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Chondrichthyan guide for fisheries managers

A practical guide for mitigating chondrichthyan bycatch

Heather M Patterson and Michael J Tudman

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Bureau of Rural Sciences and Australian Fisheries Management Authority
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Note on references

The references provided in this document include both the specific papers cited in the text and appendices as well as general papers that provide some relevant background knowledge. This list is by no means exhaustive, but rather is focused on fisheries management, mitigation and the high risk chondrichthyan species listed.

ACKNOWLEDGEMENTS

CONTENTS

SUMMARY

Shark bycatch

Chondrichthyans (sharks, skates and rays) typically display K-selected life history strategies whereby they are slow growing, late maturing and have low fecundities (Stevens *et al.* 2000). They are particularly vulnerable to exploitation and are slow to recover. Bycatch in marine fisheries is a source of mortality for chondrichthyan species as they are caught incidentally while targeting other species and may not survive when returned to the sea. Survivorship of live animals returned to the sea after being captured is often unknown.

Working group

The Australian Fisheries Management Authority (AFMA) has been conducting ecological risk assessments (ERAs) for the fisheries under its jurisdiction. These assessments take numerous biological factors into account and give an indication of which species are at high risk from fishing in each fishery. In order to address and mitigate the risks to chondrichthyans identified as 'high risk' in this process, AFMA convened the Chondrichthyan Technical Working Group (CTWG). This working group consisted of recognised shark experts, as well as representatives from non-government organisations (NGOs), government departments and the fishing industry. The objectives of the CTWG were to provide practical mitigation options for the noted high risk chondrichthyan species and groups that could be implemented by AFMA in both the long and short-term and provide suggestions for directed research, including research which may remove species from the 'high risk' list. The information presented in this guide is based on the suggestions and opinions of the CTWG.

Mitigation options

The CTWG discussed several shark groups and subgroups including dogfish, pelagic sharks, skates, rays and hammerheads/whalers. The group also briefly discussed Threatened, Endangered and Protected (TEP) species of sharks. Each group or subgroup was discussed and mitigation options put forward. These options were then ranked and assessed qualitatively against a series of criteria. These rankings are presented in tables and are followed by detailed comments of the CTWG. The CTWG also provided general recommendations about the options that could be implemented immediately versus those that required more research. Finally, the group noted which options would likely work well together and more specific comments on the options that are most viable.

Conclusions

The CTWG concluded that there is no panacea for the problem of chondrichthyan bycatch in marine fisheries, but that this guide will provide managers with the most appropriate options to mitigate fisheries impacts and improve the survival of chondrichthyan species. Indeed, it was noted that addressing chondrichthyan bycatch is a problem for fisheries management agencies world wide. It was also

noted that what works for one fishery may not be suitable for another, and that managers will have to weigh their options and work with industry and other stakeholders to determine which is best for their fishery. This guide will aid in such decisions. In many cases practical changes in the way fishing is conducted are required to improve the survivorship of these important animals.

ABBREVIATIONS

AFMA	Australian Fisheries Management Authority
BRD	Bycatch Reduction Device
BRS	Bureau of Rural Sciences
CAAB	Codes for Australian Aquatic Biota
CPUE	Catch Per Unit Effort
CSF	Coral Sea Fishery
CSIRO	Commonwealth Science and Industry Research Organisation
CTS	Commonwealth Trawl Sector (part of the SESSF)
CTWG	Chondrichthyan Technical Working Group
DEWHA	Department of the Environment, Water, Heritage and the Arts
DLL	Demersal longline
ERA	Ecological Risk Assessment
ETBF	Eastern Tuna and Billfish Fishery
EPBC	Environmental Protection and Biodiversity Conservation
GAB	Great Australian Bight Trawl Sector (part of the SESSF)
GHT	Gillnet, Hook and Trap Sectors (part of the SESSF)
IPOA	International Plan of Action
NPF	Northern Prawn Fishery
NPOA	National Plan of Action
NWS	North West Slope
PLL	Pelagic longline
SESSF	Southern and Eastern Scalefish and Shark Fishery
TED	Turtle Excluder Device
TEP	Threatened, Endangered and Protected

INTRODUCTION

Background

Chondrichthyan fishes, comprising the cartilaginous sharks, skates and rays, are a major taxonomic group that inhabit all the oceans of the world. These animals range widely in their habitats, prey and size. Ecologically, they occupy numerous niches and particularly sharks often occupy the position of apex predator, regulating ecosystems and balancing prey populations. These animals are an integral part of marine ecosystems.

Chondrichthyans are typically K-selected species. That is, they are long-lived, late maturing, slow growing and produce few, well-developed offspring (Stevens *et al.* 2000). Most bony fishes offset high mortality rates by producing millions of externally fertilised eggs. Chondrichthyans reproduce through internal fertilisation that generates fewer, though better provisioned young and have a range of reproductive modes from laying eggs to producing pups directly (Last and Stevens 2009). Because of these life history traits, chondrichthyan fishes are particularly prone to overfishing and depletion. The scientific community and managers are now focusing a great deal of attention on chondrichthyans and the risks they face in light of these life history characteristics. In addition, despite efforts to stem illegal and unsustainable shark catch in Australia and other countries, there is growing exploitation internationally due to fishing and the demand for shark products such as fins (Stevens *et al.* 2000; Barker & Schluessel 2005; Clarke *et al.* 2006; Dulvy *et al.* 2008; García *et al.* 2008). As many sharks are apex predators, their decline or removal from ecosystems may have profound effects (Stevens *et al.* 2000; Shepherd & Myers 2005; Heithaus *et al.* 2008). For example, removing sharks from an ecosystem may result in trophic cascades and changes in competition structure (Stevens *et al.* 2000; Heithaus *et al.* 2008).

The Australian Government has measures and processes currently in place to address chondrichthyan issues. In 1999 the United Nations Food and Agriculture Organization (FAO) developed the *International Plan of Action for the Conservation and Management of Sharks* (IPOA-Sharks). This is a voluntary instrument under the 1995 FAO *Code of Conduct for Responsible Fisheries* and directs that FAO member states 'should adopt a national plan of action for the conservation and management of shark stocks (NPOA-Sharks), if their vessels conduct directed fisheries for sharks or if their vessels regularly catch sharks in non-directed fisheries'. Australia's *National Plan of Action for Conservation and Management of Sharks* was released in 2004 and is currently under review.

The Department of the Environment, Water, Heritage and the Arts (DEWHA) also addresses chondrichthyan issues through the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act). Under the EPBC Act species can be declared threatened and varying degrees of protection and stock rebuilding mandated. There are currently twelve shark species listed as protected in one or more Australian jurisdictions. Three additional species (Harrisson's Dogfish, Southern Dogfish and Endeavour Dogfish) are currently under consideration for listing. The National Shark Recovery Group advises DEWHA on the implementation of recovery plans for EPBC Act listed shark species.

The Australian Fisheries Management Authority (AFMA) has more direct and day-to-day requirements pertaining to sharks and commercial fishing. For example, shark finning (the process of cutting off the fins of a shark and discarding the body) is banned from all Commonwealth, state and territory fisheries. The body must be landed with the fins attached. This measure has also been adopted in other countries, such as the United States, and is designed to counter the illegal and unregulated international fin trade. Similarly, shark

livers may not be landed without the body in Commonwealth fisheries. Trip limits on sharks are in place in many Commonwealth fisheries as well. For example, in the Eastern Tuna and Billfish Fishery (ETBF) there is a 20 shark trip limit. This prevents targeting of sharks but also limits the amount discarded. Wire tracers are also prohibited in this fishery, making it easier for sharks to escape by biting off the hook. AFMA has also developed bycatch work plans for each fishery to directly address bycatch issues, including those pertaining to sharks. The information presented in this report will be considered in those work plans.

AFMA is also developing an ecological risk management (ERM) framework for its fisheries. This involves managing the risks of fishing on the environment by focusing those high risk priorities identified through the ecological risk assessment (ERA) process. ERAs identified species at greatest risk from the pressures of commercial fishing and associated activities. The species specifically addressed in this guide have been identified through AFMA's risk assessments, from EPBC Act obligations as well as species identified from data deficient fisheries which are considered likely to be at high risk from commercial fishing operations.

ERAs have been completed for most of Australia's Commonwealth fisheries where sufficient information was available. This process was based on the Ecological Risk Assessment for the Effects of Fishing (ERAEF) framework, which is a hierarchical approach going from a qualitative, scoping analysis (Level 1 SICA – Scale Intensity Consequence Analysis), through a semi-quantitative analysis (Level 2 PSA – Productivity Susceptibility Analysis) and finally, if required, to a fully quantitative analysis (Level 3– either Sustainability Assessment for Fishing Effects (SAFE) or a full stock assessment) of assessing risk (Hobday *et al.* 2007).

As discussed, ERAs progress through a number of steps and involve a hierarchy of methodologies. This approach screens out low risk activities and species, and focuses more intensive and quantitative analyses on those species assessed as being at greater environmental risk within Australia's fisheries. For more information please go to: http://www.afma.gov.au/environment/eco_based/eras/risk.htm

Project objectives

The overarching objective of this guide is to provide fisheries managers with practical options to mitigate chondrichthyan TEP (Threatened, Endangered or Protected) and high risk species bycatch. The options provided are applicable over a range of time frames; some may be implemented immediately while others may require more research to fully develop. These options apply to a range of species, fisheries and gear types, not just those specifically listed in this guide.

The options presented in this guide can be applied to many fisheries and used by fisheries managers from a range of agencies both domestically and internationally. Specifically, the objectives of the CTWG workshop were:

- to consider and discuss the high risk groups that were identified through the ERA process and provide potential mitigation measures that may be practically implemented by AFMA

- to identify potential mitigation measures which may be useful in the future

- to provide suggestions for directed research specific to mitigation measures which may enable more mitigation options to be considered

- a to give suggestions for research to provide information which may remove species from the high risk category.

HOW TO USE THIS GUIDE

Shark groups overview

The groups and subgroups presented in Table 1 are management groupings, developed by BRS and CSIRO. They are not based strictly on taxonomy, but rather also take into account fisheries information like gear type and identified high risk fishery. Management and mitigation suggestions generally apply to groups or subgroups rather than to specific species, although in some cases species may be considered independently. TEP species are also listed independently, as they already have special status under the EPBC Act and therefore by law already have a level of protection.

Some species that are not currently considered as high risk in the ERAs have been added to the list to give the resulting mitigation options a greater depth and a broader applicability. Those species that have been added to the list are noted with an asterisk. In one case an entire group of sharks was added (Reef Sharks). This is because the Coral Sea Fishery has yet to undergo a Level 2 ERA and therefore no high risk species for that fishery have been identified. However, when an ERA is conducted Reef Sharks are likely to be categorised as high risk given their characteristics, such as small home ranges. For each subgroup a mean productivity measure resulting from the ERAs is given. This measure takes life history characteristics such as age at maturity, longevity and fecundity into account and generates a score to indicate relative risk based on these characteristics. The range of the measure is 1 to 3; 3 being the highest level of risk. A high productivity score because of life history characteristics like low fecundity and late onset of maturity was often the driver for a high risk listing in the ERA process.

Finally, some species and groups were removed from further discussion on the advice of the CTWG. These are indicated in Table 1 with a '+' and include benthic / demersal subgroups 3 and 4. Subgroup 3 contains the Banded Wobbegong. However, the CTWG felt this species was on the list in error, as its distribution does not intersect the fishery area of the NPF. Therefore, they asked that this be clarified in the ERA so the correct species may be discussed. This clarification has yet to be made. In addition, Subgroup 4 which contains the Whiskery and School sharks were removed from further discussion. This is because the CTWG felt they are not at high risk. The latest Whiskery Shark stock assessment done by the Department of Fisheries Western Australia indicates that the stock size is increasing (McAuley 2007). As Whiskery Sharks are known to comprise a single stock from WA to eastern Australia, this increase in stock indicated that further discussion of this species was not warranted. Similarly, the CTWG felt that School Sharks should be removed from the list as this species already has a formal rebuilding strategy in place (www.afma.gov.au).

