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Sustainability assessment of fish species potentially impacted in the Southern and Eastern Scalefish and Shark Fishery: 2007-2010

Shijie Zhou, Mike Fuller, and Ross Daley

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www.csiro.au

Enquiries should be addressed to:

Shijie Zhou (Shijie.zhou@csiro.au)

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Summary

As requested by Australia Fisheries Management Authority, a sustainability assessment for fishing effect (SAFE) is updated for the Southern and Eastern Scalefish and Shark Fishery (SESSF). The SAFE method was initially developed for the SESSF in 2007 and applied to fish bycatch species impacted by five sub-fisheries: South East Trawl, Great Australian Bight Trawl, Shark Gillnet, Danish Seine, and Automatic Longline sub-fisheries (Zhou et al. 2007). This method is improved and used again in this assessment. The following data used previously are also applied in this report: species distribution based on bioregional mapping and core range species mapping, catchability and post-release mortality and life history parameters based on ERAEF (Daley et al. 2007; Walker et al. 2007; Wayte et al. 2006, 2007).

Improvement and changes have been made in several aspects in this updated assessment. The major changes include:

(1) using the most recent (2007-2010) fishery distribution and effort data;
(2) including a new fishery—Great Australian Bight Danish Seine in 2011;
(3) adding seven new species from recent logbook and observer records. In addition, Southern Dogfish has recently been formally described as an endemic species: *Centrophorus zeehaani*. This name replaces *Centrophorus uyato* used in previous ERA studies and distribution is updated accordingly.
(4) using instantaneous fishing mortality rate *F* instead of exploitation rate *u*; and
(5) adopting new relationships between sustainability reference points and life-history parameters for both chondrichthyans and teleosts.

The summary results for the six sub-fisheries and their cumulative risk are as follows.

Trawl sector: The analysis includes 447 species of fish. Twenty-two species (all are chondrichthyans) are at medium risk while four of them are at extreme high risk.

GAB Trawl sub-fishery: includes 204 species and none is found to have estimated fishing mortality greater than any reference points.

Danish Seine Sub-fishery: includes 73 species and none is found to have estimated fishing mortality rate greater than any reference points.

Shark Gillnet Sub-fishery: includes 195 species. Five species (all chondrichthyan) are at medium risk while two of them are at high risk.

Automatic Longline Sub-fishery: includes 161 species. Ten species (9 chondrichthyans and one teleosts) are at medium risk while four (all chondrichthyan) of them are at extreme high risk.

GAB Danish Seine Sub-fishery: includes 20 species and none is found to have estimated fishing mortality greater than any reference point.

Cumulative risk: includes 508 species. The assessment results in 45 species (43 chondrichthyans and 2 teleosts) at medium risk and 18 species (17 are chondrichthyans) at extreme high risk.

Keywords: sustainability, ecological, risk, assessment, reference points, fishing mortality, Southern and Eastern Scalefish and Shark Fishery, bycatch, chondrichthys, teleosts

1. Introduction

The Southern and Eastern Scalefish and Shark Fishery (SESSF) is one of the most important Commonwealth-managed fisheries. The fishery extends from waters off southern Queensland, south and west to Cape Leeuwin in Western Australia (Figure 1.1). It is a complex multi-sector, multi-gear and multi-species fishery targeting scalefish and shark stocks of various size, distribution and composition. Almost half the waters of the Australian Fishing Zone off southern mainland Australia and Tasmania are in the fishery management area.

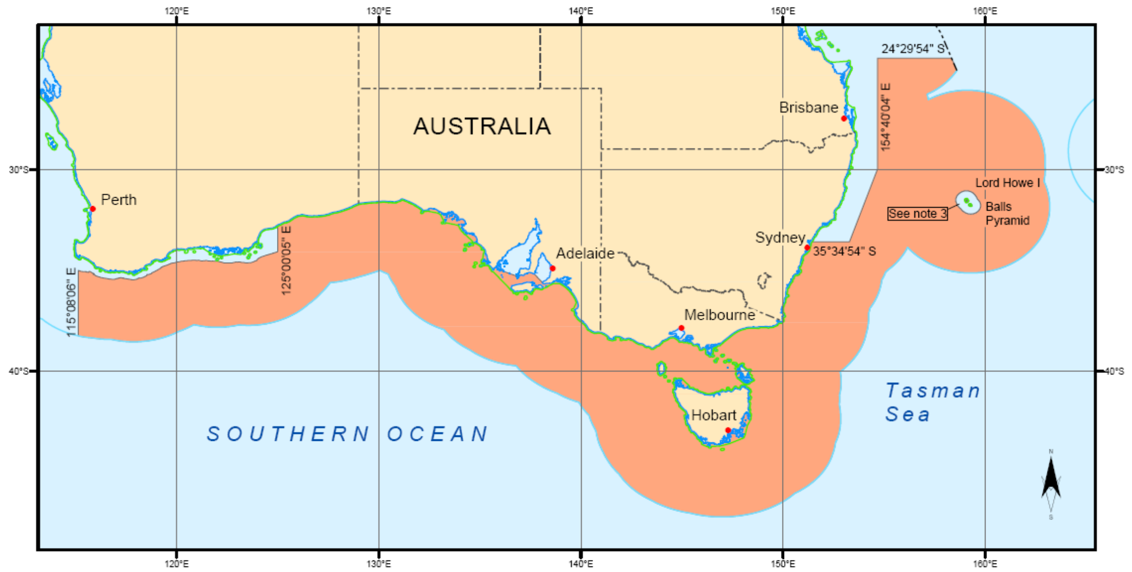

Figure 1.1. Area of the Southern and Eastern Scalefish and Shark Fishery.

A quantitative ecological risk assessment for fishing effects was conducted for the SESSF Fishery in 2007 (Zhou et al. 2007). The current export approval for the Fishery is valid until 30 July 2012 and the fishery is now due for assessment for ongoing export accreditation. In November 2011 AFMA requested that the assessment be updated using more recent fishery data. The requested research was to be a rapid assessment using existing techniques and information, with results expected to be delivered within 4 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.

In this report, a sustainability assessment for fishing effect (SAFE) is performed for six major sectors in the SESSF: the South East Otter trawl fishery, the Great Australian Bight Trawl Fishery, the Danish Seine Fishery, the Shark Gillnet Fishery, the Auto Longline Fishery, and the Great Australian Bight Danish Seine Fishery. The method is similar to the previous assessments (Zhou et al. 2007; Zhou et al. 2011). However, there are some changes and modifications in this updated assessment based on more recent research. This report details the assessment results for these fisheries.

2. Materials and methods

The method of sustainability assessment for fishing effect is very similar to the previous studies (Zhou et al. 2007, 2011). In this chapter we describe the method including any modifications so that the readers can have a better understanding of this report.

2.1. Fishery data

The list of fish species included in the assessment is based on previous ERAEF studies (Daley et al. 2007a; Daley et al. 2007b; Walker et al. 2007; Wayte et al. 2006, 2007; Zhou et al. 2007). Fishing effort and distribution come from AFMA logbook records. We analysed four years of annual fishing impact from 2007 to 2010. We examined logbook and observer data in recent years for new species potentially encountering the fishery. We found at least 20 species were recorded erroneously in logbook and observer data due to misidentifications or data collation errors. A subset of seven new species was added into the assessment (Table 2.1). Bioregional mapping and core range species mapping provided species distribution (Commonwealth of Australia 2005; Heap et al. 2005). Fish life history parameters are also based on previous studies.

Table 2.1. New species included in the assessment.

Taxa	Scientific name	Common name	Potential fishery	Comment
Chond	*Urolophus sufflavus*	Yellow-backed Stingaree	Seine, Trawl	A stingaree to be included in the assessment.
Chond	*Zameus squamulosus*	Velvet Dogfish	Longline, Traw	A pelagic shark has definitely been recorded by an observer on an auto-liner.
Teleost	*Dicotylichthys punctulatus*	Threebar Porcupinefish	Seine, Trawl	Low overlap; life history parameters poorly known.
Teleost	*Epigonus telescopus*	Black Deepsea Cardinalfish	Trawl	Currently low overlap but this may change if more fishing in deep waters.
Teleost	*Platycephalus longispinis*	Longspine Flathead	Trawl	Species listed in the Southeast Fishery species identification Guide.
Teleost	*Repomucenus calcaratus*	Spotted Stinkfish	Trawl	May have previously been identified as *Callionymus* sp.
Teleost	*Schedophilus huttoni*	New Zealand Ruffe	Trawl	Does get caught in trawl but rarely. Widespread in the Southern Ocean, less around the continent. Deepwater species, poorly known.

2.2. Estimating fishery impacts

2.2.1. Otter Trawl

Fishing impact is expressed as annual instantaneous fishing mortality rate within the SESSF management jurisdiction. For species *i*, fishing mortality in year *y* is derived as:

$$F_{y,i} = \frac{C_{y,i}}{\bar{N}_{y,i}} = \frac{q_i^h q_i^\lambda (1 - S_i) \sum_t L_{t,i} W}{A_i} \tag{2.1}$$

where C_i the catch of species *i* dead after discard, $\bar{N}_{y,i}$ the mean population size over the one year, q_i^h habitat-dependent encounterability, q_i^λ size- and behaviour-dependent selectivity, S_i the discard survival rate, W width of trawl wing spread, $L_{t,i}$ trawl length based on start and end locations at time *t* that occurs within the species distribution range, and A_i the occupied area within the fishery jurisdiction.

Based on the likelihood of being caught and retained in the trawl mesh, we adopted q^λ_i = 0.33 for species smaller than 10 cm or larger than 500 cm, q^λ_i = 0.67 for species between 10 and 20 cm or between 400 and 500 cm, and q^λ_i = 1.0 for species between 20 and 400 cm (Wayte et al. 2006; Smith et al. 2007).

Habitat preference also influences the chance that a fish will be taken by trawl gear. Where habitat/water column preference for a species in the PSA analyses which preceded the SAFE analysis was described as demersal (i.e. habitats subject to trawling) the species was considered as high risk for habitat-dependent encounterability; benthopelagic type was considered medium risk; and epipelagic or mesopelagic type was considered as low risk. We used q^h_i = 0.33, 0.67, and 1.0 for species that live in habitats with low, medium, and high risk of being caught in the trawls based on the Level 2 PSA analyses (Wayte et al. 2006).

Post-capture survival rate resulted from two separate processes: surviving handling on the deck and surviving after being returned to the water. Following the PSA approach and fishing mortality for elasmobranchs (Walker 2005), we assumed S_i = 0.0, 0.33, and 0.67 for species that have low, medium, and high probability of surviving after being caught and returned to the water. Logically, assigning three levels to these quantities that are hard to estimate for hundred of bycatch species should be more sensible than assuming a maximum value (i.e., all fish that are captured are dead). The PSA approach adopted the convention of assuming low survival ($S_i = 0$) in the absence of direct evidence to the contrary, so the method is precautionary in this respect.

As stated for equation (2.1), we assumed that the mean fish density for each species did not vary between trawled area and non-trawled area within their distributional range. Hence, the level of risk would be over-estimated for species found primarily in non-trawl habitat, while risk would be under-estimated for species that prefer trawl habitat.

2.2.2. Danish Seine

In the seine fishery, vessels tow the nets to encircle the fish. The affected area in one shot can be estimated by $a = \pi R^2$, where *R* is the radius of circling net. Similar to trawl gear, the fishing mortality rate for species *i* in year *y* is estimated by

$$F_i = \frac{q_i^h q_i^\lambda (1 - S_i) \sum_t a f_t}{A_i} \tag{2.2}$$

where f_t is the fishing effort (number of shots). Other parameters are similar to the trawl fishery. In the SESSF Danish Seine Sub-fishery, the net length ranged from 1,000 to 2,800 m. We used 2,000 m as the circumference to estimate fished area in one operation. The annual total affected area was the sum of fishing efforts f_t (number of shots) multiplied by affected area a. For operations when the nets are towed before encircling, the linear area covered by the nets could be included in the total area fished. Similar to the trawl fishery, we used size-dependent selectivity $q^\lambda{}_i$ and habitat-dependent encounterability $q^h{}_i$ and set them to 0.33, 0.67, and 1.0 for species with low, medium, and high selectivity scores and encounterability scores in the Level 2 PSA analysis (Wayte et al. 2007). We also assumed S_i = 0.00, 0.33, and 0.67 for species that have low, medium, and high probability of surviving after being caught and returned to the water (Wayte et al. 2007; Walker 2005).

2.2.3. Gillnet

The affected fishing area (i.e., the maximum area within which a fish could encounter the net), is a function of gillnet length, soak time, and swimming speed of fish. Until recently the gillnet fishery reported catch and effort at low spatial resolution (30 min by 30 min grid). Since 2007, reports are based on the start and end coordinates of an operation. The gear affected area a_i during one fishing operation (shot) is species-specific and can be estimated as:

$$a_i = 2\, l\, D_i + \pi\, D_i^2. \tag{2.3}$$

Where a_i = affected fishing area by gillnet for species i, l = gillnet length, D_i = maximum distance from the net where a fish has a probability of larger than zero of encountering the net. This distance is $D_i = \tau\, v_i$, where τ is net soak-time and v_i is sustained swimming speed for species i.

