Rapid quantitative risk assessment for fish species in seven Commonwealth fisheries

Shijie Zhou, Mike Fuller, Tony Smith
April 2009
Australian Fisheries Management Authority

Rapid quantitative risk assessment for fish species in additional seven Commonwealth fisheries

Shijie Zhou, Mike Fuller, Tony Smith
April 2009
Australian Fisheries Management Authority

Enquiries should be addressed to:

Shijie Zhou, Ph.D.
Marine and Atmospheric Research
233 Middle Street, Cleveland, Qld 4163
Phone: (07) 3826-7263
Fax: (07) 3826-7222
Email: shijie.zhou@csiro.au

Distribution list

Project Manager	
On-line approval to publish	
Client	
Authors	
Other CSIRO Staff	
National Library	
State Library	
CMAR Library as pdf (Meredith Hepburn)	
CMAR Web Manager as pdf (Diana Reale)	

Important Notice

© Copyright Commonwealth Scientific and Industrial Research Organisation ('CSIRO') Australia 2005

All rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of CSIRO.

The results and analyses contained in this Report are based on a number of technical, circumstantial or otherwise specified assumptions and parameters.

Use of this Report

The use of this Report is subject to the terms on which it was prepared by CSIRO. In particular, the Report may only be used for the following purposes.

- this Report may be copied for distribution within the Client's organisation;
- the information in this Report may be used by the entity for which it was prepared ("the Client"), or by the Client's contractors and agents, for the Client's internal business operations (but not licensing to third parties);
- extracts of the Report distributed for these purposes must clearly note that the extract is part of a larger Report prepared by CSIRO for the Client.

The Report must not be used as a means of endorsement without the prior written consent of CSIRO.

The name, trade mark or logo of CSIRO must not be used without the prior written consent of CSIRO.

Table of contents

List of Tables

List of Figures

Non-Technical Summary

This report is an extension of the project "Rapid quantitative risk assessment for fish species in selected Commonwealth fisheries" (Zhou et al. 2007). In the previous report sustainability assessment for fishing effects (SAFE) was conducted for three major Commonwealth fisheries: the Southern and Eastern Scalefish and Shark Fishery (SESSF, including five sub-fisheries), the Eastern Tuna and Billfish Fishery (ETBF), and the Northern Prawn Fishery (NPF). In this report, we performed SAFE for seven additional Commonwealth fisheries:

(1) North West Slope Trawl Fishery (NWSTF);
(2) Skipjack Tuna Fishery (SKJTF);
(3) Small Pelagic Fishery (SPF), including Purse Seine Sub-fishery and Mid-water Trawl Sub-fishery;
(4) Southern Bluefin Tuna Fishery (SBTF);
(5) Western Deepwater Trawl Fishery (WDWTF);
(6) Western Tuna and Billfish Fishery (WTBF); and
(7) Sub-Antarctic Fishery, including Heard Island & McDonald Islands Fishery (HIMI) demersal Trawl Sub-fishery, HIMI Mid-water Trawl Sub-fishery, HIMI Longline Sub-fishery, Macquarie Island (MIF) Trawl Sub-fishery, and MIF Mid-water Trawl,

The data sources and methods are essentially the same as in Zhou et al. report (2007). The focus is on fish taken as byproduct or bycatch. The general approach for fishing mortality estimation involves estimating spatial overlap between species distribution and fishing effort distribution, catchability resulting from probability of encountering the gear and size-dependent selectivity, and post-capture mortality. Fish life history parameters are used to established reference points. These parameters are the same as used in the ERAEF Level 2 PSA for fisheries (2) to (7) listed above (Smith et al. 2007; Hobday et al. 2007). However, there are a few new features in this report:

(1) PSA was not carried out for fish species potentially impacted by the NWSTF. The analysis was started from scratch for fish species in this fishery.
(2) The assessment was for the four years duration between 2004 and 2007 rather than 2003-2006 as in the previous report.
(3) We used instantaneous fishing mortality rate F instead of exploitation rate u. This will allow easier comparison of the results with the Harvest Strategy Framework (DAFF 2007).

(4) For species that do not have spatial distribution information or their distribution cannot be determined because of pelagic behaviour, we used longer effort time-series data and/or fraction of fishable areas fished to infer current relative fishing impacts.
(5) There is no spatial distribution of fish species for the sub-Antarctic fisheries. We developed an alternative approach using logbook and observer data to derive species distribution.
(6) We derived and applied a new relationship between reference points and life history parameter for chondrichthyans, which is more conservative than the one adopted in a wide range of literature and our previous studies.

We included all non-target fish species (chondrichthyans and teleosts), either by-product, discarded, or TEPs, on the PSA list, but excluded other taxa (invertebrates, reptiles, birds, and mammals). Where available data exist, we also looked at target species in some fisheries. The results are summarized as follows:

North West Slope Trawl Fishery: 65 species (9 chondrichthyans and 56 teleosts). No species suffers fishing mortality greater than or equal to the fishing mortality corresponding to the maximum sustainable number of death due to fishing during 2004-2007 assessment period. According to the definition of risk categories (Zhou et al 2007), this means that the current fishing intensity imposes low risk to all species assessed in this fishery.

Skipjack Tuna Fishery: 144 species (8 chondrichthyans and 136 teleosts). The current fishing intensity imposes low risk to all species assessed in this fishery.

Small Pelagic Fishery: 100 species (3 chondrichthyans and 97 teleosts) in Purse Seine and Mid-water sub-fisheries. The current cumulative fishing intensity from the two sub-fisheries imposes low risk to all non-target species assessed in this fishery.

Southern Bluefin Tuna Fishery: 83 species (6 chondrichthyans and 77 teleosts). The current fishing intensity imposes low risk to all non-target species assessed in this fishery.

Western Deepwater Trawl Fishery: 103 species (23 chondrichthyans and 80 teleosts). The current fishing intensity imposes low risk to all non-target species assessed in this fishery.

Western Tuna and Billfish Fishery: 187 species (38 chondrichthyans and 149 teleosts). The current fishing intensity imposes low risk to all non-target species assessed in this fishery.

Sub-Antarctic Fishery: the Heard Island & McDonald Islands Fishery including three sub-fisheries: HIMI demersal Trawl Sub-fishery, HIMI Mid-water Trawl Sub-fishery, and HIMI Demersal Longline Sub-fishery. The Macquarie Island Fishery includes MI Demersal Trawl Sub-fishery.

HIMI Fishery: we included 67 species (8 chondrichthyans and 59 teleosts) in the assessment. No species has estimated current fishing mortality greater than its mean maximum sustainable fishing mortality reference point (mean F_{msm}). However, three chondrichthyans (skates in family Rajidae) have estimated fishing mortality greater than their minimum sustainable fishing mortality (min[F_{msm}]): *Bathyraja irrasa*, *B. murrayi*, and *B. eatonii*. It is possible that these may be false positive risks as the fishing mortalities may have been overestimated for the HIMI Fishery due to the method of determining spatial distribution for the species (see main report for details).

MIF Fishery: 56 species (2 chondrichthyans and 54 teleosts). No species has estimated current fishing mortality greater than its sustainability reference points.

Reference

DAFF. (2007) Commonwealth Fisheries Harvest Strategy: policy and guidelines. Australian Department of Agricultrue, Fisheries and Forestry. Canberra.

Hobday, A. J., A. Smith, H. Webb, R. Daley, S. Wayte, C. Bulman, J. Dowdney, A. Williams, M. Sporcic, J. Dambacher, M. Fuller, T. Walker. (2007) Ecological Risk Assessment for the Effects of Fishing: Methodology. Report R04/1072 for the Australian Fisheries Management Authority, Canberra

Smith , A.D.M., A. J. Hobday, H. Webb, R. Daley, S. Wayte, C. Bulman, J. Dowdney, A. Williams, M. Sporcic, J. Dambacher, M. Fuller, D. Furlani, S. Griffiths, R. Kenyon and T. Walker. (2007) Ecological Risk Assessment for the Effects of Fishing: Final Report R04/1072 for the Australian Fisheries Management Authority, Canberra

Zhou, S., Smith, T., and Fuller, M. 2007. Rapid quantitative risk assessment for fish species in major Commonwealth fisheries. Report to the Australian Fisheries Management Authority.

Acknowledgements

We thank many people who provided data, suggestions, comments, or other contributions to this project. Ross Daley gave a variety of assistance (data, comments, and suggestions) from the beginning of the project. Geoff Tuck provided MIF stock assessment reports and results. Dirk Welsford at the AAD provided stock assessment reports and suggestions for the HIMI fisheries. We benefited from discussions with Cathy Bulman, Peter Last, and Alan Williams on data sources and qualities. Many colleagues in AFMA provided data, fishery information, and guidelines, including Dave Johnson, Mandy Goodspeed, Peter Neave, and Selvy Coundjid. This project was funded by the Australian Fisheries Management Authority.

Chapter 1. Introduction

Ecological risk assessments (ERAs) have been prepared for most AFMA managed fisheries (Smith et al. 2007). In these assessments the risks calculated are based on qualitative and semi-quantitative methods that use proxies for fishing impact. These methods provide relative risk for impacted species but do not provide quantitative management benchmarks similar to that in the harvest strategy framework (Hobday et al. 2007).

A rapid quantitative sustainability assessment of the complete list of species identified by the ERA process as likely to interact with fishing operations of the Southern and Eastern Scalefish and Shark Fishery and the Eastern Tuna and Billfish Fishery has recently been completed (Zhou et al. 2007). The outcome of this analysis, when considered with the results of the ERA Level 2, provides AFMA with a more refined list of species on which to focus management responses.

In April 2008, AFMA requested that the rapid quantitative methodology be applied to those species identified as a priority from the outcome of the ERA Level 2 process for the following seven Commonwealth managed fisheries:

North West Slope Trawl Fishery
Skipjack Tuna Fishery
Small Pelagic Fishery
Southern Bluefin Tuna Fishery
Western Deepwater Trawl Fishery
Western Tuna and Billfish Fishery
Sub-Antarctic Fisheries

The requested research was to be a rapid assessment using currently available techniques and information, with results expected to be delivered within 6 to 12 months. Some consideration has been given to applying a consistency of terms between this assessment and those used in the ERA Level 2 and Harvest Strategy Framework to ensure greater end user understanding and comparison of results.

The results of research under this project scope will directly feed into AFMA’s Ecological Risk Management (ERM) process. It provides direct measures of risk from direct impacts of fishing for a large number of species from both individual and the cumulative effects resulting from all Commonwealth managed fisheries examined so far. This will more clearly define the level of risk that fishing poses to particular species – and directly facilitate more informed/better decision making.

We applied the SAFE method (Zhou and Griffiths 2008; Zhou et al. 2007) to the above seven Commonwealth fisheries. To avoid being impacted by any possible false negative results from ERA Level 2, we included not only those species identified at risk but all non-target fish species identified by the ERA process as likely to interact with fishing operations in these seven fisheries. The methods of analysis have been modified or further improved for these additional fisheries. This report details the assessment results for these fisheries.

Reference

Hobday, A. J., Smith, A. D. M, Webb, H. Daley, R., Wayte, S., Bulman, C., Dowdney, J., Williams, A., Sporcic, M., Dambacher, J., Fuller, M., and Walker, T. (2007) Ecological Risk Assessment for the Effects of Fishing: Methodology. Report R04/1072 for the Australian Fisheries Management Authority, Canberra

Smith, A. D. M., Hobday, A. J., Webb, H., Daley, R., Wayte, S., Bulman, C., Dowdney, J., Williams, A., Sporcic, M., Dambacher, J., Fuller, M., Furlani, D., Griffiths, S., Kenyon R. and Walker, T. (2007) Ecological Risk Assessment for the Effects of Fishing: Final Report R04/1072 for the Australian Fisheries Management Authority, Canberra

Zhou, S., and Griffiths, S. P. (2008) Sustainability Assessment for Fishing Effects (SAFE): a new quantitative ecological risk assessment method and its application to elasmobranch bycatch in an Australian trawl fishery. Fisheries Research 91: 56-68.

Zhou, S., Smith, T., and Fuller, M. (2007) Rapid quantitative risk assessment for fish species in major Commonwealth fisheries. Report to the Australian Fisheries Management Authority.

Chapter 2. North West Slope Trawl Fishery

2.1. Introduction

The North West Slope Trawl Fishery (NWSTF) is located in deepwater off the north-western coast of Western Australia and operates seaward from a management boundary approximating the 200 m isobath to the edge of the Australian Fishing Zone (AFZ) (Figure 2-1). The fishery's western boundary adjoins the Western Deepwater Trawl Fishery at longitude 114°E. The eastern boundary forms at roughly 125°E but does not extend to the outer limit of the AFZ due to the arrangement of the Australian-Indonesian maritime boundaries in the Timor Sea.

The NWSTF is based on commercial stocks of deepwater crustaceans, principally scampi and prawns. There are three main commercially important species of scampi (*Metanephrops velutinus, M. australiensis,* and *M. boschmai*) and four penaeid species (*Aristaeomorpha foliacea*, *Haliporoides sibogae*, *Aristeus virilis* and *Aristaeopsis edwardsiana*).

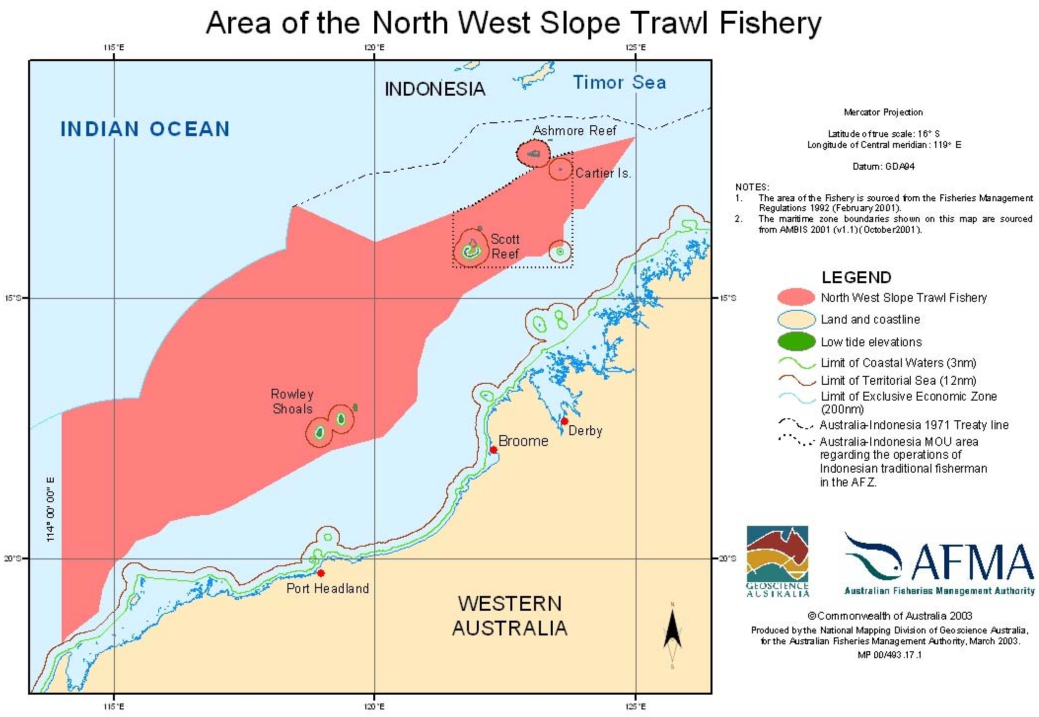

Figure 2-1. Map of the **North West Slope Trawl Fishery**.

Prawn trawlers are modified for deepwater trawling operations in the NWSTF (Wayte et al. 2007). Florida flyer banana prawn nets used in the Northern Prawn Fishery are modified and used in the NWSTF. Vessels tow nets in either dual or triple arrays giving a total headrope length of between 47 and 75 m depending on vessel power (Evans 1992). Wing mesh size is typically 60 mm for prawns and 90mm for scampi with codends generally a heavier gauge 45 mm mesh regardless of the target species (Evans 1992). There is no restriction on net headrope length but a maximum mesh size (50 mm) applies in order to discourage any targeting of demersal finfish.

Trawling is generally considered as non-selective. It operates at depths between 200 m to 600 m. The nets are typically towed at 3 knots along relatively flat mud or silt substrates. Hard bottom areas or rocky outcrops are avoided as these areas are not ideal scampi habitat and also lead to snaring and damage of nets. Shot duration is typically 3-5 hours with a combined shoot-away and haul-up time of around one hour at 500 m (Evans 1992). In order to minimise product damage, shot duration is reduced when targeting deepwater prawns due to their more fragile nature (Evans 1992). Trawling usually occurs around the clock.

The SAFE method considers actual fishing effort as an important factor that affects sustainability of species encountered by the fishery. If the fishery is closed or fishing effort is zero then there is no fishing impact on any species. Between 5 and 10 vessels operated in the NWSTF and annual effort varied between 4,936 h and 8,147 h during 2001-2004 (Wayte et al. 2007). Such a level of effort is relatively low considering the large area fished.

In the ERA report, the Level 2 PSA was performed for the seven target invertebrate species only (Wayte et al. 2007). In this assessment, we built life history attributes from various data sources similar to the Level 2 assessment of other fisheries. We included a total of 64 fish species (of which 9 are chondrichthyans).

2.2. Method

2.2.1. Estimating instantaneous fishing mortality *F*

To ensure greater end user understanding and comparison of results, we have tried to be more consistent with terms used in this assessment and those used in the Harvest Strategy Framework. Therefore in this report we used instantaneous fishing mortality F instead of annual fishing mortality rate expressed as a fraction of population death due to fishing (u used in the previous assessment (Zhou et al. 2007), which is similar to the exploitation rate). We used actual logbook data from 2004 to 2007 to map effort distribution, while Bioregional mapping and Core range species mapping provided species distribution (Commonwealth of

Australia 2005; Heap et al. 2005). First, the number of individual for species *i* in year *y* caught and killed by trawling between time t1 to t2 is:

$$
\begin{aligned}
C_{y,i} &= \int_{t1}^{t2} a_{t.i} d_{t,i} q_i^h q_i^\lambda (1 - S_i) dt \\
&= \int_{t1}^{t2} a_{t.i} d_{0,i} e^{-Zt} q_i^h q_i^\lambda (1 - S_i) dt
\end{aligned}
\qquad (2\text{-}1)
$$

Where $C_{y,i}$ = catch of species *i* in year *y* dead after discard;
$a_{t,i}$ = area trawled at time *t* in that year;
$d_{t,i}$ = density of species *i* at time *t*;
q_i^h = habitat-dependent encounterability;
q_i^λ = size- and behaviour-dependent selectivity.
S_i = the post-capture survival rate;
$d_{0,i}$ = density of species *i* at $t = 0$ (e.g., beginning of fishing);
Z = total mortality, i.e., sum of fishing mortality F and natural mortality M.

Population size or density $d_{t,i}$ may reduce over time due to fishing mortality and natural mortality. Assuming fishing effort evenly spreads out over the year, i.e., the swept area $a_{t,i}$ is constant for all *t*, integrating over one year from *t*1 to *t*2, we then have:

$$
\begin{aligned}
C_{y,i} &= q_i^h q_i^\lambda (1 - S_i) \int_{t1}^{t2} a_{t.i} d_{0,i} e^{-Z_i t} dt \\
&= q_i^h q_i^\lambda (1 - S_i) \frac{d_{0,i}(1 - e^{-Z_i})}{Z_i} \sum_t a_{t,i} \\
&= q_i^h q_i^\lambda (1 - S_i) \frac{d_{0,i}(1 - e^{-Z_i})}{Z_i} \sum_t L_{t,i} W
\end{aligned}
\qquad (2\text{-}2)
$$

where
$L_{t,i}$ = trawl length based on start and end locations at time *t* that occurs within the species distribution range;
W = width of trawl wing spread.

Secondly, by assuming individuals of species *i* evenly distribute within occupied area A_i within the fishery jurisdiction, the mean population size over one year can be obtained as (Quinn and Deriso 1999):

$$\bar{N}_{y,i} = \frac{N_{0,i}(1-e^{-z_i})}{Z_i} = \frac{A_i d_{0,i}(1-e^{-z_i})}{Z_i} \qquad (2\text{-}3)$$

Where $N_{0,i}$ is the initial abundance of species *i* when fishing begins in year *y*. If space-dependent species density is known (e.g., fish density may vary between fished and unfished areas), there is no need to assume that individuals of species evenly distribute within occupied area. Density at different locations can be used to obtain more accurate abundance estimations in Eqns 2-2 and 2-3. Finally, the annual instantaneous fishing mortality in year *y*, $F_{y,i}$ is derived from (2.2) and (2.3):

$$F_{y,i} = \frac{C_{y,i}}{\bar{N}_{y,i}} = \frac{q_i^h q_i^\lambda (1-S_i)\sum_t L_{t,i} W}{A_i} \qquad (2\text{-}4)$$

The current fishing mortality for each species F_{cur} is the average of $F_{y,i}$ over the period 2004 to 2007. The parameters used in these equations are the same as in Zhou et al. (2007) and Wayte et al. (2007).

If fishing occurs year-round, the fraction of population killed by fishing, i.e., exploitation rate $u_{y,i}$ will be:

$$u_{y,i} = \frac{C_{y,i}}{N_{0,i}} = \frac{\sum a_i \frac{d_{0,i}(1-e^{z_i})}{Z_i} q_i^h q_i^\lambda (1-S_i)}{A_i d_{0,i}} = \frac{q_i^h q_i^\lambda (1-S_i)(1-e^{z_i})\sum_t L_{t,i} W}{A_i Z_i} = F_{y,i}\frac{1-e^{-z_i}}{Z_i} \qquad (2\text{-}5)$$

For species with a low natural mortality, if fishing occurs in a relatively short time, then ignoring natural mortality during the fishing season the estimated fraction of population killed by fishing $u_{y,i}$ will be:

$$\begin{aligned} u_{y,i} &= \frac{C_{y,i}}{N_{0,i}} \\ &= F_{y,i} \frac{1-e^{-Z_i}}{Z_i} \\ &\approx 1-e^{-F_{y,i}} \end{aligned} \qquad (2\text{-}6)$$

Similarly, the current fishing mortality expressed as a fraction of population death for each species u_{cur} is the average of $u_{y,i}$ over four years from 2004 to 2007. The actual fishing impact should be between Eqns (2-4) and (2-5) but may be closer to the former. *F* and *u* are similar at low values. Table 2-1 gives some examples using Eqn 2-6.

Table 2-1. Some values of instantaneous fishing mortality *F* and annual exploitation rate *u*.

F	*u*	*F*	*u*	*F*	*u*
0.10	0.10	0.80	0.55	1.50	0.78
0.20	0.18	0.90	0.59	1.60	0.80
0.30	0.26	1.00	0.63	1.70	0.82
0.40	0.33	1.10	0.67	1.80	0.83
0.50	0.39	1.20	0.70	1.90	0.85
0.60	0.45	1.30	0.73	2.00	0.86
0.70	0.50	1.40	0.75	2.10	0.88

2.2.2. Reference points

We defined the following three biological reference points based on a simple surplus production model as in Zhou et al. 2007:

F_{msm} = instantaneous fishing mortality corresponding to the maximum sustainable death due to fishing (maximum sustainable mortality of fishing, *MSM*) at B_{msm} (biomass that supports *MSM*). This is similar to the F_{msy} that supports a maximum sustainable yield for target species. For simplicity we call F_{msm} “maximum sustainable (instantaneous) fishing mortality (rate)”;

F_{lim} = instantaneous fishing mortality corresponding to limit biomass B_{lim}, where B_{lim} is defined as half of the biomass that supports a maximum sustainable fishing mortality ($0.5B_{msm}$). We refer F_{lim} as “limit fishing mortality (rate)”; and

F_{crash} = minimum unsustainable fishing mortality that, in theory, will lead to population extinction in the longer term.