Table 1. Chondrichthyan groupings discussed in the guide (* = not high risk in ERA but added to the list; + = excluded from the list by CTWG)

Group	Subgroup	Common name	Scientific name	High risk fishery	Gear interaction
Dogfish	1	Harrisson's Dogfish	*Centrophorus harrissoni*	CTS / GHT	Trawl / DLL
		Southern Dogfish	*Centrophorus zeehaani*	CTS / GHT	Trawl / DLL
		Endeavour Dogfish*	*Centrophorus moluccensis*	---	Trawl / DLL
		Western Gulper Shark*	*Centrophorus westraliensis*	---	Trawl / DLL
	2	Leafscale Gulper Shark	*Centrophorus squamosus*	CTS	Trawl
		Longsnout Dogfish	*Deania quadrispinosa*	CTS / GHT	Trawl / DLL
		Brier Shark*	*Deania calcea*	---	Trawl / DLL
		Blackbelly Lanternshark	*Etmopterus lucifer*	GHT	DLL
	3	Greeneye Dogfish	*Squalus spp (chloroculus montalbani, grahami, albifrons)*	CTS / GHT	Trawl / DLL
Benthic/Demersal	1	Blotched Fantail Ray	*Taeniura meyeni*	NPF	Trawl
		Reticulate Whipray*	*Himantura uarnak*	---	Trawl
		Cowtail Stingray*	*Pastinachus sephen*	---	Trawl
	2	Bight Skate	*Dipturus gudgeri*	GHT	DLL
		Grahams Skate*	*Dipturus grahami*	---	DLL
		Sydney Skate*	*Dipturus australis*	---	DLL
		Grey Skate*	*Dipturus canutus*	---	DLL
		Whitley's Skate*	*Spiniraja whitleyi*	---	DLL
	3+	Banded Wobbegong	*Orectolobus ornatus*	NPF	Trawl

Group	Subgroup	Common name	Scientific name	High risk fishery	Gear interaction
	4+	Whiskery Shark	*Furgaleus macki*	GHT	DLL
		School Shark	*Galeorhinus galeus*	---	Trawl / DL
Pelagic	1	Pelagic Thresher	*Alopias pelagicus*	ETB	PLL
		Bigeye Thresher*	*Alopias superciliosus*	---	PLL
		Thresher*	*Alopias vulpinus*	---	PLL
	2	Porbeagle*	*Lamna nasus*	---	PLL
		Shortfin Mako	*Isurus oxyrinchus*	GHT	Gill / PLL
		Longfin Mako	*Isurus paucus*	ETB	PLL
	3	Crocodile Shark	*Pseudocarcharias kamoharai*	ETB	PLL
	4	Oceanic Whitetip*	*Carcharhinus longimanus*	---	PLL
		Silky Shark*	*Carcharhinus falciforms*	---	PLL
		Blue Shark*	*Prionace glauca*	---	PLL
Whalers/Hammerheads	1	Bronze Whaler	*Carcharhinus brachyurus*	GHT	Gill
		Dusky Whaler	*Carcharhinus obscurus*	GHT	Gill
		Broadnose Shark	*Notorynchus cepedianus*	GHT	Gill
		Sandbar Shark*	*Carcharhinus plumbius*	---	---
	2	Smooth Hammerhead	*Sphyrna zygaena*	GHT	Gill
Reef	1	Grey Reef Shark*	*Carcharhinus amblyrhynchos*	---	DLL
		Blacktip Reef Shark*	*Carcharhinus melanopterus*	---	DLL
		Whitetip Reef Shark*	*Triaenodon obesus*	---	DLL
		Silvertip Shark*	*Carcharhinus albimarginatus*	---	DLL

Group	Subgroup	Common name	Scientific name	High risk fishery	Gear interaction
TEP		Grey Nurse Shark	*Carcharias Taurus*	---	---
		Whale Shark	*Rhincodon typus*	---	---
		White Shark	*Carcharodon carcharias*	GHT	Gill
		Freshwater Sawfish*	*Pristis microdon*	---	---
		Green Sawfish*	*Pristis zijsron*	---	---

Management worksheets overview

The worksheets provided formed the basis of what the CTWG addressed during the workshop and provide a ranking system by which options may be compared. The worksheets are broken down by fishing gear type and species group or subgroup and additional notes are provided. The CTWG ranked the mitigation options against eight criteria which pertained to the biology of the sharks, how the option may impact sustainability, how easy and costly it would be to measure the effect of the option and the likely reaction of industry. All criteria were assumed to be of equal weighting for the purposes of the work shop although it was acknowledged that this may be reassessed by AFMA.

Ranking systems for worksheets

++ve   very positive

+ve   positive

--ve   very negative

-ve   negative

0   no effect

UK   effect unknown

P   potential (indicates the noted effect is a potential effect)

SM   small (indicates the noted effect is a small effect)

ST   short term (indicates the noted effect is short term only)

NA   not applicable

How to read the management worksheets

As noted above, the worksheets used a qualitative ranking system with caveats such as 'potential' and 'short-term'. This system was adopted to provide the most information to managers. An example of how to interpret the tables and the responses given is noted below in Table 2. In some cases a particular response (e.g. +ve) is not viable due to the criterion being assessed. These criteria have been noted.

Table 2. An example mitigation option worksheets with instructions on how the response is to be interpreted.

Group or subgroup: Gear type	Options				
Performance against criteria	**1.** Option x	**2.**	**3.**	**4.**	**5.**
1. Ability to reduce interactions.	+ve = will reduce interactions -ve = will increase interactions				
2. Ability to minimise level of discarding.	+ve = will reduce discarding -ve = will increase discarding				
3. Ability to improve survivorship (once caught).	+ve = will improve survivorship -ve = will reduce survivorship				
4. Impact of option on other species and or habitats.	+ve = will positively impact other species and habitats -ve = will negatively impact other species and habitats				
5. Technical feasibility to detect a response.	+ve = a response can be detected -ve = a response cannot be detected				
6. Cost of monitoring (to detect response). (+ve not a viable response for this criterion)	-ve = there is a monitoring cost 0 = there is no cost of monitoring				
7. Level of industry support.	+ve = industry is supportive -ve = industry is not supportive				
8. Impact on currently collected catch data. (+ve not a viable response for this criterion)	-ve = options will impact current catch data 0 = there will be no impact on current catch data				

DOGFISH GROUP

The Dogfish group contains dogfish and gulper sharks, as well as several other deepwater species. As with other deepwater sharks, the low fecundity, particularly for gulper sharks or species of the family Centrophoridae (one to two pups maximum every one to two years), high longevity (Fenton 2001; Irvine 2004) and late age at first maturity (Whiteley 2004), not only result in extremely rapid population depletion in fisheries, but also prevent quick recovery after such depletion. Species within the family Centrophoridae are believed to have the lowest reproductive potential of all shark species (Irvine 2004; Kyne and Simpfendorpher 2007), thereby placing them at extreme risk. As a result, the CTWG identified this shark group as the highest priority in terms of mitigation need and the IUCN Shark Specialist Group described deepwater sharks as being more vulnerable to over-exploitation than perhaps any other marine species group. Indeed, declines of over 99 per cent of some species of deepwater sharks have been reported in Australian waters (Andrew *et al.* 1997; Graham *et al.* 2001).

Subgroup 1 is the most vulnerable of the dogfish group and Harrisson's Dogfish is listed as critically endangered on the IUCN red list. Endeavour Dogfish (*Centrophorus moluccensis*), Harrisson's Dogfish (*C. harrissoni*) and Southern Dogfish (*C. spp.* – now *C. zeehaani*) were nominated for listing in 2005 as threatened species under the EPBC Act and were included in the Proposed Priority Assessment List for the Minister for the Environment, Heritage and the Arts to consider. Western Gulper Sharks are newly described and form what was previously thought to be the western population of Harrisson's Dogfish.

The CTWG considered the dogfishes in two groups based on depth distribution: the first group contained the upper-slope species (300–700 m) while the second group contained the mid-slope species (700 m+). Two gear types were also considered (trawl and demersal longline). The responses to the proposed mitigation options for both groups and both gear types were similar, noting that mid-slope species are from deeper waters and therefore have a lower survival rate if released after capture. Additionally, research of any kind conducted in deeper water would be more expensive, which would increase the costs of determining if the option was effective.

Subgroups

Dogfish – Subgroup 1

Centrophorus moluccensis
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Harrisson's Dogfish	**CAAB Code**	37 020010
	Southern Dogfish		37 020011
	Endeavour Dogfish*		37 020001
	Western Gulper Shark*		37 020050

Scientific name	*Centrophorus harrissoni, C. zeehaani, C. moluccensis*, C. westraliensis**
Family	Centrophoridae
Status	High risk

Geographical distribution: *C. zeehaani* and *C. westraliensis* endemic to Australia; *C. harrissoni*: Clarence River NSW to Maria Island TAS; *C. zeehaani and C. moluccensis*: Northern NSW/southern QLD to central WA including TAS; *C. westraliensis*: south of Cape Leeuwin to Shark Bay WA.

Depth distribution: 220–790 m

Fisheries / classification: High risk in the CTS and GHT auto longline sectors of the SESSF

High risk gear interaction: Trawl and demersal longline

Life History Characteristics

Maximum size: 76–110 cm

Size at birth: 22–35 cm

Size at maturity: 61–85 cm (males)

Mode of reproduction: Viviparous[1]

Litter size: 1–2 pups

Timing of reproduction: Continuous with pregnant females found year round

Mean ERA productivity measure: 2.52

Summary of current management or mitigation strategies:

- trip limit in the CTS and auto-longline sectors
- finning and landing of livers only is prohibited
- 700 m closure in CTS
- spatial closures in place (e.g. 183 m closure for gillnets, NSW Gulper Shark closure (Endeavour Dogfish), eastern Bass Strait Gulper Shark closure (Harrisson's Dogfish), GAB Gulper Shark closure (Southern Dogfish))
- general shark landing restrictions.

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[1] Viviparous – producing live young from the body of the female (Last and Stevens 2009)

Dogfish – Subgroup 2

Deania calcea
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Leafscale Gulper Shark	**CAAB Code**	37 020009
	Longsnout Dogfish		37 020004
	Brier Shark*		37 020003
	Blackbelly Lanternshark		37 020005
Scientific name	*Centrophorus squamosus, Deania quadrispinosa, D. calcea*, Etmopterus lucifer*		
Family	Centrophoridae, Dalatidae		
Status	High risk		

Geographical distribution: *C. squamosus*: Recorded in TAS, VIC and NSW but likely more widespread; other species from central/northern QLD to Perth WA.

Depth distribution: 870–920 m; *D. calcea* and *E. lucifer* generally 400–800 m

Fisheries / classification: High risk in the CTS sector (*C. squamosus*), the CTS and auto-longline sectors (*D. quadrispinosa*) and just the auto longline sector (*E. lucifer*).

High risk gear interaction: Trawl and demersal longline

Life History Characteristics

Maximum size: 47–115 cm

Size at birth: 15–35 cm

Size at maturity: 30–100 cm (males); 35–110 cm (females)

Mode of reproduction: Viviparous

Litter size: 1 to 17 pups

Timing of reproduction: Continuous with pregnant females found year round

Mean ERA productivity measure: 2.57

Summary of current management or mitigation strategies:

- finning and landing of livers only is prohibited
- 700 m closure in CTS
- general shark landing restrictions.

