Ecological Risk Assessment for the Proposed Western Australian Shark Hazard Mitigation Drum Line Program (2014-2017)

Department of Fisheries, Research Division – May 2014

Executive Summary

Following a seventh fatal shark attack in just over three years, in November 2013 the WA Government decided to take a more proactive approach to the mitigation of shark attacks. In combination with the extensive shark hazard mitigation strategies already in place (e.g. research projects, aerial patrols, monitoring network), the Government proposed the use of an additional direct action strategy for public safety purposes. This proposal involved the capture of large sharks using large-hook drum lines within two Marine Monitored areas (MMAs) located off the metropolitan and south west regions of Western Australia.

Within these two MMAs, large (300cm Total Length or greater) white sharks, tiger sharks and bull sharks were to be captured by (i) drum lines being routinely deployed at specified beaches and (ii) vessels will deploy available drum lines in response to specific instances where large sharks have been identified as a threat within these areas. After obtaining necessary State and Commonwealth approvals which included the completion of a risk assessment for this trial period (DoF, 2014a), an initial deployment of up to 36 baited drum lines in each MMA began in late January 2014 and ceased on 30 April 2014. The WA Government has now proposed that a similar program be undertaken between 15 Nov and 30 April for a further three years, commencing in 2014.

The use of drum lines in this Program is designed to only have a localised impact on the relative number of individuals of the targeted species (white, tiger and bull sharks) of specific sizes ($\geq$ 300 cm TL) that may occur within each of the MMAs. It is not designed to substantially affect the overall population size of each of the species across their distribution over the entire WA coast.

This study undertakes a formal assessment of the ecological (environmental) risks that may result from the proposed Western Australian Shark Hazard Mitigation Drum Line Program (2014-2017) (the Program). The issues that were subjected to individual analyses of the risks included each of the targeted species, the potential suite of non-target species (including all relevant listed, threatened, migratory species) and potential cumulative impacts on habitat and the community structure that may be generated by direct and indirect interactions with

the drum line gear. The scope of the risk assessments did not, however, include an examination of any social issues arising from this proposal or the degree to which the proposal affects risks associated with human-shark interactions.

The potential risks to targeted and non-targeted species arising from implementation of the set of activities listed within the proposed Marine Monitored Areas strategy were assessed using risk assessment procedures that conform with international standards (ISO 31000, 2009; SA, 2012) and are applied by many WA Government Agencies through WA RiskCover. The risk analyses used the information currently available which included, but was not limited to, the results obtained from the trial drum line program completed in Jan-April 2014.

The analyses considered the relative likelihoods of different consequence levels actually occurring to either population size, habitat condition or community structure based on all lines of evidence and the identified risk mitigation strategies. The most important lines of evidence were the actual captures generated by the trial program that ran from Jan- April 2014 compared to the levels estimated by the previous (initial) risk assessment.

The Program as proposed, which includes significant risk mitigation components, was assessed as posing only negligible risks to the population status of two of the three targeted species, the non-targeted species and the broader ecosystem. It identified that the Program would represent only a low risk to population viability of the tiger shark population off WA. This acceptable level of risk requires a higher level of monitoring and a specific assessment of tiger sharks to be completed at the end of the Program.

Prior to the trial Program, the potential catch of large dusky sharks was identified as an issue that may require additional management interventions (DoF 2014a). However, with only one individual caught during the trial program, this meant that no intervention was required. Additional acoustic tracking data now available on their more offshore migration routes suggests their rates of capture during the proposed Program are most likely to remain at the observed insignificant levels. The risk to this stock is therefore now considered to be negligible.

The rate of capture for other potential or actual bycatch species (including all relevant listed, threatened or migratory species) found during the trial program was, as predicted, low or non-existent. These rates of capture are anticipated to all remain at their very low or non-existent levels for the proposed Program. Consequently, for all of these non-target species, the risks of the Program are considered negligible.

In terms of potentially generating broader ecosystem effects, the Program is anticipated to generate negligible impacts on each of the species which is also consistent with no trophic impacts being generated. Based on the capture of 40 t of tiger sharks, five tonne of other shark species and a negligible catch of non-shark species, the cumulative total for all captures of all species is very small (i.e. 45 t/year) when compared to the total combined levels of commercial capture of sharks and other fish species that previously occurred within this bioregion (> 500 t/year). This historical level was found to not have generated any

measurable shift in the community structure for this region (Hall & Wise, 2011). Following a series of management interventions over the past decade (a major component being their removal from the metropolitan region for sectoral allocation purposes), the level of commercial shark capture in the WCB has been reduced from 500 t to less than 250 t annually, and is anticipated to operate at this lower level into the future. Consequently, the additional 45 t/year of sharks to be captured by this Program poses a negligible risk to the community structure of the Leeuwin-Naturaliste ecosystem.

A significant factor in determining these risk levels was the set of risk mitigation procedures that have been proposed. These include (1) the short duration of the proposed activities (15 November – 30 April), (2) the proposal is for just three years, (3) the very limited geographic extent of their operation compared to the broad distribution of the potentially affected species and (4) the gear configuration (including hook size and design) which has demonstrably kept the level of bycatch species to a minimum, especially non sharks species, (5) the high level of monitoring of the gear which enables release of unwanted captures.

Given the documented influences of environmental conditions on the spatial and temporal distribution of many species in the West Coast bioregion, it is recommended that annual reviews of the actual versus anticipated catches are undertaken. Furthermore, if the rates of capture of one or more listed species/groups begins to materially exceed the anticipated levels, a within season review of the risks would also be appropriate.

Finally, if this Program, or similar, was to continue beyond the current three year proposal period (2017) or a material change to operations occurred, a further full risk assessment would be necessary.

Contents

INTRODUCTION

In direct response to the unprecedented number of shark related fatalities that occurred in WA over the past several years, starting in 2008 the WA Government funded a number of initiatives designed to assist in mitigating the risks of further attacks and fatalities. This included a series of research programs, enhancements to the level of shark monitoring and aerial patrols (WA Govt, 2012).

Following a seventh fatal attack in just over three years, in November 2013 the WA Government decided to take a more proactive approach to mitigation of shark attacks (WA Govt, 2013). In combination with the extensive shark hazard mitigation strategies already in place, the Government proposed use of an additional direct action strategy (Strategy) for public safety purposes. This proposal involved the capture of large sharks using large-hook drum lines within two Marine Monitored Areas (MMAs) located off the metropolitan and south west regions (see map Figure 1).

Within these two MMAs, large (300cm Total Length or greater) white sharks, tiger sharks and bull sharks were to be targeted by (i) drum lines being routinely deployed at specified beaches and (ii) vessels deploying some of the available drum lines in response to instances where large sharks have been identified as a threat within these areas. After obtaining necessary State and Commonwealth approvals which included the completion of a risk assessment for this trial period (DoF, 2014a), an initial deployment of up to 36 baited drum lines in each MMA began in early January 2014 and ceased on 30 April 2014. The WA Government has now proposed that a similar program be undertaken between 15 Nov and 30 April 30 for a further three years commencing in 2014.

This study undertakes a formal assessment of the ecological (environmental) risks that may result from the proposed Western Australian Shark Hazard Mitigation Drum Line Program (2014-2017) (the Program). The scope of the risk assessments completed do not include the examination of any social issues that may arise from this proposal or the degree to which this proposal may affect the relative risks associated with human-shark interactions.

The report includes an outline of the activities to be undertaken within the Proposal including the risk mitigation strategies that have already been identified and applied during the trial program. Given their importance for calculating the risk levels for the proposed three year extension, a summary of the results obtained during the trial Drum Line Program completed in Jan –April 2014 is presented (full results are presented in DoF, 2014b). A short comparison of the methods used and resultant levels of capture obtained from other shark control programs undertaken elsewhere in the world is also provided.

A description of the international standards based risk assessment methodology (IEC/ISO 31000, 2009; SA, 2012) that was applied is provided. This includes the specific techniques used to undertake the three steps involved in completing a risk assessment - risk (issue) identification, risk analysis and risk evaluation. The results of these assessments are documented in full.

BACKGROUND

Proposed Drum Line Program (2014 – 2017)

Activities

The proposed Program will continue to deploy a maximum of 36 baited drum lines in coastal waters about one kilometre off specified beaches in each of the MMAs. This covers (i) the 30 drum lines used for routine deployment and (ii) the 6 available for response to an identified shark threat or incident in each MMA. Therefore, the maximum number of drum lines for the Program across both MMAs is 72. Contractors will be required to bait, maintain and patrol the drum lines between 0600 hours to 1800 hours, 7 days per week from 15 November through to 30 April each year, for a three year period (2014-2017).

White, tiger or bull sharks 300 cm Total Length (TL) or greater captured on these drum lines will be destroyed by the contractor using a firearm. Any other captured animals that are not considered to be in a condition to survive will also be destroyed. Deceased sharks (whether destroyed or killed by their capture) will be fitted with uniquely-identified disposal tags and removed to a specified distance offshore and discarded or, where practical, retained for scientific study.

Captured animals that are considered to have a chance of survival will be released as swiftly and carefully as possible after measurement and other basic data are recorded. Where appropriate, including not unreasonably compromising their chances of survival, released sharks may have other scientific samples taken (e.g. genetic samples) and be tagged with conventional fin tags. Provision will also be made for some level of electronic tagging if such tagging is determined to be scientifically beneficial and to not unduly compromise the sharks' survival rates.