We assumed these reference points to be a function of basic life history parameters of each species. Recently, we developed a new relationship between management reference points and life history using data collected for more than 100 fish species from literature. We divided them into two major taxonomic groups: teleosts and chondrichthyans. For teleosts we linked them to the intrinsic population growth rate *r* and instantaneous natural mortality *M*. Many species have published estimates for *r* and/or *M*. We also estimated *M* based on growth parameters, maximum length, environmental temperature, longevity, and age at maturity. We applied a total of six methods to derive these reference points:

(1) $F_{msm} = r/2$, $F_{lim} = 0.75\, r$, and $F_{crash} = r$;
(2) $F_{msm} = M$, $F_{lim} = 1.5\, M$, and $F_{crash} = 2M$;
(3) $F_{msm} = M$, $F_{lim} = 1.5\, M$, and $F_{crash} = 2M$, where $\ln(M) = -0.0152 - 0.279 \ln(L_\infty) + 0.6543 \ln(k) + 0.4634 \ln(T)$ (Pauly 1980; Quinn and Deriso 1999);
(4) $F_{msm} = M$, $F_{lim} = 1.5\, M$, and $F_{crash} = 2M$, where $\ln(M) = 1.44 - 0.982 \ln(t_m)$ (Hoenig 1983).
(5) $F_{msm} = M$, $F_{lim} = 1.5\, M$, and $F_{crash} = 2M$, where $M = 10^{0.566-0.718\ln(L_\infty)} + 0.02T$ (www.Fishbase.org);
(6) $F_{msm} = M$, $F_{lim} = 1.5\, M$, and $F_{crash} = 2M$, where $M = 1.65/t_{mat}$ (Jensen 1996);

In these equations, *k* and L_∞ are von Bertalanffy growth parameters, *T* = average annual water temperature, t_m = maximum reproductive age, and t_{mat} = average age at maturity. If L_∞ is unknown but the maximum length L_{max} is known, we estimated length infinity as: $\log(L_\infty) = 0.044 + 0.9841 \log(L_{\max})$ (Froese and Binohlan 2000). Considering the uncertainty in the parameters themselves that come from the literature and from applying the methods, we gave equal weight to these six methods to derive the mean and ranges of F_{msm}, F_{lim}, and F_{crash}.

For chondrichthyans, we derived $F_{msm} = 0.42\, M$, based on data from 24 species. Similar to teleosts, we defined $F_{lim} = 0.63\, M$, and $F_{crash} = 0.84\, M$.

2.3. Results

We included 9 chondrichthyan and 56 teleost species in the assessment. Among these 65 species, 4 chondrichthyans and 16 teleosts have no spatial distribution information. The estimated spatial overlap between fishing effort and species distribution is low, ranging from 0 to 0.015 for the 45 species that have spatial data. As a result, estimated fishing mortality F_{cur} is low and no species has $F_{cur} > F_{msm}$ within the assessment period (2004-2007, Figure 2-2).

For the 20 species that do not have spatial distribution information, we attempted to deduce fishing impact based on historical fishing effort. Fishing effort has generally declined since early 2000 for this fishery (Figure 3-4). The total trawled lengths in 2001 were 49,480 km and the effort reduced to an average of 26,164 km during 2004-2007, which is 53% of the 2001 level. Suppose fishing mortality rate were very high in 2001, e.g., $F_{2001,\,i} = F_{crash,i}$, then $F_{cur,\,i}$ would be approximately 0.53 $F_{crash,i}$.

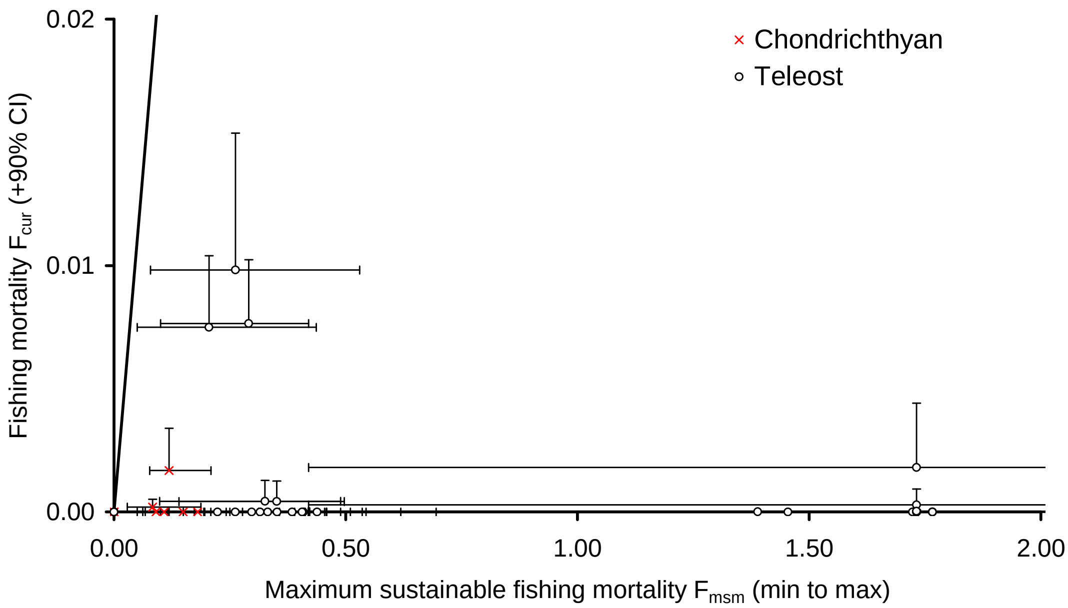

Figure 2-2. Comparison of estimated fishing mortality F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **Northwest Slope Trawl Fishery**. The diagonal line is where $F_{cur} = F_{msm}$.

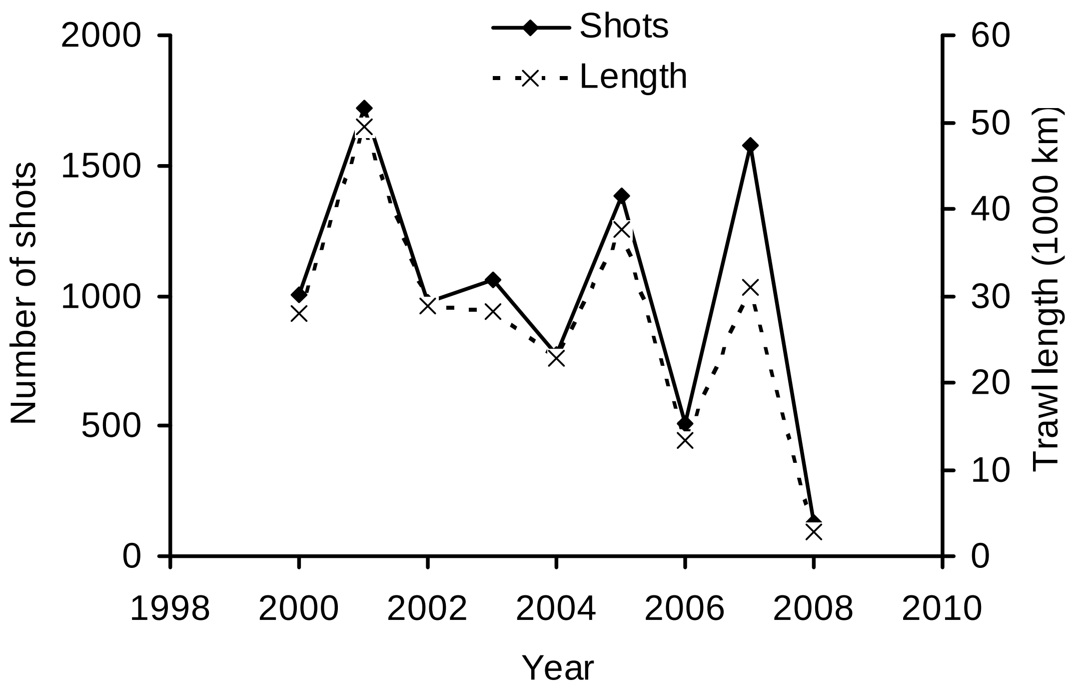

Figure 2-3. Fishing effort for the **Northwest Slope Trawl Fishery** from 2000 to 2008.

2.4. Discussion

Because the fishing mortality F_{cur} is very low and no species has $F_{cur} > F_{msm}$ (including uncertainty in both fishing mortality and reference point estimations) for the 45 species that have spatial distribution information, and the fishing effort is reduced during 2004-2007, based on the assumptions of this method, the likelihood of $F_{cur} > F_{msm}$ is low for the other 20 species (4 chondrichthyans and 16 teleosts) that do not have spatial distribution information in this fishery.

2.5. Reference

Commonwealth of Australia. (2005) National Marine Bioregionalisation of Australia. Summary. Department of Environment and Heritage, Canberra, Australia.

Evans, D. (1992) The Western Deep Water Trawl and North West Slope Trawl Fisheries, pp. 19-27. In The fisheries biology of deepwater crustacea and finfish on the continental slope of Western Australia, Rainer, S.F. (ed). Final Report FRDC Project 1988/74, 308pp.

Froese, R. and Binohlan, C. (2000) Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishers, with a simple method to evaluate length frequency data. Journal of Fish Biology, 56: 758-773.

Heap, A. D., Harris, P. T., Last, P., Lyne, V., Hinde, A., Woods, M. (2005) Draft Benthic Marine Bioregionalisation of Australia's Exclusive Economic Zone. Geoscience Australia Report to the National Oceans Office. Geoscience Australia, Canberra.

Hoenig, J. M. (1983) Empirical use of longevity data to estimate mortality rates. Fisheries Bulletin 82: 898–903.

Jensen, A. L. (1996) Beverton and Holt life history invariants result from optimal tradeoff of reproduction and survival. Canadian Journal of Fisheries and Aquatic Science 53: 820-822.

Pauly, D. (1980) On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. de la Mer 39: 75–284.

Quinn, T. J. and Deriso, R. B. (1999) Quantitative Fish Dynamics. Oxford University Press. New York.

Wayte, S., Dowdney, J., Williams, A., Fuller, M., Bulman, C, Sporcic, M., and Hobday, A. (2007) Ecological risk assessment for effects of fishing: Report for the North West Slope Trawl Fishery. Report for the Australian Fisheries Management Authority, Canberra.

Zhou, S., Smith, T., and Fuller, M. (2007) Rapid quantitative risk assessment for fish species in major Commonwealth fisheries. Report to the Australian Fisheries Management Authority.

Chapter 3. Skipjack Tuna Fishery

3.1. Introduction

The Skipjack Tuna Fishery (SKJ) extends throughout almost all of the area of the continental Australian Fishing Zone (AFZ) off mainland Australia. AFMA divides the SKJ fishery into the Eastern Skipjack Fishery and Western Skipjack Fishery (Figure 3-1 and Figure 3-2). The major catch in Australia has traditionally been taken on the Pacific coast of Australia between New South Wales and Victoria.

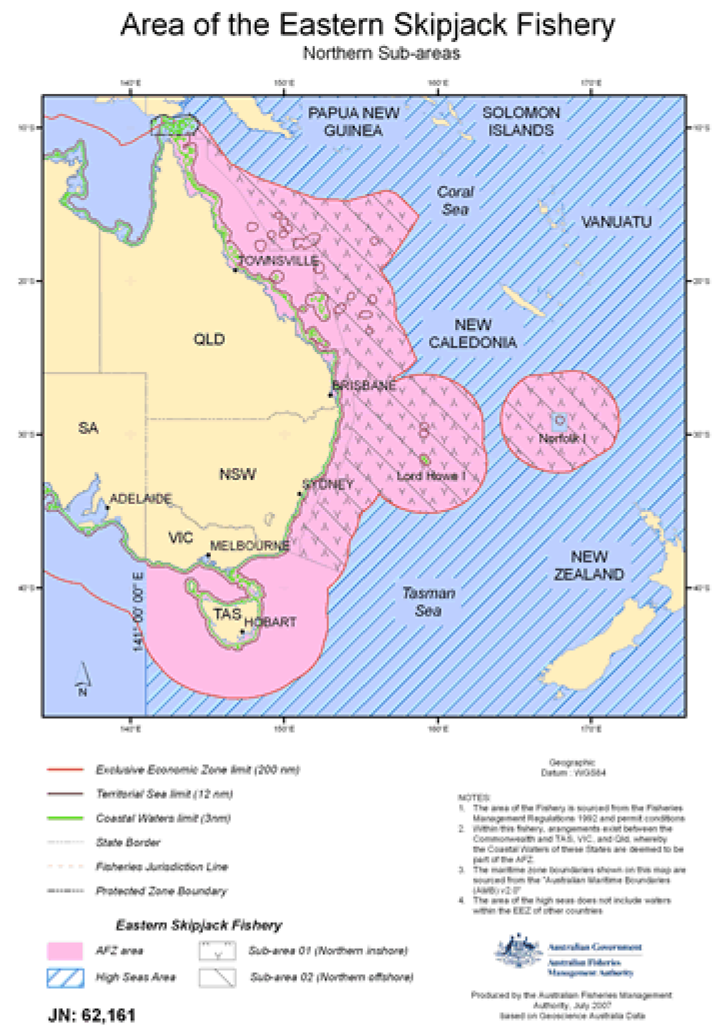

Figure 3-1. Map of the **Eastern Skipjack Tuna Fishery**.

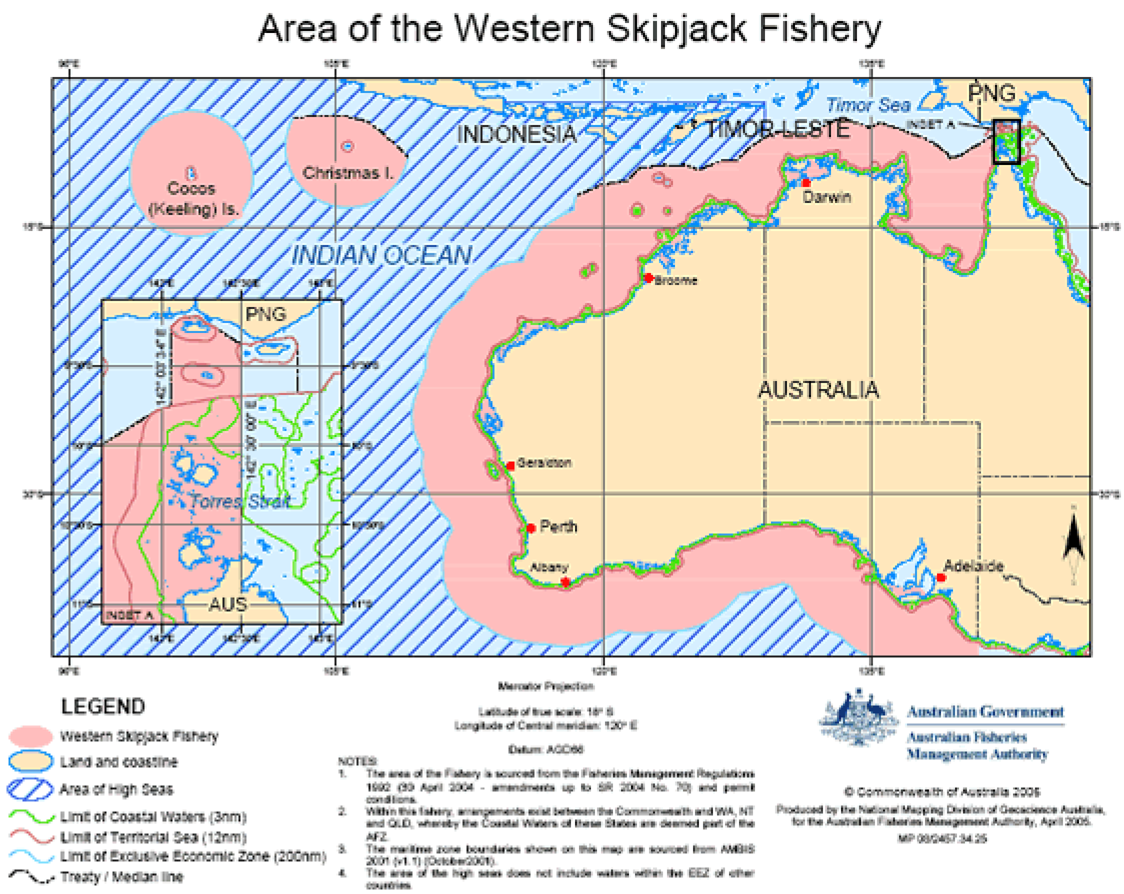

Figure 3-2. Map of the Western Skipjack Tuna Fishery.

This fishery uses purse seine nets to target skipjack tuna. Because uniform schools of fish are targeted, the purse seine method is considered to be a highly size- and species- selective method. Incidental catch includes bigeye and yellowfin tuna, frigate mackerel, sharks, mahi mahi, rays and marlins but the landings of these species are believed to be much less than 2% of the total landings (Daley et al. 2007).

We used a similar method developed for the seine fishery in Zhou et al. (2007) to estimate bycatch fishing mortality in the Skipjack Tuna Fishery. We included a total of 144 fish species (of which 8 are chondrichthyans).

3.2. Method

3.2.1. Estimating instantaneous fishing mortality *F*

In the purse seine fishery, vessels tow the nets to encircle the fish. The affected area in one shot can be estimated by $a = \pi R^2$. We adopted a net rope of 1,000 m and an affected area of

0.1 km^2/shot (more accurately 0.08 km^2/shot). Similar to trawl gear, the fishing mortality rate for species *i* in year *y* is estimated by

$$
\begin{aligned}
F_{y,i} &= \frac{C_{y,i}}{\bar{N}_{y,i}} \\
&= \frac{q_i^h q_i^\lambda (1-S_i) \sum_t a \ f_{y,i}}{A_i},
\end{aligned}
\qquad (3\text{-}1)
$$

where $f_{y,i}$ is the annual fishing effort (number of shots). Similar to the trawl fishery, we used size-dependent selectivity q^λ_i and habitat-dependent encounterability q^h_i and set them to 0.33, 0.66, and 1.0 for species with low, medium, and high selectivity scores and encounterability scores in the PSA analysis (Daley et al. 2007). We also assumed S_i = 0.00, 0.34, and 0.67 for species that have low, medium, and high probability of surviving after being caught and returned to the water.

3.2.2. Reference points

Reference points are the same as described in 2.2.2.

3.3. Results

We included 8 chondrichthyan and 136 teleost species in the assessment of the Skipjack Tuna Fishery. Among these 144 species, all species but 29 teleosts have spatial distribution information. The estimated spatial overlap between fishing effort and species distribution is low, ranging from 0 to 0.00005 for the 115 species that have spatial data. As a result, estimated fishing mortality F_{cur} is low and no species has $F_{cur} > F_{msm}$ within the assessment period (2004-2007, Figure 2-2).

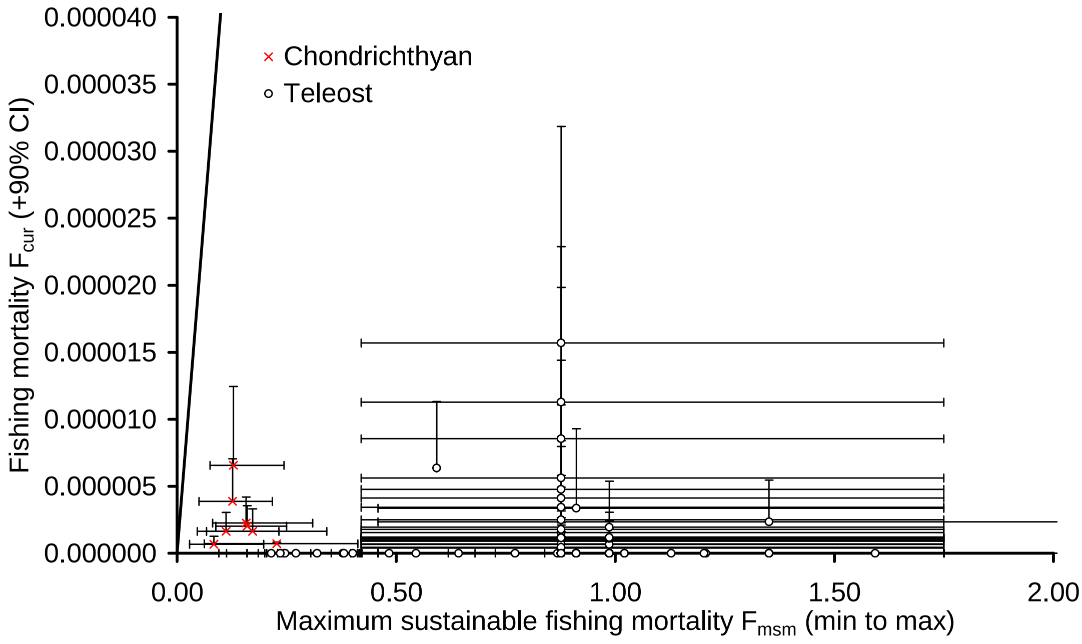

Figure 3-3. Comparison of estimated fishing mortality F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **Skipjack Tuna Fishery**. The diagonal line is where $F_{cur} = F_{msm}$.

For the 29 species that do not have spatial distribution information, we attempted to deduce fishing impact based on historical fishing effort. From 1999 fishing effort has changed dramatically for this fishery (Figure 3-4). The total recorded shots in 2000 were 287 and the effort reduced to 25, 0, 28, and 0 during 2004-2007. On average, the fishing effort in 2004-2007 is only 4.6% of the 2000 level. Suppose fishing mortality rate were very high in 2000, e.g., $F_{2000,\,i} = F_{crash,i}$, then $F_{cur,\,i}$ would be approximately 0.046 $F_{crash,i}$. It is unlikely that such a low level of fishing impact would cause risk to the sustainability of these species.

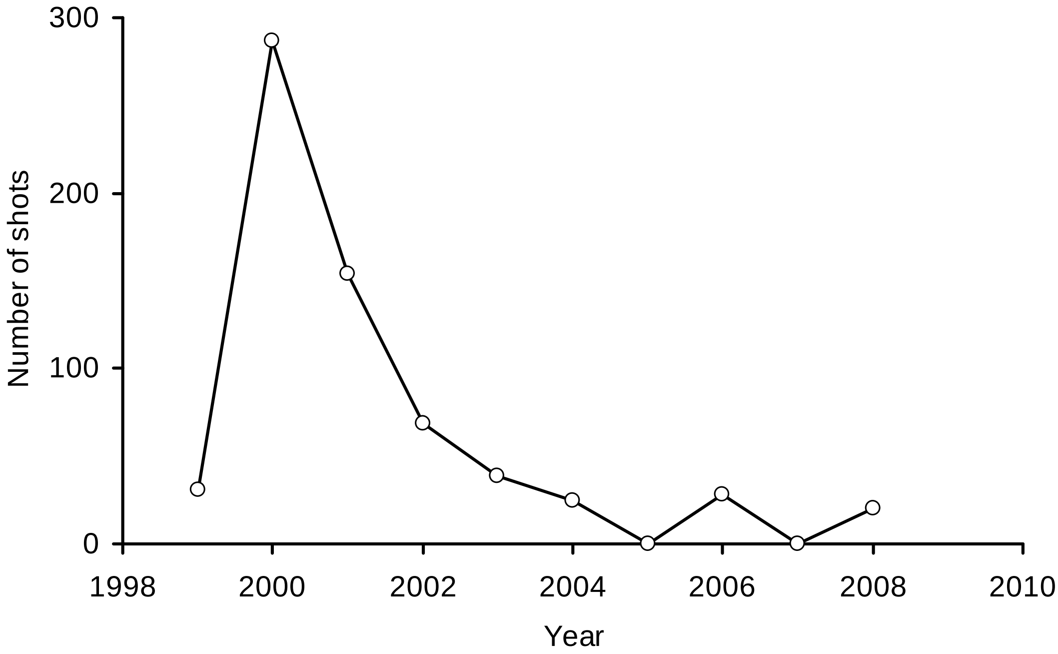

Figure 3-4. Fishing effort expressed as number of shots for the **Skipjack Tuna Fishery** from 1999 to 2008.

3.4. Discussion

Because the fishing mortality F_{cur} is very low and no species has $F_{cur} > F_{msm}$ (including uncertainty in both fishing mortality and reference point estimations) for the 115 species that have spatial distribution information, and because of the fishing efforts during the last four years (2004-2007) are only 4.6% of year 2000's level, based on the assumptions of this method, the likelihood of $F_{cur} > F_{msm}$ is low for the non-target species among those 29 teleost species that do not have spatial distribution information in the Skipjack Tuna fishery.

3.5. Reference

Daley, R., Dowdney, J., Bulman, C, Sporcic, M., Fuller, M., Ling, S. and Hobday, A. (2007) Ecological Risk Assessment (ERA) for the Effects of Fishing: Skipjack Tuna Fishery. Report for the Australian Fisheries Management Authority. Canberra, Australia.

Zhou, S., Smith, T., and Fuller, M. (2007) Rapid quantitative risk assessment for fish species in major Commonwealth fisheries. Report to the Australian Fisheries Management Authority.

Chapter 4. Small Pelagic Fishery

4.1. Introduction

The Small Pelagic Fishery jurisdictional boundary extends from border of the Queensland/New South Wales on the east coast, across southern Australia to north of Perth on the west coast. It includes waters from 3 – 200 miles and waters inside three nautical miles around Tasmania (Figure 4-1. Map of the **Small Pelagic Fishery** jurisdictional boundary..