Dogfish – Subgroup 3

Squalus montalbani
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Greeneye Dogfish	**CAAB Code** 37 020007
Scientific name	*Squalus spp.* (*chloroculus, montalbani, grahami, albifrons*)	
Family	Squalidae	
Status	High risk	

Geographical distribution: Townsville QLD to Shark Bay WA, including TAS
(endemic to Australia)

Depth distribution: 180–600m

Fisheries / classification: High risk in the SET and GHT auto-longline sectors of the SESSF

High risk gear interaction: Trawl and demersal longline

Life History Characteristics

Maximum size: 76 cm

Size at birth: 22 cm

Size at maturity: 61 cm (males)

Mode of reproduction: Viviparous

Litter size: 4–10 pups

Timing of reproduction: Continuous with pregnant females found year round

ERA productivity measure: 2.43

Summary of current management or mitigation strategies:

- finning and landing of livers only is prohibited
- 700 m closure in CTS
- spatial closures in place (e.g. 183 m closure, NSW gulper shark closure, eastern Bass Strait Gulper Shark closure)
- general shark landing restrictions.

Note that published Integrated Scientific Monitoring Program (ISMP) observer data shows a 91 per cent decline in catch rates in trawls off southern Australia from 1996–2006 (Walker & Gason 2007).

Mitigation options by method

Trawl - Upper Slope (300–700 m) mitigation options

Refer to Table 3

(Includes: Harrisson's Dogfish, Southern Dogfish, Endeavour Dogfish, Western Gulper Shark, Blackbelly Lantern Shark, Bight Skate and Grey Skate)

Temporal & spatial closures / depth closures

- Any spatial closure erodes the access rights of industry to fishing grounds. Furthermore, closures always affect some stakeholders more than others due to the location of the closure and the accessibility of the fisher (e.g. home port). Such factors would need to be considered when designing a closure.

- Spatial closures displace fishing effort, and unless combined with other measures, may have a negative impact on other species and habitats.

- Spatial closures also create the issue of how to assess the stock if no fishing is occurring. One option may be to use CPUE outside the closed area as an indicator, but this would need to be considered for each closure.

- Spatial closures that move over time or are flexible in nature were not considered a desirable option as they increase management costs and make compliance difficult. However, closures in general will be the most cost-effective option in terms of monitoring and enforcement costs.

- These species have a very restricted range of distribution. Much is already being done in terms of spatial and temporal closures for dogfish.

- Depth closures would be effective but would get no support from industry as the most effective depth for a closure would be 300–600 m which is also where pink ling are distributed.

Turtle excluder devices (TEDs) Bycatch reduction devices (BRDs)

- These may be effective for skates generally but not for sharks as the target species are around the same size as the sharks. Thus, the dogfish are unlikely to derive much benefit from this option.

- Industry would likely be relatively supportive of this option, as it reduces the damage to their product that occurs when there is a large animal in the trawl net that can crush the target species. There would also be less handling time associated with the set because the large animals do not have to be cleared from the net, which can be time consuming.

No landings / stricter trip limits

- Trip limits may be effective but the survivorship rate is unknown. A tagging program could estimate survivorship and determine how effective this option is.

- As dogfish are brought to the surface their liver oils change from a solid to a liquid which is why they often float on their backs when they reach the surface. Mortality from this effect is unknown, as is the potential for this effect to be reversed.

Reduce total allowable catch (TAC) / Reduce effort

- Although a reduction in TAC/effort would be effective, CSIRO has calculated that, based on available data, there would need to be a significant reduction in the target TAC (50 per cent for Pink Ling) to get the desired effect for sharks. Again, this would be similar to closing the fishery itself and therefore industry would not be supportive of this measure.

Deterrents (refers to rare earth metal and chemical deterrents)

- It is currently unknown how such measures would impact target species or the quality of the target species if they have been exposed to deterrents such as rare earth metals. But the potential benefits from this measure could be quite high as these deterrents can be very selective.

- Rare earth metals and chemical repellents are potentially of high benefit but are more than five years away from being practically applied to fisheries as more research is required.

Handling practices

- An improvement in handling practices could be beneficial for dogfish.

- Industry would be generally supportive of these measures as they would be easy to implement with relatively little expense. Such measures could also have flow on effects to other species and could thus improve handling of other shark species, as well as the target species. (See the General Recommendations section for a more complete discussion of handling practices).

Gear modifications (smaller nets i.e. smaller door spread / smaller net mouth / smaller capacity)

- Smaller nets could potentially increase the number of interactions because more shots would be required to reach the TAC or desired catch. This could also impact other species and habitats negatively because of the increased number of shots and because with smaller nets operators may explore new fishing grounds that before were not available to them.

Shorter shots

- Could potentially increase survivorship but requires analysis before such a conclusion can be reached.

- There is the potential to do some course analysis on this option based on existing data by comparing shorter shots that operators have already done vs. longer shots. Therefore, how effective this measure is could be tested.

Table 3: Mitigation options and ranking against criteria for upper slope (300–700 m) and mid-slope (700 m+) dogfish and trawl gear.

Dogfish: Gear =Trawl	Options									
Performance against criteria	**1.** Spatial/ temporal closures	**2.** TEDs/BRDs (skates only)	**3.** Stricter depth closures	**4.** No landings	**5.** Reduce effort	**6.** Reduce selected TAC (target sp.)	**7.** Deterrents	**8.** Handling practices	**9.** Gear modifications (smaller nets)	**10.** Shorter shots
1. Ability to reduce interactions	++ve	+ve	++ve	0	++ve	++ve	P +ve	0	P -ve	P -ve
2. Ability to minimise level of discarding	++ve	+ve	++ve	--ve	++ve	++ve	P +ve	0	P -ve	P -ve
3. Ability to improve survivorship (once caught)	0	P +ve	0	P +ve (SM)	0	0	UK	+ve	P +ve	P +ve
4. Impact of option on other species and or habitats	+ve	P +ve	++ve	0	++ve	++ve	UK	P +ve	P -ve	P -ve
5. Technical feasibility to detect a response	+ve	+ve	+ve	P +ve (SM)	+ve	+ve	+ve	+ve	+ve	+ve
6. Cost of monitoring (to detect response)	--ve	-ve	-ve	--ve	-ve	--ve	--ve	--ve	-ve	-ve
7. Level of industry support	-ve	P +ve	--ve	-ve	--ve	--ve	+ve	+ve	--ve	--ve
8. Impact on currently collected catch data	ST -ve	ST -ve	-ve	-ve	ST -ve (SM)	ST -ve (SM)	ST -ve	0	--ve	-ve

Trawl - Mid-Slope (700 m+) mitigation options

Refer to Table 3

(Includes: Leafscale Gulper Shark, Longsnout Dogfish and Brier Shark)

- Overall the responses given for the upper-slope species apply to mid-slope species with the caveat that working in deeper water increases research costs. Thus, the costs associated with determining if the options were working would be increased.

- Post-capture survivorship of this group is essentially zero, whereas for the upper-slope species it is known that some can survive. Mid-slope species landed from greater depths generally come up dead while upper-slope species are generally alive, but tend to float on their backs because their livers have expanded due to the oils they contain. Whether or not their livers can return to normal and they consistently survive once being landed remains to be demonstrated.

- Handling practices will also be important for the mid-slope dogfish (if they are alive upon capture), as well as for Sleeper Sharks.

Timeframe for implementing mitigation measures

Table 4. Timetable for how quickly mitigation options for dogfish trawling could be implemented. A = Measure able to be implemented without further analysis; B = The uncertainty of the measure can be reduced in a relatively short time through analysis of existing data; C = Further assessment needed based on research.*

	Mitigation options: Trawling	A	B	C
1	Spatial & temporal closures		X	
2	TEDs / BRDs (skates only)			X
3	Stricter depth closures	X		
4	No landings	X		
5	Reduce effort	X		
6	Reduce selected TAC (target species)	X		
7	Deterrents			X
8	Handling practices	X		
9	Gear modifications			X
10	Shorter shots		X	

* Note: The time tables provided are based on the state of research only. The efficacy of the measure for a particular fishery and how appropriate the measure is for a particular fishery based on other factors was not considered by the CTWG. Therefore, terms such as "implemented without further analysis" indicates that the measure would likely not require further data collection and scientific analysis, but would still have to undergo an extensive process of consultation to assess issues such as compliance, cost, practicality of implementation, existing measures, etc. This caveat applies to all the time tables in this report.

Demersal longline Upper & Lower Slope Species mitigation options

Refer to Table 5

Many of the comments and footnotes pertaining to dogfish demersal longline are the same as those for dogfish trawl.

Temporal & spatial closures / Depth closures

- These species have a very restricted range of distribution. Much is already being done in terms of spatial and temporal closures for dogfish.

- Depth closures would be effective but would get no support from industry as the most effective depth for a closure would be 300–600 m which is also where Pink Ling, the main target species, is primarily distributed.

Reducing Effort / Total allowable catch (TAC)

- A reduction in TAC would likely not be supported by industry.

No landings

- A no landings provision may be effective but the survivorship rate is unknown. A tagging program may estimate survivorship and determine how effective this option is.

- As dogfishes are brought to the surface their liver oils change from a solid to a liquid which is why they often float on their backs when they reach the surface. Mortality from this effect is unknown as is the potential for this effect to be reversed. However, it is known that at least some proportion of captured dogfish survive after being released.

Bait restrictions

- There are data available on the effect of bait (squid vs. pilchards) that needs to be analysed to determine if bait restrictions are a viable option for dogfish (i.e. less dogfish are taken on a particular type of bait).

Corrodible hooks

- Industry would likely be supportive of this measure. It was noted that this option should be used in conjunction with handling practices to achieve the best result.

Reduction in soak time

- There was so much uncertainty associated with this option that discussion on it was not continued further by the CTWG.

Increase in hook size

- Data are available on this issue but need to be analysed to assess the efficacy of the option (i.e. does increasing the hook size reduce the catch of dogfish).

Handling practices

- This is likely the preferred option from an industry perspective as it would be relatively easy and cost effective to implement.

- Likely very effective for dogfish, depending on post-release survivorship, particularly if the de-hooking machine could be redesigned (see General Recommendations section).

Size limits (not ranked in the options worksheet because of a lack of information)

- Given the current trip limits for these species it was decided that size limits would not be useful and this option was not discussed further.

Floating line (not ranked in the options worksheet because of a lack of information)

- It was noted that a floating line (i.e. a line that did not sit on the bottom but floated above the bottom) could be an issue because it is possible that some species (i.e. *C. harrissoni* and *C. zeehaani*) may travel vertically in the water column to feed on Lantern Fish which move up in the water column at night and then return to deeper waters during the day (Ross Daley, unpublished data). Therefore, if these animals are migrating up into the water column to feed, a floating line may increase fisheries interactions.

- It is noted that this may be an impractical measure for operators as well, as it will be very difficult for them to float the line at a consistent, predictable depth. Further advice should be sought from operators to determine how viable this method is for bycatch mitigation. In addition, it may be possible to compare shots of Pink Ling with shots of Blue-Eye Trevalla, where the gear is floated off the bottom, to determine if floating the line impacts the catch of dogfish.

