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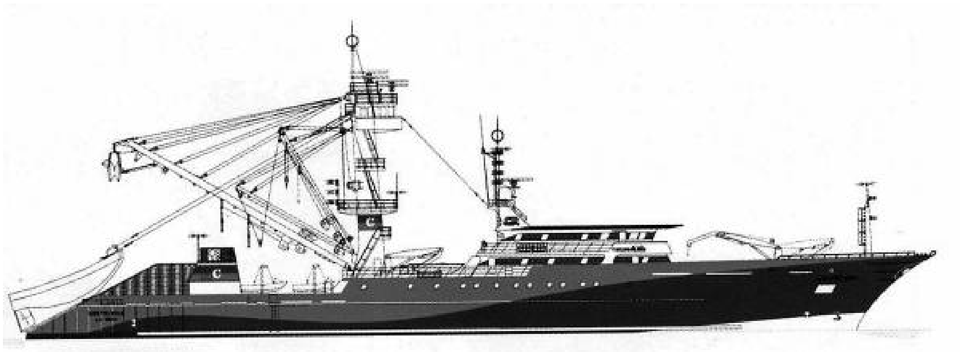
Measuring effective longline effort in the Australian Eastern Tuna and Billfish Fishery



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Measuring Effect Longline Effort in the Australian Eastern Tuna and Billfish Fishery: Project Outline

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1. Introduction

The longline sector of the Eastern Tuna and Billfish Fishery (ETBF) off eastern Australia has undergone considerable expansion over the past 5-7 years, both in the level of annual effort and spatial extent. However, as the fishery has expanded, catch and effort data have indicated that some of the earlier regions to be fished are now reporting significantly lower catch rates than previously (Campbell and Hobday 2003). As changes in catch rates are widely used as a broad indicator of changes in resource availability, this has lead to increased concern as to whether recent catch levels can be sustained.

The importance of being able to adequately interpret changes in catch rates in the ETBF is also highlighted by a constraint on assessing the resource status in the ETBF due to the fact that many of the species taken in this fishery are part of single stocks which occur throughout the broader western and central Pacific Ocean (WCPO). Due to the shared nature of these resources it is not possible to undertake a "stock assessment" on only that portion of the stock which occurs off eastern Australia unless one has an understanding of movement rates of fish into and out of this region. While stock-wide assessment models have been developed for the principal tuna species in the WCPO (SCTB 2003) the results of these assessments still remain uncertain. Furthermore, due to uncertainties in the spatial distribution of both the resource and patterns of recruitment, it remains difficult to infer from these assessments the status of a portion of the resource in a limited region such as off eastern Australia.

Given this situation, the Resource Assessment Group for the ETBF has recommended that appropriate performance indicators, based on the monitoring of temporal and spatial changes in catch rates (and sizes), be used to monitor the resource status and the success of fisheries management in the ETBF (Anon, 2003). Accurate indices of resource availability will also a critical input for the development of assessment models for those stocks (such as swordfish and striped marlin) which have a more regional SW Pacific distribution. However, if unbiased indicators of resource status are to be developed, it will be necessary to develop a better understanding of those factors, apart from resource availability, which influence catch rates.

It is well accepted that catch rates are influenced by a multitude of factors apart from resource availability and so interpreting changes in catch rates remains problematic. For example, catch rates are highly dependent on the operational and gear setting practices associated with the targeting of different species making it difficult to account for changes in the effective effort directed at particular species. Indeed, industry has suggested that recent declines in swordfish catch rates in the ETBF are due to changes in targeting practices. However, without a detailed knowledge on how such changes influence the effective effort directed at particular species, it is not possible to account for the influence of these changes on catch rates. In turn, this severely limits our ability to assess the impact of the fishery on the underlying resource.

In order to help overcome this problem, the Fisheries Research and Development Corporation (FRDC) in Australia is funding a project to collect and analyse the data on a number of factors which influence the operational effectiveness of longline fishing gears to help improve the interpretation of catch rates as indices of resource availability and help address a number of other related issues pertinent of the successful management of the ETBF. This paper provides an outline of this project (which commenced in July 2005), the types of information to be collected and analyses to be undertaken.