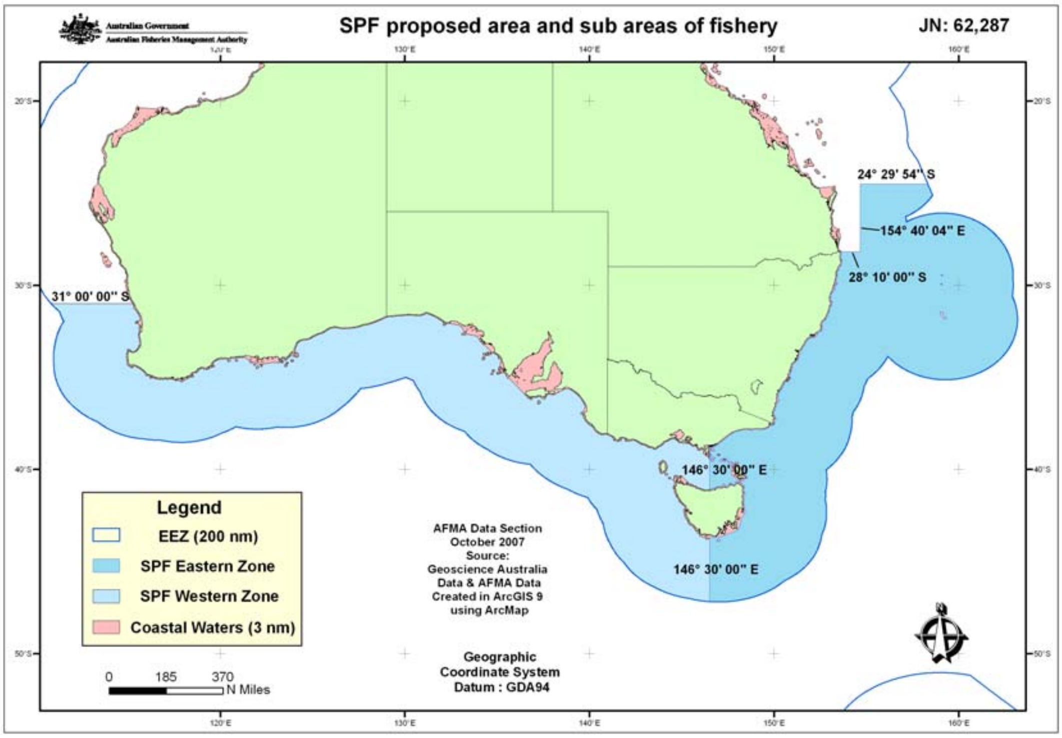

Figure 4-1. Map of the **Small Pelagic Fishery** jurisdictional boundary.

This fishery has two sub-fisheries: the Purse Seine Sub-fishery and the Mid-water Trawl Sub-fishery. In the Purse Seine sub-fishery, purse seine is used to catch five major species: Jack mackerel (*Trachurus declivis*), Peruvian mackerel (*T. murphyi*), Yellowtail scad (*T. novaezealandiae*), Blue mackerel (*Scomber australasicus*), and Redbait (*Emmelichthys nitidus*). Fishing effort has increased in the last two years (2006-2007). The nets are typically about 1000 m in length for the commercial sets (Daley et al. 2007a).
The Mid-water Trawl sub-fishery catches the same five major species as in the Purse Seine sub-fishery (Daley et al. 2007b). Both Purse Seine and Mid-water Trawl sub-fisheries occur

throughout most of the year with most catches in the warmer months and a peak in April-May.

4.2. Method

4.2.1. Estimating instantaneous fishing mortality *F*

For the Purse Seine sub-fishery we used the same method as described in Chapter 3, section 3.2.1 to estimate the fishing mortality rate. We adopted a = 0.1 km^2/shot as an affected area in Equation (3-1).

For the Mid-water Trawl Sub-fishery, we used the similar method as described in Chapter 2, section 2.2.1 to estimate the fishing mortality rate. We adopted W = 48 m in Equation (2-4) as the horizontal opening of the trawl (Daley et al. 2007b).

4.2.2. Reference points

Reference points are the same as described in 2.2.2.

4.3. Results

4.3.1. Purse Seine Sub-fishery

We included 3 chondrichthyan and 90 teleost species in the Purse Seine Sub-fishery assessment. Among these 93 species, all chondrichthyans and 80 teleosts have spatial distribution information. The estimated spatial overlap between fishing effort and species distribution is low (less than 1%) for the 83 non-target species that have spatial data. As we are assessing recent years' impact and used fishing effort between 2004-2007 to derive overlap, low fishing effort during this period is one of the reasons that some species have 0 overlap with fishing activities. As a result, estimated fishing mortality F_{cur} is low and no species has $F_{cur} > F_{msm}$ within the assessment period (2004-2007, Figure 4-2). However, fishing effort appears to increase during 2006 and 2007 (Figure 4-3).

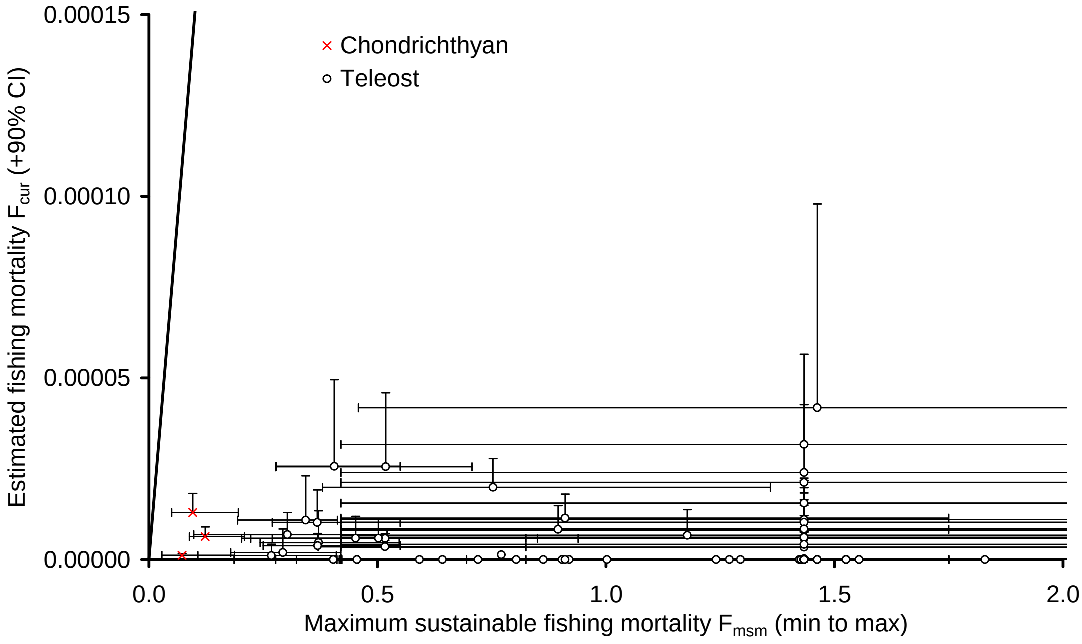

Figure 4-2. Comparison of estimated fishing mortality F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **Purse Seine Sub-fishery** of the **Small Pelagic Fishery**. The diagonal line is where $F_{cur} = F_{msm}$.

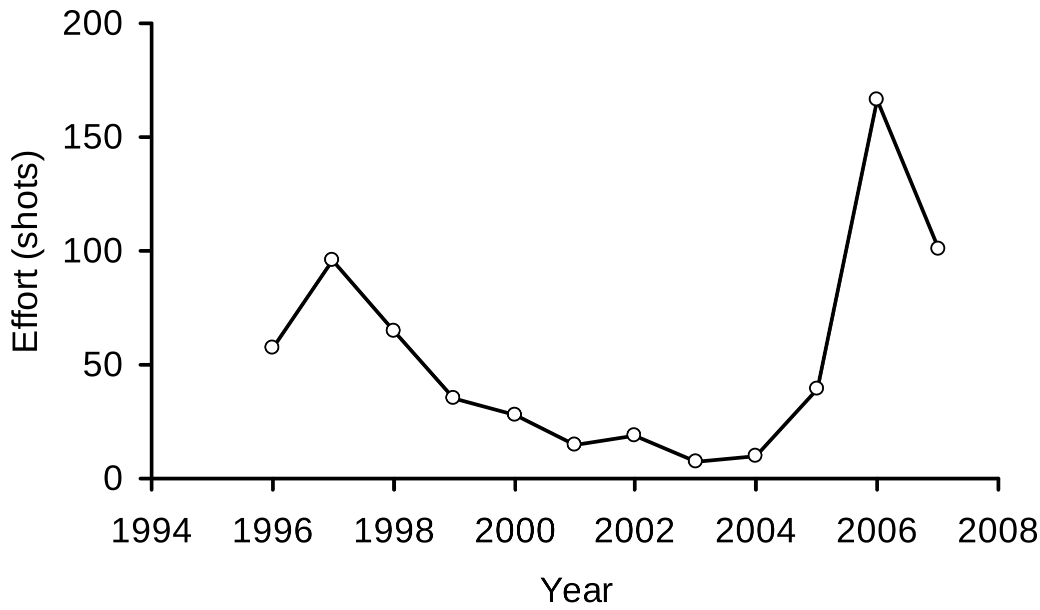

Figure 4-3. Fishing effort expressed as number of shots for the **Purse Seine Sub-fishery** of the **Small Pelagic Fishery** from 1996 to 2007.

4.3.2. Mid-water Trawl Sub-fishery

We included 3 chondrichthyan and 95 teleost species in the Mid-water Trawl Sub-fishery assessment. Among these 98 species, all chondrichthyans and 84 teleosts have spatial distribution information. The estimated spatial overlap between fishing effort and species distribution is low, ranging from 0 to 0.002 for these 87 species that have spatial data. As a result, estimated fishing mortality F_{cur} is low and no species has $F_{cur} > F_{msm}$ within the assessment period (2004-2007, Figure 4-2).

4.3.3. Cumulative impact from the two Sub-fisheries

Most species assessed above in the Purse Seine Sub-fishery and the Mid-water Sub-fishery are the same species with a few exceptions. Combining the two sub-fisheries, there are 3 chondrichthyans and 97 teleosts. Among these 100 species, all chondrichthyans and 84 teleosts have spatial distribution data. As fishing mortality in both sub-fisheries is small, the cumulative fishing mortality rates combined from two sub-fisheries are also small. None of the species that have spatial data has a cumulative $F_{cur} > F_{msm}$ within the assessment period (2004-2007, Figure 4-2).

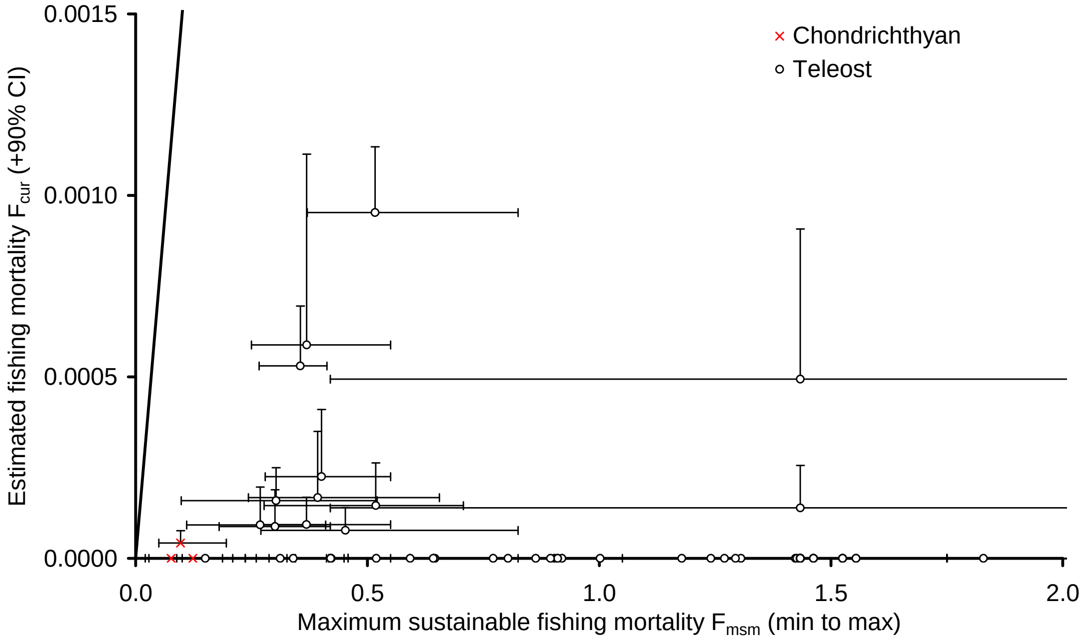

Figure 4-4. Comparison of estimated fishing mortality F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **Mid-water Trawl Sub-fishery** of the **Small Pelagic Fishery**. The diagonal line is where $F_{cur} = F_{msm}$.

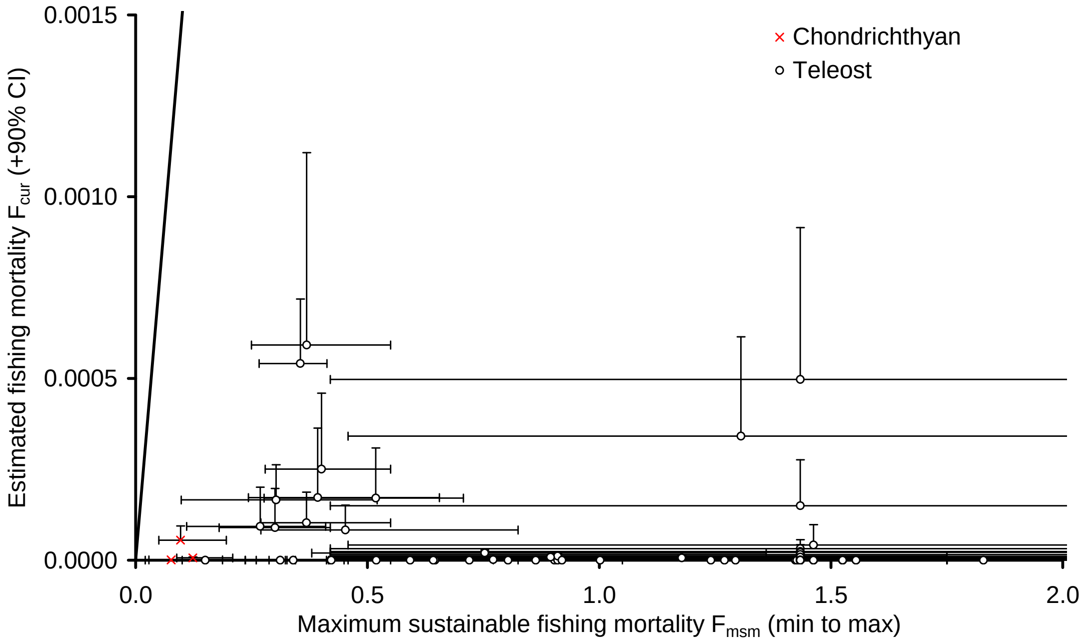

Figure 4-5. Comparison of estimated **cumulative fishing mortality** in the recent years (2004-2007) F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **Small Pelagic Fishery**. The diagonal line is where $F_{cur} = F_{msm}$.

4.4. Discussion

In the Small Pelagic Fishery, even though fishing effort shows an increasing trend between 2005-2007 (at least for the Purse Seine Sub-fishery), the cumulative fishing mortality F_{cur} is less than 0.1% for any of the 89 species that have spatial distribution information and no species has $F_{cur} > F_{msm}$ (including uncertainty in both fishing mortality and reference point estimations). Based on this result alone, the likelihood of $F_{cur} > F_{msm}$ should be low for the 13 non-target teleost species that do not have spatial distribution information in this fishery.

4.5. Reference

Daley, R., Dowdney, J., Bulman, C, Sporcic, M., Fuller, M., Ling, S., Milton, D., and Hobday, A. (2007a) Ecological Risk Assessment (ERA) for the Effects of Fishing: Report for the purse seine sub-fishery of the Small Pelagic Fishery. Report for the Australian Fisheries Management Authority. Canberra, Australia.

Daley, R., Dowdney, J., Bulman, C, Sporcic, M., Fuller, M., Ling, S. and Hobday, A. (2007b) Ecological Risk Assessment for the Effects of Fishing. Report for the midwater trawl sub-fishery of the Small Pelagic Fishery. Report for the Australian Fisheries Management Authority. Canberra, Australia.

Chapter 5. Southern Bluefin Tuna Fishery

5.1. Introduction

The Southern Bluefin Tuna Fishery uses purse seines to target southern bluefin tuna. This fishery mainly occurs in the Great Australian Bight between approximately 130 to 137° E and 32 to 36° S (Hobday et al. 2007). The major fishing season is from December to April, although the quota year runs from 1 December to 30 November each year. Several other pelagic fisheries operate in the same region as the Southern Bluefin Tuna Fishery, including the Commonwealth managed fisheries (Eastern Tuna and Billfish Fishery, Southern and Western Tuna and Billfish Fishery, Skipjack Tuna Fishery, and Small Pelagic Fishery), and the State managed fisheries (Western Australian Pilchard Fishery and South Australian Pilchard Fishery). In this chapter, we only assess the impact of the Southern Bluefin Tuna Fishery on fish species within its jurisdictional boundary (Figure 5-1).

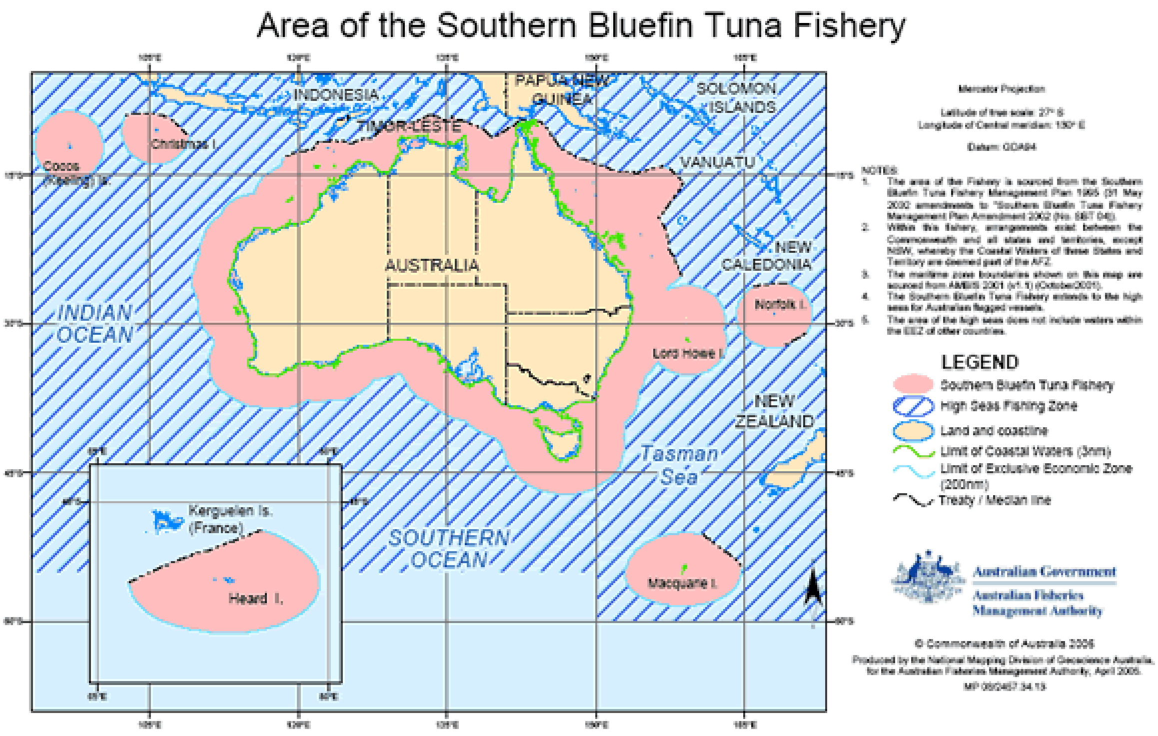

Figure 5-1. Map of the **Southern Bluefin Tuna Fishery** jurisdictional boundary.

5.2. Method

5.2.1. Estimating instantaneous fishing mortality *F*

We used the same method as described in Chapter 3, section 3.2.1 to estimate the fishing mortality rate. We adopted an affected area a = 0.1 km^2/shot in Equation (3-1).

5.2.2. Reference points

Reference points are the same as described in 2.2.2.

5.3. Results

We included 6 chondrichthyan and 77 teleost species in the Southern Bluefin Tuna Fishery assessment. Of these 83 species, all chondrichthyans and 60 teleosts have spatial distribution information. The estimated spatial overlap between fishing efforts during 2004-2007 and species distribution is low, ranging from 0 to 0.0001 for these 67 species that have spatial data. As a result, estimated fishing mortality F_{cur} is low and no species has $F_{cur} > F_{msm}$ within the assessment period (2004-2007, Figure 4-2).

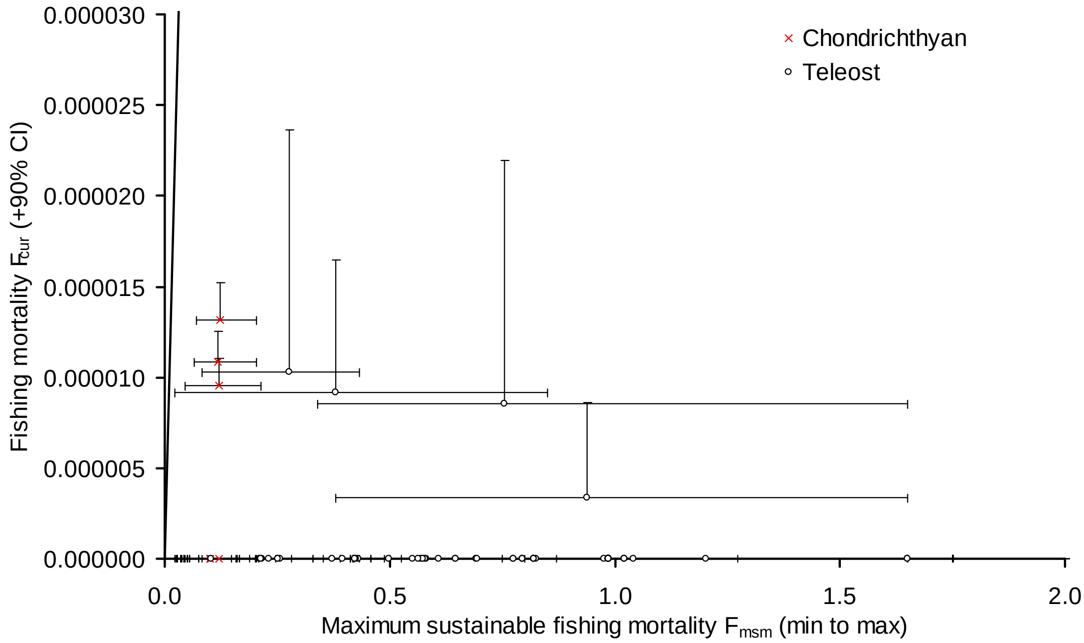

Figure 5-2. Comparison of estimated fishing mortality in the recent years (2004-2007) F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **Southern Bluefin Tuna Fishery**. The diagonal line is where F_{cur} = F_{msm}.

For the 17 species that do not have spatial distribution information or whose spatial distribution cannot be determined because they are pelagic, we attempted to deduce fishing impact based on historical fishing efforts. From 1996 fishing effort has changed significantly for this fishery (Figure 3-4). The total recorded shots in 1999 were 636 and the effort reduced to 186, 194, 251, and 293 during 2004-2007. On average, the fishing effort in 2004-2007 is 36% of the 2000 level. Suppose fishing mortality rate were very high in 1999, e.g., $F_{1999,i} = F_{crash,i}$, then $F_{cur,i}$ would be approximately 0.36 $F_{crash,i}$, which is less than $F_{msm,i}$. Based on the assumptions of this method, the likelihood of risk to the sustainability of non-target species is low.

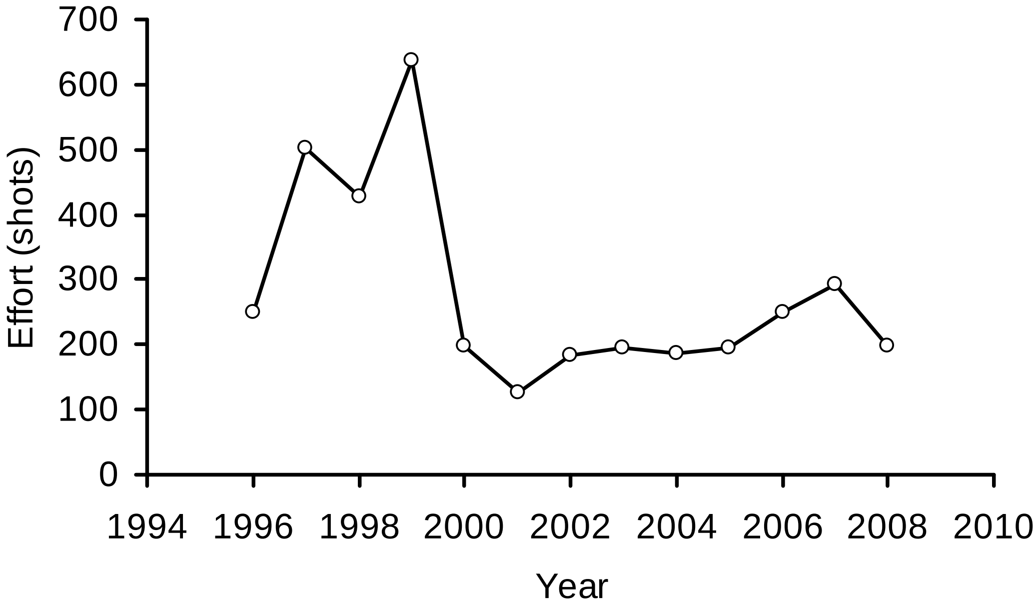

Figure 5-3. Fishing effort expressed as number of shots for the **Southern Bluefin Tuna Fishery** from 1996 to 2008.