The probability of a fish at any (x, y) position encountering the net (which ranges between 0 and 0.5 as a fish nearly contacting the net has 0.5 probability of swimming away from the net) can be obtained by:

$$p_{i,xy}(encounter \mid x, y) = \frac{\alpha_{xy}}{2\pi} \tag{2.4}$$

where α_{xy} is the angle intersecting with the gillnet when a fish is at location x, y. This angle is determined by the distance D when the net is set. We divided the affected area into four sections to estimate the expected probability of encountering the net. For these four sections, integrating Equation (2.4) over the entire section area results in the expected probability of encountering the net for fish in that section. The overall encounter probability within the affected area is:

$$p_{i,E}(encounter \mid a_i, x, y) \approx \frac{0.636 l D_i - 0.003 D_i^2}{2 l D_i + \pi D_i^2} \tag{2.5}$$

Using this approach, the annual fishing mortality rate in the gillnet fishery is estimated as:

$$\begin{aligned} F_i &= \frac{\sum_f a_{i,f} E[p_{i,E}]}{A_i} q_i^h q_i^\lambda \frac{\int_{\lambda_1}^{\lambda_2} s_{i,\lambda} d\lambda}{\lambda_2 - \lambda_1} (1 - S_i) \\ &\approx \frac{\sum_f [0.636 l_f t_f v_i - 0.003 (t_f v_f)^2]}{A_i} q_i^h q_i^\lambda \frac{\int_{\lambda_1}^{\lambda_2} s_{i,\lambda} d\lambda}{\lambda_2 - \lambda_1} (1 - S_i) \end{aligned} \tag{2.6}$$

where q^h_i is habitat related encounterability of species i, q^λ_i is the size-dependent maximum overall fishing power (gear efficiency), $s_{i,\lambda}$ is the relative gear selectivity on size λ, λ_1 and λ_2 are size range of species i caught by the gillnet, and f is fishing activity (number of shots). In equation (2.6), $a_{i,f}$ E[$p_{i,E}$] is the "effective fishing area", which is a theoretical area where all individuals have 100% probability of encountering the net.

In estimating the affected area, we assumed a fish continuously swims in a straight line and in a fixed but random direction (i.e. in any direction around 2π radius). We obtained sustained swimming speed for a few species. For the majority of species, we used fish body length (average length at maturity) to estimate sustained swimming speed: $v_i = \lambda_{mat,\,i}^{0.8}$ (Blake 1983). This method may over- or under-estimate the swimming speed. The mean gillnet length used in the SESSF Shark Gillnet Sub-fishery was 3.7 km (SD = 0.87, n = 10850), the mean mesh size was 15.8 cm (SD =0.7, n = 10850), and the mean net soak time was 2.39 h (SD = 1.50, n = 10850). We used actual values from the logbooks in the above equations to estimate fishing mortality.

We used q^h_i = 0.33, 0.67, and 1.0 for species that live in habitat with low, medium, and high risk of encountering gillnet based on the Level 2 PSA analyses (Walker 2005; Walker et al. 2007). For the size-dependent overall catchability we used the size-dependent selectivity score from the PSA analysis and assumed q^λ_i = 0.33, 0.67, and 1.0 for low, medium, and high scores (Walker 2005; Walker et al. 2007). As a gillnet is a reasonably selective gear, only a fraction of the population will be retained by the gear even when the q^λ_i = 1.0 for that species. Hence, additional selectivity parameter s_i is needed in Equation 2.6 to estimate the fraction of the population retained. We adopt the value of 0.4 from previous study for a species having a q^λ_i = 1.0 with sizes corresponding to $s_{i,\lambda} \geq 1\%$ could be selectively retained (Zhou et al. 2007). Again, we 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 (Walker 2005; Walker et al. 2007).

2.2.4. Longline

Longlines employed in the SESSF are set at or close to the bottom and typically measure over 6 km and fish over 10 hours before being retrieved. Until recently, the longline fishery reported catch and effort at low spatial resolution (30 min by 30 min grid). Since 2007, reports are based on the start and end coordinates of an operation. Therefore, we modified the method so the gear affected area is estimated similar to that used for sub-Antarctic demersal longline fishery (Zhou et al. 2009). 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., a 1 km-wide band along the length of the longline within a species distribution area is assumed as the zone of influence of the gear.

We used the following method to estimate fishing mortality rate for the longline fishery:

$$F_i = \frac{A_{i,f}}{A_{i,J}} q_i^h q_i^\lambda \rho (1 - S_i)\,, \qquad (2.7)$$

where $A_{i,f}$ is the gear affected area described above within species i's distribution area, and $A_{i,J}$ is the total distribution area for species i within the fishery jurisdiction. This ratio between the two areas is essentially the fraction of species spatial distribution overlapping with the longline fishery. Again, the habitat-dependent encounterability $q^h{}_i$ was set to 0.33, 0.66, and 1.0 for species with low, medium, and high scores of encountering the fishing gear in the Level 2 PSA analysis (Walker 2005; Daley et al. 2007). We assigned the size-dependent catchability $q^\lambda{}_i$ based on average length at maturity: 0.33 for fish < 10 cm or > 500 cm, 0.67 for fish between 10 and 20 cm and between 400 and 500 cm, and 1.0 for fish between 20 and 400 cm (Daley et al. 2007). We derived the correction parameter ρ from target species in the longline fishery as:

$$\rho = \frac{1}{n}\sum_{i=1}^{n} \frac{F_i^T A_{i,J}^T}{q_i^h q_i^\lambda A_{i,f}^T}, \tag{2.8}$$

where F_i^T is the fishing mortality for target species i in the assessed year. This is essentially Equation 2.7 where $S_i = 0$ for target species. The longline sub-fishery targets two main species: blue eye trevalla (*Hyperoglyphe Antarctica*) and pink ling (*Genypterus blacodes*). Using catch curve method, Klaer (N. Klaer, CSIRO, Hobart, Australia. Personal communication) estimated that the mean fishing mortality from 2006-2010 was 0.207 y^{-1}. However, this estimate was believed to be biased due to the use of a dome-shaped selectivity. Nevertheless, we included this result in estimating ρ. Taylor (B. Taylor, Victorian Marine and Freshwater Fisheries Research Institute, personal communication) estimated the non-trawl fishing mortality for pink ling ranged from 0.07 to 0.10 in SESSF from 2007 to 2010. Based on these target species, we calculated ρ = 0.73 (SE = 0.18). We also used S_i = 0.00, 0.33, and 0.67 for species that have low, medium, and high probability of surviving after being caught and returned to the water similar to other studies (Daley et al. 2007; Walker 2005).

2.2.5. Uncertainty

We quantify uncertainty around the estimated fishing mortality by including variances in encounterability, selectivity, survival rate, fishing effort and gear affected areas between years, etc. In estimating variances in q_i^h, q_i^h, and S_i, we assume individual fish encountering fishing gear, being retained, and surviving after discard follow binomial distributions. For simplicity, we use a delta method to calculate the variance of fishing mortality rate F_i. For example, variance of fishing mortality in the longline fishery results from variances of q_i^h, q_i^h, ρ, and S_i, and area overlap between 2007 and 2010.

2.2.6. Cumulative impacts

The methods for estimating fishing mortality rate described above are quantitative. Within the same jurisdiction, if we assume each sub-fishery kills fish from the same population, fishing mortality by multiple fisheries can be added together to derive cumulative impacts. That is, the cumulative fishing mortality for species *i* from all sub-fisheries is:

$$F_i^c = \sum_f F_{i,f} \quad . \qquad (2.9)$$

The subscript *f* denotes sub-fisheries. The assumption behind this equation is that sub-fisheries within the jurisdiction impose impact on the same stock for each species. This might not be the case over the very large area of the SESSF but there is little or no information on stock structure for most bycatch species. To estimate uncertainty we simply assume that the operation of sub-fisheries are independent of each other so the variance associated with fishing mortality $F_{i,f}$ in each sub-fishery can be summed to obtain the total uncertainty.

2.3. Sustainability reference points

Three fishing mortality reference points used in the previous risk assessments (Zhou et al. 2007; Zhou et al. 2009; Zhou et al. 2010) are adopted here:

F_{msm} = instantaneous fishing mortality rate that corresponds to the maximum number of fish in the population that can be killed by fishing in the long term. The latter is the maximum sustainable fishing mortality (MSM) at B_{msm} (biomass that supports MSM), similar to target species MSY (Figure 2.1);

F_{lim} = fishing mortality rate corresponding to limit biomass B_{lim}, where B_{lim} is defined as half of the biomass that supports a maximum sustainable fishing mortality ($0.5B_{\mathrm{msm}}$);

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

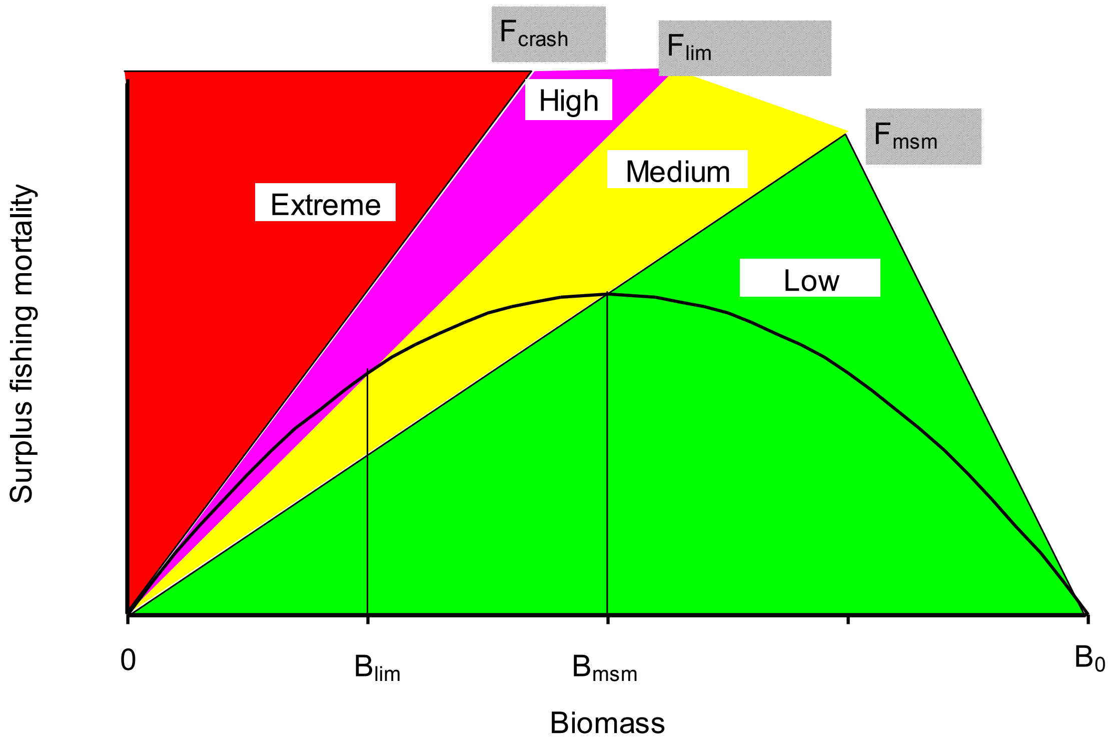

Figure 2.1. Stock productivity, biological reference points and ecological risk categories for managing bycatch species.

These reference points are linked to life history parameters of each species. A meta-analysis reveals that maximum sustainable fishing mortality F_{msy} is a function of natural mortality M (Zhou et al. 2012). That study was based on analysis of 245 fish species (both chondrichthyes and teleosts) worldwide and linked three types of reference points (F_{BRP}: F_{msy}, F_{proxy}, and $F_{0.5\mathrm{r}}$) to M and other life-history parameters. The best model resulted in $F_{\mathrm{msy}} = 0.87\ M$ (SD 0.05) for teleosts and $F_{\mathrm{msy}} = 0.41\ M$ (SD 0.09) for chondrichthyans. For chondrichthyans, the shape of the biomass-fishing mortality relationship (Figure 2.1) is a flatter curve. Hence, we adopt the relationships for chondrichthyans and teleosts as:

Chondrichthyans: $\omega = F_{msy}/M = 0.41$;

Teleosts: $\omega = F_{msy}/M = 0.87$.

The reference points are derived from the following methods:

i. $F_{\mathrm{msm}} = r$;

ii. $\mathrm{F}_{\mathrm{msm}} = \omega M$, and $F_{crash} = 2\ \omega M$, where M is obtained from literature;

iii. $F_{msm} = \omega\ M$, and $F_{crash} = 2\ \omega M$, where

$$\ln(M) = -0.0152 - 0.279\ln(L_{\infty}) + 0.6543\ln(k) + 0.4634\ln(T)$$ (Pauly 1980; Quinn and Deriso 1999);

iv. $F_{msm} = \omega M$, and $F_{crash} = 2\ \omega M$, where $\ln(M) = 1.44 - 0.982\ \ln(t_m)$ (Hoenig 1983).

v. $F_{msm} = \omega M$, and $F_{crash} = 2\ \omega M$, where $\log(M) = 0.566 - 0.718Log(L_{\infty}) + 0.02T$ (www.Fishbase.org);

vi. $F_{msm} = \omega M$, $F_{lim} = 1.5\ \omega M$, and $F_{crash} = 2\ \omega M$, where $M = 1.65/t_{mat}$ (Jensen 1996).

In these equations, r is the intrinsic population growth rate, 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 estimate length at infinity as: $\log(L_{\infty}) = 0.044 + 0.9841\log(L_{\max})$ (Froese and Binohlan 2000). As data availability varies, one or more of the above methods is applied to each species. Considering the uncertainty in the parameters themselves that come from the literature and from applying the methods (as well as potential correlation between these methods), these methods are given equal weight to derive the mean and ranges of F_{msm} and F_{crash}.

2.4. Risk-based performance measures

Because input parameters for estimating fishing mortality and reference points typically involve large uncertainty, as well as the simplicity of the method, the results also have high uncertainty for many species. The risk categories are as follows:

Low risk (L): $F < F_{msm}$;
Medium risk (M): $F_{msm} \leq F < F_{lim}$;
Precautionary medium risk (m): $F \geq \min[F_{msm}]$ or $F + 90\%\mathrm{CI} \geq F_{msm}$;
High risk (H): $F_{lim} \leq F < F_{crash}$;
Precautionary high risk (h): $F \geq \min[F_{lim}]$ or $F + 90\%\mathrm{CI} \geq F_{lim}$;
Extreme high risk (E): $F \geq F_{crash}$;
Precautionary extreme high risk (e): $F \geq \min[F_{crash}]$ or $F + 90\%\mathrm{CI} \geq F_{crash}$.

