuna catches*, (2) the subsection *Whole raw material for canning* of the section *Selection of key prices and price series analysis* and (3) the subsection *The market for raw material and canned tuna* of the section *Conclusion*.

[6] The next section, "tuna industry analysis", will provide an overview of the world market for tuna commodities, with a particular focus on international demand (imports) and prices.

trolling gear. Until the mid-1950s the growth in tuna catches came mostly from pole-and-line vessels, but thereafter, up to 1964, most of the expansion in tuna catches can be attributed to increases in the numbers of longliners. Subsequently, power blocks, synthetic nets and improved equipment for freezing fish at sea greatly improved the efficiency of purse seining. After 1966, most of the growth in total catches was a consequence of the increase in the number of purse seiners and in their fishing power (Allen, 2002). It is estimated that, at present, there are nearly 600 high-seas purse seiners, with a total carrying capacity of 600 000 tonnes, which take about 60 percent of the total catch of tuna (Joseph, 2003).

Tunas are highly mobile, frequently moving between the Exclusive Economic Zones (EEZs) of different countries and areas beyond the EEZs of any country. Bilateral agreements between DWFNs and coastal states are implemented through the sale of fishing licences to vessels, such as purse seiners and longliners, registered in DWFNs. The mobility of the tunas and the vessels that fish for them make it impossible to institute regulations to conserve them unless all of the countries that have vessels participating significantly in the fishery agree to abide by whatever regulations are adopted.

Some countries, such as Angola, Equatorial Guinea, Mauritius and the Seychelles have granted licences to purse-seine vessels from members of the European Union (EU) to fish in their waters or allowed vessels to register under their flags in exchange of a financial compensation, sometimes aimed at funding research, training and management of their fishery industries (FAO/GLOBEFISH, 2000a). In the South Pacific, the Treaty on Fisheries between Governments of Certain Pacific Island States and the U.S.A. allows 50 purse-seine vessels from the United States to enter the waters of the member countries of the South Pacific Forum Fisheries Agency Convention (FFA); the agreement also includes comprehensive fisheries management related provisions (Tamate, 2000). Also, Japan has made fishing agreements granting fishing licences in the EEZs of various coastal countries, such as Morocco, the Republic of South Africa and several South Pacific islands (FAO/GLOBEFISH data bank).

The fisheries for tunas are characterized by the highly-migratory nature of the fish, including occurrence on the high seas, the high mobility of the vessels that take most of the catch, the fact that there are several types of gear, each of which takes several species of tunas and tuna-like fishes and the fact that most of the stocks of tunas are fully exploited or overexploited. This has made it necessary to establish regional fishery bodies and arrangements (RFBAs) aimed at the management of tunas in the various ocean regions. The tuna RFBAs include:

- The Commission for the Conservation of Southern Bluefin Tuna (CCSBT), aimed at the sustainable management of southern bluefin tuna through measures such as quotas and import and re-export certificates under the Trade Information Scheme (TIS) (http://www.ccsbt.org);
- The Inter-American Tropical Tuna Commission (IATTC), responsible for the conservation and management of the fisheries of tunas and related species in the eastern Pacific Ocean (EPO) (http://www.iattc.org);
- The International Commission for the Conservation of Atlantic Tunas (ICCAT), responsible for the conservation of tuna and tuna-like species in the Atlantic Ocean and adjacent seas; it has launched, *inter alia*, management measures (including quotas) and trade certificates, the Bluefin Statistical Document, BFSD (1993), a swordfish statistical document and the Bigeye Statistical Document, BESD, in 2002 (http://www.iccat.es) and its positive list of fishing vessels system (2002);
- The Indian Ocean Tuna Commission (IOTC), aimed at the management of tunas and tuna-like species in the Indian Ocean and adjacent areas, launched, *inter alia*, a trade documentation scheme for bigeye tuna (http://iotc.free.fr/English/index.htm);

- the recently-established Western and Central Pacific Fisheries Commission (Allen, 2002).

These RFBAs have the responsibility to ensure the conservation and optimum utilization of tuna resources through stock assessment and management measures. The latter include catch quotas, limitation of fishing effort, restriction on the use of fish-aggregating devices (FADs) and minimum size limits for individual fish that are caught (Allen, 2002). The actions of these bodies affect not only the catches of tuna and tuna-like species, but also international trade. For example, under the BFSD and TIS scheme, all imports and re-exports of Atlantic and Pacific bluefin, through the BFSD, and southern bluefin, through the TIS, must be certified as to origin. The export certificate must be endorsed by an authorised competent authority in the fishing and exporting countries and must include details of the shipment, e.g. name of fishing vessel, gear type, area of catch, dates, etc. The re-export certificate should include, *inter alia*, the re-exporting country or fishing entity and a description of the commodity to be re-exported, accompanied by the original BFSD. Further trade-restrictive actions have been taken in accordance with recommendations by ICCAT to its member countries for prohibiting imports of certain species from countries identified as undermining conservation measures.

Recently, ICCAT, IOTC and IATTC adopted positive vessel list system, through which tunas taken by vessels more than 24 metres in overall length that are not listed in the positive lists would not purchased by members of those RFBAs.

The creation of other international bodies has had an impact on the marketing of the catches of tunas and tuna-like species, as well as their conservation. On 1 December 2000, at the second World Tuna Boat Owners Meeting (now institutionalized as the World Tuna Purse-seine Organization, WTPO), a drastic reduction in skipjack fishing was adopted; vessels of all participating countries would not fish for more than 30 of the next 60 days, or would implement a reduction of 35 percent in their fishing effort. The aim was to reduce the supply of skipjack sufficiently to increase the prices, which had fallen to a historical low of US$350-450/tonne during 2000 (FAO/GLOBEFISH, 2000b). The market stabilized in 2001 (FAO/GLOBEFISH, 2001b), but prices declined once again in 2002. In early 2003 the WTPO required that the vessels remain longer in port after unloading; the larger vessels would remain on port longer than the smaller ones.(ATUNA.com data).

The WTPO Asian Group meeting, held in Seoul (Republic of Korea) in February 2003, addressed, once again, the price decline of whole round frozen skipjack on the Bangkok market. The price had fallen from US$700/tonne in December 2002 to US$600/tonne cost and freight (c&f) in February 2003 (ATUNA.com data). The so-called "Bangkok bottleneck" was brought about by vessels in the Indian and Atlantic Ocean selling and unloading their fish in the nearby Bangkok market, rather than using traditional sales channels such as the Seychelles, Mauritius and the Maldives. With an already oversupplied Bangkok market, this practice caused world skipjack prices to decline (ATUNA.com data).

The WTPO proposed that the skipjack catches be reduced by increasing the number of days in spent in port after unloading, and that the French and Spanish fleets make a commitment not to supply the Bangkok market at prices below the current market levels (ATUNA.com data). Because of the unwillingness of members to complying with the WTPO recommendations, they were reformulated two months later. By that time (late April 2003) frozen skipjack prices had dropped to US$450/tonne (ATUNA.com data).

The new system of reduction involving the fishing vessels is related to the capacities of the boats. Boats with capacities less than 1 300 tonnes would remain in port for at least eight days, boats with capacities of 1 300 to 1 700 tonnes would remain in port for at least ten days and boats with capacities of more than 1 700 tonnes would remain in

BOX 1

El Niño

Easterly surface winds blow almost constantly over northern South America, which causes upwelling of cool, nutrient-rich subsurface water along the equator east of 160ºW, in the coastal regions off South America, and in offshore areas off Mexico and Central America. El Niño events are characterized by weaker-than-normal easterly surface winds, which cause above-normal sea-surface temperatures and sea levels and deeper-than-normal thermoclines over much of the tropical eastern Pacific Ocean (EPO). In addition, the Southern Oscillation Indices (SOIs) are negative during El Niño episodes. (The SOI is the difference between the anomalies of sea-level atmospheric pressure at Tahiti, French Polynesia, and Darwin, Australia. It is a measure of the strength of the easterly surface winds, especially in the tropical Pacific in the Southern Hemisphere.) La Niña events, which are the opposite of El Niño events, are characterized by stronger-than-normal easterly surface winds, below-normal SSTs and sea levels, shallower-than-normal thermoclines, and positive SOIs (IATTC, 2004). During El Niño events the catches of tunas tend to decline due to the greater depth of the thermocline, which reduces the catchability of the fish, whereas during La Niña events the catches of tunas tend to increase.

The catches per unit of effort (CPUEs) of tunas in the EPO declined considerably during the El Niño event of 1982-1983, which caused many of the vessels to transfer their operations to the western and central Pacific Ocean (WCPO), and the catches of yellowfin tuna in the EPO by surface gear declined from 181 813 tonnes in 1981 to 94 256 tonnes in 1983 (IATTC, 2004). In turn, the catches in the WCPO, until 1979 almost a virgin ground for commercial tuna fishing, increased from 3 759 tonnes in 1980 to 155 733 tonnes in 1984 (FISHSTAT Plus data).

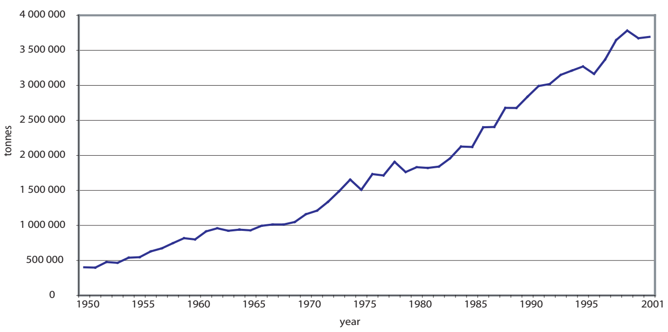
The greatest catches of skipjack in the WCPO are taken in an area where relatively cool, more-saline water from the central and eastern Pacific Ocean converges with relatively warm, less-saline water of the western Pacific warm pool. The area of convergence shifts eastward and westward, in accordance with oceanographic conditions, by as much as 50° of longitude. During El Niño events it is displaced eastward, and during La Niña events it is displaced westward. The areas of greatest skipjack catches can be predicted several months in advance by examination of oceanographic data (Lehodey *et al*., 1997).

The situation in the Indian Ocean is somewhat similar to (but not related to) that in the Pacific Ocean. Normally, the water is relatively warm in the eastern Indian Ocean, near Indonesia, and relatively cool in the western Indian Ocean, near Africa. However, due to changes in the winds and ocean currents the normal pattern can become reversed, which happened in 1961, 1967, 1972, 1994, and 1997-1998 (Saji *et al.*, 1999; Webster *et al.*, 1999). This condition is known as the "Indian Ocean dipole". The subsequent surface warming of the Western Indian Ocean affects the productivity of the area in the same way as an *El Niño* event affects the productivity of the EPO. Hence, commercial tuna fleets moved their operations from the western to the eastern Indian Ocean during 1998 (INFOFISH, Pers. Comm.). The catches of tunas in the western Indian Ocean decreased from 572 393 tonnes in 1996 to 545 022 tonnes in 1998, while those in the eastern Indian Ocean increased from 148 807 tonnes in 1996 to 193 248 tonnes in 1998 (FISHSTAT Plus data).

port for at least 12 days. Taiwan Province of China and the Philippines left deposits of US$140 000 and US$100 000, respectively, which would be lost if any of their vessels failed to comply with the measures. In the months which followed, skipjack prices in the Bangkok market increased to US$700-720/tonne in July 2003 and US$750-780/tonne in December 2003 (FAO/GLOBEFISH data bank).

The principal non-human induced factors influencing the availability of tuna resources are climatic and meteorological conditions. The clearest example is given by the impact of *El Niño* (see Box 1) on the catchability of tuna in the EPO in 1982-1983 (IATTC, 2004). Other factors include the balance of the ecosystem, including availability and abundance of forage and predators.

FIGURE 1
World catches of the principal market species of tunas



According to FISHSTAT Plus data, total catches of tunas increased from 402 350 tonnes in 1950 to 3 782 379 tonnes in 1999, decreased to 3 672 202 tonnes in 2000 and then increased to 3 692 701 tonnes in 2001 (Figure 1). The catches of tunas in 2001 represented 63 percent of world catch of tunas, bonitos and billfishes. Skipjack is the principal species caught, followed by yellowfin, bigeye, albacore and the three species of bluefin.

The world catches of skipjack increased from 162 329 tonnes in 1950 to 1 988 826 tonnes in 1999, and then declined to 1 836 438 tonnes in 2001. The principal fishing ground is the WCPO; other relatively important fishing grounds are the western Indian Ocean and the northwestern Pacific Ocean. The greatest catches of skipjack are taken by Japan, followed by Indonesia, Taiwan Province of China and the Republic of Korea.

The world catches of yellowfin increased from 109 605 tonnes in 1950 to 1 202 312 tonnes in 2001. The principal yellowfin fishing ground is the WCPO, followed by the EPO and the western Indian Ocean. The greatest catches of yellowfin are taken by Mexico, Venezuela, Taiwan Province of China and Japan.

The world catches of bigeye increased from 808 tonnes in 1950 to 410 595 tonnes in 2000, and then decreased to 372 110 tonnes in 2001. The principal bigeye fishing grounds are the EPO, the western Indian Ocean and the eastern central Atlantic Ocean. The greatest catches of bigeye are taken by Japan and Taiwan Province of China.

The world catches of albacore increased from 103 676 tonnes in 1950 to 221 473 tonnes in 2001, after reaching a peak of 244 269 tonnes in 1989. The principal fishing area is the northwestern Pacific Ocean. The greatest catches of albacore are taken by Japan, Taiwan Province of China, the United States and Spain.

The world catches of Atlantic bluefin tuna increased from 24 480 tonnes in 1950 to 52 581 tonnes in 1996, and then decreased to 35 682 tonnes in 2001. The principal fishing area is the Mediterranean Sea. The greatest catches of Atlantic bluefin are taken by France, Spain and Italy.

The world catches of southern bluefin tuna declined from 55 487 tonnes in 1972 to 15 543 tonnes in 2001. The principal fishing area is the eastern Indian Ocean. The greatest catches of southern bluefin are taken by Japan and Australia.

The world catches of Pacific bluefin tuna declined from 31 542 tonnes in 1961 to 9 143 tonnes in 2001. The principal fishing area is the northwestern Pacific Ocean. The greatest catches of Pacific bluefin tuna are taken by Japan and Taiwan Province of China.

3. ANALYSIS OF THE TUNA INDUSTRY

This section, which provides a detailed analysis of the world tuna industry, represents the core of the paper. It focuses on the following points:

- the tuna processing chain, including health and safety issues;
- the analysis of the international demand for tuna commodities; and
- developments in world tuna prices.

The findings of this section will provide a basis for estimation of the impact of the tuna market (import and prices) on tuna fishing capacity, and data for evaluation of options for management of total vessel capacity.

3.1 The tuna processing chain

The main internationally traded tuna forms are:

1. raw material for canning:
   a. round or headed and gutted (H&G), frozen;
   b. round or H&G, fresh or chilled (minor amounts).
2. pre-cooked loins for canning, frozen.
3. tuna for direct consumption (*sashimi* and other non-canning uses):
   a. round, gilled and gutted (G&G) and H&G, fresh and chilled;
   b. round, G&G and H&G, frozen;
   c. loin and fillet form, generally frozen.
4. Canned:
   a. solid pack;
   b. chunks;
   c. flakes (also in pouch pack);
   d. grated.
5. smoked and dried.
6. oil and meal, pet food or animal feed.

(ADB/INFOFISH 1991; INFOFISH, Pers. Comm.).

Tuna flesh is extremely sensitive. The fish must be handled carefully in order to prevent "burning", e.g. bruising and damage to the flesh. If the tuna is killed under stress, the flesh undergoes chemical changes, the so-called "burning", which causes the flesh to become mushy and, for some purposes, inedible. Therefore, the best fishing method to catch tuna is line fishing (handline, pole-and-line and longline), as it generates minimal damage.

3.1.1 Tuna for direct consumption: sashimi and steaks

Sashimi is prepared from fresh raw tuna meat, or from tuna frozen at temperatures below -40°C immediately after capture. Traditional *sashimi* is prepared from the three species of bluefin, bigeye and yellowfin tunas. Albacore, which is caught mainly pole-and-line and longline gear, and which was formerly used only for canning, is increasingly being processed as *sashimi* in Japan. A different kind of *sashimi*, called *tataki*, is prepared from pole-and-line caught skipjack. Similarly, skipjack caught by using pole-and-line is consumed as *sashimi* other than *tataki*. Furthermore, billfishes (swordfish, marlins, spearfish and sailfish) are considered as tuna in Japan and processed into *sashimi* (Tanabe, 2000).

Tuna for the *sashimi* market is first judged objectively for *sashimi*-grade by species, time and area of catch, size, condition (fresh or frozen), core temperature and fishing method. They are also graded subjectively on the basis of visual characteristics, such as fatness, bright/clear appearance of the skin, clear and moist eyes, elastic skin, undamaged abdominal walls, colour, clarity and texture of the flesh and odour (ADB/INFOFISH 1991). According to connoisseurs, the best *sashimi* is processed from large individuals caught prior to the spawning season. Different *sashimi* cuts from different species have different market values, depending on the fat content: the greater the fat content, the greater the value of the *sashimi*. The best *sashimi* comes from *toro*, the peripheral layer of the fish belly, with a fat content of about 25 percent. *Toro* is further divided into *otoro*, pink, which is considered to be the prime *sashimi*, and *chutoro*, darker pink (ADB/INFOFISH 1991).

The prime *sashimi*-graded tuna must be:

- fresh or chilled (or frozen at sea at temperatures below -40°C);
- brightly coloured (red to pink, depending to the species);
- with a firm, but crispy, texture.

The order of preference is, in general, Atlantic or Pacific bluefin, southern bluefin, bigeye, yellowfin and albacore. (There is some overlapping between species, however.

For example, good-quality bigeye is considered to be better than poor-quality bluefin.) The preference also differs in different regions of Japan. For example, consumers in northern Japan prefer red and fat meat, while consumers in southwestern Japan prefer less fat and pink-coloured meat. In general, however, fish with higher fat contents are sold at higher prices. As mentioned above, other elements, such as freshness, colour, odour and texture, may also be very important. Generally, the best-quality tuna are those taken by handlines and landed fresh. Purse-seine catches are not suitable for *sashimi* unless handled very carefully and landed fresh immediately after capture. Tuna frozen at temperatures greater than -40°C is not suitable for the *sashimi* market.

Sashimi is served in thin slices, dipped in soy sauce and/or *wasabi* (Japanese horse radish) and consumed raw (Harada, 2002). *Sushi* is a cylinder of rice combined with vinegar, with a slice of *sashimi* on the top or in the middle. *Tataki* is raw skipjack, broiled outside slightly and sliced, served with onion or garlic and other spices in vinegar and soy sauce.

Tunas that are not acceptable for *sashimi* are sold in the steak market, generally in Europe and the United States. The borderline between *sashimi*-quality and steak-quality tuna is variable. The vendors, often exporters, decide which market is the most profitable for a certain product, based on the quality of the tuna meat, the costs of shipping and the market prices in various countries. In general, the prices in the Japanese *sashimi* market are higher than those in the world steak market, but this has been changing somewhat in the recent years.

Steaks are generally prepared from bigeye, yellowfin and albacore tunas, mostly fresh but also frozen. The fish are loined and skinned prior to being cut into steaks.

3.1.2 Canning

The principal species used for canning are skipjack and yellowfin. The prices of yellowfin are higher than those of skipjack because yellowfin are often considered to be of better quality and also, because they are larger, produce less waste than do skipjack during processing. Canned yellowfin and skipjack are usually labelled as light-meat tuna, except in Japan, where skipjack cannot be legally labelled as tuna. Locally-caught bluefin, particularly in Italy are also canned as a high-quality product. The belly of the tuna, canned in olive oil and marketed as *ventresca*, is considered a delicacy. Albacore is marketed as white-meat tuna, which has a higher value than light-meat tuna.

Packs are also classified by the condition of the meat cut, e.g. solid pack, chunks and flake or grated tuna. Solid packs are prepared from whole tuna loins that have been cut into transverse segments, while chunk packs are prepared by cutting tuna loins into smaller pieces (Chicken of the Sea, 2002). The smallest pieces that are devoid of blood and skin are canned as flake or grated tuna.

Several steps are involved in converting fish to the canned product. When the fish (generally frozen) are unloaded from the fishing vessels or freezer vessels they are thawed in running water in thawing tanks or with sprays of water (US DOL, 2003). If the fish are whole they must be gilled, gutted and deheaded. In the past, butchering was done manually, with knives and machetes, but currently it is done with multiple automated stainless steel saws (Carril Diaz, 2002).

After cutting, the tunas are sorted by size and loaded onto trays. The trays are stacked on wheeled shelf racks and taken to the pre-cooker, or first cooker. During pre-cooking and cooling, up to 30-percent weight loss occurs, mostly by overcooking (which can be minimized by placing fish of only one size in a given cooker and varying the cooking time in accordance with the size of the fish). The pre-cooking process generally takes from 45 minutes to three hours, depending on the size and species of tuna (US DOL, 2003).

After pre-cooking and cooling, the tuna are put on conveyor belts that carry the fish to the cleaning or filleting tables. Cleaning is a completely manual process

(Carril Diaz, 2002). The cleaners remove the skin and dark meat from the fish and separate the loins from the skeleton (US DOL, 2003). The dark meat scraped from the loins is used to prepare pet food (ADB/INFOFISH, 1991). The waste from the cleaning tables, together with the offal from the eviscerating tables go to the reduction plant, where the oil and water are extracted and the remainder is dried and ground to produce fish meal (ADB/INFOFISH, 1991).

The last step, canning, is a totally automated process. The first tuna-packing machine, designed in 1956, produced a maximum of 36 cans per minute. Present machines produce 300 cans per minute, and the quality of the product is better (Carril Diaz, 2002). Canned tuna is packed in oil, brine, spring water or sauce. Various flavouring and seasoning additives, including oil, salt, vegetable broth, lemon, monosodium glutamate, vinegar, hydrolysed protein and spices, are used. After the cans are sealed they are placed in a retort, where they are cooked for two to four hours, which, of course, kills any bacteria that are present. After that the cans are cooled, labelled and packed into cardboard cartons for distribution (US DOL, 2003).

Over the past 20 years, the phenomenon of loining has been expanding rapidly. When a fish is loined it is first cooked, and then the large masses of muscle on either side of the backbone are removed (ADB/INFOFISH, 1991). It is a relatively common practice to land fish in developing countries near the fishing grounds, where the loining is carried out, and then to export the frozen loins to canneries in developed countries (FIAC, pers. comm.).

The loining process (including cutting and cleaning), accounts for up to 80 percent of the labour costs in a full-scale tuna cannery (US DOL, 2003). Carrying out the loining process in developing countries and the final canning in investor countries provides employment in developing countries, reduces the costs of transportation of the fish to the canneries (because the loins weigh less than the whole fish) and reduces overall labour costs (but still provides partial protection of employment in the canneries of investor countries).

The operations required for the production of frozen loins and of canned tuna are essentially the same up to the point where the tuna is cut into loins. In a loin-producing facility, after the pre-cooking and cleaning process, the loins are packed in plastic and frozen for shipment to the canneries. In the tuna canneries, in turn, the loins are cut into pieces for solid packs or chunks and packed into the cans (US DOL, 2003).

Tuna may be packed in steel cans or in glass jars. In the United States the standard weight of tuna cans has shrunk progressively from 7 ounces (198 g) to 6 ounces (170 g) net weight (ATUNA.com data). In the EU there is no standard weight for tuna cans, but smaller cans generally contain 80 or 120 g of tuna, while larger cans generally contain 160, 185, 200, 240 or even 500 g of tuna. Cans used by restaurants, etc., usually contain 2 to 5 kg of tuna.

Tuna is also processed into other value-added products, such as tuna salad, tuna in a pouch, tuna steaks, tuna paste and tuna burgers. Tuna salads, *hors d'oeuvres* and paste are very popular among western consumers. In France the consumption of tuna salads and *hors d'oeuvres* exceeds that of canned tuna in brine or in olive oil. Albacore and yellowfin fillets in olive oil are considered as a delicacy in European markets. Tuna roe is often processed into *poutargue* or *bottarga*[7] (FAO/GLOBEFISH, 2002d).

Tuna in a pouch is a recently-developed product, which has spread from the United States to Europe. Some analysts believe that tuna in a pouch will replaced canned tuna

[7] The term *poutargue* or *bottarga* comes from the Arab *bot-ah-rik*, which means "raw fish eggs". It comes mainly from mullet and tunas, and, despite the tuna *poutargue* or *bottarga* being less delicate than its mullet equivalent, it is nevertheless an estimed delicacy. It is prepared by extracting the eggs from the fish while still in their protective sacs, washing and purifying them, putting them in salt, rinsing them and drying them in storage rooms. *Bottarga* is sold in pieces, i.e. unbroken sacs, and may be vacuum-packed. It is also possible to find *bottarga* paste, i.e. grated dried *bottarga* packed in glass jars or vacuum-packed *bottarga* slices (FAO/GLOBEFISH 2002d).

in a few years, while others believe that, as a consequence of high investments in the tuna canning industry and of its efficiency, the alternative pouch product will remain within a limited market niche (ATUNA.com data).

According to 2002 data (NMFS, 2003), import of tuna (including albacore) in a pouch represents about 11 percent of United States' canned tuna imports in terms of quantity and 12 percent in terms of value. Import of tuna in a pouch is also equivalent to 7 percent of total imports of tuna by the United States both in terms of quantity and of value (NMFS, 2003). In 2002 Faleomavaega (2002), cited by Gillett, McCoy and Itano (2002), forecast that tuna in a pouch could grow to an 8 percent share of the United States' total tuna trade by 2005, to a 12.2 percent share by 2007 and to a 15.4 percent share by 2012.

3.1.3 Other tuna products

Dried and smoked products, called *fushi* in Japanese, include:

- *Katsuobushi*, e.g. skipjack loins boiled, broiled or smoked over charcoal several times; the partially-dried product is then subject to a moulding process;
- *Kezuribushi*, products made by shaving *Katsuobushi* fillets;
- *Arabushi*, produced by drying and smoking skipjack loins;
- *Namaribushi*, similar to the former, but softer, obtained by reducing the duration of the smoking period.
- *Katsuobushi* extract, a purified, concentrated water-soluble powder that serves as raw material for the preparation of broth, and it is used by many Asian nations instead of *kezuribushi*.

In order to prepare *katsuobushi*, skipjack tuna is boiled, smoked and then naturally dried. It is important that there be mould on surface to reduce the amount of fat in the flesh. A special tool is used to flake the extremely hard chunks. *Katsuobushi* can be purchased in Asian markets and in the specialty sections of some large supermarkets. When preparing *kezuribushi*, after drying, the fish is shaved into fine strands or short, slightly thicker flakes. *Katsuobushi* and *kezuribushi* are used in Japanese cuisine, either as a garnish, placed directly on top of salads or chilled tofu, or in cooked preparations such as *dashi* soup.

Other products include *tsukudani*, a product prepared from skipjack flesh, cooked in soybean sauce, sugar and other flavouring material. *Shiokara* is a salt-fermented product produced from the viscera, stomach or low fat meat of skipjack (ADB/INFOFISH, 1991). Dried and salted tuna (*mojama*) is considered a local delicacy in coastal regions of Spain.

3.2 Health and safety

The Hazard Analysis and Critical Control Point (HACCP) principle is generally applied to the tuna industry. HACCP requires that food safety controls be integrated within all processing stages, rather than applied just to the final product. Tuna-importing countries that implement HACCP in their domestic production refuse to import tuna products from countries not ensuring equivalent health and safety standards.

The most likely hazard when consuming improperly-handled scombroids (tunas and mackerels) is histamine poisoning. Histamine is produced in certain types of fish when microbes break down the amino acid histidine. Failure to promptly chill or freeze recently-caught fish accelerates the growth of micro-organisms normally present in the fish, accelerating the breakdown of histidine into histamine.

Histamine is a toxin that produces symptoms similar to an allergic reaction. It is very difficult to diagnose, in most cases being mistaken for a food allergy. When a person has an allergic reaction the body releases histamine, but when a person has scombroid poisoning he or she consumes histamine, rather than releasing it (CNN, 2001).

The symptoms of scombroid poisoning may include rashes, a metallic taste in the mouth, nausea, vomiting, diarrhoea, hypotension, palpitations, tingling, muscle weakness and respiratory paralysis, and sometimes death (Neogen, 1998).

Raw fish can be contaminated with faecal bacteria when gutted, and if the fish are stored at temperatures above freezing, the bacteria grow. They produce an enzyme that dissolves the tissues of the fish, resulting in the production of histamine. Cooking tuna might kill the bacteria, and even destroy the enzymes, but histamine is not affected by heat after it is produced (CNN, 2001).

Raw tuna used for *sashimi* is less likely to be contaminated because it is usually stored in large pieces and at freezing temperatures and sliced right before serving, making it less susceptible to warming temperatures. On the other hand, when tuna is ground to prepare tuna burgers, the friction could raise the temperature of the fish, thus promoting bacterial growth and histamine production. The easiest way to prevent this type of food poisoning is to store the fish at temperatures below 0°C. Each time the fish is handled its temperature is likely to increase; so it is essential to keep it at or below 0°C while handling it (CNN, 2001).

A different problem is represented by carbon monoxide (CO). CO is a colourless, odourless, highly-poisonous gas produced by the incomplete combustion of fossil fuels such as gas, oil, coal and wood used in boilers, engines, oil burners, gas fires, water heaters, solid fuel appliances and open fires (Carbon Monoxide Kills, 2003). This gas is naturally released by fish when smoked. In a few cases, tuna used for the preparation of steaks and *sashimi* is artificially coloured by CO treatment. The use of CO as a colour additive in food is banned in the United States, by EU legislation (Official Journal of the European Communities, 1994) and in many nations. The health and safety risks from the use of CO *per se* are fairly limited, because of the high reactivity of CO in combination with fish muscle compounds, mainly haemoglobin. However, apart from the consumer deception issue (the consumer may think that the fish is fresher and of a better quality than what it really is), the most likely health and safety risk is histamine poisoning, as the bright colour could conceal poor handling and temperature abuse (FIIU, pers. comm.).

Another cause of concern possibly linked to the consumption of tuna and tuna-like species is mercury content. Mercury occurs naturally in the environment, or it can be released into the air as industrial pollution and absorbed by surface waters. Bacteria living in water convert inorganic mercury into methyl mercury, and fish absorb it through the water and by feeding on other aquatic organisms. Long-lived predators such as sharks, tilefish (Macalanthidae), swordfish and king mackerel (*Scomberomorus cavalla*) tend to accumulate the highest levels of methyl mercury.

The primary danger of methyl mercury in fish is the harmful effect it has on the development of the nervous system in unborn children and in children of less than six years of age. Therefore, in March 2001 the United States Food and Drug Administration issued a consumer advisory warning pregnant women and women of childbearing age who may become pregnant about the risk of mercury poisoning (FDA, 2001).

According to the FDA, while pregnant women and women of childbearing age who want to become pregnant should abstain from eating sharks, tilefish, swordfish and king mackerel, they may nevertheless eat 12 ounces per week (0.454 kg) of other cooked fish (FDA, 2001). Because of the chronic toxicity of methyl mercury on the cardiovascular and immune system, in June 2001 the Environmental Protection Agency (EPA) recommended the following more precise and stringent monthly limits for adult consumers (70 kg body weight):

- 16 meals (3.632 kg) per month of fish with 0.03 to 0.06 ppm methyl mercury concentration levels; or
- 12 meals (2.724 kg) per month of fish with 0.06 to 0.08 ppm methyl mercury concentration levels; or

- 8 meals (1.816 kg) per month of fish with 0.08 to 0.12 ppm methyl mercury concentration levels; or
- 4 meals (0.908 kg) per month of fish with 0.12 to 0.24 ppm methyl mercury concentration levels, this group possibly including canned tuna according to the estimates made by FDA (FDA, 2001); or
- 3 meals (0.681 g) per month of fish with 0.24 to 0.32 ppm methyl mercury concentration levels, this group possibly including fresh and frozen tuna according to the estimates made by FDA (FDA, 2001); or
- 2 meals (0.454 kg) per month of fish with 0.32 to 0.48 ppm methyl mercury concentration levels, this group possibly including fresh and frozen tuna according to the estimates made by FDA (FDA, 2001); or
- 1 meal (0.227 kg) per month of fish with 0.48 to 0.97 ppm methyl mercury concentration levels; or
- 0.5 meals (0.114 kg) per month of fish with 0.97 to 1.9 ppm methyl mercury concentration levels.

Consumption of fish with more than 1.9 ppm methyl mercury concentration levels should be avoided or limited to less than 0.5 meals per month (EPA, 2001).

The EPA's warnings should be of greatest concern to women of childbearing age who eat more than 10 g of fish a day and women of childbearing age who eat fish with high methyl mercury levels (EPA, 2001). Some states have set even more stringent protection levels. For some sectors of the population, e.g. pregnant women, nursing mothers and young children, some states have issued either "no consumption" or "restricted consumption" advisories (EPA, 2001).

Later on, the warnings of the EPA and the FDA were incorporated in a "Draft advice for women who are pregnant, or who might become pregnant, and nursing mothers, about avoiding harm to your baby or young child from mercury in fish and shellfish" (FDA and EPA, 2003). The advisory can be easily summarised into its three rules for pregnant, pregnant-to-be and nursing women:

1. "Do not eat shark, swordfish, king mackerel or tilefish because they contain high levels of mercury";
2. "Levels of mercury in other fish can vary. You can safely eat up to 12 ounces [340 g] (2 to 3 meals) of other purchased fish and shellfish a week. Mix up the types of fish and shellfish you eat and do not eat the same type of fish and shellfish more than once a week";
3. "Check local advisories about the safety of fish caught by family and friends in your local rivers and streams. If no advice is available, you can safely eat up to 6 ounces [170 g] (one meal) per week of fish you catch from local waters, but do not consume any other fish during that week".

Health Canada and the Canadian Food Inspection Agency (CFIA), in turn, advised pregnant women and women of childbearing age to limit the consumption of shark, swordfish and fresh and frozen tuna (which contain 0.5 to 1.5 ppm methyl mercury) to no more than one meal per month[8]. For other consumers, Health Canada recommended a level of not more than one meal per week. This limit does not apply to canned tuna, which contains less than 0.5 ppm methyl mercury (Health Canada, 2001).

EU regulation 466/2001 sets the maximum level of mercury in fish, which should amount to 0.5 mg/kg wet weight as a rule and 1 mg/kg wet weight for large predators, including Scombroidei (OJ, 2001). The EU is currently establishing specific maximum levels for contaminants in food intended for infants and young children. According to

[8] On 22 March 2004, the FDA and EPA issued a new advisory acknowledging the low concentration of mercury in canned light meat tuna, but at the same time recommending pregnant, pregnant-to-be, nursing women and young children not to exceed the consumption of canned albacore to six ounces (one average meal) per week. In fact, according to FDA, albacore has a higher mercury concentration than other tunas.

the British Food Standards Agency (FSA), pregnant and breast-feeding women and women who intend to become pregnant should limit their consumption of tuna to no more than two medium-sized cans or one fresh tuna steak per week. Such groups should also avoid eating sharks, swordfish and marlins. This advice does not apply other adults or to children, but infants and children under 16 years if age are still advised to avoid eating sharks, swordfish and marlins. These three fish can have levels of mercury approximately five to seven times greater than that of canned tuna and two to four times greater than that of fresh tuna (ATUNA.com data).

There are numerous health benefits that can be derived from eating tuna. Tuna[9], like other oily fish (salmon, mackerel and swordfish) is rich in Omega-3, a polyunsaturated fat. The consumption of fish that are rich in Omega-3 is associated with a decreased risk of heart diseases, cholesterol reduction, regulation of high blood pressure, prevention of arteriosclerosis and other health benefits (ATUNA.com data). Tuna also contains minerals, such as phosphorous, which is important for the nervous system and the bones, and iodine, which is conducive to balanced growth. It also contains proteins and vitamin B_{12} for cell growth, and niacin, which ensures correct metabolism of fatty acids and cholesterol. Studies by the Trinity College and the Saint James' Hospital in Dublin demonstrated the link between Alzheimer's disease and low levels of docosahexaenoic acid (DHA) a fatty acid that is easy to consume by regularly eating oily fish such as tuna (ATUNA.com data).

3.3 Animal welfare concerns: the tuna-dolphin issue[10]

The tuna-dolphin issue is reviewed by Joseph (1994) and Gosliner (1999).

Among the reasons behind the crisis of the United States' tuna industry during the 1990s the tuna-dolphin issue is generally thought to have been the most significant (although Sakagawa (1991) stated that "the down-sizing of the U.S. purse-seine fleet and the transfer of U.S. vessels to foreign flags in the 1980s occurred because of changes in the economic climate of the industry, not because of government tuna-dolphin regulations").

The United States' Marine Mammal Protection Act (MMPA) of 1972 set dolphin protection standards for domestic fishing boats catching yellowfin tuna in the EPO. The MMPA also provided for the embargo of the products of any nation whose vessels fishing for tuna in the EPO did not meet the same standards as U.S. vessels. In April 1990, as a result of threatened boycotts of their products, the principal North American canners stopped processing tuna caught by encircling dolphins. Shortly thereafter, the United States government defined "dolphin-safe" to be tuna captured without encircling dolphins, and prohibited dolphin-unsafe tuna from being marketed in the United States. This led most of the United States tuna fleet to transfer its operations from the EPO, where dolphins and yellowfin tuna associate with one another, to the WCPO, where they do not, creating the conditions to embargo tuna imports from countries such as Mexico and Venezuela that catch tunas associated with dolphins.