Table 5. Mitigation options and rankings against criteria for dogfish and demersal longline (DLL) gear**.**

Dogfish: Gear = DLL	Options										
Performance against criteria	**1.** Spatial / temporal closures	**2.** Reduce effort	**3**. Reduce selected TAC (target sp.)	**4.** Stricter depth closures	**5.** No landings	**6.** Bait restriction	**7.** Corrodible hooks	**8.** Deterrents	**9** Reduction in soak time	**10.** Increase in hook size	**11** Handling practices
1. Ability to reduce interactions	++ve	++ve	++ve	++ve	0	P +ve	0	P +ve	UK	P +ve	0
2. Ability to minimise level of discarding	++ve	++ve	++ve	++ve	--ve	P +ve	0	P +ve	UK	P +ve	P-ve
3. Ability to improve survivorship (once caught)	0	0	0	0	+ve	0	+ve	P -ve	P +ve	P -ve	+ve
4. Impact of option on other species and or habitats	+ve	++ ve	++ve	++ve	0	UK	+ve	UK		UK	P +ve (SM)
5. Technical feasibility to detect a response	+ve	+ve	+ve	+ve	P +ve (SM)	++ve	+ve	+ve		+ve	+ve
6. Cost of monitoring (to detect response)	--ve	- ve	--ve	-ve	--ve	-ve (SM)	--ve	--ve		-ve	--ve
7. Level of industry support	-ve	--ve	--ve	--ve	-ve	-ve	ST -ve	+ve		ST -ve	+ve
8. Impact on currently collected catch data	ST -ve	ST -ve (SM)	ST -ve (SM)	--ve	-ve	-ve (SM)	P -ve	P -ve / UK		ST -ve	0

Timeframe for implementing mitigation measures

Table 6. Timetable for how quickly mitigation options for dogfish demersal longline could be implemented. A = Measure able to be implemented without further analysis; B = The uncertainty of the measure can be reduced in a relatively short time through analysis of existing data; C = Further assessment needed based on research.*

	Mitigation options: Dogfish / Demersal Longline	A	B	C
1	Spatial & temporal closures			X
2	Reduce effort	X		
3	Reduce TAC	X		
4	Depth closures	X		
5	No landings		X	
6	Bait restrictions			X
7	Corrodible hooks			X
8	Deterrents			X
9	Reduce soak time		X	
10	Increase in hook size			X
11	Handling practices	X		
12	Floating line			X
13	Gear configuration		X	

* Note: The time tables provided are based on the state of research only. The efficacy of the measure for a particular fishery and how appropriate the measure is for a particular fishery based on other factors was not considered by the CTWG. Therefore, terms such as "implemented without further analysis" indicates that the measure would likely not require further data collection and scientific analysis, but would still have to undergo an extensive process of consultation to assess issues such as compliance, cost, practicality of implementation, existing measures, etc. This caveat applies to all the time tables in this report.

BENTHIC/DEMERSAL GROUP

After revision by the CTWG - see the above section with notes on the groupings - the Benthic/Demersal Group contains only the rays and skates. Rays and skates are typically bottom dwellers which can inhabit a vast range of geographical regions. Both groups consume a variety of prey species which include crustaceans and smaller fish. These species are often not considered explicitly when bycatch issues are being discussed, but interact with both trawl and demersal longline gear. This group suffers from problems of misidentification and several new species of skates were recently described compounding the problem. As a result of the difficulty associated with identification, very little is known about the individual behavioural differences among species. The CTWG considered rays and skates separately. Rays were considered for trawl, while skates were considered for both trawl and demersal longline. Blotched Fantail rays are listed as vulnerable on the IUCN red list.

Subgroups

Benthic/Demersal – Subgroup 1

Taeniura meyeni
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Blotched Fantail Ray	CAAB Code	37 035017
	Reticulate Whipray*		37 035003
	Cowtail Stingray*		37 035011

Scientific name   *Taeniura meyeni, Himantura uarnak*, Pastinachus sephen**

Family   Dasyatidae

Status   High risk

Geographical distribution: Northern Australia: Clarence River NSW to Shark
Bay WA; Lord Howe Island

Depth distribution: 1–60 m

Fisheries / classification: High risk in the NPF

High risk gear interaction: Trawl

Life History Characteristics

Maximum size: 160–200 cm (disc width); 300–450 cm TL

Size at birth: 18–35 cm (disc width)

Size at maturity: 82–110 cm (males; disc width)

Mode of reproduction: Viviparous

Litter size: 2–4 pups

Timing of reproduction: Unknown

Mean ERA productivity measure: N/A

Summary of current management or mitigation strategies:

- TEDs and BRDs compulsory
- no part of all species of sharks, skates and rays may be retained.

Benthic / Demersal – Subgroup 2

Dipturus gudgeri
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Bight Skate	**CAAB Code**	37 031010
	Sydney Skate*		37 031002
	Graham's Skate*		37 031029
	Grey Skate*		37 031028
	Whitley's Skate*		37 031006

Scientific Name *Dipturus gudgeri, D. australis*, D. grahami*, D. canutus*,*
*Spiniraja whitleyi**

Family Rajidae

Status High risk

Geographical distribution: Southern QLD through southern WA, including TAS; some species restricted to NSW coast

Depth distribution: 22–765 m

Fisheries / classification: High risk in the GHT auto-longline sector of the SESSF

High risk gear interaction: Demersal longline

Life History Characteristics

Maximum size: 50–200 cm

Size at birth: 13–26 cm

Size at maturity: 43–127 cm (males)

Mode of reproduction: Oviparous[2]

Litter size: Unknown

Timing of reproduction: Unknown

Mean ERA productivity measure: 2.29

Summary of current management or mitigation strategies:

- finning and landing of livers only is prohibited

- spatial closures in place (e.g. 183 m closure, South Australian shark hook closure, West coast Tasmania 130 m closure)

- general shark landing restrictions.

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[2] Oviparous – producing eggs that hatch after being ejected from the body of a female (Last and Stevens 2009)

Mitigation options by method

Rays – Trawl – Mitigation options

Refer to Table 7

Spatial / temporal closures

- Any closure erodes the access rights of industry to fishing grounds and closures always affect some stakeholders more than others due to the location of the closure and the accessibility of the fisher (e.g. home port). Such factors would need to be considered when designing a closure.

- Spatial closures displace fishing effort, and unless combined with other measures, may have a negative impact on other species and habitats.

- Spatial closures also create the issue of how to assess the stock if no fishing is occurring. One option may be to use CPUE outside the closed area as an indicator, but this would need to be considered for each closure.

- Spatial closures that move over time or are flexible in nature were not considered a desirable option as they increase management costs and make compliance difficult. However, closures in general will be the most cost-effective option in terms of monitoring and enforcement costs.

- Limited information currently available to aid in effective closure design. An analysis of available data on habitat distribution of rays in the relevant fisheries (i.e. NPF) would be useful.

Reduce effort

- Although this option would likely have positive effects, it may encounter resistance from industry.

Deterrents (refers to rare earth metal and chemical deterrents)

- It is currently unknown how such measures would impact target species or the quality of the target species if they have been exposed to deterrents such as rare earth metals. But the potential benefits from this measure could be quite high as these deterrents can be very selective.

- Rare earth metals and chemical repellents are potentially of high benefit but are more than five years away from being able to be practically applied in fisheries as more research is required.

Handling practices

- An improvement in handling practices may be beneficial for some species. Such improvements could include the use of hoppers.

Depth limits

- Depth limits may potentially be beneficial to rays and may have benefits to other species and habitats, but more information on depth distributions is required.

Table 7. Mitigation options and rankings against criteria for rays and trawl gear**.**

Rays: Gear = Trawl	Options				
Performance against criteria	**1.** Spatial/ temporal closures	**2.** Reduce effort	**3.** Deterrents	**4.** Handling practices	**5.** Depth limits
1. Ability to reduce interactions	P +ve	+ ve	P +ve	0	P +ve
2. Ability to minimise level of discarding	P +ve	+ve	P +ve	0	P +ve
3. Ability to improve survivorship (once caught)	0	0	UK	+ve	0
4. Impact of option on other species and or habitats	P +ve	+ ve	UK	P +ve	P +ve
5. Technical feasibility to detect a response	+ve	+ve	+ve	+ve	+ve
6. Cost of monitoring (to detect response)	-ve	-ve	--ve	--ve	-ve
7. Level of industry support	P -ve	--ve	+ve	+ve	-ve
8. Impact on currently collected catch data	P -ve	ST -ve (SM)	ST -ve	0	ST -ve

Skates – Demersal longline mitigation options

The CTWG generally agreed that most of the options for pelagic longline would apply for demersal longline with the addition of two other options.

Refer to Table 8

Handling practices

- Industry would be willing to adjust to new handling practices but it will take time to make that adjustment.

Depth restrictions

- Could potentially be useful but would have to be done on a species by species basis. The 183m depth restriction is also already in place and likely is beneficial for a suite of species.

Table 8: Mitigation options and rankings against criteria for skates and demersal longline (DLL) gear.

Skates, Gear = DLL	Options										
Performance against criteria	**1.** Closures	**2.** Reduce effort	**3.** Use of circle hooks	**4.** Decrease trip limits	**5.** Bait restriction	**6.** Corrodible hooks	**7.** Deterrents	**8**. Reduction in soak time	**9.** Increase in hook size	**10.** Floating line	**11.** Handling practices
1. Ability to reduce interactions.	P +ve	++ve	P -ve	0	P +ve	0	P +ve	P +ve	P +ve	P +ve	0
2. Ability to minimise level of discarding.	P +ve	++ve	-ve	- ve	P +ve	0	P +ve	+ve	P +ve	P +ve	0
3. Ability to improve survivorship (once caught).	NA	0	+ve	+ve	0	+ve	P -ve	+ve	P -ve	0	++ve
4. Impact of option on other species and or habitats.	-ve	+ve	P +ve	0	UK	P +ve	UK	+ve	P +ve	UK	+ve
5. Technical feasibility to detect a response.	+ve	+ve	+ve	+ve	++ve	-ve	++ve	+ve	+ve	+ve	+ve
6. Cost of monitoring.	--ve	++ve	-ve	-ve	-ve	--ve	-ve	-ve	-ve	ST -ve	--ve
7. Level of industry support.	-ve	ST -ve	++ve	-ve	- ve	-ve	UK	-ve	-ve	-ve	+ve (SM)
8. Impact on currently collected catch data.	-ve	- ve	ST -ve	P -ve	-ve	0	ST -ve	ST -ve	ST -ve	ST -ve	0

Skates – Trawl mitigation options

Refer to Table 9

Spatial / temporal closures

- Any closure erodes the access rights of industry to fishing grounds and closures always affect some stakeholders more than others due to the location of the closure and the accessibility of the fisher (e.g. home port). Such factors would need to be considered when designing a closure.

- Spatial closures displace fishing effort, and unless combined with other measures, may have a negative impact on other species and habitats.

- Spatial closures also create the issue of how to assess the stock if no fishing is occurring. One option may be to use CPUE outside the closed area as an indicator, but this would need to be considered for each closure.

- Spatial closures that move over time or are flexible in nature were not considered a desirable option as they increase management costs and make compliance difficult. However, closures in general will be the most cost effective option in terms of monitoring and enforcement costs.

- Skates can be very restricted in their distribution (some species) which may make closures more effective for this group than other groups discussed.

Bycatch reduction devices (BRDs)

- BRDs would only have an impact on larger animals. The smaller skates would not benefit from this option.

No landings

- A zero trip limit or low trip limit may increase the survivorship of some species but it would depend on the proportion of skates currently being landed, handling practices and survivorship.

- In general, industry would be ok with trip limits, but operators do not like having to throw things back that are already dead and view this as a waste of the resource.

Size limits

- The implementation of size limits may improve survivorship although not to the same extent as implementing a no landings policy.

- The industry reaction to the implementation of size limits would depend on the limit that is set.

Table 9: Mitigation options and rankings against criteria for skates and trawl gear.

Skates: Gear = trawl	Options							
Performance against criteria	**1.** Closures	**2.** Reduce effort	**3.** Deterrents	**4.** Handling practices	**5.** Depth limits	**6.** TEDs / BRDs	**7.** No landings/trip limits	**8.** Size limits
1. Ability to reduce interactions	P +ve	+ve	P +ve	0	P +ve	+ve	0	0
2. Ability to minimise level of discarding	P +ve	+ve	P +ve	0	P +ve	+ve	-ve	-ve
3. Ability to improve survivorship (once caught)	0	0	UK	+ve	0	UK	+ve	+ve
4. Impact of option on other species and or habitats	P +ve	+ve	UK	P +ve	UK	+ve	0	0
5. Technical feasibility to detect a response	+ve	+ve	+ve	+ve	+ve	+ve	+ve	+ve
6. Cost of monitoring (to detect response)	--ve	-ve	--ve	--ve	-ve	-ve	--ve	--ve
7. Level of industry support	-ve	--ve	+ve	+ve	-ve	+ve	-ve	-ve
8. Impact on currently collected catch data	P -ve	ST-ve (SM)	ST -ve	0	ST -ve	ST -ve	0	0

PELAGIC SHARK GROUP

The pelagic shark group is perhaps the best known shark group and the one most associated with issues of bycatch. It has been suggested that excessive removal of such species from the environment can have both direct and indirect consequences including species extinction and altered trophic interactions (Stevens *et al.* 2000). These sharks are generally large in size and roam large areas in the pelagic zone, which extends beyond the continental margins, and are capable of long migrations (Dulvy *et al.* 2008). Such wide ranging behaviour makes these species vulnerable to capture in international fisheries, outside of Australia's jurisdiction and thus international fisheries were identified as a source of mortality for these species.