2. Measuring Effective Longline Effort

The catch of tunas and billfish by longline gear is known to be strongly affected by the fishing depth of the gear (Suzuki 1977, Hanamoto 1987, Boggs 1992, Uozumi and Okamoto 1997) with the relationship between catch and depth fished believed to be based on the habitat preferences of the various tuna and billfish species. Given this situation, if targeting and fishing practices (i.e. the manner in which the longline is configured and deployed) were to remain constant over time then one can assume that the depths fished by the gears and the general effectiveness of the gear in relation to any given target species will also remain generally constant over time.

However, for most fisheries it is well established that targeting and fishing practices have not remained constant over time. For example, during the mid-1970s the Japanese fleets introduced a 'deeper' longline technique to increase the effectiveness of hooks at targeting bigeye tuna which occur deeper in the water column (Suzuki et al 1977). At its simplest, deep longlining was achieved by removing every second float along the mainline. This resulted in a doubling of the length of line between floats (and a concomitant doubling of the number of hooks between floats from 5-6 to 10-12) with the result that the line hung deeper in the water column (increasing from approximately 90-150m using conventional sets to approximately 100-250m). Due to this change, there has been a need to standardize longline fishing effort for differences in gear configurations and effective fishing depths. In the ETBF a variety of fishing strategies are used to target a range of tuna and billfish species (eg. yellowfin and bigeye tuna, swordfish and striped marlin) and there have been significant changes in targeting practices over the past decade (Campbell 2005).

Based on the practice of Japanese longline vessels, most attempts to standardise longline effort have relied upon using the number of hooks between the floats as a proxy for stratifying the difference in the deeps attained by the longline gear. However, a number of recent studies in the Pacific using temperature-depth recorders (Mizuno et al 1996) and hook-timers (Somerton et al 1988) have shown that a number of factors apart for the number of hooks-between-floats influence the depths attained by longline hooks and the capture of fish. These factors include the floatline and branchline length (Nakano et al 1997, Yano et al 1998), speed at which the line is set (Mizuno et al 1997), and the prevailing currents (Boggs 1992, Uozumi and Okamoto 1997, Mizuno et al 1997, 1999). The catch is also influenced by the time-of-the-day that the set is made (Campbell et al 1997) and the capture of fish during the setting and retrieval process (when the hooks are in shallower, Boggs 1996). These studies also confirmed that the catch of particular species is highly influenced by the depths fished by the hooks (see also Mohri and Yasuaki 1997). Based on the results from these studies a number of relationships have been developed which allow prediction of the approximate depths fished by hooks given information on gear configurations and surface currents (see Bigelow et al, 2002).

While methods to standardise fishing effort to account for these “other” factors have been developed and are routinely used as part of stock assessments world-wide, in most instances the success of this exercise is limited by the absence of data on many of these factors. This is particularly the case in a multi-species fishery such as the ETBF, where one needs to know not only whether there have been changes in the effectiveness of fishing gears, but whether there have been changes in the effective targeting of particular species.

Despite these short-comings, a number of recent developments have greatly improved the ability to collect and analyse the data required to characterise the effectiveness of longline effort in the ETBF.

i) First, an observer program commenced in July 2003 within the ETBF and provides an ongoing ability to collect verified catch and effort data and other at-sea data (such as information on fishing practices) which until now has not available
ii) Second, there have recently been promising advances in the statistical integration of fisher behaviour (their targeting practices and effective depths of longline sets) with data from archival and pop-up tags on fish habitat preferences to standardize longline effort (Hinton and Nakano 1996, Bigelow, et al 2002, 2003). Put simply, these methods examine the effective fishing depths of longline hooks relative to the water mass, depth, temperature, oxygen etc preferences of the fish they are targeting to standardize the effort unit. However, the approach requires detailed information on the depth distributions of both the hooks fished by longlines and the different species which are caught, and application of this approach is presenting constrained by the lack of such data.
iii) Third, CSIRO Marine and Atmospheric Research has recently purchased longline monitoring gear (25 temperature-depth recorders and 250 hook-timers) to be deployed by ETBF observers. These gears will provide a means by which the information relating to the depths fished by longline gears together with the depths at which fish are caught can be collected.
iv) Finally, recent advances and use of archival tags, such as the recent work on bigeye in the Coral Sea (Gunn et al 2005) and further plans to release around 75 electronic tags in large pelagics off eastern Australia over the period 2004-06, together with the integration of remotely sensed data and ocean-circulation models, are greatly assisting in our ability to map the spatial habitat of target species.