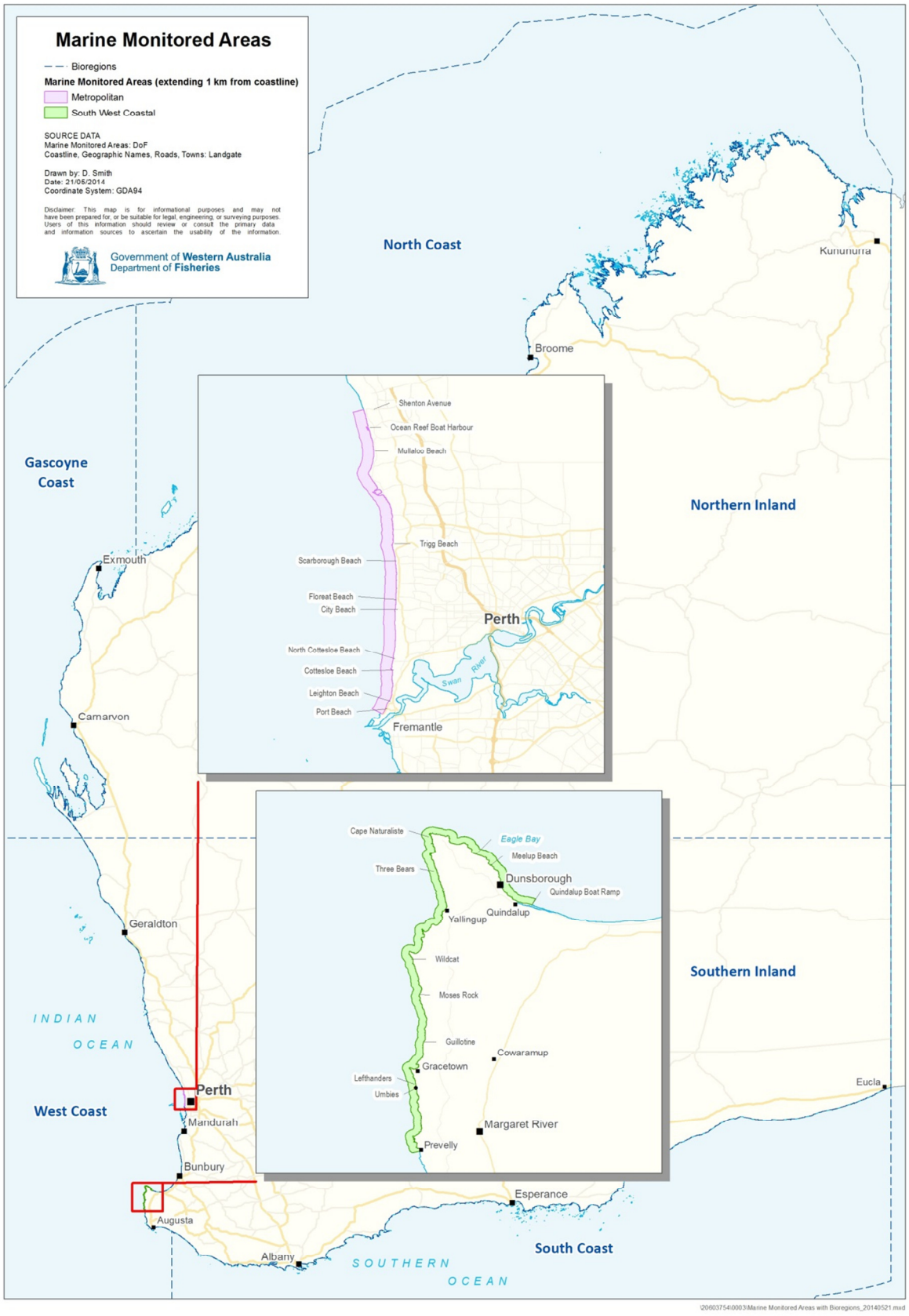


Figure 1. Map of Western Australia indicating the size and location of the two Marine Monitored Areas as defined for the proposed Program.

Risk mitigation

The Program is designed to reduce the risk of human-shark interactions within the MMAs for the time period of the activities. The use of a limited number of drum lines to capture sharks within the MMAs is therefore designed to only have a localised impact on the abundance of large individuals of specified shark species (white, tiger and bull sharks 300 cm TL or greater) within these MMAs, not to significantly affect the total population size of these species. Based on the experiences in other locations, it is recognised that the use of drum lines can capture species other than the target sharks.

To minimise the risks associated with the potential capture and/or mortality of non-target species, specifically dolphins, sea lions, turtles and non-target sharks, the following has been proposed:

- The gear includes using significantly larger hooks than are used elsewhere in the world for this purpose. Moreover, the hook design is circle like with a closed gape. These two features should substantially limit the types and sizes of non-targeted individuals likely to be captured. This gear configuration has already proven to be highly effective in limiting the number of non-targeted, bycatch species captured in the trial WA program (January – April 2014) compared to those captured in other drum line and netting programs. Importantly, only one non-chondricthyan individual was captured.

- Daily monitoring and maintenance of drum lines occurs between 0600 hours to 1800 hours to ensure any non-target species or small (< 300 cm TL) target species that may be unintentionally caught are freed and released as soon as possible.

- Aerial and land patrols operate at most of the beaches where the drum lines will be deployed, so that the drum line contractor can be notified of any captures.

- The drum line program will be limited in its area (two MMAs) and time of operation (5.5 months per year).

The risk levels associated with the potential impacts of the capture and/or mortality of non-target species are also minimised because they will be closely monitored. This will ensure that the rates and composition of capture are consistent with those anticipated and used in determining the risk evaluations. The monitoring and review program includes:

- Drum line contractors will be required to maintain detailed records of all catches (including digital photos of all captures) and provide this information to relevant authorities for assessment purposes.

- The drum line program will be assessed throughout and after its operation by relevant technical experts from the Department of Fisheries and, where necessary, the Department of Parks and Wildlife (DPaW).

- The range or levels of acceptable catch will be developed for each of the target species and other potential bycatch species. The actual numbers captured will be

examined against these acceptable ranges each year to ensure that the risks levels have not materially altered.

- If a major increase in the rate of captures for any species occurs within a season, an additional review can be undertaken prior to the standard annual review.
- The program is proposed to operate for only three years after which a further review of the program will be undertaken.

Summary of WA drum line catch during Trial Period (January to April 2014)

Total Catches

The catches obtained by the drum lines during the period January 25 – 30 April 2014 were mostly (91%) tiger sharks (Table 1). The number of individuals of the other species caught in the drum lines varied from 1–7 individuals per species. For many of the species/groups that were examined during the original risk assessment (DoF, 2014a) no individuals were caught.

Table 1. Numbers of animals caught on Western Australian drum lines. The "dead" category includes target species of sharks that were killed based on their size (≥300 cm TL) and all shark species that were dead upon retrieval or killed due to a very low likelihood of surviving.

	Total catch		Metro		Geographe Bay		Capes	
Common name	Dead	Released alive	Dead	Released alive	Dead	Released alive	Dead	Released alive
Tiger shark	64	99	34	75	15	5	15	19
Shortfin mako	4	1	0	0	2	0	2	1
Dusky shark	0	1	0	1	0	0	0	0
Spinner shark	0	1	0	0	0	1	0	0
Bull shark	0	1	0	1	0	0	0	0
Unidentified shark	0	1	0	0	0	0	0	1
Ray	0	7	0	7	0	0	0	0
North-west blowfish	0	1	0	1	0	0	0	0

Target species

White Sharks

No white sharks were caught during the trial drum line program.

Bull Sharks

A single bull shark (197 cm TL) was caught in the Metro region. It was tagged and released alive.

Tiger sharks

In total, 163 tiger sharks were caught (67% in the Metro; 12% in Geographe Bay and 21% in the Capes). Ninety-nine (61%) were released alive with a greater proportion of these in the Metro region (Table 1; Figure 2).

A total of 17 (10%) were dead upon gear retrieval. These were distributed across all regions and occurred throughout the duration of the trial. The remainder (29%) of the captured tiger sharks were destroyed either because they were 300 cm or greater in total length (TL) or in three instances because the individual shark was considered unable to survive.

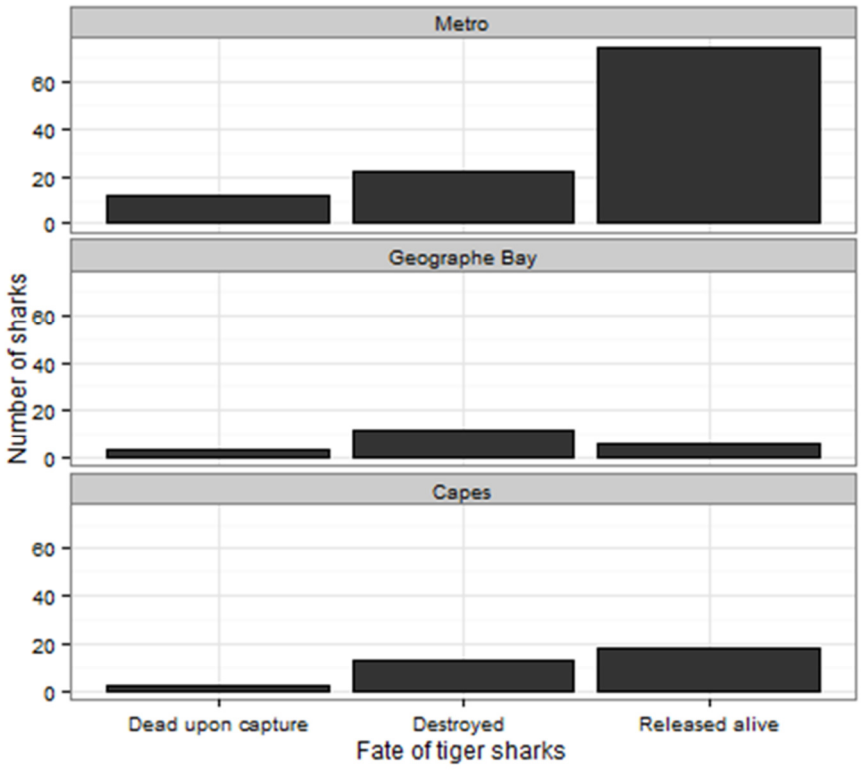


Figure 2. Fate of tiger sharks caught on Western Australian drum lines by region. Destroyed sharks were generally those 300 cm TL or greater.

Non-target species

Sharks

In total, 9 individuals of non-targeted sharks species were caught (Table 1). This included five shortfin mako sharks (*Isurus oxyrinchus*) which were caught in the south west (ranging from 170 – 264 cm TL), one of which was tagged and released, three of which were dead upon gear retrieval and one which was destroyed because it was unlikely to survive release. A single dusky shark (290 cm TL) and a single spinner shark (180 cm TL) were caught and each was tagged and released. One unidentified shark removed itself from the hook and swam off before it could be identified.

Non-shark

Seven rays (species unknown) were caught in the Metro region, all of which were released alive. Two of the rays were identified as sting rays (Family Dasyatidae). A single north-west blowfish (*Lagocephalus sceleratus*) was caught and released alive.

Comparison of Actual Catches with Predictions from Initial Assessment (DoF 2014a)

For most species or species groups, the observed levels of catch by the drum line program were consistent with the predictions (low for most species) that were presented in the initial risk assessment (DoF, 2014a, Table 2). For one species the actual level of capture was lower than predicted (dusky sharks), only the actual catch of tiger sharks was higher than expected. The comparison of the actual versus predicted capture levels of each of the main species or groups are considered below.

Table 2. Summary comparison of actual catch levels taken during the trial program versus predictions presented in the initial risk assessment (DoF, 2014a).