As in previous assessment, we present these risk categories, their corresponding ecological consequence, as debatable management rules in Table 2-1.

Table 2.2. Biological reference points, proposed ecological risk category, ecological consequence, and provisional management rules for bycatch species

	$F < F_{msm}$	$F_{lim} > F > F_{msm}$	$F_{crash} > F > F_{lim}$	$F > F_{crash}$
ERA risk	Low (L)	Medium (M)	High (H)	Extreme high (E)
Ecological consequence	Overfishing not occurring. May keep population above 50% of virgin level	Overfishing is occurring but population can be sustainable	May drive population to very low levels in longer term	Population is unsustainable in long term – possibility of extinction
Management rule	Reduction of *F* not needed	Reduction in *F* may be required if this level of *F* occurs over seven consecutive years	Reduce fishing mortality below F_{msm} if this *F* occurs in five consecutive years	Reduce fishing mortality below F_{msm} if this *F* occurs in three consecutive years

3. South East Trawl Sub-fishery

The analysis of the trawl sub-fishery sector includes 447 species of fish, of which 90 are chondrichthyans and 357 are teleosts. Figures 3.1 and 3.2 compare the estimated fishing mortality with reference points F_{msm} and F_{crash} for all fish species caught in the SESSF Otter Trawl sub-fishery from 2007 to 2010.

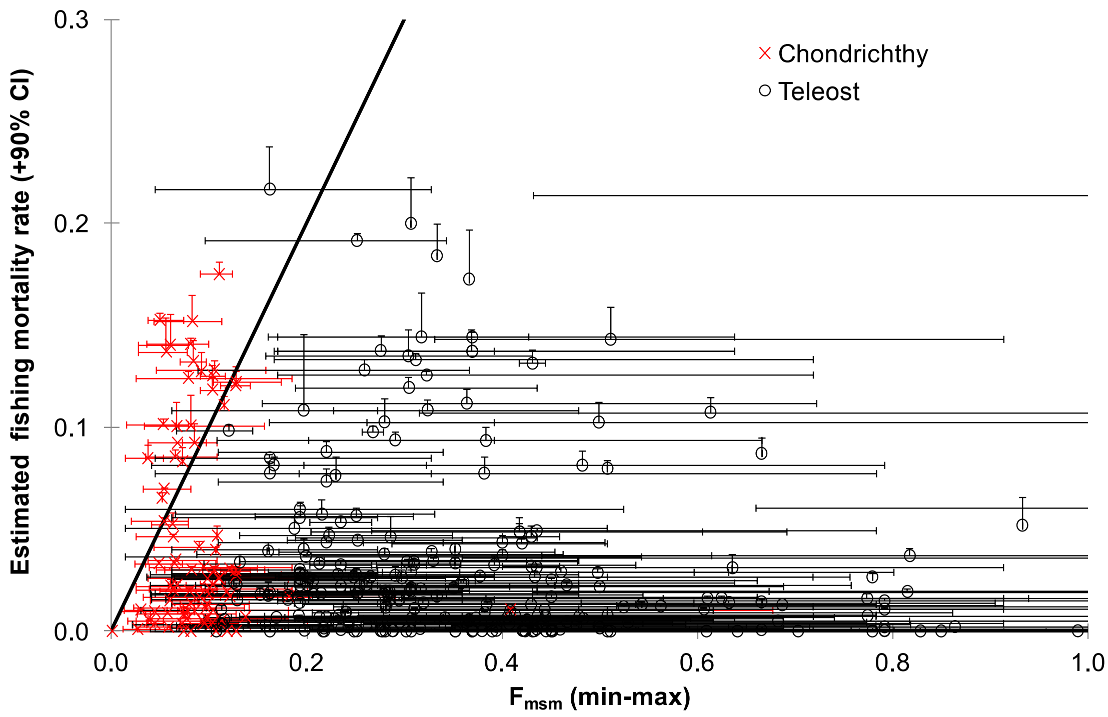

Figure 3.1. Comparison of estimated fishing mortality in 2007-2010 with maximum sustainable fishing mortality F_{msm} for fish species caught in the SESSF **Otter Trawl sub-fishery**. The diagonal line is where $F = F_{msm}$.

Four species have estimated mean fishing mortality rate greater than mean F_{crash} (*Dipturus gudgeri*, *Centrophorus harrissoni*, *Centrophorus zeehaani*, and *Dipturus australis*) (Table 3.1). All are chondrichthyans. *D. gudgeri*, *Centrophorus zeehaani*, and *C. harrissoni* are endemic species with narrow bathymetric distributions on the upper continental slope.

The Southern Dogfish has previously been referred to as *Centrophorus uyato*. However, this scientific name has previously been used for more than one species and was found to be invalid (White et al. 2008). Subsequently Southern Dogfish was formally described as an endemic species: *C. zeehaani* (White et al. 2008). Both *C. harrissoni* and *C. zeehaani* have extremely low productivity and have been depleted across significant parts of their former ranges by fishing (Andrew et al. 1997; Daley et al. 2002; Graham and Daley 2011). These species are the subject of comprehensive management arrangements currently under development as part of AFMAS Upper Slope Dogfish Management Strategy. .

The two species of *Dipturus* are endemic skates. Twenty-one species (including the above three) are found to be at medium risk (mean F over the four year is greater than mean F_{msm}). If we include uncertainty in both estimated fishing mortality rate and the reference pointsh 34 species are at risk of potential overfishing (precautionary medium risk, $F \geq \min[F_{msm}]$, or F + 90% CI $\geq F_{msm}$) (Table 3.1).

Note that Table 3.1 includes all precautionary risk species when uncertainty is taken into account. For 13 of these species, they are in the list of potential risk not because of their point estimates but because of uncertainty associated with the estimates. The 90% CI of the fishing mortality rates and the range of reference points may have been over- or under-estimated for some species.

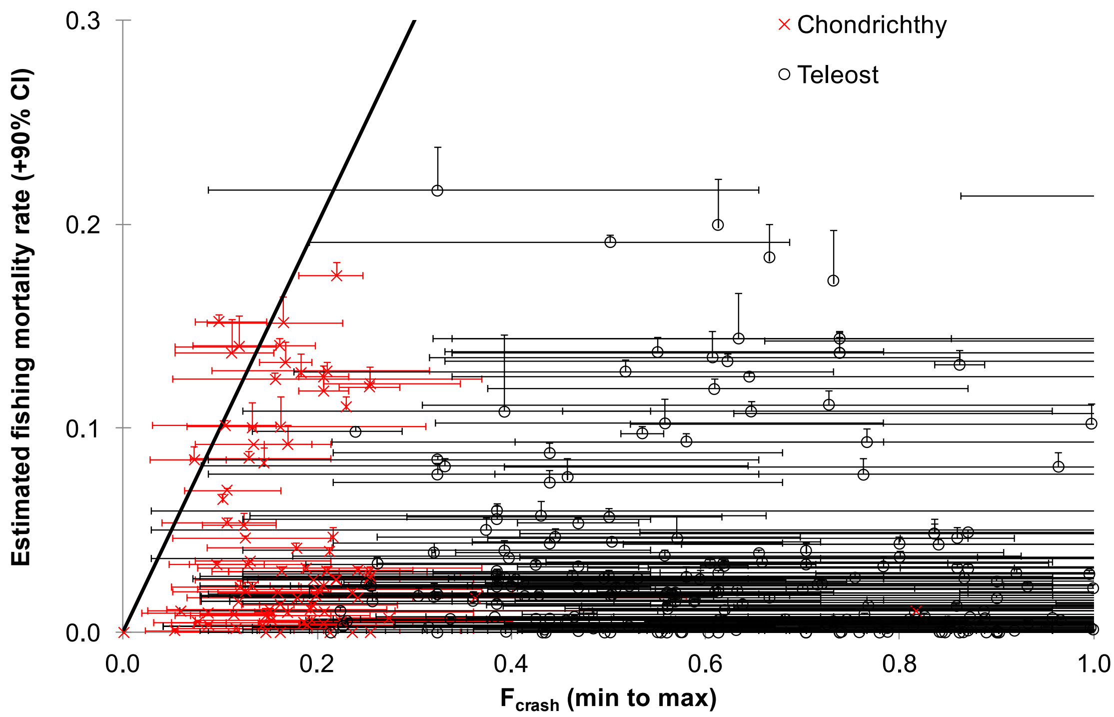

Figure 3.2. Comparison of estimated fishing mortality in 2007-2010 with unsustainable fishing mortality F_{crash} for fish species caught in the SESSF **Otter Trawl sub-fishery**. The diagonal line is where $F = F_{\text{crash}}$.

Biologists with first-hand knowledge of the SESSF (see Acknowledgements) scrutinized these listed species and believed the results are credible for most species. In addition to these species, they overrode some species based on their experience and felt uncertain for an additional few species, which are listed on the lower part of Table 3.1. Specific comments for these species are as follows.

Odontaspis ferox (Sand-tiger Shark): Limited distribution within the SESSF; has probably been confused with the Grey Nurse Shark (*Carcharias Taurus*).

Hoplostethus latus (Palefin Sawbelly): rarely caught off southern Australia.

Heterodontus galeatus (Crested Port-Jackson Shark): occurs mainly off QLD and northern NSW. Almost certainly a mis-identification of *Heterodontus portusjacksoni.*

Isistius brasiliensis (Cookie-cutter Shark): a benthopelagic species rarely caught by demersal trawl.

Hoplostethus intermedius (Blacktip Sawbelly): rarely caught off southern Australia *Gephyroberyx darwinii* (Darwin's Roughy): not normally caught in significant in quantities (<30 kg/trip).

Caelorinchus fasciatus (Banded Whiptail): Uncertain about the vertical overlap with the trawl fishery.

Zenopsis nebulosus (mirror dory): a benthopelagic species with apparently high spatial variability (and perhaps recruitment success). If this species is at risk then its close relative, the king dory, may also be at risk.

Table 3.1. Species at potential risk of overfishing in the SESSF **otter trawl sub-fishery in 2007-2010**. Species are sorted by [F - F_{msm}]. I_A = fraction of species distribution area affected; q = overall catchability, S = post-capture survival rate, Method = methods used for estimating the reference points. Risk category codes: E = extreme high, e = precautionary extreme high, H = high, h = precautionary high, M = medium. Species without a risk code are in the precautionary medium risk (m) only. Risk 2007 is the risk categories assessed in 2007.

					F		F_{msm}		F_{lim}		F_{crash}			Risk	
Scientific name	Common name	I_A	q	1-S	Mean	se	Mean	Min	Mean	Min	Mean	Min	Method	Current	2007
Dipturus gudgeri	Bight Skate	0.15	1.00	1.00	0.15	0.00	0.05	0.04	0.07	0.06	0.10	0.07	23456	EeHhM	EeHhM
Centrophorus harrissoni	Harrison's Dogfish	0.13	1.00	1.00	0.14	0.01	0.06	0.03	0.08	0.04	0.11	0.05	23456	EeHhM	h
Centrophorus zeehaani	Southern Dogfish	0.14	1.00	1.00	0.14	0.01	0.06	0.03	0.09	0.04	0.12	0.05	23456	EeHhM	h
Hydrolagus lemures	Bight Ghost Shark	0.18	1.00	1.00	0.18	0.00	0.11	0.09	0.16	0.14	0.22	0.18	356	HhM	
Dipturus canutus	Grey Skate	0.14	1.00	1.00	0.14	0.00	0.08	0.04	0.12	0.05	0.16	0.07	23456	eHhM	
Deania quadrispinosa	Platypus Shark	0.10	1.00	1.00	0.10	0.00	0.05	0.01	0.08	0.02	0.10	0.03	23456	eHhM	eh
Dipturus australis	Common Skate	0.08	1.00	1.00	0.08	0.00	0.04	0.01	0.05	0.02	0.07	0.03	23456	EeHhM	
Trygonorrhina fasciata	Eastern Fiddler Ray	0.14	1.00	1.00	0.13	0.01	0.08	0.07	0.12	0.10	0.17	0.14	56	HhM	NA
Etmopterus lucifer	Blackbelly Lantern Shark	0.13	1.00	1.00	0.12	0.00	0.08	0.02	0.12	0.04	0.16	0.05	23456	eHhM	
Parascyllium collare	Collared Catshark	0.14	1.00	1.00	0.13	0.01	0.09	0.09	0.14	0.14	0.18	0.18	5	M	NA
Squalus mitsukurii	Green-Eyed Dogfish	0.09	1.00	1.00	0.09	0.00	0.07	0.04	0.10	0.06	0.13	0.07	123456	ehM	h
Cephaloscyllium albipinnum	Whitefin Swell Shark	0.13	1.00	1.00	0.13	0.00	0.10	0.05	0.16	0.07	0.21	0.09	23456	ehM	
Hydrolagus ogilbyi	Ogilbys Ghost Shark	0.13	1.00	1.00	0.13	0.00	0.10	0.09	0.15	0.14	0.21	0.18	35	M	NA
Centroscymnus crepidater	Deepwater Dogfish	0.09	1.00	1.00	0.09	0.00	0.06	0.03	0.10	0.05	0.13	0.07	23456	ehM	NA
Galeocerdo cuvier	Tiger Shark	0.10	1.00	1.00	0.10	0.01	0.08	0.03	0.12	0.05	0.16	0.07	123456	ehM	
Urolophus sufflavus	Yellow-backed Stingaree	0.14	1.00	1.00	0.13	0.01	0.11	0.05	0.17	0.08	0.23	0.11	3456	ehM	NA
Centroscymnus plunketi	Plunket's Shark	0.07	1.00	1.00	0.07	0.00	0.05	0.03	0.08	0.05	0.11	0.06	456	ehM	
Chlamydoselachus anguineus	Frilled Shark	0.06	1.00	1.00	0.07	0.00	0.05	0.05	0.08	0.08	0.10	0.10	5	M	NA
Chimaera fulva	Southern Chimaera	0.12	1.00	1.00	0.12	0.00	0.10	0.09	0.15	0.14	0.21	0.18	35	M	NA
Harriotta raleighana	Spookfish	0.09	1.00	1.00	0.08	0.00	0.07	0.07	0.11	0.11	0.14	0.14	5	M	NA

Table 3.1 continues.