3. ETBF Project

Temperature-depth monitors used in previous studies provide a good means of discriminating between the depths attained by longline hooks given differences in gear configuration, line setting practices and prevailing oceanographic conditions. As a result, the current project will make use of the methodologies developed during these previous studies to investigate the depths and temperatures fished by longline gears deployed in the ETBF and the gear configuration and line setting factors which influence the depths obtained. Together with the associated catch data, this information will be used to investigate the depth and temperature profiles at which fish are caught and the associated habitat preferences of these species within the ETBF. Using this information, and the information recorded in logbooks for the entire fleet, both the traditional GLM based method and the new habitat-based method (developed by Hinton and Nakano, 1996) will then be used to determine the effective effort targeted at the various species caught in the ETBF from which indices of resource availability based on standardised CPUE will be developed.

Given this background, the project has the following specific objectives:

1. Determination of the depths attained by longline fishing gears deployed in the ETBF and investigation of the relationships between targeting and gear setting practices and hook depths and longline shape characteristics.
2. Investigation of the relationships between hook depth and the capture depths and associated water temperatures for the principal species caught by longline gears in the ETBF.
3. Investigation of the time-of-capture of the principal catch species caught by longline gears in the ETBF.

4. Investigation, and where necessary refinement, of the technical assumptions used in the habitat based models being used to standardise longline catch per unit effort in the WCPO.
5. Development of habitat based method for standardizing longline catch rates and application to the ETBF.
6. Investigation of the relationships between longline fishing practices, gear configurations and the incidental capture of bycatch and byproduct species in the ETBF.

4. Project Methodology

Data Collection

The data on catch, effort and individual fishing practices in the longline sector of the ETBF will be collected by observers employed by the Australian Fisheries Management Authority (AFMA). The anticipated coverage of this program is 5.1% of annual effort (hooks deployed) and it has been agreed that two of the eight observers monitoring the ETBF will be associated with this project. This will provide a coverage rate for the project of approximately 1.275% of total annual effort or approximately 150 longline sets (155,000 hooks) per year. It is planned to collect data for a two year period.

Apart from the full set of catch and effort data routinely recorded by each observer, additional data on the specific setting and targeting practices used by individual vessels (eg. setting speed of vessel, hook-type, irregular gear configurations, monitoring of ocean conditions, etc) will also be collected. Furthermore, the longline monitoring gears will be used to collect information on the depth and environmental conditions in which hooks are deployed and the capture-time of fish. It is anticipated that around 12 TDRs and 100 HTs will be used by each of the two AFMA observers used during the project.

Data Analysis

A database will be established that will link all observer collected and logbook recorded data. The database will also be populated with ancillary remotely sensed oceanographic data and modelled variable-at-depth data sourced from local and global data sets to ascertain oceanic environmental conditions and to assist in the mapping of preferred habitat distributions. For example, Bigelow et al (2002) made use of a time series of oceanic temperatures-at-depth and currents obtained from an Ocean Global Circulation Model (OGCM) developed at the National Centre for Environmental Prediction (NCEP, Behringer et al 1998) and profiles of dissolved oxygen obtained from a climatological database (Levitius and Boyer 1994).

The data will be used to investigate a number of relationships, including:

i) Hook depth, longline shape characteristics, line configuration and line setting practices (Objective1). The TDRs will record the depths of monitored hooks from the time of being deployed to retrieval back on deck. By monitoring the depths of a range of hook positions the different depth profile of the hooks deployed between particular sections of the longline will be determined. The observed depths will then be related to the line configuration and line setting practices recorded by the observers for each set in order to determine those factors which influence the depths attained by hooks. Equations will be developed for predicting fishing depths based on the configuration of the gear and setting practices. Correlations between depths attained by hooks and the gear information recorded in logbooks will also be investigated. This will allow differences in targeting and setting practices (both between operators and between seasons for the same operator) identifiable from logbook entries to be related to differences in the depths attained by the longline gear.

ii) Hook depth and capture depth and temperature of target species (Objective 2). For each fish caught, the hook number (ie. the position of that hook between the float) will be recorded by observers. Combining this information with the depth and temperature profile of each hook position determined by the TDRs will allow the distribution of capture depths and temperatures for each species will be determined.

iii) Time-of-capture for target species (Objective 3). The deployed HTs will record the elapsed time between capture and the landing of the catch on the deck of the vessel. By recording the actual time that the catch is landed it will be possible to determine the actual time of capture. Combining the data from all hooks with an associated triggered HT will allow a time-profile of capture for the main target species to the determined. Note: as the hook-timers provide information on the catch versus time-of-day, the data collected will allow possible biases in the analysis of preferred catch depths to be identified due to the capture of fish upon line setting and line retrieval.