Species/Group	Level of capture consistent with predictions?	Comments
White Sharks	Yes	-
Bull Sharks	Yes	-
Tiger Sharks	No – Higher than predicted	Possible effect of increased water temperatures in recent years.
Dusky Sharks	No – Lower than predicted	Drum lines inshore of main migration route
Grey Nurse	Yes	-
Demersal Scalefish	Yes	-
Dolphins	Yes	-

Seals/Sea Lions	Yes	-
Whales	Yes	-
Turtles	Yes	-

Target Species

Tiger Sharks

It was predicted that most of the captures of this species would be released, with the number expected to be killed in the order of 10-20 individuals. The level of catch of tiger sharks in the drum line trial program was, however, higher than expected. Thus, while the proportion that was released alive was consistent with predictions (being over 60%), the actual number killed was 64.

Having a higher than expected number of tiger sharks (which is a tropical to semi-tropical species) off the west coast of WA during this recent period is consistent with the observed trend in warming water temperatures occurring off this part of the coast and, moreover, in the past 4-5 years this region has experienced marine heat wave events (Pearce et al., 2011). These have been associated with major effects on a number of species including affecting their distributions (Caputi et al., 2014), which could have also led to increased numbers of this mainly tropical species being located towards the southern extent of their distribution off WA. Additional monitoring of this species would be required to determine whether the catch rates experienced in 2014 are now typical or not.

Despite the higher numbers encountered in the trial program than was expected, the initial risk assessment indicated that the number of tiger sharks that would need to be killed before even a measurable change in their total population would occur was likely to be in the order of 100s. The number known to have died during the trial (see Table 1), while higher than anticipated, was still less than the levels considered necessary to potentially make a material effect on total stock size even assuming high post release mortality.

The potential levels of mortality generated from the trial period (up to 160) therefore still did not exceed those outlined within the risk assessment as necessary to generate more than a negligible risk. However, the higher than anticipated level of captures obtained in the trial period combined with the possibility of high-levels of post-release mortality has prompted a more detailed examination of the risks associated with this level of capture should this program be maintained for a number of years (see below).

Bull sharks

All available information that has been obtained by the Department's shark research program over the past two decades suggested that within the MMAs this species' distribution is largely confined to the Swan/Canning system. Consequently, given their apparent scarcity in near-shore marine waters off south-western WA, the expected number of bull sharks caught in this program was considered to be negligible.

Consistent with this prediction, only bull shark was caught (and released alive) in the trial period.

White sharks

Based on the low rates of capture of white sharks during the targeted fishing operations (which have been designed to enable tagging of these sharks) completed off WA in the past few years, especially during this time of the year, it was expected that the capture of white sharks would be small (< 10).

The lack of any white shark captures in the trial period within the MMA locations is consistent with this prediction with white sharks being more common in winter and spring off the West Coast when water temperatures are lower (DoF, 2012).

Non-targeted Species

Dusky shark

One of the most important and economically valuable species that was considered to be a potential bycatch of this drum line program was the dusky shark (*Carcharhinus obscurus*). There were initial concerns that the level of captures of this species may be relatively high and if it were to exceed 30 this would represent a moderate risk to the stock. Only one was caught in the trial period, which was much less than predicted.

It is likely the lower than predicted catch of this species is due to the drum line gear being set well inshore of what emerging data suggests is this species' offshore migratory pathway.

Shortfin mako

Due to concerns for populations of shortfin mako (*Isurus oxyrinchus*) elsewhere in the world this species has recently (2010) been included in Appendix II of the *Convention on Conservation of Migratory Species of Wild Animals* and therefore it had to be listed as a migratory species under the EPBC Act. Consequently it has now been considered separately in this report.

There are no particular concerns about anthropogenic impacts on shortfin mako in Australian waters with continued recreational and commercial catches still being allowed by the Commonwealth despite their listing (CoA, 2010). Moreover the very small number caught in the trial program (see Table 1) would have negligible impacts on this species' Australian population.

Grey Nurse

The number of captures of this species was expected to be very low and their survival prior to release (even if caught) should be high given their ability to buccally ventilate and maintain neutral buoyancy.

Consistent with the predictions, no individual of this species was caught in the trial program, supporting the initial assessment that the risk to this population is negligible.

Demersal scalefish

The design of the gear (e.g. size and design of hooks) made it highly unlikely that any demersal scalefish species would be caught in the drum line program.

As no demersal scalefish were caught on drum lines in the trial program this is consistent with the prediction.

Seals and Sea lions

The size and design of the hooks made it a remote likelihood that any individual pinniped would be captured in the program.

Consistent with the predictions, none of these species were caught during the program.

Turtles

Turtles are not common in the more temperate regions where the MMAs are located. Individuals of most turtle species are therefore highly unlikely to be in the vicinity of the MMAs and therefore even interact with the drum lines. The size and design of the hooks make it a remote likelihood that any turtle would be captured on the drum lines.

Consistent with the predictions, none were captured in the trial period.

Whales

The trial period (January–April) occurred outside the typical migration seasons for the whale species that migrate along the WA coast, reducing the likelihood of encountering drum line ropes. In addition, the positioning of the lines well inshore of where the majority of whale movements occur also reduced the likelihood of entanglements if they are encountered.

Consistent with the predictions, no interactions with whales occurred during the trial period.

Dolphins

Given the size and design of the hooks used, it was highly unlikely that dolphins would be captured by the drum line gear.

Consistent with the predictions, no dolphins were captured during the trial period.

Broader ecosystem effects

The footprint of the operation was extremely small compared to the distribution of the species most likely to be directly affected, with only very small numbers of species other than tiger sharks captured and/or killed. As outlined above, the trial program has therefore generated only negligible impacts on each of the affected species.

There was no species captured in the trial drum line program that would significantly affect the original assessment that this program would have negligible impacts on the ecosystem. Consistent with this prediction, no effects to other species have been identified.

The removal in one year of up to 25 tonnes of a number of common species of shark (mostly tiger sharks), each of which has a diverse diet, distributed across effectively three small areas of the west coast bioregion by this trial program is still unlikely to have had any measurable

effect on the functioning of the broader mesoscale, Leeuwin-Naturaliste ecosystem. This ecosystem extends across the southern half of the West Coast bioregion where the MMAs are located. Nonetheless, the potential effects of this level of capture extending over a number of years will be assessed in more detail below.

Comparisons with shark control measures used elsewhere

Drum lines, long lines and gillnets have been used to target potentially dangerous sharks in other locations including Queensland, New South Wales, South Africa, Brazil and Hawaii (McPhee, 2012; Table 1). Direct comparisons between the operations of different shark control measures are complicated by a number of factors. These include differences in oceanographic conditions and therefore regional species composition, background abundance levels and movements of different shark species, histories of commercial fishing effort, fishery management and marine conservation measures plus differences in available data series and how long after initiation of the programs that the data were started to be collected. In addition, gear types, hooks sizes and bait types also vary among these programs.

In terms of the number of hooks used, the trial WA program was similar in scope to the drum line program coordinated by the Natal Sharks Board in KwaZulu-Natal, South Africa but much smaller than the number used in the Queensland drum line program. The hook size used in WA was much larger than used elsewhere. Importantly, the customized hook-design featured a point that was strongly recurved back towards the shank, analogous to the design found on circle hooks. This design closes the gape of the hook compared to standard J hooks. As was predicted in the initial risk assessment (DOF, 2014a), the larger hook size with the additional aspect of the closed-gape arrangement appears likely to have contributed to the very low numbers of non-shark bycatch species captured in the trial program compared to the captures in other locations. Essentially the catch was dominated by tiger sharks, which was a target species, with minimal other species captured and effectively no non shark bycatch.

Similar to WA, tiger sharks form a major component of the Queensland drum line catch with an annual average of over 200 tiger sharks having been caught by the Queensland Shark Control Program over the past 10 years. The composition is less similar to the long line catch taken in Brazil and even less similar to the catch composition taken in the South African programs (Figure 5). This pattern probably reflects the susceptibility of tiger sharks to static baits (i.e. they are recognized as scavengers, as well as being active predators) along with differences in average water temperatures and the tropical/subtropical distribution of this species. Most of the other programs capture a wider range of species including non-shark bycatch.