Scientific name	Common name	I_A	q	1-S	F Mean	F se	F_{msm} Mean	F_{msm} Min	F_{lim} Mean	F_{lim} Min	F_{crash} Mean	F_{crash} Min	Method	Risk Current	Risk 2007
Aptychotrema rostrata	Shovelnose Ray	0.09	1.00	1.00	0.09	0.01	0.08	0.07	0.13	0.11	0.17	0.14	56	M	NA
Centrophorus squamosus	Nilson's Deepsea Dogfish	0.06	1.00	1.00	0.05	0.00	0.05	0.02	0.08	0.03	0.11	0.04	23456	ehM	eHhM
Etmopterus pusillus	Slender Lantern Shark	0.11	1.00	1.00	0.11	0.00	0.11	0.11	0.17	0.17	0.23	0.23	5		NA
Galeus boardmani	Sawtail Shark	0.12	1.00	1.00	0.12	0.00	0.13	0.10	0.19	0.15	0.25	0.21	235		NA
Trygonoptera testacea	Common Stingaree	0.13	1.00	1.00	0.12	0.01	0.13	0.11	0.19	0.17	0.25	0.22	35		NA
Deania calcea	Brier Shark	0.06	1.00	1.00	0.05	0.00	0.06	0.04	0.09	0.06	0.12	0.08	23456		NA
Carcharodon carcharias	White Shark	0.03	1.00	1.00	0.03	0.00	0.05	0.02	0.07	0.03	0.10	0.05	123456		NA
Polyprion oxygeneios	Hapuku	0.15	0.67	1.00	0.10	0.00	0.12	0.07	0.18	0.10	0.24	0.13	23456		
Zameus squamulosus	Velvet Dogfish	0.01	0.67	1.00	0.01	0.00	0.04	0.01	0.07	0.01	0.09	0.02	123456		NA
Azygopus pinnifasciatus	Righteye Flounder	0.19	1.00	1.00	0.19	0.00	0.25	0.10	0.38	0.14	0.50	0.19	123456	eh	NA
Neocyttus rhomboidalis	Spiky Oreo	0.08	1.00	1.00	0.08	0.00	0.17	0.04	0.25	0.06	0.33	0.08	123456	eh	
Ventrifossa nigrodorsalis	Rattail	0.14	1.00	1.00	0.11	0.02	0.20	0.06	0.29	0.09	0.39	0.12	23456	h	NA
Epigonus lenimen	Big-eyed Cardinalfish	0.18	0.33	1.00	0.06	0.00	0.19	0.01	0.29	0.02	0.38	0.03	456	eh	eh
Epigonus robustus	Robust Cardinalfish	0.05	1.00	1.00	0.05	0.00	0.19	0.01	0.28	0.02	0.37	0.03	456	eh	eh
Epigonus denticulatus	White Cardinalfish	0.11	0.33	1.00	0.04	0.00	0.20	0.01	0.30	0.02	0.40	0.03	456	eh	eh
Species overridden by experts															
Heterodontus galeatus	Crested Port Jackson Shark	0.10	1.00	1.00	0.10	0.01	0.07	0.06	0.10	0.10	0.13	0.13	56	HhM	NA
Odontaspis ferox	Sand Tiger Shark	0.16	1.00	1.00	0.15	0.01	0.08	0.04	0.12	0.06	0.16	0.09	23456	eHhM	ehM
Hoplostethus intermedius	Common Sawbelly	0.13	0.67	1.00	0.08	0.00	0.16	0.04	0.24	0.07	0.32	0.09	123456	h	h
Gephyroberyx darwinii	Darwin's Roughy	0.12	0.67	1.00	0.08	0.00	0.16	0.04	0.24	0.07	0.32	0.09	123456	h	
Hoplostethus latus	Giant Sawbelly	0.34	0.67	1.00	0.22	0.01	0.16	0.04	0.24	0.07	0.32	0.09	123456	ehM	eh
Isistius brasiliensis	Cookie-cutter Shark	0.14	0.33	1.00	0.05	0.00	0.06	0.02	0.09	0.04	0.13	0.05	23456	h	eh
Zenopsis nebulosus	Mirror Dory	0.13	1.00	1.00	0.13	0.00	0.26	0.09	0.39	0.13	0.52	0.17	123456		

4. Great Australian Bight Trawl Sub-fishery

A total of 204 species of fish (52 chondrichthyans and 152 teleosts) that may be impacted by the GAB trawl fishery are included in this assessment. Estimated fishing mortality rate is low for this fishery, mainly due to low overlap between fishing effort and species distribution. No species is found to have fishing mortality (including uncertainty) greater than any reference point (either F_{msm} or F_{crash}, including minimum reference points) (Figures 4.1).

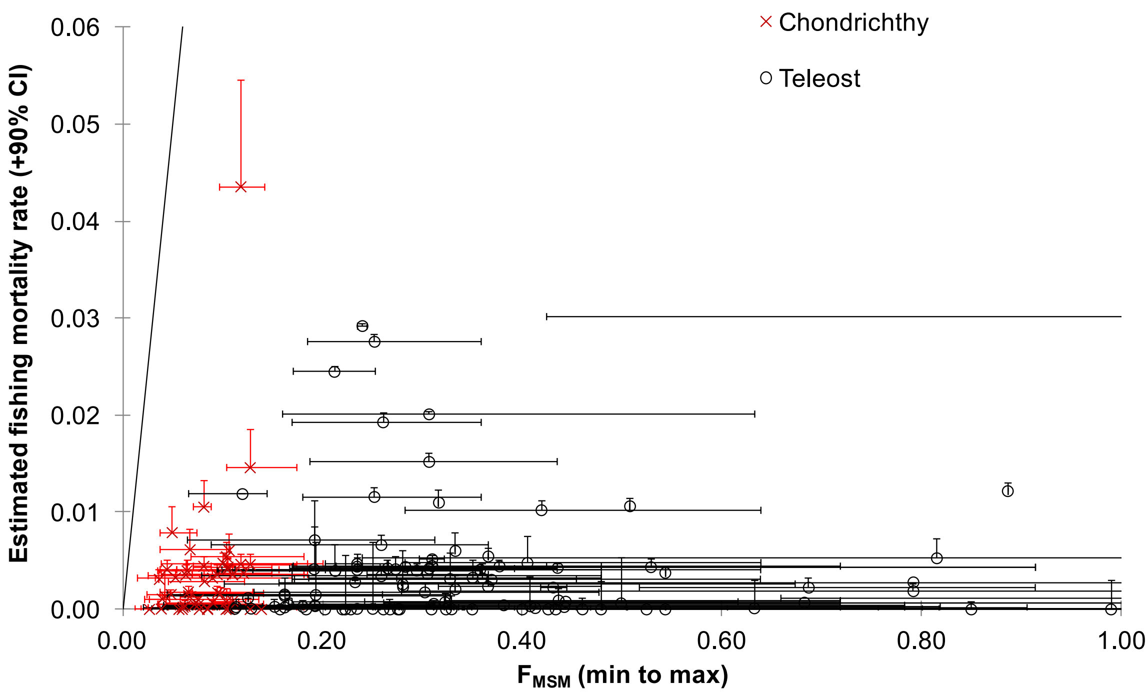

Figure 4.1. Comparison of estimated fishing mortality in 2007-2010 with maximum sustainable fishing mortality F_{msm} for fish species caught in the **Great Australian Bight Trawl** sub-fishery. The diagonal line is where $F = F_{\mathrm{msm}}$.

5. Danish Seine Sub-fishery

A total of 73 species of fish (4 chondrichthyans and 69 teleosts) that may be impacted by the Danish seine fishery are included in this assessment. Fishing efforts and affected area in the seine fishery are relatively small compared with other sub-fisheries. As a result, the estimated fishing mortality rate is low for this fishery. No species is found to have fishing mortality rate (including uncertainty) greater than the minimum F_{msm} or F_{crash} (Figures 5.1).

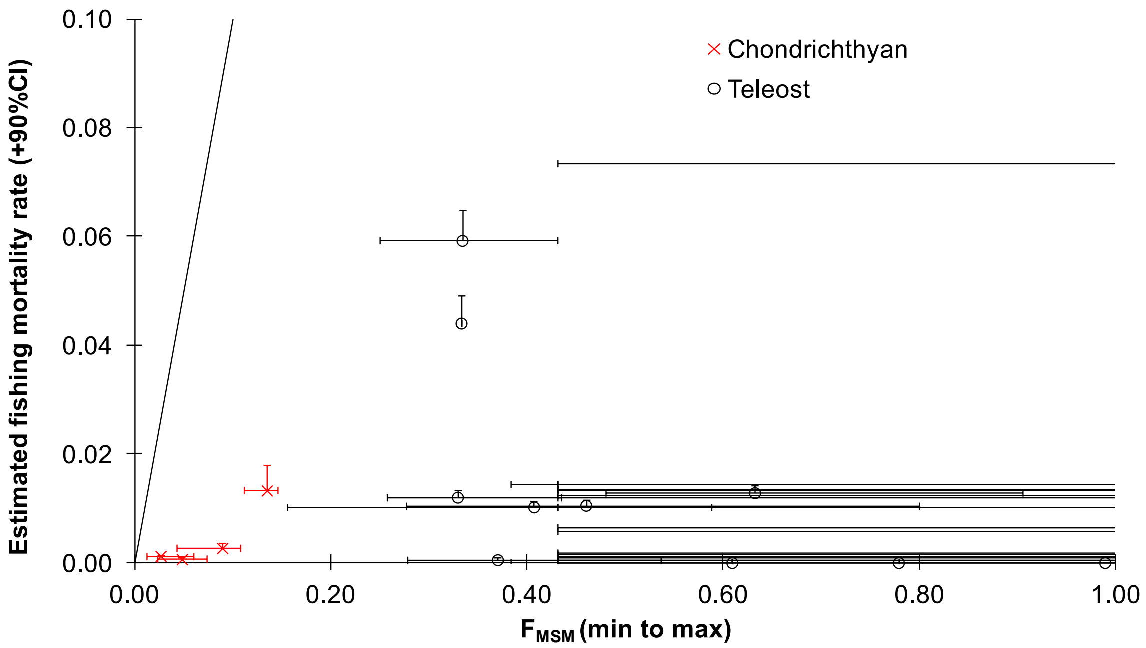

Figure 5.1. Comparison of estimated fishing mortality in 2007-2010 with maximum sustainable fishing mortality F_{msm} for fish species caught in the SESSF **Danish Seine** sub-fishery. The diagonal line is where $F = F_{msm}$.

6. Shark Gillnet Sub-fishery

We included 40 chondrichthyans and 155 teleosts in this assessment (a total of 195 species) that may encounter shark gillnet. Our assessment indicates that 5 species have estimated mean fishing mortality rate greater than mean F_{msm} (Table 6.1). These are all chondrichthyan species. Among these species, experts believe *Sphyrna zygaena* (hammerhead) may be at risk only because the juveniles are demersal (adults are pelagic) so the early life history stage may be vulnerable. Two species have mean fishing mortality rate greater than mean F_{crash} (Tab le 6.1). If we include uncertainty in both estimated fishing mortality rate and the reference points, 11 species are at precautionary medium risk category (either $F \geq \min[F_{msm}]$, or $F + 90\%\mathrm{CI} \geq F_{msm}$), and 5 species are at precautionary extreme high risk category (either $F \geq \min[F_{crash}]$, or $F + 90\%\mathrm{CI} \geq F_{crash}$) (Table 6.1).

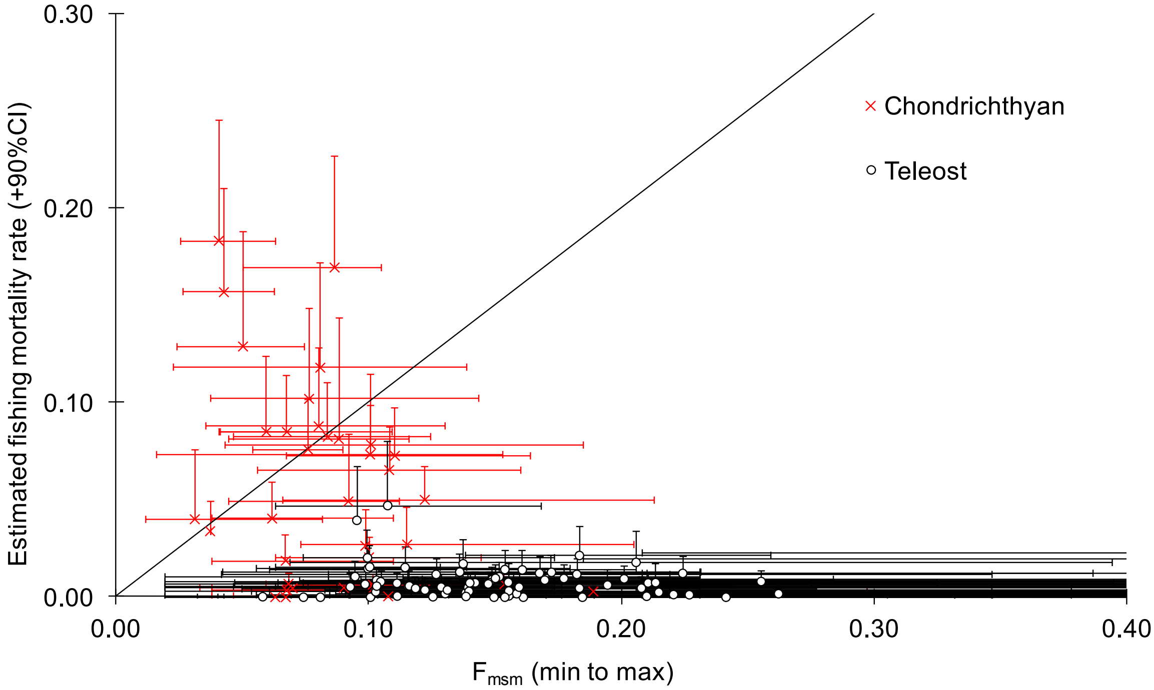

Figure 6.1. Comparison of estimated fishing mortality in 2007-2010 with maximum sustainable fishing mortality F_{msm} for fish species caught in the SESSF **Shark Gillnet** sub-fishery. The diagonal line is where $F = F_{\mathrm{msm}}$.