5.4. Discussion

Fishing mortality F_{cur} is very low and no species has $F_{cur} > F_{msm}$ (including uncertainty in both fishing mortality and reference point estimations) for the 67 species that have spatial distribution information, and the fishing effort during the last four years (2004-2007) is only 36% of year 1999's level. Therefore, based on the assumptions of this method, the likelihood of $F_{cur} > F_{msm}$ is low for the non-target species of those 17 species that do not have spatial distribution information in the Southern Bluefin Tuna Fishery.

5.5. Reference

Hobday, A. J., Dowdney, J., Bulman, C., Sporcic, M., Fuller, M., Ling, S. (2007) Ecological Risk Assessment for the Effects of Fishing: Southern Bluefin Tuna Purse Seine Fishery. Report for the Australian Fisheries Management Authority.

Chapter 6. Western Deepwater Trawl Fishery

6.1. Introduction

The Western Deepwater Trawl Fishery (WDWTF) is located in deepwater off Western Australia from approximating the 200 m isobath outwards to the edge of the AFZ. The fishery's northern most point is formed by the boundary of the AFZ to longitude 114^{o}E where it runs adjacent to the waters of the North West Slope Trawl Fishery. The southern extremity lies on the boundary of the AFZ with longitude 115^{o}08'E where the fishery runs adjacent to the Great Australian Bight Trawl Fishery (Figure 6-1. Map of the **Western Deepwater Trawl Fishery**.).

A diverse range of vessels have operated in the fishery. Vessels range from 18 m converted tuna boats to 85-90 m factory ships, and include Northern Prawn Fishery, Shark Bay Scallop and South East Fishery trawlers. A wide variety of nets, targeting techniques and processing methods have also been employed. Either demersal fish trawls or crustacean trawls are typically utilised (Wayte et al. 2007). Demersal fish trawlers in the WDWTF tow a net along the ocean floor in depths from 200 m to greater than 700 m. The finfish gear typically uses a mesh size of 90 mm, and crustacean gear uses a mesh size of 45 mm.

The WDWTF is open to fishing the entire year. However, fishermen have generally accessed the fishery on a part time or opportunistic basis as an adjunct to other Commonwealth fisheries. There is a distinct increase in effort in June to August, corresponding to seasonal closures in the Northern Prawn Fishery.

A wide range of species have been taken in low volumes in the WDWTF. The important commercial fishes include orange roughy (*Hoplostethus atlanticus*), oreos (Oreosomatidae), big spine boarfish (*Pentaceros decacanthus*), alfonsino (*Beryx splendens*), mirror dory (*Zenopsis nebulosus*), gemfish (*Rexea solandri*), deepwater flathead (*Platycephalus conatus*), snappers (Lutjanidae: Etelinae and Apsilinae) and sea bream (Lethrinidae). According to logbooks for 2001 and 2002, between a third and a half of the total catch is discarded. Of these discards, about a quarter is not identified (Wayte et al. 2007).

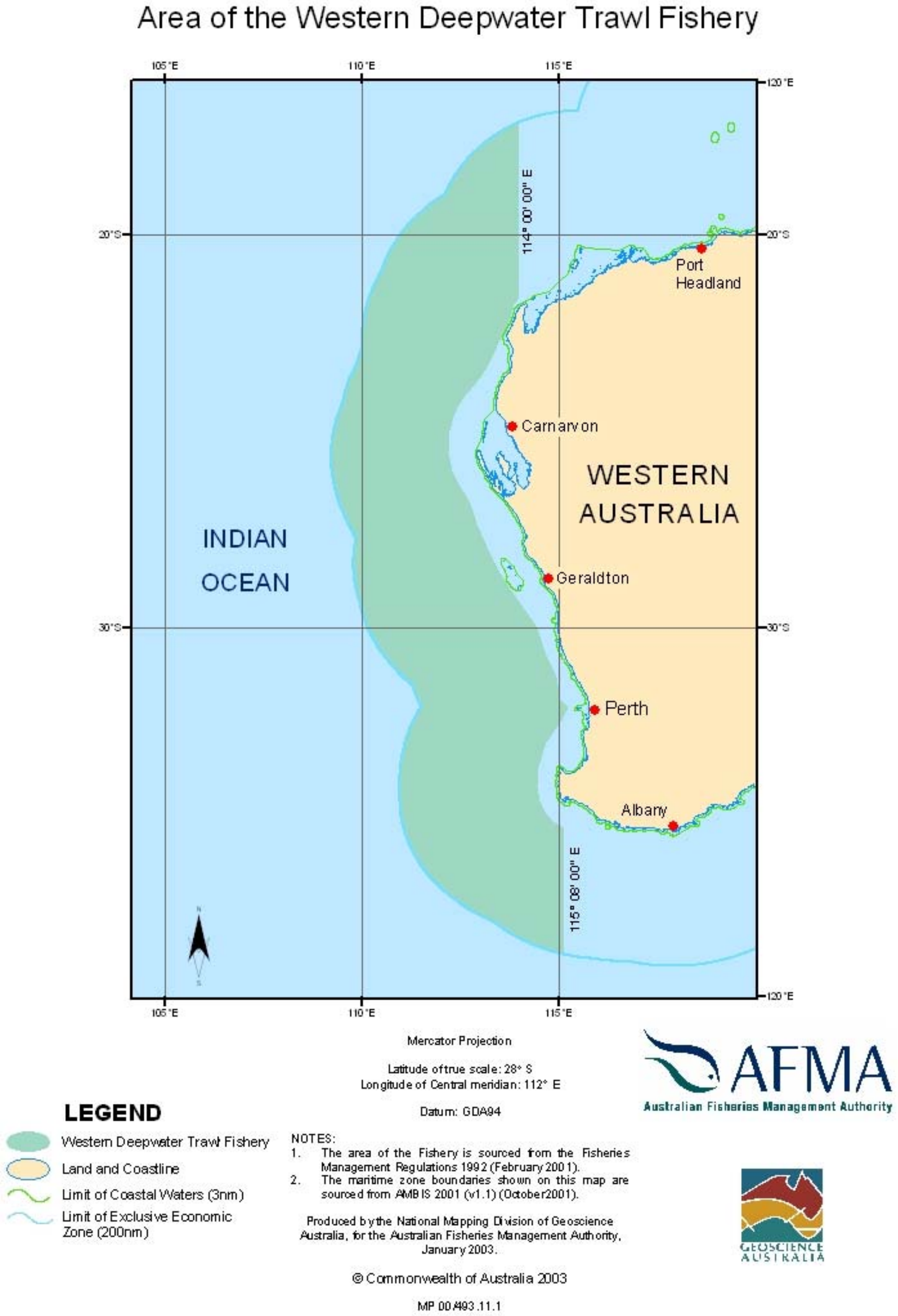

Figure 6-1. Map of the **Western Deepwater Trawl Fishery**.

6.2. Method

6.2.1. Estimating instantaneous fishing mortality *F*

We used the same method as described in Chapter 2, section 2.2.1 to estimate the fishing mortality rate. We adopted an average net wing spread W = 23 m in Equation (2-4).

6.2.2. Reference points

Reference points are the same as described in 2.2.2.

6.3. Results

We included 23 chondrichthyan and 80 teleost species in the WDWTF assessment. Of these 103 species, all chondrichthyans and 68 teleosts have spatial distribution information. Due to low fishing efforts, the estimated spatial overlap between fishing efforts during 2004-2007 and species distribution is low, ranging from 0 to 0.013 for these 91 species that have spatial data. As a result, estimated fishing mortality F_{cur} is low and no species has $F_{cur} > F_{msm}$ within the assessment period (2004-2007, Figure 4-2).

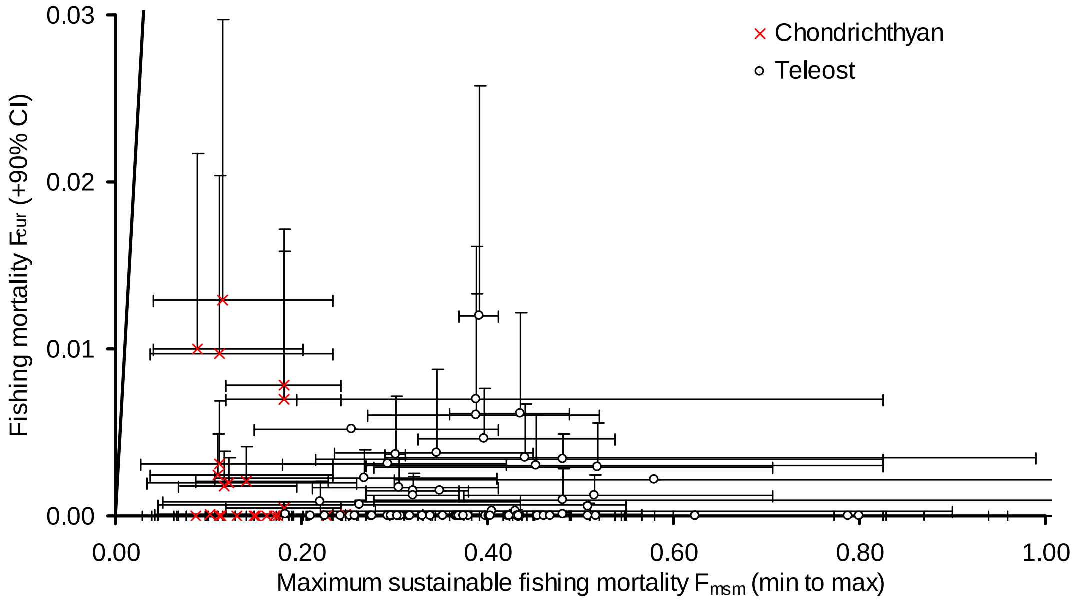

Figure 6-2. Comparison of estimated fishing mortality in the recent years (2004-2007) F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **Western Deepwater Trawl Fishery**. The diagonal line is where $F_{cur} = F_{msm}$.

Fishing effort has declined since 2002 from 1,147 shots to an average of 185 shot during 2004-2007 (Figure 6-3), which is 13% of the 2002 level. Suppose fishing mortality rate were very high in 2002, e.g., $F_{2002,\, i} = F_{crash,i}$, then $F_{cur,\, i}$ would be approximately 0.13 $F_{crash,i}$.

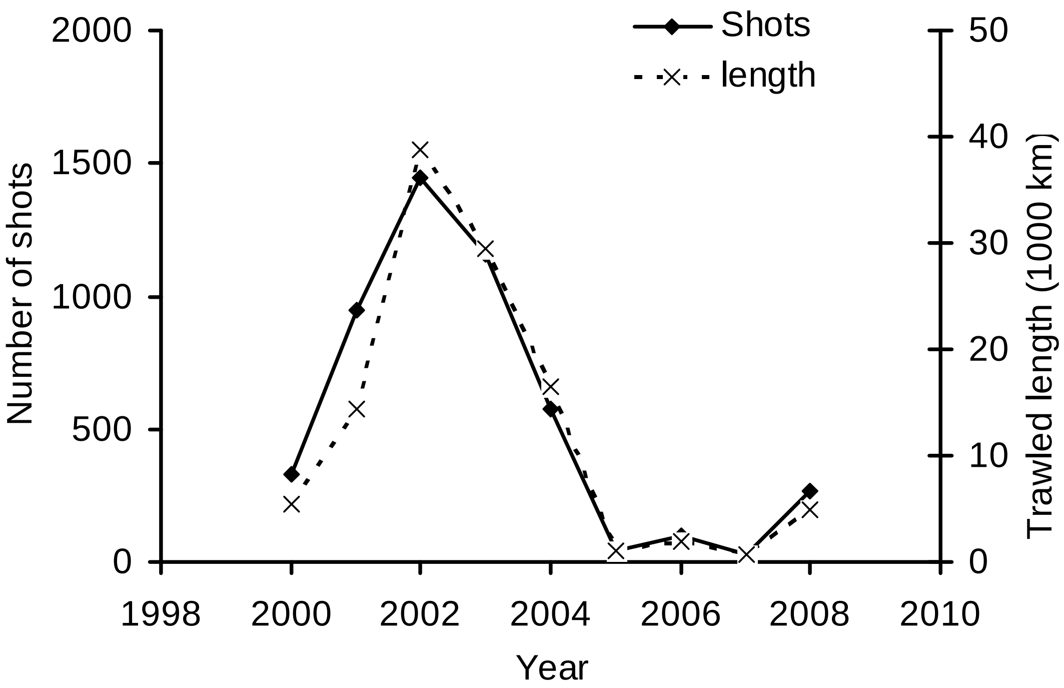

Figure 6-3. Fishing effort for the **West Deepwater Trawl Fishery** from 2000 to 2008.

6.4. Discussion

Because the fishing mortality F_{cur} is low and no species has $F_{cur} > F_{msm}$ (including uncertainty in both fishing mortality and reference point estimations) for the 91 species that have spatial distribution information, and low fishing effort during the assessment period, based on the assumptions of this method, the likelihood of $F_{cur} > F_{msm}$ is low for the non-target species among those 12 species that do not have spatial distribution information in the Western Deepwater Trawl fishery.

6.5. Reference

Wayte, S., Dowdney, J., Williams, A. Fuller, M., Bulman, C., Sporcic, M., Smith, A. (2007) Ecological Risk Assessment for the Effects of Fishing: Report for the Western Deepwater Trawl Fishery. Report for the Australian Fisheries Management Authority, Canberra.

Chapter 7. Western Tuna and Billfish Fishery

7.1. Introduction

The Western Tuna and Billfish Fishery (WTBF) extends from AFZ off Queensland, the Northern Territory, Western Australia, South Australia, and around Christmas Island and the Cocos (Keeling) Islands (Figure 7-1).

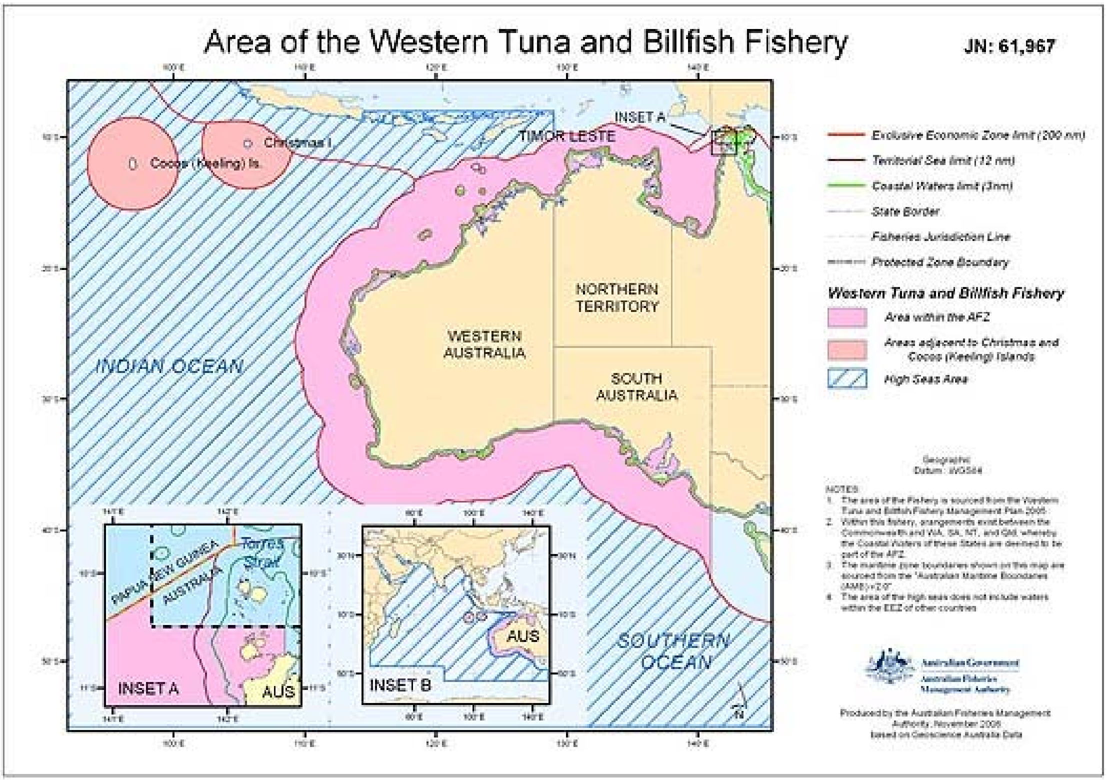

Figure 7-1. Area of the **Western Tuna and Billfish Fishery**.

The WTBF includes four sub-fisheries: longline, purse seine, pole and line, and trolling (Webb et al. 2007). However, because the pelagic longlining is currently the dominant commercial fishing method in the WTBF, we only assessed sustainability of fishes impacted by this sub-fishery in this report.

Pelagic longlining is mostly undertaken in waters beyond the continental shelf break (~ 200 m isobath). Pelagic longlines are many kilometres long and carry thousands of hooks. They are set 30 to 200 m from the surface, not anchored but set to drift in the water column. This fishing gear is usually used to catch large tuna and billfish species. The targeted species in this fishery include broadbill swordfish, bigeye tuna, yellowfin tuna, albacore tuna, and striped marlin etc. Fishing activities occur year round, with seasonal spatial and temporal variation.

7.2. Method

7.2.1. Estimating instantaneous fishing mortality *F*

We used a method described in Zhou et al. (2007) for the ETBF pelagic longlines to estimate the fishing mortality rate. We estimated effort area from shot start and end locations, analysed as an arc between the coordinates and overlayed on a 1 km^2 grid. Since gears are set at below 30 m from surface, we limited the species distributions to waters greater than 30 m depth for estimating fishing efforts. The gear-affected area will be underestimated if without correction. Zhou et al. (2007) developed a correction factor ρ from stock assessment of target species to adjust estimated fishing impacts on non-target species:

$$\rho = \frac{1}{n}\sum_{i=1}^{n} \frac{u_i^T A_{i,J}^T}{q_i^h q_i^\lambda A_{i,f}^T}, \qquad (7\text{-}1)$$

where $A_{i,f}$ is the area within species i's distribution and where longline fishing activity has been recorded during 2004 – 2007 period, $A_{i,J}$ is the total core distribution area for species i within the fishery jurisdiction, u_i^T is the exploitation rate for target species i., and n is the number of target species that have estimated exploitation rate from formal stock assessment.

This parameter ρ can be considered as a correction factor adjusting actual gear affected area (due to drifting and bait odour dispersion) and gear efficiency. In the Eastern Tuna and Billfish fishery ρ is estimated to be 1.48 (SE = 0.82) from four target species (Zhou et al. 2007). Unfortunately, there is no formal stock assessment for any species caught in the WTBF. Hence, we conservatively adopted $\rho = 2$ in this assessment.

The habitat-dependent encounterability $q^h{}_i$ is set to 0.33, 0.66, and 1.0 for species with low, medium, and high scores encountering the fishing gear in the PSA analysis (Webb et al. 2007). We assigned the size-dependent catchability $q^\lambda{}_i$ based on average length at maturity as in PSA: 0.33 for fish < 50 cm or > 500 cm, 0.66 for fish between 50 and 100 cm and between 400 and 500 cm, and 1.0 for fish between 100 and 400 cm. We used S_i = 0.00, 0.34, and 0.67 for species that have low, medium, and high probability of surviving after being caught and returned to the water.

7.2.2. Reference points

Reference points are the same as described in 2.2.2.

7.3. Results

There is a total of 187 fish species (38 chondrichthyans and 149 teleosts) in this WTBF assessment. Of these 187 species, 36 chondrichthyans and 109 teleosts have spatial distribution information. Due to low fishing efforts, the estimated spatial overlap between fishing efforts during 2004-2007 and species distribution is low, ranging from 0 to 0.031 for these 145 species that have spatial data. As a result, estimated fishing mortality F_{cur} is low even after we applied a correction factor $\rho = 2$ for all species. No species has $F_{cur} > F_{msm}$ within the assessment period (2004-2007, Figure 4-2).

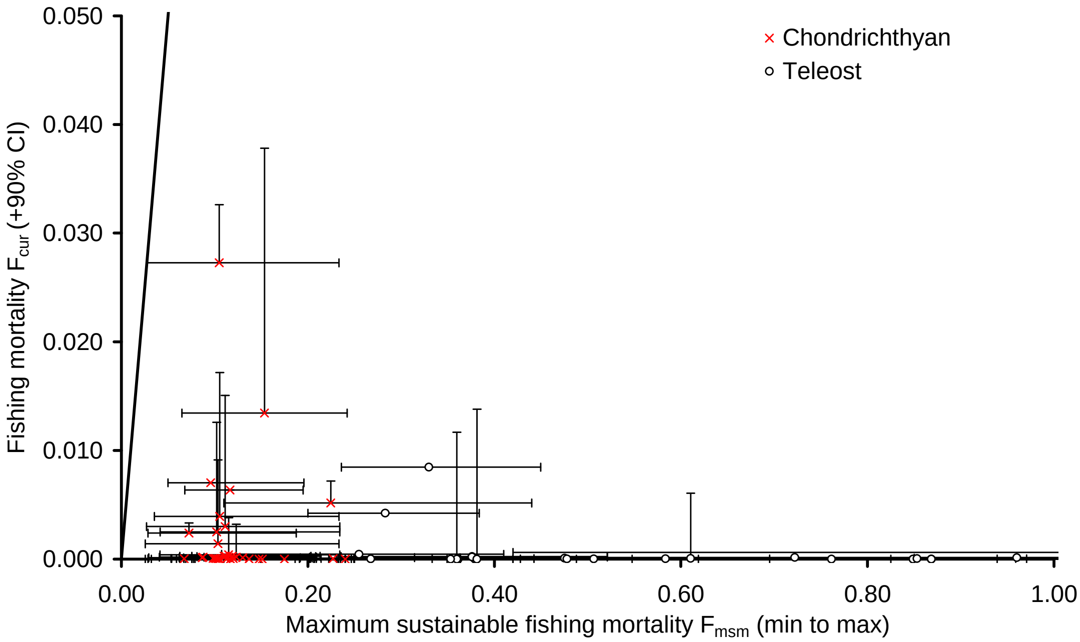

Figure 7-2. Comparison of estimated fishing mortality in the recent years (2004-2007) F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **Western Tuna and Billfish Fishery**. The diagonal line is where $F_{cur} = F_{msm}$.

For the 42 species that do not have spatial distribution information or whose spatial distribution cannot be determined because they are pelagic, we attempted to deduce fishing impact based on historical fishing efforts. We approached this in two ways.

First, the total fishable area deeper than 30 m is 3,269,644 km^2 in the jurisdiction of WTBF fishery. If we assume these 42 species are distributed in all fishable areas, the overlap with fishing effort ranged from 0.0003 to 0.0047 during 2004-2007 (Figure 3-4). Based on this assumption, the estimated F_{cur} is low for these species and no species has $F_{cur} > F_{msm}$ within the assessment period.

Second, from 2002 fishing effort has declined significantly for in the WTBF fishery (Figure 3-4). The total recorded hooks in 2002 were 4.91 millions and the effort reduced to 1.09, 0.28, 0.41, and 0.02 millions from 2004 to 2007, respectively. On average, the fishing effort in 2004-2007 is 9% of the 2002 level. Supposing fishing mortality rate were very high in 2002, e.g., $F_{2002,\,i} = F_{crash,i}$, then $F_{cur,\,i}$ would be approximately 0.09 $F_{crash,i}$, which is much less than $F_{msm,i}$. Therefore, the likelihood of risk to the sustainability of these non-target species is very low.