Many pelagic sharks are known to survive capture and may have a high survivorship rate when released. The CTWG considered pelagic sharks as one group in their discussions of mitigation options. Porbeagle Sharks and Longfin Threshers are listed as vulnerable on the IUCN red list. In late 2008 the Convention on Migratory Species added Porbeagle and Shortfin Mako sharks to Appendix II.

Subgroups

Pelagic – Subgroup 1

Alopias superciliosus
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Pelagic Thresher	**CAAB Code** 37 012003
	Bigeye Thresher*	37 012002
	Thresher*	37 012001
Scientific name	*Alopias pelagicus, A. superciliosus, A. vulpinus*	
Family	Alopiidae	
Status	High risk	

Geographical distribution: Brisbane QLD to central WA, including TAS plus North West Shelf WA

Depth distribution: Surface–650 m

Fisheries / classification: High risk in the ETBF

High risk gear interaction: Pelagic longline

Life History Characteristics

Maximum Size: 390–570 cm

Size at birth: 100–160 cm

Size at maturity: 245–340 cm (males); 264–400 cm (females)

Mode of reproduction: Oophagous[3]

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[3] Oophagous – method of embryonic nutrition in viviparous species where the embryo feeds on unfertilised eggs in the uterus (Last and Stevens 2009).

Litter size: 2–7 pups

Timing of reproduction: Year round, not synchronous

Mean ERA productivity measure: 2.57

Summary of current management or mitigation strategies:

- shark trip limit
- finning and land of livers only is prohibited
- use of wire traces is prohibited
- general shark landing restrictions.

Pelagic – Subgroup 2

Isurus oxyrinchus
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Shortfin Mako	**CAAB Code**	37 010001
	Longfin Mako		37 010002
	Porbeagle*		37 010004
Scientific name	*Isurus oxyrinchus, I. paucus, Lamna nasus**		
Family	Lamnidae		
Status	High risk		

Geographical distribution: Generally throughout Australia except the Torres Strait, Gulf of Carpentaria and Arafura Sea; *L. nasus* in cooler waters

Depth distribution: Surface–650 m

Fisheries / classification: High risk in the GHT gillnet sector of the SESSF and ETBF

High risk gear interaction: Demersal gillnet and pelagic longline

Life History Characteristics

Maximum size: 325–417 cm

Size at birth: 60–120 cm

Size at maturity: 195–228 cm (males); 245–280 cm (females)

Mode of reproduction: Oophagous

Litter size: 1–16 pups

Timing of reproduction: Pup in November off NSW (*I. oxyrinchus*); pup in winter, gestation ~9 months (*L. nasus*)

Mean ERA productivity measure: 2.62

Summary of current management or mitigation strategies:

- finning and landing of livers only is prohibited

- spatial closures in place (e.g. 183 m closure)

- general shark landing restrictions in pelagic longline fisheries

- shark trip limit (ETBF)

- wire traces are prohibited (ETBF).

Pelagic – Subgroup 3

Pseudocarcharias kamoharai
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Crocodile Shark	**CAAB Code** 37 009003
Scientific name	*Pseudocarcharias kamoharai*	
Family	Pseudocarchariidae	
Status	High risk	

Geographical distribution: QLD coast; inhabit tropical and subtropical waters

Depth distribution: Surface–590 m

Fisheries / classification: High risk in ETBF

High risk gear interaction: Pelagic longline

Life History Characteristics

Maximum size: 110 cm

Size at birth: 40 cm

Size at maturity: 73 cm (males); 90–100 cm (females)

Mode of reproduction: Viviparous

Litter size: 4 pups

Timing of reproduction: Possibly year round without synchronicity

ERA productivity measure: 2.57

Summary of current management or mitigation strategies:

- shark trip limit
- finning and land of livers only is prohibited
- wire traces are prohibited
- general shark landing restrictions.

Pelagic – Subgroup 4*

Carcharhinus falciformis
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Oceanic Whitetip*	**CAAB Code**	37 018032
	Silky Shark*		37 018008
	Blue Shark*		37 018004
Scientific name	*Carcharhinus longimanus*, C. falciformis*, Prionace glauca**		
Family	Carcharhinidae		
Status	Potentially high risk		

Geographical distribution: Throughout Australia, although *C. longimanus* and *C. falciformes* are generally restricted to warmer waters from Sydney north to central WA; all species absent from Gulf of Carpentaria.

Depth distribution: Surface–1000+ m

Fisheries / classification: N/A

High risk gear interaction: Although not listed as high risk, these species generally interact with PLL

Life History Characteristics

Maximum size: 300–383 cm

Size at birth: 35–85 cm

Size at maturity: 175–220 cm (males); 180–220 cm (females)

Mode of reproduction: Viviparous

Litter size: 1–16 pups (*C. longimanus* and *C. falciformis*); 30–40 pups (*P. glauca*)

Timing of reproduction: Not seasonal (*C. longimanus*); unknown (*C. falcif*ormis and *P. glauca*)

Mean ERA productivity measure: 2.52

Summary of current management or mitigation strategies:

- shark trip limit
- finning and land of livers is prohibited
- wire traces are prohibited
- general shark landing restrictions.

Mitigation options by method

Pelagic sharks – Pelagic longline mitigation options

Refer to table 10.

Spatial closures

- For spatial closures, certain species may derive some benefits if a particular life history period or specific area where they are abundant can be targeted. For example, Crocodile Sharks are known to be found in large numbers at certain times off the Western Australian coast. Similarly, Threshers and Shortfin Mako Sharks may benefit from closures placed in specific near-shore areas. Overall, however, spatial closures will likely not be beneficial to the larger pelagic group.

- It was recognised that any closure erodes the access rights of industry to fishing grounds and that closures always affect some stakeholders more than others due to the location of the closure and the accessibility of the fisher (e.g. home port). Such factors would need to be considered when designing a closure.

- Spatial closures displace fishing effort, and unless combined with other measures, may have a negative impact on other species and habitats.

- Spatial closures also create the issue of how to assess the stock if no fishing is occurring. One option may be to use CPUE outside the closed area as an indicator, but this would need to be considered for each closure.

- Spatial closures that move over time or are flexible in nature were not considered a desirable option as they increase management costs and make compliance difficult. However, closures in general will be the most cost-effective option in terms of monitoring and enforcement costs.

Deeper sets

- Requiring deeper sets for pelagic longlines will likely be positive as a whole, but could have negative impacts for some species that are found in deeper waters (i.e. Pelagic Thresher, Bigeye Thresher and Crocodile Shark) and may inadvertently target new species that inhabit deeper waters.

- Deeper sets are technically difficult because operators cannot set their hooks to an exact depth with certainty on every set. Therefore, increased observer coverage or additional equipment such as depth loggers would be required to ensure compliance. In addition, the issue of depth of the line vs. depth of the hooks would need to be considered before this measure could be implemented.

- Deeper sets also may potentially have a conflict with spatial closures in place that occur shallower than 200 m and may completely eliminate the potential to fish in that area. AFMA would need to consider that conflict before implementing a deeper set policy.

- Blue Shark may benefit from a depth closure in waters less than 300m deep as their preferred habitat is the upper water column.

- Deeper sets may result in higher mortality rates (survivability issues) and may also cause increased discarding of other species.

Reduce effort

- The industry reaction to this measure is dependent upon the amount of the decrease, but generally any reduction in fishing effort is unlikely to be favoured.

- Individual transferable quotas could change the dynamics of the fleet and have different implications which would need to be considered.

Circle hooks

- There has been conflicting information on the effectiveness of circle hooks on the survivorship of sharks. Supporters of circle hooks suggest that these hooks attach to the sharks mouth region and as such the shark can be cut free and the hook will eventually corrode and drop from the mouth. Traditional J-hooks tend to be ingested deep into the stomach and while the shark can be still be cut free the internal wounding from the ingested hook is likely to decrease survivorship.

- Detecting the effect on survivorship would be difficult and requires a tagging program.

- The effect on existing catch data depends on the resulting change in catch rates. If circle hooks significantly increase the number of sharks that escape, then new data would not be able to be used with the existing time series of data as the catchability rates would be significantly different.

- Industry may be supportive in the long term, although it would depend on the impact circle hooks had on the catch rates of the target species.

Trip limits / No landings

- A zero take trip limit would potentially increase compliance costs.

- A zero take trip limit may encourage operators to return more animals to the sea alive than they currently do.

- The effects of the current trip limit are not known. It would be difficult to determine the relative success of bringing in more stringent limits.

- Industry generally does not like landing dead animals and having to discard them, so this option, depending on how strict the limit was, may not be favoured by industry.

Bait restrictions

- Oily fish bait is more attractive to sharks so other bait types may be effective in reducing interactions.

- Industry would likely be supportive of this option if it could be demonstrated it was effective and did not reduce catch rates of target species. However, the available data on this issue is not sufficient to draw conclusions at this time.

Corrodible hooks

- Corrodible hooks would likely have more industry support than other mitigation options.

- Although corrodible hooks would have to be replaced more often than the low-grade stainless steel hooks currently being used, corrodible hooks also cost less than stainless hooks. Once the initial changeover to the new hooks was in place it would

just be a matter of replacing gear as required, which operators currently do on a regular basis due to loss of hooks from bite offs, entanglements etc.

- The efficacy of this option could be determined in a one-off tagging study to measure any changes in mortality rate.

Deterrents (refers to rare earth metal and chemical deterrents)

- It is currently unknown how such measures would impact target species or the quality of the target species if they have been exposed to deterrents such as rare earth metals. But the potential benefits from this measure could be quite high as these deterrents can be very selective.

- Rare earth metals and chemical repellents are potentially of high benefit but are more than five years away from being practically applied to fisheries.

- It was also noted that using these devices adds weight to the longlines which can be dangerous and is therefore generally not liked by operators.

- If the deterrent is effective it would also reduce shark depredation on target species and bite offs and so it may be more readily accepted by industry than other options.

No light sticks

- There was not enough information on light sticks and the effect they have as an attractant/repellent on sharks. This option was therefore not ranked on the worksheets.

Reduce soak time

- Shorter soak times are likely to result in less interactions and improved survivorship per set. However, if fishers increased the number of sets then the overall effort level is likely to be the same and therefore may not result in an overall change.

- A reduced soak time is also likely to increase survivorship of other species, such as turtles. A reduced soak time would also improve the quality of the target species.

- A reduced soak time would be difficult to monitor and ensure compliance.

Increase hook size

- While this could be a very simple change similar to the use of corrodible hooks, industry may not be supportive of this measure if it affects the catchability of the target species. Any change in hook size would need to be carefully considered before being implemented.

- Larger circle hooks could potentially reduce the impact on the capture of Crocodile Sharks and could also potentially be positive for smaller sharks. May also reduce turtle interactions.

Restrict setting times

- Shark species generally spend more time near the surface at night which could result in an increase of sharks caught when night setting.

- As there is a known impact on seabirds when day setting, impacts vary dependant upon species.

Size limits

- A maximum size limit may be useful as it will protect the breeding stock and larger sharks likely have a better chance of surviving after being hooked.

- Legal minimum size restrictions are easier for industry to accept as opposed to legal maximum size.