The MMPA also provided for a secondary embargo to be applied to "intermediary" countries processing and canning tuna en route from an embargoed country such as Mexico to the United States, e.g. Costa Rica, Italy, Japan and Spain, and before that on France, the Netherlands Antilles and the United Kingdom. Many other countries, including Canada,

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[9] 100 g of *Rio Mare* solid pack canned yellowfin in brine (drained weight), provide 123.50 kcal energy, 25.5 g protein, 0 g carbohydrate and 1.5 g fat. They contain 3 µg vitamin B12 (300 percent of RDA, Recommended Dietary Allowance) and 11.2 mg niacin (62 percent RDA). They also contain 182 mg phosphorous (22 percent RDA) and 50 µg iodine (33 percent RDA). 100 g of *Conservas Antonio Alonso* solid pack canned albacore in olive oil (drained weight) provide 182.5 kcal energy, 24.7 g protein, 0 g carbohydrate and 9.3 g fat. 100 g of solid pack canned Atlantic bluefin in extra-virgin olive oil (drained weight), produced by the *Tonnara di San Cusumano* for SMA-Auchan, provide 242 kcal energy, 24.5 g protein, 0.1 g carbohydrate and 16 g fat.

[10] Sources: WTO at http://www.wto.org/english/tratop_e/envir_e/edis04_e.htm, http://www.atuna.com and James Joseph (pers. comm.).

Colombia, New Zealand, the Republic of Korea and members of the Association of Southeast Asian Nations (ASEAN), were also considered to be "intermediaries".

In January 1991 Mexico challenged the legality of the embargoes imposed by the United States government, and requested that a Dispute Settlement Panel be convened by the General Agreement on Tariffs and Trade (GATT). On September 3, 1991, the Panel published its decision in favour of Mexico. It concluded that the United States could not embargo imports of tuna products from Mexico simply because Mexican regulations *on the way* that tuna was produced did not satisfy United States' regulations. However, the United States could apply its regulations on *the quality or content* of the tuna imported. This became known as a "product versus process" issue. Furthermore, GATT rules did not allow a country to take measures to force other countries to implement its domestic legislation (extra-territoriality).

The Panel's task was restricted to examining how GATT rules applied to the issue. The environmental correctness of the policy was not confronted. The Panel suggested that the United States' policy could have been made compatible with GATT rules if members had agreed on amendments or reached a decision to waive the rules especially for this issue. The Panel was also asked to judge the United States' policy of requiring tuna products to be labelled "dolphin-safe", therefore leaving it up to consumers to choose whether to buy the product. The Panel concluded that this did not violate GATT rules because it did not represent deceptive advertising on all tuna products, whether imported or domestically-produced. However, both Mexico and the United States agreed to not adopt the Panel report, so the matter was not taken to the plenary.

In 1992 the EU lodged its own complaint, which led to a second report, similar to the previous one, which was also not adopted. Subsequently, Mexico and the United States held their own bilateral consultations aimed at reaching an agreement outside GATT, which eventually led to the Agreement on the International Dolphin Conservation Program (AIDCP), which entered into force in February 1999.

The AIDCP is a legally-binding multilateral agreement for the conservation of dolphins in the EPO. The primary objective of the Agreement is to reduce dolphin mortality caused by the fishery to levels approaching zero. In tandem with approval of the Agreement, the Parties agreed to define "dolphin-safe" to include any tuna captured in the EPO in which no dolphins were killed or seriously injured. In the case of the United States, the Secretary of Commerce must make a finding that intentional encirclement of dolphins is not having a significant adverse impact on any depleted dolphin stock in the EPO before the definition of dolphin-safe could be changed.

By the end of December 2002, the Secretary of Commerce of the United States found that encircling dolphins was not having a significant adverse impact on any depleted dolphin stock in the EPO and that the definition of dolphin-safe could be changed. Such a finding would open the door for Mexico and other countries to market tuna in the United States as dolphin-safe. The AIDCP requires that observers from the AIDCP member countries to be placed on all vessels capable of catching tuna in association with dolphins to monitor whether the tuna is dolphin-safe. Should all encircled dolphins be safely rescued from the nets, the tuna could be marketed as dolphin-safe, as opposed to the previous definition of "dolphin-safe", introduced by the Earth Island Institute (EII), which would not allow the label of "dolphin-safe" to be applied to tunas caught in association with dolphins.

EII, supported by several other environmental non-governmental organizations (NGOs), immediately filed a lawsuit challenging the finding by the Secretary of Commerce. In early April 2003, the Federal Court in San Francisco granted an injunction to the implementation of the new definition on the basis of:

- the reliance, by the Department of Commerce, on factors that the Congress of the United States did not intend to consider, and

- the demonstration, by the plaintiffs, that they were likely to succeed in their claim that the final finding of the Department of Commerce was contrary to the best available scientific evidence.

In early May 2003 the same court ruled against the intervention of tuna companies in the case, the motivation for that decision being the fact that the interests of Mexican and Venezuelan tuna industry was not sufficient to allow them to take part in the case, and further that the Department of Commerce was already adequately representing their interests in changing the "dolphin safe" tuna label standards (ATUNA.com data).

Finally, on 9 August 2004, the Federal Court of San Francisco ordered that the findings of the Secretary of Commerce stating that the encircling of dolphins by purse seine nets was not having a significant adverse effect on the depleted dolphin stock in the eastern tropical Pacific Ocean were declared "arbitrary, capricious, an abuse of discretion and contrary to law". Hence, "dolphin safe" shall continue to mean that "no tuna were caught on the trip in which such tuna were harvested using a purse seine intentionally deployed on or to encircle dolphins, and that no dolphins were killed or seriously injured during the sets in which the tuna were caught."

3.4 Global tuna trade

Unless stated otherwise, the data on weights and values in this section were obtained from FISHSTAT Plus. FISHSTAT Plus provides a series of data on world trade of whole tuna (fresh or frozen) and of world trade of canned tuna. In order to ensure consistency of analysis, this chapter will utilize FISHSTAT Plus data on international trade in the principal market species of tunas (albacore, bigeye, bluefin, skipjack and yellowfin) and of tunas nei (not elsewhere identified). Available FISHSTAT Plus data suggest that countries that provided data on tunas nei during the seventies and eighties, began to provide information on the species of the fish during the late eighties and the early nineties. At the same time, with the exception of canned albacore, FISHSTAT Plus does not identify canned tuna according to species, so data on canned tuna are generally presented as "canned tuna, nei".

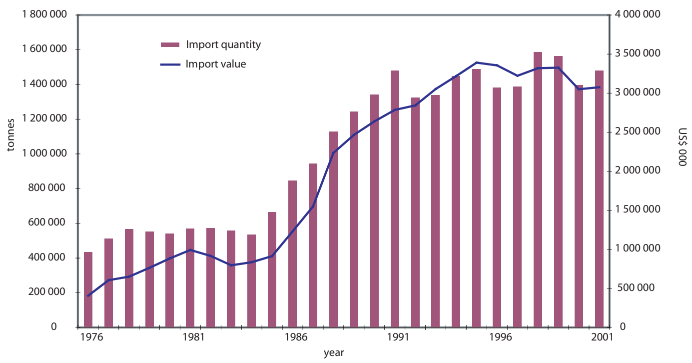
All import data taken from FISHSTAT Plus are in net (product) weight. Live weight (or round weight) can be 20 to 50 percent greater than net weight.

3.4.1 General (frozen, fresh, chilled and canned)

World imports of tuna (frozen, fresh, chilled, tuna fillets, canned, dried and smoked) increased from 524 639 tonnes in 1976 to 2.4 million tonnes in 1999, declined to 2.2 million tonnes in 2000 and then increased to 2.3 million tonnes in 2001. In terms of value, imports increased from US$597 million in 1976 to US$5.5 billion in 1999, decreased slightly to US$5 billion in 2000 and then increased to US$5.2 billion in 2001. In 2001 total imports of tuna were equivalent to 9 percent of total world imports of fish commodities, in terms of both volume and value.

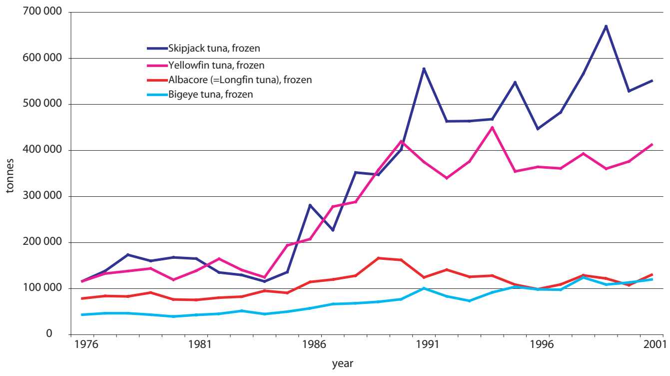
World imports of frozen, fresh and chilled tuna increased from 434 896 tonnes in 1976 to 1.6 million tonnes in 1998, decreased to 1.4 million tonnes in 2000 and then increased to 1.5 million tonnes in 2001 (Figure 2). In terms of value, world imports of frozen, fresh and chilled increased from

FIGURE 2
World imports of frozen, fresh and chilled tuna*



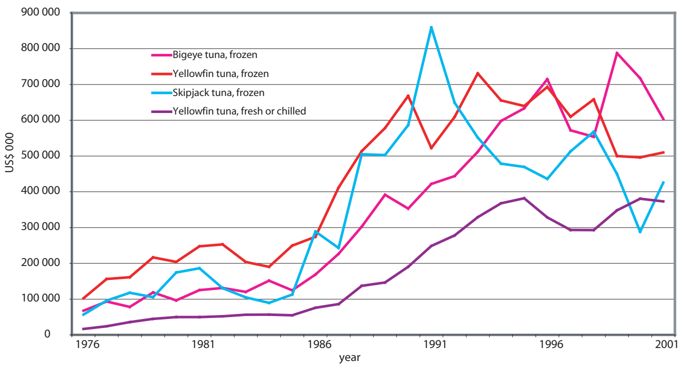
* Including Atlantic, Pacific and southern bluefin tuna.

FIGURE 3A
World imports, by quantities, of the most important species of frozen, fresh and chilled tuna*



* Including Atlantic, Pacific and southern bluefin tuna.

FIGURE 3B
World imports, by value, of the most important species of frozen, fresh and chilled tuna



US$406 million in 1976 to US$3.4 billion in 1995, decreased to US$3 billion in 2000 and 2001, but showed a slight improvement in the latter year (Figure 2).

In terms of volume, the principal imported tuna commodities are frozen skipjack and frozen yellowfin, while, in terms of value, the principal imported commodities are frozen bigeye and frozen yellowfin (Figures 3a and 3b).

The principal importers of frozen, fresh and chilled tuna commodities are Thailand (first in terms of volume; second in terms of value), which imports mainly frozen skipjack for its canneries, and Japan (first in terms of value; second in terms of volume), which import mainly frozen bigeye for the *sashimi* market (Figures 4a and 4b).

Thailand's imports decreased from 496 257 tonnes in 1991, equivalent to US$888 million, to 319 190 tonnes in 1996, equivalent to US$352 million (Figures 4a and 4b), as a consequence of a crisis of the Thai tuna industry. In 2000 Thai imports reached their lowest value since 1987 (US$262 million for 359 509 tonnes), which was due mainly to a decrease in its imports of frozen skipjack.

Imports to the United States decreased from 306 629 tonnes (US$268 million) in 1978 to 68 061 tonnes (US$304 million) in 2001 (Figures 4a and 4b), due to increased use of frozen pre-cooked loins in order to reduce production costs.

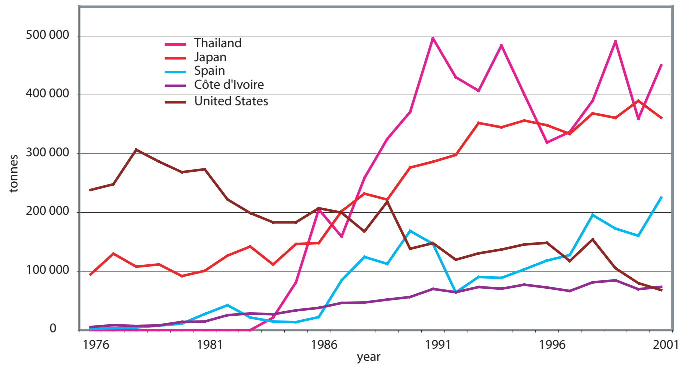
The principal exporters of frozen, fresh and chilled tuna are Taiwan Province of China, Spain, France and the Republic of Korea. In 2001 exports of tuna from Taiwan Province of China totalled 437 116 tonnes, equivalent to US$1.2 billion (due to the high value of the commodities exported, e.g. high-priced bigeye for the Japanese market and high-quality yellowfin for the Japanese and European markets). Exports of tuna from Spain totalled 165 630 tonnes[11], equivalent to US$269 million, those from France 158 416 tonnes[12], equivalent to US$140 million and those from the Republic of Korea 85 365 tonnes, equivalent to US$250 million.

Exports of tuna from Australia were only 14 499 tonnes, but since they consisted mainly of the high-value fresh and chilled southern bluefin tuna, their value amounted to US$178 million. While the exports from most of these countries increased progressively over the 1976-2001 period, exports from the Republic of Korea declined considerably.

[11] 162 758 tonnes, according to EUROSTAT data.
[12] 158 315 tonnes, according to EUROSTAT data.

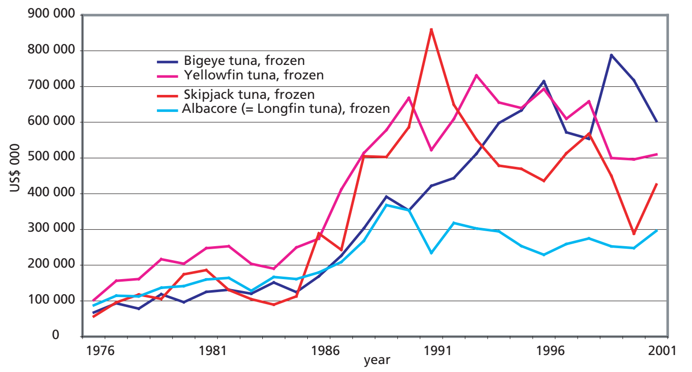
International trade in frozen pre-cooked tuna loins for canning is not reported here because normally national statistics classify loins[13] under the 1604 tariff code (prepared and processed fish), and do not distinguish them from other processed and semi-processed products.

FIGURE 4A
World imports, by quantities, of frozen, fresh and chilled tuna* by the principal countries



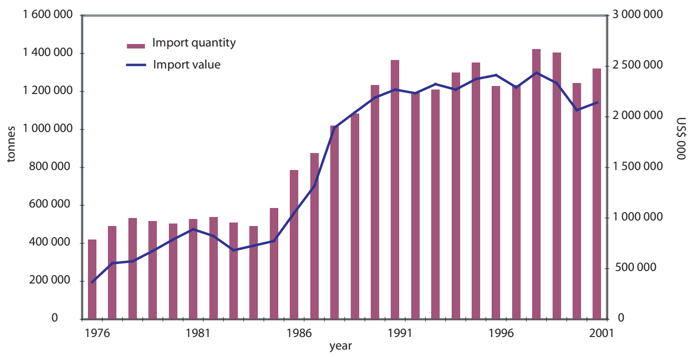
* Including Atlantic, Pacific and southern bluefin tuna.

FIGURE 4B
World imports, by value, of frozen, fresh and chilled tuna* by the principal countries



* Including Atlantic, Pacific and southern bluefin tuna.

FIGURE 5
World imports of frozen tuna*



* Including Atlantic, Pacific and southern bluefin tuna.

3.4.2 Frozen tuna

Imports of frozen tuna increased from 420 618 tonnes in 1976, equivalent to US$368 million, to 1.4 million tonnes in 1998, equivalent to US$2.4 billion, and then declined slightly to 1.3 million tonnes in 2001, equivalent to US$2.1 billion (Figure 5). During the nineties imports of frozen tuna remained relatively stable in terms of quantity, but decreased in terms of value as a consequence of a decline in the price of frozen raw material, mainly skipjack, for canning.

The principal frozen species of tuna traded are skipjack and yellowfin, in terms of quantity (Figure 6a), and bigeye, yellowfin and skipjack, in terms of value (Figure 6b). The bigeye are used almost entirely for the *sashimi* market and the skipjack and yellowfin almost entirely for the canning industry.

Imports of frozen bigeye increased from 43 347 tonnes in 1976 to 124 274 tonnes in 1998, and then declined to 119 722 tonnes in 2001 (Figure 6a). In terms of value, imports of frozen bigeye increased from US$68 million in 1976 to US$788 million in 1999, but then decreased to US$604 million in 2001 (Figure 6b).

Imports of frozen skipjack increased from 116 082 tonnes in 1976 to a peak of 669 250 tonnes in 1999, declined to 528 920 tonnes in 2000 and then increased slightly to 551 017 tonnes in 2001 (Figure 6a). In terms of value, imports of frozen skipjack increased from

[13] The FISHSTAT Plus entries "tuna loins and fillets, fresh and chilled" and "tuna loins and fillets, frozen" refer to filleted fish for direct consumption. Imports of tuna loins and fillets increased from 238 tonnes in 1976, equivalent to US$123 000, to 19 658 tonnes in 2001, equivalent to US$113 million (FISHSTAT Plus data). The principal importer was Japan, and the principal exporter was Spain (FISHSTAT Plus data).

FIGURE 6A
World imports, by quantities, of the most important species of frozen tuna

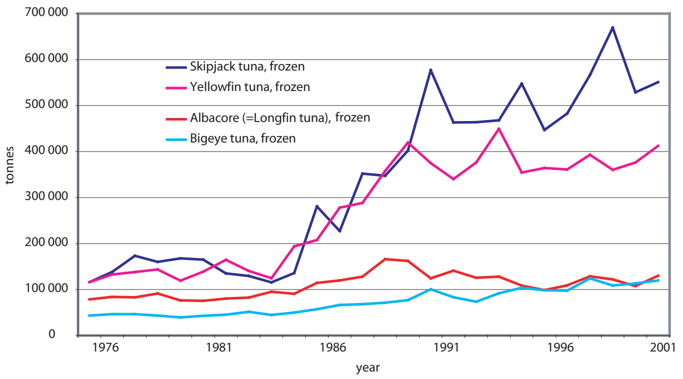


FIGURE 6B
World imports, by value, of the most important species of frozen tuna

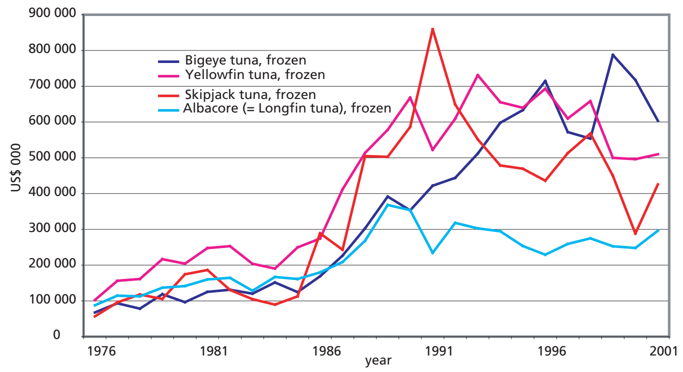
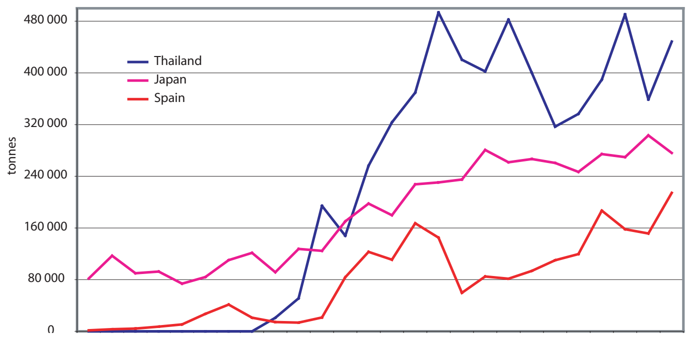


FIGURE 7A
World imports, by quantities, of frozen tuna* by the principal countries



* Including Atlantic, Pacific and southern bluefin tuna.

US$57 million in 1976 to US$859 million in 1991, declined to US$288 million in 2000 and then increased to US$426 million in 2001 (Figure 6b).

Frozen yellowfin imports increased from 116 125 tonnes in 1976 to 449 387 tonnes in 1994 (Figure 6a). In terms of value, frozen yellowfin imports increased from US$102 million in 1976 to US$731 million in 1993 (Figure 6b). In the years that followed, yellowfin imports remained relatively sta-ble in terms of quantity, but declined in terms of value, reaching 412 391 tonnes in 2001, equivalent to US$510 million.

The principal importers of frozen tuna are Thailand, Japan and Spain (Figures 7a and 7b). Imports of frozen tuna (mainly skipjack) by Thailand declined sharply in terms of value during the nineties, but increased slightly in 2001 due to measures by the WTPO to reduce the oversupply of this commodity (Figure 7b). The situation is different for Spain and Japan, which import mainly higher-value species, such as yellowfin (Spain) and bigeye (Japan) (Figures 7a and 7b).

Other significant importers of frozen tuna are Côte d'Ivoire and the United States. The amounts of frozen tuna imported by the United States have decreased as a consequence of the general decline of its tuna-canning industry. Frozen albacore is currently the principal species of tuna imported by the United States. Côte d'Ivoire buys mainly frozen tuna from EU vessels, which is processed in canneries of Bolton/*Saupiquet*.

3.4.3 Fresh and chilled tuna

World imports of fresh and chilled tuna increased from 14 278 tonnes in 1976 (US$38 million) to 160 177 tonnes in 2001 (US$935 million), although the peak in terms of value was reached in 1995, when total imports of fresh and chilled tuna (135 634 tonnes) were worth more than US$1 billion (Figure 8). Fresh and chilled tunas are generally destined primarily for *sashimi* and secondarily for the steak market. Over the period analysed the values have increased more than the quantities of fish because larger portions of the imports have consisted of fish for preparation of *sashimi* and tuna steaks[14]. After 1995, however, import values declined (Figure 8).

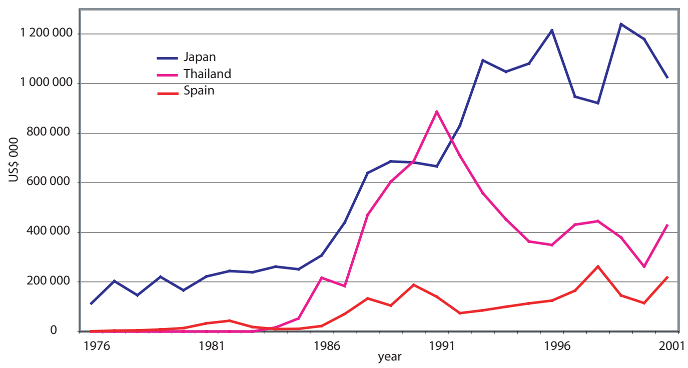
Yellowfin is the principal species of imported fresh and chilled tuna species. The imports of this species increased from 5 432 tonnes (US$17 million) in 1976, to 65 526 tonnes (US$373 million) in 2001 (Figures 9a and 9b). In 1995 the import value of fresh and chilled yellowfin peaked at US$382 million (Figure 9b). Yellowfin is imported mainly by Japan for the medium-quality *sashimi* market and by the United States for the preparation of both *sashimi* and tuna steaks.

Imports of bigeye tuna increased from 429 tonnes (US$1.4 million) in 1976 to 21 907 tonnes (US$157 million) in 2001 (Figures 9a and 9b). In 1994, the import value of fresh and chilled bigeye peaked at US$228 million (Figure 9b). Bigeye is imported mainly by Japan for the *sashimi* market.

The imports of Atlantic and Pacific bluefin grew from 622 tonnes (US$3.3 million) in 1976 to 18 269 tonnes (US$200 million) in 1999, and then declined slightly to 15 660 tonnes (US$197 million) in 2001 (Figures 9a and 9b). The principal importer of bluefin is Japan (for the *sashimi* market), followed by France and Spain. The increases in recent years are due mainly to increased amounts of bluefin available from farming activities.

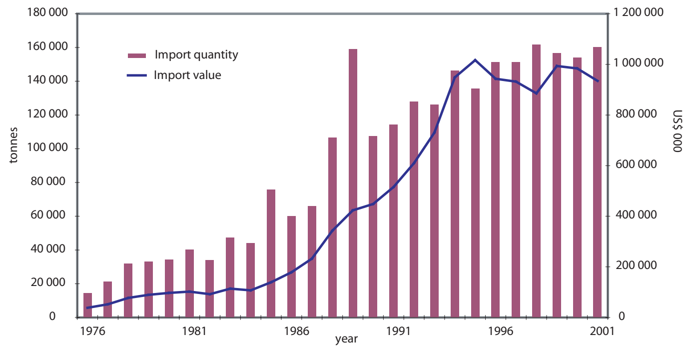
The principal exporters of fresh and chilled tuna are Indonesia, Spain and Taiwan Province of China. In 2001 these were as follows: Indonesia, 25 743 tonnes (US$91 million); Spain, 12 612 tonnes[15], (US$153 million); Taiwan Province of China, 12 522 tonnes (US$57 million). Australia exported only 9 033 tonnes, but, as its exports consisted mainly of southern bluefin tuna, the export value was US$94 million (Figures 10a and 10b).

FIGURE 7B
World imports, by value, of frozen tuna* by the principal countries



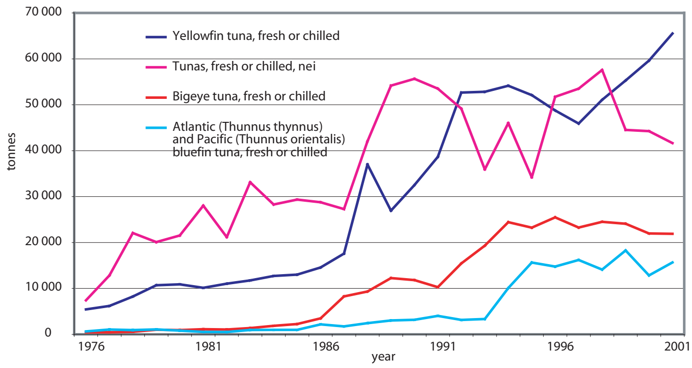
* Including Atlantic, Pacific and southern bluefin tuna.

FIGURE 8
World imports of fresh and chilled tuna*



* Including Atlantic, Pacific and southern bluefin tuna.

FIGURE 9A
World imports, by quantities, of the most important species of fresh and chilled tuna



[14] Also the quality of products improved markedly by improved infrastructure of fishing countries and transportation.

[15] 12 567 tonnes as according to EUROSTAT.

FIGURE 9B
World imports, by value, of the most important species of fresh and chilled tuna

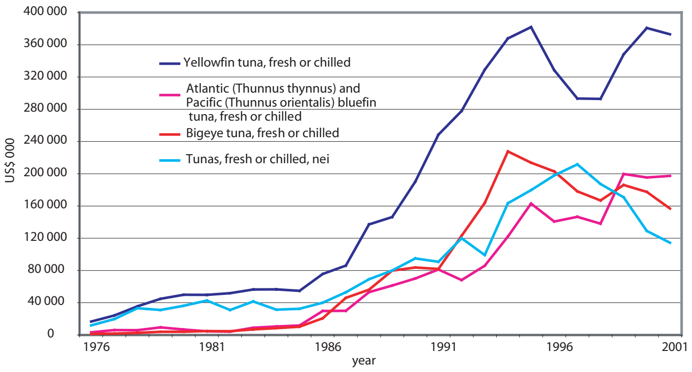
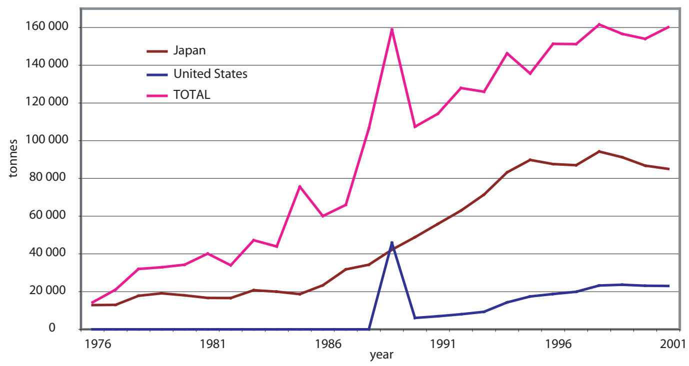
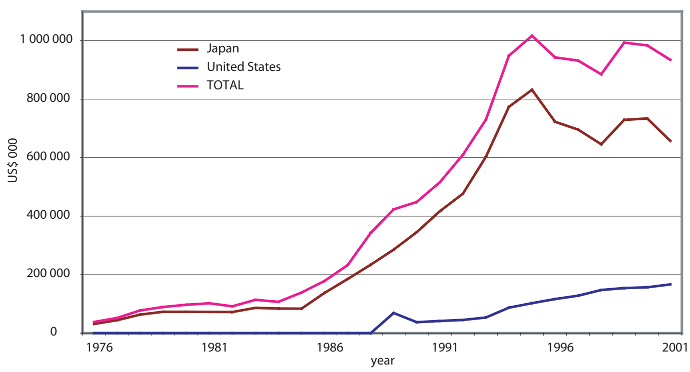


FIGURE 10A
World imports, by quantities, of the most important species of fresh and chilled tuna* by the principal countries



* Including Atlantic, Pacific and southern bluefin tuna.

FIGURE 10B
World imports, by value, of the most important species of fresh and chilled tuna* by the principal countries



* Including Atlantic, Pacific and southern bluefin tuna.

3.4.4 Canned tuna

The annual production of canned tuna increased from 499 448 tonnes (net weight) in 1976 to 1.4 million tonnes between 1998 and 2001 (Figure 11). The principal producers of canned tuna are Thailand, the United States[16] and Spain. Thailand increased its production from 4 679 tonnes in 1981 to 269 700 tonnes in 2001. Production of canned tuna in the United States fluctuated around an average of about 280 000 tonnes during 1976-2000, and declined to 230 267 tonnes in 2001. The production of canned tuna in Spain increased from 19 707 tonnes in 1976 to 229 116 tonnes in 2001.

Imports of canned tuna, in terms of volume, increased from 89 369 tonnes in 1976 to 836 266 tonnes in 2001 (Figure 12). In terms of value, they increased from US$186 million in 1976 to US$2.4 billion in 1998, decreased to US$1.8 billion in 2000 and then increased to US$2.0 billion in 2001. During 1998-2000 the imports increased in volume but decreased in value, probably due to the decline in the price of skipjack.

The principal importers of canned tuna are the United States, the United Kingdom and France, in terms of both quantity and value (Figures 13a and 13b). Thailand is, by far, the principal exporter, followed by Spain and Ecuador.

3.5 Tuna farming

Atlantic, Pacific and southern bluefin tuna are commercially farmed, mainly for the Japanese *sashimi* market. The fish are caught by purse seining, or in mackerel traps, and transferred to holding pens, where they are held for later sale. Two types of tuna, juveniles and post-spawning adults, are utilized. Most of the current farming uses juveniles, which are caught by purse seiners. These would not be suitable for the *sashimi* market at the time that they are captured. During the time that they are in captivity (about four to six months), they are fed, so their weight increases

[16] Really, American Samoa.

by about 15 percent, and their fat content also increases, which makes them acceptable to the Japanese *sashimi* market. The fish are usually caught during the northern summer and harvested near the end of the calendar year, when the prices for *sashimi* are highest.

The live fish are frequently traded after capture, in which case fish captured by a vessel registered in one country are transported to the waters of another country for holding. While some countries request trade certificates for live bluefin, other countries do not[17]. For this reason, live bluefin trade sometimes escapes international and regional monitoring. After harvesting, the fish are shipped to the consumer market (almost always Japan), either fresh by air freight or frozen by cargo vessels with facilities for holding the fish at very low temperatures. However, some fish are transhipped to a third country, on their way to Japan, for additional processing (Miyake, *in press*).

The fattening period of the tunas varies among areas, depending on the size of fish, the water temperature, and market conditions. About four to six months seems to be about the optimum time of confinement – enough to increase the fat content, but not enough to permit the flesh to become too soft. The density of fish in the pens is also important, because if there are too many fish in a pen the quality of the flesh deteriorates. Also, the quality of the food is important; if the fish are given just one type of food their flesh may taste like that food (FAO/GLOBEFISH, 2000a).

FIGURE 11
World production of canned tuna by the principal countries

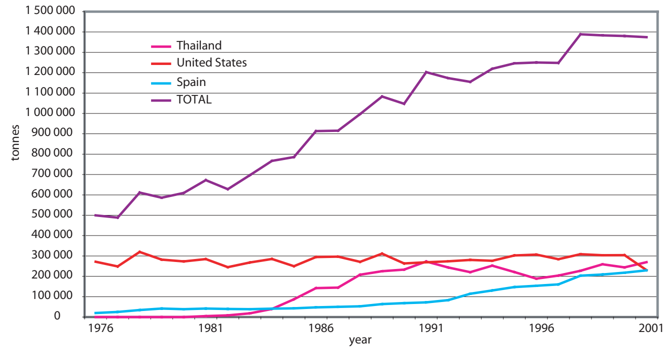


FIGURE 12
World imports of canned tuna

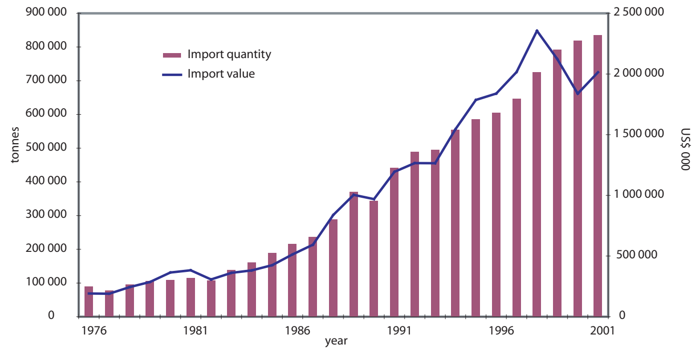
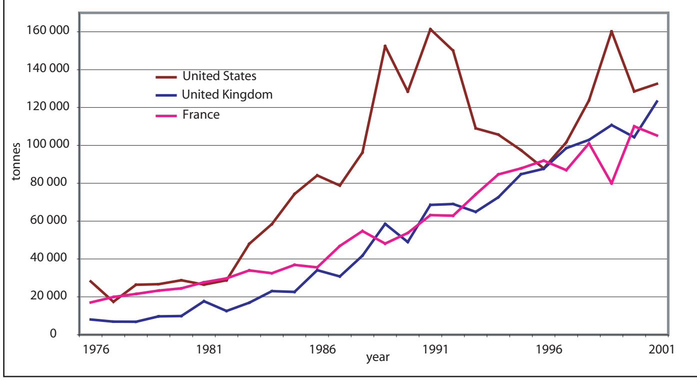


FIGURE 13A
World imports, by quantities, of canned tuna by the principal countries

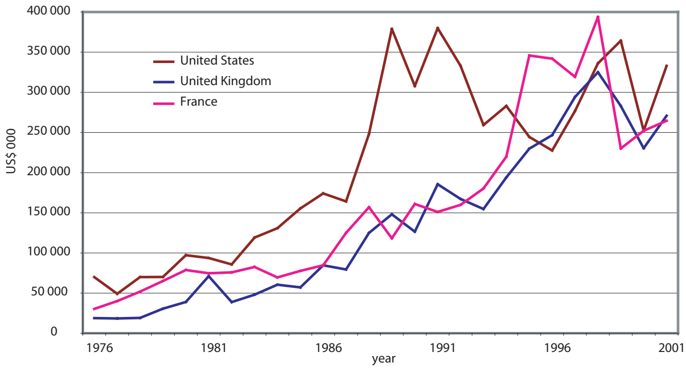


Tuna farming was first carried out in 1975 in eastern Canada, where large bluefin were caught in mackerel traps and transferred to holding pens. The first eight pens held a total of about 600 fish, weighing an average of about 500 kg each. The early success of this enterprise prompted the attempts at tuna farming in other parts of the world.

There are currently more than 30 tuna farms, with more than 200 pens, in the Mediterranean Sea region, located mainly in Spain, Italy, Malta, Turkey, Libyan Aran Jamahiriya, Tunisia and Croatia. Many of them are subsidised by the EU. Data

[17] The BFSD is not mandatory for live bluefin trade.

FIGURE 13B
World imports, by value, of canned tuna by the principal countries



on the production of tuna raised in captivity are not provided in FISHSTAT Plus, as the fish cannot be considered to be either catch or as a product of aquaculture. However, total production of the tuna farming industry in 2002 was estimated to be 5 000 tonnes in Spain, 4 000 tonnes in Croatia, 2 000 tonnes in Turkey, 1 800 tonnes in Italy and 1 000 tonnes in Malta (GFCM/ICCAT). It is estimated that during 1997-2002 imports of farm-raised bluefin tuna from the Mediterranean Sea area increased from virtually nil to 70 percent of total imports of bluefin tuna by Japan from the Mediterranean Sea area (Miyake, *in press*). Prices of farm-raised Atlantic and Pacific bluefin tuna originating from Spain decreased from ¥4 000 to ¥5000 (highest prices) to ¥1 800 to 3 000 (lowest prices) during December 2003. (INFOFISH, 2001 and 2003b).