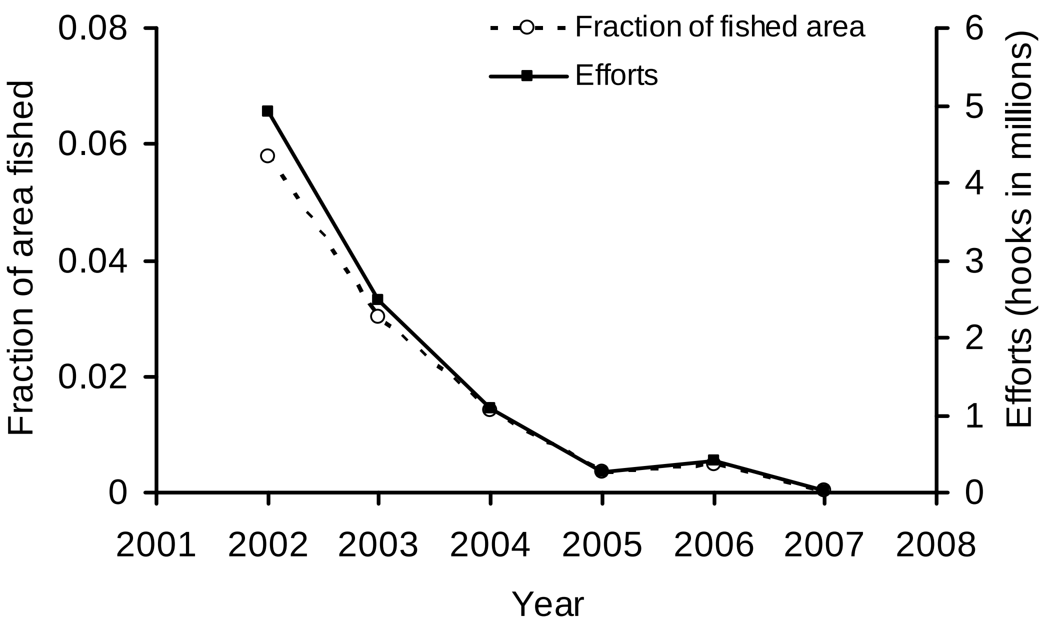

Figure 7-3. Fraction of fishable area with fishing effort for the Western Tuna and Billfish Fishery from 2002 to 2007.

7.4. Discussion

Because the fishing mortality F_{cur} is low and no species has $F_{cur} > F_{msm}$ (including uncertainty in both fishing mortality and reference point estimations) for the 145 species that have spatial distribution information, based on the assumptions of this method, the likelihood of F_{cur} >

F_{msm} is low for the non-target species among those 42 species that do not have spatial distribution information in the Western Tuna and Billfish fishery.

7.5. Reference

Webb, H., Bulman, C., Sporcic, M., Dowdney, J., Fuller, M., Smith, T., Hobday, A. (2007) Ecological Risk Assessment for the Effects of Fishing: report for Western Tuna and Billfish sub-Fishery. Report for the Australian Fisheries Management Authority.

Zhou, S., Smith, T., and Fuller, M. (2007) Rapid quantitative risk assessment for fish species in major Commonwealth fisheries. Report to the Australian Fisheries Management Authority.

Chapter 8. Sub-Antarctic Fishery

8.1. Introduction

The Sub-Antarctic Fishery comprises two fisheries: Heard and McDonald Islands (HIMI) fishery and the Macquarie Island Fishery (MIF). Unlike any other fisheries in this report or the previous report (Zhou et al. 2007), there is no species distribution information from either Bioregional mapping or Core range species mapping for this fishery. We take a new approach to derive species distribution from logbook and observer reports (see Method section for details). We treat HIMI fishery and MIF fishery separately in this report.

8.1.1. Heard Island and McDonald Island (HIMI) fishery

The HIMI fishery has four sub-fisheries: Demersal Trawl Sub-fishery, Mid-water Trawl Sub-fishery, Demersal Longline Sub-fishery, and Pot and Trap Sub-fishery. These sub-fisheries target *Dissostichus eleginoides* (Patagonian toothfish) and *Champsocephalus gunnari* (Mackerel icefish). The pot and trap fishing for Patagonian toothfish began in 2005 and the scale is small. There is close to 100% observer coverage on all trips to the regions. In this report we only include the first three sub-fisheries in the assessment (Daley et al. 2007).

Heard Island and McDonald Islands are external territories of Australia located in the Southern Indian Ocean about 4,000 km south-west of Perth. The HIMI fishery operates in waters adjacent to these islands (Figure 8-1). The Islands and the 12 nautical mile territorial sea around them are on the World Heritage List. Fishing is prohibited within 13 nautical miles of the Islands, providing a buffer zone of one nautical mile. The fishery extends from 13 nautical miles offshore to the edge of the 200 nautical mile Australian Economic Exclusive Zone (EEZ) around the Islands.

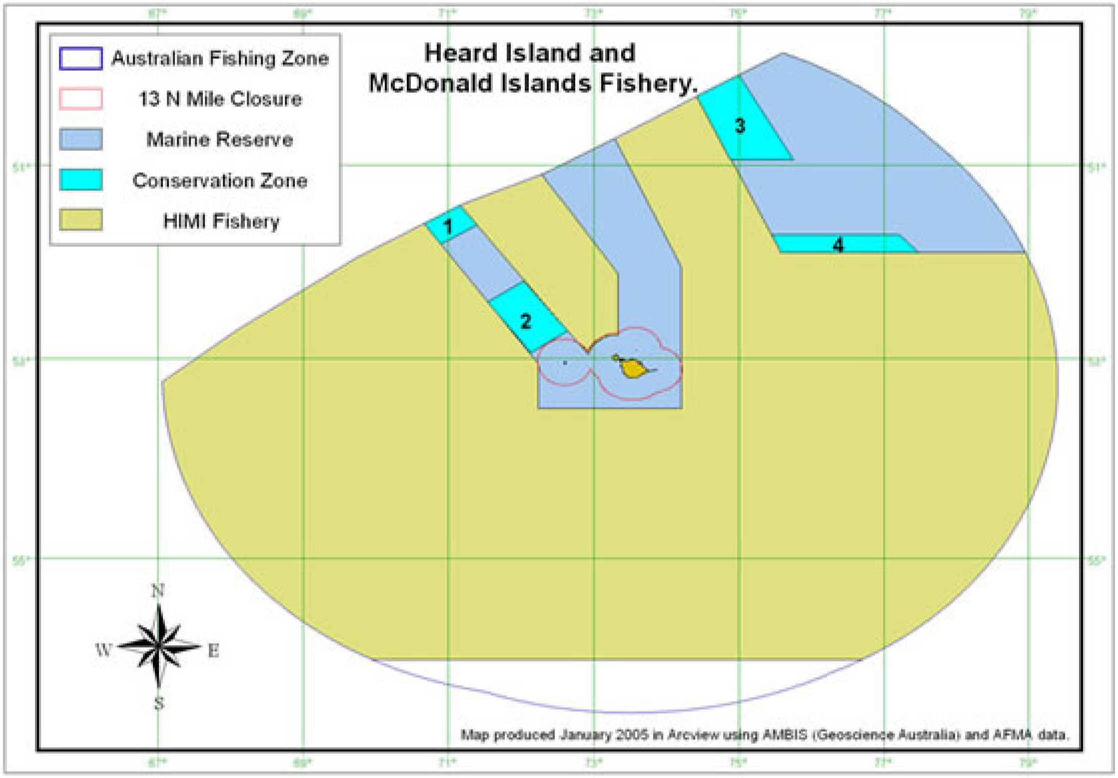

Figure 8-1. Map of the **Heard Island and McDonald Island Fishery** including Marine Reserve and Conservation Zones.

For the HIMI Demersal Trawl Sub-fishery, there are three main trawl grounds for the Patagonian toothfish between 450 m and 700 m deep. Icefish are fished at shallower depths. The minimum mesh-size of the trawl nets is limited to 120 mm for targeting Patagonian toothfish and 90 mm for targeting mackerel icefish. The fishery is open year-around.

The Mid-water Trawl Sub-fishery mainly targets Mackerel icefish (Bulman et al. 2007). Patagonian toothfish are caught incidentally but are not targeted. The net is similar to, but typically larger than, a demersal trawl and is limited to a 90 mm minimum mesh size. Trawl nets for mackerel icefish have minimum mesh size of 90 mm. When targeting Icefish, gear is deployed between 180-270 m, bottom depth between 350-400 m. Mid-water trawling generally results in little or no bycatch.

The Demersal Longline Sub-fishery targets Patagonian toothfish (Bulman et al. 2008). The gear has a main-line containing several thousand short, evenly spaced branch-lines or snoods, each with a terminal baited hook. The snoods are between 1-2 m apart. The lines are stored in “magazine”, a line of 1 to 1.8 km long, with 950-1200 ready-baited hooks. Several “magazines” can be joined together. The lines are deployed between 500 and 2000 m and are left for 24 hrs to attract toothfish. The gear selects for larger Patagonian toothfish. It also has a greater catch rate of skates and rays.

8.1.2. Macquarie Island (MIF) fishery

Macquarie Island is part of the State of Tasmania and is located in the Southern Ocean about 1,500 km south-east of Hobart. The MIF extends from 3 nautical miles to the limit of the 200 nautical mile AFZ. The observer program covers nearly 100% fishing trips. MIF has two sub-fisheries: Demersal Trawl and Mid-water Trawl.

The Demersal Trawl Sub-fishery uses otter board trawls to target Patagonian toothfish. Gear restrictions include a minimum mesh size of 120 mm. Fishing grounds are located in a valley three nautical miles west of the island on the continental slope of the island and in a complex of valleys 30 nautical miles to the north. Gear is set in water deeper than 400 m, usually between 600 and 1200 m. The fishery is open year-around.

The scale of the Mid-water Trawl Sub-fishery is much smaller than the Demersal Trawl Sub-fishery. Only one shot is reported during 2004-2007 period. As fishing mortality is extremely low, the Mid-water Trawl Sub-fishery is not considered in this report.

8.2. Method

8.2.1. Estimating instantaneous fishing mortality *F*

There is no species distribution information from the Bioreg distributions used for the other sub-fisheries available for the sub-Antarctic fisheries (neither HIMI nor MIF fisheries). We developed an alternative method to derive species distribution. In this method, we used 10 km by 10 km grid resolution to map potential species distribution area. The data include all logbook and observer’s records obtained from AAD from 1994-2008. If a particular species has been detected one or more times in a particular grid, then this grid is considered as occupied and included in the calculation of the total distribution area for that species. Bias may result in this method. Underestimation of distribution area occurs when there has never been fishing activity within the true distribution area, when gear efficiency is less than one (i.e., a species is not caught when it is indeed there), and/or when only a small part of the grid has been trawled without detection. Overestimation occurs when a grid is historically occupied but not during the assessment period.

After species distribution areas were obtained, we used the same method as described in Chapter 2, section 2.2.1 and in Zhou et al. (2007) to estimate the fishing mortality rate. For the demersal trawling, we adopted an average net wing spread W = 38 m. For the mid-water trawling, we used W = 43.9 m (R. Daley, CSIRO, Hobart, personal communications).

For the demersal longlining, the gear affected area in one shot is derived as the length of the longline overlapping with a species distribution area times 1 km., i.e., 1 km-wide band along the length of the longline within a species distribution area. Unfortunately, formal stock assessment has not been conducted for the Demersal Longline Sub-fishery for any species and we do not have a correction factor ρ as in equation 7-1 for this sub-fishery. The logbook records show that the catch of the target species Patagonian toothfish by the demersal longline gear is only a fraction of the catch by the demersal trawl (CCAMLR 2007). The average ratio between the catches in these two sub-fisheries is 0.34 (SD = 0.09) during 2004-07. Assuming this ratio is the same for other species caught in the Demersal Longline Sub-fishery and the fishing mortality rate estimated for the Demersal Trawl Sub-fishery is correct, then we can use this auxiliary information to derive fishing mortality in the Demersal Longline Sub-fishery.

8.2.2. Reference points

Reference points are the same as described in 2.2.2.

8.3. Results

8.3.1. Heard Island and McDonald Island (HIMI) fishery

Demersal Trawl Sub-fishery

We included a total of 61 non-target fish species (6 chondrichthyans and 55 teleosts) in this sub-fishery assessment. Of these 61 species, all chondrichthyans and 49 teleosts have been caught or observed from commercial fishery so we have derived spatial distribution for these 55 species. The estimated spatial overlap between fishing efforts during 2004-2007 and species distribution ranged from close to 0 to 0.049 for these 55 species that have ever been caught. The estimated fishing mortality F_{cur} is generally low for all non-target species. However, two species of skates (chondrichthyans) may have F_{cur} greater than their minimum F_{msm}: *Bathyraja murrayi* and *Bathyraja eatonii*, although the estimated F_{cur} is smaller than their mean F_{msm}.

In the Sub-Antarctic fisheries, we also analysed available data for the targeted species, Patagonian toothfish. We estimated that this species has F_{cur} = 0.186 (± 90% CI 0.037) in this

Demersal Trawl Sub-fishery alone (compared to a total exploitation rate < 5% from stock assessment. See 8.4. Discussion for details). This mean F_{cur} is greater than mean F_{msm} (Figure 8-2), and is greater than the minimum F_{lim} (0.13) and minimum F_{crash} (0.17) from the six method in section 2.2.2, but less than the mean F_{lim} (0.26) and F_{crash} (0.35). Fishing effort may have increased during 2004-2007 (Figure 8-3).

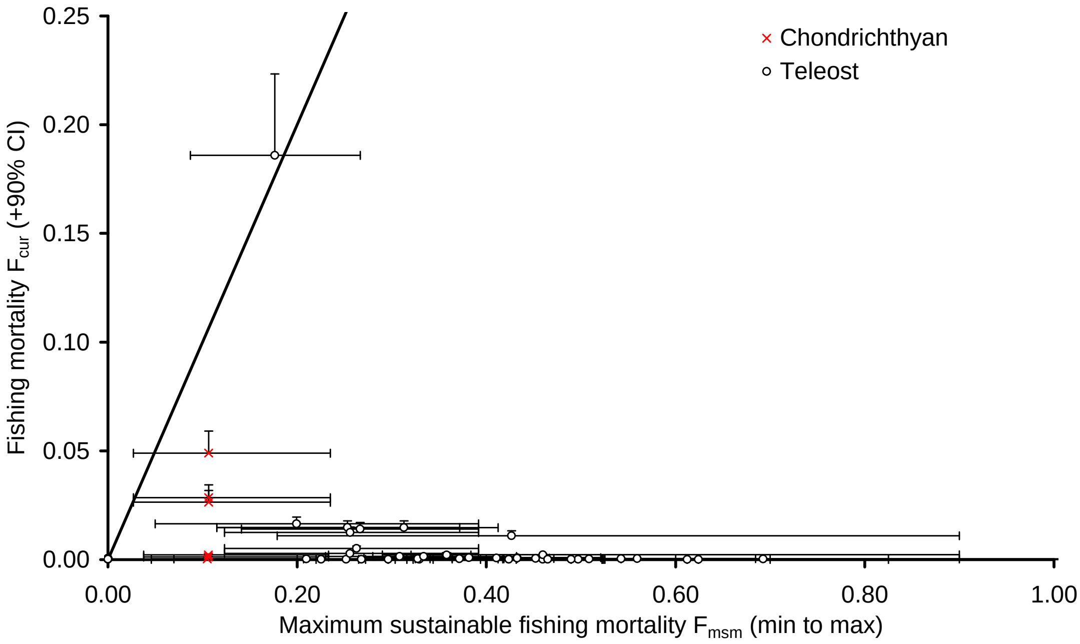

Figure 8-2. Comparison of estimated fishing mortality in the recent years (2004-2007) F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **HIMI Demersal Trawl Sub-fishery**. The diagonal line is where $F_{cur} = F_{msm}$. The species whose F_{cur} is above this diagonal line is Patagonian toothfish.

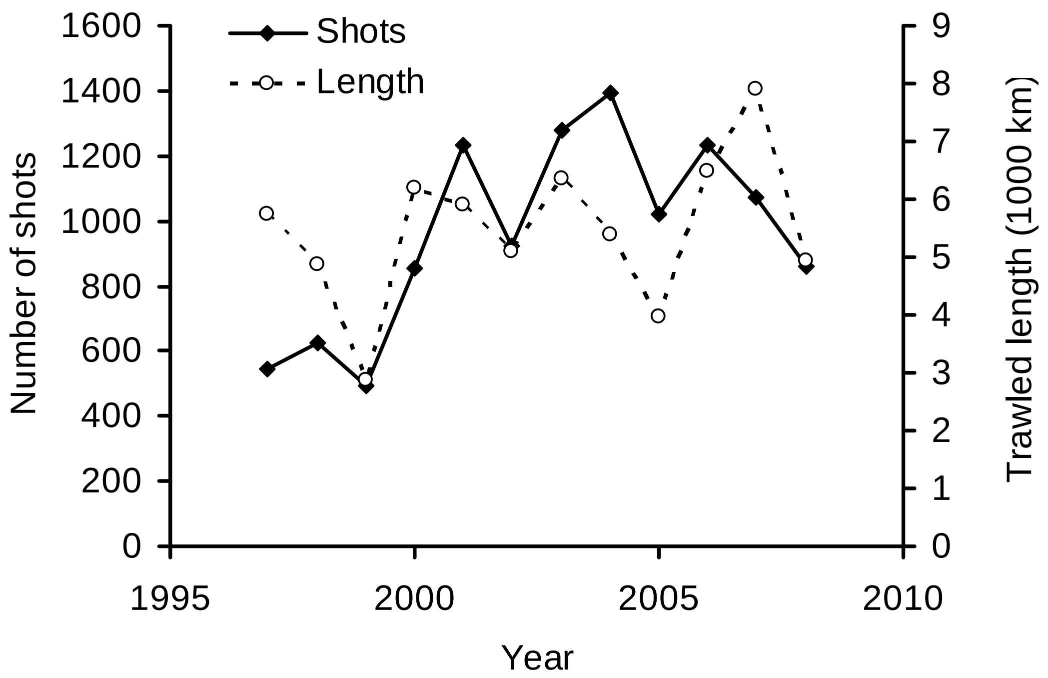

Figure 8-3. Fishing effort for the **HIMI DemersalTrawl Sub-fishery** from 1997 to 2008.

Mid-water Trawl Sub-fishery

We included a total of 22 non-target fish species (8 chondrichthyans and 14 teleosts) in this sub-fishery assessment. Of these 22 species, only one teleost has never been recorded from commercial fishery so we have no spatial information for this species. The estimated spatial overlap between fishing efforts during 2004-2007 and species distribution ranged from close to 0 to 0.008 for the remaining 21 species that have ever been caught. Accordingly, the estimated fishing mortality rate F_{cur} is low and is less than F_{msm} for all 21 species (including uncertainty) and no species has $F_{cur} > F_{msm}$ within the assessment period (Figure 8-4). Fishing effort during 2004-2007 has also declined from a high level in 2002 (Figure 8-5).

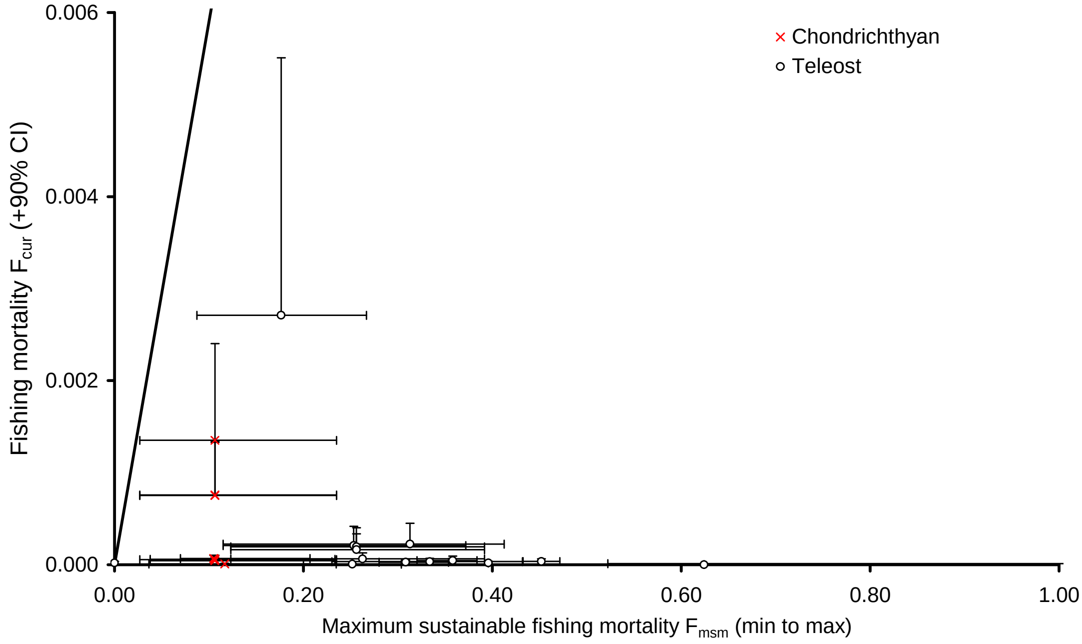

Figure 8-4. Comparison of estimated fishing mortality in the recent years (2004-2007) F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **HIMI Mid-water Trawl Sub-fishery**. The diagonal line is where $F_{cur} = F_{msm}$.

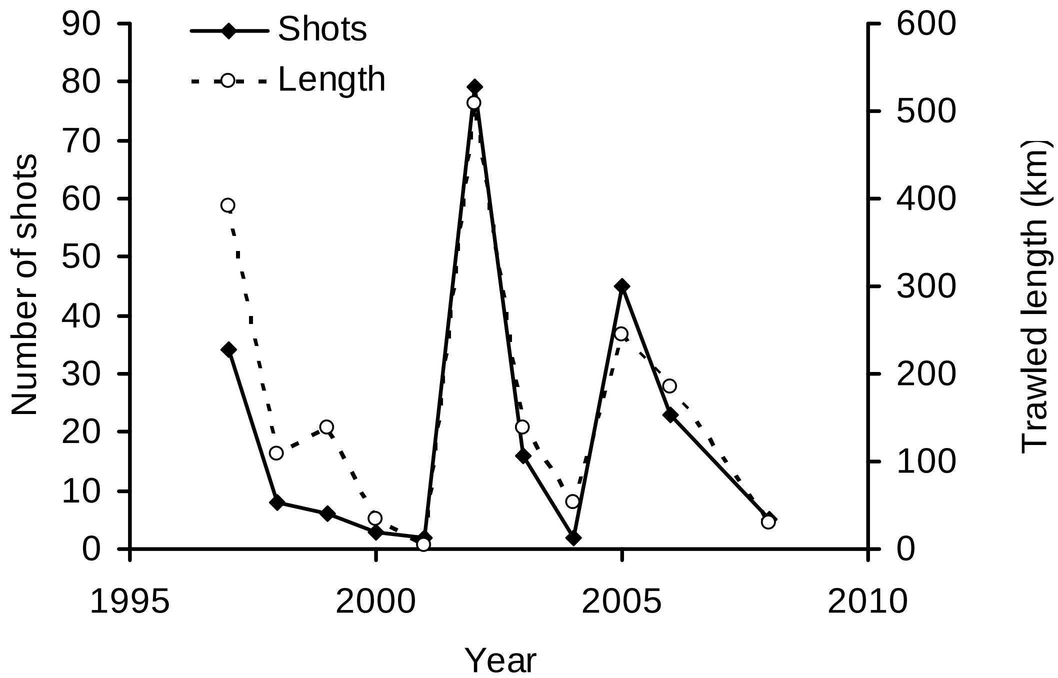

Figure 8-5. Fishing effort for the **HIMI Mid-water Trawl Sub-fishery** from 1997-2008.

Demersal Longline Sub-fishery

There are 14 nont-target fish species (7 chondrichthyans and 7 teleosts) included in this sub-fishery assessment. Of these 14 species, one teleost has never been recorded from commercial fishery so we have no spatial information for this species. The estimated spatial overlap between fishing efforts during 2004-2007 and species distribution ranged from close to 0 to 1.01 for the remaining 14 species that have ever been caught. This implies that using this simple method and 10 km by 10 km grids (see section 9.2. for discussion on potential bias of this method), species distribution areas may have been fished slightly more than once on average for some species. We also analysed the available data for the target species, Patagonian toothfish, which has a overlap of 2.85. We combined this overlap with auxiliary data for this target species to derive fishing mortality rates for other species. The estimated F_{cur} for this target species in the Demersal Trawl Sub-fishery is 0.186, and the ratio between the two sub-fisheries is 0.34, so we applied a correction factor $\rho = 0.022$ (= 0.186 × 0.34 / 2.85) to all species caught in the Demersal Longline Sub-fishery to estimate their fishing mortality (Figure 8-6). However, fishing effort has increased during 2004-2007 compared to 2003 level (Figure 8-7).