- Smaller sharks are likely to experience a decrease in survivorship rates, as the likelihood that they will be retained as part of the trip limits is greater once fishers are not allowed to retain larger sharks.

Table 10: Mitigation options and rankings against criteria for pelagic sharks and pelagic longline (PLL).

Pelagic sharks: Gear = PLL	Options											
Performance against criteria	**1.** Closures	**2.** Deeper sets	**3.** Reduce effort	**4**. Circle hooks	**5**. Decrease trip limits	**6.** Bait restriction	**7.** Corrodible hooks	**8.** Deterrents	**9**. Reduce soak time	**10**. Increase hook size	**11.** Restrict setting time	**12.** Size Limits
1. Ability to reduce interactions	P +ve	+ve	++ve	P -ve	0	P +ve	0	P +ve	P + ve	P +ve	P +ve	0
2. Ability to minimise level of discarding	P +ve	P +ve	++ve	-ve	-ve	P +ve	0	P +ve	+ ve	P +ve	P +ve	P -ve
3. Ability to improve survivorship (once caught)	NA	P -ve	0	+ve	+ve	0	+ve	P -ve	+ ve	P -ve	0	+ve
4. Impact of option on other species and or habitats	-ve	-ve	+ve	P +ve	0	UK	P +ve	UK	+ ve	P +ve	UK	0
5. Technical feasibility to detect a response	+ve	+ve	+ve	+ve	+ve	++ve	--ve	++ve	+ ve	+ve	+ve	+ve
6. Cost of monitoring	--ve	-ve	++ve	-ve	-ve	-ve	--ve	- ve	-ve	-ve	-ve 0	--ve
7. Level of industry support	-ve	-ve	ST -ve	++ve	-ve	-ve	-ve	UK	-ve	-ve	-ve	-ve
8. Impact on currently collected catch data	-ve	--ve	- ve	ST -ve	P -ve	-ve	0	ST -ve	ST -ve	ST -ve	ST -ve	0

Timeframe for implementing mitigation measures

Table 11: Timetable for how quickly mitigation options for pelagic longlining could be implemented. A = Measure able to be implemented without further analysis; B = The uncertainty of the measure can be reduced in a relatively short time through analysis of existing data; C = Further assessment needed

	Mitigation options: Pelagic sharks / PLL	A	B	C
1	Closures		X	X
2	Require deeper set depths		X	X
3	Reduction in effort	X		
4	Use of circle hooks		X	
5	Decrease trip limits (zero an option)	X		
6	Bait restriction			X
7	Rusting hooks			X
8	Earth metal / chemical repellents			X
9	No light sticks			X
10	Reduction in soak time		X	
11	Increase in hook size			X
12	Restricting setting time		X	
13	Size limits	-	-	-

* Note: The time tables provided are based on the state of research only. The efficacy of the measure for a particular fishery and how appropriate the measure is for a particular fishery based on other factors was not considered by the CTWG. Therefore, terms such as "implemented without further analysis" indicates that the measure would likely not require further data collection and scientific analysis, but would still have to undergo an extensive process of consultation to assess issues such as compliance, cost, practicality of implementation, existing measures, etc. This caveat applies to all the time tables in this report.

WHALERS/HAMMERHEADS GROUP

The Whalers and Hammerhead group was also considered by the CTWG as a single group for discussion on mitigating interactions with gillnets. The unique 'hammer' shaped head of these sharks make this group easily distinguishable. However, difficulty distinguishing among species is common. Similarly, the whalers comprise a group of common sharks that are also often misidentified. Also included in this discussion were White Sharks and Shortfin Makos which are captured in gillnets, typically as juveniles. Juvenile White Sharks are often misidentified as Mako Sharks because of the similarity in their juvenile characteristics.

Subgroups

Whalers / Hammerheads – Subgroup 1

Carcharhinus obscurus
Image courtesy of: ©Mike Gerner

Common name		CAAB Code	
	Bronze Whaler		37 018001
	Dusky Whaler		37 018003
	Broadnose Shark		37 005002
	Sandbar Shark*		37 018007
Scientific name	*Carcharhinus brachyurus, C. obscurus, Notorynchus*		
	Cepedianus, Carcharhinus plumbius		
Family	Carcharhinidae, Hexanchidae		
Status	High risk		

Geographical distribution: Generally throughout Australian waters, but concentrated from Coffs Harbour NSW to Jurien Bay WA

Depth distribution: 10–280 m

Fisheries / classification: High risk in the GHT gillnet sector of the SESSF

High risk gear interaction: Gillnet

Life History Characteristics

Maximum size: 295–365 cm

Size at birth: 40–100 cm

Size at maturity: 150–280 cm (males); 220–310 cm (females)

Mode of reproduction: Viviparous

Litter size: 7–24 pups; up to 82 pups (*N. cepedianus*)

Timing of reproduction: Unknown

Mean ERA productivity score: 2.81

Summary of current management or mitigation strategies:

- finning and landing of livers only is prohibited

- other closures in place (e.g. 183 m closure)

- general shark landing restrictions.

Whalers/Hammerheads – Subgroup 2

Figure 1 *Sphyrna zygaena*
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Smooth Hammerhead	**CAAB Code** 37 019004
Scientific name	*Sphyrna zygaena*	
Family	Sphyrnidae	
Status	High risk	

Geographical distribution: Occurs from Coffs Harbour NSW to Jurien Bay WA, including TAS

Depth distribution: Surface to at least 20 m

Fisheries / classification: High risk in the GHT gillnet sector of the SESSF

High risk gear interaction: Gillnet

Life History Characteristics

Maximum size: 350 cm

Size at birth: 50–60 cm

Size at maturity: 250 cm (males); 265 cm (females)

Mode of reproduction: Viviparous

Litter size: 20–50 pups

Timing of reproduction: Pups in January–March

ERA productivity measure: 2.71

Summary of current management or mitigation strategies:

- finning and landing of livers only is prohibited
- spatial closures in place (e.g. 183 m closure)
- general shark landing restrictions.

Mitigation options by method

Whalers/Hammerheads – gillnet mitigation options

Refer to table 12.

Spatial / temporal closures

- Closures would need to be species specific to be effective (i.e. general closures not taking into account species information would likely not be effective).

- Closures could be accepted by industry if they were incorporated as much as possible with existing closures, such as those already in place for sea lions and School Sharks.

No landings / trip limits / size limits

- Trip limits and size limits may be effective options but it would depend on the post-capture survivorship.

- Species identification could be an issue as there is often confusion between Dusky Whalers, Bronze Whalers and Sandbar Sharks which could impact the efficacy of the option.

- Educating fishers and observers on species identification would be relatively simple and worthwhile.

- Size limits are problematic in the gillnet fishery because of the size selectivity of the gear, and this option would need to be considered in conjunction with mesh size restrictions.

Gear configuration

- Changing gear configurations would be difficult for gillnetters and would hinder their ability to catch target sharks like Gummy Sharks.

- Changing the net hanging ratio would improve survivorship, but would not impact the number of interactions.

- sea lion interactions would be affected by any changes to gear size.

Soak time

- Shorter soak times would likely lead to an increased number of sets. As fishers would be moving their gear around more, this would potentially increase the number of interactions.

- Survivorship would be increased as there would be less chance of drowning.

Setting time

- The group considered a provision of setting the nets at night only as an option but after further discussion decided to remove the option from consideration as it would

only be effective on a species specific basis and there was not enough potential for the method to warrant further discussion.

Reduction in total allowable catch (TAC) / effort

- An effective method but would not be favoured by industry.

Handling practices

- Likely not effective as gillnetters currently keep all the sharks they catch with the exception of threatened, endangered and protected (TEP) species.

- Industry would likely be supportive of any improvement in handling practices.

Table 12: Mitigation options and ranking against criteria for whalers, hammerheads, White sharks and Shortfin makos and gillnets.

Gear = gillnet	Options								
Performance against criteria	**1.** Closures	**2.** No landings / trip limits	**3**. Gear configuration	**4.** Size limits	**5.** Soak time	**6**. Set time	**7.** Reduce TAC	**8.** Reduce effort	**9.** Handling practices
1. Ability to reduce interactions	++ve	0	++ve	0	P -ve	UK	++ve	++ve	0
2. Ability to minimise level of discarding	++ve	-ve	++ve	-ve	P -ve	UK	++ve	++ve	0
3. Ability to improve survivorship (once caught)	0	+ve	+ve	+ve	+ve	0	0	0	+ve
4. Impact of option on other species and or habitats	UK	P +ve	--ve	0	+ve		+ve	+ve	+ve
5. Technical feasibility to detect a response	+ve	+ve	+ve	+ve	+ve		+ve	+ve	+ve
6. Cost of monitoring (to detect response)	-ve	-ve	-ve (SM)	-ve	-ve (SM)		-ve	-ve	--ve
7. Level of industry support	-ve	-ve	-ve	-ve	-ve (SM)		--ve	--ve	+ve
8. Impact on currently collected catch data	ST -ve	ST -ve	-ve (SM)	0	0		0	0	0

Timeframe for implementing mitigation measures

Table 13: Timetable for how quickly mitigation options for gillnetting could be implemented. A = Measure able to be implemented without further analysis; B = The uncertainty of the measure can be reduced in a relatively short time through analysis of existing data; C = Further assessment needed based on research.*

	Mitigation options: Whalers/Hammerheads - Gillnet	A	B	C
1	Closures			X
2	No landings/trip limits		X	
3	Gear configuration			X
4	Size limits			X
5	Soak time		X	
6	Setting time			X
7	Reduce TAC	X		
8	Reduce effort	X		
9	Handling practices	X		

* Note: The time tables provided are based on the state of research only. The efficacy of the measure for a particular fishery and how appropriate the measure is for a particular fishery based on other factors was not considered by the CTWG. Therefore, terms such as "implemented without further analysis" indicates that the measure would likely not require further data collection and scientific analysis, but would still have to undergo an extensive process of consultation to assess issues such as compliance, cost, practicality of implementation, existing measures, etc. This caveat applies to all the time tables in this report.

REEF SHARKS GROUP*

As the name suggests, reef sharks inhabit shallow, tropical and warm temperate environments and are associated with coral reef habitats. Some of these animals (i.e. Whitetip and Blacktip Reef Sharks) may be particularly vulnerable to localised depletion as studies have found they have narrow home ranges of only a few kilometres. Given their close association, habitat degradation and localised fishing may be particularly problematic for them. In addition, the depletion of strong apex predators, such as reef sharks, could have significant impacts for reef ecosystems. For example, it has been demonstrated that overfishing of sharks in the Caribbean may have initiated trophic cascades which led to the collapse of reef ecosystems in this area (Bascompte *et al.* 2005).

A recent study has indicated that a similar collapse may be occurring in the Great Barrier Reef Marine Park, and that 'no-take zones' provide almost no protection for reef sharks as they are difficult and costly to enforce, whereas 'no-entry zones' are easier to enforce (Robbins *et al.* 2006). Such results are alarming and indicate that even in the world's best-managed marine park shark populations are declining with potentially severe consequences.

The CTWG generally considered ways in which bycatch of these animals could be mitigated in the CSF, however, options were not ranked using the worksheets for this group as little information on fisheries interactions in the CSF was available.

