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ECONOMIC AND MANAGEMENT IMPLICATIONS OF STOCK ASSESSMENTS ON KEY TUNA STOCKS IN THE WCPO

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Economic and management implications of stock assessments on key tuna stocks in the WCPO

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Abstract

The paper describes the approach to multi-species, multi-gear analysis of management options being used by the FFA Secretariat . Options are assessed against Convention criteria of ensuring sustainability, promoting optimum utilization and avoiding a disproportionate burden on small island developing states and territories. As an example, summary results are presented for four broad options. In considering these options we draw on a paper by Reid (2006) which is attached to this document.

1. Purpose

The purpose of this paper is to present the approach to analysis of management options being used by the FFA Secretariat as an illustration of the use of the science for analyzing management options, and an indication of the way in which management options are assessed by FFA Members.

2. The Convention and Measures

The WCPFC Convention provides at Article 5, section a) that members of the Commission shall:

> *"adopt measures to ensure long-term sustainability of highly migratory fish stocks in the Convention Area and promote the objective of their optimum utilization"*

This indicates that proposals for measures should be tested against the criteria of ensuring long-term sustainability and promoting the objective of optimum utilization.

In addition, the Convention provides at Article 30, section 2 c) that the Commission shall take into account:

> *"the need to ensure that such measures do not result in transferring, directly or indirectly, a disproportionate burden of conservation action onto developing States Parties, and territories and possessions"*

which is of particular importance to FFA Members.

3. Multi-Species, Multi-Gear Management

The WCPO tuna fisheries are multi-species, multi-gear fisheries. Figure 1 shows the estimated sustainable yields of the four main species in relation to changes in effort[1], illustrating that two stocks (bigeye and yellowfin) are subject to overfishing, while yields of albacore and skipjack can be sustainably increased at least in biological terms, but

[1] Yield curve data taken from the most recent stock assessment analyses reported at October 2006

perhaps not in economic terms. In this situation, optimizing the volume and value of overall yields and assessing the expected outcomes of proposed measures requires consideration of multi-species, multi-gear aspects.

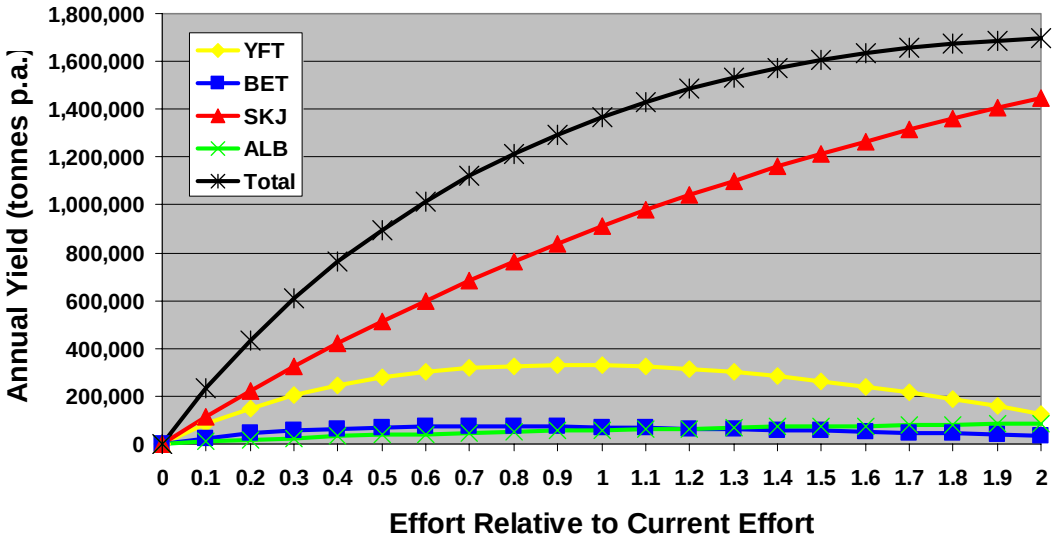

Figure 1: Multi-Species Yield Analysis (source: data from SPC-OFP)

4. Analysis of Management Options

As an example of the approach used, Table 2 sets out some results from an analysis of these four management options:

Option	**Represented by**
25% across the board effort cut	25% reduction in longline, purse seine and Indonesia/Philippines domestic effort
3 month WCPO purse seine closure	25% reduction in purse seine effort
10 week WCPO FAD closure	20% reduction in purse seine associated sets effort, transferred to unassociated effort
25% longline effort cut	25% reduction in longline effort

tested against these criteria:

a) ensuring sustainability - measured by the multiple of fishing effort required to achieve $F_{MSY;}$

b) promotion of optimum utilization - measured by the change in the overall volume and value of long term yields and major changes in catch rates; and

c) burden on small island developing states (SIDS) and territories - measured by the share and value of any reduction in long term yields taken in the waters of FFA Member Pacific Island states and territories.

The estimates of volume and value of yield changes are drawn from the analysis presented in the Reid paper attached (Reid 2006), adjusted to include yield changes in the Indonesian and Philippines domestic fisheries which are not included in the Reid analysis. The Reid analysis is based on stock assessment and catch data provided by SPC-OFP.

The estimated fishing effort multipliers and changes in CPUE for bigeye and yellowfin are calculated directly from the SPC-OFP stock projection data used for the Reid analysis.