Farming of Pacific bluefin tuna is also carried out in northern Mexico, using purse-seine caught juveniles. The current annual production is about 1 000 to 2 000 tonnes.

In 2002 Australia was estimated to have produced about 8 000 tonnes of farm-raised southern bluefin for the Japanese *sashimi* market (FAO/GLOBEFISH, 2003).

Bluefin tuna are subject to catch quotas, and hence the original fish placed into pens should be subject to regulations. However, it is difficult to trace the output from the farming back to the catch, and hence farming provides ambiguity in implementing regulations. For this reason, RFBAs and environmental organizations are concerned about the practice (FAO SIPAM, 2003). In addition, yellowfin farming is carried out in Mexico (ATUNA.com data). The target is, once again, the Japanese *sashimi* market.

3.6 Selection of key prices and price series analysis

The main purpose of this section is to provide information on the world prices of tuna for preparation of *sashimi*, frozen raw tuna for canning, tuna loins and canned tuna, which will be used for the market analysis in the last section of this paper. The main sources of information used were:

- the GLOBEFISH Highlights;
- the GLOBEFISH EPR; and
- the GLOBEFISH data bank[18].

The above sources were complemented by the data and information provided by the Services of the FISH INFOnetwork[19], by external GLOBEFISH correspondents and by the Japan International Research Center for Agricultural Sciences.

The historical data available for some commodities, such as frozen skipjack, frozen yellowfin and canned light-meat tuna permitted the Services of the FISH INFOnetwork and other agencies to undertake consistent price series analyses of the world tuna market. This was possible because there has been a relatively uniform world market for these types of products. However, because of the complexities of the markets for albacore, bigeye, and the three species of bluefin, it is more difficult to perform such analyses for these species. Such being the case, most of the analyses in this paper are for frozen skipjack and yellowfin tuna and canned light-meat tuna.

[18] Available (restricted access) at http://www.globefish.org.
[19] Through their publications INFOFISH Trade News (ITN), INFOPÊCHE Trade News African Edition (ITN African Edition) and INFOPESCA Noticias Comerciales (INC) and through personal communications.

However, the generalised increase in the demand of tuna for non-canning uses throughout the western world and the development of bluefin tuna farming have been turning the attention of the world business community toward the non-canning sector. Therefore, information on the prices for species other than skipjack and yellowfin is likely to improve in the future.

3.6.1 Tuna for sashimi

At the Japanese wholesale market, prices of bluefin, bigeye and yellowfin for *sashimi* preparations are determined by the demand and the supply of fresh, chilled and frozen fish, but also by objective and subjective quality factors. These different quality factors generate different prices, according to the piece of fish auctioned. Furthermore, prices of *sashimi*-grade tuna fluctuate widely during the year, depending on the periods of peak consumption of *sashimi*:

- the Golden Week in May;
- the Bon Festival, which takes place during July and August; and
- the New Year festivities.

The analysis in this subsection will rely on average year prices calculated from high and low monthly quotations on INFOFISH Trade News (ITN):

- southern bluefin tuna, G&G, Tsukiji market auction (Japan), origin Australia;
- Atlantic and Pacific bluefin tunas[20], Tsukiji market auction (Japan), average low price and average high price reported by ITN[21];
- fresh and chilled bigeye, G&G, Tsukiji market auction (Japan), origin Indonesia[22];
- frozen bigeye, G&G, Tsukiji market auction (Japan), origin Atlantic Ocean and western Pacific Ocean;
- fresh and chilled yellowfin, G&G, Tsukiji market auction (Japan), origin Indonesia[23];
- frozen yellowfin, G&G, Tsukiji market auction (Japan), origin Japan.

Consistent southern bluefin tuna prices are available only for 1995 and the years after that (Figures 14a and 14b). The high prices of southern bluefin tuna peaked in 1996 and 1997 at average quotations of ¥11 100/kg and ¥11 292/kg, respectively. After that they declined to ¥7 508/kg in 2000, and fluctuated around these values

FIGURE 14A

Monthly prices of *sashimi*-grade southern bluefin tuna in Japan (G&G, fresh and frozen, auction Tsukiji market, origin: Australia)

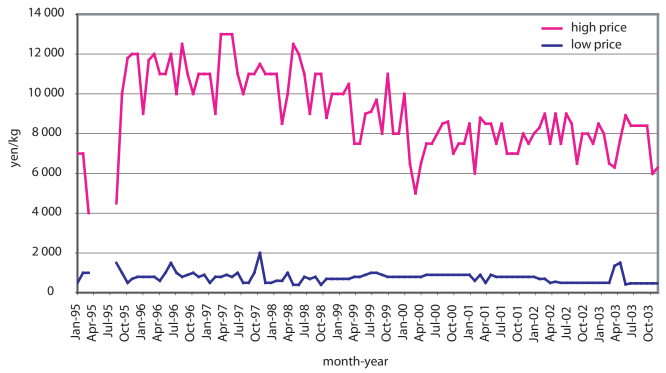
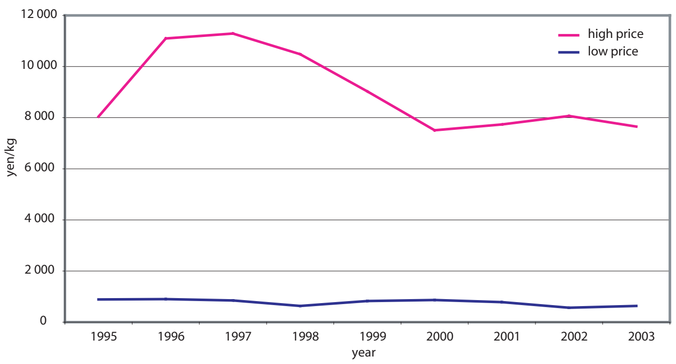


FIGURE 14B

Annual prices of *sashimi*-grade southern bluefin tuna in Japan (auction Tsukiji market)



20 Mostly fresh and chilled.

21 In the case of bluefins, ITN has rarely provided prices on either wild-caught or farm-raised fish.

22 Indonesia is the main exporter of fresh and chilled bigeye to Japan (Japanese Customs data).

23 Indonesia is the main exporter of fresh and chilled yellowfin to Japan (Japanese Customs data).

FIGURE 15A
Monthly prices of *sashimi*-grade Atlantic and Pacific bluefin tuna in Japan (auction Tsukiji market)

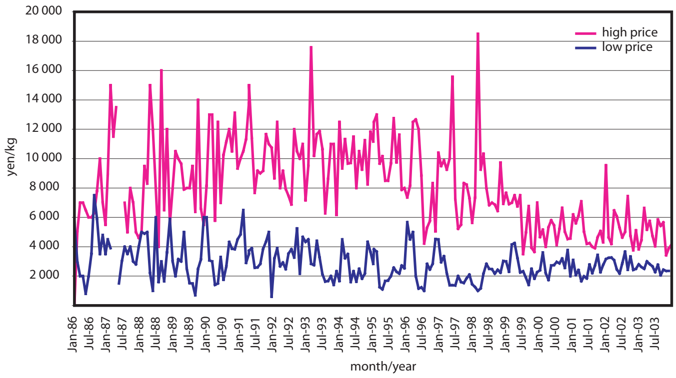


FIGURE 15B
Annual prices of *sashimi*-grade Atlantic and Pacific bluefin tuna in Japan (auction Tsukiji market)

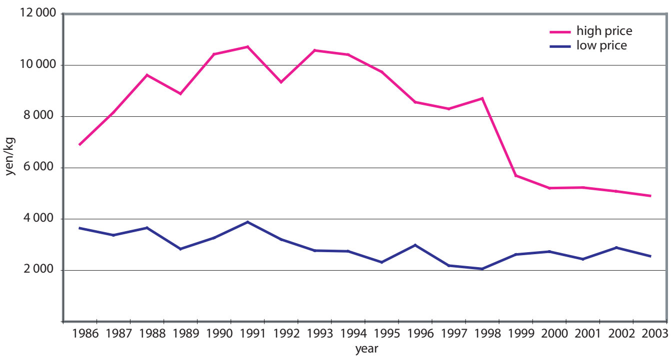
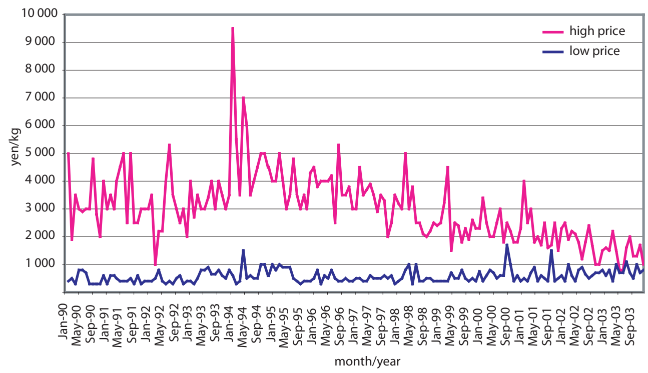


FIGURE 16A
Monthly prices of *sashimi*-grade fresh and chilled bigeye tuna in Japan (G&G, fresh and chilled, auction Tsukiji market, origin: Indonesia



during 2001-2003. In 2003 the high prices of southern bluefin tuna were ¥7651/kg, while the low prices declined from ¥887/kg in 1995 to ¥635/kg in 2003 (Figure 14b).

The peak prices of southern bluefin tuna reported in Japan in 1996 and 1997 were due to low supplies of whole fish from domestic captures and imports, coupled with strong demand (FAO/GLOBEFISH, 1996d). During 1999-2003 the decline in Japanese prices was a result of the market penetration by cheaper *sashimi* prepared from farm-raised bluefin.

Beginning in 1999, ITN began to report quotations of farm-raised Atlantic and Pacific bluefin. In December 2003 prices of farm-raised Atlantic bluefin tuna originating in Spain decreased from a price range between ¥4 000 (low price) and ¥5000 (high price) to a price range between ¥1 800 (low price) and 3 000 (high price) due to oversupply (INFOFISH, 2001 and 2003b). During 2002 and 2003 these quotations were lowering the average bluefin quotations at the Tsukiji market.

The high prices of bigeye tuna (Figures 16a, 16b, 17a, 17b and 18), like those of Atlantic, Pacific (Figure 15a and 15b) and southern bluefin (Figures 14a and 14b), have been declining since 1994. This was the result of better-than-average catches of bigeye during 1991-2000[24], increased supplies of average-quality fish caught by foreign fleets and the increased supply of farm-raised tuna. The increase in the high prices in 2003 is apparently due largely to a low supply of bigeye and a high demand for it (INFOFISH, 2003a). Prices of yellowfin seem to follow the same declining trend of the other species (Figures 19a, 19b 20a, 20b and 21).

The average prices of all species of *sashimi*-grade tuna began to decline during the early nineties (Figure 22). This is a consequence of the general economic situation in

[24] More information on this is provided in the subsection *The market for sashimu-grade tuna* in the section *Conclusion*.

Japan, declining price indices and the increased supply of farm-raised bluefin and cheaper bigeye and yellowfin from Taiwan Province of China and Indonesia.

3.6.2 Whole raw material for canning

3.6.2.1 Skipjack

Frozen skipjack for canning is the most important raw material traded at the global level. The most important market for frozen skipjack is Bangkok (Thailand). Other important markets are Vigo (Spain) and Abidjan (Côte d'Ivoire). Puerto Rico (the United States) has been, historically, the main market reference for skipjack prices in North America. However, the Puerto Rican skipjack market has been losing importance over time, due to the progressive closure of its main canneries. As a result, prices of frozen skipjack in Puerto Rico after December 2002 are not available. Hence, the world average frozen skipjack (raw material for canning) price has been calculated from the following price series:

- ITN data on skipjack prices on the Bangkok market;
- INFOPÊCHE Trade News–African Edition (ITN-African Edition): data on skipjack prices on the Abidjan market;
- NMFS/GLOBEFISH data on skipjack prices on the Puerto Rico market (through 2002);
- GLOBEFISH EPR data on skipjack prices on the Spanish market.

The prices of frozen skipjack in the four reference markets are shown in Figure 23, and the estimated world prices, based on the average prices on the four reference markets, are shown in Figure 25.

FIGURE 16B
Annual prices of *sashimi*-grade fresh and chilled bigeye tuna in Japan (auction Tsukiji market)

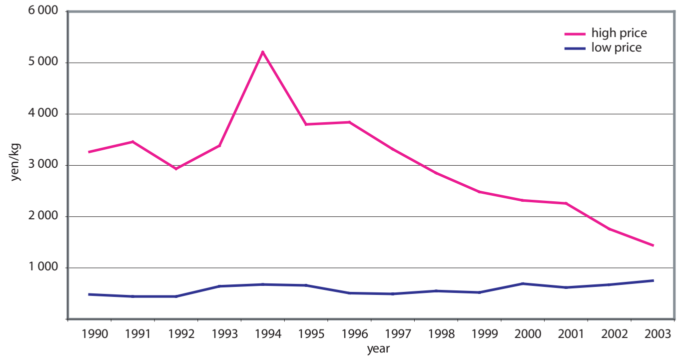


FIGURE 17A
Monthly prices of *sashimi*-grade frozen bigeye tuna in Japan (G&G, frozen, auction Tsukiji market)

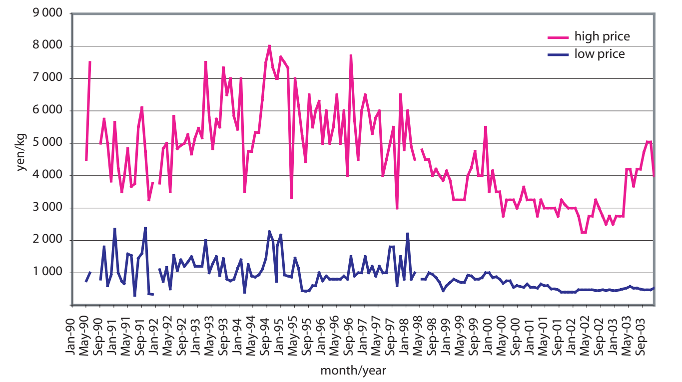
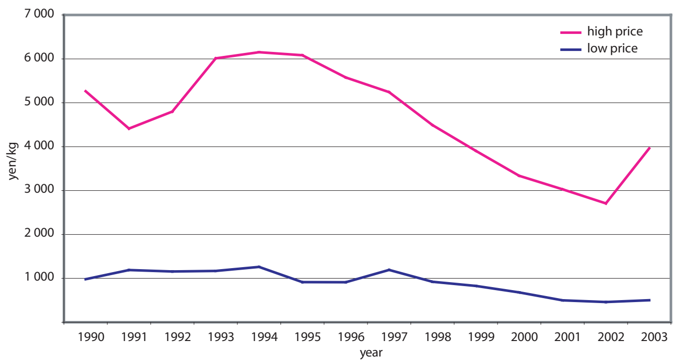


FIGURE 17B
Annual prices of *sashimi*-grade frozen bigeye tuna in Japan (auction Tsukiji market)



In Thailand frozen skipjack prices c&f (cost and freight) reached a peak of US$1 200/tonne in February 1988 (Figure 23). From September 1988 to December 1992 these prices averaged slightly more than US$800/tonne, due mainly to the oversupply of raw material during that period. The lesser availability of tuna during 1993 and 1994 generated an increase in frozen skipjack prices, and in September 1994 the price of frozen skipjack for canning reached US$1 100/tonne. After that, however, the

FIGURE 18
Annual prices of *sashimi*-grade frozen, fresh and chilled bigeye tuna in Japan (auction Tsukiji market)

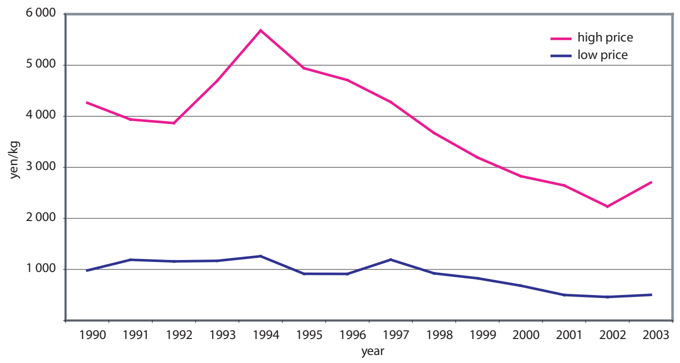


FIGURE 19A
Monthly prices of *sashimi*-grade fresh and chilled yellowfin tuna in Japan (G&G, fresh and chilled, auction Tsukiji market, origin: Indonesia)

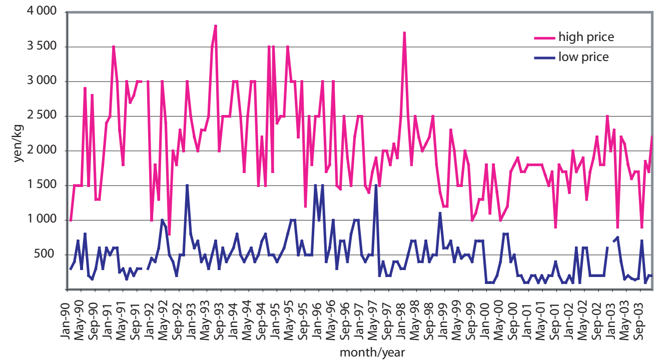
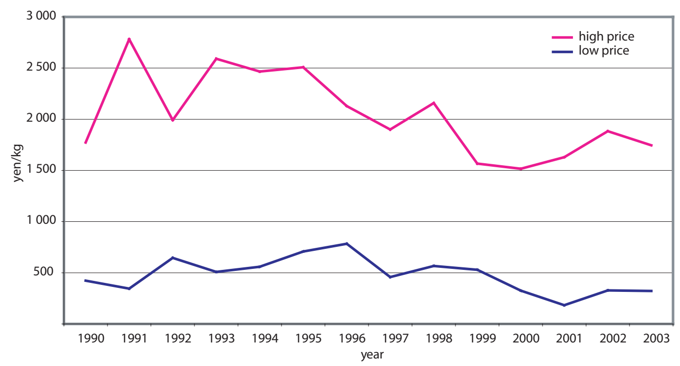


FIGURE 19B
Annual prices of *sashimi*-grade fresh and chilled yellowfin tuna in Japan (auction Tsukiji market)



prices decreased, reaching a low of US$670/tonne in May 1995 (FAO/GLOBEFISH, 1995a). The catches of skipjack catches in the western Pacific Ocean were low from August to October 1995, which generated an increase in prices to US$1 100/tonne. As a result, the Thai canning giant UNICORD closed in August 1995 (FAO/GLOBEFISH, 1995b).

The situation for skipjack was unstable in 1996, due to low catches and high prices during the first nine months of the year. UNICORD in Thailand sold its canneries to Bumble Bee Seafoods, a former United States canner that had been purchased by Thai interests in 1989 (FAO/GLOBEFISH, 1996c). The UNICORD crisis is reflected in the import figures of skipjack tuna and production of canned tuna in Thailand. Thai imports of frozen tuna declined from 399 960 tonnes in 1995 to 316 805 tonnes in 1996; Thai production of canned tuna declined from an estimated 221 250 tonnes in 1995 to an estimated 188 440 tonnes in 1996 (Figure 11). Thai exports of canned tuna declined from 221 243 tonnes in 1995 to 188 434 tonnes in 1996 (FISHSTAT Plus data).

During late 1996 the catches of skipjack increased and the prices decreased (FAO/GLOBEFISH, 1997a). During early 1997, however, the catches decreased and the prices increased (FAO/GLOBEFISH, 1997b). The catches continued to be low, and the prices of frozen skipjack reached their all time high in April 1998, at US$1 250/tonne (Figure 23). Subsequently the catches increased greatly, and oversupply persisted for two years. Between May and December 2000, skipjack prices decreased to their minimum levels, ranging from US$350 to US$450/tonne in the principal skipjack markets (Figure 23). The decreased fishing effort, due to restrictive measures imposed by the WTPO, together with a possible decline in abundance of skipjack, caused prices to increase to US$950/tonne in April 2001 and to an average of US$750/tonne during the following months leading up to December 2002 (albeit with a declining pattern). The “Bangkok bottleneck” caused skipjack prices on the Bangkok market to decline again, until they reached US$500/tonne in April 2003. However, WTPO measures led to an increase in prices in the following months, even reaching US$860/tonne in October and November 2003 (Figure 23).

3.6.2.2 Yellowfin

Yellowfin and skipjack are both canned as "light-meat tuna", although canned yellowfin is generally considered to be of higher quality than canned skipjack. Also, because they are larger, it is easier to prepare a given quantity of yellowfin for canning, and the percentage of the meat that can be canned as solid or chunk tuna is greater for yellowfin. Finally, yellowfin yield more meat per kilogram than do skipjack. The principal area of consumption of canned yellowfin is Southern Europe. Due to its reliance on yellowfin as raw material for canning, the Southern European market can be considered as the reference for yellowfin raw material prices. The following information on other important yellowfin markets is given by FISHSTAT Plus data:

- Japan utilizes yellowfin mainly for preparation of *sashimi*;
- Côte d'Ivoire and Ghana import raw yellowfin to supply the EU market with canned tuna and loins, and;
- the market for frozen yellowfin for canning has been declining in the United States since the early nineties due to the tuna-dolphin issue.

Historically, the California (until the mid-eighties) and Italian markets have provided the global reference prices for frozen whole yellowfin for canning. Between the mid- and late nineties, due to substitution of frozen whole yellowfin for canning with frozen loins, Italy ceased to be the world market reference of frozen yellowfin prices.

In 2001 Spain[34] became the top importer of frozen yellowfin, with 109 614 tonnes of frozen yellowfin, (26 percent of the world's frozen yellowfin imports according

FIGURE 20A

Monthly prices of *sashimi*-grade yellowfin tuna in Japan (G&G, frozen, auction Tsukiji market)

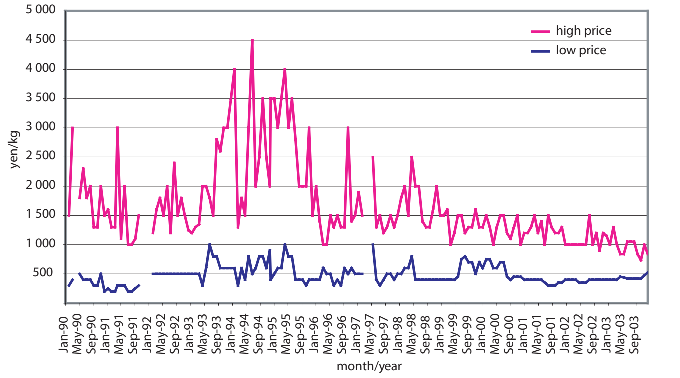


FIGURE 20B

Annual prices of *sashimi*-grade yellowfin tuna in Japan (G&G, frozen, auction Tsukiji market)

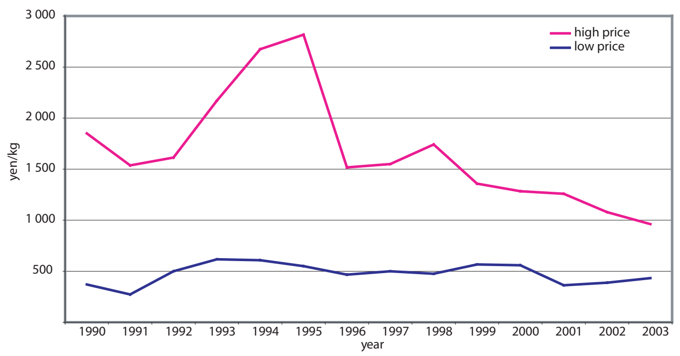
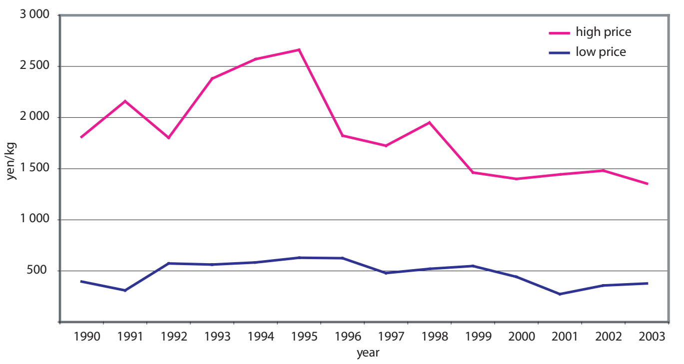


FIGURE 21

Annual prices of *sashimi*-grade fresh, chilled and frozen yellowfin tuna in Japan (auction Tsukiji market)



[25] Spain is also a major importer of frozen pre-cooked loins. Spanish imports of loins increased from 5 917 tonnes in 1994 to 19 355 tonnes in 2000, declined to 6 294 tonnes in 2001 and then increased to 13 309 tonnes in 2002 (EUROSTAT data).

FIGURE 22
Annual prices of *sashimi*-grade tuna in Japan (a comparison between the species'average prices)s

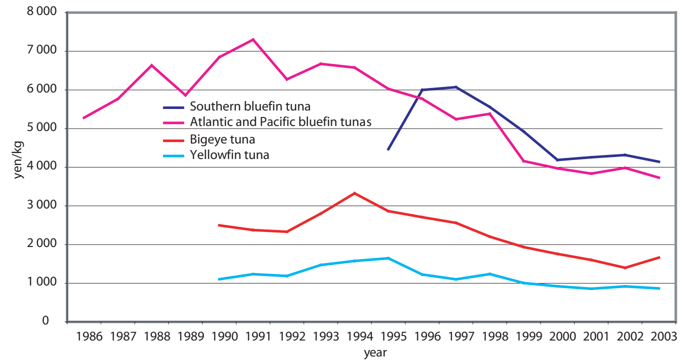


FIGURE 23
Frozen skipjack prices in Asia (Thailand), Europe (Spain), United States and Africas

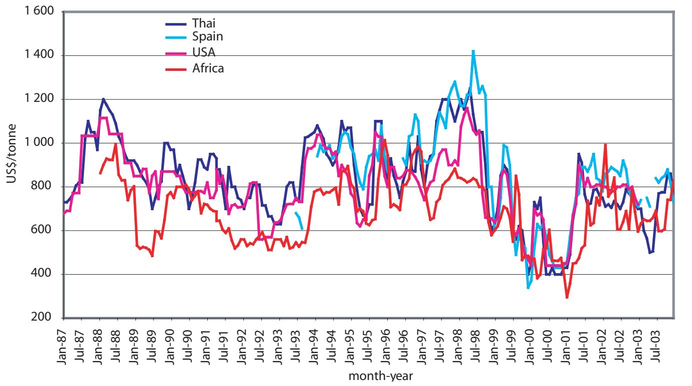
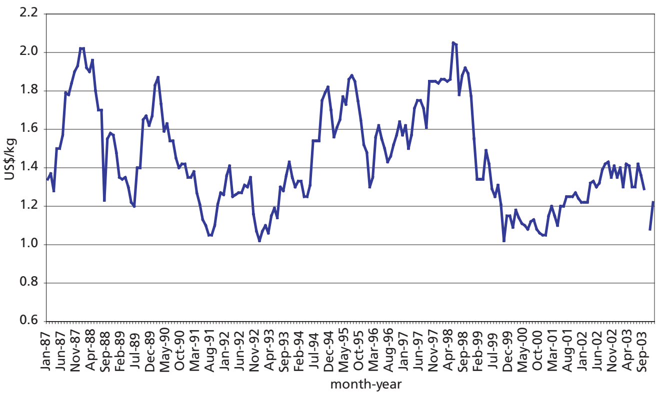


FIGURE 24A
Prices in Italy for whole frozen yellowfin from the Indian and Atlantic Oceans for canning



to FISHSTAT Plus data). Italy is also an important importer of frozen yellowfin. According to FISHSTAT Plus and EUROSTAT data, Italian imports of frozen yellowfin for canning increased from 52 000 tonnes in 1976 to a peak of 103 140 tonnes in 1987, and then declined during the following years to a low of 35 780 tonnes in 2002. However, due to the historical importance of Italy as an importer of frozen tuna for canning; and the presence of important price quotations in the Italian market for frozen whole yellowfin from the Indian and Atlantic Ocean, the world average frozen yellowfin, prices have been calculated on the basis of the following series (as in Figures 24a, 24b and 24c):

- GLOBEFISH EPR data on the Spanish market (origin: Spanish vessels);
- GLOBEFISH EPR data on the Italian market (origin: western and eastern Pacific Ocean);
- GLOBEFISH EPR data on the Italian market (origin: Atlantic Ocean and Indian Ocean).

The world indicative price series of frozen yellowfin for canning for 1987-2003 is the result of the average price quotations on the Spanish market (since 1993) and the Italian market (Figures 24a, 24b and 24c).

The Italian yellowfin prices increased during the nineties, but declined toward the end of the decade (Figures 24a and 24b). The nineties opened with good yellowfin catches, and the Italian market was not affected by the tuna-dolphin issue. Furthermore, the First Gulf War prompted Italian consumers to buy large quantities of canned food, such as tuna (FAO/GLOBEFISH, 1991). The prices of yellowfin from the Indian and Atlantic Oceans, which had reached US$2.02/kg in December 1987 and January 1988 decreased to US$1.05/kg in August 1991. The corresponding figures for yellowfin from the EPO were US$1.83/kg in January 1988 and US$0.90/kg in September 1991.

Declining yellowfin catches moved prices up once again, reaching US$1.41/kg in February 1992 for fish from the Indian and Atlantic Oceans. Beginning in November

1992, Italy implemented a ban on yellowfin from the EPO due to the tuna-dolphin issue (FAO/GLOBEFISH databank). Increasing awareness of this issue caused Italian yellowfin imports from other areas to drop as well. Therefore, prices of raw material from the Indian and Atlantic Oceans declined to US$1.02/kg in December 1992. The embargo was eventually lifted in May 1995 (Figure 24b).

The catches of yellowfin declined during the early nineties. While canneries in developing countries preferred to shut down, rather than to continue paying high prices for tuna, Italian and Spanish canneries continued to buy yellowfin. In Italy (Figures 24a and 24b), prices of yellowfin increased to US$1.88/kg for Indian and Atlantic Ocean yellowfin in July 1995 and US$1.73/kg for EPO yellowfin between June and August 1995.

Increased catches then led to declines in prices. Yellowfin tuna prices were US$1.30/kg for fish from the Indian and Atlantic Oceans and US$1.24/kg for fish from the EPO in January 1996. However, low catches during the following months, exacerbated by the *El Niño* event of 1997-1998, caused the price of yellowfin to increase to the unprecedented level of US$2.05/kg for fish from the Indian and Atlantic Oceans in May 1998. At the end of the decade, however, The catches increased and the prices declined, averaging about US$1.00/kg to US$1.20/kg during 2000 (Figures 24a and 24b).

FIGURE 24B

Prices in Italy for whole frozen yellowfin from the eastern and western Pacific Ocean for canning

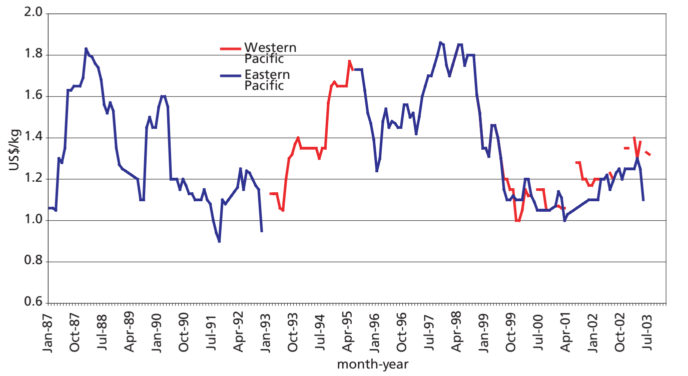
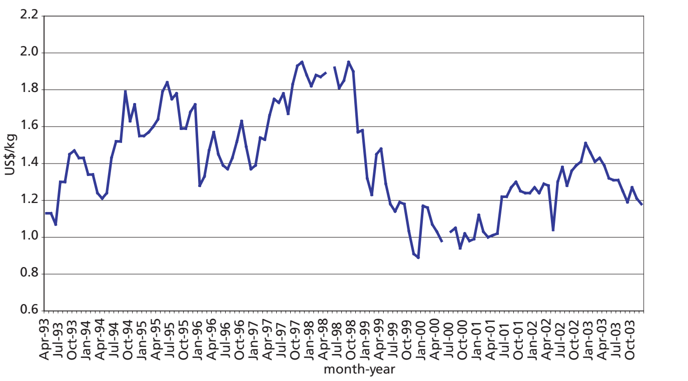


FIGURE 24C

Prices in Spain for whole frozen yellowfin from Spanish vessels for canning



By the end of 2000, owners of purse seiners, within the framework of the WTPO, agreed to reduce their catches, particularly of skipjack, to increase the prices of the raw material (FAO/GLOBEFISH, 2001a). Subsequently, poor catches of yellowfin in most oceans (FAO/GLOBEFISH, 2001b, 2001c, 2001d, 2001e, 2001f, 2001g and 2001h) increased prices further. The prices of yellowfin from the Indian and Atlantic Oceans increased from US$1.15/kg in January 2001 to 1.27/kg in October 2001, and those of yellowfin from the western Pacific Ocean increased from 1.07 US$/kg in January 2001 to 1.20 US$/kg in January 2002. On the other hand, the prices of yellowfin from the EPO declined from US$1.14/kg in January 2001 to US$1.00/kg in March 2001, and then increased slightly to US$1.09/kg in October 2001.

In Spain the prices of yellowfin (origin: Spanish vessels) increased from US$0.98/kg in November 2000 to US$1.30/kg in September 2001, and then declined to US$1.24/kg in December 2001 (Figure 24c) (GLOBEFISH data bank).

During the following months declining catches, including those in the eastern central Pacific, (FAO/GLOBEFISH, 2002a, 2002b and 2002c), caused the prices to increase to US$1.25/kg for fish from the EPO, US$1.35/kg for fish from the western Pacific Ocean and US$1.41/kg for fish from the Indian and Atlantic Oceans in November 2002 (Figure

24a). In Spain the prices increased to US$1.51/kg in December 2002 (Figure 24c) (GLOBEFISH data bank).

The catches and prices paid for yellowfin were relatively stable in 2003. The catches of yellowfin were above average in the Indian Ocean, but below average in the Pacific and the Atlantic Oceans, which tended to stabilize the prices. In July 2003 the prices were US$1.32/kg for fish from the western Pacific Ocean and US$1.42/kg for fish from the Indian and Atlantic Oceans. After that the prices for large fish (50 kg) caught in the Indian Ocean[26] declined to US$1.29/kg in September 2003, and US$1.08/kg in November 2003, but then increased to US$1.22/kg in December 2003. No price quotes for this period are available for the Pacific Ocean (Figures 24a and 24b).

In Spain, prices of yellowfin declined from US$1.46/kg in January 2003 to US$1.18/kg in December 2003 (Figure 24c), probably because of the above-average catches in the Indian Ocean, the origin of more than 50 percent of Spain's catches of yellowfin.

The data that will be used in the Conclusions section of this report are unweighted annual averages for yellowfin and skipjack; yellowfin prices have been converted from US$/kg to US$/tonne (Figure 25). The upward and downward trends for the two species were similar. The prices increased slightly from 1989 to 1998, decreased precipitously from 1998 to 2000 and then increased at a modest rate from 2000 to 2003.

FIGURE 25
Average world prices for whole frozen skipjack and yellowfin for cannings

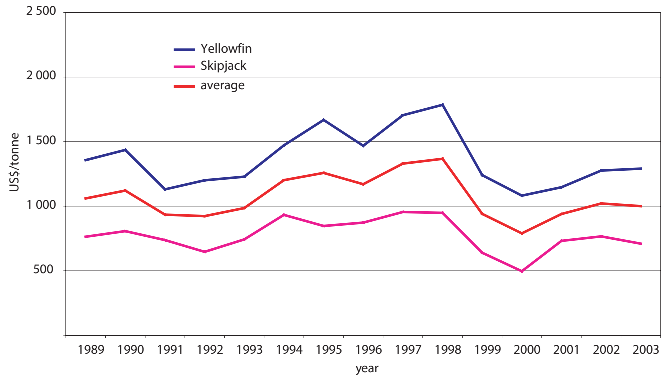
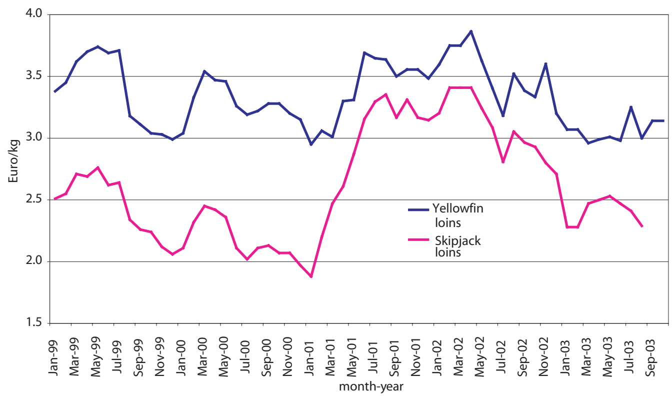


FIGURE 26
Prices of skipjack and yellowfin loins from Latin America in Italy



3.6.3 Loins

It is a common practice for tuna that are caught in tropical waters to be landed in Africa or Latin America, where they are pre-cooked and loined. Then the frozen loins are transported to Europe or North America, where they are canned.