The data and resulting gear-depth-temperature-catch relationships will be compared with the results of similar research carried out in other regions of the Pacific Ocean (eg. Boggs 1992, Mizuno et al 1998, Mohri 1997). The observed relationships of catch-by-depth and habitat preferences will also be compared with the relationships inferred from the data being retrieved from archival tags, both within the ETBF and elsewhere (see Bigelow et al 2002 for summary). This will be used to validate and where necessary improve our current understanding about hooks depths and species habitat preferences being used in the habitat-based models used to standardise catch rates in the WCPO (Objective 4). Where model assumptions are found to be invalid, alternative models will be developed.

Development of Standardised CPUE Indices (Objective 5).

The above results will be used to develop a habitat-based method to estimate effective effort and standardise catch rates in the ETBF. The resulting indices of annual abundance will be compared with the indices based on a tradition GLM based standardisation.

Habitat-based Approach: The variation in fishing depths of longlines and the depth of the preferred habitat can be used directly to standardize longline CPUE. The approach used will be based on the method first described by Hinton and Nakano (1996), who applied this method to blue marlin in the Pacific, and more recently used by scientists at SPC as part of the annual stock assessments for yellowfin and bigeye tuna in the WCPO (see Bigelow et al 2002, 2003). The essential elements in the model are: (1) estimation of the depth distribution of the longline gear deployed by vessels in the ETBF - this will be achieved using information on fishing practices described in logbooks and the information relating depths and gear configurations investigated by the project; (2) estimation of the depth distribution of the species of interest, based on habitat preference and oceanographic data - this will be achieved by combining the habitat preference information gained this project and other projects undertaken elsewhere in the Pacific with the oceanographic data obtained from various sources; (3) estimation of effective longline effort - this is achieved by integrating over the product of the depth distributions of the hooks and species described above; and (4) aggregation of catch and effective effort over appropriate spatial zones to produce time series of standardised CPUE.

Interactions with By-Product Species (Objective 6)

Information on catch-by-hook position for by-catch and by-product species (recorded by observers) will be combined with information on depths and temperatures fished by the various hook positions and gear configurations to investigate the relationships between the capture of non-target species and fishing depths. Furthermore, where sufficient observations exist to establish the time-of-capture for non-target species, the susceptibility of these species to capture during the line setting and line hauling process will also be investigated. The methods used will be similar to described by Boggs (1992) and Campbell et al (1997) and used for investigating the relationship between fishing practices and the capture of black marlin in the Coral Sea.

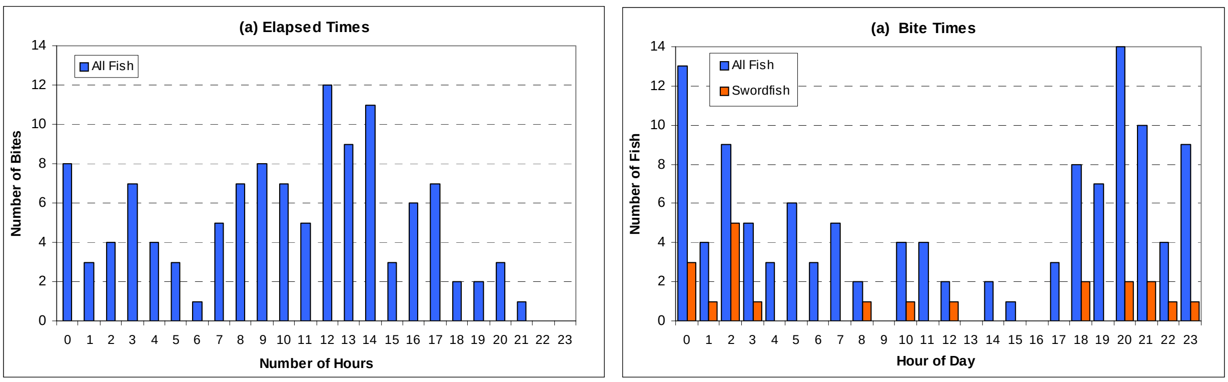
5. Preliminary Results

Hook-timer information has been obtained from 30 longline sets and the time of capture has been ascertained for 118 fish. The list of species, elapsed times since capture, and the estimated times of capture are detailed in Table 1 and Figures 1a,b. Over half (54%) of the triggered hook-timers have been retrieved with no fish attached to the hook (recorded as UNK in Table 1). It is possible that the hook-timer may be triggered during the line-retrieval process, but the proportion of timers with an elapsed time less than 1 hour is not significantly different from other elapsed times (cf. Figure 1a). Given this observation it is considered more likely that a high proportion of baits are being taken without the fish being hooked. This is supported by multiple baits sometime being noted in the stomachs of landed fish. The estimated bite-times (cf. Figure 1b) shows a preference for night hours, though this result will no doubt be influenced by the actual soak times of each set. Further analysis is required to account for this effect.