In examining the table the following should be noted:

1. the changes are calculated as the changes from a default scenario of maintaining the current pattern of fishing effort,
2. the key gains are the bigeye and yellowfin CPUE changes which need to be valued and aggregated with the value of the yield changes.
3. the data provide useful indicators, but in terms of national impacts there is a need to consider the extent to which the changes in yield volumes and values, and CPUE, are likely to be reflected in incomes, fees, jobs, exports etc
4. the data for bigeye and yellowfin are based on stock projections for 10 and 5 years respectively, whereas the albacore and skipjack data are based on equilibrium data. The effect of this is to understate the long term values associated with yield changes and CPUE for bigeye and yellowfin, especially in the longline fisheries
5. the analysis is static and does not take account of dynamic effects such as changes in targeting that might result from the proposed measures
6. planned future work includes using updated stock assessments and projections, valuing CPUE gains and wider economic impacts and trade-offs, and considering sub-regional impacts.

Table 1: Consideration of 4 management options

Option	Ensuring Sustainability[a]		Promotion of Optimum Utilization		Burden on SIDS
	F_{mult} BET	F_{mult} YFT	Estimated Annual Long Term Yield (Value) Change[b]	Major Long Term CPUE Changes	% (and value) of reduction in yield in SIDS waters
25 per cent across the board effort reduction	1.01	1.19	-136,300mt (-$152.7m)	LL BET +34%, YFT +24%	61% (-$84.3m)
10 week FAD closure	0.81	0.92	-16,900mt (+$3.1m)	LL BET +6%, PS -3%	68% (-$2.0m)
25 per longline effort reduction	0.87	0.96	-20,900mt (-$133.9m)	LL BET +19%, YFT +5%	35% (-$50.6m)
3 month purse seine closure	0.83	1.00	-122,000mt (-$62.4m)	LL BET & YFT +4%	66% (-$53.5m)

Notes: **a**. F_{mult} is the multiple of fishing effort required to achieve $F_{MSY;}$ F_{mult} for the status quo = 0.76 for bigeye and 0.90 for yellowfin. **b**. Value estimates do not account for changes in value of Indonesia/Philippine domestic fisheries yields.

References

Langley A., Hampton J. 2006. Management options for yellowfin and bigeye tuna in the WCPO fishery. Pacific Economic Bulletin Volume 21 Number 3.

Reid, C. 2006 An analysis of economic implications and tradeoffs in achieving maximum sustainable yield for bigeye and yellowfin tuna in the western and central Pacific Ocean.

Focus

TUNA RESOURCE MANAGEMENT

Economic implications and trade-offs in achieving maximum sustainable yield for bigeye and yellowfin tuna in the Western and Central Pacific Ocean

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The Western and Central Pacific Tuna Fishery (WCPTF), a multi-species, multi-sector and multi-jurisdictional fishery, is the world's largest and most valuable tuna fishery. Current fishing mortality on bigeye and yellowfin tuna in the Western and Central Pacific is believed to be approaching or is above that associated with maximum sustainable yield (MSY). Consequently, there have been numerous calls from various government and regional bodies for fishing mortality on these stocks to be reduced. At the same time, current fishing mortality on albacore and skipjack is significantly below that associated with MSY.

The second meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission (WCPFC-SC2) recommended that to ensure that bigeye and yellowfin tuna were not fished above the level associated with their MSY fishing mortality on the stocks be reduced by 25 and 10 per cent respectively from the average levels of 2001–04. This paper provides a simple analysis of possible economic implications and trade-offs of a range of possible measures that reduce fishing mortality on bigeye and yellowfin stocks. The analysis looks at trade-offs between three areas within the competence of the WCPFC, that is, within Pacific island countries' national waters, other national waters and international waters.

The analysis indicates that constructing management regimes that do not result in a disproportionate burden being imposed on Pacific island countries and that achieve an outcome whereby all stocks are maintained at or above the level associated with MSY is likely to be extremely difficult. This is because the value of the fisheries of Pacific island countries is derived to a large extent from skipjack and albacore, whereas the benefits from possible management measures are likely to accrue primarily in the bigeye longline fishery as a result of CPUE increases driven by a recovery in the stock.

Introduction

The WCPTF is the world's largest tuna fishery in terms of volume and value, supplying about half the world's tuna supplies. In 2005, total catches were about 2.1 million metric tonnes and the estimated value of the catch was in excess of US$3 billion.

The fishery is diverse, ranging from small-scale artisanal operations in the coastal waters of Pacific states, to large-scale industrial purse seine, pole-and-line and longline operations in the exclusive economic zones (EEZ) of Pacific states and on the high seas. The main species targeted by these fisheries are skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*), bigeye tuna (*T. obesus*) and albacore tuna (*T. alalunga*).

The Western and Central Pacific Fisheries Commission (WCPFC) was established in June 2004. Its objective is to ensure the long-term conservation and sustainable use, in particular for human food consumption, of highly migratory fish stocks in the Western and Central Pacific Ocean for present and future generations.

Current fishing mortality rates for bigeye and yellowfin tuna in the Western and Central Pacific are believed to be approaching or are above those associated with maximum sustainable yield (MSY). Consequently, there have been numerous calls from various government and regional bodies for fishing mortality on these stocks to be reduced. At the same time, current fishing mortality rates on albacore and skipjack are significantly below those associated with MSY.

The second meeting of the Scientific Committee of the Western and Central Pacific Fisheries Commission (WCPFC-SC2) recommended that to ensure that bigeye and yellowfin tuna were not fished above the level associated with their MSY fishing mortality on the stocks should be reduced by 25 and 10 per cent respectively from the average levels of 2001–04 (WCPFC 2006).