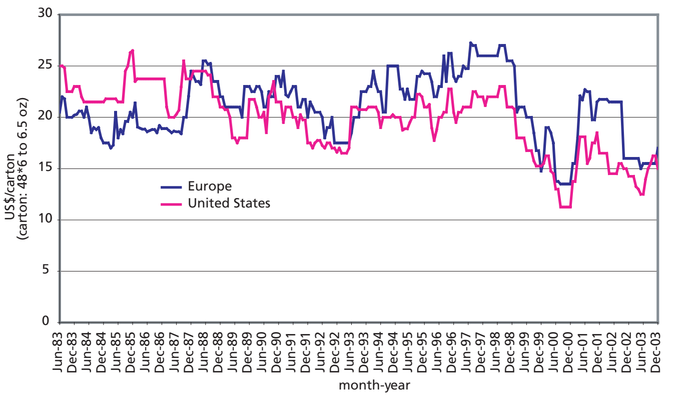
The prices of yellowfin and skipjack loins in the Italian market from 1999 to 2003 are shown in Figure 26. About 70 percent of total canned tuna production in Italy during 1994-2001 came from loins. Prices of yellowfin loins averaged €3.40/kg until 2002. After that the demand for loins decreased, and prices declined.

The prices of skipjack loins declined from €2.51/kg in January 1999 to €1.88/kg in January 2001. The restrictive measures taken by the industry on skipjack catches implemented between the end of 2000 and the beginning of 2001 caused the prices of skipjack loins to increase to €3.35/kg in August 2001. After that they fluctuated

[26] Due to the large size of the fish (50 kg) and the origin (Indian Ocean), the prices reported between mid- late 2003 seem to apply to frozen raw material for preparation of superior-quality canned tuna. In fact, while most mass producers of canned tuna in Italy seem to utilize frozen pre-cooked loins as raw material for canning, luxury lines and artisanal brands still rely on the traditional whole raw materials.

between €3.15 and €3.20/kg, and then increased to €3.41/kg during February-April 2002. After that the prices of skipjack loins declined to €2.28/kg in January and February 2003. Restrictions on catches implemented by the members of the WTPO led the prices of skipjack loins to increase to €$2.53/kg in May 2003 (Figure 26).

FIGURE 27
Monthly prices of canned skipjack in brine from Thailand in the EU and the United States



3.6.4 Canned tuna

The prices, per carton, of canned chunk skipjack tuna in brine (or in oil, when prices of canned tuna in brine were not available[27]) from Thailand in the two major world markets, the EU and the United States, are shown in Figure 27. A carton consists of 48 6- to 6.5-ounce (170- to 184-g) cans[28].

During 1983-1988 the prices were higher in the United States than in Europe, during 1989-1993 they were roughly the same, and since then, especially during 1996-1999 and from mid-2001 through 2002, the prices have been higher in Europe than in the United States. During the period when the demand and prices were high in Europe, the prices in the United States were declining due to:

- elimination of fixed prices for tuna landed by vessels of the United States (FAO/GLOBEFISH, 1996a);
- reduced consumption of canned tuna because of competition from other food products and reduced advertising (FAO/GLOBEFISH, 1996b).

Due to relatively low catches and buoyant demand, European prices of canned tuna reached their peak in July-September 1998 (US$27/carton). In 1999 and 2000, however, exceptionally large catches of skipjack caused the prices to decrease, reaching their minimum levels, US$13.50/carton in Europe and US$11.25/carton in the United States during August-December 2000.

The restrictions on fishing effort implemented by the WTPO at the end of 2000 decreased the supply to tuna, causing the prices of canned tuna to increase to US$22.70/carton in Europe in June 2001 and US$18.10/carton in the United States during April-June 2001). Prices of canned tuna in Europe and in the United States remained turbulent during the rest of 2001, mainly because the restrictive measures imposed by the tuna industry were a last-resort artificial solution. The prices of canned tuna remained stable in Europe from January to September 2002, while those in the United States dropped from US$16.50/carton in January to US$15.50/carton in September of that year. The difference was due to decreased demand for canned tuna in the United States (Lischewski, 2002), but not in Europe (FAO/GLOBEFISH, 2002b).

Beginning in October 2002, the prices of canned tuna declined in both markets, due to an oversupply of skipjack. and in June 2003 the prices were US$15.50/carton in Europe and US$12.50/carton in the United States. However, in the months that followed, canned tuna prices in the United States increased to US$15.50/carton in September 2003 and US$16.25/carton in October and November 2003 (exceeding the EU price US$15.50/carton). These increases were probably the result of WTPO measures agreed

[27] Since October 2002 European prices of canned tuna have been made available only for tuna in oil.

[28] In the United States the standard capacity of tuna cans has been reduced various times; therefore, the data referring to the United States' markets apply to 6.5-oz (184 g) cans until August 1991, to 6.125-oz (174 g) cans until September 1998 and to 6-oz (170 g) cans until the present.

FIGURE 28
Monthly prices of skipjack and yellowfin canned in brine in the EU

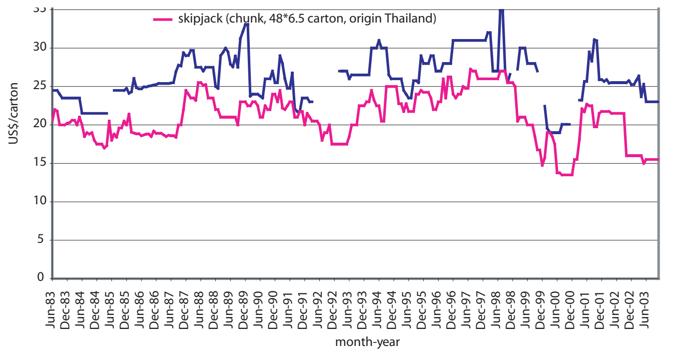


TABLE 1
Tuna conversion factors (net weight to live-weight equivalent from FAO FIDI data)

Albacore, fresh or chilled	1
Albacore, frozen	1
Albacore, G&G, frozen	1.1
Albacore, heads-off, etc., frozen	1.3
Albacore, canned	1.92
Albacore, in brine, canned	1.92
Albacore, in oil, canned	1.92
Albacore, solid pack, canned	1.92
Bluefin tuna, fresh or chilled	1
Bluefin tuna, frozen	1.1
Skipjack tuna, canned	1.92
Skipjack tuna, fresh or chilled	1
Skipjack tuna, frozen	1
Skipjack tuna, in brine, canned	1.92
Skipjack tuna, in oil, canned	1.92
Tuna loins (not for canning) and fillets	1.3
Tunas nei, canned*	1.92
Tunas nei, frozen	1.16
Tunas, bonitos, billfishes, etc., canned	1.92
Tunas, bonitos, billfishes, frozen	1.16
Tunas, chunk-pack, canned	1.92
Tunas, chunk-pack, in brine, canned	1.92
Tunas, chunk-pack, in oil, canned	1.92
Tunas, flakes and grated, canned	1.92
Tunas, flakes and grated, in brine, canned	1.92
Tunas, flakes and grated, in oil, canned	1.92
Yellowfin tuna, fresh or chilled	1
Yellowfin tuna, frozen	1
Yellowfin tuna, gilled, gutted, frozen	1.1
Yellowfin tuna, heads-off, etc., frozen	1.3

* And tuna loins for canning.

upon in April 2003. In December 2003 the prices in Europe increased to US$17/carton, while those in the United States declined to US$15/ carton.

Traditionally, market analysts have not collected nor analysed the prices of solid-pack canned yellowfin because it is more expensive than other types of canned yellowfin, and hence not representative of the canned tuna market. However, a consistent series of prices for solid-pack canned yellowfin in the EU (origin: African, Caribbean and Pacific, ACP) is available in past issues of the ITN; the trend seems to be consistent with that for canned skipjack.

Imports to the EU accounted for 52 percent of the world imports of canned tuna during 1976-2001 (FISHSTAT Plus data). The United States is also an important market for canned tuna, but the progressive reduction of the capacity of the standard can from 6.5 to 6 oz (184 to 170 g) operated by the government does not allow a reliable price estimate. Therefore, canned tuna prices are based on:

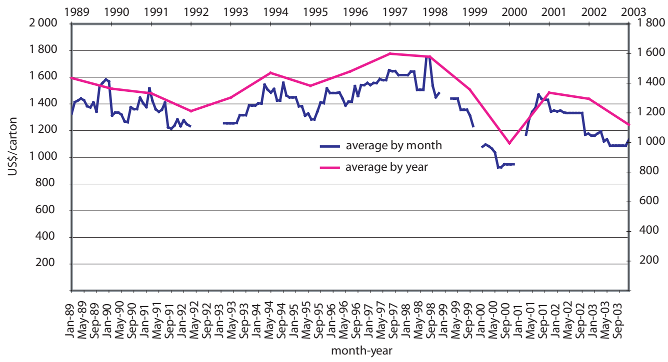
- ITN data on EU prices of chunk-pack skipjack from Thailand US$/carton (1 carton = 48*6.5 oz or 184 g); and
- ITN data on EU prices of solid-pack yellowfin from ACP, US$/ carton (1 carton = 48*7 oz or 198 g).

It is in this way possible to calculate the average prices of canned skipjack and yellowfin in the EU market, the most important market for canned skipjack and yellowfin in the world (Figure 29). Due to the different can sizes, the values have been converted from US$/carton into US$/tonne and divided by the conversion factor of 1.92 (see Table 1), in order to estimate the prices in live-weight equivalents. These values will be used in the concluding chapter.

The average prices of canned tuna declined from US$1 435/tonne in 1989 to US$1 212/tonne in 1992, mainly due to a persisting oversupply of raw material and the impact of the tuna-dolphin issue. In the years that followed, prices increased, reaching US$1 599/tonne in 1997 and US$1 578/tonne in 1998. Oversupplies of raw material during the years that followed reduced the prices to US$995/tonne in 2000. WTPO measures aimed at restricting the supply of raw material caused the prices of canned tuna, as well as those of raw material, to increase. The prices of canned tuna increased to US$1 336/tonne in 2001, but declined during the years that followed, reaching US$1 120/tonne in 2003.

FIGURE 29

Average prices for canned skipjack and yellowfin tuna in the EU (net of conversion factors, in US$/tonne, by month 1989-2003 and by year 1989-2003)



4. CONCLUSION

The ultimate aim of this paper is to demonstrate the relationship between the tuna market (*sashimi*, raw material and canned tuna) and tuna catches by utilizing a practical "bottom-up" approach. Such an approach relies on the analysis of empirical data series as a necessary pre-requisite for the elaboration of a theoretical model.

The analysis of the relationship between the *sashimi* tuna market and tuna catches is based on the following data:

- tuna prices (FISH INFOnetwork data);
- imports of *sashimi*-grade tuna (Japanese customs data);
- catches of Atlantic, Pacific and southern bluefin and of bigeye (FISHSTAT Plus and tuna RFBAs data).

On the other hand, the analysis of the relationship between the markets for raw material and canned tuna and the catches of tuna is based on the following data:

- prices for tuna (FISH INFOnetwork data);
- imports of raw material for canning (FISHSTAT Plus, EUROSTAT and NMFS data), live-weight equivalent[29];
- imports of canned tuna (FISHSTAT Plus data), live-weight equivalent[30];
- catches of skipjack and yellowfin (FISHSTAT Plus and RFBAs data).

The results of this paper will be used in the estimation of tuna fishing capacity, and hence for the estimation of the optimum management of fishing capacity to achieve sustainability in tuna fisheries.

4.1 The market for *sashimi*-grade tuna

The analysis of the *sashimi* market will focus on Atlantic, Pacific and southern bluefin and on bigeye, the four species that best represent this market.

Due to the similar nature of the markets for Atlantic, Pacific and southern bluefin, and their similar prices, the data for the three species are combined (Figure 30). The data for the catches of bluefin are taken from FISHSTAT Plus and from world import data (converted into live-weight data[31]). The prices were obtained from price data for the Japanese Tsukiji market. The market prices of bluefin shown in Figure 30 are averages of the low and high prices of Atlantic, Pacific and southern bluefin tunas from the subsection *Tuna for sashimi* of the section *Selection of key prices and price series analysis*.

The data presented here must be interpreted with caution, however, because of the large amounts of juvenile bluefin (sometimes up to 60 percent of catches) that are not *sashimi*-quality, and hence do not appear in bluefin market prices. These juveniles

[29] Each import, export or production figure must be multiplied by its conversion factor to obtain its live-weight equivalent for comparison with the catches (in live weight) of the same year. Conversion factors are given in Table 1.

[30] See above reference.

[31] Conversion factors are given in Table 1.

FIGURE 30
World market for Atlantic, Pacific and southern bluefin tunas for *sashimi*

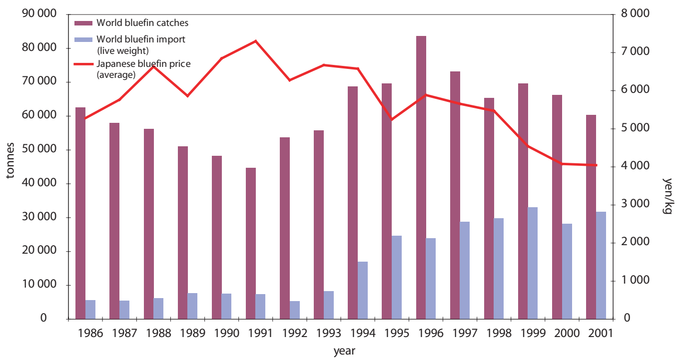
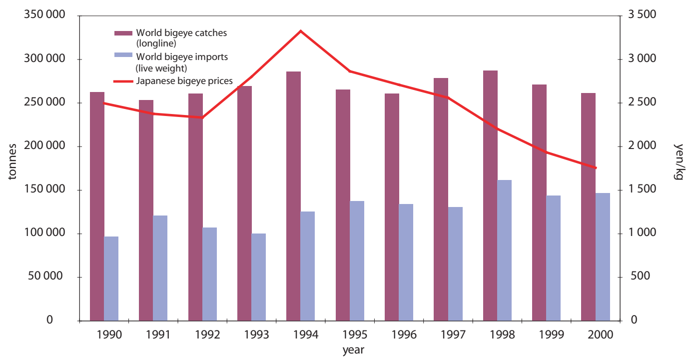


FIGURE 31
World market for bigeye for *sashimi*



may be consumed as *meji* (young tuna), canned or confined in pens for later sale as *sashimi*-grade tuna. Furthermore, especially prior to the introduction of documents such as the BFSD[32], large quantities of bluefin were traded under different names or just as tunas nei, so the data for the years prior to mid-nineties shown below almost certainly do not represent the full extent of the bluefin market.

Imports of bluefin increased from 5 564 tonnes (live-weight equivalent) in 1986 to 7 542 tonnes in 1990 and 7 354 tonnes in 1991. However, as in the previous paragraph, these data are almost certainly underestimates. At the same time, the catches of bluefin decreased from 62 549 tonnes in 1986 to 44 669 tonnes in 1991. As a result of strong demand and low catches, prices increased from ¥5 279/kg in 1986 to ¥7 299/kg in 1991 (Figure 30).

During the years that followed, imports increased more substantially, from a low of 5 287 tonnes (live-weight equivalent) in 1992 to 24 642 tonnes in 1995, and then declined slightly to 23 937 tonnes in 1996. The catches increased to a record high of 83 666 tonnes in 1996. Increasing imports from 1991 to 1996 indicate an increase in demand, but the prices did not increase due to the increased supply. In fact, prices decreased from ¥7 299/kg in 1991 to ¥5 246/kg in 1995 and ¥5 885/kg in 1996 (Figure 30).

After that, as a result of stringent ICCAT and CCSBT quotas, the catches declined to 65 435 tonnes in 1998. The catch increased slightly to 69 623 tonnes in 1999, but eventually decreased to 60 368 tonnes in 2001. The imports of bluefin were 33 003 tonnes (live-weight equivalent) in 1999, declined slightly to 28 194 tonnes in 2000 and then increased to 31 709 tonnes in 2001. In turn, Japanese prices declined over the entire 1997-2001 period, reaching ¥4 046/kg in 2001. Despite substantial imports and declining catches, the development of tuna farming in the Mediterranean Sea and elsewhere since 1997 has made available increasing quantities of cheaper farm-raised bluefin in the world market, lowering the average bluefin tuna prices. The average bluefin tuna prices reached a low of ¥3 936/kg in 2003.

Information on the world market for bigeye tuna for *sashimi* is shown in Figure 31. The catch data (for longline gear only) were obtained from Miyake *et al.* (in press), and those for imports (live-weight equivalent[33]) are based on FISHSTAT Plus data. The prices were obtained from price data for the Japanese Tsukiji market. The market prices of bigeye shown in Figure 31 are averages of the prices of fresh/chilled and frozen bigeye from obtained from the subsection *Tuna for sashimi* of the section *Selection of key*

[32] BFSD was introduced in 1993.
[33] Conversion factors are given in Table 1.

prices and price series analysis.

The longline catches of bigeye increased from 262 337 tonnes in 1990 to 286 129 tonnes in 1994, declined during 1995 and 1996, increased during 1997 and 1998, reaching 287 148 tonnes in the latter year and then decreased again, to 261 261 tonnes in 2000. The imports of bigeye increased from 96 484 tonnes in 1990 to 146 404 tonnes in 2000. Prices of bigeye in the Japanese market increased from ¥2 947/kg in 1989 to ¥3 324/kg in 1994, but declined in the years that followed, reaching a low of ¥1 757 in 2000.

It is interesting to note that the catches and prices of bigeye both peaked in 1994. However, the decline of bigeye prices during the latter half of the nineties was the result of increased supplies of cheaper bigeye from imports (and also increased imports of cheaper bluefin from farming), even though the catches of bigeye decreased.

4.2 The market for raw material for canning and for canned tuna

The present analysis will cover the canned tuna market during the 1989-2001 period, which was characterized by:

- the progressive substitution of loins for whole frozen raw material at the canneries in developed countries;
- the tuna-dolphin issue, which is still unresolved;
- the internationalization of the EU tuna industry, and its integration with the ACP industry;
- the strengthening of the position of Thailand as the world's top producer of canned tuna (despite the mid-decade crisis, which resulted in the closure of UNICORD);
- the establishment of the WTPO as a measure to eliminate the problem of oversupply of raw material, and the resulting extremely low prices, that occurred at the end of the decade.

The analysis will cover the markets for skipjack and yellowfin for canning. The catch data should be interpreted with caution, however, as not all skipjack caught are canned: in Japan, for example, large amounts of skipjack are used to prepare *tataki* or *fushi*.

The market for skipjack raw material has followed a variable trend over the past decade. At the beginning of the decade, the catches of skipjack increased from 1.2 million tonnes in 1989 to 1.6 million tonnes in 1991, while the imports[34] of whole frozen skipjack for canning increased from 347 347 tonnes in 1989 to 577 016 tonnes in 1991. The increased demand for skipjack generated a price increase from US$763/tonne in 1989 to US$806/tonne in 1990. In the months that followed, oversupply caused by an increase in catches (from 1.3 million tonnes in 1990 to 1.6 million tonnes in 1991), caused a decline in prices from US$806/tonne in 1990 to US$737/tonne in 1991, despite the increase in demand, as measured by the increase in imports from 402 087 tonnes in 1990 to 577 016 tonnes in 1991. As a consequence of the exceptionally high catches of 1991, however, the demand declined in 1992 to 463 266 tonnes and the price to US$646/tonne (Figure 32).

During 1992-1993 skipjack catches were lower, 1.4 million tonnes in 1992 and less than 1.5 million tonnes in 1993, as compared to a previous peak of 1.6 million tonnes in 1991. Imports were virtually constant for the next three years, 463 266 tonnes in 1992, 463 852 tonnes in 1993 and 467 987 tonnes in 1994. According to market analysts at the time (FAO/GLOBEFISH, 1994), a prolonged period of relatively low catches and buoyant demand resulted in a record price of US$1 100/tonne in the Bangkok market in September 1994 (Figure 32).

The catches increased to more than 1.6 million tonnes in 1995. Despite the high import level (547 483 tonnes), the increased catches and the reduced imports (446 967 tonnes)

[34] All import figures in this sub-chapter are live-weight equivalents.

FIGURE 32
World market for whole frozen skipjack for canning

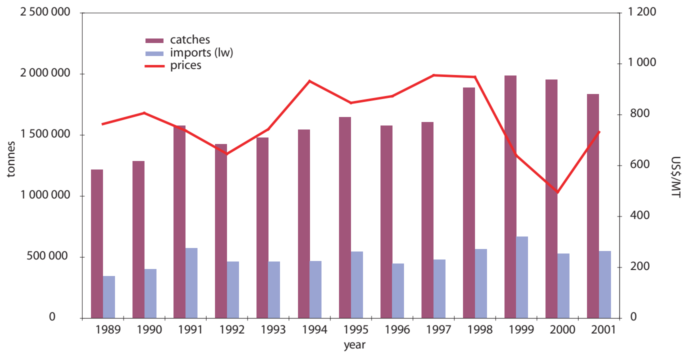


FIGURE 33
World market for whole frozen yellowfin for canning

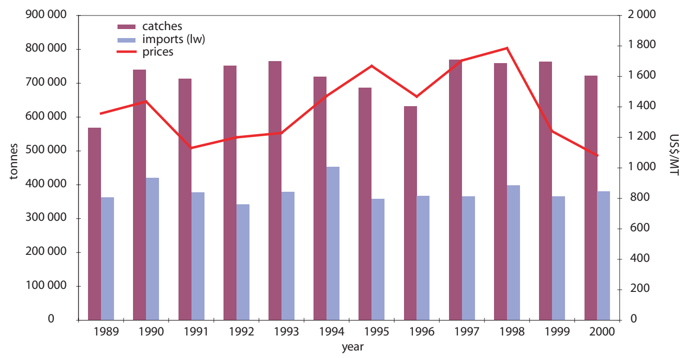
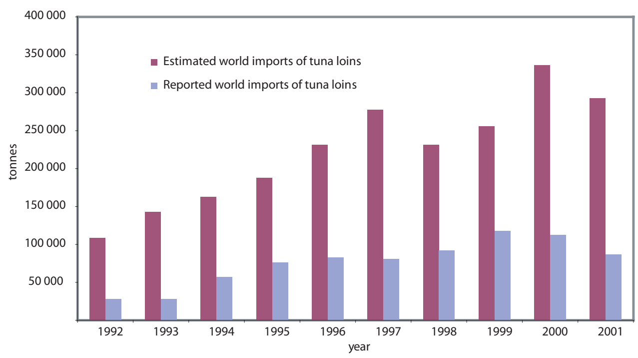


FIGURE 34
World market for tuna loins



brought the price down to US$847/tonne. In 1996 the catches (1.58 million tonnes) and imports (446 967) were lower, but the price increased to US$873/tonne. The explanation for this apparent paradox lies in the reduced imports by the world's top skipjack importer, Thailand. Due to the crisis at UNICORD, the Thai tuna giant, which was forced to sell its assets to Bumble Bee Seafoods, the imports of skipjack in Thailand declined from 320 431 tonnes in 1995 to 240 872 tonnes in 1996 (FISHSTAT Plus data).

The good demand for skipjack in 1997 (482 779 tonnes) and 1998 (566 541 tonnes), coupled with stable catches in 1997 (1.6 million tonnes) and lower catches during the first half of 1998, brought skipjack prices to an all-time high of US$1 101/tonne in the United States and US$1 250/tonne in Bangkok in April 1998. During the second half of 1998 the catches began to increase, reaching about 1.9 million tonnes for 1998 and 2 million tonnes in 1999, which led skipjack prices to decline from US$948/tonne in 1998 to US$640/tonne in 1999. The demand increased from 566 541 tonnes in 1998 to 669 250 tonnes in 1999 (Figure 32).

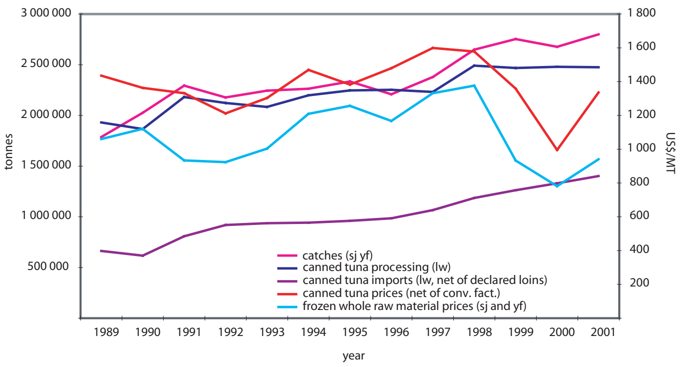
In 2000 the excess of supply caused skipjack prices to reach an all-time low of US$496/tonne, and created considerable economic hardship for vessel owners and fishers. The catches declined slightly, and, due to an oversupply of raw material, imports dropped to 528 920 tonnes. The implementation of WTPO-led measures to reduce fishing effort reduced the catches to 1.8 million tonnes and increased the prices to US$732/tonne. In the same year, imports increased to 551 017 tonnes, due to the reduction of the supply while the prices were still relatively low. However, the problem of skipjack oversupply re-emerged in 2002 and early 2003, resulting in another WTPO intervention[35].

Information on the world market of yellowfin for canning is shown in Figure 33. Yellowfin is considered to be of higher quality than skipjack, and a significant portion of the yellowfin catches, especially those of vessels of Japan, Taiwan Province of

[35] See section *Analysis of the factors affecting tuna catches* and section *Selection of key prices and price series analysis*, subsection *Whole raw material for canning*.

China and the Republic of Korea are destined to the non-canning sector. In some areas of the world, particularly Southern Europe, yellowfin is almost the only species utilized for canning. The catches were relatively steady throughout the period, and the prices less so, having been lowest during 1991-1993 and 1999-2000.

FIGURE 35
World market for canned tuna



Tuna loins were introduced in 1989, first in the United States and then in Europe, as a way to cut production costs in the canneries of developed countries without having to reduce employment drastically. The imports of loins estimated by the author of this paper from FISHSTAT Plus data are much greater than the imports of loins reported by the principal importers (Figure 34).

The estimation was done with FISHSTAT Plus and EUROSTAT data as follows: {EU production of canned tuna live weight – [EU catches of skipjack and yellowfin + [(EU imports of frozen skipjack and yellowfin live weight – EU exports of skipjack and yellowfin live weight)]} + {United States production of canned tuna live weight - [United States catches of skipjack and yellowfin + [(United States imports of frozen skipjack and yellowfin live weight – United States exports of skipjack and yellowfin live weight)]} = estimated imports of the equivalent live weights of the loins by the tuna industries of the EU and the United States live weight. Multiplication of this by the appropriate conversion factor results in estimated imports of loins by the tuna industries of the EU and the United States.

The international demand for canned tuna, as measured by imports, is the driving force behind the evolution of the market. However, in contrast to the other more expensive commodities, the relation between imports and prices of canned tuna is relatively weak, as shown by Figure 35. Because the raw material and canned tuna are relatively inexpensive, importers and consumers do not limit their purchases of these when the prices increase[36]. However, a drastic decline in prices of canned tuna, such as that of 1998-2000, may increase purchases of canned tuna significantly (Figure 35). Nevertheless, increasing demand for canned tuna has not always contributed to increases in the prices of canned tuna.

The imports of canned tuna increased during 1990-1995[37], while prices declined during 1989-1992 and 1994-1995. Both imports and prices increased during 1995-1997. During the years that followed the imports of canned tuna continued to increase, but the supply of raw material increased more rapidly, which led to a plunge in prices of raw material. In 2001 the prices of canned tuna increased, due to measures restricting fishing effort implemented by the WTPO. In 2002 and 2003, however, the prices of canned tuna declined again, as a result of an oversupply of raw material.

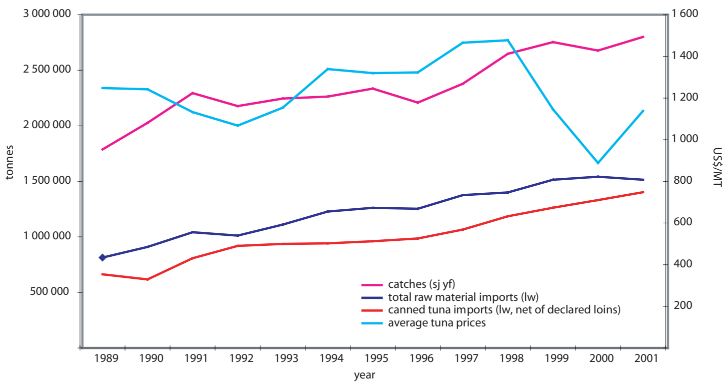
On the other hand, it can be seen in Figure 35 that the trends in the prices of canned tuna and raw material correspond closely with one another: hence prices of canned tuna are most influenced by the prices of raw material, which are controlled by the supplies

[36] In at least some areas of the world, such as North America, the demand for canned tuna appears to be affected more by issues such as animal welfare or methyl mercury (see subsections *Health and safety* and *Animal welfare concerns: the tuna-dolphin issue* of section *Tuna industry analysis*).

[37] The decline in imports (and prices) of canned tuna during 1989-1990, driven by the decline in imports by the United States, was a result of the tuna-dolphin issue.

FIGURE 36

Catches of tuna, imports of raw material, imports of canned tuna, and average tuna prices



of raw material. It is apparent, from monthly price data from the GLOBEFISH data bank, that the prices of canned tuna respond quickly to variations in the prices of raw material.

It can also be seen in Figure 35 that an average of 85 percent of the catches of skipjack and yellowfin during 1989-2001 was processed as canned tuna (live-weight equivalent).

The link between the amounts of canned tuna processed and amounts of raw material available is obviously strong, but the links between either of these and the prices of canned tuna prices are relatively weak (Figure 35). In theory, processing should be inversely proportional to the prices of raw material prices and directly proportional to prices of canned tuna prices, but the amounts of raw material and the prices of canned tuna are almost parallel, and the processing curve does not follow any of the price curves. The principal reason for this is the fact that there are producers of canned tuna of a reasonably high quality (yellowfin) who are willing to pay high prices for raw material to supply the demand for canned tuna. If it were possible to separate skipjack and yellowfin in the processing data, skipjack processing would probably appear to be more dependent than yellowfin on the prices of raw material.

It is now possible to compare the imports and the prices of tuna (raw material and canned tuna) with the catches of skipjack and the purse-seine and pole-and-line catches of yellowfin[38] in order to determine the extent of the interactions between supply and demand.

Buoyant international demand for canned tuna generated an increase in catches and imports of raw material from 1992 to 1998. However, as the increase in catches was not enough to create an oversupply[39], the prices increased during that period. The price declines between 1990 and 1992 and (more seriously) between 1998 and 2000 were caused by excess supplies. The price depression reached a hypogeum at the end of 2000 (Figure 36). The supply-restricting measures implemented by the WTPO limited catches between the end of 2000 and the beginning of 2001, increased the prices, but, as far as skipjack was concerned, its benefits proved to be only temporary (Figure 36).

In a situation for which natural resources are regarded as inexhaustible and where oversupply conditions do not exist, increasing demand for canned tuna would generate an increase in imports of raw material, catches and prices. At the same time, increasing prices of raw material and canned tuna would stimulate the construction of fishing vessels, which would, of course, increase the catches.

At the same time, variations in the catches (supply) and imports (demand) of raw material have opposite impacts over tuna prices. If the increase in catches exceeds the increase in imports (creating an oversupply) the prices decline; if the increase in imports exceeds the increase in catches, the prices increase.

The amount of canned tuna processed is determined by the supply of raw material available to feed a constantly growing demand, rather than by variations in raw material or canned tuna prices. Catches of tuna and production of canned tuna followed an

[38] The 2001 catches are estimated.

[39] There were also periods of lower captures, such as 1996.

almost parallel trend in the period under examination (Figure 35). However, the processing of canned tuna has been growing more slowly than the catches, mainly because tuna-processing capacity has been growing more slowly than tuna-fishing capacity. In fact, tuna processing capacity is linked more to state of technology than to the abundance of natural resources and the ability to concentrate on the most productive fishing grounds.

When the market is oversupplied the positive correlations between catches, imports, processing and prices break down, and prices decline. The decreases in price that occurred between late 1998 and late 2000 were, ultimately, the result of excess fishing capacity. The prices of raw material and canned tuna had been elevated since 1992, and had increased since 1996 (Figure 36). As a result, it was appropriate to try to maximise the catches by maximising the numbers of days spent at sea and by constructing more vessels. In late 1998, however, the abundance of resources, combined with increased fishing capacity, generated large increases in the catches. These continued in the following years until in late 2000 the WTPO had to implement measures to limit the supply in order to increase the prices of raw material. Had the WTPO not intervened, the continuing excess of fishing capacity input might have had adverse effects on one or more of the target or non-target species.

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SECTION 4

Tuna fishing capacity management options and implications

Past developments and future options for managing tuna fishing capacity, with special emphasis on purse-seine fleets

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ABSTRACT

There has recently been a great deal of concern expressed by regional tuna fisheries management organizations, governments and the tuna fishing industry that there is excess fishing capacity in the world's tuna fleets, which could lead to overfishing of some populations, such as yellowfin and bigeye, and to harvests of skipjack in excess of demand, resulting in reduced ex-vessel prices.

Analyses have shown for the world's purse-seine fleet that fishing capacity, measured as the ability of vessels or fleets to catch fish, is greater than that needed to sustain current levels of harvest. Although similar analyses have not been conducted for other gear types, the longline industry has initiated measures to reduce capacity of large-scale longline fleets by 20 percent.

There have been several efforts by regional tuna bodies to implement measures to limit the capacity of some tuna fleets operating in their respective regions. The most comprehensive of these has been the Regional Vessel Register (RVR) of the Inter-American Tropical Tuna Commission (IATTC).

In the present study, two categories of options for managing fishing capacity, particularly for purse-seine fleets, are presented: 1) open-access and common property-based options, and 2) limited-entry and rights-based options. The first category includes the options of *i*) maintaining the status quo and *ii*) reducing capacity by closing off part of a vessel's fish-storage space, but not its fishing power, or requiring vessels to remain in port at the end of each trip for periods longer than necessary for unloading the catch and re-supplying the vessel. Neither of these options is considered to be an effective means of addressing the capacity problem. The second category includes *i*) an RVR similar to that of the IATTC, but with a vessel buy-back option, *ii*) a self-regulating measure that assigns individual quotas and *iii*) licensing schemes, including fractional licences and the use of auctions for the sale and transfer of licences.

It is concluded that the common-property and open-access nature of tuna fisheries has been a major cause of excess capacity in these fisheries, and that moving away from these concepts toward rights-based management schemes might resolve the problems of excess capacity.

Because the process of developing acceptable measures to reduce capacity will be slow and difficult to achieve, it is recommended that the regional tuna bodies strengthen and/or implement as soon as possible moratoria on the growth of capacity in all industrial-scale tuna fisheries. It is also recommended that the regional tuna bodies work together

to establish a list of all medium- and large-scale tuna vessels, including the vessel characteristics and specifications needed to monitor world tuna fishing capacity.

1. INTRODUCTION

Over the last several years there has been a great deal of attention given to the problem of excess capacity[1] in fisheries (Gréboval and Munro, 1999). This has led to the development of an International Plan of Action for the management of fishing capacity (IPOA-CAPACITY), which was approved in 1999 by the Food and Agriculture Organization (FAO) of the United Nations (Cunningham and Gréboval, 2001). The IPOA-CAPACITY called on states and regional fishery bodies to achieve efficient, equitable and transparent management of fishing capacity worldwide, preferably by 2003, but no later than 2005. Although the IPOA-CAPACITY did not specifically or uniquely address the issue of tuna fishing capacity, tuna fisheries are apparently suffering the same woes of excess capacity as are most other fisheries. This general concern over excess capacity in the world's tuna fisheries has been expressed by all of the regional tuna bodies. For the most part, these regional tuna bodies have initiated measures to address the problem of excess capacity. In addition, the tuna industry itself has expressed concern, and, indeed, has initiated, in some cases, measures to mitigate the problem.

The problem of excess capacity in the world's tuna fleets was the object of a study by Joseph (2003), who attempted to show for the eastern Pacific Ocean (EPO), and, by inference, for other areas, that there was more purse-seine tuna fishing capacity than needed to harvest the available resources. In that study, he presented a series of ideas that might be considered in the search for effective mechanisms for managing capacity.

In response to this growing concern over excess capacity in the world's tuna fisheries, during the latter half of 2002 FAO started a project on management of tuna fishing capacity. The objectives of the project are to provide technical information necessary for addressing problems associated with the world-wide management of tuna fishing capacity, taking into account conservation of the tuna stocks and socio-economic issues. Majkowski (2003) defined the project's activities to consist of 1) technical work preparatory to an Expert Consultation on Management of Tuna Fishing Capacity, 2) a consultation to review and integrate the results of the preparatory work and to formulate conclusions and recommendations, and 3) dissemination of these findings. To assist FAO in achieving its objectives regarding the project, a Technical Advisory Committee on capacity (TAC) was established to provide technical advice on the best way of implementing the project. The motivation for the present paper is to provide background information to the TAC, which, in turn, will provide advice to FAO and the Expert Consultation on Management of Tuna Fishing Capacity on measures for limiting fishing capacity in the world's tuna fisheries.