Table 1. List of species captured on hooks with associated hook-timer data.

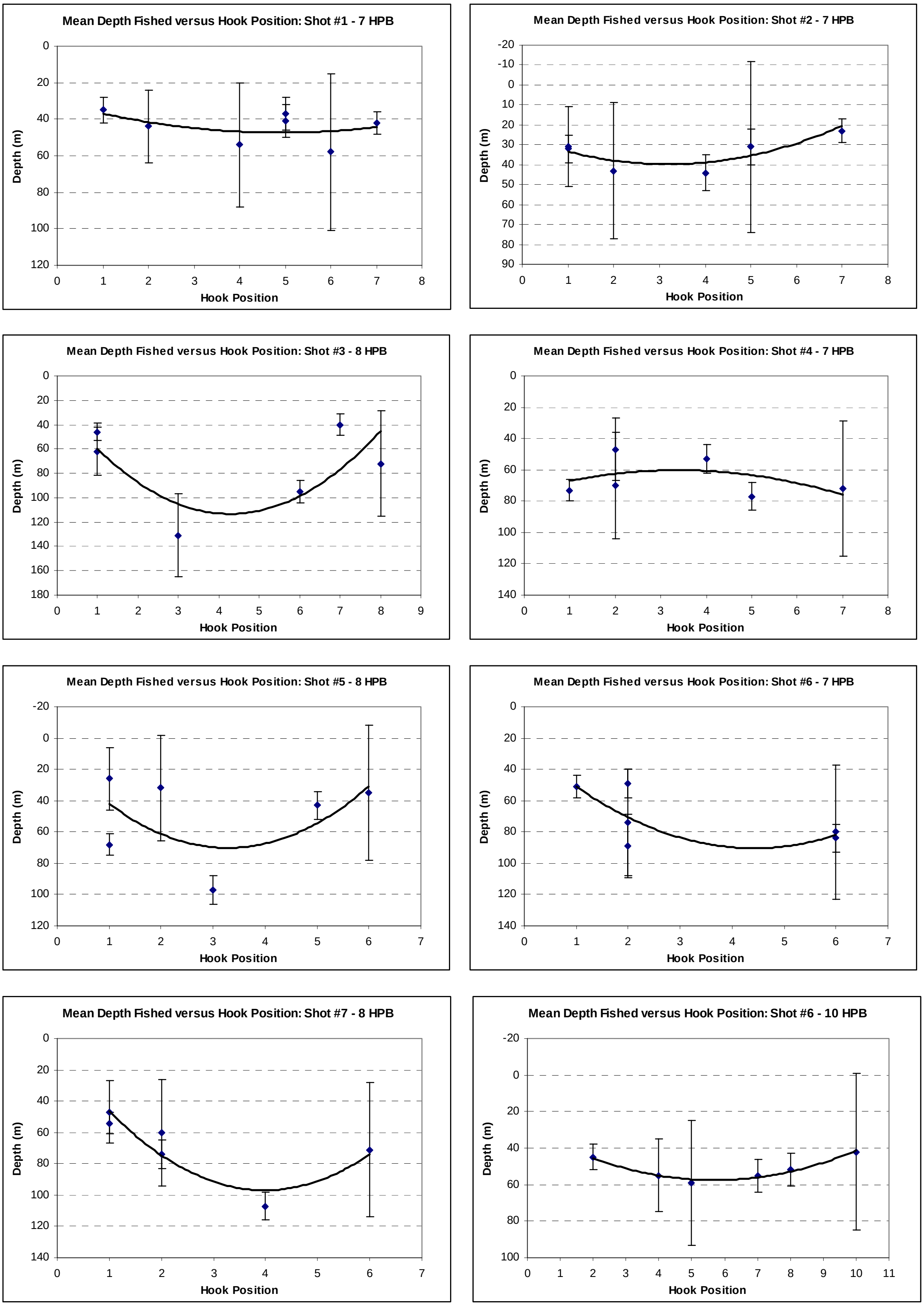
Species Code	Species Name	Number
UNK	Unknown	64
SWO	Swordfish	21
ALB	Albacore Tuna	10
MLS	Striped Marlin	5
DOL	Dolphin Fish	4
YFT	Yellowfin Tuna	3
BET	Bigeye Tuna	3
LEC	Black Oilfish	3
BSH	Blue Shark	2
MOP	Sunfish	1
TIG	Tiger Shark	1
MOO	Moonfish	1
Total		118