While the need for information on biological implications of possible management measures is self evident, there is also a need to consider the economic implications and trade-offs of such measures to obtain some insight into possible total and relative burdens borne by participants in the fishery—coastal and fishing states—and by the different components of the industry. The need for the WPCFC to consider economic advice is clear given Article 10 paragraph 1j) of the *Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean*, which includes as a function of the commission that it shall 'obtain and evaluate economic and other fisheries-related data and information relevant to the work of the Commission' and that, under Article 6 paragraph 1b) on the precautionary approach notes, the commission has to take into account, among other factors, 'socioeconomic conditions'.

In Reid (2006), an analysis of economic trade-offs in terms of an across-the-board reduction in effort of 15 per cent was undertaken based on the results of the work done for the WCPFC-SC1 (Hampton et al. 2005; Langley and Hampton 2005; Langley et al. 2005). This study concluded that the major beneficiary of an across-the-board reduction in effort levels would be the frozen longline fleet targeting sashimi-grade tuna, which operates primarily on the high seas, while the economic costs of such a policy would be borne primarily by the purse-seine fleet and the Pacific island countries in whose waters this fleet operates.

This paper re-examines the economic implications of an across-the-board effort reduction based on outcomes of stock assessments conducted for the SC2 and extend the analysis to examine four other possible management options that might be

considered as ways to reduce fishing mortality on bigeye and yellowfin. These implications are compared between three areas within the competence of the WCPFC—Pacific island country national waters,[1] other national waters and international waters—and between the three major fleets operating within the WCPFC Convention Area—purse-seine, fresh longline and frozen longline.

Analysis and results

The analysis is conducted by comparing the equilibrium yields for the *status quo*[2] with five management scenarios.

1. A 25 per cent across-the-board effort reduction, including in the Philippine and Indonesian domestic fisheries.
2. A 10-week ban on associated fishing sets in the purse-seine fishery.[3]
3. A 25 per cent reduction in effort in the longline fishery.
4. A closure of high seas waters to the purse-seine fishery.[4]
5. A six-week closure of the purse-seine fishery.[5]

The equilibrium yield for the *status quo* and the differences in equilibrium yield under each scenario and under the *status quo* are provided in Table 1. The bigeye and yellowfin estimates are based on equilibrium yield estimates provided by the Oceanic Fisheries Program of the Secretariat of the Pacific Community (Langley 2006).

Albacore and skipjack equilibrium yields were available only for the fishery as a whole and not by gear type. These were also provided by the Oceanic Fisheries Program (OFP). Therefore, equilibrium yields for the *status quo* for purse-seiners for skipjack shown in Table 1 are derived as the proportion of the skipjack catch taken by purse-seiners compared with the total skipjack catch in the WCPTF during 2001–04, that is, 68.5 per cent. Longline-caught albacore was calculated in a similar manner based on total catches and longline catches of southern albacore, with the proportion being 90.5 per cent. For changes under each scenario involving an effort reduction, the estimates are based on equilibrium yield analysis of effort reductions across the respective fisheries and the proportion of the change in equilibrium yield attributed to a gear estimated in the same manner. For scenario two (a 10-week ban on associated sets), no effort change arises as it is assumed that all the displaced effort is redirected to unassociated sets. The difference in catch is estimated based on the difference in observed CPUE for these set types during 2001–04.

Also shown in Table 1 is the multiple of fishing effort, under the *status quo* and each scenario, required to achieve the level of fishing effort associated with MSY (F_{MSY}). For example, under the *status quo*, effort needs to be reduced by 23 per cent for bigeye MSY to be produced.

From this analysis, several points can be drawn from a biological viewpoint. First, the only option analysed that results in fishing mortality being less than that which would achieve F_{MSY} is the across-the-board effort reduction. While this is the best outcome of all the scenarios examined from a biological viewpoint, it is important to bear in mind that this assumes that effort reduction in the order of 25 per cent can be achieved in all fisheries including the domestic fisheries of the Philippines and Indonesia. Aside from an across-the-board effort reduction, the option that best moves fishing mortality for bigeye towards F_{MSY} is the 25 per cent reduction in longline catch. For yellowfin, the second best options to move fishing mortality towards F_{MSY} are, equally, the 25 per cent reduction in longline catch, the high seas purse-seine closure and the six-week purse-seine closure. The closure on associated sets, while improving the situation with regard

Table 1 **By species: equilibrium yield under the *status quo* (in metric tonnes), difference in equilibrium yield under each scenario compared with the *status quo* and the multiple of fishing effort required to achieve F_{MSY}**

	Albacore	Bigeye	Skipjack	Yellowfin
Equilibrium yield for the *status quo*				
Multiple of fishing effort required to achieve F_{MSY}	n.a.	0.77	n.a.	0.92
Purse-seine catch	n.a.	12,516	622,981	104,052
Longline catch	53,304	50,587	n.a.	71,723
Scenario 1: 25 per cent reduction in effort across all fisheries				
Multiple of fishing effort required to achieve F_{MSY}	n.a.	1.01	n.a.	1.19
Change in purse-seine catch	n.a.	–1,294	–126,687	–6,239
Change in longline catch	–9,645	311	n.a.	–5,081
Scenario 2: 10-week closure on associated (FAD/log) sets				
Multiple of fishing effort required to achieve F_{MSY}	n.a.	0.81	n.a.	0.92
Change in purse-seine catch	n.a.	–1,220	–23,704	4,229
Change in longline catch	n.a.	2,889	n.a.	133
Scenario 3: 25 per cent reduction in longline fishing				
Multiple of fishing effort required to achieve F_{MSY}	n.a.	0.87	n.a.	0.96
Change in purse-seine catch	n.a.	277	n.a.	2,461
Change in longline catch	–9,645	–5,306	n.a.	–15,503
Scenario 4: A closure of high seas waters to the purse-seine fishery				
Multiple of fishing effort required to achieve F_{MSY}	n.a.	0.83	n.a.	0.96
Change in purse-seine catch	n.a.	–1,779	–126,687	–18,874
Change in longline catch	n.a.	4,438	n.a.	5,737
Scenario 5: Six-week purse-seine closure				
Multiple of fishing effort required to achieve F_{MSY}	n.a.	0.80	n.a.	0.96
Change in purse-seine catch	n.a.	–833	–76,177	–8,982
Change in longline catch	n.a.	2,034	n.a.	2,777

Source: Oceanic Fisheries Program, Secretariat for the Pacific Community, Noumea.