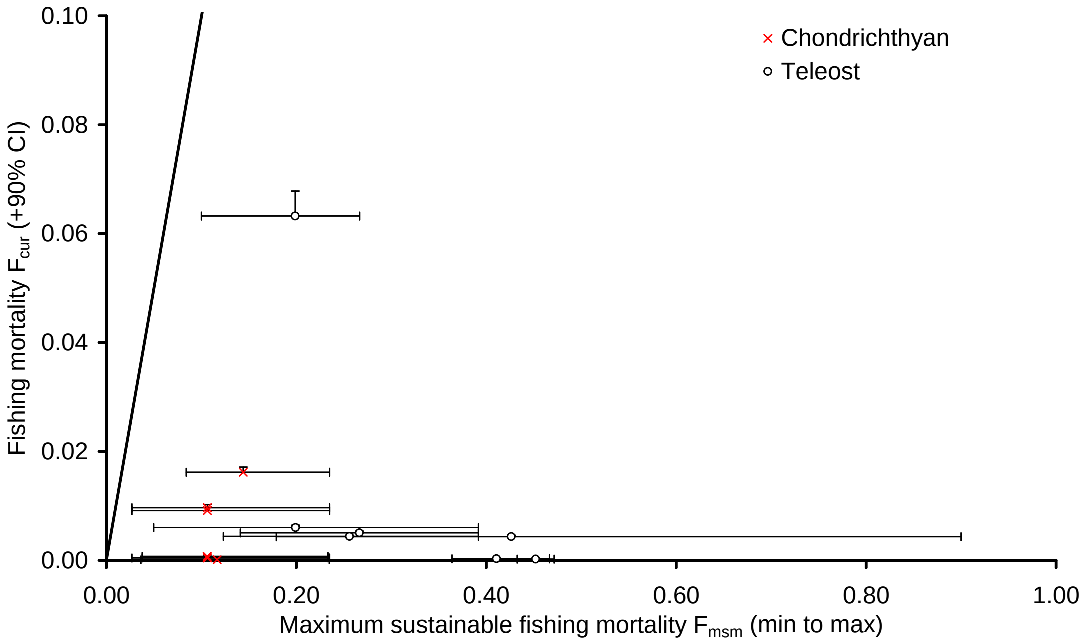

Figure 8-6. Comparison of estimated fishing mortality in the recent years (2004-2007) F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **HIMI Demersal Demersal Longline Sub-fishery**. The diagonal line is where $F_{cur} = F_{msm}$.

Figure 8-7. Fishing effort for the **HIMI Demersal Longline Sub-fishery** from 2003 to 2008.

Cumulative fishing mortality:

Most species assessed above in the Mid-water Trawl Sub-fishery and the Demersal Longline Sub-fishery are the same species as in the Demersal Trawl Sub-fishery. Combining the three sub-fisheries, there are 8 chondrichthyans and 59 teleosts (plus one target species). The target Patagonian toothfish has a cumulative $F_{cur} > F_{msm}$ within the assessment period (2004-2007, Figure 8-8). In addition, three chondrichthyans (skates in family Rajidae) have $F_{cur} >$ min[F_{msm}]: *Bathyraja irrasa*, *B. murrayi*, and *B. eatonii*.

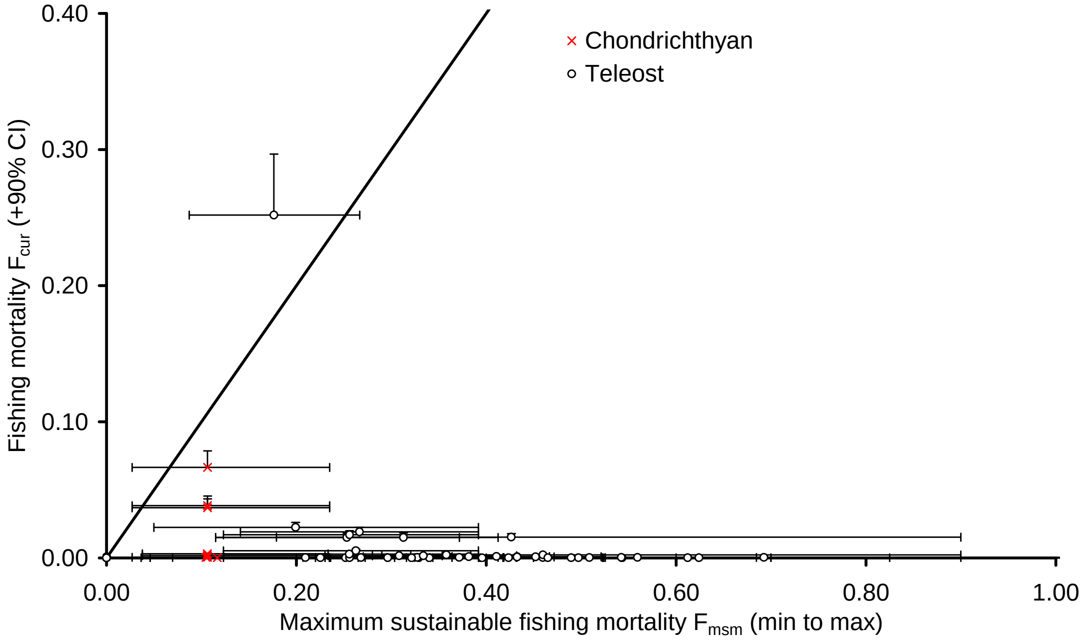

Figure 8-8. Comparison of estimated cumulative fishing mortality in recent years (2004-2007) F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **three HIMI Sub-fisheries**. The diagonal line is where $F_{cur} = F_{msm}$. The species whose F_{cur} is above this diagonal line is Patagonian toothfish.

8.3.2. Macquarie Island Fishery (MIF)

The Demersal Trawl Sub-fishery includes a total of 56 non-target fish species (2 chondrichthyans and 54 teleosts). Of these 56 species, all chondrichthyans and 51 teleosts have been caught or observed from commercial fishery so we have derived spatial distribution for these 53 species. The estimated spatial overlap between fishing efforts during 2004-2007 and species distribution ranged from close to 0 to 0.09 for the 53 species that have ever been caught. Accordingly, the estimated fishing mortality is low for these species (Figure 8-9). We also looked at the target Patagonian toothfish and estimated its F_{cur} = 0.25, which is greater than its mean F_{msm} (= 0.18, Figure 8-9) and min[F_{crash}] (= 0.16). Fishing effort in the assessment period is lower than the peak during 1995-1997 (Figure 8-10).

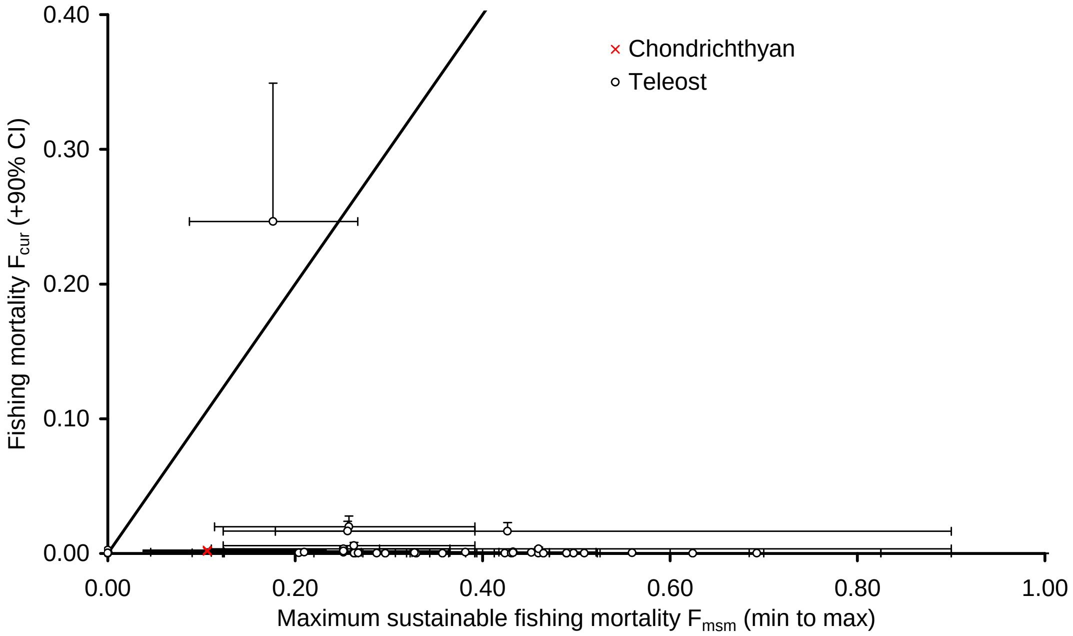

Figure 8-9. Comparison of estimated fishing mortality in the recent years (2004-2007) F_{cur} and the reference fishing mortality corresponding to the maximum sustainable mortality for fish species caught in the **Macquarie Island Demersal Trawl Sub-fishery**. The diagonal line is where $F_{cur} = F_{msm}$.

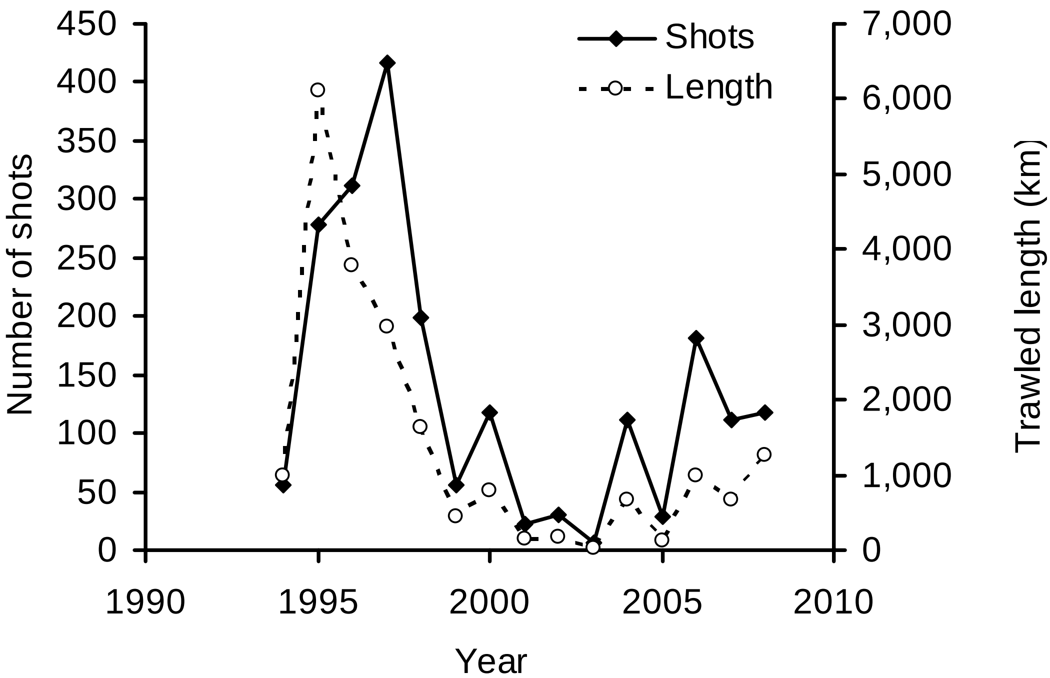

Figure 8-10. Fishing effort for the **Macquarie Island Demersal Trawl Sub-fishery** from 1994 to 2008.

8.4. Discussion

The new method described in section 8.2.1 may have overestimated the fishing impact. The results show fishing mortality for the target Patagonian toothfish in recent year has been greater than its maximum sustainable fishing mortality. Using five alternative models formal stock assessment for the Patagonian toothfish in the HIMI region shows that the virgin biomass ranges from 78,314 tons to 152,332 tons (Candy and Constable 2008). Based on the estimated spawning biomass status in 2007 and the total removal of this species, the average exploitation rate from the five models outputs is less than 5%. This is much lower than our estimated cumulative fishing mortality F_{cur} = 0.25. Assuming the formal stock assessment results are accurate it seems reasonable to suppose that other species in the HIMI region may also have lower fishing mortalities than our estimations.

The assessment of non-target species in the HIMI sub-fishery indicates that three skates (*Bathyraja irrasa*, *B. murrayi*, and *B. eatonii*) may have estimated cumulative fishing mortality greater than their minimum reference point min[F_{msm}]. This min[F_{msm}] = 0.03 for all three species, which is the minimum values from six methods described in Chapter 2. Although these skates may only sustain very low fishing impact, the value of 0.03 may be over-precautious. Further, as discussed above for the target species, we may have overestimated fishing mortality for these skates. Based on the assumptions of the new method we tend to conclude that no species is at risk of overfishing at the current fishing level. However, further analysis of data for the three skate species seems warranted.

Stock assessment for the Macquarie Island Patagonian toothfish results in an exploitation rate of 0.021, 0.085, 0.065, and 0.051 from 2004 to 2007 (G. Tuck, CSIRO Hobart, personal communications). This corresponds to an average F_{cur} = 0.057, which is much smaller than our estimated F_{cur} = 0.25 for the MIF Demersal Trawl Sub-fishery. Assuming the formal stock assessment results are accurate it seems reasonable to conclude that other species in the MI region also have lower fishing mortalities than our estimates and no species is at risk of overfishing at the current fishing level.

8.5. Reference

Bulman, C., Daley, R., Sporcic, M., Fuller, M., Stevenson, D., and Hobday, A. (2007) Ecological Risk Assessment for the Effects of Fishing: Report for the Midwater Trawl Sub-fishery of the Heard and McDonald Islands Fishery. Report for the Australian Fisheries Management Authority, Canberra.

Bulman, C, Daley, R, Stevenson, D., Hobday, A., Sporcic, M. and Fuller, M. (2008) Ecological Risk Assessment for the Effects of Fishing: Report for Demersal Longline Sub-fishery of the Heard and McDonald Islands Fishery. Report for the Australian Fisheries Management Authority, Canberra.

Candy, S. G. and Constable, A. J. (2008) An Integrated Stock Assessment for the Patagonian toothfish (Dissostichus eleginoides) for the Heard and McDonald Islands using CASAL. CCAMLR Science 15: 1–34.

CCAMLR. (2007) Fishery Report: Dissostichus eleginoides Heard Island (Division 58.5.2). http://www.ccamlr.org/pu/e/e_pubs/fr/07/appL.pdf.

Daley, R., Bulman, C., Stevenson, D., Hobday, A., Sporcic, M., and Fuller, M. (2007) Ecological Risk Assessment for the Effects of Fishing: Report for the Demersal Trawl Sub-fishery of the Heard and McDonald Islands Fishery. Report for the Australian Fisheries Management Authority, Canberra.

Daley, R., Bulman, C, Stevenson, D., Hobday, A., Sporcic, M., and Fuller, M. (2008) Ecological Risk Assessment for the Effects of Fishing: Report of the Demersal Trawl Sub-fishery for the Macquarie Island Fishery. Report for the Australian Fisheries Management Authority, Canberra.

Zhou, S., Smith, T., and Fuller, M. (2007) Rapid quantitative risk assessment for fish species in major Commonwealth fisheries. Report to the Australian Fisheries Management Authority.

Chapter 9. General discussion

We have completed SAFE for seven additional major Commonwealth fisheries in this report. During the assessment we encountered some challenges and developed new methods to tackle these problems. Some difficulties remain. In this chapter we briefly discuss these issues and provide suggestions for future research.

9.1. Sustainability reference points

Sustainability reference points are one of the two components in the SAFE method. Linking reference points to fish life history parameter is one of the key advances of this method. Such generalization avoids data limitation difficulties and circumvents a formal stock assessment when it cannot be conducted. A “rule of thumb” setting F_{msy} equals M has been widely adopted for management of target species when stock assessment cannot or has not been carried out (Zhou and Griffiths 2007). Research has shown that instantaneous natural mortality rate is a reasonable surrogate for F_{msy} for some stocks, although it can be too high for other stocks (Francis, 1974; Deriso, 1982; Garcia et al., 1989). Clark (1991) showed that from calculations made with a range of life history parameter values typical of demersal fish, and using a range of realistic spawner–recruit relationships, the optimal harvest rate is often close to the natural mortality. On the other hand, for stocks with little or no growth data, a maximum fishing mortality rate of 80% of the natural mortality rate has been suggested as a precautionary approach (Thompson, 1993). A more conservative suggestion is that an optimal fishing mortality should be less than a half of that species’ natural mortality (Walters and Martell 2002).

We have also applied the popular notion of $F_{msy} = M$ for all fish species in our previous study (Zhou et al. 2007) but have been concerned that this simple relationship may be risky for some species, especially chondrichthyans. Recently, in a separate project we carried out a meta-analysis using empirical data for more than a hundred species. The preliminary results indicated that the classical $F_{msy} = M$ relationship is fairly reasonable for teleosts. However, it appears unacceptable for chondrichthyans. Therefore, we adopt a fresh equation $F_{msm} = 0.42 M$. A more rigorous study is underway to verify these results.

9.2. Lack of species distribution data

One of the outstanding challenges is the lack of species distribution information for a few species in almost all fisheries in this report. Some of these species are pelagic and it is difficult to determine their distribution range. One approach to solve this problem is to borrow information from formal stock assessments of target species in the same fishery to adjust estimates resulting from the simple method (Zhou et al. 2007). Unfortunately, formal stock assessments have not been conducted for any species in some fisheries. In this report, we use fishing effort data to infer fishing impact. In contrast to the Level 2 PSA method, fishing intensity is critical in the SAFE method. If fishing effort is zero there is no effect of fishing. Because fishing efforts have declined dramatically in some fisheries in recent years (i.e., the Skipjack Tuna Fishery, the Southern Bluefin Tuna Fishery, and the Western Tuna and Billfish Fishery), we believe this is useful information to indicate fishing mortality changes over time. Other information or new method is needed for fisheries when species distribution data are not available and fishing effort in recent years does not show a declining trend.

9.3. Uncertainty of input data

From Chapter 2 and Zhou et al. (2007), six methods based on fish life history parameters were used to derive sustainability reference points. The results clearly show large uncertainty among different methods. Close examinations reveal that the differences come from two sources: the method and the data themselves. The latter appears to introduce larger uncertainty than the former. Life history parameters may have been adopted from other species or averaged from species in the same family or genus. Due to lack of time and large number of species, we are unable to clean up the original input data in this rapid assessment project. It is recommended that input data be verified for the future analyses.

9.4. Key assumptions in the method

The SAFE method provides a considerable advance over previous ERA methods applied to Commonwealth fisheries, including the Level 2 PSA method, because it provides a means of directly estimating fishing mortality for species. Moreover it is able to do this without requiring detailed time series of data on catch or catch composition, and so can be applied to a much wider range of species than those normally assessed using conventional stock assessment methods. However, due to limited data these benefits come at the cost of requiring some fairly strong assumptions to be able to apply the methods to the seven major Commonwealth Fisheries in this report. Key among these is that the overlap of fishing effort with the distribution of species allows an estimate of fishing mortality (taking into account some other factors such as catchability). The method assumes that species are evenly distributed within their distributional ranges, so that a unit of fishing effort anywhere within the range has the same impact on mortality. Even distributions of fish are the exception rather than the rule, and the distribution of effort relative to density (rather than distribution) is the key determinant of fishing impact. The important point to note is that the methods used in this report can lead to underestimates of fishing mortality if effort is concentrated in areas of high density. This will tend to be the case for target species, but may also apply to a range of other species if these are in some way associated with target species in terms of their distribution (e.g. predators, prey, shared habitat preferences). While there are clear advantages of a rapid screening method (such as SAFE) using existing simple data, it is important to note that it may underestimate fishing mortality for some species. Further screening of species with restricted distributions, or that are highly aggregating, would be a useful next step in the analysis of species impacted by fishing. Of course, the accuracy of estimated fishing mortality can be improved when species spatial density data become available.

9.5. Sub-Antarctic Fisheries

Sub-Antarctic Fisheries differ from other fisheries because distribution has not been mapped for any species. We developed a novel method by using logbook and observers records. This method tends to underestimate the distribution ranges because areas that have never been fished, but are occupied by a species, are not included. Further, the resolution of grids is an important factor affecting an accurate estimation. Overestimation of distribution occurs when the grid size is too large while underestimation of distribution occurs when the grid size is too small. If distribution areas or fishing mortalities are available for a range of species from rigorous methods (e.g., scientific surveys or stock assessment), it may be possible to derive a relationship between grid sizes (resolution) and distribution ranges. For example, we tried using grid size of 1 km^2 for the HIMI and MIF fisheries and found such a resolution is too fine to represent species occupancy in the area.

9.6. Reference

Francis, R.C. (1974). Relationship of fishing mortality to natural mortality at the level of maximum yield under the logistic stock production model. Journal of Fisheries Research Board of Canada 31: 1539–1542.

Deriso, R. B. (1982) Relationship of fishing mortality to natural mortality and growth at the level of maximum sustainable yield. Canadian Journal of Fisheries and Aquatic Science 39: 1054–1058.

Garcia, S., Sparre, P., Csirke, J. (1989) Estimating surplus production and maximum sustainable yield for biomass data when catch and effort time series are not available. Fisheries Research 8: 13–23.

Clark, W. G. (1991) Groundfish exploitation rates based on life history parameters. Canadian Journal of Fisheries and Aquatic Science 48: 734–750.

Thompson, G. G. (1993) A proposal for a threshold stock size and maximum fishing mortality rate. Canadian Journal of Fisheries and Aquatic Science 120: 303–320.

Walters, C., Martell, S. J. D. (2002) Stock assessment needs for sustainable fisheries management. Bulletin of Marine Science 70: 629–638.

Zhou, S., Smith, T., and Fuller, M. (2007) Rapid quantitative risk assessment for fish species in major Commonwealth fisheries. Report to the Australian Fisheries Management Authority.

Zhou, S. and Griffiths, S. P. (2008) Sustainability Assessment for Fishing Effects (SAFE): A new quantitative ecological risk assessment method and its application to elasmobranch bycatch in an Australian trawl fishery. Fisheries Research 91: 56-68.