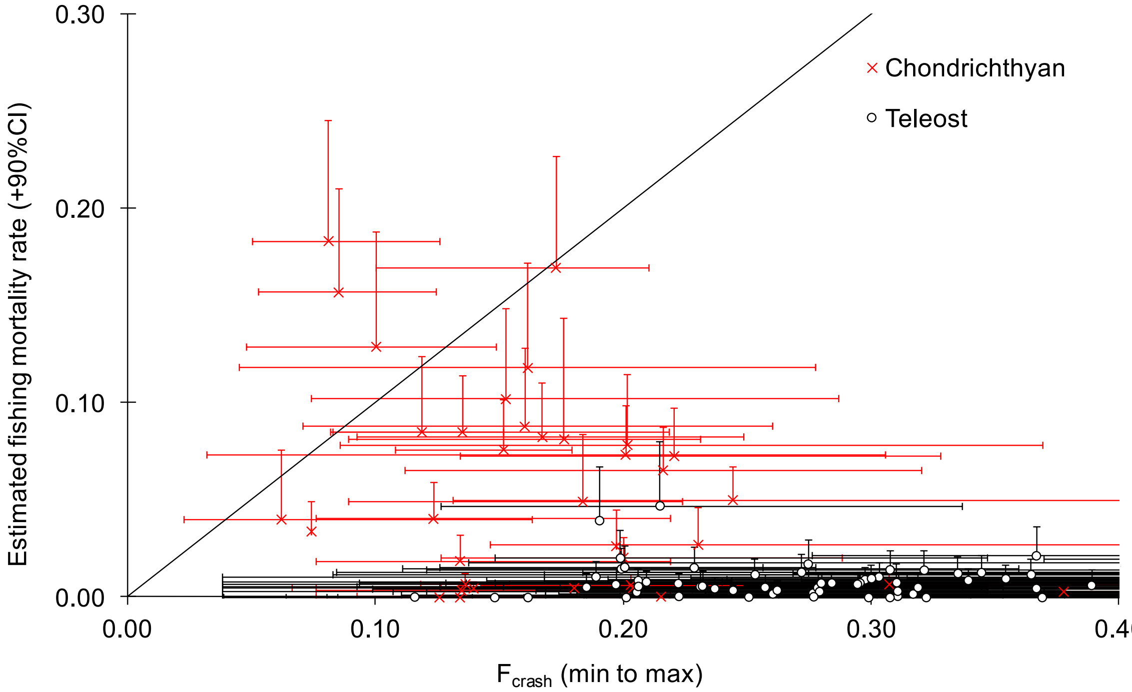

Figure 6.2. Comparison of estimated fishing mortality in 2007-2010 with unsustainable fishing mortality F_{crash} for fish species caught in the SESSF **Shark Gillnet** sub-fishery (including species overridden by experts). The diagonal line is where $F = F_{crash}$.

As for the trawl fishery, Table 6.1 includes species that are overridden by experienced biologists (see acknowledgements) or are felt uncertain. All these species are shown in Figures 6.1 and 6.2. The estimated impact (especially the upper 90% CI) may have been overestimated or the reference points underestimated (especially the minimum value of a reference points) for some species. Specific comments for overriden species and a few others are as follows.

Carcharhinus obscurus (Dusky Shark): has been historically over-fished off Western Australia.

Alopias vulpinus (Thresher Shark): adults are mainly pelagic although juveniles are demersal.

Isurus oxyrinchus (Shortfinned Mako): adults are pelagic and encounterability with gillnet is low but high catches of juveniles are taken off eastern Bass Strait.

Lamna nasus (Porbeagle): mainly pelagic and encounterability with gillnet is low because they tend to be high in the water column.

Rhincodon typus (Whale Shark): the overlap of fishing effort with species distribution may have been overestimated. Result should be verified by actual data.

Prionace glauca (Blue Shark): mainly pelagic and encounterability with gillnet is low because they tend to be high in the water column.

Orectolobus maculates (Spotted Wobbegong): tends to occur mostly on reef bottom whereas gillnets are set on sandy substrates. Also the highest densities of this species occur mostly off NSW where gillnetting is prohibited.

Odontaspis ferox (Sandtiger Shark): Fishing impact, especially the overlap of effort with species distribution, may have been overestimated. This species is only found off New South Wales and the shark gillnet fishery is excluded from this area. Almost certainly a misidentification of the Grey Nurse Shark which has been recorded from the Great Australian Bight.

Table 6.1. Species at potential risk of overfishing in the SESSF **Shark Gillnet sub-fishery in 2007-2010**. Species are sorted by [F - F_{msm}]. I_A = fraction of species distribution area affected; q = overall catchability, S = post-capture survival rate, Method = methods used for estimating the reference points. Risk category codes: E = extreme high, e = precautionary extreme high, H = high, h = precautionary high, M = medium. Species without a risk code are in the precautionary medium risk (m) only. Risk 2007 is the risk categories assessed in 2007.

					F		F_{msm}		F_{lim}		F_{crash}			Risk	
Scientific name	Common name	I_A	q	1-S	Mean	se	Mean	Min	Mean	Min	Mean	Min	Method	Current	2007
Carcharhinus brachyurus	Bronze Whaler	0.46	0.40	1.0	0.18	0.04	0.04	0.03	0.06	0.04	0.08	0.05	123456	EeHhM	EeHhM
Sphyrna zygaena	Smooth Hammerhead	0.42	0.40	1.0	0.17	0.03	0.09	0.05	0.13	0.07	0.17	0.10	23456	eHhM	ehM
Carcharodon carcharias	White Shark	0.49	0.26	1.0	0.13	0.04	0.05	0.02	0.07	0.04	0.10	0.05	123456	EeHhM	eHhM
Galeorhinus galeus	School Shark	0.21	0.40	1.0	0.09	0.02	0.07	0.04	0.10	0.06	0.13	0.08	123456	ehM	
Squatina australis	Australian Angelshark	0.19	0.40	1.0	0.08	0.02	0.08	0.05	0.11	0.08	0.15	0.11	3456	M	
Pristiophorus cirratus	Common Sawshark	0.21	0.40	1.0	0.08	0.02	0.08	0.05	0.13	0.07	0.17	0.09	2456	h	
Squalus acanthias	Whitespotted Dogfish	0.15	0.26	1.0	0.04	0.01	0.06	0.04	0.09	0.06	0.12	0.08	123456		NA
Notorynchus cepedianus	Broadnose Shark	0.30	0.26	1.0	0.08	0.02	0.10	0.04	0.15	0.06	0.20	0.09	123456	h	ehM
Furgaleus macki	Whiskery Shark	0.18	0.40	1.0	0.07	0.02	0.10	0.02	0.15	0.02	0.20	0.03	123456	eh	eh
Hypogaleus hyugaensis	Pencil Shark	0.18	0.40	1.0	0.07	0.01	0.11	0.07	0.17	0.10	0.22	0.13	123456		NA
Carcharias taurus	Greynurse shark	0.37	0.13	1.0	0.05	0.02	0.09	0.04	0.14	0.07	0.18	0.09	23456		NA
Species overridden by expert															
Carcharhinus obscurus	Dusky Shark	0.39	0.40	1.0	0.16	0.03	0.04	0.03	0.06	0.04	0.08	0.05	123456	EeHhM	EeHhM
Alopias vulpinus	Thresher Shark	0.45	0.26	1.0	0.12	0.03	0.08	0.02	0.12	0.03	0.16	0.04	23456	ehM	eh
Isurus oxyrinchus	Shortfinned Mako	0.39	0.26	1.0	0.10	0.03	0.08	0.04	0.11	0.06	0.15	0.07	123456	ehM	h
Lamna nasus	Porbeagle	0.32	0.26	1.0	0.09	0.02	0.06	0.04	0.09	0.06	0.12	0.08	123456	ehM	h
Rhincodon typus	Whale Shark	0.46	0.09	1.0	0.04	0.02	0.03	0.01	0.05	0.02	0.06	0.02	13456	ehM	ehM
Prionace glauca	Blue Shark	0.33	0.26	1.0	0.09	0.02	0.08	0.04	0.12	0.05	0.16	0.07	123456	ehM	
Orectolobus maculatus	Spotted Wobbegong	0.13	0.26	1.0	0.03	0.01	0.04	0.04	0.06	0.06	0.07	0.07	5		
Odontaspis ferox	Sandtiger Shark	0.62	0.13	1.0	0.08	0.04	0.09	0.04	0.13	0.07	0.18	0.09	23456	h	h

7. Automatic Longline Sub-fishery

We assessed 161 species of fish (40 chondrichthyans and 121 teleosts), including one new species not assessed before (*Zameus squamulosus*) . The assessment result indicates that 10 species have estimated mean fishing mortality rate greater than mean F_{msm} (Table 7.1), nine of which are chondrichthyans and one is a teleost. Five species have mean fishing mortality rate greater than mean mean F_{crash} (Table 7.1). If we include uncertainty in both estimated fishing mortality rate and the reference points, 15 species are at precautionary medium risk category (either $F \geq \min[F_{msm}]$, or F + 90%CI $\geq F_{msm}$), and 10 species are at precautionary extreme high risk category (either $F \geq \min[F_{crash}]$, or F + 90%CI $\geq F_{crash}$).

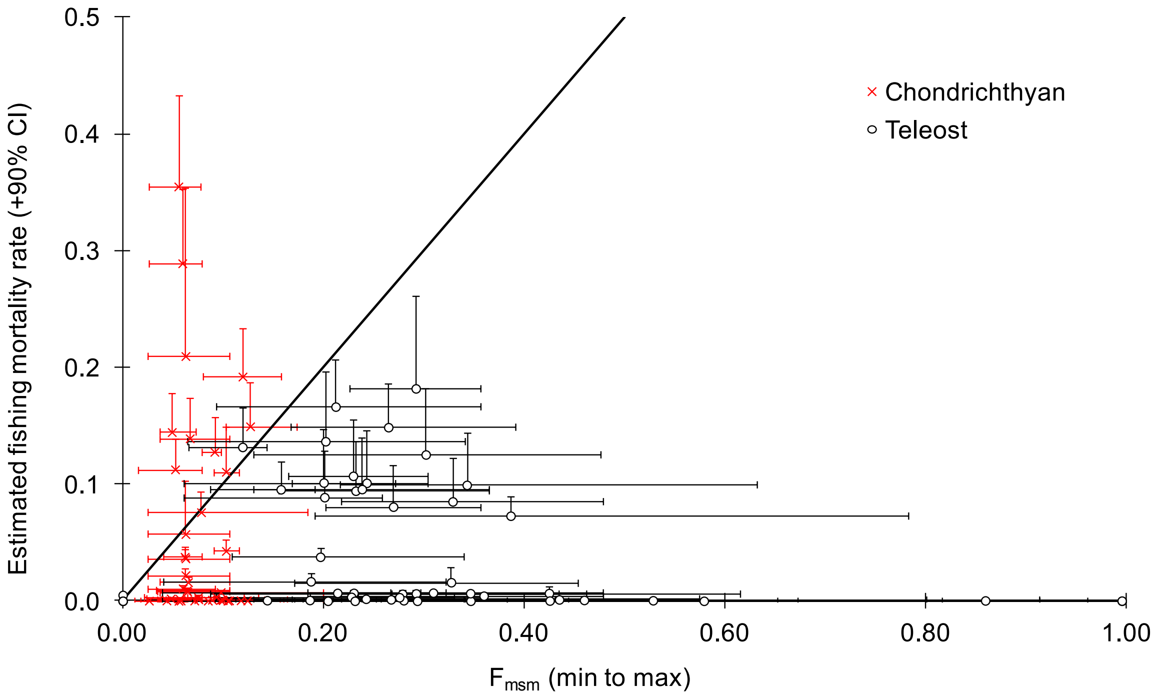

Figure 7.1. Comparison of estimated fishing mortality in 2007-2010 with maximum sustainable fishing mortality F_{msm} for fish species caught in the SESSF **Automatic Longline** sub-fishery. The diagonal line is where $F = F_{\text{msm}}$.