Table 2 **Proportion of catch as a percentage taken by each gear by species and area, 2001–04**

	Albacore	Bigeye	Skipjack	Yellowfin
Proportion of 2001–04 purse-seine catch caught in				
Pacific island country national waters	n.a.	59	64	62
Other national waters	n.a.	18	12	19
International waters	n.a.	23	23	19
Proportion of 2001–04 longline catch caught by fresh longliners in				
Pacific island country national waters	23	15	n.a.	20
Other national waters	33	14	n.a.	32
International waters	9	6	n.a.	7
Proportion of 2001–04 longline catch caught by frozen longliners in				
Pacific island country national waters	6	28	-	21
Other national waters	0.06	0.10	n.a.	0.04
International waters	29	37	n.a.	19

Source: Personal communication, P. Williams, Fisheries Database Supervisor, Oceanic Fisheries Program, April 2006.

to bigeye (that is, fishing mortality is reduced), has no impact on yellowfin as a result of the effort being transferred to unassociated sets.

In addition, for the analysis equilibrium yield, changes for each species are required for

- purse-seine operations in the national waters of Pacific island countries, other national waters and international waters
- fresh longline operations in the national waters of Pacific island countries, other national waters and international waters
- frozen longline operations in the national waters of Pacific island countries, other national waters and international waters.

The OFP analysis used to obtain the differences in the equilibrium yields shown in Table 1 is at a different spatial and gear level to that required for this analysis. To overcome this, aggregated results are used for purse-seine and longline fishing operations from the OFP analysis and proportion these using the observed 2001–04 spatial distribution of catch and, in the case of the longline fleets, observed 2001–04 catch proportions between the fresh and frozen fleets,[6] as provided in Table 2.

In Table 3, the estimated equilibrium yield under the *status quo* (in metric tonnes) and the difference in equilibrium yield under each scenario compared with the *status quo* are shown by species, gear and area. These estimates assume that the distribution of catch remains the same after the introduction of any management measures except under scenario three (closure of high seas waters to the purse-seine fishery), where it is assumed that all the reduction in catch for the purse-seine fishery is borne in the high seas.

To estimate the change in the gross value of the fishery under each scenario, the difference in equilibrium yield is multiplied by the price received for the catch where price is specified by gear and species. For consistency, the prices are based on those observed during 2001–04 and specified in Table 3. While this approach keeps the period used for the prices consistent with the effort levels used in the modelling, it is important to note that the actual supplies of fish associated with these prices are not consistent with the supply that would be expected under equilibrium yield. As such, these prices are best treated as indicative only. Further, it is important to note that there is considerable variation in prices, particularly for purse-seine-caught fish, within and across years, and that not all fish will be sold on the market on which the prices are based or necessarily attract an equivalent price on other markets. Also, no allowance is made for any impact on prices that would occur as a result of changes in catch levels. Such impacts might be significant. It is important to note that the prices used are delivered, not ex-vessel, prices.

Figure 1 provides the estimated changes when comparing equilibrium yields for the *status quo* and the respective scenario by gear type. From this, several points can be drawn: firstly, that scenarios one (25 per cent across-the-board effort reduction), four (closure of high seas purse-seine fishery) and five (six-week purse-seine closure) all result in significant reductions in the gross value of the purse-seine fishery. Scenario one sees an 18 per cent reduction in the gross value of the purse-seine fishery with some simultaneous reductions in the gross value of the fresh longline fishery (7 per cent) and a smaller reduction in the value of the frozen longline fishery (4 per cent). Given that this is associated with a 25 per cent effort reduction and assuming constant costs per unit effort, the major benefits of such a management measure in terms of profitability are likely to accrue to the frozen longline fishery, then the fresh longline fishery, with relatively marginal gains made in the purse-seine fishery.

Table 3 **By species, gear and area: equilibrium yield (in metric tonnes) under the *status quo* and difference in equilibrium yield under each scenario compared with the *status quo***

	Albacore	Bigeye	Skipjack	Yellowfin
Equilibrium yield for the *status quo*				
Purse seine				
Pacific island national waters	-	7,422	401,672	64,741
Other national waters	-	2,197	75,239	19,946
International waters	-	2,897	146,070	19,365
Total	-	12,516	622,981	104,052
Fresh longline				
Pacific island national waters	12,021	7,537	-	14,639
Other national waters	17,733	6,953	-	23,276
International waters	4,970	3,021	-	5,120
Total	34,724	17,510	-	43,035
Frozen longline				
Pacific island national waters	3,040	14,348	-	14,822
Other national waters	30	49	-	30
International waters	15,510	18,681	-	13,837
Total	18,580	33,077	-	28,688
Scenario 1: 25 per cent reduction in effort across all fisheries				
Purse seine				
Pacific island national waters	-	–767	–81,682	–3,882
Other national waters	-	–227	–15,300	–1,196
International waters	-	–300	–29,704	–1,161
Total	-	–1,294	–126,687	–6,239
Fresh longline				
Pacific island national waters	–2,175	46	-	–1,037
Other national waters	–3,209	43	-	–1,649
International waters	–899	19	-	–363
Total	–6,283	108	-	–3,049
Frozen longline				
Pacific island national waters	–550	88	-	–1,050
Other national waters	–6	0	-	–2
International waters	–2,806	115	-	–980
Total	–3,362	203	-	–2,032
Scenario 2: 10 week closure on associated (FAD/log) sets				
Purse seine				
Pacific island national waters	-	–723	–15,283	2,631
Other national waters	-	–214	–2,863	811
International waters	-	–282	–5,558	787
Total	-	–1,220	–23,704	4,229
Fresh longline				
Pacific island national waters	-	430	-	27
Other national waters	-	397	-	43
International waters	-	173	-	9
Total	-	1,000	-	80