Group

Reef sharks

Carcharhinus melanopterus
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Grey Reef Shark*	CAAB Code	37 018030
	Blacktip Reef Shark*		37 018036
	Whitetip Reef Shark*		37 018038
	Silvertip Shark*		37 018027

Scientific name *Carcharhinus amblyrhynchos*, C. melanopterus*, Triaenodon obesus*, C. albimarginatus**

Family Carcharhinidae

Status Potentially high risk (ERA has yet to be completed)

Geographical distribution: Morton Bay QLD to Shark Bay WA in tropical waters; *C. albimarginatus* does not occur in the Gulf of Carpentaria or Arafura Sea

Depth distribution: Surface–300 m recorded, down to 800 m for *C. albimarginatus*

Fisheries / classification: Potentially high risk in the CSF

High risk gear interaction: Although not high risk, these species interact with DLL

Life History Characteristics

Maximum size: 170–275 cm

Size at birth: 50–80 cm

Size at maturity: 95–195 cm for both sexes

Mode of reproduction: Viviparous

Litter size: 1–11 pups

Timing of reproduction: Pup in summer

Mean ERA productivity measure: N/A

Summary of current management or mitigation strategies:

- automatic or random baiting equipment is prohibited unless special permission is acquired and requirements met

- finning and landing of livers only is prohibited

- general shark landing restrictions.

Mitigation options by method

Reef sharks – Demersal longline mitigation options

Closures

- Closures may have a bigger benefit for reef sharks than other groups as they are known to occupy particular reef areas. The potential for local depletion is also increased in this group as stock structuring is likely, although the movement between reef areas is currently unknown. Seamounts may be particularly prone to depletion and may have associated endemic species.

Trip limits

- Currently, there are no trip limits for sharks in the CSF. The CTWG expressed concern that this is the case.

- Queensland has a trip limit of one Grey Reef Shark and one Whitetip Reef Shark and the Commonwealth should look to adopting similar standards.

- Because of the high potential for localised depletion, if the CSF were to consider expanding, surveys should be conducted to determine if expansion is sustainable.

Handling practices

- As these species inhabit shallow waters, they will not suffer from barotrauma when captured. However, a general improvement in handling practices would likely be beneficial.

THREATENED, ENDANGERED AND PROTECTED (TEP) SPECIES

TEP species are a distinct group in that they are already recognised under the EPBC Act as requiring special protection. These species were considered individually by the CTWG, although it was noted that for most it was difficult to provide additional mitigation options in light of the protection they already receive. In addition, the CTWG noted that TEP species will be addressed in detail by the National Shark Recovery Group. Therefore, TEP species mitigation options were not extensively discussed and ranked similar to the other groups, with the exception of White Sharks which were included in the 'gillnet' discussion, but rather TEP species were generally discussed. Conservation status of species is subject to regular review and re-classification. Further information regarding these species and their TEP status can be found at www.environment.gov.au/cgi-bin/sprat/public/sprat.pl.

Greynurse Sharks

Greynurse Sharks are well-known for being the world's first protected shark. They became a protected species in NSW in 1984 because of the heavy exploitation they endured in the 1960s and current declining populations. There are two populations (east and west) listed under the EPBC Act; the east coast population is considered critically endangered while the west coast population is considered vulnerable. In 2002 a recovery plan was developed for the species. They are listed as protected species in all Australian states in which they occur and in Commonwealth waters, as well as internationally (i.e. Florida, Namibia and South Africa).

Whale Sharks

Whale Sharks are an iconic species in Australia and are listed as both vulnerable and migratory under the EPBC Act. Up until the 1980s little work had been done on this animal and relatively few confirmed sightings have been documented. Since that time more research has been focused on the species and regular sightings in Australian waters occur, particularly at Ningaloo Marine Park in Western Australia (WA), where a lucrative tourist industry based on observing the sharks has developed. Although not targeted in Australia, they are fished in other countries. Thus, their highly migratory behaviour lends to their vulnerability.

White Sharks

White Sharks are listed as vulnerable and migratory under the EPBC Act. White Sharks were also listed in Appendix II of the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) in 2002. The species is threatened by the illegal trade of products such as fins and jaws. As noted previously, the juveniles are also caught as bycatch in gillnets, although they are often misidentified as juvenile Shortfin Makos. This species is an apex predator and its global abundance appears to be declining.

Sawfish

Both the Freshwater and Green Sawfish are listed as vulnerable under the EPBC Act. The name 'Freshwater' Sawfish is a misnomer as this species spends the first 3 to 4 years of its life in freshwater, but then moves to marine/estuarine habitats. Sawfish species have undergone drastic declines in the past several decades due to fishing mortality and habitat loss. Australia has four species of sawfishes, all of which are listed as Critically Endangered under the IUCN Red List of Threatened Species.

TEP Species group details

Greynurse Shark

Carcharias taurus
Image courtesy of: ©George Burgess, Florida Museum of Natural History

Common name	Greynurse Shark	**CAAB Code** 37 008001
Scientific name	*Carcharias taurus*	
Family	Odontaspididae	
Status	TEP	
Conservation status	East coast population CRITICALLY ENDANGERED (EPBC)	
	West coast population VULNERABLE (EPBC)	
	Both populations VULNERABLE (IUCN Red List)	

Geographical distribution: All states except TAS but rare in the NT

Depth distribution: Surf zone–190 m

Fisheries / classification: TEP

High risk gear interaction: N/A

Life History Characteristics

Maximum size: 318 cm

Size at birth: 100 cm

Size at maturity: 190–195 cm (males); 220–230 cm (females)

Mode of reproduction: Oophagous

Litter size: 2 (one in each uterus)

Timing of reproduction: Gestation 9–12 months

ERA productivity measure: 2.71

Summary of current management or mitigation strategies:

Protected species; no take permitted.

Mitigation options:

Interactions for this species are possible with trawl, gillnet and longline gear. Handling practices are important for this species and providing more information to operators on what to do if a Greynurse is caught could improve survivorship. This is because Greynurse Sharks swallow air, and thus must be properly vented before being released. It is possible that given their size, BRDs brought into a fishery for another group or animal may have positive impact on this species. Finally, as there are known aggregation sites, spatial closures are likely an effective measure for this species.

White Shark

Carcharodon carcharias
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	White Shark	**CAAB Code** 37 010003
Scientific name	*Carcharodon carcharias*	
Family	Lamnidae	
Status	High risk / TEP	
Conservation status	VULNERABLE (EPBC)	

Geographical distribution: Southern QLD to North West Cape WA

Depth distribution: Surface–1280 m

Fisheries / classification: High risk in the GHT gillnet sector of the SESSF

Gear interaction: Demersal gillnet

Life History Characteristics

Maximum size: 600 cm

Size at birth: 130 cm

Size at maturity: 360 cm (males); 450 cm (females)

Mode of reproduction: Oophagous

Litter size: 2–17

Timing of reproduction: 18 month gestation and possible 3 year cycle

ERA productivity measure: 2.86

Summary of current management or mitigation strategies:

Protected species; no take permitted.

Mitigation options:

Due to the size of this species, BRDs may have some positive impact in trawl fisheries. Changing hooks, as for the pelagic species, may have positive benefits for White Sharks interacting with longlines as well. Closures around sea lion colonies would likely have benefits as they are known aggregation sites. White Sharks may also interact with purse seines in the Southern Bluefin Tuna fishery and can be found around sea cages for bluefin. Good handling practices to release White Sharks from seines or cages should increase their survivorship.

The options discussed in the gillnet section apply to this species as juvenile White Sharks are captures in gillnets.

Whale Shark

Rhincodon typus
Image courtesy of: ©Rob Harcourt

Common name	Whale Shark	**CAAB Code** 37 014001
Scientific name	*Rhincodon typus*	
Family	Rhincodontidae	
Status	TEP	
Conservation status	VULNERABLE (EPBC & IUCN)	

Geographical distribution: Occurs mainly off NT, QLD and northern WA

Depth distribution: Surface– 500+ m

Fisheries / classification: TEP

Gear interaction: N/A

Life History Characteristics

Maximum size: 1200+ cm

Size at birth: 40–50 cm free-swimming

Size at maturity: 440–560 cm (females)

Mode of reproduction: Viviparous

Litter size: 300+ pups in only pregnant female recorded

Timing of reproduction: Unknown

ERA productivity measure: 2.71

Summary of current management or mitigation strategies:

Protected species; no take permitted.

Mitigation options:

The CTWG noted they could not add to the measures already in place for this species.

Freshwater Sawfish

Pristis microdon
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Freshwater Sawfish*	**CAAB Code** 37 025003
Scientific name	*Pristis microdon*	
Family	Pristidae	
Status	TEP	
Conservation status	CRITICALLY ENDANGERED (IUCN Red List)	

Geographical distribution: Northern Australia: Cape York through the Gulf of Carpentaria across to the Pilbara in northern WA (one record from Cape Naturaliste in southwest WA)

Depth distribution: Surface–10 m

Fisheries / classification: TEP

Gear interaction: N/A

Life History Characteristics
Maximum size: 200 cm in Australia

Size at birth: 50 cm

Size at maturity: N/A

Mode of reproduction: Viviparous

Litter size: 1–12 pups

Timing of reproduction: Unknown; gestation period ~5 months; likely breeds in freshwater

ERA productivity measure: N/A

Summary of current management or mitigation strategies:
Protected species; no take permitted.

Mitigation options:
Localised depletion is an issue for this species as there is recent evidence of stock structuring and states have an impact on populations that needs to be considered, likely through barramundi fishery and inshore gillnet fisheries. Distributional data are lacking for sawfish but adults may interact with Commonwealth fisheries as they are not confined strictly to freshwater. It was also noted that they may not occur throughout the entire range of the NPF. TEDs and BRDs are not effective for reducing interactions or survivorship for these species, as their rostrum is generally caught in the net either before they reach these devices or outside the net.

Green Sawfish

Pristis zijsron
Image courtesy of: ©CSIRO Marine and Atmospheric Research

Common name	Green Sawfish*	**CAAB Code** 37 0250031	
Scientific name	*Pristis zijsron*		
Family	Pristidae		
Status	TEP		
Conservation status	CRITICALLY ENDANGERED (IUCN Red List)		

Geographical distribution: Sydney north to Shark Bay WA

Depth distribution: Surface–5 m

Fisheries / classification: TEP

Gear interaction: N/A

Life History Characteristics

Maximum size: 500 cm in Australia

Size at birth: N/A

Size at maturity: 430 cm (males)

Mode of reproduction: Viviparous

Litter size: N/A

Timing of reproduction: N/A

ERA productivity measure: N/A

Summary of current management or mitigation strategies:

Protected species; no take permitted.

Mitigation options: See above for Freshwater Sawfish

GENERAL RECOMMENDATIONS

The CTWG provided more specific recommendations and information pertaining to the most plausible and readily applicable mitigation options that were identified at the workshop. These options could be implemented relatively quickly and would likely yield results, at least for some species. The specific advice for these options is provided below.

Handling practices

Improving handling practices could have a significant impact on the survivorship of chondrichthyans that have been captured and this measure would likely be accepted by industry as the costs of implementing such measures would be relatively low compared to other options. In addition, improvements in the handling of chondrichthyan species may have flow on effects that improve the handling of target species, which would be beneficial to fishers. Recommended options related to handling practices are listed below.

- Keep animals in the water if possible (i.e. do not bring them on the deck, but release them in the water as being pulled on deck causes great stress).

- For longline fisheries, cut sharks off close to the hook so that they are not trailing large amounts of line (this option is best used with corrodible hooks).

- If a shark must be brought on the deck then minimise the time it takes to return it to the water to maximise survivorship.

- Get information to industry with simple, easy to understand handling instructions; importantly, make sure industry feels that their safety is considered.

- Best practice standards should be put into writing with visual aids to make the information easier to access. This information can be placed on boats, in co-ops and on wharfs.

- National standards should be developed that are consistent across fisheries and jurisdictions.

- Generally, small sharks are quite fragile and need to be handled very carefully.

- Further research on shark stress and post-release survival will be useful in improving handling practices.

- Queensland already has handling practices for sawfish that can be adopted for other fisheries.

- For dogfish it is important that they do not come in contact with the de-hooking machine on auto-longliners. This may not be practical if a large number of sharks have to be removed by hand, although it may be possible to redesign the machine so that it does not inflict damage on the animals.

Trip limits

- Trip limits would also be easy to implement, although costly to monitor, and could be implemented quickly. Specifically, differential trip limits may be useful (i.e. trip limits that do not apply equally to all species but rather are designed to exclude high

risk species). However, as noted previously, little is known on post-capture survivorship.