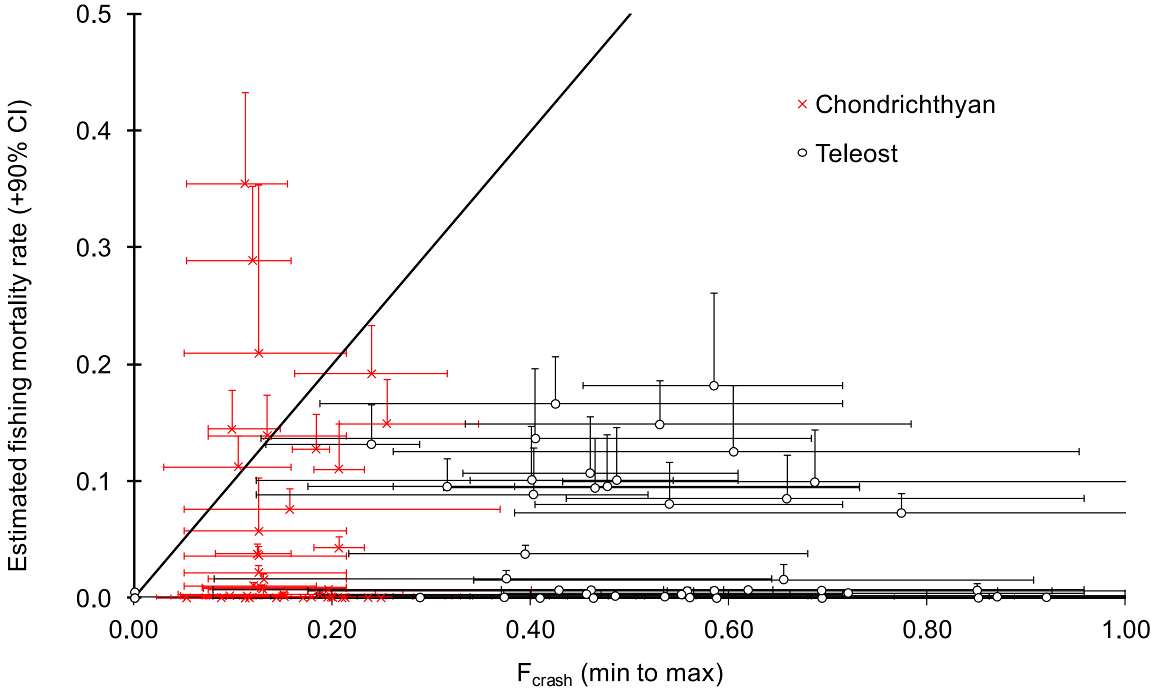

Figure 7.2. Comparison of estimated fishing mortality in 2007-2010 with unsustainable fishing mortality F_{crash} for fish species caught in the SESSF **Automatic Longline** sub-fishery. The diagonal line is where $F = F_{crash}$.

Biologists have commented and overridden three species that are estimated to be above the precautionary medium risk in this sub-fishery (lower part of Table 7.1), but all species are included in Figures 7.1 and 7.2.

Cirrhigaleus barbifer (Mandarin Shark): not a common species.

Caelorinchus fasciatus (Banded Whiptail): a benthic feeder with a small ventral mouth so catchability may have been overestimated.

Lepidorhynchus denticulatus (Toothed Whiptail): a very abundant true benthopelagic species that spends a lot of time in mid-water. Catchability may be too high or the species requires a closer look at actual catch as most individuals are rather small in relation to the hooks and bait used by at least the temperate fishery.

Table 7.1. Species at potential risk of overfishing in the SESSF **Auto Longline sub-fishery in 2007-2010**. Species are sorted by [F - F_{msm}]. I_A = fraction of species distribution area affected; q = overall catchability, S = post-capture survival rate, Method = methods used for estimating the reference points. Risk category codes: E = extreme high, e = precautionary extreme high, H = high, h = precautionary high, M = medium. Species without a risk code are in the precautionary medium risk (m) only. Risk 2007 is the risk categories assessed in 2007.

					F		F_{msm}		F_{lim}		F_{cash}			Risk	
Scientific name	Common name	I_A	q	1-S	Mean	se	Mean	Min	Mean	Min	Mean	Min	Method	Current	2007
Centrophorus harrissoni	Harrison's Dogfish	0.49	1.0	1.0	0.36	0.05	0.06	0.03	0.06	0.03	0.08	0.04	23456	EeHhM	ehM
Centrophorus zeehaani	Southern Dogfish	0.40	1.0	1.0	0.29	0.04	0.06	0.03	0.06	0.03	0.12	0.05	23456	EeHhM	ehM
Dipturus gudgeri	Bight Skate	0.20	1.0	1.0	0.14	0.02	0.05	0.04	0.05	0.04	0.10	0.07	23456	EeHhM	hM
Cephaloscyllium albipinnum	Whitefin Swell Shark	0.26	1.0	1.0	0.19	0.03	0.12	0.08	0.12	0.08	0.24	0.16	2345	eHhM	
Squalus chloroculus	Greeneye Spurdog	0.19	1.0	1.0	0.14	0.02	0.07	0.04	0.07	0.04	0.13	0.07	123456	EeHhM	h
Deania quadrispinosa	Platypus Shark	0.15	1.0	1.0	0.11	0.02	0.05	0.01	0.05	0.01	0.10	0.03	23456	EeHhM	ehM
Dipturus sp. B	Grey Skate	0.17	1.0	1.0	0.13	0.02	0.09	0.08	0.09	0.08	0.18	0.16	2345	HhM	
Figaro boardmani	Sawtail Catshark	0.20	1.0	1.0	0.15	0.02	0.13	0.10	0.13	0.10	0.25	0.21	235	HhM	NA
Polyprion oxygeneios	Hapuku	0.18	1.0	1.0	0.13	0.02	0.12	0.07	0.12	0.07	0.24	0.13	23456	eHhM	hM
Hydrolagus lemures	Blackfin Ghost Shark	0.15	1.0	1.0	0.11	0.02	0.10	0.09	0.10	0.09	0.21	0.18	35	HhM	NA
Etmopterus lucifer	Blackbelly Lantern Shark	0.10	1.0	1.0	0.08	0.01	0.08	0.02	0.08	0.02	0.16	0.05	23456	eh	h
Isistius brasiliensis	Cookie-cutter Shark	0.24	0.3	1.0	0.06	0.03	0.06	0.02	0.06	0.02	0.13	0.05	23456	eh	NA
Dalatias licha	Black Shark	0.05	1.0	1.0	0.04	0.00	0.06	0.02	0.06	0.02	0.13	0.05	23456	h	
Helicolenus barathri	Bigeye Ocean Perch	0.28	0.7	1.0	0.14	0.04	0.20	0.06	0.20	0.06	0.40	0.13	23456	eh	
Zenopsis nebulosus	Mirror Dory	0.20	0.7	1.0	0.10	0.03	0.24	0.09	0.24	0.09	0.48	0.17	12345	h	NA

Species overridden by experts

Scientific name	Common name	I_A	q	1-S	F Mean	F se	F_{msm} Mean	F_{msm} Min	F_{lim} Mean	F_{lim} Min	F_{cash} Mean	F_{cash} Min	Method	Risk Current	Risk 2007
Cirrhigaleus barbifer	Mandarin Shark	0.29	1.0	1.0	0.21	0.09	0.06	0.02	0.06	0.02	0.13	0.05	23456	EeHhM	h
Caelorinchus fasciatus	Banded Whiptail	0.21	0.7	1.0	0.10	0.03	0.20	0.06	0.20	0.06	0.40	0.12	2345	h	
Lepidorhynchus denticulatus	Toothed Whiptail	0.18	0.7	1.0	0.09	0.02	0.20	0.06	0.20	0.06	0.40	0.12	2345	h	

8. Great Australian Bight Danish Seine Sub-fishery

The GAB Danish Seine sector is a new trial fishery in 2011. AFMA provided the list of species that may interact with seine, as well as fishing effort and distribution data for this fishery. We included all 20 fish species (2 chondrichthyans and 18 teleosts) in this assessment. The results show that the estimated fishing mortality for all species is lower than any of their sustainability reference points (Figure 8.1), mainly due to low fishing effort.

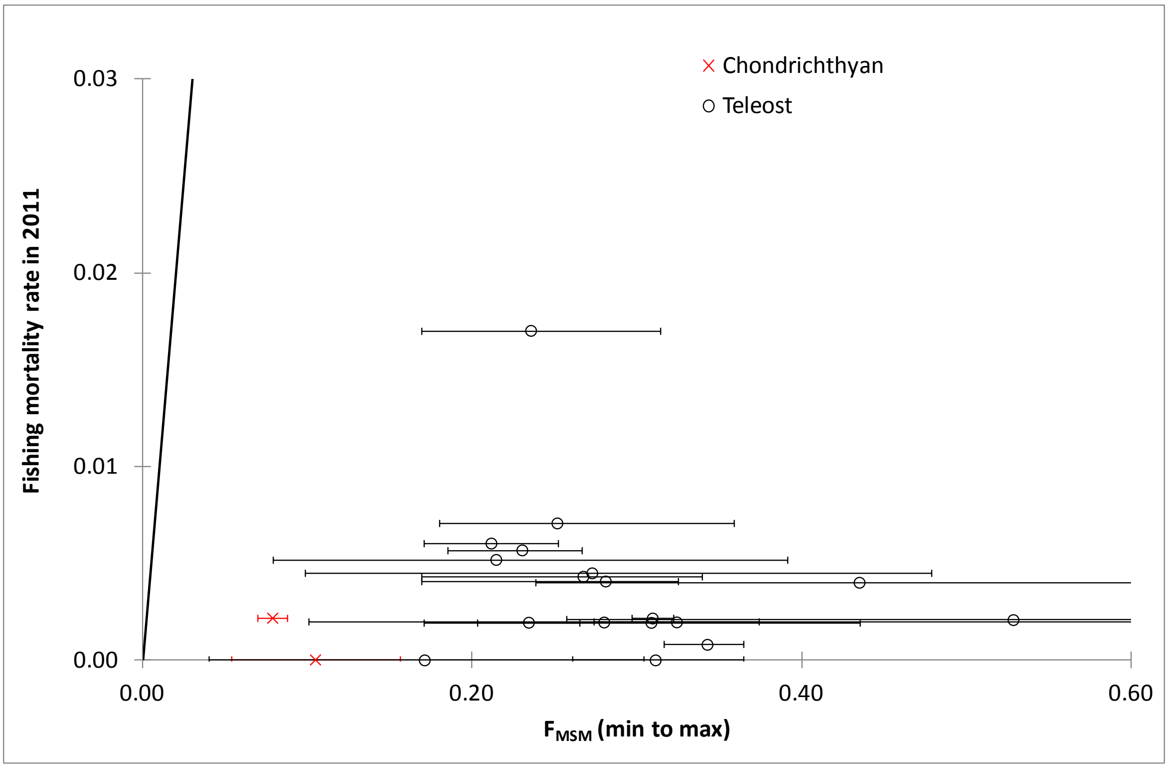

Figure 8.1. Comparison of estimated fishing mortality in 2011 with maximum sustainable fishing mortality F_{msm} for fish species caught in the **GAB Danish Seine** trial sub-fishery. The diagonal line is where $F = F_{msm}$.

9. Cumulative risk from SESSF sub-fisheries

The cumulative fishing impacts result from combined fishing mortality from 5 sub-fisheries in 2007-2010. This analysis includes a total of 508 fish species in SESSF, among which 100 are chondrichthyans and 408 are teleosts.

The assessment result shows that 45 species (43 chondrichthyans and 2 teleosts) have estimated mean cumulative fishing mortality rate greater than mean F_{msm} (Tables 9.1 and 9.2, Figures 9.1 and 9.2), 18 species (17 are chondrichthyans) have estimated mean cumulative fishing mortality rates greater than mean F_{crash} (Figure 9.3). If we include uncertainty in both estimated fishing mortality rate and the reference points, 70 species (52 chondrichthyans and 18 teleosts) are at precautionary medium risk category (either $F \geq \min[F_{msm}]$, or $F + 90\%\text{CI} \geq F_{msm}$), 43 species (34 chondrichthyans and 9 teleosts) are at precautionary extreme high risk category (either $F \geq \min[F_{crash}]$, or $F + 90\%\text{CI} \geq F_{crash}$) (Table 9.1 and Table 9.2). This list of potential risk species excludes species that have been overridden by experts in sub-fisheries.

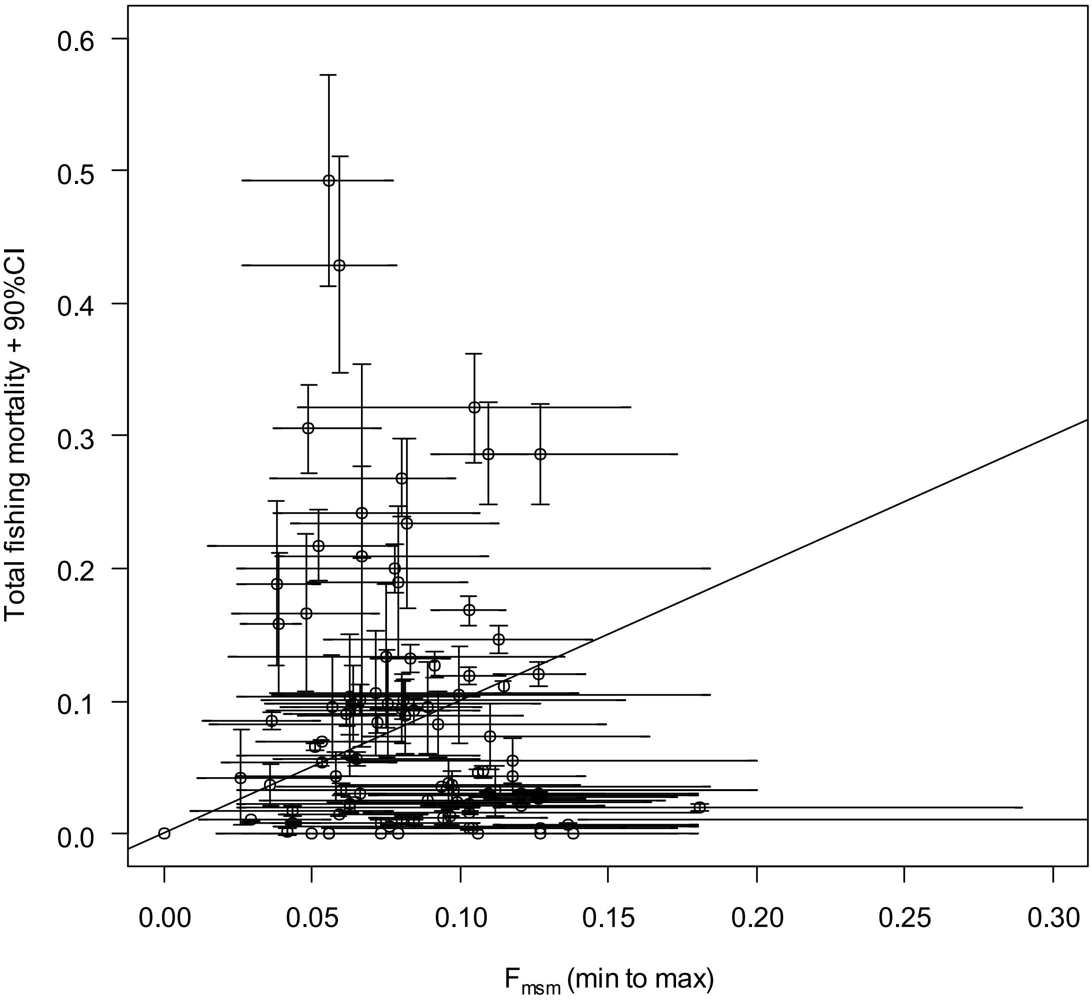

Figure 9.1. Comparison of estimated cumulative fishing mortality from 5 SESSF sub-fisheries in 2007-2010 with maximum sustainable fishing mortality $\boldsymbol{F_{msm}}$ **for chondrichthyan** species. The diagonal line is where $F = F_{msm}$.