Figure 1



To date, time series of temperatures and depths fished by individual hooks have been collected for several hundred hooks. This data is in the process of being loaded into the data base before being analysed. An example of the mean depths fished by hook position collected during eight sets deployed during a single trip is shown in Figure 2.

Figure 2. Mean depth fished versus hook position between floats for eight longline sets deployed during a single trip. The standard deviation of the depths fished by each hook is also shown. A quadratic trend line of depth versus hook position has been fitted to the data. The number of hooked-per-basket (HPB) in indicated for each set. Note: these sets deployed float lines of length 10m or 20m, and branch lines of length 28m.



Acknowledgements

This project would not be possible without the support of the ETBF. In particular, we would like to extend our thanks the following people: 1) the AFMA observers who have deployed the gears monitors and collected data: Andrew Bayne, Steve Hall, Craig Bambling and Dave Penson, 2) the manager of the AFMA observer programr, Martin Scott, and 3) the skippers and crew of the vessels who have participated in the project to date.

Note: A list of other ongoing and recently completed projects related to the ETBF is provided as an attachment.

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Attachment

1) Other ongoing projects related to the ETBF

a) Stock assessment of striped marlin in the south-western Pacific Ocean (PI: Don Bromhead, BRS)

b) Determination of the ecological impacts of longline fishing in the ETBF (PI: Jock Young, CSIRO)

c) Development of a robust suite of stock status indicators for the Southern and Western and Eastern Tuna and Billfish fisheries (PI: Marinelle Basson, CSIRO)

d) Determination of effective longline effort in the ETBF (PI: Robert Campbell, CSIRO)

e) Reduction of interactions by marine mammals with longline and gillnet gears: development and assessment of predation and by-catch mitigation devices (PI, Geoff MacPherson, QDPI)

f) Archival hard parts collection, a basis for routine ageing of tuna and billfish (PI: Clive Stanley, CSIRO)

g) Mitigation measures to reduce longline interaction with seabirds (PI: Graham Robertson, AAD)

h) Integrated assessment and the development and evaluation of an assessment framework for the ETBF (PI: Robert Campbell, CSIRO)

2) Recently completed projects related to the ETBF

a) Byproduct: Catch, economics and co-occurrence in Australia's tuna and billfish fisheries (PI, Don Bromhead, BRS, in press)

b) Integrated analysis and assessment of the ETBF (PI: Robert Campbell, CSIRO, in press)

c) Migration and habitat preferences of bigeye tuna on the east coast of Australia (PI, John Gunn, CSIRO, May 2005)

d) Crossing the line: sea turtle handling guidelines for the longline fishing industry (PI: Caroline Robins, Belldi Consultancy, Feb 2005)

e) Age and growth of broadbill swordfish from Australian waters (PI: Jock Young, CSIRO, Sep 2004)

f) New deep setting longline technique for bycatch mitigation (PI: Steve Beverley, SPC, Seanet, Aug 2004)

g) Assessment of blue shark population status in the western south Pacific (PI: John Stevens. CSIRO, 2004)

h) Age and growth of bigeye tuna from the eastern and western AFZ (PI: Jock Young, CSIRO, Dec 2003)

i) Development of an operating model and evaluation of harvest strategies for the ETBF (PI: Robert Campbell, CSIRO, Nov 2003)

j) Swordfish-environment-seamount-fishery interactions off eastern Australia (PI: Robert Campbell, CSIRO, Oct 2003)

k) Striped marlin: biology and fisheries (PI: Don Bromhead, BRS, 2003)

Note:
PI: Principal Investigator
CSIRO: Commonwealth Scientific and Industrial Research Organisation
BRS: Bureau of Rural Science, Canberra
AAD: Australian Antarctic Division
QDPI: Queensland Department of Primary Industries