Appendix

Table A-1. Species included in the assessment of the **North West Slope Trawl Fishery** and their assessment results. I_A = fraction of distribution area within the fishery jurisdiction fished; q = overall catchability, S = post-capture survival rate, F_{cur} = instantaneous fishing mortality rate during 2004-2007, F_{msm} = instantaneous fishing mortality rate that corresponds to the maximum sustainable fishing mortality, Method = methods used for estimating the reference points, and Role = code in the fishery (BP = byproduct, DI = discards, NA = not assigned). TEP species are excluded in the table.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Callorhinchus milii	Elephantfish	0	0.44	1.0	0	0.15	123456	BP
Hydrolagus ogilbyi	Ogilbys Ghost Shark	0	1.00	1.0	0	0.18	35	DI
Carcharhinus, Loxodon & Rhizoprionodon spp	Blacktip sharks	NA	0.33	1.0	NA	0.11	23456	NA
Chimaeridae - undifferentiated	shortnose chimaeras	NA	0.33	1.0	NA			NA
Dasyatidae - undifferentiated	stingrays	NA	0.33	1.0	NA			NA
Squalidae - undifferentiated	dogfishes	NA	0.33	1.0	NA			NA
Genypterus blacodes	Ling	0	1.00	1.0	0	0.26	123456	BP
Gephyroberyx darwinii	darwin's roughy	0.01	1.00	1.0	0.01	0.21	123456	BP
Lutjanus erythropterus	Saddle-tailed Sea Perch	< 0.005	0.11	1.0	< 0.005	0.35	123456	BP
Lutjanus malabaricus	Scarlet Sea Perch / Large Mouth Nannygai	< 0.005	0.11	1.0	< 0.005	0.33	123456	BP
Centroberyx gerrardi	bight redfish	0	0.29	1.0	0	0.32	123456	DI
Pleuroscopus pseudodorsalis	blue stargazer	0	1.00	1.0	0	0.41	23456	DI
Trachipterus arawatae	Ribbon or Dealfish	NA	1.00	1.0	NA	0.22	3	DI
Etelis carbunculus	Ruby snapper; Northwest Ruby Fish	0.01	0.66	1.0	0.01	0.26	123456	NA
Lutjanus spp.	Sea Perch	NA	0.11	1.0	NA	0.35	123456	NA
Pagrus auratus	Snapper/Squirefish	0	0.44	1.0	0	0.33	123456	NA
Priacanthus spp	Red bullseye (All Australian members of	NA	0.44	1.0	NA	0.41	35	NA
Pristipomoides multidens & Pristipomoides typus	goldband snapper	NA	1.00	1.0	NA	0.38	123456	NA

Table A-1 continued.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Trachurus declivis	Jack Mackerel	0	0.33	1.0	0	0.44	123456	NA
Uranoscopidae - undifferentiated	stargazers	NA		1.0	NA			NA
Zenopsis nebulosus	Mirror Dory	0.01	1.00	1.0	0.01	0.29	123456	NA
Centroberyx affinis	Redfish	NA	0.66	1.0	NA	0.30	123456	NA

Table A-2. Species included in the assessment of the **Skipjack Tuna Fishery** and their assessment results. I_A = fraction of distribution area within the fishery jurisdiction fished; q = overall catchability, S = post-capture survival rate, F_{cur} = instantaneous fishing mortality rate during 2004-2007, F_{msm} = instantaneous fishing mortality rate that corresponds to the maximum sustainable fishing mortality, Method = methods used for estimating the reference points, and Role = code in the fishery (BP = byproduct, DI = discards, NA = not assigned). TEP species are excluded in the table.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Carcharhinus obscurus	Dusky Shark	< 0.005	1.00	1.00	< 0.005	0.11	123456	DI
Isurus oxyrinchus	Shortfinned Mako or Blue Pointer	< 0.005	1.00	1.00	< 0.005	0.17	123456	DI
Lamna nasus	Porbeagle shark	< 0.005	1.00	1.00	< 0.005	0.13	123456	DI
Manta birostris	Manta Ray	< 0.005	1.00	1.00	< 0.005	0.23	356	DI
Prionace glauca	Blue Shark	< 0.005	1.00	1.00	< 0.005	0.16	123456	DI
Coryphaena hippurus	Dolphin Fish (mahi mahi)	NA	1.00	1.00	NA	1.59	23456	BP
Sarda australis	australian bonito	NA	1.00	1.00	NA	0.48	123456	BP
Thunnus alalunga	Albacore	NA	1.00	1.00	NA	0.27	123456	BP
Thunnus albacares	Yellowfin Tuna	NA	1.00	1.00	NA	0.40	123456	BP
Thunnus maccoyii	Southern Bluefin Tuna	NA	1.00	1.00	NA	0.21	123456	BP
Thunnus obesus	Bigeye Tuna	NA	1.00	1.00	NA	0.38	123456	BP
Auxis thazard	Frigate mackerel	NA	1.00	1.00	NA	0.55	123456	DI
Makaira indica	Black Marlin	NA	1.00	1.00	NA	0.25	23456	DI
Makaira mazara	Blue Marlin	NA	1.00	1.00	NA	0.24	23456	DI
Tetrapturus audax	Striped marlin	NA	1.00	1.00	NA	0.38	23456	DI
Xiphias gladius	Broad Billed Swordfish	NA	1.00	1.00	NA	0.32	23456	DI

Table A-3. Species included in the assessment of the **Purse Seine Sub-fishery** of the **Small Pelagic Fishery** and their assessment results. I_A = fraction of distribution area within the fishery jurisdiction fished; q = overall catchability, S = post-capture survival rate, F_{cur} = instantaneous fishing mortality rate during 2004-2007, F_{msm} = instantaneous fishing mortality rate that corresponds to the maximum sustainable fishing mortality, Method = methods used for estimating the reference points, and Role = code in the fishery (BP = byproduct, DI = discards, NA = not assigned). TEP species are excluded in the table.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Decapterus russelli	red tailed round scad	0	0.33	1.00	0	0.72	123456	BP
Hyperoglyphe antarctica	Blue Eye Trevalla	< 0.005	0.33	1.00	< 0.005	0.27	123456	BP
Macruronus novaezelandiae	Blue Grenadier	< 0.005	0.66	1.00	< 0.005	0.29	123456	BP
Pseudocaranx dentex	Silver Trevally	< 0.005	0.33	1.00	< 0.005	0.30	123456	BP
Sardinops neopilchardus	pilchard	< 0.005	1.00	1.00	< 0.005	0.75	123456	BP
Seriola lalandi	Yellowtail Kingfish	< 0.005	1.00	1.00	< 0.005	0.52	123456	BP
Seriolella brama	Blue Warehou	< 0.005	0.33	1.00	< 0.005	0.37	123456	BP
Seriolella punctata	Spotted Warehou	< 0.005	0.33	1.00	< 0.005	0.37	123456	BP
Thyrsites atun	Barracouta	< 0.005	0.66	1.00	< 0.005	0.41	123456	BP
Centroberyx lineatus	swallowtail	< 0.005	0.33	1.00	< 0.005	0.34	123456	DI
Lepidopus caudatus	Southern Frostfish	< 0.005	0.66	1.00	< 0.005	0.37	23456	DI
Nelusetta ayraudi	Chinaman-Leatherjacket	< 0.005	0.33	1.00	< 0.005	0.45	123456	DI

Table A-4. Species included in the assessment of the **Mid-water Trawl Sub-fishery** of the **Small Pelagic Fishery** and their assessment results. I_A = fraction of distribution area within the fishery jurisdiction fished; q = overall catchability, S = post-capture survival rate, F_{cur} = instantaneous fishing mortality rate during 2004-2007, F_{msm} = instantaneous fishing mortality rate that corresponds to the maximum sustainable fishing mortality, Method = methods used for estimating the reference points, and Role = code in the fishery (BP = byproduct, DI = discards, NA = not assigned). TEP species are excluded in the table.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Centroberyx lineatus	swallowtail	< 0.005	1.00	1.00	< 0.005	0.36	123456	BP
Centrolophus niger	Rudderfish	0	1.00	1.00	0	0.34	123456	BP
Cyttus australis	Silver dory	0	1.00	1.00	0	0.42	123456	BP
Hyperoglyphe antarctica	Blue Eye Trevalla	< 0.005	1.00	1.00	< 0.005	0.27	123456	BP
Macruronus novaezelandiae	Blue Grenadier	< 0.005	1.00	1.00	< 0.005	0.30	123456	BP
Mola mola	ocean sunfish	NA	1.00	1.00	NA	0.15	356	BP
Nelusetta ayraudi	Chinaman-Leatherjacket	< 0.005	1.00	1.00	< 0.005	0.45	123456	BP
Neoplatycephalus richardsoni	Flathead	0	1.00	1.00	0	0.52	123456	BP
Pseudocaranx dentex	Silver Trevally	< 0.005	1.00	1.00	< 0.005	0.30	123456	BP
Scomber australasicus	Blue Mackerel	NA	1.00	1.00	NA	0.42	123456	BP
Seriolella brama	Blue Warehou	< 0.005	1.00	1.00	< 0.005	0.37	123456	BP
Seriolella punctata	Spotted Warehou	< 0.005	1.00	1.00	< 0.005	0.37	123456	BP
Thyrsites atun	Barracouta	< 0.005	1.00	1.00	< 0.005	0.40	123456	BP
Trachurus declivis	Jack Mackerel	< 0.005	1.00	1.00	< 0.005	0.52	123456	BP
Zenopsis nebulosus	Mirror Dory	0	0.66	1.00	0	0.31	123456	BP
Lepidopus caudatus	Southern Frostfish	< 0.005	1.00	1.00	< 0.005	0.39	23456	DI
Lepidotrigla vanessa	butterfly gurnard	0	1.00	1.00	0	0.65	123456	DI

Table A-5. Species included in the assessment of the **Southern Bluefin Tuna Fishery** and their assessment results. I_A = fraction of distribution area within the fishery jurisdiction fished; q = overall catchability, S = post-capture survival rate, F_{cur} = instantaneous fishing mortality rate during 2004-2007, F_{msm} = instantaneous fishing mortality rate that corresponds to the maximum sustainable fishing mortality, Method = methods used for estimating the reference points, and Role = code in the fishery (BP = byproduct, DI = discards, NA = not assigned, TB = target bait species). TEP species are excluded in the table.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Carcharhinus obscurus	Dusky Shark	< 0.005	1.00	1.00	< 0.005	0.12	123456	DI
Isurus oxyrinchus	Shortfinned Mako or Blue Pointer	< 0.005	1.00	1.00	< 0.005	0.12	123456	DI
Prionace glauca	Blue Shark	< 0.005	1.00	1.00	< 0.005	0.12	123456	DI
Arripis trutta	Australian Salmon	NA	0.22	0.33	NA	0.43	123456	BP
Arripis truttaceus	Western australian salmon	NA	0.22	0.33	NA	0.37	123456	BP
Katsuwonus pelamis	Skipjack Tuna	NA	0.22	0.33	NA	0.39	123456	BP
Thunnus alalunga	Albacore	NA	0.33	0.33	NA	0.50	123456	BP
Thunnus albacares	Yellowfin Tuna	NA	0.22	0.33	NA	0.26	123456	BP
Thunnus obesus	Bigeye Tuna	NA	0.11	0.33	NA	0.21	123456	BP
Makaira indica	Black Marlin	NA	0.11	0.33	NA	0.56	23456	DI
Makaira mazara	Blue Marlin	NA	0.22	0.33	NA	0.55	23456	DI
Nelusetta ayraudi	Chinaman-Leatherjacket	0.00	0.22	0.33	< 0.005	0.25	123456	DI
Tetrapturus audax	Striped marlin	NA	0.33	0.33	NA	0.69	23456	DI
Xiphias gladius	Broad Billed Swordfish	NA	0.22	0.33	NA	0.22	235	DI
Arripis georgianus	Tommy rough	0	0.66	0.33	0	0.42	123456	TB
Emmelichthys nitidus	Redbait	< 0.005	0.22	0.33	< 0.005	0.28	2456	TB
Engraulis australis	australian anchovy	0.00	0.22	0.33	< 0.005	0.98	123456	TB
Pseudocaranx dentex	Silver Trevally	0.00	1.00	0.33	< 0.005	0.23	123456	TB
Pseudocaranx wrighti	Skipjack trevally	0.00	0.66	0.33	< 0.005	0.43	123456	TB
Sardinops neopilchardus	Pilchard	< 0.005	0.22	0.33	< 0.005	0.94	123456	TB
Scomber australasicus	Blue Mackerel	NA	0.33	0.33	NA	0.25	123456	TB
Trachurus declivis	Jack Mackerel	< 0.005	0.33	0.33	< 0.005	0.75	123456	TB
Trachurus murphyi	Peruvian Jack Mackerel	NA	0.22	0.33	NA	0.69	123456	TB
Trachurus novaezelandiae	Yellow tail scad	< 0.005	0.33	1.00	< 0.005	0.38	123456	TB

Table A-6. Species included in the assessment of the **Western Deep Water Trawl Fishery** and their assessment results. I_A = fraction of distribution area within the fishery jurisdiction fished; q = overall catchability, S = post-capture survival rate, F_{cur} = instantaneous fishing mortality rate during 2004-2007, F_{msm} = instantaneous fishing mortality rate that corresponds to the maximum sustainable fishing mortality, Method = methods used for estimating the reference points, and Role = code in the fishery (BP = byproduct, DI = discards, NA = not assigned). TEP species are excluded in the table.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Callorhinchus milii	Elephantfish	0	1.00	1.00	0	0.17	123456	BP
Carcharhinus brachyurus	Bronze Whaler	0	1.00	1.00	0	0.09	123456	BP
Carcharhinus dussumieri	Whitecheek shark	0	1.00	1.00	0	0.11	123456	BP
Carcharhinus obscurus	Dusky Shark	0.01	1.00	1.00	0.01	0.09	123456	BP
Carcharhinus sorrah	Sorrah shark	0	1.00	1.00	0	0.15	123456	BP
Centrophorus moluccensis (west)	Endeavour Dogfish	0.01	1.00	1.00	0.01	0.11	2345	BP
Chimaera sp. A [in Last & Stevens, 1994]	southern chimaera	< 0.005	1.00	1.00	< 0.005	0.18	35	BP
Chimaera sp. C [in Last & Stevens, 1994]	longspine chimaera	< 0.005	1.00	1.00	< 0.005	0.25	5	BP
Chimaera sp. E [in Last & Stevens, 1994]	whitefin chimaera	0.01	1.00	1.00	0.01	0.18	35	BP
Deania calcea	Brier Shark	< 0.005	1.00	1.00	< 0.005	0.10	23456	BP
Deania quadrispinosa	Platypus Shark	< 0.005	1.00	1.00	< 0.005	0.11	2345	BP
Galeorhinus galeus	School Shark, Tope shark	< 0.005	1.00	1.00	< 0.005	0.12	123456	BP
Hydrolagus lemures	bight ghost shark	0.01	1.00	1.00	0.01	0.18	35	BP
Mustelus antarcticus	Gummy Shark	< 0.005	1.00	1.00	< 0.005	0.16	123456	BP
Pristiophorus cirratus	common saw shark	0	1.00	1.00	0	0.15	245	BP
Rhizoprionodon acutus	Milk shark	0	1.00	1.00	0	0.23	123456	BP
Squalus mitsukurii	Green-Eyed Dogfish	0.01	1.00	1.00	0.01	0.11	123456	BP
Squatina tergocellata	ornate angel shark	< 0.005	1.00	1.00	< 0.005	0.14	356	BP
Alopias vulpinus	Thintail Thresher Shark, thresher shark	< 0.005	1.00	1.00	< 0.005	0.12	23456	DI
Isurus oxyrinchus	Shortfinned Mako or Blue Pointer	0	1.00	1.00	0	0.11	123456	DI
Manta birostris	Manta Ray	0	1.00	1.00	0	0.13	3456	DI

Table A-6 continued.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Notorynchus cepedianus	Broadnose sevengill shark	0	1.00	1.00	0	0.17	123456	DI
Squalus megalops	Piked Dogfish	< 0.005	1.00	1.00	< 0.005	0.11	123456	DI
Achoerodus viridis	Eastern Blue Groper	0	1.00	1.00	0	0.80	23456	BP
Allocyttus niger	Black Oreo	< 0.005	1.00	1.00	< 0.005	0.18	123456	BP
Aphareus rutilans	rusty jobfish	NA	1.00	1.00	NA	0.35	123456	BP
Argyrosomus hololepidotus	Jewfish	0	1.00	1.00	0	0.28	123456	BP
Beryx splendens	Alfonsino	0.01	1.00	1.00	0.01	0.39	123456	BP
Bodianus vulpinus	Pigfish	0	0.66	1.00	0	0.79	23456	BP
Centroberyx affinis	Redfish	0	1.00	1.00	0	0.31	123456	BP
Centrolophus niger	Rudderfish	< 0.005	1.00	1.00	< 0.005	0.34	123456	BP
Cleidopus gloriamaris	pineapple fish	< 0.005	0.33	1.00	< 0.005	0.48	23456	BP
Cyttus australis	Silver dory	0	1.00	1.00	0	0.42	123456	BP
Cyttus traversi	King Dory	< 0.005	1.00	1.00	< 0.005	0.58	123456	BP
Dannevigia tusca	Australian Tusk	< 0.005	1.00	1.00	< 0.005	0.31	123456	BP
Diretmichthys parini	parins spinyfin	NA	1.00	1.00	NA	0.43	5	BP
Elagatis bipinnulata	rainbow runner	0	1.00	1.00	0	0.51	123456	BP
Epinephelus lanceolatus	rock cod	0	1.00	1.00	0	0.27	23456	BP
Epinephelus multinotatus	white-spotted rock cod	0	1.00	1.00	0	0.31	23456	BP
Epinephelus radiatus	Oblique-banded Grouper /Radiant cod	0	1.00	1.00	0	0.30	23456	BP
Etelis coruscans	sea perch/snapper	0	1.00	1.00	0	0.32	123456	BP
Genypterus blacodes	Ling	0.01	1.00	1.00	0.01	0.25	123456	BP
Gephyroberyx darwinii	darwin’s roughy	< 0.005	0.66	1.00	< 0.005	0.22	123456	BP
Glaucosoma buergeri	Northern Jewfish	0	1.00	1.00	0	0.32	23456	BP
Glaucosoma hebraicum	West Australian dhufish	0	1.00	1.00	0	0.30	23456	BP
Helicolenus percoides	Ocean Perch – inshore	0	0.66	1.00	0	0.29	123456	BP
Hyperoglyphe antarctica	Blue Eye Trevalla	< 0.005	1.00	1.00	< 0.005	0.27	123456	BP
Latridopsis forsteri	Bastard Trumpeter	0	1.00	1.00	0	0.26	23456	BP
Lepidoperca pulchella	Orange Perch	0	1.00	1.00	0	0.45	23456	BP

Table A-6 continued.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Lutjanus malabaricus	Scarlet Sea Perch / Large Mouth Nannygai	0	1.00	1.00	0	0.34	123456	BP
Lutjanus russelli [The eastern form]	[a tropical snapper]	NA	1.00	1.00	NA	0.37	123456	BP
Lutjanus sebae	Red Emperor	0	1.00	1.00	0	0.38	123456	BP
Lutjanus sp. (in Yearsley, Last & Ward, 1999) [The western form]	Russell's snapper	0	1.00	1.00	0	0.37	123456	BP
Macruronus novaezelandiae	Blue Grenadier	< 0.005	1.00	1.00	< 0.005	0.29	123456	BP
Metavelifer multiradiatus	veilfin	< 0.005	1.00	1.00	< 0.005	0.51	25	BP
Mora moro	Ribaldo	< 0.005	1.00	1.00	< 0.005	0.43	12356	BP
Neatypus obliquus	Footballer Sweep	0	1.00	1.00	0	0.40	2345	BP
Nelusetta ayraudi	Chinaman-Leatherjacket	< 0.005	1.00	1.00	< 0.005	0.45	123456	BP
Nemadactylus macropterus	Jackass Morwong	< 0.005	1.00	1.00	< 0.005	0.26	123456	BP
Nemadactylus valenciennesi	queen snapper	< 0.005	1.00	1.00	< 0.005	0.25	123456	BP
Neocyttus rhomboidalis	Spiky Oreo	< 0.005	1.00	1.00	< 0.005	0.23	123456	BP
Oplegnathus woodwardi	Knifejaw	0.01	1.00	1.00	0.01	0.39	25	BP
Pagrus auratus	Snapper/Squirefish	0	1.00	1.00	0	0.35	123456	BP
Paristiopterus gallipavo	Yellow-Spotted Boarfish	< 0.005	1.00	1.00	< 0.005	0.30	25	BP
Plagiogeneion macrolepis	bigscale rubyfish	< 0.005	1.00	1.00	< 0.005	0.32	25	BP
Plagiogeneion rubiginosus	Ruby Fish	< 0.005	1.00	1.00	< 0.005	0.32	25	BP
Priacanthus hamrur	bigeye	0	1.00	1.00	0	0.44	345	BP
Priacanthus macracanthus	bigeye	0.01	1.00	1.00	0.01	0.44	345	BP
Priacanthus tayenus	bigeye	0	1.00	1.00	0	0.46	345	BP
Pristipomoides multidens	Gold Band Snapper	0	1.00	1.00	0	0.47	123456	BP
Pristipomoides typus	threadfin snapper;sharptooth snapper	< 0.005	1.00	1.00	< 0.005	0.40	123456	BP
Protonibea diacanthus	banded/spotted croaker	0	1.00	1.00	0	0.42	123456	BP

Table A-6 continued.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Pseudocaranx dentex	Silver Trevally	0	1.00	1.00	0	0.30	123456	BP
Pseudocyttus maculatus	Smooth oreo	< 0.005	1.00	1.00	< 0.005	0.21	123456	BP
Pseudopentaceros richardsoni	Richardson's Boarfish /Southern	< 0.005	1.00	1.00	< 0.005	0.35	25	BP
Pterygotrigla polyommata	Latchet	< 0.005	1.00	1.00	< 0.005	0.48	123456	BP
Rachycentron canadum	cobia	NA	1.00	1.00	NA	0.37	23456	BP
Ruvettus pretiosus	Oilfish	0.01	1.00	1.00	0.01	0.39	123456	BP
Sarda australis	ustralian bonito	NA	1.00	1.00	NA	0.56	123456	BP
Sargocentron rubrum	Red Squirrel Fish	0	1.00	1.00	0	1.69	12345	BP
Schedophilus labyrinthica	ocean blue-eye	0	1.00	1.00	0	0.33	123456	BP
Scomber australasicus	Blue Mackerel	NA	1.00	1.00	NA	0.40	123456	BP
Scomber scombrus	Atlantic mackerel	NA	1.00	1.00	NA	0.41	123456	BP
Scomberomorus commerson	Spanish Mackerel	NA	1.00	1.00	NA	0.48	123456	BP
Scorpaena papillosa	Red Rock Cod	< 0.005	0.66	1.00	< 0.005	0.51	2356	BP
Scorpis lineolata	Sweep	0	1.00	1.00	0	0.43	2345	BP
Seriola dumerili	Eye Streak Kingfish/ Amberjack	NA	1.00	1.00	NA	0.41	123456	BP
Seriola lalandi	Yellowtail Kingfish	0	1.00	1.00	0	0.52	123456	BP
Seriolella brama	Blue Warehou	0	1.00	1.00	0	0.37	123456	BP
Seriolella caerulea	White Trevalla	0	1.00	1.00	0	0.38	123456	BP
Seriolella punctata	Spotted Warehou	0	1.00	1.00	0	0.37	123456	BP
Thunnus obesus	Bigeye Tuna	NA	1.00	1.00	NA	0.38	123456	BP
Thyrsites atun	Barracouta	< 0.005	1.00	1.00	< 0.005	0.41	123456	BP
Trachurus declivis	Jack Mackerel	< 0.005	1.00	1.00	< 0.005	0.52	123456	BP
Trichiurus lepturus	smallhead hairtail	< 0.005	1.00	1.00	< 0.005	0.44	23456	BP
Zeus faber	John Dory	< 0.005	1.00	1.00	< 0.005	0.40	123456	BP
Carangoides caeruleopinnatus	trevally	0	1.00	1.00	0	0.62	123456	DI
Carangoides chrysophrys	trevally	0	1.00	1.00	0	0.62	123456	DI
Dentex tumifrons	Yellowback bream	0.01	0.66	1.00	< 0.005	0.48	123456	DI

Table A-6 continued.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Lepidopus caudatus	Southern Frostfish	0	1.00	1.00	0	0.37	23456	DI
Mola mola	ocean sunfish	NA	1.00	1.00	NA	0.15	356	DI
Satyrichthys cf moluccense	Armoured Gurnard	0	1.00	1.00	0	0.43	5	DI
Trachipterus arawatae	Ribbon or Dealfish	NA	1.00	1.00	NA	0.24	35	DI

Table A-7. Species included in the assessment of the **Western Tuna and Billfish Fishery** and their assessment results. I_A = fraction of distribution area within the fishery jurisdiction fished; q = overall catchability, S = post-capture survival rate, F_{cur} = instantaneous fishing mortality rate during 2004-2007, F_{msm} = instantaneous fishing mortality rate that corresponds to the maximum sustainable fishing mortality, Method = methods used for estimating the reference points, and Role = code in the fishery (BP = byproduct, DI = discards, NA = not assigned). TEP species are excluded in the table.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Carcharhinus longimanus	Oceanic Whitetip Shark	< 0.005	1.00	1.00	< 0.005	0.12	123456	BP
Carcharhinus obscurus	Dusky Shark	< 0.005	1.00	1.00	< 0.005	0.09	123456	BP
Isistius brasiliensis	Cookie-cutter shark (cigar shark)	< 0.005	0.33	1.00	< 0.005	0.10	23456	BP
Isurus oxyrinchus	Shortfinned Mako or Blue Pointer	< 0.005	1.00	1.00	< 0.005	0.11	123456	BP
Lamna nasus	Porbeagle shark	< 0.005	1.00	1.00	< 0.005	0.10	123456	BP
Prionace glauca	Blue Shark	< 0.005	1.00	1.00	< 0.005	0.12	123456	BP
Pseudocarcharias kamoharai	Crocodile Shark	NA	1.00	1.00	NA	0.23	5	BP
Alopias superciliosus	Bigeye thresher shark	< 0.005	1.00	1.00	< 0.005	0.12	2356	DI
Alopias vulpinus	Thintail Thresher Shark, thresher shark	< 0.005	1.00	1.00	0.01	0.12	23456	DI
Callorhinchus milii	Elephantfish	0	0.22	1.00	0	0.17	123456	DI
Carcharhinus brachyurus	Bronze Whaler	< 0.005	0.33	1.00	< 0.005	0.09	123456	DI
Carcharhinus dussumieri	Whitecheek shark	< 0.005	0.22	1.00	< 0.005	0.11	123456	DI
Carcharhinus falciformis	Silky Shark	< 0.005	1.00	1.00	< 0.005	0.11	123456	DI
Carcharhinus leucas	Bull Shark	< 0.005	0.33	1.00	< 0.005	0.10	123456	DI
Carcharhinus plumbeus	Sandbar shark	< 0.005	0.33	1.00	< 0.005	0.10	123456	DI
Carcharhinus sorrah	Sorrah shark	< 0.005	0.66	1.00	< 0.005	0.15	123456	DI
Carcharhinus tilstoni	Australian blacktip	0	1.00	1.00	0	0.15	123456	DI
Centrophorus moluccensis (west)	Endeavour Dogfish	< 0.005	0.22	1.00	< 0.005	0.11	2345	DI
Centroscymnus coelolepis	Portuguese dogfish	0	0.22	1.00	0	0.24	5	DI
Centroscymnus crepidater	Deepwater dogfish	0.01	0.22	1.00	< 0.005	0.11	23456	DI
Centroscymnus owstoni	Owston's dogfish	0.03	0.22	1.00	0.01	0.15	45	DI