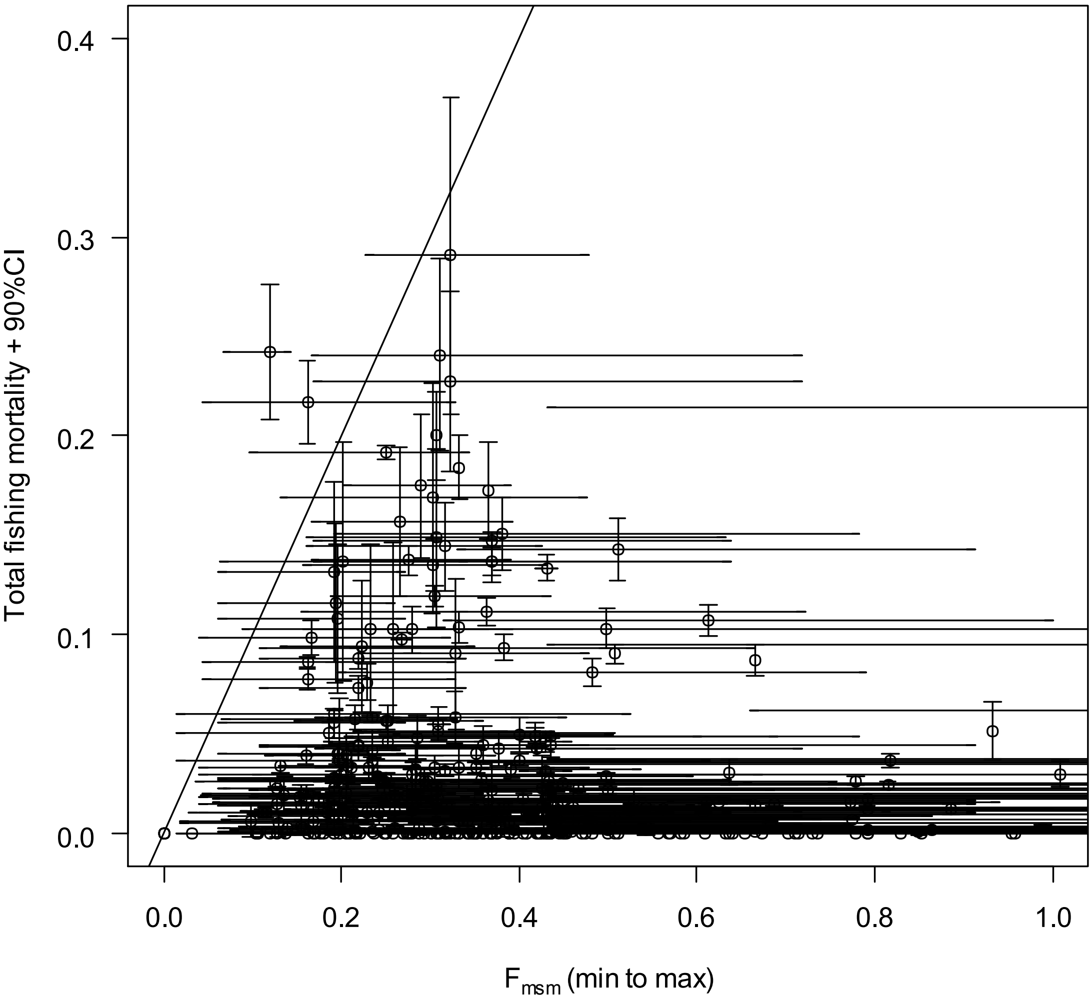

Figure 9.2. Comparison of estimated cumulative fishing mortality from 5 SESSF sub-fisheries in 2007-2010 with maximum sustainable fishing mortality $\boldsymbol{F_{\mathrm{msm}}}$ **for teleost** species. The diagonal line is where $F = F_{\mathrm{msm}}$.

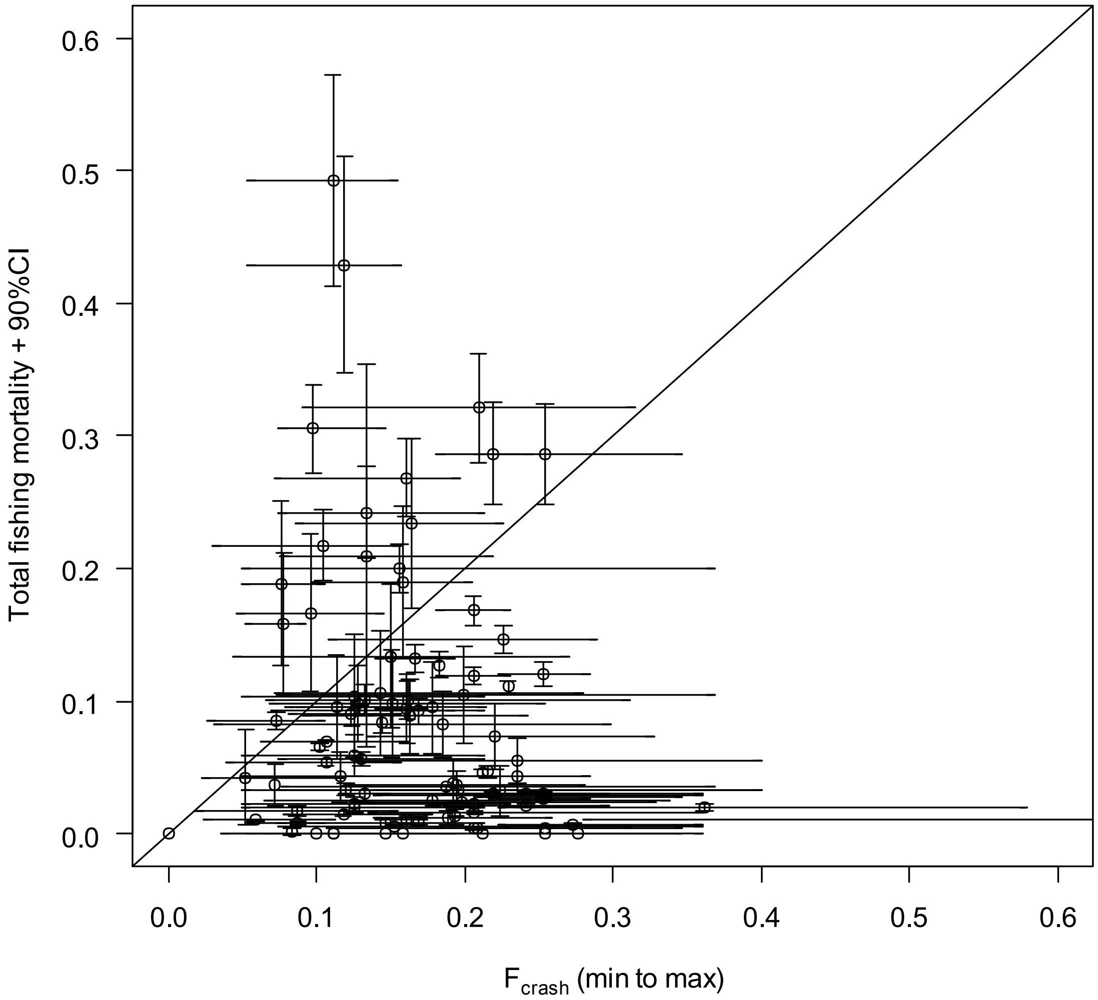

Figure 9.3. Comparison of estimated cumulative fishing mortality from 5 SESSF sub-fisheries in 2007-2010 with unsustainable fishing mortality $\boldsymbol{F_{crash}}$ **for chondrichthyan** species. The diagonal line is where $F = F_{crash}$.

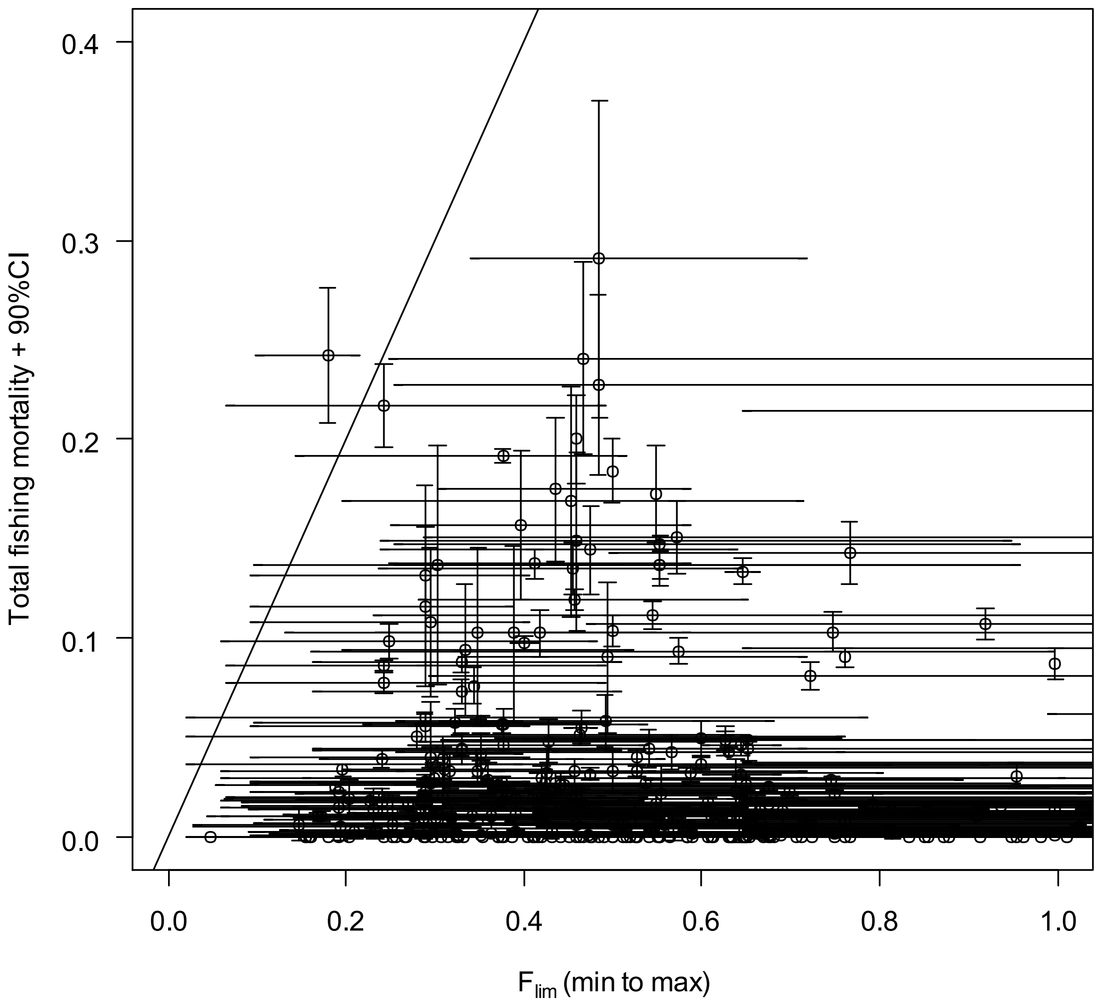

Figure 9.4. Comparison of estimated cumulative fishing mortality from 5 SESSF sub-fisheries in 2007-2010 with limit fishing mortality $\boldsymbol{F}_{\mathbf{lim}}$ **for teleosts** species. The diagonal line is where $F = F_{\mathrm{lim}}$.

Table 9.1. Chondrichthyan species at potential risk of overfishing from cumulative impact in the SESSF in 2007-2010. Risk category codes: E = extreme high, e = precautionary extreme high, H = high, h = precautionary high, M = medium. Species without a risk code are in the precautionary medium risk (m) only. Risk 2007 is the risk categories assessed in 2007.