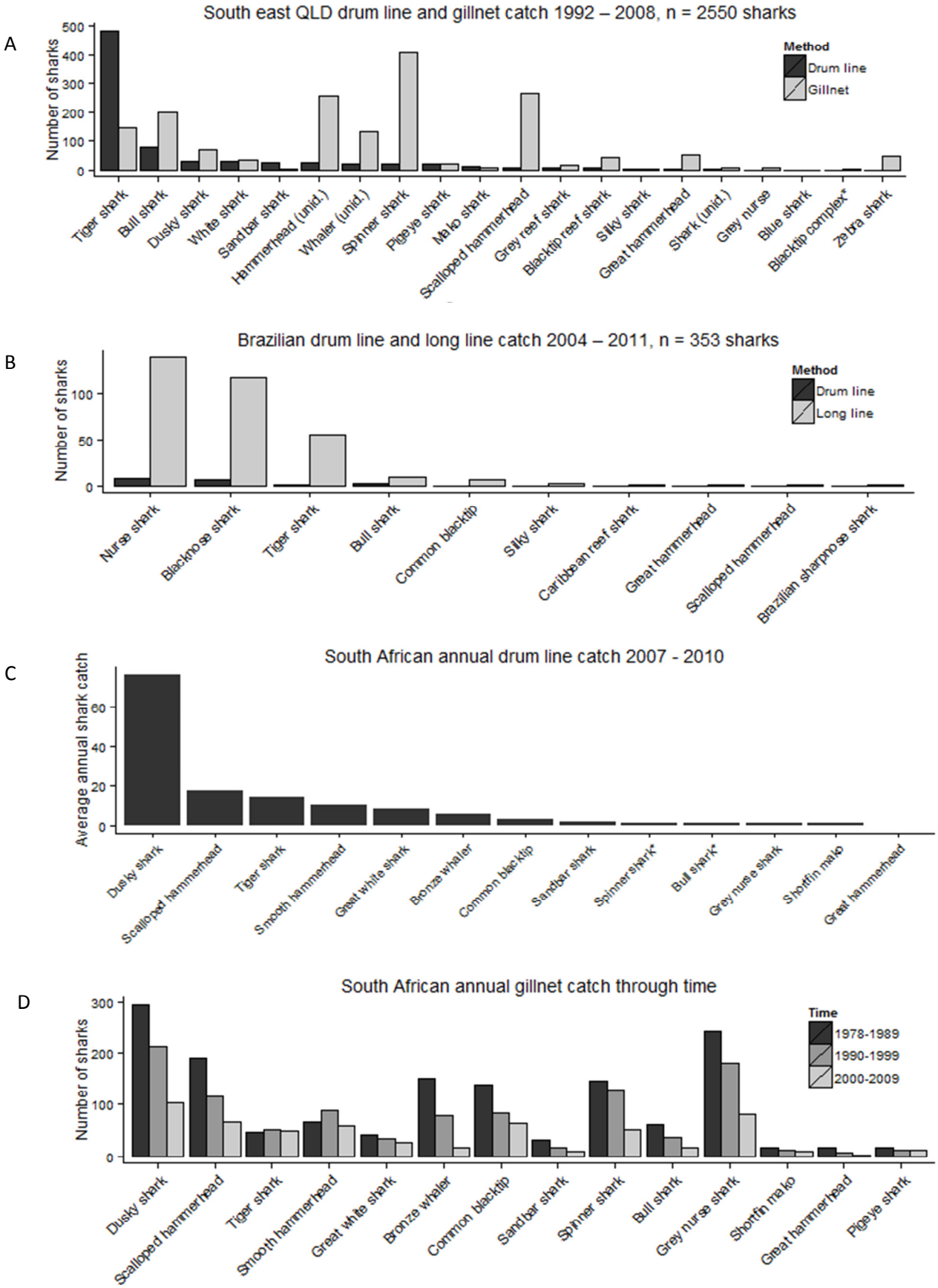


Figure 5. Shark catch from shark control measures in (A) south east Queensland, (B) Recife, Brazil, (C) KwaZulu-Natal (KZN) South Africa – drum line and (D) KZN – gillnets. Note that graph (C) and (D) shows the annual catch and not the total catch. * = less than one shark a year. Graphs reproduced from data presented in Cliff and Dudley (2011), Sumpton et al. (2011) and Hazin and Afonso (2013).

Table 1.Examples of shark control measures using drum lines, long lines or gillnets

Location	Time scale	Gear used	Fishing duration	Target species	Main shark species	Non-shark bycatch
Western Australia	January to April 2014	Drum lines - 72 hooks (25/0 Customised – Closed Gape – circle like). initially baited with Bonito, Mackerel and since with miscellaneous fish heads and frames. Set approx. 1 km offshore.	24 hours a day. Hooks are baited or checked at least once a day.	White shark, tiger shark, bull shark. < 3m released alive and tagged	Tiger shark (>90%)	1 north-west blowfish (silver toadfish, *Lagocephalus sceleratus*). 7 rays
Queensland [1]	Ongoing from 1962	Drum lines - 352 hooks (14/0 Mustad J design) baited with sea mullet and set in water 8 – 10 m depth. 35 hooks set off south east Queensland beaches. Hooks are checked 20 days a month. Gillnets – Approx. 35 surface large-mesh nets (186 m TL, 6 m drop, stretched mesh size of 50 cm) set in water 8 – 10 m depth.	24 hours a day. Hooks are baited and checked 20 days a month. 24 hours a day. Nets are checked 20 days a month.	Bull shark, tiger shark, white shark Most killed	Tiger shark, bull shark	Drum lines and Gillnets- Mostly loggerhead turtle (approx.10 per year at Gold Coast, Sunshine Coast and Rainbow Beach). Also small number of green turtle, leatherback turtle, common dolphin, bottlenose dolphin, white-spot eagle ray, *Manta* spp . and other rays.
New South Wales [2]	Ongoing from 1937	Gillnets – Bottom-set large-mesh nets used at 51 beaches (150 m TL, 6 m drop, stretched mesh size of 50 – 60 cm) set in water 10 – 12 m depth.	Soak time varies from 12 – 96 hours. Nets are set every weekend day and nine week days per month from September to April.	White shark, bull shark Most are found dead	Hammerhead shark, whaler shark (*Carcharhinus*. Spp), angel shark	Currently around 5 bottlenose dolphins a year.
South Africa [3]	Ongoing from 2005	Drum lines – 79 hooks (14/0 Mustad J design) baited with Southern Rover or Jacobever species. Gillnets – 23.4 km of netting used along a 320 km stretch of coast (most nets are 214 m long, 6.3 m deep and 300 – 500 m offshore).	24 hours a day (although hooks and nets are sometimes removed in winter during the 'sardine run'). Hooks and nets are checked daily from Monday – Friday.	Bull Shark, white Shark Alive sharks are towed as far offshore as possible, tagged and released.	Dusky Shark, scalloped hammerhead	Drum lines - Less than 10 animals a year consisting of *Manta* spp., loggerhead turtles, leatherback turtle, other turtles, long-beaked and common dolphins.
Brazil [4]	2004 to 2011	Drum lines – 23 lines with two different hook types and sizes (9/0 J-style and 17/0 circle) baited with Moray Eels or Oilfish. Long lines – Two lines (100 hooks per line, same hooks size and bait as drum lines).	Drum lines fished 24 hours a day and hooks baited and checked daily at dawn. Long line hooks had an average soak time of 15 hrs	Tiger Shark, bull shark Live animals relocated, tagged and released.	Nurse Shark, Tiger Shark	Less than 100 teleosts a year (mostly Ariidae). Eight turtles Cheloniidae) in total.
Hawaii [5]	1959 to 1976	Long lines – various configurations with up to 100 hooks at any one time. Skipjack tuna was the main bait. Light long lines and hand lines were also fished sporadically between 18 – 118 m.	Not reported for each gear type.	Tiger Shark, Most were killed.	Sandbar Shark, Tiger Shark	None reported in the Wetherbee et al. 1994 publication.

1 = Sumpton et al. (2011); 2 = Reid et al. (2011); 3 = Cliff and Dudley (2011); 4 = Hazin and Afonso (2013); 5 = Wetherbee et al. (1994). Other drum line shark mitigation measures may have been deployed elsewhere. Note that the shank length and gape diameter of hooks varies among models making direct comparisons of hook size difficult.

Assessments of Ecological Risks for Program (2014-2017)

Context and Scope

The ecological risk assessments presented in this report have been undertaken to assist in determining whether exemptions to relevant State and Commonwealth legislation should be granted for the proposed Program.

The International standards definition of risk is "*the effect of uncertainty on objectives*" (ISO, 2009). This definition of risk makes it clear that examining risk will inherently include the level of uncertainty generated from having incomplete information (SA, 2012). In the context of assessing the risks of this proposed Program, the objectives that are to be achieved are the longer term sustainability of the species at the whole of population level, and the maintenance of the ecosystem structure at the regional level. This is consistent with meeting the EPA objective of "*To maintain the diversity, geographic distribution and viability of fauna at the species and population levels.*" (EPA 2014b).

Consequently a "significant impact" that would result in a high risk would be one for which there was a reasonable likelihood that the number of individuals of a species that are captured and ultimately died from this program would materially affect the longer term sustainability and population dynamics of the species at the whole of population level, or that these cumulative level of captures would materially affect the ecosystem structure at a regional level.

The risk analyses assume that the activities will be undertaken in accordance with the terms outlined above. This includes the operations will only occur between 15 November and 30 April each year for a three year term within the two MMAs and only with the specified number of drum lines (30 routinely deployed and 6 for response to identified shark threats or incidents in each MMA with a maximum of 72 for the program).

As outlined above, the set of assessments does not examine any risks associated with the social concerns about the capture of sharks. It also does not include an assessment of the degree to which this proposal may affect the relative risks associated with human-shark interactions.

Risk Assessment Methodology

The assessment of risks that may be generated by the proposed Program was completed using methods that are consistent with the international standards for risk management and assessment (ISO 31000, 2009; IEC/ISO; 2009; SA-HB89; 2012). The process for risk assessment includes three components – risk identification, risk analysis and risk evaluation (see Figure 2).

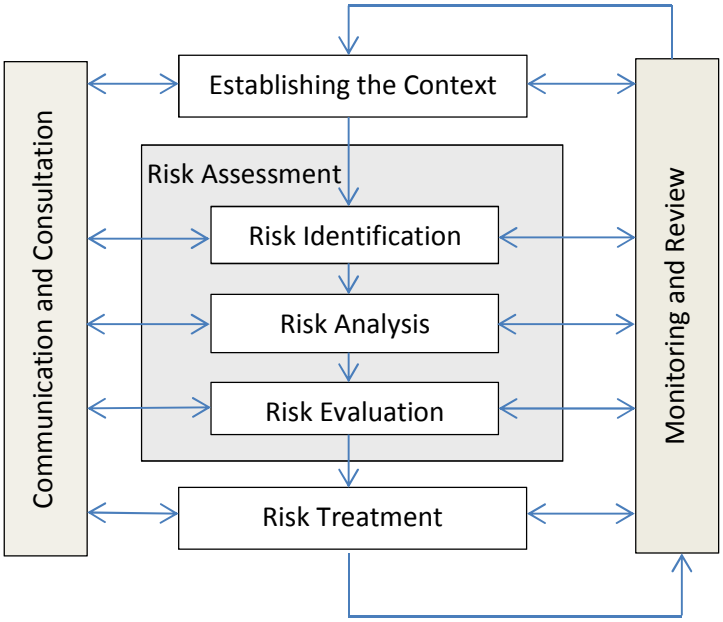


Figure 2. Description of risk assessment within the risk management process (SA, 2012).

The specific protocols to complete each of these steps have been specifically tailored and extensively applied across a number of different aquatic management situations in Australia (e.g. Fletcher et al., 2002; Fletcher, 2005; Jones & Fletcher, 2012; Fletcher, in press). Moreover this methodology has now been widely applied in many other locations in the world (e.g. Cochrane et al., 2008; Fletcher, 2008; FAO, 2012; Fletcher & Bianchi, 2014) and are considered one of the 'must be read' methods supporting the implementation of the ecosystem approach (Cochrane 2013).

Risk Identification

The identification of risks utilised the component tree approach which assists with the orderly identification of issues (components) for an assessment by providing a standardized starting point and framework to structure identified components in a consistent and hierarchical manners (FAO, 2012). The generic component tree structure was used to assist with the identification of the ecological components that need to be assessed as a result of undertaking a fishing activity (which is essentially what the Drum Line Program is undertaking). There are three main branches to these trees: target species, non-retained/bycatch species and ecosystem impacts (see Fletcher et al, 2005; FAO, 2012 for more details). These three categories are consistent with the set of potential impacts as listed in the EPAs Environmental Scoping Document (ESD) (EPA, 2014b). The components within each of these branches were then tailored to suit the particular circumstances for the potential impacts that may occur through the Program.

The risk identification process utilised the extensive knowledge of the species or categories of species that reside in the West Coast Bioregion that may be directly affected by being caught, or entangled in, the proposed drum line gear. In addition, the components identified included the potential for indirect effects on the broader ecosystem impacts to be generated by the cumulative removals of all target and non-target species.