Frozen longline				
Pacific island national waters	-	819	-	27
Other national waters	-	3	-	0
International waters	-	1,067	-	26
Total	-	1,889	-	53
Scenario 3: 25 per cent reduction in longline fishing				
Purse seine				
Pacific island national waters	-	164	-	1,531
Other national waters	-	49	-	472
International waters	-	64	-	458
Total	-	277	-	2,461
Fresh longline				
Pacific island national waters	–2,175	–791	-	–3,164
Other national waters	–3,209	–729	-	–5,031
International waters	–899	–317	-	–1,107
Total	–6,283	–1,837	-	–9,302
Frozen longline				
Pacific island national waters	–550	–1,505	-	–3,204
Other national waters	–6	–5	-	–6
International waters	–2,806	–1,959	-	–2,991
Total	–3,362	–3,469	-	–6,201
Scenario 4: A closure of high seas waters to the purse seine fishery				
Purse seine				
Pacific island national waters	-	0	0	0
Other national waters	-	0	0	0
International waters	-	–1,779	–126,687	–18,874
Total	-	–1,779	–126,687	–18,874
Fresh longline				
Pacific island national waters	-	661	-	1,171
Other national waters	-	610	-	1,862
International waters	-	265	-	410
Total	-	1,536	-	3,442
Frozen longline				
Pacific island national waters	-	1,259	-	1,186
Other national waters	-	4	-	2
International waters	-	1,639	-	1,107
Total	-	2,902	-	2,295
Scenario 5: Six week purse seine closure				
Purse seine				
Pacific island national waters	-	–494	–49,116	–5,589
Other national waters	-	–146	–9,200	–1,722
International waters	-	–193	–17,861	–1,672
Total	-	–833	–76,177	–8,982
Fresh longline				
Pacific island national waters	-	303	-	567
Other national waters	-	280	-	901
International waters	-	121	-	198
Total	-	704	-	1,666
Frozen longline				
Pacific island national waters	-	577	-	574
Other national waters	-	2	-	1
International waters	-	751	-	536
Total	-	1,330	-	1,111

Source: Oceanic Fisheries Program, Secretariat for the Pacific Community, Noumea.

Table 4 **Average 2001–04 prices by gear and species** (US$/metric tonnes)

	Albacore	Bigeye	Skipjack	Yellowfin
Purse-seine[a]	n.a.	1,052	782	1,052
Fresh longline[b]	2,086	7,136	n.a.	6,604
Frozen longline[c]	2,086	5,641	n.a.	3,644

[a] Skipjack and yellowfin: Thai imports of frozen skipjack and frozen yellowfin. Bigeye is usually not separated and tends to be sold in yellowfin lots and so is assumed to attract the same price as yellowfin.
[b] Bigeye and yellowfin: Japanese imports of fresh yellowfin and bigeye. Albacore: Thai imports of frozen albacore.
[c] Yellowfin: Longline-caught yellowfin sold at Yaizu (Japan). Bigeye: Frozen bigeye landings at selected Japanese ports. Albacore: Thai imports of frozen albacore.
Source: Oceanic Fisheries Program, Secretariat for the Pacific Community, Noumea.

Scenarios four and five see increases in the value of both longline fisheries, but these are more than offset by the declines in the value of the purse-seine fishery. Scenario two (10-week closure on associated sets) has small impacts on all fisheries, but, as previously stated, only marginally improves the stock status situation with regard to bigeye and has no impact on the yellowfin status as a result of the effort being transferred to unassociated sets. Scenario three (25 per cent reduction in longline effort) has the greatest impact on the fresh longline fishery due to its much greater dependence on the albacore fishery, for which the effort reduction has the least offset resulting from an increase in catch per unit effort as a result of the effort reduction.

Figure 2 provides the estimated changes when comparing equilibrium yields for the *status quo* and the respective scenario by species. From this, several points can be drawn: first, all scenarios except scenario three (25 per cent reduction in longline effort) result in declines in the gross value of the skipjack catch with scenarios one (25 per cent across-the-board effort reduction), four (high seas purse-seine closure) and five (six-week purse-seine closure) resulting in declines in the order of US$60–100 million. Conversely, all scenarios except scenario three result in increases in the gross value of the bigeye catch, with scenarios two (10-week closure on associated sets), four and five seeing increases in the order of US$12–25 million.

It is interesting to note that for bigeye under scenario one, despite longline effort being reduced by 25 per cent, the value of the bigeye catch increases marginally as increases in CPUE in the longline fishery more than offset the decline in effort. For albacore, the only scenarios impacting on the fishery—that is, scenarios one and three—result in declines in the value of the fishery of about US$20 million. For yellowfin, those scenarios not involving a reduction in longline effort see increases in the value of the catch for this species, whereas when longline effort is reduced the value of the yellowfin catch declines.