Since the preliminary work of Joseph (2003), several more comprehensive studies have been completed, many as a result of the work of the TAC, dealing with trends in the capacity of tuna fishing fleets and with the measurement of fishing capacity in the world's purse-seine and longline fleets (Gillett; Reid *et al.*; and Miyake, this collection). The studies, which are reviewed in Section 2 of this report, conclude that there is more capacity in the world's purse-seine and longline fleets than is needed to take the current levels of catch. In other words, the levels of catch being made in these fisheries today could be taken with significantly less capacity. For the purposes of this paper the

[1] In terms of an input indicator such as potential fishing days, excess capacity exists when the actual days fished by a fleet are less than the potential days fishing that that same fleet is capable of generating if fully utilized.

conclusions of Reid *et al.* (this collection), will be considered accurate, and it will be assumed that there is excess capacity in the world's purse-seine fisheries.

As stated in Joseph's (2003) review, there have been several initiatives taken by regional tuna bodies, and by the tuna industry, to address the problem of excess capacity. Notable among these is the program of the Inter-American Tropical Tuna Commission (IATTC) to limit purse-seine capacity in the EPO, the efforts of the International Commission for the Conservation of Atlantic Tunas (ICCAT) to limit the number of vessels fishing for northern albacore and bigeye in the Atlantic Ocean, the Organization for the Promotion of Responsible Tuna Fisheries (OPRT) to reduce world longline fleets by 20 percent and the efforts of the World Tuna Purse-seine Organization (WTPO) to place a moratorium on the entry of new purse-seine vessels into the world's tuna fisheries. Based on the initiatives of the OPRT, it will be assumed that there is excess capacity in the world's longline fisheries. These topics will be reviewed and updated in Section 3 of this report.

Considering the assumption made above, that there is more fishing capacity in the world's purse-seine and longline fleets than is needed to take current levels of harvest, this paper will examine a series of options that might be considered for managing tuna-fishing capacity. These options, which will be presented in Section 4 of this report, will deal primarily with possible measures for controlling the capacity of purse-seine vessels that normally fish beyond the near-coastal zone and that were included in the analysis of Reid *et al.* (this collection). The current size of the world fleet of large purse-seiners is about 570 vessels, which capture slightly more than 60 percent of all of the principal market species[2] of tunas taken from the world's oceans. By moving quickly to address the capacity problem in the purse-seine fleet, the potential impact of too much fishing mortality could be averted. However, in any lasting and equitable solution to the capacity problem, all fleets that harvest tunas must be incorporated into capacity-limitation programs. Therefore, although it is not the intention of the author to address the issue of capacity in non-purse-seine fisheries, some attention will be given to these other fleets, particularly the distant-water longline fleets.

In the final sections of this report the author will summarize his findings with respect to possible options for managing fishing capacity, and, as appropriate, address recommendations to the TAC, regional tuna bodies, national fishery administrations and the private sector.

2. A REVIEW OF ESTIMATES OF TUNA-FISHING CAPACITY

In this section of the report available information on the current numbers and capacities of tuna-fishing vessels and data on past trends, and also published reports on whether there is excess capacity in the tuna fisheries, will be reviewed. The amount and quality of the information available varies greatly. The most complete and current data are for purse-seine fleets, particularly those that operate primarily in the Pacific Ocean, followed by information on large-scale longline vessels. There is limited information available on capacity in the pole-and-line fleets, trolling fleets and miscellaneous other types of fishing fleets. The only detailed and readily-available information on long-term trends in the capacity of tuna fleets is for purse-seine and pole-and-line vessels in the EPO.

2.1 Defining capacity

Before going further with this discussion, it is necessary to discuss what is meant by the term capacity in this report, since it is defined and used in so many different ways. The

[2] The principal market species of tuna are: skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), bigeye (*T. obesus*), albacore (*T. alalunga*), Atlantic bluefin (*T. thynnus*), Pacific bluefin (*T. orientalis*) and southern bluefin (*T. maccoyii*).

term capacity is generally used to reflect what a vessel can catch, or how much fishing mortality a vessel is capable of generating. Most fisheries scientists use some input indicator such as the size of a vessel or its engine power to define capacity because they believe them to be related to the ability of a vessel to generate fishing mortality. The fishing industry most often uses size as a measure of capacity because it is related to how much fish a vessel can catch in a single trip. Economists generally prefer some technological-economic approach, using potential output to measure fishing capacity, because such an approach can be used to compute optimal inputs (Morrison, 1985). The economists' approach is widely applied by governments throughout the world (largely administered through surveys of businesses) when measuring the amount of productive capacity that is utilized in different industries and in the economy at large (Corrado and Mattey, 1997).

The most common indicators of capacity for high-seas tuna vessels used by fisheries scientists are: 1) Gross Registered Tonnage (GRT), which is the total of all the enclosed space within a vessel, and is expressed in tons, each of which is equivalent to 100 cubic feet. The GRT of a vessel can be easily changed by changing bulkheads and walls; 2) Net Registered Tonnage (NRT), which is the total of all enclosed space within a vessel available for cargo and expressed in tons. The NRT can also be easily altered by changing partitions; and 3) Fish-Carrying Capacity (FCC), which generally relates to how many tonnes of fish the vessel can carry when fully loaded. For most large tuna vessels there is a close linear relation between each of the measures, GRT, NRT and FCC. The FCC has been one of the most commonly-used measures of capacity for purse-seine and pole-and-line vessels. It is easily understood by the fishing industry, and generally easy to compute. However, like GRT and NRT, FCC is a plastic measure which can change with the size of fish that are being loaded on board or the way the fish is packed for quality purposes (Gillette and Lewis, 2003). Because the measure is somewhat plastic, management agencies have had difficulties in fixing the exact value of FCC for individual vessels when regulations and/or monetary assessments have been based on the measure. To get around these problems, cubic metres of refrigerated fish storage space, a less pliable measure of how much fish a vessel can carry, is being used more frequently as a measure of capacity.

The FAO Fisheries Department convened technical meetings of experts to address the issues of how to define, measure and control fishing capacity in 1988 and 1999. The primary result of these meetings was to define fishing capacity in terms of potential output. The definition arrived at was that fishing capacity is the maximum amount of fish or fishing effort that can be produced over a period of time by a fishing fleet if fully utilized, given the biomass and age structure of the fish stock and the present state of technology; in other words, it is the ability of a vessel or vessels to catch fish. To facilitate the measurement of excess capacity, which the meetings concluded was the difference between capacity output and a target level of capacity output, target fishing capacity was defined. Target fishing capacity is the maximum amount of fish that can be produced over a period of time by a fishing fleet if fully utilized, while satisfying fishery management objectives designed to ensure sustainable fisheries.

Although fisheries scientists may have some difficulty in applying these technological-economic definitions of fishing capacity to their studies to estimate fishing effort and fishing mortality, the definitions facilitate studies to determine whether excess capacity exists. A series of such analysis for tuna fisheries have been commissioned by FAO for evaluation by the TAC; the results of these analyses will be discussed later in this section.

2.2 Estimates of capacity

2.2.1 Purse-seine

As noted above, the most detailed information available on the numbers and capacities of vessels is for the tuna purse-seine fleets.

2.2.1.1 Eastern Pacific Ocean (EPO)

Joseph (2003) showed trends in Fish-Carrying Capacity (FCC), measured in tonnes, for the purse-seine fleet of the EPO for 1960-2001. These statistics have been updated for 1961-2002 and expressed in cubic metres of well volume (IATTC, 2004). In 1961 there were 125 purse-seine vessels with an average capacity of 256 cubic metres, and a combined FCC of 32 thousand cubic metres. By 1980 the average capacity of the purse-seine vessels had increased to 726 cubic metres, and the combined FCC to 196 thousand cubic metres. During this period of fleet expansion the catches of tuna, after reaching the highest levels then recorded, began to decline as a result of the excess fishing mortality generated by this very large fleet. Because of reduced stock abundance and poor catches, much of the fleet left the fishery during 1980-1984. After the stock of tuna recovered, many, but not all, of the vessels returned to the fishery in 1985-1986. Between 1984 and 1996 FCC averaged about 130 thousand cubic metres. During this period catch rates per vessel were high, which attracted new investment in vessels. Capacity began to increase, and by the end of 2002 it reached about 200 thousand cubic metres, the greatest in the history of the fishery. There has been concern that these increases in capacity will result in a repeat of the situation during the 1970s, when there was more fishing capacity than needed to harvest the available resources, which caused the catch rates to decline.

To look at the problem of excess capacity, Joseph (2003) applied a linear programming technique, Data Envelopment Analysis (DEA), which was first applied to problems of fishing capacity by Kirkley and Squires (1999) to estimate the technical efficiency and potential catching capacity of the EPO purse-seine fleet. The estimates of fishing capacity from the analysis were based on the greatest observed catches in a year, and took into account yearly changes in stock biomass and sea-surface temperatures. Two analyses were conducted, one for yellowfin alone and one for skipjack, yellowfin and bigeye combined. In both cases the estimated fishing capacity, that is the maximum potential output of the fleet, was greater than the observed catch. For the 1970-2000 period, the ratio of the combined annual catch of skipjack, yellowfin and bigeye to the DEA-estimated fishing capacity, which is a measure of capacity utilization, was between 0.5 and 0.7, indicating that there was excess capacity in the EPO purse-seine fleet. In other words, if all the vessels in the fleet operated as well as the most efficient vessels, the observed catches could have been taken with fewer vessels than operated in the fishery. It was concluded in the study that, even though substantial excess capacity existed in the fishery, it was probably overestimated because individual vessel data were not used and yield curves, including estimates of average maximum sustainable yield (AMSY) were not incorporated into the analyses. In addition to these estimates of excess capacity in the fishery, the IATTC has estimated that the fleet is probably about 25 percent greater than that needed to take current levels of catch.

In a more recent DEA study for the EPO, Reid *et al.* (this collection), estimated capacity output and technical efficiency for the purse-seine fleet during 1998-2002. They found that excess capacity for combined catches of skipjack, yellowfin and bigeye, defined as capacity output minus observed landings, exists for all vessel size classes. Between 1998 and 2002, excess capacity, purged of technical efficiency, increased by about 60 percent. In terms of capacity utilization (CU), the ratio of landings to capacity output, current levels of catch in the EPO could be taken with a fleet that is between 60 and 75 percent of its current size.

2.2.1.2 Western and central Pacific Ocean (WCPO)

Gillett and Lewis (2003) estimated the numbers and carrying capacities of purse-seine vessels participating in the tuna fishery of the WCPO during 1988, 1995 and 2003. They considered any vessel with a capacity greater than 400 cubic metres that fished during the year to be participating in the fishery in that year, and excluded vessels that fished only in the Exclusive Economic Zones (EEZs) of Indonesia, the Philippines, Australia, New Zealand and other countries of the WCPO. For 1988, they estimated that there were 136 purse-seine vessels with a combined capacity of 140 thousand cubic metres (average capacity equal to 1073 cubic metres). For 1995, they estimated that there were 175 vessels, with a combined capacity of 200 thousand cubic metres (average capacity equal to 1143 cubic metres). By 2003 the number of vessels had increased to 191, with a combined carrying capacity of 233 thousand cubic metres. This represents a growth of 66 percent between 1988 and 2003 in the capacity of the purse-seine fleet in the WCPO.

Joseph (2003) also estimated the numbers and capacities of purse-seine vessels operating in the western Pacific Ocean, but his estimate for 2000 was greater than that of Gillett and Lewis (2003). This is particularly evident if the figures expressed in the Joseph study are converted to cubic metres, to make them comparable to those of Gillett and Lewis figures; the conversion would increase the estimate by about seven percent. This was probably due to several factors. First, vessels over 250 tonnes of carrying capacity were counted in the Joseph study, whereas only vessels over 400 cubic metres were counted in the Gillett and Lewis study. Second, some vessels that fished only in domestic waters were included in the Joseph study, whereas these were not included in the Gillett and Lewis study. Third, Gillett and Lewis considered they may have underestimated capacity by about ten percent.

Similar to the situation in the EPO, the growing fleet size and increased catches in the WCPO, and the recent extremely low ex-vessel prices paid for canning-grade tuna worldwide, have led to concern on the part of many of the nations involved in the WCPO fishery as to whether there is a potential problem concerning the size of the purse-seine fleet in the fishery. Reid *et al.* (2003), provide some insight into this problem. They used catch data by set type (sets on floating objects, payaos and schools) within categories of vessel size and DEA to estimate potential catches under observed levels of fishing effort. They used two approaches regarding the number of sets per day and the types of sets made by an average vessel. In one analysis, technical efficiency, or skipper skill, was purged, and in the other it wasn't. Analyses were run for each national fleet and for all fleets combined. For all fleets combined the "non-purged" analysis estimated that if all vessels worked at the full-capacity level the annual catches taken during 1997-2000 could have been taken with 77 percent of the actual effort expended. Alternatively, if all vessels worked at their fleet's best-practice production frontier by using the appropriate level of variable inputs and were fully technically efficient, the observed number of fishing days during the same period would have produced 25 percent more catch. When the number of sets per day was fixed and technical efficiency or skipper skill purged, the excess capacity is estimated to be much less. In this case, if effort days were reduced by seven percent the same catches during 1997-2000 could be made. Alternatively if all vessels operated at the production frontier level, the same number of days generated during 1997-2000 would have harvested eight percent more fish. These results suggest that the recent levels of catch observed in the fishery could have been taken with a smaller fleet, or that the current fishery has a capacity in excess of what is needed to take current levels of harvest.

In a more recent study, Reid *et al.* (this collection), confirmed the results presented in the earlier study mentioned above, and concluded that if WCPO vessels operated efficiently, fully utilizing their variable inputs, and harvesting the average annual reported levels of landings, fleet sizes could be reduced by around 12 percent.

2.2.1.3 Atlantic Ocean

Joseph (2003) estimated that there were approximately 53 purse-seine vessels with a carrying capacity of about 48 thousand tonnes that were available to fish in the Atlantic Ocean during 2000. Most of these vessels were in the 800- to 1200-tonne class. Data on long-term trends in fleet carrying capacity have not been generally available for the

Atlantic. However, Reid *et al.* (this collection) were able to obtain some data on purse-seine fleets with which they could extend their DEA studies to the Atlantic Ocean. They found excess capacity to exist, but that it was not as severe as those for some of the other oceans. They concluded that if vessels operated efficiently, fully utilized their variable inputs, and harvested the average annual reported level of landings, fleet size could be reduced by about 13 percent.

2.2.1.4 Indian Ocean

The purse-seine fishery in the Indian Ocean did not develop significantly until the early 1980s, when French and Spanish vessels began to fish for part of the year in the Indian Ocean. Detailed estimates of the number of vessels that operated in the Indian Ocean are not readily available, but Joseph (2003) estimated that in 2000 there were approximately 67 purse-seine vessels with a carrying capacity of nearly 130 thousand tonnes available to fish in the Indian Ocean. Most of these vessels had capacities of more than 1800 tonnes. Using aggregated data for 1981-2002, Reid *et al.* (this collection), estimated that the current fleet size for the Atlantic could be reduced by about 23 percent without reducing the recent average levels of catches of skipjack, yellowfin, bigeye and albacore. They stressed that for both the Atlantic and Indian Ocean the estimates of capacity output are extreme lower-bound estimates.

2.2.2 Longline

Longline vessels operate wherever tunas are found throughout the oceans of the world. The large-scale longliners fish primarily for the *sashimi* market; their catches are frozen at ultra-low temperatures, and fishing voyages may last up to a year. Although most of the regional tuna organizations attempt to maintain lists of large-scale longline vessels that operate in their areas, the lists are not adequate for examining trends in fleet capacity.

Miyake (this collection) has estimated the numbers of longline vessels currently fishing for tunas throughout the oceans of the world. He broke his estimates into two groups, small longliners greater than 24 metres, but equal to or less than 35 metres in overall length, and large-scale longliners that are greater than 35 metres in overall length. He estimated that there are currently 1622 large-scale longliners and 1421 small longliners that fish for tunas. In addition, there are 106 large-scale longliners and 503 small longliners that fish primarily for swordfish, but may occasionally fish for tunas.

Miyake also estimated the amounts of tuna taken by these longline fleets. The large-scale longliners annually capture about 390 thousand tonnes of all species of tunas combined, and the small longliners take about 200 thousand tonnes annually. He notes that the economic break-even point for a large longliner is about 240 tonnes of tuna per year, which is very close to the actual per-vessel production per year, and that, because the species of tuna longliners exploit are fully exploited, increased catches cannot be expected. (Longliners also catch billfishes in addition to tunas and, depending on the quantities taken, this could affect the economic break-even point). He concluded that there is excess capacity in the longline fleets of the world, and if capacity could be reduced, catch and earnings per vessel would increase. The fact that the longline fishing industry is undertaking measures to reduce the number of longline vessels by 20 percent is cited by Miyake as clear evidence of excess capacity. As further evidence of the problems of capacity in the longline fleets, Miyake showed that the number of longliners in the Japanese fleet is declining. In 1980 there were 864 large-scale longliners in the Japanese fleet, but this number declined to 503 in 2000. Similarly, the corresponding numbers for small longliners in the Japanese fleet are 554 and 134. Finally, he notes that data on artisanal longline vessels that fish mostly for subsistence purposes are not available, but that the numbers are significant.

2.2.3 Other gear

Purse-seine and longline vessels account for about 75 percent of the world catch of the principal market species of tuna. Of the remaining 25 percent, pole-and-line vessels account for about 18 percent and miscellaneous other gear for the rest. Obviously, for any management schemes to be effective, all significant gear types must be considered. However, there have been few analyses of the impact of these other gear types on the problems of excess capacity. There are few data available on trends or current levels of capacity for these gear types.

In studies on the control and management of fishing capacity in the world's tuna fisheries, the TAC was interested in evaluating the impact of small-scale and artisanal type fisheries on measures to control fishing capacity. After considering this matter, it was decided that it would be virtually impossible to estimate the capacity of small-scale and artisanal fleets, given the complexity of such fisheries and the time and cost needed to complete such a study. Therefore, it was concluded that an estimate should be made of how much tuna these small-scale and artisanal type fisheries harvest annually, so that information could be used to evaluate their importance to any efforts to manage fishing capacity. Consequently the FAO commissioned a study to look at this problem (Gillett, this collection). In his report, Gillett notes "Rather than attempting to formulate a clever definition of small-scale/artisanal tuna fishing and then apply it globally to tuna fisheries, it may be more appropriate to establish a boundary for information to be collected by this study in accordance with objectives of the FAO tuna fishing capacity work. That is, the boundary should be established in view of the aim of knowing the level of catches of all tuna fisheries for which capacity estimation is not possible". He divided tuna fisheries into industrial and non-industrial categories. Non-industrial fisheries were subdivided into small-scale and medium-scale components. Industrial and small-scale fisheries were defined by gear and/or vessel attributes. The small-scale category included handlines, trolling from open vessels, rod and reel, recreational fishing, and the use of undecked, unpowered or sail vessels, or vessels powered by outboard engines. Medium-scale fisheries were considered to be those that fell between industrial fisheries and small-scale fisheries. Gillett estimated that about 320 thousand tonnes of the principal market species of tuna are harvested by the small-scale fisheries, but he was unable to estimate the proportion of the catch taken by the medium-scale component. The eight percent of the world catch of the small-scale fisheries is significant enough to require that any effective plan to manage tuna fisheries include this component of the fishery.

3. CURRENT MANAGEMENT MEASURES THAT IMPACT THE CAPACITY OF TUNA FISHING FLEETS

Owing to a number of unique characteristics of tunas and the fisheries for them, their effective management offers several challenges. Tunas are widespread throughout the oceans of the world. Most of the species of tuna undertake extensive migrations that carry them through the jurisdictional waters of many coastal states and onto the high seas, which are beyond the jurisdiction of any single state. If they are to be properly managed any management measure must apply to wherever the tuna are found. It would do no good to provide protection for them when they are in one area if they do not receive equal protection when in another. The fleets that fish for tunas are also very specialized, and very mobile. An entire fleet of vessels can move from a fishery in one region of the world to one in another region with great ease. A single vessel may fish in two or three oceans in a single year. Likewise, the market for tunas is international, the product moving throughout the markets of the world. A small change in production in one area can have an almost instant effect on price world wide. The nations framing the 1982 United Nations Convention on the Law of the Sea (LOSC) recognized the migratory characteristics of tunas, and the uniqueness of the fisheries for them, and called on states with an interest in tunas, including fishing and coastal states, to work jointly through international regional bodies to manage tunas. This concept is included in Article 64 of the Convention, which mandates that nations work cooperatively through regional fishery bodies in managing highly-migratory species, and, where such organizations do not exist, to create them. Highly-migratory species, which include the principal market species of tunas discussed in this report, are listed in an annex to the LOSC. In keeping with the objectives of the LOSC, there are presently Article 64-type tuna bodies in all the oceans of the world (although one of these is not yet operational). These organizations are responsible for managing the tunas.

Until recently, there have been few attempts to manage tuna fisheries by the implementation of input controls, such as limits on the number of days that can be fished or the number of vessels authorized to fish. Most efforts to manage tuna have involved output controls, particularly catch quotas and minimum size limits. The success of output controls in conserving tuna stocks has been limited because they have not controlled the number of vessels that can participate in harvesting the allowable catch. In fact, in the few examples in which catch quotas have been applied to tunas, they have frequently stimulated fleet growth rather than limiting it. So long as there is open access to the resource being managed there is an incentive for fishers to increase their opportunity to take a greater share of the allowable harvest by adding to their fishing capacity, either through the addition of new vessels, by increasing the efficiency of the vessels already operating in the fishery, or both. This tendency of input substitution or "capital stuffing", as it is referred to by Cunningham and Gréboval (2001), has been a major problem in fisheries management in general, and the tuna fisheries have not been immune to it. In the following paragraphs the various efforts of nations, international organizations and the private sector to manage tuna fisheries are discussed.

3.1 Governmental and intergovernmental arrangements

3.1.1 Early efforts by Japan to limit the number of longline vessels in its fleet

In an effort to stimulate economic growth after World War II, the Japanese government directed considerable effort toward developing its fisheries. High-seas tuna fleets were one of the primary targets for growth, and by the latter part of 1960 Japanese longline vessels fished throughout the oceans of the world. The fishery was profitable, and attracted increasing investment in vessel construction. The increasing number of vessels and the growing labor costs eventually began to erode the profitability of the fishery, so the Japanese government introduced programs to limit the number of Japanese vessels that could operate in the fishery. By limiting the number of longline vessels, catch rates and economic returns were kept high. However, because the tuna species targeted by the Japanese longline fleet are found throughout the oceans of the world, and because they constituted at that time a common property resource available to whomever could catch them, the action taken by the Japanese government was not successful in halting fleet growth. Japanese expertise and capital was invested in the construction and operation of longline vessels in nations that had placed no controls on fleet growth. This flow of capital stimulated the development of large fleets of longline vessels in the Taiwan Province of China and the Republic of Korea, and, more recently, China and Indonesia.

It became abundantly clear from the failure of the Japanese attempt to unilaterally resolve the problem of excess capacity that any effective program to limit fleet size and growth would have to involve all states with vessels participating in the fishery.

3.1.2 The Inter-American Tropical Tuna Commission (IATTC)

In 1966 the IATTC adopted a catch quota limiting the harvest of yellowfin tuna in order to prevent the near-shore portion of the stock in the EPO from being driven to below the level of abundance at which it could support the AMSY. This event marked the first time that an international high-seas fishery had come under conservation controls. At the time the purse-seine fleet consisted of about 40 thousand tonnes of carrying capacity, and nearly all of it was under a single flag. The quota was structured in a manner that allowed catches to be taken on a "first-come, first-served" basis. The season for unrestricted yellowfin fishing commenced on January 1, and would be closed on a date at which the current catch, plus the expected catch to be taken by vessels that were at sea at closure, plus catches taken under special allocations, plus the expected catch to be taken incidentally when fishing for other species, equaled the catch quota.

The conservation program stimulated vessel owners to add capacity, rather than to reduce it. Because yellowfin abundance remained high as a result of the conservation quotas, catch rates remained high as well. Processors, faced with a limited supply of raw material, raised prices. Profitability for the vessel operators was high. This attracted new investment in vessels, and capacity continued to grow. As a result of the growth in capacity, the season for unrestricted fishing decreased from 10 months to less than 4 months as more and more vessels raced to catch as much as they could before the season for unrestricted fishing was closed. Pressure to increase catch quotas beyond the recommendations of the scientists mounted. Most of the catch was taken by a single nation, and the coastal states of the region complained that the first-come, first-served basis of the conservation program discriminated against them because they had smaller fleets of smaller boats and could not compete. This resulted in intense negotiations among the nations with interests in the fishery to allocate shares of the quota to coastal states. In some cases the shares assigned to the coastal states were sufficient to allow their vessels to continue fishing throughout the year. This marked a significant change in the way management of tuna resources was viewed.

Because of their highly-migratory nature, and the fact that at that time most nations subscribed to a narrow coastal jurisdiction, tuna were considered to belong to whomever could catch them. However, in the mid- and late-1970s most of the world had moved to or was moving toward extended jurisdictions. Because coastal states under this regime of extended jurisdiction controlled access to a significant, if not a major, share of the world's tuna resources, their position regarding special recognition in sharing of the resources was strengthened. By 1978 the purse-seine fleet in the EPO increased to about 192 thousand cubic metres of carrying capacity, an increase of 500 percent over that of 1961. Pressure from all sides for increased catch limits and increased allocations was so great that agreement could not be reached on implementation of a catch quota, which resulted in overfishing the stock of yellowfin. As yellowfin abundance declined, much of the fleet left the EPO to fish in other ocean areas or remained in port because catch rates were so low that vessels could not meet operating expenses. (This transfer of the fleet to other regions had a serendipitous affect on tuna production, because at that time tuna stocks in other ocean areas were mostly underexploited, and the developments by this transferred fleet led to new tuna supplies. However, the situation has now changed; there are no new frontiers for tuna production). This situation continued, and fishing effort in the EPO remained low until the mid-1980s, by which time yellowfin abundance had increased to above AMSY levels and vessels began to return to the fishery. In 1985 purse-seine carrying capacity was 138 thousand cubic metres, and catch rates and profits were high. The size of the fleet was in balance with the ability of the yellowfin stock to sustain current levels of catch, and there was no need to place restrictions on the harvest. This situation attracted more vessels, and the fleet has continued to grow.

Recognizing that the pattern of fleet growth was repeating that of the 1970s, in 1987 the Director of the IATTC began calling for measures to limit the number of vessels entering the fishery, but such efforts were mostly unsuccessful. The purse-seine fleet continued to grow, and this larger fleet resulted in increased fishing effort on yellowfin, requiring conservation limitations to be implemented so the stock would not be overfished. It also resulted in substantial increases in the catch of small bigeye tuna, resulting in measures to limit the fishing effort on small bigeye taken by the surface fishery. Until 1999 none of the conservation measures that were implemented resulted in limiting or halting the growth of the fleet. In fact, it seemed that the mere introduction of the idea of limiting capacity stimulated fleet growth. Those without fleets or with small fleets wanted to establish a larger presence in the fishery before they were prevented from doing so by the introduction of capacity-limitation measures.

By the end of 1998 the purse-seine fishery for tunas in the EPO was probably the most regulated tuna fishery in the world, and possibly one of the most regulated of any fishery. There were limits on the catch of yellowfin tuna and small bigeye, limits on the amount of fishing for tunas in association with floating objects, quotas on how many dolphins could be taken in the fishery for tuna associated with dolphins, restrictions on types of gear and fishing practices, requirements to carry observers, requirements to contribute monetarily to the observer program, and a host of other regulations. It was clear that such "micromanagement" of the fishery would likely result in failure to sustain a conservation program and failure to fulfill the objective of maintaining the populations at AMSY levels. Consequently the governments with an interest in the fishery decided to work through the IATTC to implement measures to put a halt to the growth in fleet, and eventually reduce it to more manageable levels. After a year of negotiations among the members of the IATTC and other interested governments, the first measures to limit purse-seine fleet capacity in the EPO fishery were implemented in 1999. The resolution defining the capacity-limitation program assigned purse-seine carrying capacity limits to each of the 13 nations involved in the fishery. Not all of the 13 nations were members of the IATTC, but all participated in the negotiations to assign limits.

During the negotiations several factors were taken into account in assigning limits. The most important was the level of catches taken by each of the 13 nations during 1985-1998. Other factors that were considered were the levels of catch taken within the EEZs of the nations bordering the EPO, the landings of tunas from the EPO in each of the participating countries, and the contribution of each country to the conservation program of the IATTC. For those countries that were participating in the fishery during 1985-1998, the allocations of fleet capacity were approximately identical to the actual fleets operating during 1998. In the case of one coastal state that did not have a fleet, but which had a longstanding and significant interest in the tuna fishery of the EPO, a capacity limit that would allow that nation to acquire a tuna fleet was assigned. There were several other coastal states participating in the negotiations that did not have tuna fleets at the time, but insisted that the agreement provide the opportunity for them to acquire fleets; such provision was made, thereby assuring that capacity limits could be assigned to those coastal states. The total limit set by the resolution for purse-seine vessels in the EPO for 1999 was 158 thousand tonnes of carrying capacity. The staff of the IATTC noted that a carrying capacity of purse-seine vessels of about 130 thousand tonnes was adequate to harvest the current catches of tuna. The actual carrying capacity operating at the end of 1998 was 138 thousand tonnes. By the end of 1999 carrying capacity reached 158 thousand tonnes. It was clear that there was a rush to bring new capacity into the fishery before regulations prohibiting new entries could be enacted. Unfortunately, it was not possible for the nations to agree to extend the resolution in its original form beyond 1999, and the result was continued fleet growth.

Negotiations to seek a solution to the excess capacity problem continued. Nearly all nations with tuna purse-seine vessels under their flags, and nearly all tuna boat operators, agreed that there was excess capacity in the tuna fishery of the EPO, and that measures were needed to halt the growth in capacity, and to even reduce it. However, agreement to limit capacity could not be reached among the member governments of

IATTC, and capacity continued to grow. By the end of 2002, carrying capacity of the purse-seine fleet in the EPO reached 200 thousand cubic metres, the greatest in the history of the fishery.

In an effort to seek a solution to the problem, the IATTC established a working group to examine alternative means of limiting fishing capacity. Inspired by the FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas, and on recommendation of the working group, the Commission approved a resolution in 2000 to establish and maintain a record of vessels authorized by their governments to fish in the IATTC convention area for species under the purview of the Commission. The resolution also called for the IATTC to maintain an inventory of the pertinent characteristics, and features for vessel identification, for each vessel on the Regional Vessel Register (RVR), as called for in the FAO compliance agreement. Once the RVR was established the working group recommended that fleet capacity be restricted to those vessels on the RVR. In June 2002 the Commission approved the Resolution on the Capacity of the Tuna Fleet Operating in the Eastern Pacific Ocean. The Resolution 1) established the RVR as the definitive list of purse-seine vessels authorized by the participants to fish for tunas in the EPO, 2) noted that any purse-seine vessels fishing for tunas in the EPO that are not on the RVR would be considered to be undermining IATTC management measures, 3) indicated that only vessels flying the flags of participants could be entered on the RVR, 4) instructed that capacity would be measured as the volume of the fish wells, 5) prohibited the entry of vessels not included in the RVR to the purse-seine fleet operating in the EPO, except to replace vessels removed from the RVR, 6) made provision for five coastal states bordering the EPO to add vessels to the RVR with a total combined capacity not to exceed 20 thousand tonnes and 7) defined a participant as a member of the IATTC, and states, economic integration organizations and fishing entities that have applied for membership or that cooperate in the conservation programs of the Commission.

The concept encompassed in the RVR is that the capacity quotas are assigned to vessels, rather than to governments. The intent of this capacity limitation program is to fix the number of vessels that are authorized to fish in the EPO at current levels, although the special provisions for certain coastal states will allow it to grow by about 17 thousand tonnes. It is also the intent of the program to allow vessels on the list to be transferred to other flags, thereby allowing the flag to which the vessels transfers to increase its capacity by that of the transferred vessel, while requiring the flag from which the vessel was transferred to reduce its capacity by that amount. Although this provision for transfer is not abundantly clear in the Resolution, it was clarified in a document (IATTC, 2003b) presented by the Director of the IATTC: "The Secretariat's understanding of how the Resolution was intended to work with respect to transfers was to allow vessels on the Register to simply transfer flag from one participant to another. The participant the vessel was transferring from would not be able to replace the vessel, and there would be no restrictions on any participant being able to receive the transferring vessel".

With the implementation of the RVR, the IATTC has again taken the lead in attempting to introduce innovative and effective management measures for tunas. The RVR provides a mechanism for fixing the fleet of purse-seine vessels operating in the EPO at its current size, with an allowance for minimal expansion to fulfill the needs of several coastal states. An important feature of the arrangement is the provision for allowing vessels to transfer among the participants. Once a vessel is listed on the RVR it is authorized to fish in the convention waters. If a vessel is removed from the RVR by its flag state it can no longer fish in the area. As long as a vessel is on the RVR it can move from flag to flag. When a vessel transfers from the flag of one participant to that of another it stays on the RVR and its capacity "quota" is transferred with the vessel.

Similarly, if a vessel on the RVR is replaced, or its well capacity is increased, a vessel of equivalent size, or an amount of capacity equivalent to the increase in size, must be removed from the RVR. In a manner of speaking, the RVR creates a market for trading capacity. A vessel owner or a nation desirous of increasing its capacity can offer to purchase vessels listed on the RVR. When purchased, the vessel, which would remain on the RVR, along with its capacity quota, would go to the purchaser. Once the RVR was established through political negotiation, theoretically, any changes would result from market forces.

Since implementation of the RVR, the ownership of three vessels have transferred among participants. In each case the states from which the vessels had transferred expressed concern that they would not be able to replace the vessels that had been transferred. Obviously, if this feature of transferability were not retained in the RVR system, it would weaken considerably the effectiveness of the system. The result would be a limit on fleet size that was fixed among nations and could be not changed without difficult and time-consuming negotiations. The IATTC Permanent Working Group on Fleet Capacity will meet in the near future to discuss this issue, and hopefully it will be successful in convincing the participants to retain the transferability feature of the RVR.

3.1.3 The International Commission for the Conservation of Atlantic Tunas (ICCAT)

ICCAT is responsible for the conservation and management of tunas, billfishes and tuna-like fishes in the Atlantic Ocean and adjacent seas. Its first management measures were in the form of output controls, which were a minimum-size limit of 3.2 kg for yellowfin tuna in 1974, and a similar minimum-size limit for bigeye in 1980. The rationale for establishing the minimum size limit on yellowfin was to increase the yield per recruit, while the rationale for bigeye was primarily the fact that bigeye and yellowfin of less 3.2 kg are difficult to distinguish from one another.

Much of the concern over the status of the tuna stocks in the early years of ICCAT'S history was centered on bluefin tuna, which had been heavily exploited in the western Atlantic Ocean, resulting in declining catches. The first conservation measures adopted for bluefin were set in 1974, when a minimum size limit of 6.4 kg was established, and fleets were urged to reduce fishing mortality. Since that time more restrictions have been placed on bluefin, including closed areas and seasons and limits on catches. The catch in the western Atlantic has been set at less than 2.5 thousand tonnes over the last several years, and has been allocated to participants in the fishery. These bluefin regulations have had a potential impact on fishing capacity, in that allocating the catch among nations participating in the conservation program has provided an opportunity for those nations with allocations to limit the number of vessels authorized to fish under their flags. Not many participants have taken action to limit fleets, but the opportunity to do so exists.

Though swordfish is not one of the principal market species of tuna, the management measures taken by ICCAT for that species are pertinent to the discussions on managing tuna fishing capacity. In 1990 ICCAT expressed concern over the status of the swordfish stocks in the Atlantic, and recommended that fishing mortality should not exceed the levels of 1988. Management measures on swordfish were continued, and in 2003 quotas were set for both the northern and southern stocks and allocated among nations participating in the conservation program. Although no measures were taken for limiting capacity in the fishery, the fact that the allowable catches were allocated among participants provides an opportunity for the individual nations with allocations to limit the number and capacity of vessels operating under their allocations.

The first direct attempts to limit fishing capacity grew out of concern over the status of the northern albacore stock, which scientists estimated was being fished at unsustainable levels, and the stock of bigeye tuna, which was being harvested at increasingly earlier ages and in increasing amounts. In 1998 ICCAT approved a resolution calling on fishing nations to limit the sizes of their fleets fishing for northern albacore to 1993-1995 levels. During the same year ICCAT approved another resolution calling on nations to limit the numbers of their vessels greater than 24 metres in length fishing for bigeye tuna to 1991-1992 levels. Even though the limitations called for in the resolutions apply to the number of vessels, the numbers were to be coupled with a limitation on GRT so as to not increase total capacity. Subsequently a total allowable catch (TAC) of 34.5 thousand tonnes, allocated among the nations participating in the program, was set for northern albacore. Additional recommendations were made for bigeye, calling on participants to limit the catches made by their fleets in 2004 to the levels of their catches in 2001. Specific limitations on the catches and numbers of vessels that could operate in the bigeye fishery were placed on several, but not all, nations with fleets fishing for bigeye in the Atlantic Ocean. China was assigned a catch allocation of 5 thousand tonnes and a fleet limit of 60 vessels, the Taiwan Province of China 16.5 thousand tonnes and 125 vessels and the Philippines 2.1 thousand tonnes and 5 vessels. In order to have available information with which to monitor and ensure compliance with the resolutions, each participant was required to provide a list of vessels that operated under its flag in the northern albacore fishery in 1993-1995, and each year thereafter, and in the bigeye fishery in 1991-1992, and each year thereafter.