The final component tree structure included all the species or species groups that were captured in the initial trial program. In addition we ensured that the components that were identified for specific examination also included all relevant species that are listed in the EPA's ESD and those that are relevant as matters of national environmental significance. This includes species that listed under the EPBC Act within the threatened, migratory or marine species lists. While there are no key ecological features located within the two MMAs, given their location the relevant IMCRA based, meso-scale ecosystem which covers commonwealth marine waters (CoA, 2006) is mainly the Leeuwin-Naturaliste (Fig. 3). This was the scale used to assess the potential ecosystem effects in the West Coast Bioregion (WCB) from the cumulative removals of all individuals captured by the drum line program.

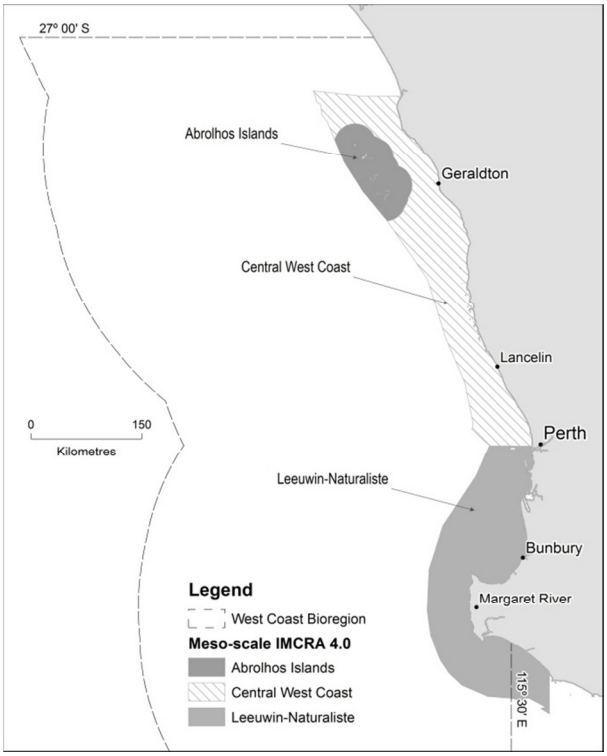


Figure 3. A map showing the IMCRA v4.0 meso-scale ecosystems located in the West Coast Bioregion.

Risk Analysis

The Consequence – Likelihood method was used to assess the level of risk for each of the identified species, groups of species that interact with the drum line gear and also the potential broader ecosystem effects resulting from the cumulative set of removals. This method is widely used methods (SA, 2012) and is applied by many WA Government Agencies through WA RiskCover.

Undertaking risk analysis using the Consequence-Likelihood (CxL) methodology involves selecting the most appropriate combination of consequence (levels of impact – for example this can include the impact on population viability) and the likelihood (levels of probability)

of this consequence actually occurring (See Figure 4). The combination of these scores is then used to determine the risk rating (IEC/ISO, 2009, SA, 2012).

		Likelihood Level				
		Remote	Unlikely	Possible	Likely	Highly Likely
Consequence level		1	2	3	4	5
Negligible	0	0	0	0	0	0
Minor	1	1	2	3	4	5
Moderate	2	2	4	6	8	10
High	3	3	6	9	12	15
Severe	4	4	8	12	16	20
Extreme	5	5	10	15	20	25

Figure 4 Risk Analysis Matrix - the numbers in each cell indicates the Risk Score, the color indicates the Risk Rankings (see Table 3).

The potential consequences, likelihoods and resultant levels of risk are all dependent upon the effectiveness of the risk mitigation controls that are in place (SA, 2012). Determining the most appropriate combinations of consequence and likelihood scores therefore involves the collation and analysis of all information available on an issue. The best practice technique for applying this method now makes use of all available lines of evidence for an issue and is effectively a risk-based variation of the 'weight of evidence' approach that has been adopted for many assessments (e.g. Wise et al., 2007; Linkov, et al., 2009).

Different consequence tables are used for the different categories of effects which for this assessment required tables to examine the potential impacts on Stocks, Habitats and the Ecosystem Structure which are presented in Appendix 1. This outlines the types of issues, risk factors or threats that need to be considered in these analyses. Importantly, the different Consequence Levels used to assess the risks to stocks are directly analogous, and incorporate all the elements, needed to assess the potential impacts of an activity to effective population viability.

Risk Evaluation

The risk evaluation step uses the outcomes of the risk analysis to help make decisions about which risks need treatment, the level of treatment and the priority for action. The different levels of management action can be determined by having the risk scores separated into different categories of risk (Table 3).

Table 3 Risk Evaluation, Rankings and Outcomes (modified from Fletcher et al., 2002; Fletcher, 2005).

Risk Category (Score)	Description	Reporting Requirements	Likely Management Response
Negligible (0-2)	Not an issue – no actions necessary	Minimal	Nil
Low (3-6)	Acceptable; no specific control measures needed	Periodic	None specific
Medium (7-10)	Acceptable; with current risk control measures in place (no new management required)	Full Annual report	Specific management and/or monitoring required
High (11-15)	Not desirable; continue strong management actions OR new and/or further risk control measures to be introduced in near future	Full Annual report	Increases to management activities needed
Severe (16-25)	Unacceptable; major changes required to management in immediate future	Full Annual report plus interim reports	Increases to management activities needed urgently

Information Utilised

The key information used to generate the risk scores included:

- The composition of the species captured during the WA drum line program January-April 2014 (summarised above). See also DoF, 2014b for more details.
- the rates of capture of these species recorded in drum line programs in other shark mitigation programs
- the rates of capture using similar equipment in WA for tagging purposes
- research survey information for the west coast region
- commercial catch and catch rate information for relevant WA fisheries

- relevant stock assessment information as presented within the annual Status Reports on the Fisheries Aquatic Resources of WA and in various Fisheries Research Reports.
- relevant biological and behavioural information on these species
- other relevant information on these species and methods including the 2012 review by McPhee
- the correlation study completed by the Department (DoF, 2012).
- Other relevant scientific studies and publications (see references)

Results

Identification of Issues requiring Assessment

Most of the issues identified for this current assessment had already been examined during the first risk assessment (DoF, 2014a). The only additional (or refined) issues that required separate assessment were (1) the potential impacts on seabirds (many of which are listed in the EPBC), (2) a separate assessment of short fin Mako sharks (which as outlined above are a listed migratory species), (3) other listed sharks and rays (e.g. Whale Sharks); and (4) an explicit assessment of habitat impacts (See Figure 5).

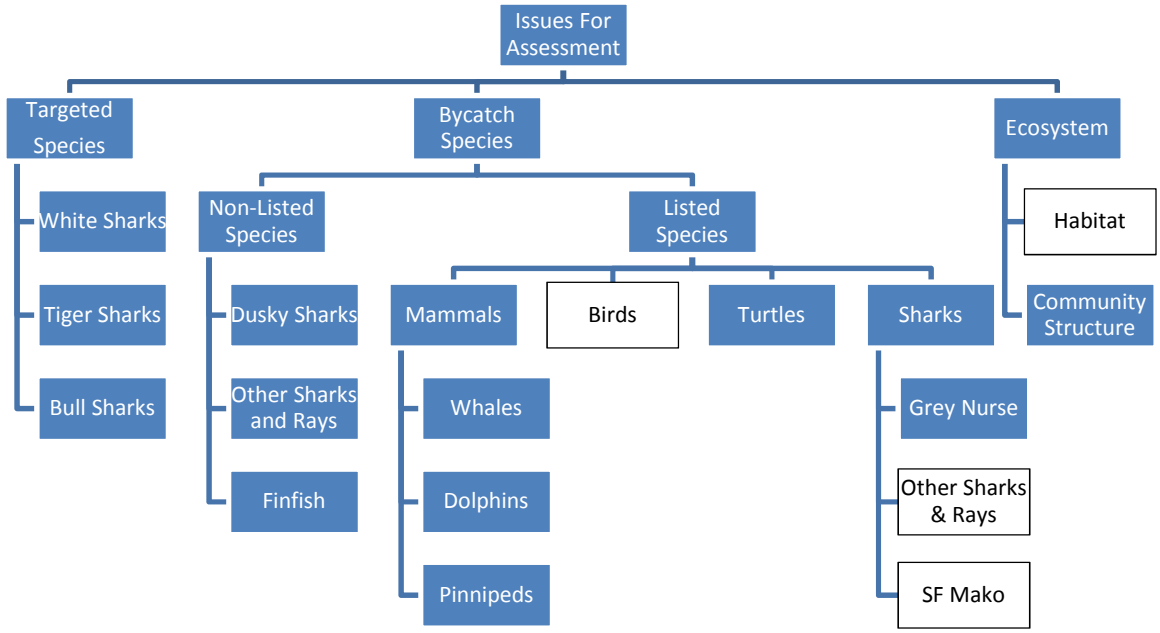


Figure 5 – Issues identified for completion of a risk analysis. Those in white boxes were not separately examined during the first risk assessment (DoF, 2014a)

Analysis of risks to targeted species

White sharks

Background

The white shark (*Carcharodon carcharias,* Linnaeus, 1758) is a very large (up to 600 cm TL) and relatively rare shark species in all locations where it is found in the world (Last & Stevens, 2009). Each of the different populations of this species covers a large spatial distribution, often including both coastal and oceanic waters. The individuals of this species can be wide-ranging and may undertake significant migrations (Bruce, et al., 2006). Their diet appears to change with size, with smaller individuals consuming mainly teleosts and elasmobranchs, with mammals becoming a more important part of the diet for larger individuals (Malcolm et al., 2001).

In Australian waters it has recently been determined that there are effectively two sub-populations of white sharks. Tracking data and genetic studies (Blower et al., 2012; Bruce and Bradford, 2012) both indicate that these two subpopulations of white sharks are separated at Bass Strait with a southwestern population that extends across the southern ocean in South Australia and Western Australia up the west coast of WA to approximately North West Cape (Last and Stevens, 2009). White sharks are widely but not evenly distributed in Australian waters with some areas appearing to have more frequent sightings especially around pinniped colonies off South Australia, areas of the Great Australian Bight as well as the Recherche Archipelago of Western Australia (Malcolm et al. 2001).

Within the geographical distribution of this southwestern population white sharks have not been directly targeted by commercial activities (mostly SA and WA), and they have now been officially protected for nearly 20 years. The majority of the white shark captures have come from their incidental bycatch by temperate demersal gillnet and longline fisheries that operate in both WA and SA waters.

Anticipated Annual Catch Levels

The use of drum lines to capture sharks by the Program in WA is intended to have a localised impact on the relative number of individuals of white sharks and other targeted species within the MMAs. It is not designed to generate a significant reduction in their overall population numbers. During the trial program period (DoF. 2014b) no white sharks were captured. This result was not surprising as it was predicted that few would be captured at this time of the year on the west coast given the water temperatures are relatively high during this period in this region of the WA coast (DoF, 2012).