Figure 3 provides the estimated changes when comparing equilibrium yields for the *status quo* and the respective scenario by area. From this, several points can be drawn: firstly, only scenarios two (10-week closure on associated sets) and three (25 per cent reduction in longline effort) have similar reductions in the gross value of the fishery across areas. Of these, only scenario three has any meaningful impact on improving the situation with regard to reducing fishing mortality and moving it towards F_{MSY}. Scenarios one (25 per cent across-the-board effort reduction) and five (six-week purse-

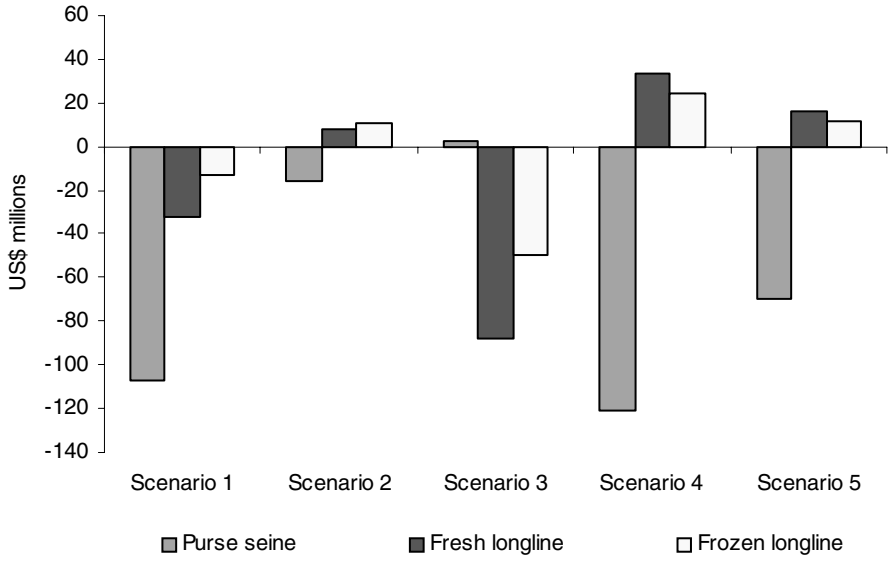
Table 5 **By species, gear and area: gross value (in US$) of the fishery at equilibrium yield under the *status quo* (in metric tonnes) and difference in the gross value of the fishery at equilibrium yield under each scenario compared with the *status quo***

	Albacore	Bigeye	Skipjack	Yellowfin	Total
Value of equilibrium yield for the *status quo*					
Purse seine					
Pacific island national waters	-	7,807,753	314,107,583	68,107,492	390,022,828
Other national waters	-	2,310,956	58,837,210	20,983,458	82,131,623
International waters	-	3,048,123	114,226,349	20,371,754	137,646,227
Total	-	13,166,832	487,171,142	109,462,704	609,800,678
Fresh longline					
Pacific island national waters	25,076,618	53,781,143	-	96,675,649	175,533,410
Other national waters	36,990,162	49,613,502	-	153,711,892	240,315,556
International waters	10,368,452	21,554,606	-	33,812,712	65,735,770
Total	72,435,232	124,949,250	-	284,200,253	481,584,735
Frozen longline					
Pacific island national waters	6,340,557	80,934,408	-	54,010,320	141,285,285
Other national waters	63,408	273,950	-	109,241	446,600
International waters	32,352,947	105,380,666	-	50,421,104	188,154,717
Total	38,756,912	186,589,025	-	104,540,665	329,886,602
Scenario 1: 25 per cent reduction in effort across all fisheries					
Purse seine					
Pacific island national waters	-	–807,225	–63,875,700	–4,083,753	–68,766,678
Other national waters	-	–238,924	–11,964,907	–1,258,177	–13,462,008
International waters	-	–315,138	–23,228,627	–1,221,499	–24,765,264
Total	-	–1,361,288	–99,069,234	–6,563,428	–106,993,950
Fresh longline					
Pacific island national waters	–4,537,445	330,637	-	–6,848,695	–11,055,503
Other national waters	–6,693,121	305,015	-	–10,889,256	–17,277,362
International waters	–1,876,102	132,514	-	–2,395,360	–4,138,947
Total	–13,106,668	768,166	-	–20,133,311	–32,471,813
Frozen longline					
Pacific island national waters	–1,147,281	497,571	-	–3,826,198	–4,475,909
Other national waters	–11,473	1,684	-	–7,739	–17,528
International waters	–5,854,048	647,862	-	–3,571,931	–8,778,117
Total	–7,012,802	1,147,117	-	–7,405,869	–13,271,555
Scenario 2: 10 week closure on associated (FAD/log) sets					
Purse seine					
Pacific island national waters	-	–761,063	–11,951,578	2,768,102	–9,944,538
Other national waters	-	–225,261	–2,238,715	852,834	–1,611,143
International waters	-	–297,117	–4,346,234	827,972	–3,815,379
Total	-	–1,283,440	–18,536,528	4,448,908	–15,371,060
Fresh longline					
Pacific island national waters	-	3,071,416	-	179,271	3,250,687
Other national waters	-	2,833,404	-	285,037	3,118,441
International waters	-	1,230,973	-	62,701	1,293,674
Total	-	7,135,793	-	527,009	7,662,802
Frozen longline					
Pacific island national waters	-	4,622,126	-	100,154	4,722,281
Other national waters	-	15,645	-	203	15,848