Both of the initiatives by ICCAT to address the problem of unsustainable exploitation of northern albacore and bigeye provided the basis for the nations participating in the fishery to manage these resources in an effective manner. By setting a TAC for each of these species, and allocating that TAC among the participants in the fishery, there is an opportunity for each nation to regulate the number of vessels authorized to fish under its country allocation. Unfortunately, hardly any of the participating nations with assigned country allocations have limited their fleets. The fleets can continue to grow, and as they grow their owners will tend to put pressure on their governments to negotiate for increasingly greater TACs and country allocations. Past experience has shown that this kind of behavior results in the failure of conservation controls.

The requirement for nations to limit the number of vessels operating in the fishery to prior levels will work only if the nations are willing to implement the controls necessary to limit the sizes of their fleets. In the reports of the ICCAT Conservation and Management Measures Compliance Committee (ICCAT, 2001) most of the participating nations did not provide the baseline data to establish fleet size in 1991-1992 and 1993-1995, nor did they subsequently provide annual vessel lists for those fleets. Thus, even though mechanisms are in place to limit fleet size, it is impossible to know if the requirements are being complied with currently, or how effective they will be in the future.

3.1.4 The Indian Ocean Tuna Commission (IOTC)

Although IOTC has a much shorter history than the IATTC or ICCAT, it has undertaken several measures that have had an impact on the problem of fishing capacity. The earliest efforts were a recognition by its members that fleet capacity in the Indian Ocean was likely to be in excess of what was needed to harvest the current catch, and that measures should be considered for limiting capacity. Accordingly, the Scientific Committee of IOTC was asked to make recommendations on the best estimate of the optimum capacity of the fishing fleet that would permit the sustainable exploitation of tropical tunas. Due to a lack of technical information at the time, the Committee was not able to make such recommendations. However, measures are being instituted to acquire the information necessary for the Scientific Committee to estimate the optimum capacity of the fishing fleet for the Indian Ocean tuna fishery.

In response to the FAO International Plan of Action to prevent, deter and eliminate illegal, unreported and unregulated fishing (IPOA-IUU), and in an effort to initiate the preliminary steps of limiting fishing capacity, the IOTC approved measures to establish and maintain a Record of Authorized Vessels (RAV) of greater than 24 metres in overall length authorized to fish in the Indian Ocean. Nations participating in the agreement can add or remove vessels to or from the RAV, so that the RAV itself does not limit the number of vessels authorized to fish. However, any vessel not on the list would be considered to be engaged in illegal, unregulated and unreported (IUU) fishing. Measures were also approved requesting the nations participating in the agreement to undertake certain actions, such as closing ports to and limiting imports from vessels involved in IUU fishing and not granting registration to vessels that had been involved in IUU fishing unless the ownership of the vessel had changed. These measures taken together would tend to reduce the number of vessels operating in the fishery because it would make it more difficult for an IUU vessel to operate profitably. However, the methods do not, in themselves, result in a reduction of the number of vessels authorized to fish in the Indian Ocean.

The IOTC took more direct action during its meetings in 2003 to initiate the process of limiting capacity. A resolution was approved that requires each nation with more than 50 vessels on the RAV to limit the number of its fishing vessels more than 24 metres in overall length to the number registered in the RAV in 2003. Although the resolution makes exceptions for some nations with fleets under development, and cautions that the measures taken could cause some nations to strive to bring their fleet capacities up to the 50-vessel guideline, resulting in an increase in capacity, approval of the resolution is a significant move in the right direction.

3.1.5 The Commission for the Conservation of Southern Bluefin Tuna (CCSBT)

The CCSBT is different from the other regional tuna bodies in that it is concerned with only one species, southern bluefin tuna, and in that its area of concern is wherever this species occurs. When the CCSBT was formed its three members, Australia, Japan and New Zealand, were the only nations fishing for southern bluefin on a significant scale. A TAC of 12 thousand tonnes was implemented, and allocated among the three members. This provided the opportunity for the three nations to place controls on their vessels fishing for bluefin under the country allocations. Japan placed restrictions on the number of longline vessels that could participate in harvesting the allocation. Australia implemented an individual transferable quota (ITQ) system in which its share of the overall quota was partitioned among various Australian fishing companies, mostly those involved in bluefin ranching. The companies control the number of vessels involved in harvesting Australia's share, and, because the industry seems to be limiting the number of vessels to reasonable levels, the Australian government has not considered it necessary to place overall limits on the number of vessels that can operate. Over the last few years the number of nations fishing for southern bluefin has increased. The Republic of Korea and Indonesia have joined the CCSBT, and the five members share a TAC of 14 thousand tonnes. An additional quota of 900 tonnes has been set aside for non-member states fishing for southern bluefin tuna.

In an attempt to stem the growing fleet size and increasing fishing pressure on southern bluefin, and in keeping with the intent of the IPOA-IUU, the CCSBT has taken action to create a record of vessels greater than 24 metres in length authorized to fish for southern bluefin tuna. The CCSBT considers any vessel that is not on the record and is fishing for southern bluefin to be engaged in IUU fishing. CCSBT members are urged to take certain actions against such IUU vessels in an attempt to correct the problem. The first action called for is to seek cooperation of the flag state of the IUU vessel in addressing the problem. If such approaches fail, then the members are urged to undertake more severe measures, including trade restrictions.

The impact of all these actions by CCSBT should serve to mitigate somewhat the problem of actual or potential excess capacity in the southern bluefin fishery. However, it is difficult to determine precisely how effective these measures are.

3.1.6 The western and central Pacific Ocean

The largest tuna fishery in the world takes place in the western Pacific Ocean. Nearly 50 percent of the world catches of the principal market species of tunas come from that area, and the single largest purse-seine fishery is prosecuted there. Not only is the fishery the largest in the world, but the characteristics of the fishery are quite different from tuna fisheries in most other ocean areas. Most notably, in the EPO slightly more than half the catch is made on the high seas. In the western and central Pacific less than 20 percent of the catch is made on the high seas, so the coastal and island states control access to almost all of the catch in the region. This potentially has a large impact on how management arrangements can and will be formulated. Nevertheless, the tuna resources are highly migratory, and the principles defined in Article 64 of LOSC and the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks ("the UN Fish Stock Agreement") apply with respect to cooperation among nations and management requirements that apply throughout the migratory range of the species. An Article 64-type regional tuna body for the western and central Pacific Ocean, the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean (Western and Central Pacific Fisheries Convention, WCPFC), has recently been established. This convention, which mandates the establishment of an Article 64-type regional tuna body for the western and central Pacific, has been signed and ratified; it entered into effect on 19 June 2004, and an inaugural session of the commission will be held on 6 December 2004. Although the new organization has not yet begun its formal work, the convention is responsive to the need for controlling fleet size when necessary. Article 5(a) of the convention states that the new Commission shall "take measures to prevent or eliminate … excess fishing capacity", Article 10(g) states that the Commission shall develop "criteria for the allocation of the total allowable catch or the total level of fishing effort", and Article 10, 2(c) states that the Commission may adopt measures for "limitations of fishing capacity". During one of the planning sessions for the establishment of the new commission the governments represented at the meeting agreed that "all States and other entities concerned to exercise reasonable restraint in respect of any regional expansion of fishing effort and capacity". It is clear that the new convention provides the legal authority for the organization to deal with the problem of excess fishing capacity, but how that will be dealt with is not yet formulated. However, there are currently several organizations and political arrangements that are working to develop measures to address the problem of fishing capacity in the western and central Pacific region.

The Forum Fisheries Agency (FFA) was created in 1979 by the 16 member countries of the South Pacific Forum to help them manage and develop their living marine resources, particularly the stocks of tunas inhabiting the western and central Pacific Ocean. Much of the activity of the FFA was directed toward assisting the 16 countries to develop access arrangements with distant-water fishing nations (DWFNs), and developing monitoring and enforcement capabilities. The FFA maintains a register of vessels that are eligible to apply for access licences for fishing in the EEZs of FFA members. Any vessel that has been found to be engaged in IUU fishing with respect to the EEZ of any FFA member country is blacklisted, and cannot obtain an access agreement. This move has tended to reduce IUU fishing and associated excess capacity.

The Palau Arrangement for the western and central Pacific purse-seine fishery, which was concluded in 1992, has the objective of limiting the level of purse-seine fishing in the region. The Arrangement provides for an overall limit of 205 purse-seine vessels that will be licensed by the parties for fishing in their waters. Of the 16 FFA members, eight are members of the Palau Arrangement. The majority of the catch of tunas from the area is taken in the waters of these eight members.

The countries that are members of the Palau Arrangement are in the process of examining a long-term management system based on national limits on the numbers of allowable purse-seine days fished. The Ocean Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC), along with the FFA, will provide technical information and advice to the Palau Arrangement countries in order to assist them in developing the management system. The system being discussed contemplates setting a total number of allowable fishing days for the combined EEZs of the parties to the Arrangement. It appears that this level of allowable effort will be set to ensure sustainable harvests of the stocks of tunas inhabiting the area. It also appears that the total allowable number of fishing days will be allocated among the coastal states that are parties to the Arrangement. It is likely that these allocations will be made in proportion to the abundance of the resource in the respective EEZs and/or the levels of harvest made in those zones. Each country will then be able to license vessels to utilize the fishing days allocated to its EEZ. At this juncture in the discussions of the proposed system there is no information available as to whether the number of vessels that can purchase licences to fish in the respective EEZs will be limited. However, the Palau Arrangement members have agreed to a combined limit of 205 vessels for all of the Palau Arrangement members. It should be kept in mind that the limit is expressed in numbers of vessels, rather than in capacity. It is possible that smaller vessels would be replaced with larger ones, resulting in an increase in fishing capacity. As scientists of the OFP have made abundantly clear, the efficiencies of various sizes and types of fishing vessels can vary considerably, so some means of standardizing the fishing effort, possibly in number of "standard" days, will be necessary. It will also be necessary to monitor efficiency changes over time because of "capital stuffing", since as soon as restrictions are adopted vessels owners will try to compensate for these by increasing the efficiencies of their vessels. If the parties to the Arrangement balance the number of vessels, taking into account the efficiencies of the vessels that they license and the number of fishing days allocated to each, any excess capacity problems would be ameliorated. However, there would have to be close cooperation among the countries in establishing this balance, as vessels may seek to purchase licences for more than one EEZ since tunas are migratory, and aren't always available in the same EEZs. The matter of subsidized vessels would also have to be considered in any system that might be developed if that system is to be effective. A vessel with subsidies would be able to fish at lower levels of catch and economic return than an unsubsidized vessel, which would tend to result in more vessels seeking licences than if there were no subsidies. Also, the area of the western and central Pacific that lies outside of any EEZ would have to be considered in any scheme for controlling fishing effort and capacity. Once the new commission is operating it will deal with the issue of controls on the high seas, but there will have to be coordination with what the coastal states are doing by way of licensing within their EEZs.

This system being considered by the Palau Arrangement countries is unique and innovative, and it holds great potential for ameliorating the capacity problem. However, the problem of excess capacity could be dealt with more directly and effectively if vessel limits were included in the allocations of total allowable fishing days. Additionally, there must be limitation of vessels other than purse seiners, particularly longline and pole-and-line vessels, which account for about 30 percent of the catch of tunas from the region. Although there are far more longline vessels than purse seiners operating in the western and central Pacific (Miyake, this collection), the same mechanisms for controlling the capacity of purse seiners can be applied to longliners.

3.2 Industry arrangements

In response to decreasing catch rates in the world longline fishery and declining ex-vessel prices in the global purse-seine fishery there have been two industry organizations created over the last few years that deal with the issue of fishing capacities of longline and purse-seine vessels.

3.2.1 The world longline fleet and the Organization for the Promotion of Responsible Tuna Fishing (OPRT)

Two major factors have impacted the profitability of the longline industry. One is the high demand and high value placed on tunas and billfishes in the *sashimi* market, which has caused the number of longline vessels to increase and the catch per vessel to decline. The other is the development of fish-aggregating devices (FADs), which have increased the catches of small bigeye and yellowfin. The increased catches of small bigeye have decreased the recruitment of large bigeye to the longline fishery, resulting in declining catches of this species. As bigeye are the primary target of the longline fishery, this situation has caused a great deal of concern for the industry. Because of this concern, and in keeping with the IPOA-CAPACITY, the Japanese longline industry has undertaken action to reduce the size of its large-scale, ultra-deep-freezing, tuna longline fleet by approximately 20 percent. Because there are large longline fleets fishing under the flags of several other nations, the Japanese industry has undertaken measures to enlist the cooperation of many of those fleets in an overall program to reduce fishing capacity of the world's longline fleet. Japan has targeted 130 vessels for removal from its fleet, and the Taiwan Province of China has agreed to limit its fleet to 600 vessels. The Taiwan Province of China will require that Taiwainese-owned vessels under flags of convenience be transferred to its registry. To stay within its 600-vessel limit, some of the recalled vessels will be "bought back" and scrapped, as will the 130 Japanese vessels. The scheme has a good chance to succeed because Japan is the primary market for *sashimi* fish, and the Japanese government has undertaken to prohibit the importation of tuna from vessels that might, by their actions, diminish the effectiveness of programs to conserve and manage tuna resources, including the efforts to control fishing capacity. Thus a vessel that ignored these restrictions would find it difficult to fish profitably.

The OPRT was originally established between the Federation of Japan Tuna Fisheries Cooperative Association, which represents all Japanese high-seas longline vessels, and a similar industry organization representing the Taiwanese longline fleet. Its objectives are to track tuna coming into the Japanese market to ensure that it is from cooperating nations, to monitor the removal and scrapping of vessels, and to assist in the reimbursement of Japanese and Taiwanese fishermen for the costs of removing their vessels from the fleet. Since the founding of OPRT, longline fleets of Indonesia, the Republic of Korea, the People's Republic of China and the Philippines have joined it. So far about 43 Japanese and Taiwanese flag of convenience (FOC) longline vessels have been bought back and scrapped by the Japanese and Taiwanese longline industries. Moneys were loaned to the industry groups by the Japanese government on a 20-year pay-back schedule.

This Japanese initiative to reduce the number of large-scale tuna longline vessels can be a useful means of controlling excess fishing capacity and contributing to better conservation of the tuna resources important to the longline fishery. However, two other important factors must be considered. First, there must be effective measures to resolve the excess capacity problem in the surface fisheries, which, because of increasingly greater catches of small bigeye, are having a serious impact on the abundance of large bigeye available to the longline fleets. Second, there are growing fleets of small and medium-sized longline vessels that fish mostly in inshore regions, particularly in many developing coastal states. These fleets are taking increasingly greater quantities of tunas, so there will be an increasing need to include these fleets in any programs to limit capacity in the world longline fleet. Until these problems are dealt with, there cannot be effective tuna management.

3.2.2 The World Tuna Purse-seine Organization (WTPO)

The number of large purse-seine vessels has been steadily increasing over the last several decades, and now comprises about 570 vessels with a total carrying capacity of nearly 600 thousand tonnes. Additionally, the individual vessels have increased their efficiency in catching tunas. This increase in fishing power has been the result of many factors, including better vessel design, the use of sophisticated electronic equipment, and the development of FADs. With this tremendous potential to catch fish, particularly when skipjack are abundant, catches increase sharply. These increases in production tend to outstrip demand, causing ex-vessel prices to decline. Conversely, when skipjack abundance is average or below average, there is more purse-seine capacity than needed to take the available fish. Since 1998 there have been abundant supplies of skipjack, and the catches have exceeded the demand, resulting in prices at the lowest levels observed over the last several decades. This has caused serious economic problems in the purse-seine industry and stimulated efforts by the vessel owners to do something to bring supply into balance with demand. In 1999 several industry organizations representing purse-seine vessels formed the World Tuna Purse-seine Organization (WTPO) to address this problem. The WTPO has attempted to treat the problem of overproduction in two ways. First, the members have agreed to reduce the level of fishing effort by requiring vessels to spend more time in port between trips. The target scheduled was for vessels of less than 1300 tonnes, 1300 to 1700 tonnes and more than 1700 tonnes of carrying capacity to spend a minimum of eight, nine or ten days in port, respectively, between trips. Second, the members have called for a limit on fleet growth. Industry organizations representing purse-seine vessels from about ten countries now belong to the WTPO, but there are several large fleets that are not members.

Although many vessels have followed the recommendations of the WTPO regarding the length of time between trips, many others have not; so it is difficult to tell whether this has had an impact on price. It has not had an impact on excess capacity, as new purse-seine vessels continue to enter the fishery. Regarding limiting capacity, the organization has called for the establishment of a world purse-seine and longline vessel register, which would include only vessels authorized by their governments. New vessels could enter the register only as replacements for vessels of an equal size removed from the register. So far, such a world register has not been implemented. Nevertheless, industry initiatives provide a number of possibilities for addressing the problems created by excess capacity in the world tuna fleet, some of which are discussed by Joseph (2003).

4. OPTIONS FOR MANAGING TUNA FISHING CAPACITY

Taken as a whole, the various methods and initiatives by governments, international organizations and the private sector, have failed to halt the growth of tuna fleets on a global scale. Some of the output controls that have been implemented, such as catch limits, have served to prevent further overfishing of the tuna stocks, but unless the growth in tuna fishing fleets is curtailed, and some fleets reduced, the management measures that have so far been instituted will be placed in jeopardy, and the possibility of further subsidies to compensate for reduced catches will increase.

As has been pointed out in the IPOA-CAPACITY, and corroborated by the regional tuna bodies, there is an urgent need to get on with the task of limiting tuna fishing capacity. There are numerous legal and economic constraints that must be addressed if effective capacity limitation is to become a reality. In the following section several options for dealing with the capacity problem, and some of the constraints that must be overcome, will be presented.

4.1 General considerations with respect to controlling capacity

Most of the major issues of a technical and policy nature have been extensively reviewed by Gréboval and Munro (1999), Kirkley and Squires (1999), Newton (1999) and Cunningham and Gréboval (2001), and in this section only the highlights of issues discussed by them will be mentioned; the reader is referred to these documents for more detail.

The concept of open access has been the major cause leading to excess capacity in most fisheries. Historically, every individual has considered it to be an inalienable right to fish. Most of the world's commercially-important fish stocks are either fully exploited or overfished. Increases in fishing mortality must be halted, and in many cases fishing mortality must be reduced. The idea of open access to fish stocks must be re-thought, and, in fact, a change is underway. The concept of common property and open access has been rapidly eroding with respect to species that spend their lives inside the EEZs of single states. The assignment of property rights to fishers is becoming more commonplace in many coastal states. There is a broad body of national experience dealing with non-fisheries issues that can be useful in supporting the concept of assigning property rights with respect to stocks of fish found in an EEZ. For example, in nearly every country there is a limit on the number of taxis that can be licensed to operate in a city. A person who wants to own and operate a taxi must be authorized to do so by his government, and most often must purchase a licence from someone already in the business who is willing to leave it. In the state of California one cannot open a liquor store or bar without a liquor licence, and the number of licences is controlled by the state. The cost of liquor licences in California is high, and climbing. Similar limited-entry concepts are being increasingly applied in a variety of forms to many fisheries. Notable among these is the assignment of Individual Transferable Quotas (ITQs) in a number of coastal fisheries. In such cases, the allowable catch from a resource is allocated to a defined group of users, individuals and/or companies, with the right to transfer their shares to others. In general, these schemes have met with success, but there are problems (Batstone and Sharp, 1999; Cunningham and Gréboval, 2001) that can arise, such as how many ITQs an individual or a company can hold and provisions for subsistence and recreational fisheries and the traditional rights of indigenous peoples.

With respect to high-seas fisheries, and exploitation of highly-migratory fishes, such as the tunas, which spend part of their lives on the high seas and part in the coastal zones of various countries, the assignment of property rights is more complicated and difficult to achieve because the resources of the high seas have traditionally been considered to belong to whomever can catch them. Nevertheless, solutions are not impossible.

Article 116 of the LOSC provides the right to nationals of all states to fish on the high seas. Even though Article 116 goes on to say that this right is subject to a state's treaty obligations and to the provisions of Article 64, it nevertheless connotes the "idea" that the option is open to a state to freely enter into tuna fisheries on the high seas and, if applicable, in their own EEZs. Again, because most of the world's stocks of tuna are fully exploited, and some even overexploited, it is unrealistic to think that every state can enjoy open access to tuna fisheries. It will be necessary for states to work together to develop systems for controlling fishing effort and the size of fleets that exert that effort. In fact, there is ample legal basis for the obligation of states to cooperate. Article 118 of the LOSC mandates that states cooperate with each other in the conservation and management of living resources on the high seas, and in other areas where states harvest the same resource, i.e. inside an EEZ in which a state harvests a resource that entered from the high seas. Additionally, the FAO Code of Conduct for Responsible Fisheries and the UN Fish Stock Agreement state that the right to fish carries with it the responsibility to do so in a responsible manner, and calls on states to prevent overfishing and excess fishing capacity, and, if excess capacity exists, to undertake measures to reduce capacity to levels in keeping with the sustainable use of the resource. To carry out their mandate to conserve and manage tuna resources, many states have cooperated toward this end by working within the regional tuna bodies. Most of the early efforts at management were the implementation of output controls, specifically catch quotas and minimum-size limits. In some cases, but not all, these output controls, especially catch quotas, have prevented overexploitation. Fleets have increased as they raced to take greater shares of the quotas, and conservation controls have weakened as a result of pressure to increase catches. The problems of overfishing are generally the result of too much fishing mortality being generated by too many vessels. Fleet capacity needs to be brought into balance with the ability of the stocks of tuna to sustain certain levels of catch. Some form of property rights must be established to accomplish effective capacity controls in tuna fisheries. How to establish property rights, and how to distribute them among users in an international fishery, is a major problem because every user believes that it has a right to an equal share, and each sovereign coastal state controls access to a share of the harvest. This problem was recognized 25 years ago by Joseph and Greenough (1978) when they noted that disputes over how to allocate among users could intensify to the point where they become so dominant in everyone's mind that finding solutions to other important problems becomes impossible. More recently Clark and Munro (2002) have concluded that, unless some method of resolving the common-property problem is applied, limited success in capacity reduction will be likely over the long run. Regardless of these dire warnings, there has been progress made in allocating catches among participants. As noted in Section 3.1.3, ICCAT has allocated catches of bluefin, bigeye and swordfish among the nations harvesting these species in the Atlantic Ocean. The IATTC has initiated a Vessel Register (Section 3.1.2), which, in a way, allocates the fleet authorized to fish in the EPO among the nations currently participating in the fishery. Once the fleet is allocated, the corresponding catches are *de facto* allocated in the same general proportions. The process of allocation is negotiated among the participants. A series of criteria that can be used in making the allocations must be established. The regional tuna bodies have attempted to define such criteria (Joseph, 2003), but the two most important ones that are integral to nearly all of the negotiations are the historical catches taken by the nations with vessels in the fishery, and the proportions of the catch or the abundance of the resource in the EEZs of the coastal states of the region.

It is apparent in Section 2 that for all of the major tuna fisheries there is more fishing capacity than is needed to take the current harvests. The resolution of this excess capacity problem is a two-step process: halting the growth in tuna fleet capacity, and reducing the sizes of the current tuna fleets. The regional tuna bodies have begun the process of halting fleet growth, but, with the exception of the work of the OPRT, there is little being done about reducing capacity. The IPOA-CAPACITY is very clear on the obligation of nations and international organizations to reduce excess fishing capacity. One approach to reducing capacity is the introduction of incentive-adjusting measures (Cunningham and Gréboval, 2001), which attempt to remove the incentive of fishers to expand harvesting capacity. Measures such as ITQs and the imposition of taxes or resource-rental fees on the opportunity to fish tend to take away the incentive to build more vessels. If the tax is set high enough, and in proportion to the price of fish, then, barring any subsidies, there would be no incentive to acquire excess capacity.

Alternatively, rather than using self-regulating measures to reduce capacity, a more direct approach, which has been used in other fisheries, would be a mechanism to remove vessels from the fishery and compensate the owners of those vessels for their removal. The success of "buy-back" schemes to reduce fishing capacity has been mixed. Holland, Gudmundsson and Gates (1999) and Clark and Munro (2003) have identified several potential problems that can occur with buy-back schemes: 1) Unless a vessel that is bought-back is scrapped or converted to some other use, such as a research vessel or a supply vessel for offshore oil rigs, it is possible that it could move to another fishery and create excess capacity problems in that fishery; theoretically a vessel could be bought-back several times as it moves from fishery to fishery. The OPRT has addressed this problem by requiring that any longline vessel removed from the fishery through a buy-back be scrapped. Such a policy is critical to the success of buy-back schemes. 2) There is generally a tendency for the owners of less efficient vessels to offer them up for buy-back. If most of the buy-backs are inefficient vessels, the reduction in vessel capacity may be ineffective in reducing fishing mortality. 3) The opportunity to have vessels bought-back could motivate the construction of new, more efficient vessels in anticipation of having the less efficient vessels bought back. A limit on vessel capacity in the fishery could block this motivation. 4) Capacity growth of those vessels remaining in the fishery could negate any reductions in capacity. Therefore, monitoring efficiency changes of the vessels remaining in the fishery would be essential to the success of the program, because increases in the fishing powers of the individual vessels could result in the reduced fleet size being capable of exerting the same level of fishing mortality as before the reduction.

A final consideration is that nearly all tuna fisheries, with the possible exception of the troll fishery for albacore, fish for more than one species at the same time. Multi-species fisheries can create problems if one species is overfished or fully exploited, while another is underfished. This is the case for many tuna fisheries. Yellowfin and bigeye are fully exploited, or, in some cases, overexploited, while in many areas skipjack could sustain greater catches (Joseph, 2003). If only skipjack were considered in management of the fishery, yellowfin and/or bigeye would probably be overfished. If only yellowfin and/or bigeye were considered in management of the fishery skipjack would probably be underfished.

4.2 Open-access and common-property approaches

4.2.1 Maintaining the status quo

Most of the management measures for tunas have been in the form of output controls, which are concerned with the results of fishing, such as catch quotas and minimum-size limits, or input controls, which are concerned with the manner in which fishing operates, such as closed areas and seasons. Some of these output controls call on nations to restrict the harvest of certain species to levels experienced in earlier years, or to not capture individuals of designated species less than a certain minimum size. In most cases, such controls have met with limited success, as the total catches and/or the numbers of undersized fish caught have not declined. Most of the input controls have involved the establishment of closed seasons, particularly to fishing with FADs during certain months, and closed areas, such as for bluefin tuna in the Gulf of Mexico.

Although these measures represent attempts to keep levels of catch in balance with the ability of the resource to sustain those levels, they do not remove the incentive for fishers to increase capacity. In fact, these measures often work in the opposite direction in that they stimulate a race to harvest the available catch, which tends to increase capacity. As fishing mortality increases through fleet growth and increasing efficiency, more regulations are needed to prevent overfishing. As more regulations are imposed the fleets continue to grow. If economic profitability decreases, the governments may subsidize their fleets, which exacerbates the problem. Under the current system used to manage tuna fisheries, the cycle is likely to continue until there is either an economic or biological collapse of the fishery.

The regional tuna bodies realize that catch quotas and closed seasons and areas alone will likely not result in long-term solutions to the threat of overfishing. These bodies also recognize the need to undertake measures to control the sizes of the fleets harvesting tuna so that micro-management of the resource by the introduction of progressively more controls on how a fleet can operate is not necessary; consequently they have all expressed the need to implement measures to limit fishing capacity. As pointed out previously, most of the measures that have been introduced to limit fleet sizes to earlier levels have apparently not worked. Based on experience to date, it seems unlikely that the tuna fisheries can be managed by the implementation of TACs, minimum size controls, and closed areas and seasons, without addressing the excess capacity problem, so maintaining the status quo does not appear to be a good option for the future.

4.2.2 The World Wildlife Fund approach for limiting full use of existing capacity

In a recent study for the World Wildlife Fund (WWF), several options for reducing excess fishing capacity in the tuna purse-seine fleets have been suggested (Oliver, 2002). The options involved implementation of measures to restrict full utilization of existing capacity.

One category of options proposes various ways of closing off a proportion of each vessel's fish storage wells in order to reduce the overall capacity to a desired level. The example given is for the purse-seine fleet of the EPO, which currently has a capacity of 208 thousand cubic metres of well space. The target 2005 capacity for the fleet is 158 thousand cubic metres of well space. The reasoning behind this option is that by reducing the capacity of the fleet by closing off well space, the target capacity of 158 thousand cubic metres could be reached, and, as a result, the amount of time spent fishing would be reduced because more time would be spent in traveling to and from port. The author points out several shortcomings to this approach, but considers that, coupled with catch quotas, it would serve to protect the fish from overexploitation. However, the vessel operators might spend less time in port in order to make up for the reduced fishing time. From an economic point of view, the capital costs would not change, variable costs would increase, and overall profitability would decrease. It is possible that if profitability decreased sufficiently it would force some vessels out of the fishery, resulting in decreases in "true" capacity. It is, however, equally likely that as profitability decreased the fishing industry would pressure their governments to relax the conservation controls, which might cancel out the benefits of reduced fishing capacity.

The other category of options presented in the WWF study would place limits on the number of days a vessel would be allowed to fish, or require vessels to remain in port for minimum periods of time (as stated previously, the WTPO has already adopted requirements that purse-seine vessels remain in port for minimum periods between trips). Neither of these methods would alter the composition of the fleet, but would merely restrict its full utilization. These approaches would reduce the fishing mortality, but would not address the problem of excess capacity. There would continue to be capital wasted, and there would be pressure on governments to ease conservation controls, thereby placing the resources at peril.

4.3 Limited-entry and rights-based approaches

4.3.1 The IATTC model for a Regional Vessel Register

The IATTC's Regional Vessel Register (RVR) is a list of purse-seine vessels authorized to fish for tunas in the EPO. Vessels on the list can be transferred among nations participating in the RVR program, and vessels that leave the fishery can be replaced by other vessels of equivalent size.

The IATTC model, with some modifications, offers a potentially effective option for managing tuna fleet capacity. This approach considers that the capacities representing different flags do not really imply “property rights” for those flags, but rather signify a right for the vessel to fish. Any vessel on the list would be able to transfer its flag to any other participating nation, and its capacity quota would follow it to that new flag, but be lost to the flag from which it transferred.

The establishment of such a register, in essence, creates a limited-entry program and the right of access. The access right would be incomplete, because exclusive rights to the catch are not established in comparison to an individual quota (Townsend, 1990).

4.3.1.1 Establishing the register

When the WCPFC becomes operational there will be a regional tuna body for every major ocean area: the Atlantic and adjacent seas, the Indian Ocean, the EPO, the WCPO, and the extent of the distribution of southern bluefin tuna. A single global register could be established, but mechanisms would have to be built into the system to control the movement of vessels from one region to another as seasonal abundance and fishing conditions change; otherwise excess capacity could develop in some areas. A more functional approach would be for each regional body to establish a register of vessels authorized to fish in the waters for which it has management responsibility, which would eliminate the possibility of excess capacity in any region (provided the register for that region does not authorize excess capacity). If a vessel wished to fish in two regions, it would need to be entered in the registers for both of the regions. The two regional tuna bodies maintaining the respective registers would need to coordinate their activities regarding the vessel(s) in question, and take into account, when calculating the overall capacity limit, the fact that the vessel(s) would be fishing only part of the time in each of the regions.

The first objective of establishing the register would be, essentially, to place a moratorium on fleet growth. Each nation with vessels whose owners would like to fish in the region would be required to submit a list of such vessels. To qualify to be entered on the register a vessel would have to be considered to be actively fishing. The term actively fishing would need to be defined, e.g. an active vessel might be one that has fished in the region during at least 6 out of the previous 18 months. To stay on the register a vessel would have to continue to be active, according to the same or a similar definition. Establishing such a requirement would prevent vessels that had not been fishing from unduly adding to excess capacity. Also, it would prevent a flood of vessels entering a region as soon as the intention to limit capacity became public knowledge.

There will be a tendency for states to want to negotiate among themselves to allocate the total capacity of the extant fleet among participants, with those nations with small fleets, particularly developing coastal states, wanting guaranteed shares that they can grow into, and states with large fleets wanting to keep what they have. An important feature of this vessel register scheme is that the capacities belong to vessels, rather than to nations. When a vessel changes its registry from Nation A to Nation B, the total capacity of the vessels of Nation A is reduced, and that of Nation B is increased. Under this scheme, there will be opportunity for states desiring fleets to acquire them. These possibilities will be discussed in the following sections.

4.3.1.2 Vessel transfers

Two types of vessel transfers are envisioned in this proposed option. A vessel owner can transfer to another flag while retaining ownership of the vessel, or an owner can sell the vessel to a different owner who will register the vessel under a different flag. In either case the capacity quota would go with the vessel to the new flag and be removed from the old flag. The concept that the capacity follows the vessels will likely be raised as a problem by states that may potentially lose capacity due to transfers. In fact, however, the capacity can be retained or even increased, depending on the states’ willingness to make it attractive for vessels to stay under their flag or to transfer from other flags. There would be an incentive for vessels to choose the flags of nations providing advantageous operating conditions, such as favorable port facilities, tax incentives, lower fuel costs, marketing advantages, etc. In essence, the market would determine which vessels stay under which flag. If a nation had a national policy to acquire a tuna fleet it could structure its conditions of flagging in such a way as to attract vessels.

As stated above, it is envisioned that each regional body would establish a vessel register. Since each regional body has indicated that there is sufficient or excess capacity in its region, and since this is corroborated by the DEA studies reviewed in Section 2 of this report, there would be little opportunity for vessels to transfer from region to region (the regional body for the WCPO is not yet operational, but a study by Reid *et al.* (this collection) indicates that there is already excess capacity in the WCPO, and during the preparatory conferences the nations agreed that increases in capacity should not be allowed). Transfers from one region to another could take place only if vessel capacity was removed from the region to which a vessel wished to transfer by sinking, scrapping or converting to some other use, or special arrangements were formulated among regional tuna bodies to allow designated vessels to move seasonally among areas.

4.3.1.3 Vessel replacement

The opportunity to replace old vessels with new ones is necessary to ensure an efficient fleet and a viable fishery. In the vessel register scheme to limit fishing capacity being discussed here, any replacement of a vessel would be permitted only if a vessel of equal or greater capacity was removed from the register. If a replacement vessel is of greater capacity than the vessel being removed, then additional capacity would have to be removed from the register; for example two 1000-tonne capacity vessels could be removed and replaced by a single 2000-tonne capacity vessel. It is likely, however, that any newly-entering replacement vessel would have a greater fishing power than the vessel being removed, so adjustments to the total fleet capacity would have to be made to account for increases in fishing power. This idea will be discussed further in the following paragraphs.

4.3.1.4 Reducing excess capacity through buy-backs

The information reviewed in Section 2 of this report shows clearly that there is more fishing capacity in the purse-seine and longline fleets operating in each major ocean region than is needed to take the current levels of harvest. If the fleets operated more efficiently, capacity could be reduced substantially without causing reductions in the catches. The problem is to identify a means of reducing capacity that is equitable, possible to administer and effective in reducing fishing mortality.

One means often suggested for reducing fishing capacity is to allow attrition to take its toll of vessels. When a vessel sank or became unserviceable it would not be replaced. There are many purse-seine vessels that are more than 40 years old, and still operating effectively. If owners were not allowed to replace their ageing vessels they would make whatever repairs were necessary to keep their vessels in service. They might even make extensive renovations that would increase the fishing powers of their vessels. Reduction of capacity through attrition would take decades to achieve, and would not be an effective means for addressing the current critical excess capacity problem.

Buy-backs offer a more direct approach to reducing fishing capacity. Tuna vessels are bought and sold on a regular basis. The market price depends on demand, which, in turn correlates closely with the price paid for fish, which affects vessel profitability. Under the vessel register scheme, which allows transfer of vessels among participants, there will be a continuing demand and an international market for tuna vessels. The respective management authorities could enter this market to purchase vessels to remove them from the fishery. There are several potential problems that have been identified in the paragraphs above that can influence this market and the success of any buy-back program. The problems however, are tractable, and solutions are available. As has been mentioned already, an essential requirement for the success of any buy-back program is that any vessel that is bought back is scrapped or converted to some other use, which would ensure that the vessel would not return to the fleet at a later date, or move to another fishery, creating an excess capacity problem there.

Funding these buy-backs can have a direct influence on the success of any buy-back program. If left entirely in the hands of governments, including the cost of the buy-back program, it would constitute a major subsidy to the fishing industry. The result would be that those vessels remaining in the fishery would be able to fish more profitably than if there had been no buybacks, because the TACs would be shared by fewer vessels. Also, the motivation of fishers to have the program succeed would diminish. If left entirely in the hands of fishers, the vessels would have to operate on an economically-efficient basis, and the interests of the fishers and their motivation to succeed would be greater. This has apparently been the experience with some buy-back programs in other fisheries. In fact, the government of Australia is leaving the issue of buy-backs in its fisheries in the hands of the fishing industry.