The drum line program is now proposed to operate between November and April for a three year period. Based on the relative catch rates of white sharks in the region adjacent to the MMA areas by local west coast fisheries, research tagging programs and the previous drum line trial program, it is expected that fewer than 10 white sharks and even fewer in the target range ($\geq$300 cm TL) will be caught each year. This would lead to a likely cumulative catch of less than 25 white sharks over the three year program and even fewer that are $\geq$ 300 cm TL.

Comparative Catch levels

The low expected level of annual catch in the WA drum line program is consistent with the low annual catches of white sharks that have been sustained for decades through the drum line and netting programs off Queensland and NSW (e.g. see Reid et al., 2011). This is also substantially lower than the numbers that were estimated to have previously been caught each year as bycatch by commercial fishing operations in WA, SA and Vic. Prior to the major reductions in effort of these fisheries that occurred in the mid-1990s (due to issues with targeted stocks) up to 260 individuals/year were estimated to be captured across the WA- Vic region (DoF, 2014c).

The estimated annual level of capture by the Program is still much lower than the current estimate of the annual bycatch of white sharks by all fisheries across this western population which is estimated to still be in the order of 50-100 individuals per year. Based on these estimates, the expected catch levels generated by the proposed drum-line Program, would only be increasing annual catch by less than 10%.

Current Population Assessment

Estimating the size of the southwestern white shark population size (west of Bass Strait) has been difficult due to the lack of long term quantitative monitoring information. Recent research has focused on reconstructing the likely historical catch levels generated from all sources (including commercial, game and recreational fishing plus captures associated with whaling) and using these in combination with different life history scenarios and initial population sizes to generate potential fishing mortalities and stock trajectories for the southwestern white shark population (DoF, 2014c). Each of the alternative scenarios is then compared against the available lines of evidence for this population using an innovative risk based, weight of evidence approach. The basis of this approach is that the more each of the independent lines of evidence are considered consistent with a specific scenario, the greater the level of likelihood that the scenario is a plausible reflection of the real situation.

The lines of evidence that are being examined included the catch rates of white sharks by commercial fishers across periods before, during and after the highest levels of white shark captures occurred, trends in the rate of attacks per head of WA population for the past twenty years, observed sighting rates by WA abalone divers for the past decade and sightings at SA cage diving sites for the last 20 years. Additional lines of evidence include comparisons with estimates of sizes of other populations of white sharks and comparisons of relative catch rates and stock estimates for co-occurring sharks in this region.

All the available lines of evidence strongly suggest that over the past decade the southwestern white shark population is stable or increasing (DoF, 2014c). None were consistent with this population decreasing during the most recent decade. Using the most plausible population scenarios for starting population size and life history characteristics suggests that the southwestern Australian white shark population either did not decline significantly or if it did, it has at least now achieved stable or increasing levels since the major reductions in fishing effort and mortality. An increasing trend is considered more likely if there were some benefits from their listing as protected species nearly two decades ago through the survival of

some of the individuals that are released after capture. The results of these analyses suggest that the current size of this southwestern population is most likely to be in the order of at least a few to several thousand individuals with the most likely estimates between 3400-5400 (DoF, 2014c). Further, the population is estimated to be at least 70% of the unexploited level with the highest likelihood scenarios suggesting the population is currently above 85% of unexploited levels.

Risk Analysis of the Impacts of the Program

All lines of evidence indicate the size of the southwestern population is either stable or increasing over the past decade. With anticipated captures less than 10 white sharks per year, the proposed Drum line Program would add less than 10% to the current annual levels of capture. Therefore, even using the most conservative plausible estimate of current population size (> 3100), with the expected very low levels of additional annual mortality the modelling identify this would generate minimal effects on the population size (DoF, 2014c).

Over the next three years if catch levels remain at the bottom of the anticipated level (only a few per year - such as occurred in the trial program) the cumulative effects of the drum line program would have a negligible impact (Consequence Level 0). If the catch levels are at the top of the anticipated range (i.e. closer to 10 each year) there is still only a **remote likelihood** (Likelihood Level 1) that this would have a **minor level of consequence** (Consequence Level 1) on the total size and therefore the population viability of the southwestern Australian population of white sharks. This combination generates a R**isk Score of 1**.

Risk Evaluation

If the mortality rates of white sharks generated by this program remain within the anticipated levels (< 10 year), this would represent only a **negligible risk** to this population.

This is an acceptable level of risk with no actions necessary.

Tiger sharks

Background

The tiger shark (*Galeocerdo cuvier,* Peron and Lesuer, 1822), is a very large species of whaler shark, which can attain approximately 600 cm TL (Last and Stevens, 2009). This species is a relatively common and wide-ranging, coastal-pelagic species, found in tropical and warm-temperate oceans around the world. They are mostly located from close inshore, to shelf habitats with depths of around 150 m, but they have also been found substantial distances from the continental shelf and around oceanic seamounts and islands (Compagno, 1984).

Within Australian waters tiger sharks have a geographic distribution that extends from the west coast of WA over the northern half of Australia to southern NSW (Fig. 6) The species is known to make seasonal excursions into temperate waters (Last & Stevens, 2009) with their range in WA possibly becoming more extensive in the last few decades. Thus, Last & Stevens (1994) suggested the range extended to south of Perth but their more recent update extended this range to Windy Harbour (Last and Stevens, 2009) with some records even

further east, presumably in response to years of stronger Leeuwin Current (DoF, 2006). The location of the drum lines that are to deployed for the Program in WA will, therefore, be located at the southern end of their range on the west coast of Australia (Figure 6).

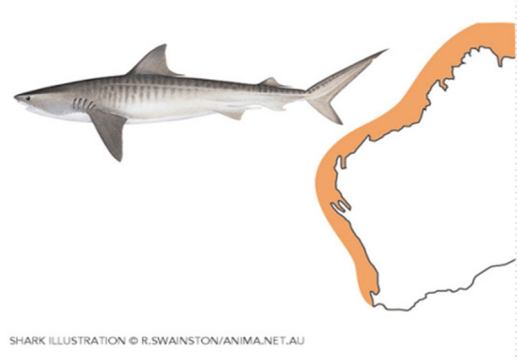


Figure 6. Distribution of the tiger sharks in WA from McAuley et al., (2002)

Anticipated Annual Catch Levels

Within the trial program a total of 163 tiger sharks were caught with 64 killed and 99 released (see Table 1). Based on length-weight conversions from northern Australia (Stevens and McLoughlin, 1991), the estimated weight of tiger sharks killed during this program (assuming 100% survival of released sharks) was approximately 17 tonnes (DoF, 2014b). The total mortality is likely to be higher than this estimate with the maximum, assuming no survival of released sharks approximately 25 tonnes.

It is possible that the level of capture was higher during the trial program was higher than was anticipated due to warmer water temperatures than historical levels (Caputi et al., 2014; Pearce et al., 2011). It is, however, also likely that these warmer water conditions will persist. Consequently, to assess the risks to this population it was assumed that the average catch per day at each of the sites observed during the trial program will be maintained across the entire season (15 Nov – April 30). This would generate a total number of tiger sharks captured per season (Nov-April) of close to 300. Accounting for the anticipated level of release (60%), this would equate to an annual mortality of in the order of 25-40t depending upon the level of release mortality (0-100%).

Comparative Catch Levels

Tiger sharks are currently subjected to only minor levels of exploitation by other fisheries along the WA coast. This species has only ever been commercially fished for relatively short and irregular intervals within WA. Generally their capture has occurred in different parts of their distribution at different times with most of these captures having occurred in the northern more tropical part of their WA range. These captures have been as a byproduct of fishing for other shark species not as a target species, because tiger sharks are generally not targeted as their flesh is not marketable. The current level of commercial capture of tiger sharks as bycatch is also now very low in WA because of a series of management actions and

other events that have affected the overall level of effort and areas remaining open for commercial shark fishing (Figure 7).

There has been the prohibition on the use of commercial shark fishing gear which covers large areas of the distribution of tiger sharks off the north-west coast of WA (see Figure 7). This prohibition was introduced in 1993 along with statewide restrictions on the retention of shark catches for commercial purposes by other fishing methods (e.g. trawl). There was a further dramatic decrease in commercial shark fishing effort within this northern bioregion that began in 2005 and in 2008/09 there was a complete cessation of the northern shark fishery due to economic issues unrelated to tiger sharks (Figure 8). For the decade prior to this cessation, this fishery alone had been capturing tiger sharks as a byproduct with up to 80 t caught during the 2004/05 season (Figure. 9).

A

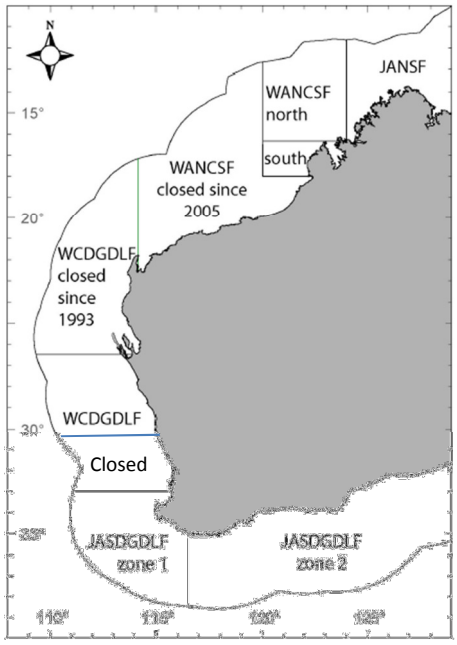


Figure 7. Map of WA coast indicating the significant areas of the western coastline where commercial shark fishing is now longer occurring.

Smaller amounts of tiger shark landings have been recorded in the West Coast Demersal Gillnet and Demersal Longline Fishery which also reached 8 tonnes in 2005 – 2006 and small numbers of tiger sharks were also caught in the Eighty Mile Beach, the Kimberley Gillnet and Barramundi Fishery and the Pilbara Fish Trawl Fishery (Heupel and McAuley, 2007). A further reduction in shark fishing occurred off the West Coast in 2008. As part of allocation decision directed towards recreational fishers for demersal scalefish, the metropolitan region was closed to all commercial wetline and shark fishing. Consequently the total capture of tiger sharks by commercial fishers has declined substantially over the past decade from an annual total close to 90 t down to the current levels < 5t (Figure 10).