		F_{msm}		F_{crash}		Estimated F							Risk	
Science name	Common name	mean	min	mean	min	Trawl	GAG T	Gillnet	Seine	Longline	Cum	se	current	2007
Centrophorus harrissoni	Harrison's Dogfish	0.06	0.03	0.11	0.06	0.14	0.00	0.00	0.00	0.36	0.49	0.08	EeHhM	EeHhM
Centrophorus zeehaani	Southern Dogfish	0.06	0.03	0.12	0.05	0.14	0.00	0.00	0.00	0.29	0.43	0.05	EeHhM	EeHhM
Dipturus gudgeri	Bight Skate	0.05	0.01	0.10	0.02	0.15	0.01	0.00	0.00	0.14	0.31	0.03	EeHhM	EeHhM
Cephaloscyllium sp. A	Whitefin Swell Shark	0.10	0.06	0.21	0.12	0.13	0.00	0.00	0.00	0.19	0.32	0.04	EeHhM	ehM
Dipturus sp. B	Grey Skate	0.08	0.04	0.16	0.09	0.14	0.00	0.00	0.00	0.13	0.27	0.03	EeHhM	eHhM
Hydrolagus lemures	Bight Ghost Shark	0.11	0.02	0.22	0.04	0.18	0.00	0.00	0.00	0.11	0.29	0.04	EeHhM	ehM
Squalus mitsukurii	Green-Eyed Dogfish	0.07	0.03	0.13	0.06	0.09	0.01	0.00	0.00	0.14	0.24	0.03	EeHhM	EeHhM
Deania quadrispinosa	Platypus Shark	0.05	0.04	0.10	0.08	0.10	0.00	0.00	0.00	0.11	0.22	0.03	EeHhM	EeHhM
Galeus boardmani	Sawtail Shark	0.13	0.02	0.25	0.05	0.12	0.01	0.00	0.00	0.15	0.29	0.04	EeHhM	
Carcharhinus brachyurus	Bronze Whaler	0.04	0.01	0.08	0.03	0.01	0.00	0.18	0.00	0.00	0.19	0.06	EeHhM	EeHhM
Etmopterus lucifer	Blackbelly Lantern Shark	0.08	0.05	0.16	0.11	0.12	0.00	0.00	0.00	0.08	0.20	0.02	EeHhM	ehM
Carcharodon carcharias	White Shark	0.05	0.02	0.10	0.05	0.03	0.00	0.13	0.00	0.00	0.17	0.06	EeHhM	EeHhM
Sphyrna zygaena	Smooth Hammerhead	0.08	0.03	0.16	0.06	0.02	0.00	0.17	0.00	0.00	0.19	0.06	EeHhM	ehM
Hydrolagus ogilbyi	Ogilbys Ghost Shark	0.10	0.01	0.21	0.03	0.13	0.00	0.00	0.00	0.04	0.17	0.01	HhM	NA
Trygonorrhina sp. A	Eastern Fiddler Ray	0.08	0.01	0.17	0.03	0.13	0.00	0.00	0.00	0.00	0.13	0.01	HhM	NA
Dipturus australis	Common Skate	0.04	0.02	0.07	0.05	0.08	0.00	0.00	0.00	0.00	0.08	0.01	EeHhM	
Parascyllium collare	Collared Catshark	0.09	0.00	0.18	0.00	0.13	0.00	0.00	0.00	0.00	0.13	0.01	M	NA
Galeorhinus galeus	School Shark	0.06	0.03	0.13	0.06	0.00	0.00	0.09	0.00	0.01	0.10	0.03	eHhM	ehM
Urolophus sufflavus	Yellow-backed Stingaree	0.11	0.06	0.23	0.12	0.13	0.00	0.00	0.01	0.00	0.15	0.01	ehM	NA
Centroscymnus crepidater	Deepwater Dogfish	0.06	0.03	0.13	0.06	0.09	0.00	0.00	0.00	0.01	0.09	0.00	ehM	NA
Deania calcea	Brier Shark	0.06	0.02	0.12	0.04	0.05	0.00	0.00	0.00	0.04	0.09	0.01	ehM	
Galeocerdo cuvier	Tiger Shark	0.08	0.05	0.16	0.10	0.10	0.00	0.00	0.00	0.00	0.10	0.01	ehM	
Centroscymnus plunketi	Plunket's Shark	0.05	0.02	0.11	0.04	0.07	0.00	0.00	0.00	0.00	0.07	0.00	ehM	

Table 9.1 continues.

		F_{msm}		F_{crash}		Estimated F							Risk	
Science name	Common name	mean	min	mean	min	Trawl	GAG T	Gillnet	Seine	Longline	Cum	se	current	2007
Chimaera sp. A	Southern Chimaera	0.10	0.01	0.21	0.03	0.12	0.00	0.00	0.00	0.00	0.12	0.01	M	NA
Chlamydoselachus anguineus	Frilled Shark	0.05	0.00	0.10	0.00	0.07	0.00	0.00	0.00	0.00	0.07	0.00	M	NA
Squatina australis	Australian Angel Shark	0.08	0.01	0.16	0.02	0.01	0.00	0.08	0.00	0.00	0.09	0.03	M	
Harriotta raleighana	Spookfish	0.07	0.00	0.14	0.00	0.08	0.00	0.00	0.00	0.00	0.08	0.01	M	NA
Aptychotrema rostrata	Shovelnose Ray	0.08	0.01	0.17	0.02	0.09	0.00	0.00	0.00	0.00	0.09	0.01	M	NA
Pristiophorus cirratus	Common Saw Shark	0.08	0.04	0.16	0.07	0.00	0.00	0.08	0.00	0.00	0.09	0.03	hM	ehM
Carcharias taurus	Greynurse Shark	0.09	0.05	0.18	0.09	0.04	0.00	0.05	0.00	0.00	0.10	0.03	ehM	
Notorynchus cepedianus	Broadnose Sevengill Shark	0.10	0.06	0.20	0.12	0.02	0.00	0.08	0.00	0.00	0.10	0.04	ehM	eHhM
Centrophorus squamosus	Nilson's Deepsea Dogfish	0.05	0.03	0.11	0.07	0.05	0.00	0.00	0.00	0.00	0.05	0.00	ehM	eHhM
Etmopterus pusillus	Slender Lantern Shark	0.11	0.00	0.23	0.00	0.11	0.00	0.00	0.00	0.00	0.11	0.00		NA
Dalatias licha	Black Shark	0.06	0.04	0.13	0.08	0.00	0.00	0.02	0.00	0.04	0.06	0.02	eh	h
Trygonoptera testacea	Common Stingaree	0.13	0.02	0.25	0.03	0.12	0.00	0.00	0.00	0.00	0.12	0.01		NA
Squalus megalops	Piked Dogfish	0.07	0.03	0.13	0.06	0.04	0.00	0.00	0.00	0.02	0.06	0.01	h	
Furgaleus macki	Whiskery Shark	0.09	0.08	0.19	0.15	0.00	0.00	0.07	0.00	0.00	0.08	0.03	eh	ehM
Squalus acanthias	White-spotted Dogfish	0.06	0.03	0.12	0.07	0.00	0.00	0.04	0.00	0.00	0.04	0.02	h	
Zameus squamulosus	Velvet Dogfish	0.04	0.03	0.09	0.07	0.01	0.00	0.00	0.00	0.01	0.02	0.00	h	NA
Centroscymnus owstoni	Owston's Dogfish	0.06	0.04	0.12	0.07	0.02	0.00	0.00	0.00	0.01	0.03	0.00		
Hypogaleus hyugaensis	Pencil Shark	0.11	0.04	0.22	0.09	0.00	0.00	0.07	0.00	0.00	0.07	0.02		NA

Table 9.2. Teleost species at potential risk of overfishing from cumulative impact in the SESSF in 2007-2010. Risk category codes: E = extreme high, e = precautionary extreme high, H = high, h = precautionary high, M = medium. Species without a risk code are in the precautionary medium risk (m) only. Risk 2007 is the risk categories assessed in 2007.

		Fmsm		Fcrash		Estimated F							Risk	
Science name	Common name	mean	min	mean	min	Trawl	GAG T	Gillnet	Seine	Longline	Cum	se	current	2007
Polyprion oxygeneios	Hapuku	0.12	0.05	0.24	0.11	0.10	0.01	0.00	0.00	0.13	0.24	0.03	EeHhM	EeHhM
Seriolella caerulea	White Trevalla	0.32	0.10	0.65	0.19	0.11	0.00	0.00	0.00	0.18	0.29	0.08		
Azygopus pinnifasciatus	Righteye Flounder	0.25	0.15	0.50	0.31	0.19	0.00	0.00	0.00	0.00	0.19	0.00	eh	
Helicolenus barathri	Ocean Perch	0.20	0.14	0.40	0.28	0.00	0.00	0.00	0.00	0.14	0.14	0.06	eh	eh
Neocyttus rhomboidalis	Spiky Oreo	0.17	0.13	0.33	0.25	0.08	0.00	0.00	0.00	0.02	0.10	0.01	eh	h
Beryx decadactylus	Imperador	0.31	0.15	0.62	0.29	0.13	0.00	0.00	0.00	0.11	0.24	0.05		
Ventrifossa nigrodorsalis	Rattail	0.20	0.13	0.39	0.27	0.11	0.00	0.00	0.00	0.00	0.11	0.04	h	NA
Beryx splendens	Alfonsino	0.32	0.15	0.64	0.31	0.13	0.00	0.00	0.00	0.10	0.23	0.05		
Epigonus lenimen	Big-eyed Cardinalfish	0.19	0.18	0.38	0.36	0.06	0.00	0.00	0.00	0.00	0.06	0.00	eh	eh
Lepidopus caudatus	Southern Frostfish	0.30	0.17	0.60	0.34	0.03	0.00	0.01	0.00	0.13	0.17	0.06		h
Epigonus robustus	Robust Cardinalfish	0.19	0.17	0.37	0.35	0.05	0.00	0.00	0.00	0.00	0.05	0.01	eh	eh
Epigonus denticulatus	White Cardinalfish	0.20	0.18	0.40	0.37	0.04	0.00	0.00	0.00	0.00	0.04	0.00	eh	eh

10. Discussion

We have updated SAFE for five sub-fisheries and their cumulative impact on non-target fish species in SESSF in this report. We have also assessed the Great Australian Bight Danish Seine Fishery. The assessments use most recent fishery data from 2007 to 2010 (2011 for GAB Danish Seine Sub-fishery). During the assessment we encountered some challenges. In this section we briefly discuss these issues and provide suggestions for future research.

10.1. Assumptions on species distribution

There is a trade-off between requirement of data (quantity and quality) and accuracy of the assessment. The benefit of applying SAFE to SESSF using limited data comes at the cost of requiring some strong assumptions. Two key assumptions about species distribution are: (1) fish distribution range is known from bioregional mapping and core range mapping refined by biologists (Commonwealth of Australia 2005; Heap et al. 2005); and (2) 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. Violation of these two assumptions will cause bias to the estimated fishing mortality. It will be very useful in future research to estimate species distribution and relative density using observed data (such as scientific surveys).

10.2. Sustainability reference points based on life history parameters

One of the major changes in this assessment is an adaptation of new relationship between sustainability reference points and natural mortality. The rule-of-thumb approach that $F_{\mathrm{msy}} = M$ has been widely used in fisheries management worldwide. However, few studies have empirically investigated this relationship. Recently, Zhou et al. (2012) compiled biological reference point data for more than 200 species and stocks worldwide that have been assessed with different methods. They conducted a meta-analysis and linked fishing mortality based reference points to natural mortality and other commonly available life-history parameters by taking errors in variables into account. The results from that study should provide more accurate relationships between reference points and life history parameters for data-poor species than the rule-of-thumb approximation.

This method of deriving sustainability reference points (based on fish life history parameters rather than full stock assessment using time-series data) requires input of life history parameters, particularly the natural mortality rate. The results of six alternative methods clearly show large uncertainty among different approaches. Both input data and the methods of estimating life history parameters must have contributed to the large uncertainty. We recommend that input data be further verified and alternative methods be compared in the future analyses.

10.3. Fishing methods that use bait

The SAFE method requires information about the range of gear affected area. This is relatively straightforward for fishing gears that actively move through water column to catch fish, such as trawl and seine. However, for the methods that use bait (i.e., longline) it is difficult to estimate the size of gear affected area in each gear deployment. We use the result of full stock assessment on target species in the some fishery to adjust the estimated fishing impact. The assumptions behind this approach are (1) the response of non-target fish to the bait is the same as target fish, and (2) fishing mortality of target species from full stock assessment is unbiased. If the bait is less attractive to a non-target species then its fishing mortality will be overestimated. This may have been the case for some species in this report.

10.4. New species

A total of more than 20 additional chondrichthyan and teleost species were recorded in logbooks and observer data since the last SAFE assessment. Including new species in the assessment required significant effort, involving validation of the species, gathering spatial distribution information, assessing vulnerability to fishing gears, and collecting life history parameters. The amount of work needed was not anticipated before the project. However, we have taken significant time and effort to carry out these tasks. The results show that majority of the species were misidentified or due to various errors. In the end we included a total of 8 new species (2 chondrichthyes and 6 teleosts) in this assessment.

In addition to these species that have only recently been identified in catches, the Southern Dogfish, *Centrophorus zeehaani*, has only recently been formally described (White et al. 2008). This species was referred as *Centrophorus uyato* in previous assessments and literature. The SAFE method uses data from multiple sources, including species list from previous ERA studies (Smith et al. 2007), bioregional mapping and core range mapping (Commonwealth of Australia 2005; Heap et al. 2005), fisheries logbooks, fisheries observer data, biological data from fishbase.org, etc. The new species name and the new species ID are used in some datasets, but the old species name and ID still remain in other databases. Hence changes in taxonomic names have the potential to cause confusion. This could be reduced by systematic use of CAAB Codes (Codes for Australian Aquatic Biota) in databases held by different government agencies. These codes are linked to a type specimen in a museum and don’t change, even when species names do. Never the less it remains essential to apply taxonomic expertise and rigour to all ecological risk assessments and the maintenance of the associated fishery and scientific databases.

10.5. Measurement of fishing mortality rate

We use instantaneous fishing mortality rate F in this report instead of exploitation rate u as used in the previous assessment. This change is to ensure greater end user understanding and comparison of results. The quantity of F is consistent with terms used in the Harvest Strategy Framework. As discussed in Zhou et al. (2009), F and u are similar at low values, such as for many bycatch species. Hence, this change should have minimal effect on the results.

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