Table A-7 continued.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Centroscymnus plunketi	Plunket's shark	< 0.005	0.33	1.00	< 0.005	0.11	456	DI
Cetorhinus maximus	Basking shark	< 0.005	0.33	1.00	< 0.005	0.07	123456	DI
Dasyatis violacea	Pelagic Stingray	0.01	0.33	1.00	0.01	0.22	1235	DI
Deania calcea	Brier Shark	0.01	0.22	1.00	< 0.005	0.10	23456	DI
Deania quadrispinosa	Platypus Shark	0.01	0.22	1.00	< 0.005	0.11	2345	DI
Galeocerdo cuvier	Tiger Shark	< 0.005	0.33	1.00	< 0.005	0.12	123456	DI
Manta birostris	Manta Ray	< 0.005	0.66	1.00	< 0.005	0.13	3456	DI
Myliobatis australis	Southern Eagle Ray	< 0.005	0.11	1.00	< 0.005	0.14	3456	DI
Rhizoprionodon acutus	Milk shark	< 0.005	0.22	1.00	< 0.005	0.23	123456	DI
Scymnodalatias albicauda	Sherwoods dogfish	NA	0.33	1.00	NA	NA		DI
Sphyrna lewini	Scalloped Hammerhead	< 0.005	0.33	1.00	< 0.005	0.10	23456	DI
Sphyrna zygaena	Smooth hammerhead	< 0.005	1.00	1.00	< 0.005	0.11	23456	DI
Squalus acanthias	White-spotted dogfish	0	0.22	1.00	0		123456	DI
Zameus squamulosus	Velvet dogfish	0.02	0.66	1.00	0.03	0.10	123456	DI
Acanthocybium solandri	Wahoo	NA	0.22	0.66	NA	0.65	123456	BP
Brama brama	Ray's Bream	0.01	0.44	0.66	< 0.005	0.36	3456	BP
Centrolophus niger	Rudderfish	0.01	1.00	0.66	0.01	0.33	123456	BP
Coryphaena hippurus	Dolphin Fish (mahi mahi)	NA	0.11	0.66	NA	1.58	23456	BP
Gasterochisma melampus	Butterfly Mackerel	NA	0.66	0.66	NA	0.54	123456	BP
Gymnosarda unicolor	Dogtooth tuna	NA	0.22	0.33	NA	0.54	123456	BP
Hyperoglyphe antarctica	Blue Eye Trevalla	< 0.005	0.22	0.33	< 0.005	0.25	123456	BP
Istiophorus platypterus	Sailfish	NA	0.33	0.33	NA	0.47	23456	BP
Lampris guttatus	Spotted moonfish	< 0.005	0.66	0.33	< 0.005	0.28	2456	BP
Lepidocybium flavobrunneum	Escolar or Black Oil fish	< 0.005	0.33	0.33	< 0.005	0.38	123456	BP
Rexea solandri	Gemfish	< 0.005	0.44	0.33	< 0.005	0.32	123456	BP
Ruvettus pretiosus	Oilfish	< 0.005	0.33	0.33	< 0.005	0.38	123456	BP
Taractichthys longipinnis	Long finned Bream (pomfret)	NA	0.33	0.33	NA	0.36	3456	BP
Thunnus maccoyii	Southern Bluefin Tuna	NA	1.00	0.33	NA	0.21	123456	BP
Thunnus orientalis	Northern Bluefin Tuna	NA	0.22	0.33	NA	0.22	123456	BP

Table A-7 continued.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Thunnus tonggol	Long-tail tuna	NA	0.22	0.33	NA	0.41	123456	BP
Alepisaurus brevirostris	Short-nosed Lancet Fish	NA	0.22	0.33	NA	0.23	25	DI
Alepisaurus ferox	Long-nosed lancet fish	NA	0.33	0.33	NA	0.16	25	DI
Allothunnus fallai	Slender Tuna	NA	0.66	0.33	NA	0.54	123456	DI
Argyrosomus hololepidotus	Jewfish	< 0.005	0.11	0.33	< 0.005	0.27	123456	DI
Auxis thazard	Frigate mackerel	NA	0.11	0.66	NA	0.60	123456	DI
Caranx sexfasciatus	Great Trevally	< 0.005	0.11	0.66	< 0.005	0.48	123456	DI
Euthynnus affinis	Eastern Little Tuna/Mackerel tuna	NA	0.11	0.66	NA	0.80	123456	DI
Lampris immaculatus	Southern moonfish	NA	0.33	0.66	NA	0.22	25	DI
Lepidopus caudatus	Southern Frostfish	< 0.005	0.44	0.66	< 0.005	0.36	23456	DI
Makaira indica	Black Marlin	NA	0.66	0.66	NA	0.29	23456	DI
Makaira mazara	Blue Marlin	NA	0.11	1.00	NA	0.22	23456	DI
Mola mola	Ocean sunfish	NA	0.33	1.00	NA	0.14	356	DI
Mola ramsayi	[an ocean sunfish]	NA	0.33	1.00	NA	0.14	356	DI
Rachycentron canadum	Cobia	NA	0.33	1.00	NA	0.35	23456	DI
Sarda australis	Australian bonito	NA	0.11	1.00	NA	0.55	123456	DI
Scomber scombrus	Atlantic mackerel	NA	0.33	1.00	NA	0.39	123456	DI
Seriola lalandi	Yellowtail Kingfish	< 0.005	0.11	1.00	< 0.005	0.51	123456	DI
Sphyraena jello	Slender Barracuda	0	0.11	1.00	0	0.38	12356	DI
Tetrapturus angustirostris	Short Bill Spearfish	NA	0.33	1.00	NA	0.42	23456	DI
Thyrsites atun	Barracouta	< 0.005	0.22	1.00	< 0.005	0.39	123456	DI

Table A-8. Species included in the assessment of the **Demersal Trawl Sub-fishery** in the **Heard Island and McDonald Island (HIMI) Fishery** and their assessment results. I_A = fraction of distribution area within the fishery jurisdiction fished; q = overall catchability, S = post-capture survival rate, F_{cur} = instantaneous fishing mortality rate during 2004-2007, F_{msm} = instantaneous fishing mortality rate that corresponds to the maximum sustainable fishing mortality, Method = methods used for estimating the reference points, and Role = code in the fishery (BP = byproduct, DI = discards, NA = not assigned).

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Bathyraja eatonii	skate	0.05	1.00	1.00	0.05	0.11	23456	BP
Bathyraja irrasa	skate	0.03	1.00	1.00	0.03	0.11	23456	BP
Bathyraja murrayi	skate	0.03	1.00	1.00	0.03	0.11	23456	BP
Etmopterus granulosus	southern lantern shark	< 0.005	1.00	1.00	< 0.005	0.11	23456	BP
Lamna nasus	Porbeagle shark	< 0.005	0.33	1.00	< 0.005	0.10	123456	DI
Somniosus antarcticus	Sleeper shark; Southern Sleeper Shark	< 0.005	1.00	1.00	< 0.005	0.11	23456	DI
Achiropsetta sp. (grey)	Southern flounder	< 0.005	1.00	1.00	< 0.005	0.43	5	BP
Alepisaurus brevirostris	Short-nosed Lancet Fish	< 0.005	1.00	1.00	< 0.005	0.27	25	BP
Anglerfish Indet		< 0.005	1.00	1.00	< 0.005			BP
Anotopterus pharao	daggerfish	< 0.005	1.00	1.00	< 0.005	0.42	235	BP
Antimora rostrata	morid cod	0.01	1.00	1.00	0.01	0.43	123456	BP
Astronesthes sp.		< 0.005	1.00	1.00	< 0.005			BP
Bathydraco antarcticus	an Antarctic dragonfish	< 0.005	1.00	1.00	< 0.005	0.54	5	BP
Bathylagus antarcticus	deep sea smelt	< 0.005	0.30	1.00	< 0.005	0.46	35	BP
Bathylagus sp.		< 0.005	1.00	1.00	< 0.005			BP
Carapidae - undifferentiated	pearlfishes	< 0.005	1.00	1.00	< 0.005			BP
Ceratias tentaculatus	seadevil	< 0.005	1.00	1.00	< 0.005	0.33	56	BP
Channichthys rhinoceratus	Unicorn icefish	0.01	1.00	1.00	0.01	0.25	13456	BP
Coryphaenoides sp.	Serrulate whiptail	NA	1.00	1.00	NA			BP
Cynomacrurus piriei	rattail/whiptail/grenadier	0.01	1.00	1.00	0.01	0.26	23456	BP
Electrona carlsbergi	lanternfish	< 0.005	0.30	1.00	< 0.005	1.04	23456	BP
Gymnoscopelus bolini	lanternfish	< 0.005	0.30	1.00	< 0.005	1.02	23456	BP
Gymnoscopelus sp.	lanternfish	< 0.005	0.30	1.00	< 0.005	1.02	23456	BP

Table A-8 continued.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Halargyreus johnsonii	Morid cod	< 0.005	1.00	1.00	< 0.005	0.46	12356	BP
Harpagifer georgianus georgianus	spiny plunderfish	NA	0.10	1.00	NA	1.05	5	BP
Himantolophidae - undifferentiated	footballfishes	NA	1.00	1.00	NA			BP
Icichthys australis	Smooth driftfish	NA	0.33	1.00	NA	0.34	123456	BP
Labichthys yanoi	snipe eel	< 0.005	0.33	1.00	< 0.005	0.33	235	BP
Lampris immaculatus	Southern moonfish	< 0.005	0.33	1.00	< 0.005	0.25	25	BP
Lepidion microcephalus	Ribaldo (market name -morid cod) : smallhead cod	< 0.005	1.00	1.00	< 0.005	0.51	12356	BP
Lepidion sp.	morid cod	< 0.005	1.00	1.00	< 0.005	0.41	2356	BP
Lepidonotothen squamifrons	Grey rockcod ; an icefish	NA	0.66	1.00	NA	0.32	23456	BP
Liparidae - undifferentiated		< 0.005	1.00	1.00	< 0.005			BP
Macrouridae	whiptail	< 0.005	1.00	1.00	< 0.005	0.26	3456	BP
Macrourus carinatus	whiptail ; Bigeye grenadier	0.01	1.00	1.00	0.01	0.27	23456	BP
Macrourus holotrachys		0.01	1.00	1.00	0.01	0.26	3456	BP
Macrourus whitsoni	[a whiptail]	0.02	1.00	1.00	0.02	0.20	23456	BP
Magnisudis prionosa	barracudina	< 0.005	1.00	1.00	< 0.005	0.69	23456	BP
Mancopsetta sp.	Southern flounder	< 0.005	1.00	1.00	< 0.005			BP
Melanonus gracilis	melanonid	< 0.005	0.66	1.00	< 0.005	0.61	5	BP
Melanostigma gelatinosum	eelpout	< 0.005	0.66	1.00	< 0.005	0.50	23456	BP
Melanostomias sp.	scaleless dragonfish	< 0.005	1.00	1.00	< 0.005	0.49	5	BP
Muraenolepis sp.	Moray cod (undifferentiated)	< 0.005	0.33	1.00	< 0.005	0.45	56	BP
Nasolychnus sp.		< 0.005	1.00	1.00	< 0.005			BP
Nemichthyidae		< 0.005	1.00	1.00	< 0.005			BP
Neocyttus rhomboidalis	Spiky Oreo	< 0.005	1.00	1.00	< 0.005	0.23	123456	BP
Notacanthus chemnitzii	spiny eel	< 0.005	0.66	1.00	< 0.005	0.30	5	BP
Notothenia (gobionotothen) acuta	Triangular notothen	< 0.005	0.66	1.00	< 0.005	0.36	23456	BP

Table A-8 continued.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Notothenia (notothenia) rossii rossii	Marbled rockcod	< 0.005	1.00	1.00	< 0.005	0.31	23456	BP
Notothenia coriiceps	[an icefish]	< 0.005	1.00	1.00	< 0.005	0.37	23456	BP
Nototheniops mizops	icefish	< 0.005	0.66	1.00	< 0.005	0.33	23456	BP
Paradiplospinus gracilis	snake mackerel/gemfish	< 0.005	1.00	1.00	< 0.005	0.38	123456	BP
Paralaemonema sp.		< 0.005	1.00	1.00	< 0.005			BP
Paraliparis gracilis	snailfish/lumpfish	< 0.005	0.66	1.00	< 0.005	0.46	2356	BP
Poromitra crassiceps	bigscale	< 0.005	0.30	1.00	< 0.005	0.62	5	BP
Pseudoachiropsetta milfordi		< 0.005	0.66	1.00	< 0.005	0.56	123456	BP
Pseudocyttus maculatus	Smooth oreo	< 0.005	1.00	1.00	< 0.005	0.21	123456	BP
Scopelosaurus sp.		< 0.005	1.00	1.00	< 0.005			BP
Stomias gracilis	Scaly dragonfish	NA	0.66	1.00	NA	0.54	235	BP
Stomias sp.	scaly dragonfishes	< 0.005	1.00	1.00	< 0.005			BP
Zanclorhynchus spinifer	Spiny horsefish	< 0.005	1.00	1.00	< 0.005	0.43	5	BP

Table A-9. Species included in the assessment of the **Mid-water Trawl Sub-fishery** in the **Heard Island and McDonald Island (HIMI) Fishery** and their assessment results. I_A = fraction of distribution area within the fishery jurisdiction fished; q = overall catchability, S = post-capture survival rate, F_{cur} = instantaneous fishing mortality rate during 2004-2007, F_{msm} = instantaneous fishing mortality rate that corresponds to the maximum sustainable fishing mortality, Method = methods used for estimating the reference points, and Role = code in the fishery (BP = byproduct, DI = discards, NA = not assigned).

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Bathyraja eatonii	[a skate]	< 0.005	0.66	1.00	< 0.005	0.11	23456	BP
Bathyraja irrasa	skate	< 0.005	0.66	1.00	< 0.005	0.11	23456	BP
Bathyraja maccaini	[a skate]	< 0.005	0.66	1.00	< 0.005	0.11	23456	BP
Bathyraja murrayi	skate	< 0.005	0.66	1.00	< 0.005	0.11	23456	BP
Etmopterus granulosus	southern lantern shark	< 0.005	0.66	1.00	< 0.005	0.11	23456	BP
Raja georgiana	[a skate]	< 0.005	0.66	1.00	< 0.005	0.12	23456	BP
Lamna nasus	Porbeagle shark	< 0.005	0.66	1.00	< 0.005	0.10	123456	DI
Somniosus antarcticus	Sleeper shark; Southern Sleeper Shark	< 0.005	0.33	1.00	< 0.005	0.11	23456	DI
Bathylagus sp.	0	< 0.005	0.33	1.00	< 0.005			BP
Channichthys rhinoceratus	Unicorn icefish	< 0.005	0.33	1.00	< 0.005	0.25	13456	BP
Cynomacrurus piriei	rattail/whiptail/grenadier	< 0.005	0.33	1.00	< 0.005	0.26	23456	BP
Lampris immaculatus	Southern moonfish	< 0.005	0.33	1.00	< 0.005	0.25	25	BP
Lepidonotothen squamifrons	Grey rockcod ; an icefish	NA	0.22	1.00	NA	0.32	23456	BP
Macrourus holotrachys	0	< 0.005	0.33	1.00	< 0.005	0.26	3456	BP
Macrourus sp.	whiptail	< 0.005	0.33	1.00	< 0.005	0.26	3456	BP
Mancopsetta maculata	[a southern flounder]	< 0.005	0.33	1.00	< 0.005	0.40	5	BP
Muraenolepis sp.	Moray cod (undifferentiated)	< 0.005	0.33	1.00	< 0.005	0.45	56	BP
Myctophidae indet	lanternfish	< 0.005	0.10	1.00	< 0.005	1.02	23456	BP
Notothenia (gobionotothen) acuta	Triangular notothen	< 0.005	0.22	1.00	< 0.005	0.36	23456	BP
Notothenia (notothenia) rossii rossii	Marbled rockcod	< 0.005	0.33	1.00	< 0.005	0.31	23456	BP

Table A-9 continued.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Nototheniops mizops	icefish	< 0.005	0.22	1.00	< 0.005	0.33	23456	BP
Poromitra crassiceps	bigscale	< 0.005	0.10	1.00	< 0.005	0.62	5	BP

Table A-10. Species included in the assessment of the **Demersal Longline Sub-fishery** in the **Heard Island and McDonald Island (HIMI) Fishery** and their assessment results. I_A = fraction of distribution area within the fishery jurisdiction fished; q = overall catchability, S = post-capture survival rate, F_{cur} = instantaneous fishing mortality rate during 2004-2007, F_{msm} = instantaneous fishing mortality rate that corresponds to the maximum sustainable fishing mortality, Method = methods used for estimating the reference points, and Role = code in the fishery (BP = byproduct, DI = discards, NA = not assigned).

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Bathyraja eatonii	[a skate]	0.73	1.00	1.00	0.02	0.11	23456	BP
Bathyraja irrasa	skate	0.44	1.00	1.00	0.01	0.11	23456	BP
Bathyraja maccaini	[a skate]	0.02	1.00	1.00	< 0.005	0.14	2356	BP
Bathyraja murrayi	skate	0.41	1.00	1.00	0.01	0.11	23456	BP
Etmopterus granulosus	southern lantern shark	0.02	1.00	1.00	< 0.005	0.11	23456	BP
Raja georgiana	[a skate]	< 0.005	1.00	1.00	< 0.005	0.12	23456	BP
Somniosus antarcticus	Sleeper shark; Southern Sleeper Shark	0.03	1.00	1.00	< 0.005	0.11	23456	DI
Antimora rostrata	morid cod	0.20	1.00	1.00	< 0.005	0.43	123456	BP
Lepidion sp.	morid cod	0.01	1.00	1.00	< 0.005	0.41	2356	BP
Lepidonotothen squamifrons	Grey rockcod ; an icefish	NA	0.66	1.00	NA	0.32	23456	BP
Macrourus carinatus	whiptail ; Bigeye grenadier	0.23	1.00	1.00	0.01	0.27	23456	BP
Macrourus holotrachys	0	0.20	1.00	1.00	< 0.005	0.26	3456	BP
Macrourus whitsoni	[a whiptail]	0.27	1.00	1.00	0.01	0.21	23456	BP
Muraenolepis sp.	Moray cod (undifferentiated)	0.03	0.33	1.00	< 0.005			BP

Table A-11. Species included in the assessment of the **Macquarie Island Demersal Trawl Sub-fishery** and their assessment results. I_A = fraction of distribution area within the fishery jurisdiction fished; q = overall catchability, S = post-capture survival rate, F_{cur} = instantaneous fishing mortality rate during 2004-2007, F_{msm} = instantaneous fishing mortality rate that corresponds to the maximum sustainable fishing mortality, Method = methods used for estimating the reference points, and Role = code in the fishery (BP = byproduct, DI = discards, NA = not assigned).

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Etmopterus granulosus	southern lantern shark	< 0.005	1.00	1.00	< 0.005	0.11	23456	BP
Somniosus antarcticus	Sleeper shark; Southern Sleeper Shark	< 0.005	1.00	1.00	< 0.005	0.11	23456	DI
Achiropsetta sp. (grey)	Southern flounder	< 0.005	1.00	1.00	< 0.005	0.43	5	BP
Alepocephalus spp.	slickhead	< 0.005	1.00	1.00	< 0.005			BP
Anotopterus pharao	daggerfish	< 0.005	1.00	1.00	< 0.005	0.42	235	BP
Antimora rostrata	morid cod	0.02	1.00	1.00	0.02	0.43	123456	BP
Astronesthes sp.	spangled trouble- shouter	< 0.005	1.00	1.00	< 0.005			BP
Bathylagus antarcticus	deep sea smelt	< 0.005	0.30	1.00	< 0.005	0.46	35	BP
Caelorinchus kaiyomaru	whiptail	< 0.005	1.00	1.00	< 0.005	0.26	23456	BP
Caelorinchus kermadecus	whiptail	< 0.005	1.00	1.00	< 0.005	0.26	23456	BP
Caelorinchus matamua	whiptail	< 0.005	1.00	1.00	< 0.005	0.26	23456	BP
Centroscymnus crepidater	deepwater dogfish	< 0.005	1.00	1.00	< 0.005	0.20	23456	BP
Ceratias tentaculatus	seadevil	< 0.005	1.00	1.00	< 0.005	0.33	56	BP
Chauliodus sloani	viper fish	< 0.005	1.00	1.00	< 0.005			BP
Coryphaenoides murrayi	whiptail	< 0.005	1.00	1.00	< 0.005	0.25	23456	BP
Coryphaenoides serrulatus	whiptail	< 0.005	1.00	1.00	< 0.005	0.25	23456	BP
Coryphaenoides subserrulatus	whiptail	< 0.005	1.00	1.00	< 0.005	0.25	23456	BP
Cynomacrurus piriei	rattail/whiptail/grenadier	0.01	1.00	1.00	0.01	0.26	23456	BP
Diastobranchus capensis	basket-work eel	< 0.005	0.66	1.00	< 0.005	0.27	5	BP
Ebinania sp.	blobfish	< 0.005	1.00	1.00	< 0.005			BP
Echiodon cryomargarites	pearlfish	< 0.005	1.00	1.00	< 0.005	0.49	5	BP
Epigonus sp.	cardinal fish	< 0.005	1.00	1.00	< 0.005			BP
Gigantactinidae	whipnose angler fish	NA	1.00	1.00	NA			BP

Table A-11 continued.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Gymnoscopelus opisthopterus	lantern fish	< 0.005	0.30	1.00	< 0.005	1.02	23456	BP
Halargyreus johnsonii	Morid cod	< 0.005	1.00	1.00	< 0.005	0.46	12356	BP
Himantolophus sp.	football fish	< 0.005	1.00	1.00	< 0.005			BP
Idiolophorhynchus andriashevi	rattail/whiptail/grenadier	< 0.005	1.00	1.00	< 0.005	0.26	23456	BP
Labichthys yanoi	snipe eel	< 0.005	0.33	1.00	< 0.005	0.33	235	BP
Lampris immaculatus	Southern moonfish	< 0.005	0.33	1.00	< 0.005	0.25	25	BP
Lepidion microcephalus	Ribaldo (market name -morid cod) : smallhead cod	< 0.005				0.51	12356	BP
Lepidonotothen squamifrons	Grey rockcod ; an icefish	NA	0.66	1.00	NA	0.32	23456	BP
Macrourus carinatus	whiptail ; Bigeye grenadier	0.02	1.00	1.00	0.02	0.26	23456	BP
Macrourus holotrachys	0	0.02	1.00	1.00	0.02	0.26	3456	BP
Magnisudis prionosa	barracudina	< 0.005	1.00	1.00	< 0.005	0.69	23456	BP
Mancopsetta sp.	Southern flounder	< 0.005	1.00	1.00	< 0.005			BP
Melanostigma gelatinosum	eelpout	< 0.005	0.66	1.00	< 0.005	0.50	23456	BP
Melanostigma sp.	an eelpout (undiferentiated)	< 0.005	0.66	1.00	< 0.005	0.50	23456	BP
Melanostomias sp.	scaleless dragonfish	< 0.005	1.00	1.00	< 0.005	0.49	5	BP
Mora moro	Ribaldo	< 0.005	1.00	1.00	< 0.005	0.43	12356	BP
Muraenolepis sp.	morid cod (undifferentiated)	< 0.005	1.00	1.00	< 0.005	0.45	56	BP
Nemichthyidae	eel	< 0.005	1.00	1.00	< 0.005			BP
Neocyttus sp.	oreo dory	NA	1.00	1.00	NA			BP
Neophrynichthys magnicirrus	fathead	< 0.005	1.00	1.00	< 0.005			BP
Nezumia pudens	Atacamgrenadier	< 0.005	1.00	1.00	< 0.005	0.29	23456	BP
Notacanthus chemnitzii	spiny eel	< 0.005	0.66	1.00	< 0.005	0.30	5	BP
Oneirodes sp.	dreamer fish	< 0.005	1.00	1.00	< 0.005			BP
Pagothenia sp.	an icefish/notothen	< 0.005	0.66	1.00	< 0.005	0.36	23456	BP
Paradiplospinus gracilis	snake mackerel/gemfish	< 0.005	1.00	1.00	< 0.005	0.38	123456	BP
Paralaemonema sp.	morid cod	< 0.005	1.00	1.00	< 0.005			BP

Table A-11 continued.

Scientific name	Common name	I_A	q	1-S	F_{cur}	F_{msm}	Method	Role
Paraliparis gracilis	snailfish/lumpfish	< 0.005	0.66	1.00	< 0.005	0.46	2356	BP
Photichthys sp.	bristlemouth	< 0.005	1.00	1.00	< 0.005			BP
Poromitra crassiceps	bigscale	< 0.005	0.30	1.00	< 0.005	0.62	5	BP
Pseudoachiropsetta milfordi	flounder	< 0.005	0.66	1.00	< 0.005	0.56	123456	BP
Pseudocyttus maculatus	Smooth oreo	< 0.005	1.00	1.00	< 0.005	0.21	123456	BP
Stomias sp.	scaleless dragonfish	< 0.005	1.00	1.00	< 0.005			BP
Zanclorhynchus spinifer	Spiny horsefish	< 0.005	1.00	1.00	< 0.005	0.43	5	BP