For the recreational sector, the annual level of catch has also been reduced from the relatively high estimates obtained in the late 1990s (Henry et al., 2001) to now be in the order of 330 per year (>80% released) with the majority caught in the Gascoyne Bioregion which includes Shark Bay (Ryan et al., 2013).

The historical catch levels far exceed the anticipated level of annual catch that would occur from the WA drum lines. Collectively all the management actions and events over the past decade have reduced the total catch levels of tiger sharks across WA to relatively low levels (Figure 8). Consequently the combined annual mortality for tiger sharks that would now occur through the drum line and current commercial fishing catches are still substantially below historic levels.

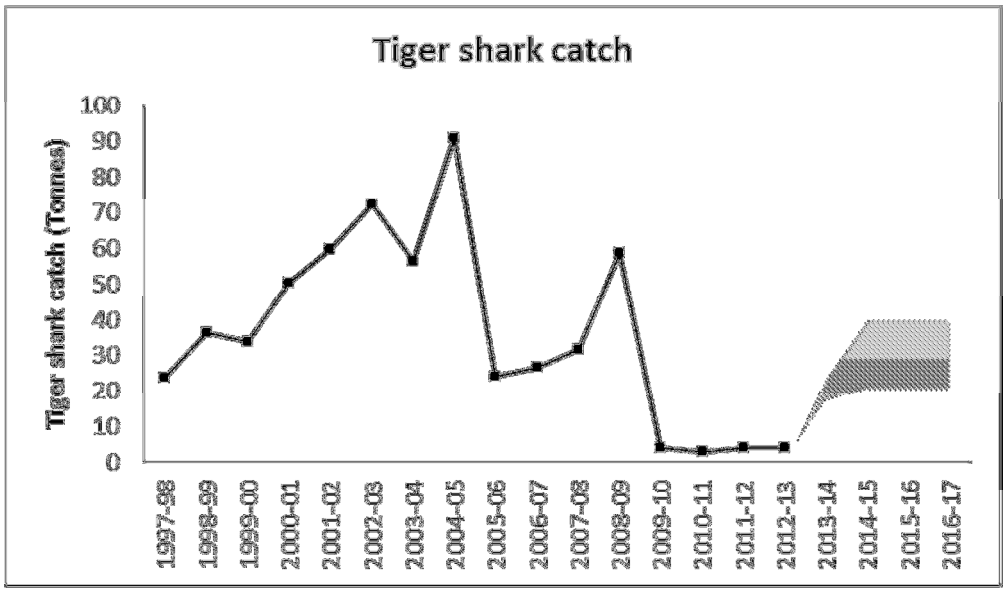


Figure 8. Total WA commercial catch of tiger sharks since 1997-98, illustrating the reductions in catch level since 2004/05 (but especially after 2008) due to management and industry changes. The shaded area is the potential range of annual mortality based on anticipated catches for the drum line program depending upon the level of release mortality (0-100%).

Population Assessment

Being a considered a relatively minor bycatch species, the stock status of tiger sharks in WA has not been formally assessed within the various assessments completed for export approvals for the West Coast and North Coast shark fisheries as required under the EPBC Act. The limited quantitative information from the northern shark fisheries indicates that the catch rate for the northern shark fisheries declined from 0.20 kg hook^{-1} in 1998/1999 to 0.06 kg hook^{-1} in 2001/02 during a period when catches were relatively low. Importantly, the catch rate for this fishery remained at relatively stable levels from 2001/02 until the end of the time series (2004/05) which equates to the time period when the highest tiger shark catch levels were occurring (Figure 9, Heupel and McAuley, 2007).

More recent catch rate data from a long term time series of annual fisheries-independent longline surveys (2001 – 2013) shows a steady increase in the catch rate for this species in the WA region north of 29^{o} (Figure 10). This survey is ongoing and will therefore continue to provide data on tiger sharks within this northern region.

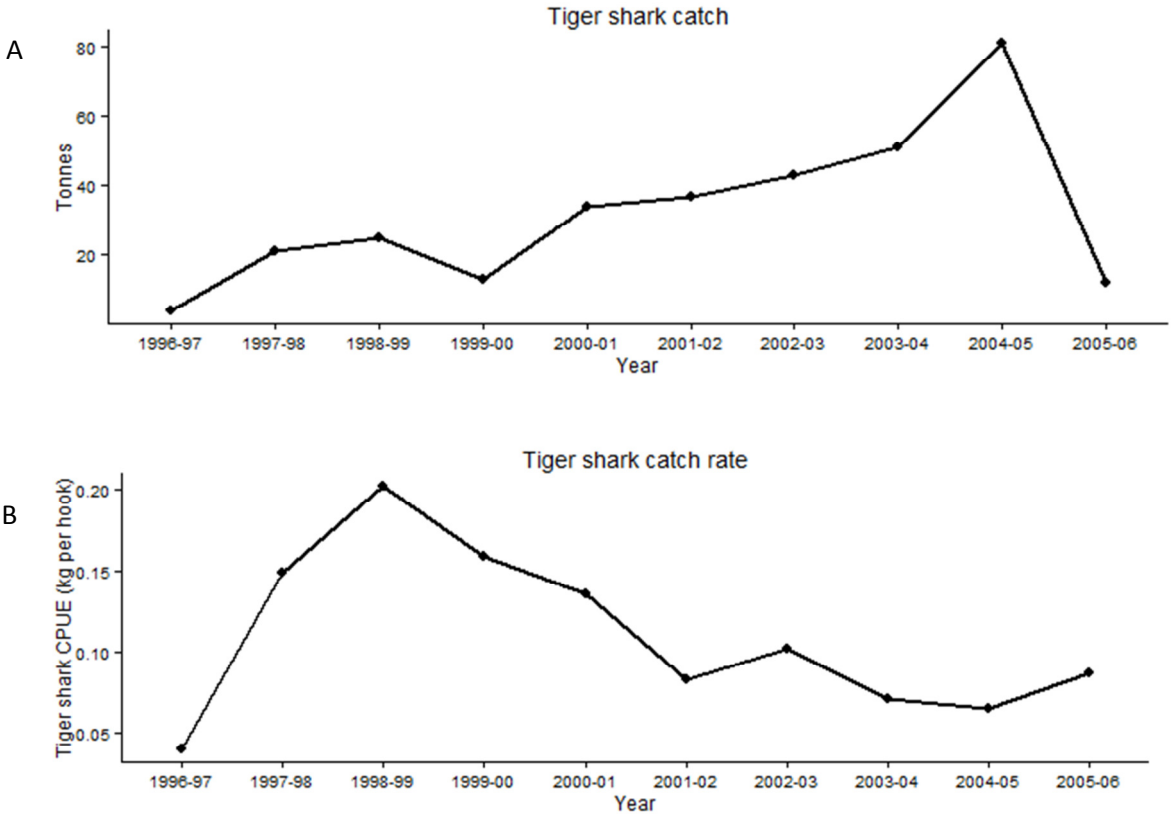
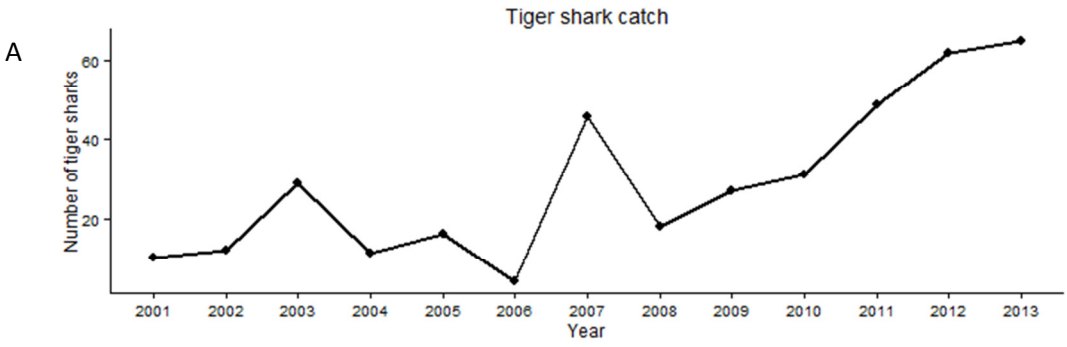


Figure 9 Tiger shark catch and catch rate in the northern shark fisheries (from Heupel and McAuley, 2007).



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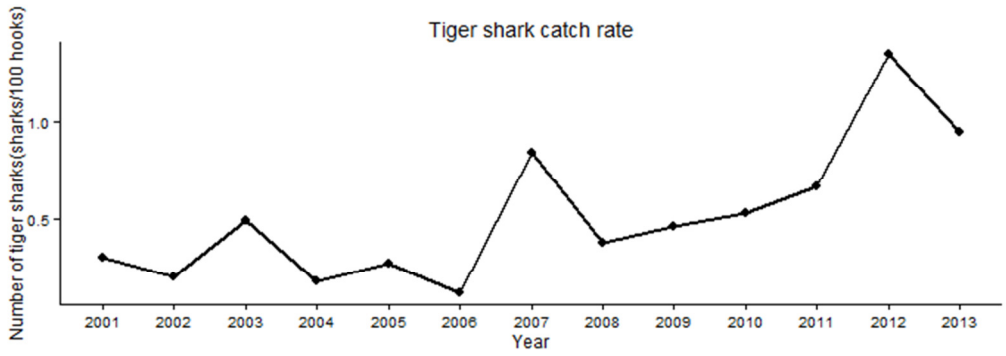
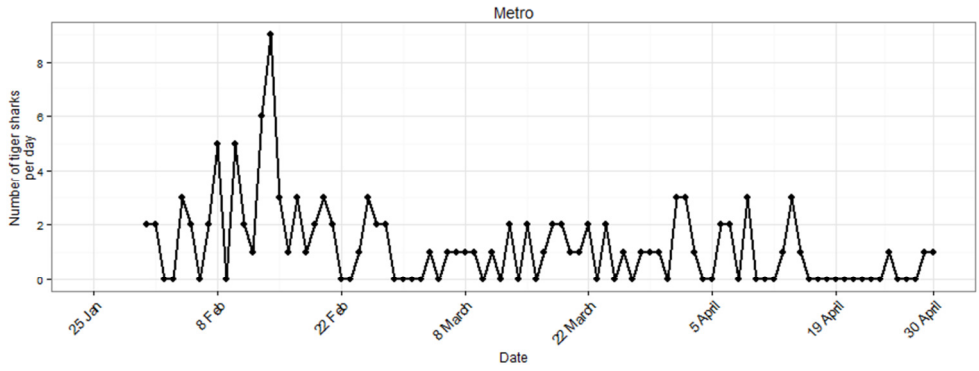


Figure 10 (A) Tiger shark catch and (B) tiger shark catch rate in a fisheries-independent survey of sharks north of 29°S latitude during 2001 – 2013.