International waters	-	6,018,241	-	93,499	6,111,739
Total	-	10,656,012	-	193,856	10,849,868
Scenario 3: 25 per cent reduction in longline fishing					
Purse seine					
Pacific island national waters	-	172,799	-	1,610,854	1,783,652
Other national waters	-	51,145	-	496,293	547,438
International waters	-	67,460	-	481,825	549,285
Total	-	291,404	-	2,588,972	2,880,376
Fresh longline					
Pacific island national waters	–4,537,445	–5,641,029	-	–20,896,541	–31,075,015
Other national waters	–6,693,121	–5,203,891	-	–33,224,983	–45,121,995
International waters	–1,876,102	–2,260,833	-	–7,308,652	–11,445,587
Total	–13,106,668	–13,105,753	-	–61,430,176	–87,642,597
Frozen longline					
Pacific island national waters	–1,147,281	–8,489,097	-	–11,674,386	–21,310,765
Other national waters	–11,473	–28,734	-	–23,613	–63,820
International waters	–5,854,048	–11,053,231	-	–10,898,573	–27,805,853
Total	–7,012,802	–19,571,063	-	–22,596,572	–49,180,437
Scenario 4: A closure of high seas waters to the purse seine fishery					
Purse seine					
Pacific island national waters	-	0	0	0	0
Other national waters	-	0	0	0	0
International waters	-	–1,871,508	–99,069,234	–19,855,448	–120,796,190
Total	-	–1,871,508	–99,069,234	–19,855,448	–120,796,190
Fresh longline					
Pacific island national waters	-	4,718,222	-	7,732,920	12,451,142
Other national waters	-	4,352,595	-	12,295,151	16,647,746
International waters	-	1,890,987	-	2,704,621	4,595,608
Total	-	10,961,804	-	22,732,692	33,694,496
Frozen longline					
Pacific island national waters	-	7,100,380	-	4,320,193	11,420,573
Other national waters	-	24,034	-	8,738	32,772
International waters	-	9,245,051	-	4,033,098	13,278,149
Total	-	16,369,464	-	8,362,029	24,731,493
Scenario 5: Six week purse seine closure					
Purse seine					
Pacific island national waters	-	–519,644	–38,408,512	–5,879,190	–44,807,346
Other national waters	-	–153,805	–7,194,509	–1,811,339	–9,159,652
International waters	-	–202,867	–13,967,393	–1,758,535	–15,928,796
Total	-	–876,316	–59,570,414	–9,449,064	–69,895,794
Fresh longline					
Pacific island national waters	-	2,162,430	-	3,743,127	5,905,557
Other national waters	-	1,994,858	-	5,951,479	7,946,337
International waters	-	866,667	-	1,309,174	2,175,841
Total	-	5,023,954	-	11,003,780	16,027,734
Frozen longline					
Pacific island national waters	-	3,254,207	-	2,091,193	5,345,401
Other national waters	-	11,015	-	4,230	15,245
International waters	-	4,237,141	-	1,952,225	6,189,366
Total	-	7,502,364	-	4,047,648	11,550,011

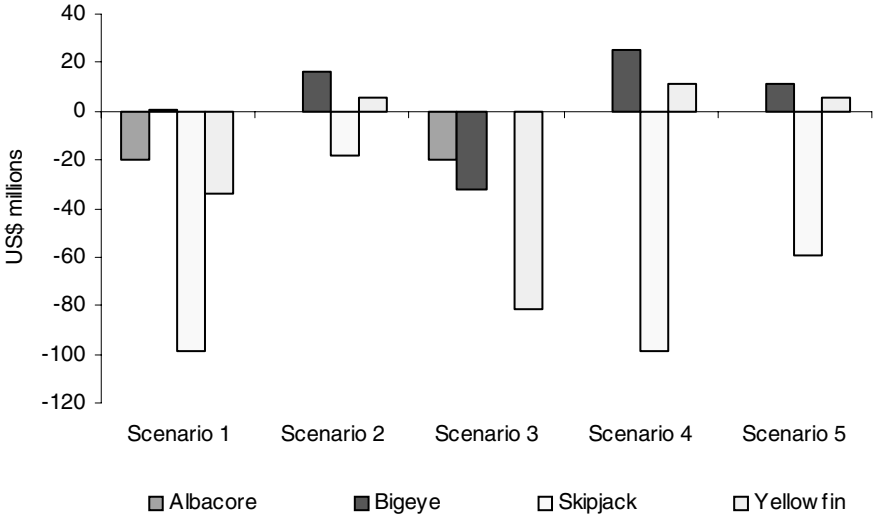
Source: Oceanic Fisheries Program, Secretariat for the Pacific Community, Noumea.

Figure 1 **Change in gross value of fishery by gear type** (US$ million)



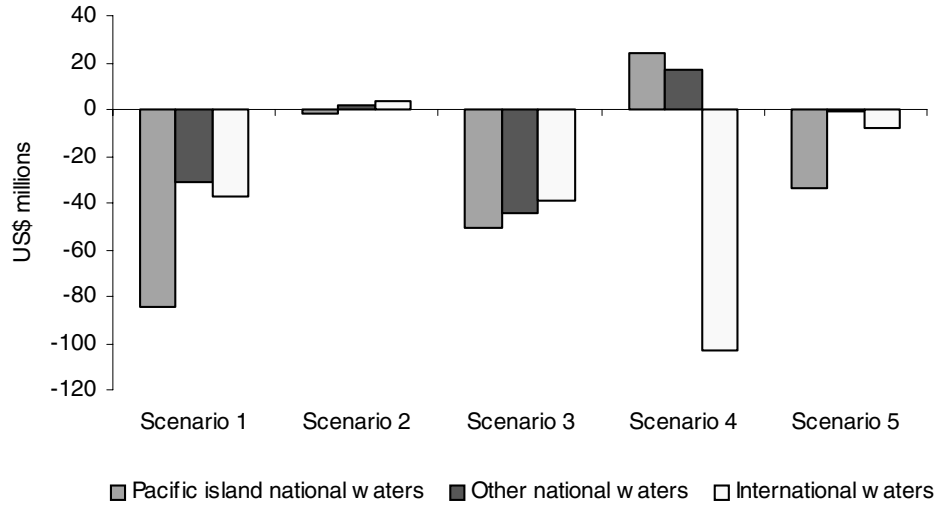
Source: Oceanic Fisheries Program, Secretariat for the Pacific Community, Noumea.