It is suggested that the vessel register scheme proposed here include a provision for buy-backs. To fund the buy-back program, an assessment or tax could be applied to each vessel on the register. Since the analyses presented earlier show that there should be reductions in the purse-seine and longline fleets for each of the major fishing regions, the assessment or tax would be applied to all purse-seine and longline vessels included in the register of each area. The assessments and development of a pool of buy-back funds would be region- and gear-specific. The amount of the assessment would be determined through economic analyses, which would be updated periodically as conditions in the fishery change. It would be expected that the catches of vessels that remained in the fishery would increase as other vessels were removed from it, so profitability would change. The tax or assessment could be based on the catches, so that the larger producers would pay more. Alternatively, all or part of the tax or assessment could be applied to the processed product, since the processors would reap the benefits of a well-managed fishery. These changes would have to be incorporated into the analyses used to determine the levels of contribution.

Determination of the level of assessments is beyond the scope of this report. In a recent study, the U.S. National Marine Fisheries Service (NMFS, 2002a and 2002b) suggested the use of a “rule-of-thumb” approach based on setting the price for a vessel equal to one year of gross revenue generated in the fishery. However, for international tuna fisheries in which abundances of the target species fluctuate widely from year to year, and the successes of the vessels vary widely, this rule of thumb may not be a good indicator of the true value of a vessel. Additionally, information on gross revenues is usually not available. There is more publicly-available information for the purse-seine fishery of the EPO than for any of the other fisheries, so data for this fishery are used to illustrate the magnitude of the costs that might be involved in a buy-back scheme. There are currently 227 purse-seine vessels listed on the IATTC register, with a total carrying capacity of approximately 208 thousand cubic metres. There is an option in the vessel register program for four coastal states to add an additional 20 thousand cubic metres of capacity. If the options were exercised, the total capacity would be 228 thousand cubic metres. The long-term target capacity for the program is 158 thousand cubic metres. To attain this target, assuming none of the options for the coastal states are exercised, there would have to be a reduction of 50 thousand cubic metres, or 24 percent of the current capacity. Since the average size of a vessel in the fleet is about 900 cubic metres, about 55 vessels would have to be bought-back in order to reach the target fleet size of 158 thousand cubic metres. At an assumed price for a used 900- cubic metres vessel of between \$3 000 000 and \$4 000 000, the total cost for the 55 vessels would be in the neighborhood of \$200 000 000. If an objective was set to make the 55 buy-backs within a 10-year period, the annual cost would be about \$20 000 000. If financed entirely by the industry, each vessel would have to contribute about \$100 000 per year. Whether the vessels could afford that amount, given the current overcapacity, prices of tuna and operating costs, would have to be determined by the suggested economic studies. At the outset it might be necessary to have joint contributions from industry and government, or at least to have low-interest government loans to the industry, for carrying forward the program. As the fleet was reduced toward the target size, the average catch per vessel would increase, thereby increasing earnings, so the industry would be better able to maintain the buy-back program needed to account for capacity growth resulting from increasing efficiency, without government help. The government contributions made during the early years of the buy-back program would be a subsidy. Though government subsidies can contribute to the excess capacity problem and lead to inefficiency Milazzo (1996 and 1998), in this case the subsidy could be considered a "good" subsidy, since it would be for a fixed term, and the end result would be a fleet capacity in balance with the ability of the resource to sustain catches at current levels (Clark, Munro and Sumaila, 2003).

Used in conjunction with a vessel register program to limit capacity, buy-backs offer an effective option for reducing capacity to target levels. In fact, this is the approach the OPRT has taken to reducing longline capacity. The organization has already removed a number of vessels from the world longline fleet. The longline industry has administered the program and provided the money for the buy-backs (with loans provided by the Japanese government). The experience in the longline fishery can provide useful information for the development of a program for the purse-seine industry.

4.3.1.5 Further considerations of vessel register programs to limit and reduce capacity

Vessel register programs, as outlined above, apply to high-seas longline and purse-seine fleets. These fleets account for about 75 percent of the world catch of the principal market species of tunas. Pole-and-line vessels take about 18 percent, and all other gears take the remaining 7 percent. DEA analyses have not been conducted for these other fleets, so there is no quantitative evidence with which to determine whether there is excess capacity in the smaller fleets, and, if so, to what extent. Nevertheless, there is qualitative evidence that indicates that there is excess capacity in nearly all tuna fisheries, and most of the regional tuna bodies indicate there is excess capacity for nearly all gear types. It would therefore seem prudent to place a moratorium on capacity in the high-seas pole-and-line fleets by instituting a register for those vessels. Failing controls on the pole-and-line fleets, there could be a flow of capital into the construction of additional pole-and-line capacity from owners of purse-seine and longline vessels who have been limited by the regional registers to current fleet sizes, and also other potential investors in the tuna industry. Similarly, the high-seas troll fleets, which target mainly albacore, could be handled in the same manner as the pole-and-line fleets, if it were concluded that there was excess capacity in those fleets.

For the smaller vessels such as handline, small longline and small gillnet vessels that fish exclusively in inshore regions, vessel register programs as similar to those for the larger vessels may not be necessary. The total catch of these smaller vessels has been estimated to constitute only a small percentage of the world catch of tunas (Gillett, this collection). A practical option for managing these fleets might be by the introduction of TACs that would be part of the general conservation programs implemented by the regional tuna bodies.

It is emphasized that the cooperation of coastal states in a regional vessel register should in no way derogate sovereignty with respect to providing licences to vessels to fish in their jurisdictional waters. However, to discourage IUU fishing, licence sales should be restricted to vessels in the regional registers. Along these same lines, and in order to facilitate the objective of the register program to limit and reduce capacity, the nations participating in the fishery should be willing to work together to take joint action to ensure that vessels not on the register do not get a "free ride" with respect to enjoying the benefits of a managed fishery. This joint action by the participants could include (but not be restricted to) restricted access to their waters, restrictions on the use of port facilities and trade sanctions. It is only through such cooperative efforts and sacrifices of the participants that a regional vessel register can be successful in maintaining optimal fleet sizes. There are several examples of successful employment of such measures (Barrett, 2003), particularly the action taken by ICCAT regarding bluefin tuna.

4.4 Allocating quotas

An alternative means of addressing the excess capacity problem is through the development of self-regulating mechanisms to control capacity. The assignment of catch quotas to participating nations in an international tuna fishery, or to individual vessels in that fishery, can be such a self-regulating mechanism. They involve determining what the TAC for a fishery should be and the allocation of that TAC among the nations or vessels participating in the fishery. If quotas are assigned properly, the incentive to build excess capacity is reduced, and the participating nation or vessel does not need to race to take its share of the catch. Theoretically, the participant would not use more capacity than is needed to take the allowable quota. However, the assignment of quotas does not guarantee that excess capacity will not be a problem. On one hand, if the quotas are assigned to individual operators the self-regulating or incentive-adjusting measure would be particularly effective, as there would be no advantage to the operator to race to take the quota; it could be taken more leisurely, and with minimal capital investment. On the other hand, if quotas are assigned to countries, and there are no limits on the number of vessels allowed to participate in a country's harvest, there would be a race within each national fleet to take maximum shares of that country's quota.

4.4.1 Allocating quotas to countries

For this option the idea would be that the TAC for a region would be allocated to the nations participating in the fishery. Knowing what their allowable catch would be, each nation could then limit its fleet to the number of vessels needed to take the harvest. This could be done independently by each nation, as is the case for the southern bluefin fishery and the Pacific halibut fishery, or it could be done in accordance with a set of standards developed by the regional tuna body responsible for the fishery.

Though the concept of allocating catches is simple, the tuna fisheries themselves are very complex, and it will be difficult to find a workable solution acceptable to all participants. The difficulties in assigning quotas in fisheries in which there are multiple species taken and market variability have been reviewed by Squires and Kirkley (1996) and Squires *et al.* (1998). Many of the problems discussed by these authors apply to the tuna fisheries. They all involve several participating nations. Some of these are coastal states, and others (DWFNs) are not. Some have well-developed economies, while others are developing. Each of the fisheries takes more than one species of tuna, some of which are overexploited, some fully exploited and others underexploited. A variety of gears harvest the different species. Longline vessels harvest relatively small amounts of large tunas (and billfishes) destined for specialty markets, while purse-seine vessels harvest large amounts of smaller tunas destined for the canned market. The vessels of some nations direct most of their effort toward one species, while others direct their effort toward several species. Finally, tunas on the high-seas have historically been considered an open-access resource, belonging to whomever catches them. All of these complex factors must be considered if a workable means of limiting capacity by means of country allocations is to be achieved.

Ideally, allocation should be determined by an algorithm that employs a series of agreed-to criteria, thereby removing the intense political and economic debate from the process each time an allocation is made. In practice, allocations in international tuna fisheries have been mostly the result of intense negotiations among the involved parties (Joseph, 2004). Although there has been a great deal of attention given to the identification of a series of criteria that can be used in the allocation process, historical and current involvement in the fishery has been the overriding criterion used. Nearly all allocations in tuna fisheries reflect the current distribution of catch among the participants, with some provision being made for developing coastal states. Precedent for moving away from the concept of open-access or common property to one of rights-based management has been set in several tuna fisheries. As already mentioned, national allocations have been made by ICCAT for albacore and bluefin tuna, and by the CCSBT for southern bluefin tuna, and in the past by the IATTC for yellowfin tuna (Bayliff, 2001). Capacity quotas were allocated in the tuna fishery of the EPO by the IATTC, but, after the first two years agreement could not be reached to continue them. Considering these experiences, there appears to be ample precedent for allocating catch and/or capacity quotas in other tuna fisheries.

In most cases, deciding on TACs to be allocated for yellowfin, bigeye or bluefin is straightforward because those species are fully exploited, and, in some instances, overexploited, so TACs can be readily agreed to. Skipjack, however, particularly in the Pacific Ocean, are not fully exploited, and the catches could be increased, so setting TACs might be done on an economic basis, rather than a biological one. Reaching agreement on economic TACs might be more difficult, however, since the fleets of some nations direct more of their effort toward skipjack than do the fleets of other nations. Similarly, because longliners catch so many species at the same time, setting capacity limits will be complicated unless allocations are made for all the species combined that the longliners catch. If all target species are included in a country allocation, then the task of determining appropriate capacity levels is a more tractable problem, the issue of "high-grading" (continuing to fish after the vessel has filled its capacity, and discarding previously-caught less valuable fish to make space for recently-caught more valuable ones) notwithstanding.

Once allocations are made, the number of vessels authorized to participate in the harvest of that allocation could be determined. This can be accomplished in several ways. The most straightforward approach would be to leave the determination of fleet size in the hands of each country with an allocation. The hope would be that each country would determine the carrying capacity of its fleet, and, if it is found to be greater than that needed to take the allocation, capacity would be reduced. Each country would probably partition its allocation among gear types and then, if necessary, limit the number of vessels in each partition. In cases for which there are fleets of artisanal or small-scale fishing craft that fish exclusively in the EEZ of a country, rather than limit capacity for them, which might be difficult or impossible to do, a portion of the catch allocation could be allotted to that fishing sector.

Leaving the task of setting fleet capacity to each country might not resolve the excess capacity problem. Countries differ with respect to management objectives; some are more interested in maximizing profits and keeping fleet capacity in balance with the resource, whereas others may be more interested in maintaining vessel efficiency at relatively low levels to ensure more vessels operate and that employment stays high. The danger, if the latter occurs, is that fleets would be larger than needed to take the allowable harvest, profits would be low, and there would be pressure to weaken conservation measures.

A more effective approach for ensuring that capacity is set at levels in balance with the allocation is to vest authority in the regional tuna body to determine the levels at which the fleets should be kept. The regional tuna body could carry out analyses to determine the appropriate fleet size for each gear type within each allocation. In this manner overall fleet capacity for the entire fishery could be kept in check, and a program to reduce excess capacity initiated.

Under this option, a buy-back program, such as the one discussed earlier, could be implemented. In this case, however, each nation with an allocation and fleet would be responsible for establishing its own buy-back program. National buy-back programs could set a fee to be paid by the industry that would be used to make the buy-backs, the governments themselves could fund the buy-back program or a combination of the two could be employed.

4.4.2 Allocating the catches to individual vessels

The assignment of IQs has been used to manage a number of fisheries (Squires, Kirkley and Tisdell, 1995; Squires and Kirkley, 1996; Squires *et al.*, 1998; Batstone and Sharp, 1999; National Research Council, 1999). These incentive-adjusting techniques have corrected problems of overcapacity. As mentioned above, the assignment of IQs removes the necessity for fishers to race to fill their quotas. Experience in other fisheries managed by IQs shows that fishers tend to utilize only enough capacity to capture their quotas. Economists have advised that, whenever possible, IQs should be used to manage fisheries (Cunningham and Gréboval, 2001). As with the case of assigning country allocations, the first step is to determine the TAC for the fishery in question, and then partition it among the users.

Because of the complex nature of most tuna fisheries, attempting to manage at the catch level, when that catch is assigned to participants, is difficult. These complexities were discussed above in the context of assigning quotas to nations. The situation is even more complex when attempting to assign the TAC to individual vessels or companies.

The first task that a regional body contemplating the assignment of IQs will need to address is the areas, species and gear types to which the IQs will apply. For example, will IQs be assigned to all gear types? In most fisheries purse-seines are the dominant gear, so any effective program would have to include this type of gear. Likewise, high-seas longline fleets operate in every major ocean area, and they harvest significant amounts of tunas, and also a variety of other species. They would also have to be included for any IQ program if that program is to be effective. In many coastal states there are fleets of small longline and handline vessels that confine their fishing activities to nearshore waters. Some of these fleets consist of large numbers of vessels, but their harvest of tunas comprises only a small percent of the total catch from the region. Many of these small vessels fish for species other than tunas for much of the year. To attempt to assign and monitor IQs for these small vessels may be impractical. A more efficient and practical means of handling such fleets would be to assign a certain share of the TAC to them as a single unit. Pole-and-line vessels also fish for tunas in all the regions. In some areas, such as the EPO, they number only a few vessels, but in other areas pole-and-line vessels take a significant share of the total catch. This category of vessel would also have to be included in any program of IQs for it to be successful. In some pole-and-line fisheries, such as that of the Maldives, in which there are many small vessels that fish during the day and return to port at night, the assignment of IQs to individual vessels may be difficult to administer. In such cases IQs might be better assigned to companies or fishing cooperatives, which would then be responsible for deciding on how many vessels would fish.

4.4.2.1 Gear and catches

In terms of tonnage, purse-seine vessels, on the average, catch several times the amounts of tuna caught by the other types of gear. Most purse-seine vessels capture various mixes of skipjack, yellowfin and bigeye tuna. Because yellowfin and bigeye are fully exploited in all oceans, it is anticipated that the TAC for these species would be the best current estimate of the surplus production for the period. For skipjack, however, because it is not fully exploited in most regions, a TAC would have to be determined on the basis of its impact on the catches of yellowfin and bigeye. Except when fishing for yellowfin tuna associated with dolphins in the EPO, it is generally not possible to catch a single species when setting the net. Without a TAC on skipjack, fishing could continue to the point that the yellowfin and bigeye would be overfished. It is, of course, possible to set limits on the catches of yellowfin and bigeye, but if the vessels were permitted to continue fishing for skipjack it is likely that they would discard yellowfin and bigeye at sea after their TACs for those species were achieved. The alternative would be to close all tuna fishing when the yellowfin and/or bigeye quota was filled, but this would discriminate against the vessels that had not filled their IQs. Therefore, in determining the IQs for purse-seine vessels, all three species would have to be considered. The species make-up by area must also to be considered. If so, then some IQs could be area-specific. In fact, Wilen (1988) suggested that if limited entry is area-specific, certain advantages would be gained. In the EPO, at least, different vessels operate in different areas of the region, and the species compositions of the catches are different in different areas. Ecuadorian purse-seine vessels fish mostly on fish associated with FADs in the area south of 5°N, where the catch is predominantly skipjack, mixed with lesser quantities of yellowfin and bigeye; Mexican and Venezuelan vessels fish mostly north of the equator on schools associated with dolphins and catch mostly yellowfin tuna, with much lesser amounts of skipjack. These characteristics of specific fisheries must be considered in determining the IQs.

Although longline vessels produce considerably less tonnage of tuna per year than do purse seiners, the value of their catch is much greater. Longlines are generally considered to be a passive gear, which has limited ability to select the target species. In reality, however, the species composition of the catch can be influenced somewhat by the areas of operation and the configuration of the gear (number of buoys between hooks, which determines the depths at which the hooks fish). Longliners normally catch two or three species of tuna, two or three species of billfish, and a variety of other species in each set of the gear. Because of these complexities in the longline fisheries, consideration should be given to computing IQs within strata of time, area and species.

Pole-and-line vessels fish mostly for yellowfin and skipjack, but occasionally harvest small amounts of bigeye. They can be much more selective with respect to the species that they target than can purse seiners and longliners. For example the Ghanaian and Maldivian pole-and-line fleets, which catch mostly skipjack, target mostly pure schools of skipjack where that species is the dominate tuna species available.

4.4.2.2 Determining IQs

The first step in determining an IQ is to select the area to which it will apply. This will be influenced by the distribution and movements of the various species and whether there are areas that are unique to certain species or gear types. IQs could be computed for each species separately, two or more species or all of species combined. Considering the fact that most of the catches by surface gear include yellowfin, skipjack and bigeye taken during the same fishing operations, the IQs might best be determined for all species combined. Before determining IQs, however, the TACs should be determined. As already mentioned, an overall TAC that includes the TACs for the individual species must be considered. For most of the species, with the exception of skipjack, the TACs would probably be set equal to the best estimates of the AMSY or the current sustainable production. Because in many areas skipjack is underfished, a TAC for that species would be set below what the AMSY might be. If appropriate, TACs could be computed for areas in which only certain species occur or in which only certain gear types operate. Initially, however, it may be more practical to compute the combined TAC for the entire region that the regional body implementing the program is responsible for.

Once the TAC is determined, the IQs can be determined. Because different fleets, and different components within the same fleets, target different species or mixes of species, it would not be practical to merely divide the TAC by the number of vessels operating in the fishery. This could require longliners to fish in a manner that is impossible for them to do, or some purse seiners to shift from catching mostly skipjack, to catching a mix of species for which they have had no experience fishing for in the past. Some means of assuring that a vessel could continue to fish in the same way, or nearly the same way, as it had in the past would have to be developed. One means of doing this could be accomplished by stratifying the recent levels of harvest into areas, gear types within these areas and average catches by species within these gear types. Based on these proportions, the IQ could specify the species compositions of the catches. If this were done properly, vessels would be able to fish their IQs in the same manner as they had been fishing before IQs were established. This would also tend to take away incentives that might develop for fishers to "high-grade." For example if an IQ were merely a percentage of the TAC, regardless of species, a vessel that normally fished for yellowfin would be able to discard any skipjack it caught to ensure that a full load of yellowfin was taken.

In some regions there are recreational and subsistence fisheries for tunas. In most cases the amounts of tunas taken by these fisheries are very small relative to commercial harvests, the most notable exception being the recreational fishery for bluefin in the western Atlantic Ocean. To attempt to assign IQs to individual non-commercial fisheries would be difficult, so the most practical approach might be to reserve a portion of the TAC for these uses. In addition, there are large numbers of small commercial fishing vessels in some coastal states, and it would be difficult to assign IQs to these vessels. One solution would be to reserve a portion of the TAC for all of these vessels, as was suggested for recreational and subsistence vessels. Alternatively, IQs could be assigned to groups of such vessels represented by fishing cooperatives or other such entities.

Tunas spend their entire lives in an oceanic environment, and, as conditions in the ocean vary, so does their abundance. In favorable years, recruitment, growth and survival increase, resulting in above-average levels of abundance, and in unfavorable years, abundance declines. Therefore any TACs set must be adjusted in accordance with natural fluctuations in abundance. Therefore, it would be unrealistic to attempt to set long-term TACs and IQs in absolute tonnages. As has been done for some other fisheries, this could be addressed by expressing IQs in terms of percentages of the TAC.

4.4.2.3 Assigning IQs

The analyses presented in Section 2 of this report concluded that all of the purse-seine and longline fleets in the oceans of the world have a greater fishing capacity than needed to harvest the available resources. If all the vessels in these fleets fished as efficiently as the most efficient ones, the numbers of vessels could be reduced without reducing the catches. Accordingly, when IQs are determined should every vessel receive a relatively small IQ, or should the number of vessels be limited and the amount of each IQ increased? If the latter, then fleet size could be brought quickly to lower and more efficient levels. However, to take this course of action would require the development of a method for selecting the vessels to receive IQs. The owners not receiving IQs would suffer severe economic hardship. One solution to this problem would be for the regional tuna body to auction off the IQs to the highest bidders, and to use the receipts from the auction to compensate the vessel owners who did not receive IQs. If this were done, a system to ensure that the vessels removed from the fishery did not move to other fisheries that already have an excess capacity problem would be needed. For example, the vessel owners who did not receive IQs would be required to scrap their vessels or convert them to some other use before receiving compensation.

Alternatively, all vessels currently in the fishery could be assigned IQs. This would mean that the excess capacity problem would continue. However, there would be a tendency for owners of more than one vessel to reduce the number of vessels that they operate to the least capacity needed to ensure that their IQ is harvested before the end of the fishing season. However, because many owners have only one vessel, there would continue to be an excess capacity problem. This excess capacity problem could be mitigated by making the IQs transferable. If they could be sold and purchased within the management scheme, the most efficient operators would tend to buy up the IQs from less efficient operators. The most efficient operators could then take their expanded IQs with less vessel capacity. Theoretically the fishery would become self regulating with regard to capacity, and the fleet would be reduced in capacity to the level that could take the allowable catch with fewer vessels.

The transferable IQs would provide a mechanism for those states that currently do not have tuna vessels, but would like to enter the fishery, to acquire them. Likewise, there would be the opportunity for individuals or groups who are opposed to fishing, for whatever reason, to purchase IQs and to then not use them to fish. Such groups might wish to acquire IQs from sectors of the fishery that have high bycatch rates of endangered, threatened or icon species.

The transferable IQs would, in essence, be a property right for those owning them. They could be bought, sold or utilized. Before assigning the IQs, the governments working through the regional tuna body would need to define the nature of the right. Would it be a right held in perpetuity that would form part of the estate of the owner, or would it be for a fixed period of years? In some fisheries IQs are held in perpetuity, are transferable, and are considered legal property (Batstone and Sharp, 1999). For many tuna vessels that are operated efficiently, loans for the purchase of the vessel are paid off within several years; therefore, the duration of the IQ might be set on the basis of the pay-off time, or on the basis of the expected life of the vessel. After that period the IQ would revert to the regional tuna body for sale to the same or other potential operators. Funds generated through such transactions could be used to offset the cost of management or to assist developing coastal states to purchase IQs.

IQs, particularly when they are transferable, offer a number of interesting possibilities for addressing the excess capacity problem in tuna fisheries. However, the tuna fisheries are so complex that developing efficient and workable means of implementing management systems that use IQs will be difficult.

4.5 Licensing

Another approach that can be used to manage fishing capacity is to limit the entry of vessels into a fishery by requiring licences to participate in that fishery. This form of limited entry has been used in many national fisheries (Sinclair, 1983; Wilen, 1988; Townsend, 1990). Unlike IQs, a licensing system does not remove the incentive for fishers to increase fishing capacity. Experience in some other fisheries where licensing has been used to control capacity is that fishers have attempted to get around the constraints placed on them by increasing the carrying capacity or efficiency of the vessel they have licensed. Such input substitution, or “capital stuffing”, has rendered many licensing schemes ineffective in managing fishing capacity.

Limiting entry can be a useful tool in managing tuna fishing capacity if the potential problems created by capital stuffing can be overcome in a licensing scheme. In most cases, working at the vessel level, such as vessel licensing or the regional vessel register discussed earlier, managing capacity would be less difficult than managing catches, as is evident from the discussions in Section 4.4.2. In the following paragraphs some suggestions for a licensing system are outlined for tuna fisheries.

Of course, the implementation of a licensing system in the tuna fisheries is complicated by the international nature of the fishery, as are rights-based management approaches. There are multiple nations involved in all tuna fisheries, some of which are developing coastal states with small or no fleets, while others are DWFNs with large, modern fleets. Those with few or no vessels want to acquire them, particularly if they are coastal states, and those with large fleets want to retain what they have. Because most of the fisheries are fully exploited, and there is excess capacity to take the catches, there must be limited access to the fisheries. Therefore there must be some means to control access in these tuna fisheries. This could be accomplished in several different ways. One way would be for each nation with vessels participating in the fishery to allot licences for its vessels, but under the guidelines issued by the regional tuna body. Another way would be for the regional tuna body to be vested with the authority to limit the number of vessels in the fishery and to issue the licences for the vessels authorized to fish. The latter method would be the most efficient means of managing a licensing system, but the issue of a perceived derogation of sovereignty might make the participating governments reluctant to transfer this authority to the regional body. The following discussion assumes that authority is vested in the regional body to manage the proposed licensing system; the fishery would no longer be one of open access, but rights to fish could be assigned to the participants.

With a licensing system, a regional tuna body would determine the appropriate number of vessels and the associated capacity needed to harvest the allowable catch for its area of responsibility, and then it would issue licences. There are several approaches for estimating the appropriate number of vessels and the associated capacity for the region under consideration. The DEA analysis discussed in Section 2 could provide insight for the purse-seine and longline fleets, the "rule-of-thumb" approach of NMFS (2002a and 2002b) could prove useful or an in-depth economic analysis could provide helpful guidelines for establishing such estimates. Licensing would be at the vessel level, and licences would be allotted to vessels on the basis of gear type and capacity. By including a gear type and capacity in the licensing unit, some undesirable elements of capital stuffing could be avoided. However, the incentive for fishers to increase the efficiency of their licensed vessel would not be affected. To adjust for these efficiency changes, studies to estimate capacity and productivity growth would have to be conducted, and the numbers of licences adjusted downward to compensate for these increases in efficiency. As is the case for several of the other schemes for managing fishing capacity, the small vessels, including subsistence and recreational vessels, would likely have to be managed under a slightly different approach than that envisioned for the larger vessels. Because of the large numbers of these small vessels, and the difficulty in administering any complicated licensing scheme, it might be more practical to issue licences to groups of vessels through cooperative arrangements or to manage their activities through the assignment of catch quotas. To some extent, defining licence groups by gear, capacity, area, etc., might also help promote cooperation among industry participants by transforming the open-access property rights structure into a set of regulated local commons (Wilen, 1988; Balard and Platteau, 1996).

As already pointed out, in almost every case there is actually more capacity available than is needed to harvest the catch. Therefore the regional tuna body would need to decide on how to initiate the program once a target capacity has been determined. One means of doing this would be to issue a licence to every longliner and purse seiner authorized by its government to fish in the region, and then commence a scheme to reduce the capacity to the target level. Another means would be to restrict the number of licences issued at the outset to the target level.

4.5.1 Unrestricted licensing with buy-backs

Under this option, a licence would be issued to every longline and purse-seine vessel authorized by its government to fish in the region to which the licence applies. The licence would apply to a single vessel, and its associated capacity would be included with the licence so as to prevent any increase in its capacity. The licence would be for all species within the responsibility of the issuing authority, thereby allowing the vessel to select the mix of species it wished to target. If the TACs were properly determined a balanced fishery would result.

The licence could be considered as a right to fish that the holder could buy or sell, or it could be considered as "rental" of property that could be harvested over a fixed period of time, but did not imply ownership on the part of the licence holder. If the licence is transferable, then it would be held in perpetuity, and if and when it is transferred among vessels, care would have to be exercised to ensure that the transfer applies to a vessel that would not be capable of generating a greater level of fishing mortality than the vessel from which the licence is being transferred. Because of the inherent difficulties in trying to standardize different gear types which exhibit different age-specific and species-specific fishing mortality rates, it would be simpler from the management point of view to allow only transfers between the same gear types, i.e. purse seiner to purse seiner, or longliner to longliner, and vessels of equal size. If the licence did not vest a right for the holder, but instead was a "rental", it would revert to the regional tuna body after its term expired for reissue.

Because there may be excess capacity licensed for some species that are fully exploited or overexploited, additional management measures would be needed. In some regions the catch of yellowfin and skipjack would need to be controlled because the species are fully exploited or overexploited. In some of these same areas skipjack is underexploited, and could sustain increased fishing effort, but because it is taken in mixed schools with yellowfin and bigeye, its levels of harvest may need to be controlled as well, in order to protect the other two species from overexploitation.

Even though under this scheme there will initially be more licences issued than are needed to take the available harvest, the regional tuna body may wish to add still more licences to the list to provide a very limited opportunity for some developing coastal states to enter the fishery. At the same time, in order to help manage the excess capacity problem, a fee could be charged for a licence. If set high enough, this could discourage some vessels from buying licences, and, indeed, some states from entering the fishery.

The funds generated through the sale of licences could be used to fund a buy-back program to reduce the number of licences, and corresponding vessels, to the target level. The same concerns and considerations presented in the earlier discussions on buy-backs would apply in this instance as well.

4.5.2 Restricting the number of licences initially issued

In the preceding paragraphs a licensing system in which, when initially implemented, every vessel operating in the fishery would be issued a licence was discussed. The important issue then was to introduce mechanisms for reducing the number of licences over time to the target level set by the regional tuna body. In the following paragraphs systems to reduce the numbers of vessels licensed at the beginning of the program are discussed, along with mechanisms for maintaining capacity at the target levels.

4.5.2.1 Fractional licences

Townsend (1992), Townsend and Pooley (1995) and Cunningham and Gréboval (2001) have suggested an alternate approach to buy-backs, which utilizes the concept of transferable fractional licences for reducing excess capacity. The technique involves the issuance of some fraction of a licence for each vessel in the fleet. The fraction would be calculated on the basis of the target fleet size as determined by the regional tuna body. When the system is implemented each participant in the fishery would be issued a fractional share of a licence. Without a full licence a participant would not be able to fish. Therefore, to fill out the licence, fractional shares would have to be purchased from someone else. For example, there might exist a fleet of 200 longline vessels and 200 purse-seine vessels in a region for which the regional tuna body has determined target levels of 150 longliners and 150 purse seiners. In order to get to the target level the regional tuna body would issue a 0.75 fractional share to each participant in the fishery, all or any part of which is transferable. Transfers would be allowed only within gear types and within capacity categories. Because the shares would be transferable, a market would be created for fractional shares. Through the sale of fractional licence shares, the number of full licences would soon approximate the target capacity levels. The fractional licensing system would not need a separate buy-back scheme associated with it, as it is, in effect, an industry-funded buy-back program.

As a result of the sales of the fractional licence shares, there would be vessels (50 purse seiners and 50 longliners in the hypothetical example given above) that would not be authorized to fish. The owners of those vessels would have been compensated for not being able to fish by the sale of their fractional shares. Because all purse-seine and longline fisheries suffer from problems of excess capacity the vessels without licences would not be moved to other fisheries. They would have to be scrapped or converted to some other use.

As with most other systems for managing capacity, some means of monitoring changing efficiency must be implemented. As efficiency increased, the numbers of licences would have to be reduced correspondingly.

4.5.2.2 Auctioning licences

Economists have long advocated the assignment of property rights in fisheries, and suggested the use of auctions to generate resource rent from the assignment of those rights. Such approaches have been successfully used in national fisheries, but to date these have not been applied to international fisheries because of the open-access nature of most international fisheries and the difficulty many governments have in moving away from that concept. Auctions offer some advantages for implementing a licensing system for managing capacity in the world's tuna fisheries.

Once the regional tuna body determines the target levels for fleet capacity in its region, which in almost every case would be less than the current fleet size, and the corresponding number of licences that it wishes to allot within each gear type and vessel size class, it could use an auction to sell the licences to the highest bidders. Such an approach would result in an immediate reduction of the fleet to near the desired target level. The regional tuna body would have to determine the terms of the licences being auctioned. The licences could be for fixed periods, for example, 10 years, and then returned to the regional tuna body for re-auctioning, or retirement if efficiency has continued to increase, or they could be held in perpetuity. If held in perpetuity the decision as to whether there should be an annual fee associated with the licence would have to be made.

There would be a great deal of opposition to the idea of auctions to sell licences, particularly from the less efficient operators, because they would be less able to bid effectively against the more efficient operators who would have more financial resources available to them. Governments would most likely have to compensate the unsuccessful bidders in some way for being driven out of the fishery. All or part of the revenues generated by the auction could be used for this purpose.

Because the most successful operators would be the successful bidders, there would not be a proportional decrease in potential fishing mortality with the decrease in vessel numbers or capacity. Additionally, with respect to the longliners, those staying in the fishery might concentrate their effort more on the higher priced *sashimi* fish such as bluefin and bigeye, rather than on the relatively lower priced yellowfin and albacore. To adjust for these possibilities, the regional tuna body would need to monitor efficiency changes in the licensed vessels, and, based on these studies, make further reductions in fishing capacity. Likewise there would need to be additional management measures, such as catch quotas, to ensure that the more desirable species are not overfished.

These further reductions in fishing capacity, which would be made to compensate for increased efficiency of the licensed vessels, could be achieved through a buy-back program. The funding for the buy-back program could come from the revenues generated by the auctioning of the licences.

Another source of opposition to such a program would be from the coastal states that do not have large purse-seine or longline vessels, but would like to acquire them. These states would argue that, as coastal states, and under the provisions of Article 116 of the LOSC, they should have special rights to bring vessels into the fishery. However, there is no more room for additional capacity. There are at least means of addressing this problem. First, it could be argued that there is not room for additional capacity, so if a nation or an individual wants to enter the fishery it would have to acquire a vessel in the same manner as anyone else, in this case through the auction. Second, when determining the number of licences to be auctioned, the regional tuna body could reserve a certain number for developing coastal states of the region, based on some predetermined set of criteria. Third, the regional tuna body could use part of the revenues generated from the sale of licences to assist developing coastal states meeting certain predetermined criteria to acquire vessels through the auction.

5. SUMMARY AND CONCLUSIONS

Although the studies referred to in Section 2 above have shown that there is more fishing capacity for purse-seine and longline vessels in all the major tuna fisheries than is needed to harvest the available resources, they do not show clearly by how much capacity should be reduced. Some idea of the magnitude of the excess capacity can be obtained from the data available for the tuna fishery of the EPO. The IATTC has suggested that the fleet of purse seiners in that region could be reduced by about 22 percent without decreasing the catches. It seems reasonable to assume that about the same reduction might apply to purse-seine fleets in many of the other major tuna fisheries. In the case of longline fleets, the OPRT has targeted a reduction of 20 percent. Purse seiners and longliners account for about 75 percent of the world catches of the principal market species of tuna. By resolving the excess capacity problem for these gear types, many of the threats of overexploitation could be contained and the fisheries could become economically more efficient. The problem would not be completely resolved, however, because other gear types take the remaining 25 percent of the catch. Unfortunately, data on the numbers and capacities of the vessels employing these gear types is limited.

Pole-and-line vessels account for about 18 percent of the remaining 25 percent of the world catch. Records of the numbers and capacity of pole-and-line vessels are not nearly as complete as they are for purse-seiners and longliners. There is an urgent need to collect such information and to undertake studies regarding the levels at which these fleets should be maintained. Each of the regional tuna bodies should collect and maintain lists of pole-and-line vessels, along with vessel characteristics, particularly characteristics related to vessel size, which operate in their regions. As a precautionary measure, once capacity limitations are implemented for purse seiners and longliners, consideration should be given to placing moratoria on the entry of new pole-and-line capacity into any of the fisheries for which limitations on the other gear have been implemented. This should be done for two reasons. First, pole-and-line capacity should be controlled until it is determined whether there is excess pole-and-line capacity. Second, if there are no controls on pole-and-line capacity there might be a flow of investment capital into new pole-and-line vessels because of restrictions on other gear types.

The remaining seven percent of the world catch of the principal market species of tuna is taken by a variety of other gear types. Most, but not all, albacore stocks are fully exploited. Therefore, from a practical point of view, it would be advantageous to implement capacity controls in the fisheries for albacore before the problem becomes acute, thereby rendering a solution more difficult. Trollers, which fish mostly for albacore, have already been the object of limited entry in some albacore fisheries. In New Zealand, consideration is being given to allowing no new entry of trolling vessels. In the Atlantic Ocean, ICCAT has requested that nations with vessels fishing for albacore limit the sizes of their fleets to the levels that they were a few years earlier. As is the case for pole-and-line vessels, there is some urgency for the regional tuna bodies to collect information on the numbers and capacities of trolling vessels, so that the need for capacity management can be evaluated. Tunas are also caught by small longliners, handlines, gillnets and other types of gear. As mentioned earlier, the numbers of small longline vessels that fish for tunas and related species are increasing in many coastal states. Most of these small longliners, and some hand-line vessels, take only small quantities of tunas during certain seasons, and they fish mostly within the EEZs of their flag states; most of their catches are other species, such as mahi-mahi and pargo. Some of their catch enters the commercial market, but some is for subsistence. Gillett (this collection) refers to the fisheries by small longliners, hand-line vessels, and other small craft, as "very small-scale fisheries", and estimates that they take about 320 thousand tonnes of tunas. It may be difficult for regional tuna bodies to monitor the number of vessels involved in such fisheries and to implement measures to control capacity for these fleets. It would probably be more efficient for controls on the numbers and capacities of these small fleets to be left in the hands of the coastal states, because the objectives of management for each of the states might be quite different than those for the region as a whole. However, there would need to be some conservation controls to prevent overfishing. These would come from the regional tuna bodies as catch quotas or closed areas or seasons.