- A provision to release all sharks that are alive and only take dead animals as part of the trip limit may be useful, although it would be difficult to enforce and would require an industry commitment.

- For these types of trip limits observer coverage or monitoring of some sort would be essential to ensure that the requirement to release live animals was being adhered to.

Spatial Management

This method would only be useful for certain species such as Crocodile Sharks in WA, reef sharks, endemic skates and dogfish.

- The efficacy of spatial management is dependent on movement patterns, spatial distribution and aggregating behaviour so information on these parameters is essential.

- When thinking of spatial management options there is a need to think beyond a single species and consider the effects on target and other species and habitats, not just sharks. There is likely to be a compromise across different species and habitats.

- Spatial management and closures need to be clearly linked to an objective and other arrangements in order to be effective and gain industry support. The efficacy of these closures also needs to be monitored.

- Any spatial management for fisheries needs to be considered in the context of the bioregional planning process carried out by DEWHA.

- Spatial management can be tailored for specific mitigation goals such as breeding biomass, nursery areas or breeding areas of particular species or species groups.

- As the effects of spatial measures are complex, monitoring requires data rich management.

Option packages

Certain combinations of the mitigation options identified may compliment each other and achieve better results than if working in isolation. Managers, in consultation with industry and other stakeholders, may wish to consider implementing 'options packages' rather than individual options if such packages are appropriate.

- Gear modifications – if one gear modification is being made, it may be prudent to make several modifications at the same time. For example, changing from non-corrodible J-hooks to corrodible circle hooks at the same time will be more cost efficient and likely more effective than making a single gear change.

- Trip limits, size limits and handling practices – changing the size and amount of the trip limits such as no take over a certain length combined with improved handling practices.

- Trip limits and effective at-sea monitoring – if strict trip limits are going to be implemented then effective monitoring (observers, e-monitoring etc) may be necessary at agreed levels.

- Soak time and handling practices / effort and handling practices – the work load on fishers will impact their handling practices. If fishers are tired from repeatedly hauling the net in they will not handle the catch as well.

- Improvement in species identification should be considered in conjunction with all options to improve data collection and the efficacy of the option.

Implementation of options

A number of options were discussed that could not be implemented immediately because of a lack of data. Some of these options (category B) required analyses, as the data had already been collected, while other options (category C) required more directed research.

Category B options included determining the impact of shorter shots, as such information could be drawn from the current logbook data and analysed to determine what effect, if any, this method is having. It was also noted that a lot of tagging information from a variety of sources exists and that such information, if drawn together, could provide much needed distributional data which could be used for a variety of mitigation options. Finally, it was noted that some information on post-capture survivorship exists, although more specific research may be required.

Category C options included a lot of the gear modification options. These options require more directed research to determine their utility, although it may be possible to address all the gear modification options in a single, well-designed experiment. In addition, as shark bycatch is an issue for fisheries worldwide, keeping abreast of international research will likely provide information that can be utilised in Australia and that may provide the data needed to assess many of the mitigation options discussed by the CTWG.

It should, however, be noted that even in the case of Category A options, there will be many practical and other management considerations in terms of implementation including consultative requirements, compliance, enforcement, etc. The costs/benefits of each option would need to be assessed in the context of the fishery and species concerned on a case by case basis.

Further issues for consideration

The CTWG identified several further issues of importance for managers to consider. The first is latent effort in fisheries. Latent effort in some fisheries is high and this effort could present a problem for chondrichthyans should such effort be utilised. If latent effort in a fishery is utilised, managers will need to reconsider the mitigation options in place to determine if those options are adequate.

Secondly, the CTWG identified the need for mitigation measures of pelagic sharks at the international level. Fishing and interactions with pelagic sharks in international waters impacts the sharks in Australian waters as these sharks migrate large distances into international waters and other jurisdictions. Australia needs to push for such measures to be adopted internationally if they are to be fully effective.

Finally, many species are at risk from more than one gear type and it therefore may be appropriate and effective in some circumstances to mitigate risk in one fishery by reducing it in another. For example, it may be valid to mitigate trawl effects by sufficiently reducing longline interactions. This would need to be considered carefully on a case by case basis.

CONCLUSION

The CTWG concluded that chondrichthyan bycatch is a difficult issue to address and there is no panacea for effective mitigation. Indeed, determining suitable mitigation options is an issue for fisheries management agencies worldwide. Australia has adopted the IPOA-sharks and has produced the NPOA-sharks; this is currently under review. Some of the issues raised in the 2004 NPOA-sharks have been dealt with effectively, while others require more attention. However, many of the regulations and fishing conditions applied by AFMA to fisheries have proven to be effective. For example:

- not using wire trace in longline fisheries has been proven to reduce shark bycatch, although post-capture mortality is still unknown

- the regulation that sharks may not be finned at sea has also helped to stem the flow of illegally taken fins to the lucrative south-east Asian market

- closures specifically created for certain sharks (i.e. gulper shark closures) are also likely to be effective, although the benefits of these closures may take decades to materialise.

That said, bycatch of chondrichthyans remains an issue and mitigation measures will continue to evolve as a process of necessary continuous improvement. With this in mind, the CTWG was convened solely to provide mitigation options from a scientific perspective. It is now up to fisheries managers to consider the options presented in this guide in consultation with stakeholder and management groups.

Some of the options suggested in this guide will be unpalatable to some stakeholders and unsuitable for some fisheries. Thus, managers will have to weigh the pros and cons of each option provided. However, it is apparent that compromises from all parties will be required to effectively mitigate chondrichthyan bycatch. Given the increasing pressures chondrichthyan species face, the task of reducing their bycatch and mortality is of increasing importance.

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Appendix A. Summary of viable mitigation options for fishery gear type.

Gear Type	Immediately Viable	Potentially Viable	Page No.
Demersal gillnets	Reduce TAC Reduce effort Improve handling practices	No landings/trip limits Soak time	53–54
Demersal longline	Reduce effort Reduce TAC Depth closures Improve handling practices	No landings Reduce soak time Gear configuration	21–24, 31-32, 59
Pelagic longline	Reduce effort Decrease trip limits	Closures Deeper set limits Use of circle hooks Reduce soak time Restrict setting time	43-48
Trawl	Stricter depth closures No landings Reduce effort Reduce TAC Improve handling practices	Closures Shorter shots	17–20, 30-31, 33-34

Appendix B. Summary of mitigation strategies that have been examined to reduce shark bycatch/fisheries interactions.

Gear	Strategy	Findings	Species/group	Reference
Pelagic longline	Reduction in soak time	Capture rates increase with soak time	Blue Shark	Ward *et al.* 2004
	Fishing in deeper water	Fishing in shallow water increases catch	Coastal sharks	Hoey & Moore 1999
		Higher CPUE on shallow set and no catch at deepest set (370–460m)	Shortfin Mako	Rey & Munoz-Chapuli 1991
		Pelagic sharks (exception of the mako) taken at a higher rate in shallow set	Pelagic sharks	Williams 1997
	Removal of lower hooks on 'semipelagic' LL	Significant reduction in deepwater shark bycatch	Catshark, Deepwater sharks	Coelho *et al.* 2003
	Decreasing the number of hooks deployed between floats	Increased hooks increases catch	Coastal sharks	Hoey & Moore 1999

Gear	Strategy	Findings	Species/group	Reference
	Setting gear farther from the seafloor	Setting gear closer to the seafloor increases catch	Coastal sharks	Hoey & Moore 1999
	Utilizing composite rope-steel branchlines	Reduction in the CPUE of juvenile sharks	Sandbar Shark	Branstetter & Musick 1993
	Switch from monofilament branchlines	Higher % of sharks caught by mono (66%) vs. multifilament branchlines (34%)	Blue Sharks	Stone & Dixon 2001
	Use of weights with monofilament line to achieve a deeper setting & reduce shark bycatch	Weights typically used with wire leaders to achieve deeper settings but can't be used with non wire – new types of weights being developed for use with non-wire	N/A	Gilman 2008
	Use of circle hooks	Higher capture rate than with J hooks	Blue Shark	Watson *et al.* 2005; Bolten & Bjorndal 2002, 2003; Ward *et al.* 2008b
		No difference in catch rate	Blue Shark	Yokota *et al.* 2006; Kerstetter *et al.* 2007; Kerstetter & Graves 2006

Gear	Strategy	Findings	Species/group	Reference
	Modelling study using circle hooks and catch-release	Combined use of circle hooks and catch and release led to an increase in shark survival	Blue Shark and other pelagic species	Kaplan *et al.* 2007
	Use of mackerel baits	Reduction in catch rates on both circle and J hooks	Blue Shark	Watson *et al.* 2005
	Use of fish baits with circle hooks (vs. squid baits with J hooks)	Reduction (36%) in shark catch	Blue Shark	Gilman *et al.* 2007a
	Use of nylon leaders	Reduction in catch rates	Whalers, Oceanic Whitetips, Tiger Shark	Ward *et al.* 2008a
	Using temperature to direct the set	Australian fishers identified setting on colder side of fronts to reduce shark catch	Pelagic Sharks	Gilman 2007b; Gilman *et al.* 2008
		Catch rates declined 9.7–11.4% in response to a temp increase of 0.6C	Blue Shark	Watson *et al.* 2005

Gear	Strategy	Findings	Species/group	Reference
Demersal longline	Use of rare earth materials (neodymium-iron-boride magnets and cerium mischmetal)	Mischmetal may be useful in reducing bycatch in halibut fishery	Spiny Dogfish	Stoner & Kaimmer 2008; Kaimmer & Stoner 2008
		Experiments with an alloy of electropositive metals (Pr and Nd) indicate that the metal deters feeding and may be useful in reducing shark interactions with longline gear.	Galapagos Whalers and Sandbar Sharks	Unpublished work by NOAA
Trawl	Use of TEDs / BRDs in NPF	Some species excluded from bycatch after TEDs made compulsory in NPF; reduction of bycatch species specific	Various species	Brewer *et al.* 1998; Stobutzki *et al.* 2002
	Use of BRDs & TEDs in NPF	Reduced by catch of sharks by 17.7% and rays by 36.3%	Various species	Brewer *et al.* 2006

Gear	Strategy	Findings	Species/group	Reference
	Use of BRDs	Nordmore grid and square mesh panel successfully released large elasmobranchs without reducing prawn catch; together prawn catch substantially reduced	Various species	Fennessy & Isaksen 2007
	Use of a filter and escape tunnel in trawl nets	Allowed most mature sharks and rays to escape with no injury	Hammerhead, Mako, Manta Ray	Zeeberg *et al.* 2006
All	Use of chemical deterrents	Paradaxin, sodium and lithium lauryl sulphate and sodium dodecyl sulphate found to repel some shark under certain conditions, but likely only useful as a directional repellent	Horn Shark, Swell Shark, Leopard Shark	Smith 1991; Sisneros & Nelson 2001
		Newly developed semiochemical deterrents shown to be effective in trials	Swell Shark	NMFS 2007 (shark finning report)
	Spatial closures	Reef sharks more abundant in no-entry zones than fished zones of the GBRMP by 80–97%; no-fish zones ineffective	Whitetip and Grey Reef Sharks	Robbins *et al.* 2006

Gear	Strategy	Findings	Species/group	Reference
		Conservation for reef sharks requires an ecosystem-based management approach including large no-take zones	Caribbean reef sharks	Chapman *et al.* 2005
		General research indicating that due to site fidelity, homing, spawning aggregations or just limited movements at some period in their life history spatial closures may be effective	Various species	Edren & Gruber 2005; Carraro & Gladstone 2006; Garla *et al.* 2006; Huveneers *et al.* 2006; Conrath & Musick 2007; Domeier & Nasby-Lucas 2007; Wiley & Simpfendorfer 2007; DeAngelis *et al.* 2008; Dewar *et al.* 2008