Figure 2 **Change in gross value of fishery by species** (US$ million)



Source: Oceanic Fisheries Program, Secretariat for the Pacific Community, Noumea.

Figure 3 **Change in gross value of fishery by area** (US$ million)



Source: Oceanic Fisheries Program, Secretariat for the Pacific Community, Noumea.

seine closure) result in the majority of the burden in terms of reduction of the value of the catch being borne by Pacific island countries. Scenario four (high seas purse-seine closure) results in reasonable improvements to the stock status with regard to fishing mortality, while ensuring the burden is not borne disproportionately by Pacific island countries.

Discussion

The analysis conducted here indicates that any management measure adopted by the WCPFC is likely to have widely varying impacts in terms of the gross value of the catch between areas and fleets.

Changes in gross values are, however, not necessarily a good indicator of changes in the economic value of fisheries with costs and other factors, including impacts on the economic value generated in countries which have onshore processing industries, being vital components in the determination of the level of net economic benefit that a country or fleet obtains from the exploitation of fish stocks. In addition, the estimated gross values do not take into consideration the forgone value that might be generated by increased catch levels of skipjack and albacore for which current catches are believed to be significantly below MSY levels (Langley et al. 2005; Langley and Hampton 2005).

Further, in many Pacific island countries there are large pools of under-utilised resources for which there are no or very little opportunity costs in their utilisation. Thus, processing of tuna in Pacific island countries, such as Papua New Guinea, might generate substantial economic benefits through the use of otherwise unemployed resources, particularly labour, aside from the benefits associated with value adding and

profit generation. As such, any comprehensive economic assessment of the trade-offs of reducing effort levels in the WCPTF needs to take into consideration the impact of any resulting reduction in supplies to the processing industries in such countries.

Nevertheless, the analysis does indicate that constructing management regimes that do not result in a disproportionate burden being imposed on Pacific island countries and that achieve an outcome whereby all stocks are maintained at or above the level associated with MSY is likely to be extremely difficult. This is because the value of the Pacific island countries' fisheries is derived to a large extent from the skipjack and albacore fisheries, whereas the benefits from possible management measures are likely to accrue primarily in the bigeye longline fishery as a result of CPUE increases driven by a recovery in the stock.

Conclusion

This paper provides some preliminary analysis of potential economic consequences and trade-offs of five possible management options aimed at addressing concerns relating to the sustainability of bigeye and yellowfin stocks in the WCPFC Convention Area. The results of the analysis indicate that whatever management option is chosen it is likely to lead to very different economic outcomes for different fishing fleets and countries, be they distant water fishing nations or coastal states. This in turns leads to the question of whether it is reasonable to expect one party or one group of parties to agree to measures that might have significant adverse economic consequences while other parties gain significant economic benefits without any form of compensation for the loss borne for the benefit of the other.

The report of the Norway–Food and Agriculture Organization Expert Consultation on the Management of Shared Fish Stocks (FAO 2002) noted that the consultation emphasised, among other things

> …that that the sharing of the benefits from the fisheries should not be restricted to allocations of TACs, or the equivalent, to national fleets, and; that consideration should also be given to the use of what the Consultation referred to as 'negotiation facilitators', or 'side payments', such as quota trades, or mutual access arrangements. These would allow to broaden the scope for bargaining over allocations, assist in achieving compromises when there are differences in the management goals of cooperating states/entities, and enhance the flexibility and resilience of the cooperative arrangements over time (FAO 2002).

The results of this paper provide evidence that the adoption of management measures by the WCPFC is likely to have substantially different economic outcomes for different fleets and commission members. To overcome the difficulties inherent in obtaining agreement on implementing management measures, members of the WCPFC will need to give serious consideration to the possibility of the use of 'negotiation facilitators' or 'side payments' in order to ensure that the costs and benefits of any such management measures are borne equitably between members.

Notes

1 Pacific island countries are defined as all FFA member countries except Australia and New Zealand.

2 The *status quo* is defined as average 2001–04 effort levels with the equilibrium yields for the *status quo* referring to the yields that are predicted when equilibrium is achieved. They do not refer to catches during 2001–04, which exceed predicted equilibrium yields for the *status quo* for all species.

[3] Associated fishing sets are sets made on objects that act as aggregating devices for tuna, typically floating logs or Fish Aggregating Devices deployed by vessels. This run is modelled by assuming a 20 per reduction in effort days on associated sets with a 31 per cent increase in effort days for unassociated sets so that the total effort days in the purse-seine fishery remain constant.

[4] Modelled as a 25 per cent reduction in effort in the purse-seine fishery.

[5] Modelled as a 12.5 per cent reduction in effort in the purse-seine fishery.

[6] The frozen longline fleet is defined as the distant water longline fleet of Japan, Korea and Taiwan; all other longline fleets are classified as part of the fresh longline fleet.

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