Several options for dealing with the excess capacity problem for large purse seiners and longliners have been presented for consideration. These options have been grouped into two categories, one in which there is open access to the fisheries, and the other involving rights-based management.

5.1 Open-access options

All large-scale tuna fisheries were developed during a period when access to the resources was open to any fisher who wished to fish on the high seas, or who was willing to pay a licence fee to a coastal state to fish inside the waters over which that state had jurisdiction. It was, of course, partially a result of open access that heavy exploitation of tuna resources took place, leading to overfishing and the building of more fishing capacity than needed to harvest the available resources.

Although the concept of open access still prevails for most tuna fisheries, it is being eroded as regional tuna bodies are increasingly attempting to allocate the catches among participants and to limit the numbers of vessels authorized to fish. However, there still persists a strong desire on the part of much of the tuna industry and some states to continue open access for tunas. Therefore, the status quo was considered as one option for dealing with the issue of overcapacity in the world's tuna fisheries. Continuing the status quo implies that most measures for managing tuna resources would involve output controls such as catch quotas and minimum size limits, and would not address the problem of limiting fleet capacity. The result will be that fleets, which are already in excess of what is needed, will continue to grow. As fleets grow economic problems in the production sector of the fishery will grow as well. As economic pressures on fishers increase, there will be increasing efforts to weaken management controls. These patterns have prevailed in the past in many fisheries, including those for tunas. This is the primary reason that many of the fisheries resources of the world are overfished. It is clear that maintaining the status quo is not a desirable option for managing the fisheries for tunas.

Oliver (2002) suggested that the capacity of purse-seine fleets be reduced by closing off a certain percentage of the fish storage capacity of each vessel. This option would reduce the fish-carrying capacity of the fleet that was the target of these restrictions, but it would not reduce the number of vessels in the fishery, nor alter substantially the ability of the fleet to catch fish. The only reduction in the catches would be due to increased time spent running to and from port as a result of reductions in the carrying capacity of the vessels. In fact, due to improvements in efficiency not related to carrying capacity, the actual catches would probably not decline over the long term. Oliver (2002) also suggested an alternate scheme that would require vessels to spend more time in port than required for normal unloading so as to reduce the number of days spent at sea fishing. However, after unloading was completed, fishermen would probably use the extra time in port to conduct annual vessel maintenance, and would be able to substitute regular repair time in port with time at sea fishing. The net result in both cases would be no change in the number or size of the vessels fishing, and little change in the actual fishing mortality exerted by the vessels to which these controls were applied. Therefore, these two options do not appear to be the best means of addressing the excess capacity problem facing most tuna fisheries.

5.2 Limited-entry and rights-based options

Based on the analyses presented in this document, and the results presented in much of the literature cited herein, it seems clear that the common-property and open-access nature of fisheries has been the major cause of the decline in many of the world's fish stocks. If we are to move away from the problems of overfishing contributed to by the application of this concept of common property, the concept must be changed. Economists have long argued that by assigning certain rights for fishers to harvest a certain share of the resource, effective management of that resource could be more easily achieved. However, assigning property rights in fisheries is a delicate political issue. Vesting the authority in an international organization to assign property rights may be perceived as a derogation of sovereignty. However, to transfer such authority is recognition that the authority existed in the first place. It is also an issue of the "haves" *vs*. the "have-nots", i.e. nations with fleets *vs*. nations without fleets or with only very small fleets. Complicating this issue is the fact that many of the "haves" are DWFNs and many of the "have-nots" are developing coastal states. Some of these coastal states, particularly in the area of the western and central Pacific, control access to large portions of the tuna stocks, so without their input and concurrence in any program to assign property rights, the program would be doomed to failure. Therefore any attempts to address this issue must take into account the positions presented by the "have-nots". Several limited-entry and rights-based options for managing fishing capacity are presented in Section 4.3 of this report.

One series of these rights-based options is directed at the catch level, and deals with different ways of allocating the catch among participants, either countries or individual vessels.

It was pointed out that by assigning IQs, the incentive for fishers to increase fishing capacity beyond the level needed to harvest their IQs would be removed. These self-regulating mechanisms must be augmented by the introduction of programs to buy back excess fishing capacity, and to further reduce the capacity to compensate for increases in efficiency. It was pointed out, however, that the assignment of IQs in tuna fisheries would be complicated because of the complex nature of those fisheries. The fisheries are multi-species, multinational and multi-gear. Some fisheries have vessels from many nations fishing in the same area for the same species. Various types of gear are used to make the harvests, with some gear types being specific to certain nations. Some species are harvested mostly by a single gear type, or only two gear types. Some of the species being taken during a single operation of the gear are overexploited, while others are not fully exploited. Some nations concentrate on one species, and other nations on different species. The definition of IQs and the efficient administration of an IQ program would be difficult for many of the tuna fisheries.

A more practical approach to capacity management might be best directed at the vessel level, rather than the catch level, particularly given the state of property rights and sovereignty. Two such vessel-level options are presented in Section 4.3. One of these is a modification of the IATTC's RVR, (which is, in essence, a weaker form of limited entry), with a buy-back scheme for reducing the current capacity of tuna fleets, and to take account of increases in vessel efficiency. The other option outlines a system for limited entry of vessels into tuna fisheries. One scheme allots a licence to each vessel in the fishery, but includes buy-back mechanisms for reducing capacities to target levels. The other scheme provides for auctioning either full or fractional shares of licences, with a buy-back provision to compensate for increases in efficiency of licensed vessels.

Of the various options presented, it appears that those directed at the vessel level would be the easiest to design and administer. Over the short term, it appears that RVRs would be most likely to be accepted by the governments making up the various regional tuna bodies.

6. RECOMMENDATIONS

The foregoing discussion of the DEA results and the initiatives taken by the OPRT provide clear evidence that excess fishing capacity is endangering the health of the world's tuna stocks. There is an urgent need to implement programs to address this excess capacity problem. The process of developing acceptable programs to reduce capacity will be difficult to achieve. The regional tuna bodies should consider implementing, in the immediate future, measures to place moratoria on the growth of capacity in all tuna fisheries. Even though information is not available on the numbers and capacities of pole-and-line, small longline and other types of vessels that fish on the high seas, the moratoria should apply to these vessels as well. A moratorium for the western and central Pacific could be achieved by strictly adhering to the principles of the Palau Arrangement, and in other areas by the introduction of RVRs. The immediate implementation of moratoria, coupled with other management measures, would help to prevent any further overfishing of the tuna stocks.

Along these same lines, the WTPO has called for the establishment of a world-wide vessel register similar to the RVR of the IATTC, but without the provision for transfer of vessels, which would freeze capital stock. If implemented, this would limit world purse-seine capacity to present levels. It would be helpful if governments placed a high priority on assisting the WTPO to implement this initiative.

There is a strong need for the regional tuna bodies to collect information on the numbers, capacities and characteristics of other tuna vessels, such as pole-and-line vessels and trollers, so that it can be used to determine whether excess capacity exists for these fleets and, if so, to what levels they should be adjusted.

For a long-term solution to the excess capacity problem, rights-based management of tuna resources should be considered. Because of the complexity of the tuna fisheries, preference should be given at the outset to evaluating options that are directed at the vessel level, rather than at the catch level. RVRs, coupled with buy-back programs, provide good possibilities for achieving this objective.

Whatever mechanisms are selected for managing fishing capacity, it is essential that there be some means of ensuring that the provisions of the program are complied with. This will require surveillance and monitoring schemes, which might require the use of on-board observers and/or global positioning satellite (GPS) equipment aboard the vessels. This would be particularly important for areas where the boundaries of the areas of concern of the regional tuna bodies abut or overlap. It would also be important to have some means of exchanging information among the regional tuna bodies regarding their programs to limit capacity and what the effects of these may be on the programs in other regions. Also important would be some mechanisms for dealing with IUU vessels. These mechanisms could take the form of various multilateral restrictions and sanctions imposed by the participating governments. A permanent committee, comprised of representatives of each of the regional tuna bodies, would be necessary to accomplish these objectives.

Finally, it is clear that tuna fisheries are at a critical juncture. With the exception of Atlantic bluefin, southern bluefin and bigeye, most stocks of tuna are not overfished. Since overfishing is the result of too much fishing capacity, and since there is too much fishing capacity in most of the tuna fisheries of the world, it is urgent that programs be implemented to stop the growth in capacity before resource degradation and economic chaos result, and to bring that capacity to levels in balance with the productivity of the resources.

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Problems of illegal, unreported and unregulated fishing and overcapacity of tuna fishing vessels

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ABSTRACT

Until almost 1960, Japanese longliners for tuna expanded all over the world. During the course of the expansion of tuna longline fishery, the Japanese Fisheries Authority had substantially improved fisheries management ability. Since the late 1980s, Taiwan Province of China expanded its longline fishing capacity at a very rapid pace. In cooperation with Japan, the control ability of Taiwan Province of China was strengthened in the mid-1990s. It resulted in Taiwanese fishermen obtaining foreign registry outside the Taiwanese fisheries authority's control. In 1999 the Japanese Government started consultations with both fishing industry and authority of Taiwan Province of China and both sides agreed to set up programmes to scrap old flag of non-compliance - large-scale tuna longline vessels (FNC-LSTLVs) and to put those LSTLVs under strict control.

1. HISTORY OF THE JAPANESE LONGLINE FISHERY FOR TUNAS AND ITS MANAGEMENT

Longline fishing for tunas was first practiced by Japanese fishers. The fishery gradually expanded to fishing grounds at greater distances from Japan. There were almost no restrictions on fishing until 1962, when the "designated fishery licensing scheme" (DFS) was introduced. Under this management scheme, a limit on total fishing capacity was set for tuna longline-fishing vessels, and within this limit fishing licences were issued to individual vessels.

1.1 The tuna longline fishery prior to the World War II

Historically, tunas were caught with nets by small un-decked, sail-powered fishing vessels. During the 1910s fishers extended their operations to offshore areas and even to the high seas. At that time larger, engine-powered vessels and longline gear were introduced.

As the fishing grounds expanded offshore, new developments, such as further increases in the sizes of the vessels and the invention of the mechanical line-hauler, increased fishing efficiency, which, in turn, served as an incentive to further expansion of the fishing grounds. In 1941 there were 1 107 Japanese longliners, with an average gross registered tonnage of 40 tons, which caught 53 651 tonnes of tunas and billfishes.

It should be noted, however, that during this period the fishery was still confined to the northwestern Pacific Ocean north of the equator.

1.2 Expansion of the longline fishery for tunas after the World War II

Between the end of World War II, in 1945, and 1952, when the Japan-US peace treaty took effect, Japan was obliged to limit its fishing operations to the area within the "MacArthur Line", set by the US occupation forces. Japanese authorities, in order to secure the compliance of Japanese fishers with this regulation, implemented a licensing system for controlling tuna fishing and construction of larger tuna-fishing vessels.

Rapid expansion of fishing grounds for the tuna longline fishery began in 1952 when the Japan-US peace treaty took effect. In response to requests from fishers, the Government of Japan allowed the construction of larger fishing vessels. With the application of the Law on Exceptional Cases, construction of fishing vessels of more than 100 gross tons (GT), conversion of medium-sized fishing vessels to larger ones and conversion from other types of fishing to longline fishing for tunas were approved. In addition, the vessels were made more efficient by improvements in navigation equipment, enlargement of fish storage capacity and improvements of freezing facilities.

Following these developments, the fishing grounds were further extended to the entire Pacific and Indian Oceans (1954) and to the Atlantic Ocean (1957).

During that period most of the tuna catches were exported to the United States for canning or used domestically for the production of fish hams and sausages.

1.3 Use of longline-caught tunas for the production of *sashimi*

By the 1960s it was apparent that the abundance of tunas had been decreasing, making longline fishing unprofitable. In addition, vessels of the Republic of Korea and Taiwan Province of China entered the fishery in 1965, which exacerbated the problem.

Due to increased prosperity in Japan, the demand for high-quality tuna *sashimi* was increasing, and this demand was met by Japanese longline vessels with equipment capable of freezing the fish at the extremely low temperatures required for production of raw material suitable for preparation of high-quality *sashimi*.

Meanwhile, beginning in 1965, Japanese vessels began fishing for southern bluefin tuna in the higher latitudes of the southern hemisphere.

Beginning in the 1970s, however, additional problems, such as (i) increasing fuel prices, (ii) adoption of 200-mile Exclusive Economic Zones by most of the nations of the world, (iii) strengthened international and regional fisheries regulations, (iv) variable fish prices and (v) decreased abundance of fish, arose, and Japan was gradually losing its superiority in tuna fisheries.

1.4 Control of fishing effort in the longline fishery for tunas

Control of fishing effort in the longline fishery for tunas began in 1962, when the Government of Japan established the DFS. The DFS was established for the purpose of properly regulating the major fisheries in response to the rapid expansion of offshore and high-seas fisheries after World War II.

Under the DFS, several fishing activities are categorized as "designated fisheries" when the following conditions were met:

- fishing activities for which restrictive measures on both operators and fishing vessels are needed for the purposes of propagation and conservation of fishery resources and/or fishery coordination;
- fishing activities for which consistent measures are deemed appropriate, in consideration of intergovernmental agreements, location of fishing grounds and other factors.

There are two distinct categories for the longline fishery, high-seas vessels of 120 GT or more (no area restriction) and offshore vessels less than 120 GT (restricted to the northwestern Pacific Ocean).

The DFS maintains effective control of fishing capacity by controlling both operators and fishing vessels, and periodically renewing the authorizations. All of the authorizations are renewed simultaneously every five years. During this process, limits on the numbers and sizes of fishing vessels that are permitted to fish in each fishing area are imposed, to avoid harmful effects on the propagation and conservation of fishery resources and other matters of public interest, taking into account conditions, such as financial performance, of the fishery in question. The numbers of renewed authorizations are made available through public notice.

Authorizations are made within the limits prescribed in the public notice, if necessary, through prioritization of applications. A licence is issued for each authorization designating one operator (or owner) and one fishing vessel to be used by the permitted operator. An authorization can be transferred to another operator during the authorization period only under certain conditions. Also, a licence can be issued for a new vessel as a replacement for a previously-authorized vessel only if the operator meets certain conditions.

2. DEVELOPMENT AND EXPANSION OF THE TUNA FISHERIES OF OTHER ASIAN COUNTRIES

2.1 The Republic of Korea, Taiwan Province of China and Indonesia

During the early 1980s, vessels of the Republic of Korea, the Taiwan Province of China and Indonesia became capable of producing raw material suitable for production of *sashimi*. Among the reasons for this were the following:

- used Japanese tuna longline fishing vessels were exported to those countries;
- fishing equipment, for which there was less demand in Japan, was exported to those countries;
- facilities for construction of fishing vessels were transferred to those countries; and
- non-Japanese fishers, who were formerly employed aboard Japanese vessels, found employment aboard vessels of their own nationalities.

2.2 Expansion of the large-scale tuna longline fishery of Taiwan Province of China, and the history of its fishing capacity controls

Among the newly-rising Asian fishing countries, the Taiwan Province of China expanded its longline fishing capacity at a particularly rapid pace. The authorities of the Taiwan Province of China reacted to that challenge by strengthening their capacity to control the Taiwanese tuna longline fishing vessels. Japan, because it was the principal market for tunas caught by these vessels, actively supported that effort. This, however, led to the reflagging of many of these vessels, and to a substantial increase in illegal, unreported and unregulated (IUU) fishing.

2.2.1 Expansion of the fishery by large-scale tuna longline fishing vessels of Taiwan Province of China

Previous to the 1980s the majority of the tuna longline fishing vessels of the Taiwan Province of China were relatively small vessels that landed fish destined for the market for fresh tunas. The rest of them (about 100 vessels) were large-scale tuna longline fishing vessels (LSTLVs) that operated on the high seas, targeting albacore destined for canning. However, since the economy of the Taiwan Province of China grew considerably beginning in the late 1980s while that of the Republic of Korea did not, the number of Taiwanese LSTLVs equipped with super-freezers increased to more than 300 by the early 1990s. The Taiwanese vessels operated mainly in the tropical areas of the Indian Ocean, where they targeted yellowfin and bigeye tuna. Large portions of their catches were sold to the Japanese market, which reduced the prices of *sashimi*-grade tuna in that market.

2.2.2 Initial approach for the improvement of fishing capacity control by Taiwan Province of China

In order to rectify the situation, representatives of the tuna industries of Japan and Taiwan Province of China, with observers from the government authorities of both Japan and Taiwan Province of China, held meetings in 1993 at which an annual export quota of 99 000 tonnes of *sashimi*-grade tuna to Japan and an export certificate system were adopted. Since Taiwanese LSTLVs producing *sashimi*-grade tuna did not have any markets other than that of Japan, it had become possible to monitor their total catches of *sashimi*-grade tuna from the export certificate data.

Subsequently, during the mid 1990s, because of excessive catches in previous years, the catches of Taiwanese LSTLVs in the Indian Ocean decreased, and vessels began to shift their operations to the Atlantic Ocean. In response to the rapid increase of catches of bigeye tuna by Taiwanese LSTLVs in the Atlantic Ocean, in 1997 the International Commission for the Conservation of Atlantic Tunas (ICCAT) adopted a limit of 16 500 tonnes per year on the catch of bigeye tuna by vessels of the Taiwan Province of China. In accordance with this catch limitation, Taiwanese authorities allocated quotas to individual Taiwanese LSTLVs, controlling them by implementing the ICCAT statistical documentation scheme (Taiwan Province of China, under the name "Chinese Taipei", had been participating in the work of ICCAT, as an observer, for several years).

2.2.3 Non-compliance of LSTLVs owned by residents of Taiwan Province of China

While the ability of the Taiwan Province of China to control its fleet of LSTLVs had strengthened during the mid 1990s, Taiwanese fishers strongly desired an increase in the numbers of LSTLVs, so they purchased a number of used Japanese LSTLVs that had been replaced by newly-constructed vessels. Since there were no excess licences to be issued by the Taiwan Province of China for those newly-purchased LSTLVs, the new owners registered them in other countries.

From 1993 on, Taiwanese residents purchased and owned large numbers of LSTLVs registered in other countries. Japanese trade statistics show that during the late 1990s the imports of bluefin and bigeye tunas from Latin-American and African countries that did not have large-scale longline fisheries for tunas increased substantially. Examination of these import data revealed that the fish had been caught by LSTLVs that were owned by Taiwanese residents, but registered in other countries.

In 1999 ICCAT granted to the Taiwan Province of China, as "Chinese Taipei", the status of "Cooperating non-Party/Entity/Fishing Entity" in accordance with a resolution adopted by ICCAT in 1997 urging non-parties to either become Contracting Parties or attain status as a "Cooperating non-Party/Entity/Fishing Entity". ICCAT requested that the Taiwan Province of China comply with ICCAT conservation and management measures, including its catch quota. Hence, duly-authorized Taiwanese LSTLVs continued to abide by international conservation and management measures, but vessels owned by residents of the Taiwan Province of China and registered in other countries continued to operate as before. To make the matters worse, these LSTLVs were not subject to the export quota of 99 000 tonnes that was, at that time, allocated to Taiwanese LSTLVs.

3. ACTIONS TAKEN FOR THE LEGALIZATION OF LARGE-SCALE TUNA LONGLINE FISHING VESSELS OWNED BY TAIWANESE RESIDENTS AND REGISTERED OUTSIDE THE TAIWAN PROVINCE OF CHINA

3.1 Detection and identification

LSTLVs owned by Taiwanese residents and registered in other countries were operating not only in the ICCAT area, but also in the Pacific and Indian Oceans. Their catches were not reported and not subject to any regulations. However, since almost all of their catches came to the Japanese market, the Government of Japan was able to estimate, from information on its tuna imports collected from importers, transshippers and other relevant business entities, that, as of 2000, there were at least 250 such LSTLVs engaged in IUU fishing all over the world.

3.2 Scrapping and re-registration program

The Government of Japan determined that almost all of the 250 LSTLVs registered in countries that are otherwise not involved in large-scale longline fishing were owned by Taiwanese residents. The Government of Japan reported the results of its investigation to ICCAT and other tuna regional fishery management organizations (RFMOs), and, in addition, in 1999 it initiated consultations with both the fishing industry and government authorities of the Taiwan Province of China.

Two types of such LSTLVs, about 120 used Japanese vessels purchased by Taiwanese residents and about 130 relatively-new vessels constructed in the Taiwan Province of China, were identified during the consultations.

After long and difficult consultations, both sides agreed in 2000 to set up two programs, one to scrap older vessels, which would be mainly the responsibility of the Japanese, and the other to re-register newer vessels to the Taiwan Province of China, which would be mainly the responsibility of the Taiwanese. The two programs resulted in the scrapping of 43 older vessels and re-registration of 47 newer ones. In addition, vessel owners of the Taiwan Province of China sold about 65 older vessels to owners in China and other countries.

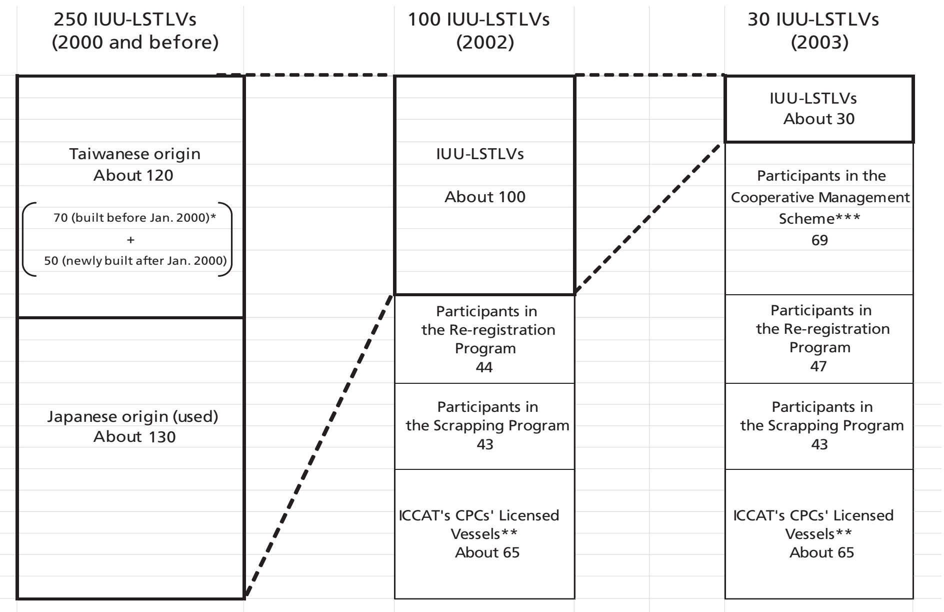
3.3 Additional cooperative management schemes

In 2002 there were still about 100 LSTLVs that were owned by Taiwanese residents and registered outside the Taiwan Province of China. About 70 percent of these were relatively new, but they could not be re-registered to the Taiwan Province of China because its limit for vessels had already been reached. Further consultations led to a new program to expeditiously dispose these vessels in accordance with the ICCAT resolution entitled “More Effective Measures to Prevent Deter and Eliminate IUU Fishing by Tuna Longline Vessels”. Officials of the Government of Japan also talked with officials of the governments of Vanuatu and the Seychelles, major flag states in which the remaining vessels were registered, and reached an agreement with them to put those vessels under strict control. The owners of 69 of such vessels committed themselves to comply with the following cooperative management schemes:

- arrangement for legalization of LSTLVs was established between the fishing authorities of the two flag states (Vanuatu and the Seychelles) and the Government of Japan, and the vessels participating in the scheme would be subject to strict joint monitoring and control measures;
- all of the owners of participating LSTLV would have to obtain Japanese fishing licences for them and freeze those licences so as to reinforce and complement the cooperative management scheme mentioned above and to prevent an increase of overall fishing capacity;
- the participating LSTLVs would be authorized to fish only in specified areas and for specified species so that their fishing operations would not pose problems in the light of regulatory measures and resolutions adopted by the relevant RFMOs. Specifically, 21 Seychelles-flag LSTLVs could fish only in the Indian Ocean, and only for yellowfin and bigeye tuna, whereas 48 Vanuatu-flag LSTLVs could fish only in the Pacific Ocean and only for albacore (although four Vanuatu-flag LSTLVs were allowed to fish also for yellowfin and bigeye tuna in the Pacific Ocean).

Even after all of the above, approximately 30 older LSTLVs owned by Taiwanese and registered outside the Taiwan Province of China are believed to remain (Figure 1).

FIGURE 1
Transition of the numbers of IUU large-scale tuna longline vessels



* Japan-Taiwan Joint Action Program to Eliminate IUU Vessels concluded in January 2000
** CPCs means "Contracting Parties" and "Cooperative non-Contracting Parties, Entities or Fishing Entities"
*** Cooperative Management Scheme between Japan and Seychelles/Vanuatu was agreed in July 2003

However, many of these are no longer engaged in longline fishing for tunas, having been transformed for purposes other than longlining for tunas or become inactive. Accordingly, the number of such LSTLVs is now very small.

4. EMERGENCE OF ANOTHER PROBLEM–INCREASED FISHING CAPACITY OF THE PURSE-SEINE FLEET

The success in reduction of IUU longline fishing is probably attributable to the fact that Japan is, by far, the most important market for *sashimi*-grade tuna, so it was relatively easy to monitor the imports of tunas caught by LSTLVs and take measures against tunas caught by IUU fishing.

In addition, it was quite fortunate that the Government of Japan could determine the ownership of the vessels that landed *sashimi*-grade tuna in Japan and consult directly with the authorities of the Taiwan Province of China to achieve an effective settlement of the matter.

Recently, however, it has become apparent that overcapacity has become a problem in the purse-seine fishery, especially in the western and central Pacific Ocean (WCPO) where, so far, no management measures have been implemented.

Despite the Palau Agreement, which limits the number of purse seiners in the WCPO, and resolutions calling for restriction over expansion of fishing effort that were adopted by Preparatory Conference for the Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific in 1999 and 2002, the catch of tunas in this region has been increasing more rapidly than those in other ocean areas (Figure 2). This increase is caused mainly by increases in purse-seine fishing capacity (Figures 3 and 4).

The expansion of purse seine fishing capacity involves the following fundamental problems:

- increased use of flags of non-compliance by purse seiners: only 41 purse-seine vessels are licensed in the Taiwan Province of China, but it has been reported that 28 large purse seiners have been constructed for Taiwanese owners and that more

FIGURE 2
Global catches of albacore, bigeye, skipjack and yellowfin by ocean area

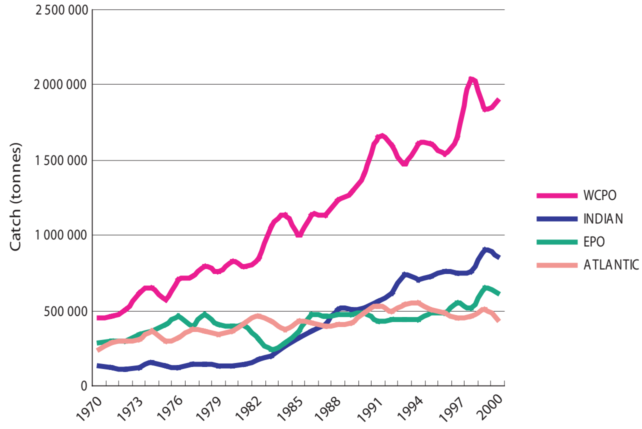


FIGURE 3
Number of purse seine vessels in each area

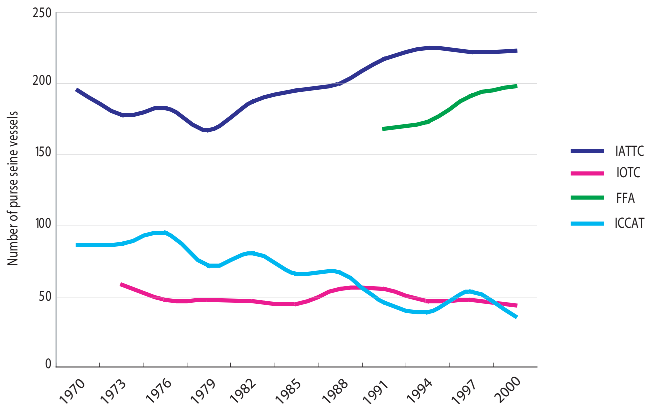
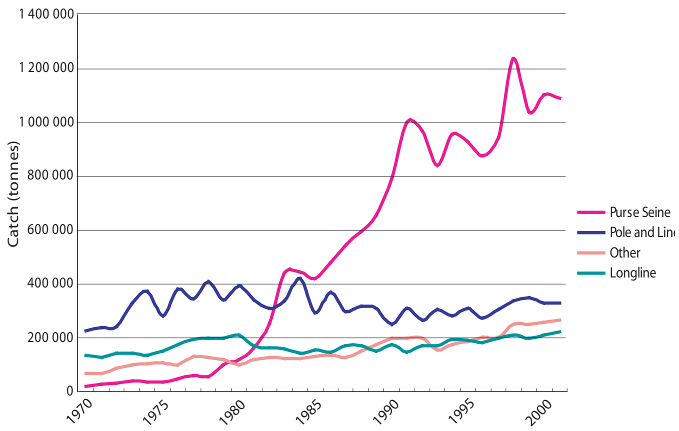


FIGURE 4
Total catches of albacore, bigeye, skipjack and yellowfin in the WCPO by gear type



are being built. Moreover, all those new vessels are larger than the older ones, as described below;

- increase in size of the vessels: in earlier years many of the purse seiners operating in this region were in the 700 GT class, but most of those brought into the area from other regions and those newly built are more than 1 300 GT. Many of them have heliports to enhance their efficiency. Therefore, even though the increase in numbers of purse seiners may seem to be relatively small, the actual total fishing capacity of purse seiners has increased significantly in this region; and,
- increased catches of small fish due to the introduction of fish-aggregating devices (FADs): at present almost all the purse seiners operating in the WCPO are using FADs to increase their catches. Unfortunately, the catches around FADs contain large numbers of small bigeye and yellowfin tuna. This has had an adverse effect on the catches of both bigeye and yellowfin by longline gear (Figures 5 and 6). In addition, catching large amounts of small fish can reduce the total catch of fish all sizes combined.

5. CONCLUSIONS AND RECOMMENDATIONS

In the recent years significant progress was made in reducing IUU fishing and uncontrolled expansion of fishing capacity for the large-scale tuna longline fishery. The highly-mobile nature of the vessels required that whatever measures were taken be applied globally, as unanimously advised at the twenty-fifth session of the FAO Committee on Fisheries. Global application of lists of vessels that were authorized to participate in various fisheries played a decisive role for this progress. Unfortunately, however, these measures apply only to longliners greater than 24 metres in overall length (LOA), so owners have been constructing vessel less than 24 metres in LOA, but fully capable of fishing for *sashimi*-grade tuna, to avoid these restrictions.

There is also excess fishing capacity for tuna purse-seine vessels, and this problem is even further from solution than that for longline vessels. The solutions to the problem are, for the most part, the same as that for the longline fishery, i.e. establishment of lists of vessels that are authorized to participate in various fisheries, scrapping of older vessels and restrictions on construction of new vessels. In addition, an industry organization, the World Tuna Purse Seine Organization, has adopted measures that require its members to reduce the times spend fishing.

At the same time, many developing states adjacent to fishing areas wish to increase their participation in the fisheries. Since there are already more vessels than needed, this can be accomplished only at the expense of the developed states, which would require difficult negotiations.

Consequently, it is recommended that the following actions be taken as promptly as possible:

- FAO should establish a global list of tuna fishing vessels, using the existing lists of tuna fishing vessels compiled by the RFMOs;
- developed states, parties and fishing entities should halt the construction of new tuna fishing vessels, except for those replacing the existing licensed vessels with equivalent fishing capacity;
- FAO should request that the RFMOs establish, as a matter of high priority, a system to transfer fishing capacity from developed states, parties and fishing entities to developing states;
- a nation, party or fishing entity whose residents caused rapid expansion of fishing capacity in the recent years should take steps to at least eliminate that expanded portion of fishing capacity.

FIGURE 5
Purse seine and longline catches (number of fish) of bigeye in the WCPO

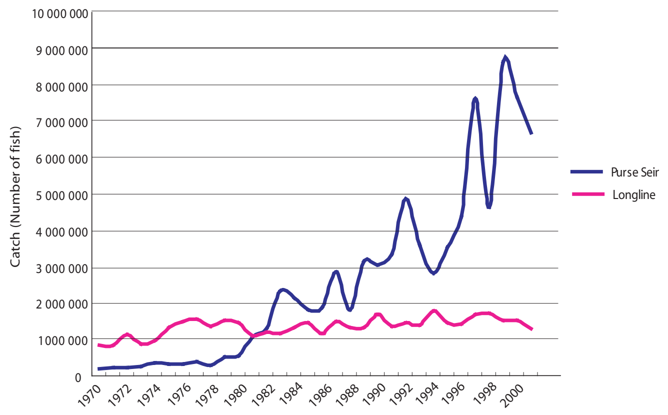
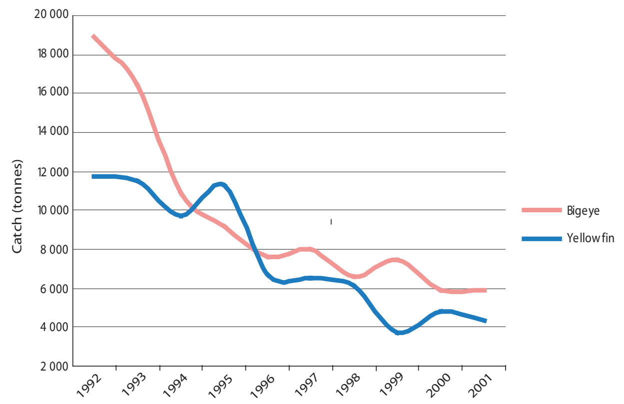


FIGURE 6
Catch trend of Japanese coastal longline



Annex 1
Agenda

Monday, 15 March 2004

1. Opening

2. Introduction of Participants

3. Adoption of the Provisional Agenda

4. Logistic Arrangements for the Meeting

5. Report of the Meeting and a Statement of TAC: Content and Arrangements

6. Overview of the Project Implementation (Jacek Majkowski)

7. Project's Studies: Progress and Results
   - 7.1. A1: Tuna Fisheries and Resources
     - "Historical Developments of Tuna Fisheries and their Catches" by Peter Miyake
     - "Tuna Data in FAO's Fisheries Global Information System (FIGIS)" by Fabio Carocci, Adele Crispoldi, Ignacio de Leiva and Jacek Majkowski
     - "Status of Tuna Stocks and its Implications for the Fishing Capacity" by Ignacio de Leiva and Jacek Majkowski
   - 7.2. A2: Characterization and Estimation of Tuna Fishing Capacity
     - "An Analysis of the Fishing Capacity of the Global Purse Seine Fleet" by Chris Reid, James Kirkley and Dale Squires
     - "The Feasibility of Applying DEA to Measure the Fishing Capacity of Global Longline and Pole and Line Fleets, Given Available Data" by Chris Reid, James Kirkley and Dale Squires
     - "Review of Longline Fleet Capacity of the World" by Peter Miyake
     - "Global Study of Non-Industrial Tuna Fisheries " by Robert Gillett

Tuesday, March 16 2004

   - 7.3. A3/4: Tuna Fishing Industry
     - "The World Tuna Industry – an Analysis of Imports, Prices, and of their Combined Impact on Tuna Catches and Fishing Capacity" by Camillo Catarci
     - "Economic and Social Impact of Tuna Industry: What Still Needs to be Studied" by Helga Josupeit
   - 7.4. A5: Tuna Fishing Capacity Management Options and Implications
     - "Past Developments and Future Options for Managing Tuna Fishing Capacity with Special Emphasis on Purse seine Fleets" by Jim Joseph
     - "IUU and Capacity Issues on the Tuna Fishery" by Miwako Takase

8. Reports on External Activities of Relevance to the Project (all participants)
   - "FAO activities related to the management of fishing capacity" by Ulf Wijkström
   - Other activities related to the management of fishing capacity

9. Review of the First draft of the Statement by TAC without the Recommendations Section

Wednesday, 17 March 2004

10. Future Research
    - *A1: Tuna fisheries and resources*
    - *A2: Characterization and estimation of tuna fishing capacity*
    - *A3/4: Tuna fishing industry*
    - *A5: Tuna fishing capacity management options and implications*

11. The Project's Future Meetings (of TAC and/or the Expert Consultation on the Management of Tuna Fishing Capacity)

12. Funds and Logistic Arrangements for the Project's Future Activities

13. Recommendations

14. Other matters

15. Review of the Second draft of the Statement by TAC

Thursday, 18 March 2004

16. Adoption of the Statement by TAC

17. Adoption of the Report

Annex 2
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