The daily catch rate data for tiger sharks obtained from the trial drum line program are presented in Figure 11. The only evidence of a decline in daily catch levels which could reflect some level of local depletion of tiger sharks was observed in the Metro region. Their continued capture in the Metro region up to the end of the program indicated tiger sharks were still present within this region. There was no evidence of any local depletion having been generated by the levels of capture within the two south west areas with the catch level remaining at consistent levels for the duration of drum line deployment at both the Geographe Bay and Capes areas. If the levels of capture recorded during the trial program were sufficient to generate a significant population wide level of impact, it would be anticipated that the levels of local depletion in the MMAs would be more noticeable than was observed.

A



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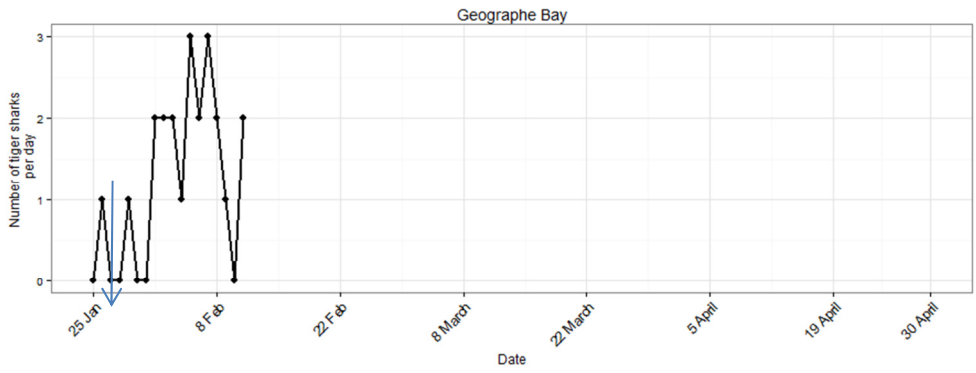

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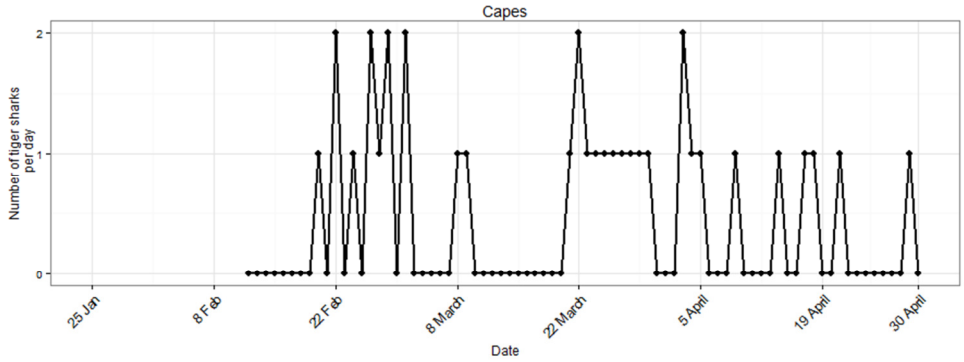

Figure 11. Daily catch of all tiger sharks captured in the (A) Metro, (B) Geographe Bay and (c) Capes regions. The dots represent every day of fishing within each region. Note the different start dates and different scales for each region.

Risk Analysis

The various lines of evidence for tiger sharks are consistent with the proposed drum line program having either a negligible or, at most, a minor impact on the total stock level of tiger sharks across their distribution in WA. These include (1) the extremely small footprint of the program; (2) the location of the program being at the southern edge of their distribution, not in the area where the main distribution of this species is considered to be located in WA; (3) the likely annual rate of captures (with the majority being released) being significantly less than was previously reported from longer term historical commercial fishing activities (up to 90 t/year); (4) the estimated levels of capture are only at a similar level to those now estimated to be captured by recreational fishers (mostly in the Gascoyne Bioregion and most of which are also released); (5) The anticipated level of capture of tiger sharks in WA by this Program is similar to the average annual catch of tiger sharks that has been taken by the Queensland Shark Control Program for at least the last decade. (6) there was only some evidence of local depletion during the trial program in the Metro region not at Geographe Bay or the Capes; (7) the relatively low levels of mortality on this species now being generated from commercial fishing in other areas of WA and (8) the relatively short term nature of the proposed program (c.f. with most fisheries activities) only 5.5 months of the year and only for three years.

Risk Evaluation

If the levels of capture of tiger sharks generated by this program remain within the anticipated levels combined with assuming high levels of release mortality rates this level of annual mortality (40t) for three years it would be **possible** (Likelihood Level 3) for the program to generate a **minor consequence** (Consequence Level 1). This would represent a potentially measurable but relatively small decrease in their total abundance could occur. This level of decline would not, however, have a material effect on their longer term population dynamics and therefore no effect on the effective viability of the WA population.

The calculated **Risk Score of 3** represents a **Low risk** to the WA population viability of tiger sharks. This is an acceptable level of risk with no specific additional management controls necessary.

A periodic report is required and it is recommended that if the Program occurs, a full assessment is completed at the end of this three year period to reassess the risk level. This assessment would be assisted by a suitable level of sampling of the tiger sharks that are captured within the MMAs, plus those found more broadly in the WCB and also from comparative work completed on tiger sharks in more northern areas of their distribution in WA. This would include the data from the long term fishery independent monitoring program.

Bull sharks

Background

The Bull Shark (*Carcharhinus leucas*, Miller & Henle, 1839) is a large, stout body shark with a tropical to warm temperate distribution across northern Australia from northern NSW to Perth, WA (Last & Stevens, 2009). It is commonly found in estuaries and even freshwater systems but only rarely in open marine waters.

Anticipated Catch Level in Program

All available data from more than 20 years of dedicated Department of Fisheries' shark research suggest that this species' distribution within the MMAs is largely confined to the Swan/Canning estuary system. Given the apparent scarcity/absence of bull sharks in near-shore marine waters off south-western WA, the anticipated number of bull sharks that will be caught by the program will be minimal.

Consistent with this prediction only one was caught in the Metropolitan region during the Trial Drum line program and this was released alive. It is, therefore, anticipated that this level of capture will be maintained in the current proposed Program.

Risk Analysis/ Evaluation

With an anticipated capture rate of none to only a few individuals each year (most of which will be less than the 300 cm level), there is a high likelihood that this Program will have no impact (Consequence Level 0) on the population numbers in WA. This generates a risk score of 0. This represents a **negligible risk**.

This is an acceptable level of risk with no actions necessary.

Assessment of risks to non- targeted species and the broader ecosystem

Dusky Whalers

Background

The dusky shark (*Carcharhinus obscurus*, Lesueur, 1818) is one of the program's most important and economically valuable shark species that occurs in the region where the drum lines will be deployed. The western Australian dusky shark stock supports significant

commercial fisheries and is the subject of a well-designed and successful recovery plan (see McAuley et al., 2005; Braccini *et al*., 2013).

For dusky sharks, the recovery program which has been successful in generating significant recovery over the past decade (see Braccini et al., 2013) assumes minimal capture of larger individuals (> 200 cm TL). Therefore, if a significant number of large dusky sharks were killed (e.g. more than 30 individuals yr^{-1}) through the drum line program each year, these activities could affect the rate of their recovery. If the numbers killed through this program begin to exceed 30 per year, a reassessment of management arrangements for the commercial fishery would need to be undertaken.

Anticipated catch level by Program

During the trial program, only one Dusky shark was captured and this was released alive. Based upon the data currently being collected on movement along the west coast using the acoustic tags and extensive acoustic monitoring network has identified that the main routes for migration of this species may be much further offshore (e.g. behind Rottnest Is) than where the drum lines are located (which are only approximately 1km from the mainland shore). Consequently, the numbers of larger dusky sharks that are now anticipated to be caught by the Program is likely to be less than 10 per year.

Risk Analysis

Given the very low capture rate experienced in the trial program (only one), combined with the increased understanding of their patterns of movement, it is now considered unlikely that the Program will generate a level of mortality of larger dusky sharks over the three year time period of the proposal that will affect the recovery of the WA stock of dusky sharks.

Risk Evaluation

If the annual level of capture and mortality of large dusky sharks remains in the anticipated range (< 10), it is now only a **remote likelihood** (Likelihood Level 1) that the Program will generate even **a minor level of impact** (Consequence Level 1) on this stock generating a **risk score of 1**. The proposed Program therefore now represents a **negligible risk** to the WA dusky shark stock.

This is an acceptable level of risk with no actions necessary.

Other non-listed elasmobranchs (sharks and rays)

Background

A number of other elasmobranch species have distributions that within the West Coast Bioregion and the MMAs and therefore have the potential to interact with the drum lines. The shark mitigation programs undertaken elsewhere in the world often capture a variety of non-targeted species of sharks and rays (see above).

Anticipated Catch Levels

The design of the gear (e.g. large hooks size) makes it highly unlikely that many other species of sharks or rays will be caught in the proposed Program. The trial program only caught one

spinner shark and seven individual rays of a number of species and these were all released alive (Table 1).

This low level of capture and even lower level of mortality is expected to continue with annual numbers with a possible range between 5-20. These will probably comprise a large number of different species.

Risk Analysis/Evaluation

There is a **high likelihood** (Likelihood Level 5) that only a few individuals from each of the other species of sharks and rays will be caught and the rays are likely to be released alive and survive and therefore generate **negligible impacts** (Consequence Level 0) on these populations generating a Risk Score of 0. With these anticipated catch levels, the Program represents **negligible risks** to this group of species.

This is an acceptable level of risk with no actions necessary.

Demersal scalefish

Background

Only two teleosts (both tuna, *Thunnus* spp.) were captured on drum lines in southeast Qld over a 16 year period and so far no demersal scalefish have been caught in WA drum lines.

Anticipated Catch Levels

The design of the gear (e.g. large hooks size) makes it highly unlikely that any of the main demersal scalefish species will be caught in the proposed WA program. It is not anticipated that many of any other finfish species will be captured on the drumlines. The only finfish species to be captured in the trial program was one blowfish.

Risk Analysis/Evaluation

There is a **high likelihood** (Likelihood Level 5) that **no demersal finfish** will be caught and also that few, if any, other finfish species will be caught (Consequence Level 0) generating a **Risk Score of 0**. With these anticipated catch levels, the Program represents **negligible** to **no risk** to these species.

This is an acceptable level of risk with no actions necessary.

Other Listed species

Grey Nurse

Background

Unlike populations in eastern state regions, the western population of Grey Nurse Sharks (*Carcharias taurus*, Rafinesque, 1810) which is located in WA has never been subjected to targeted fishing (commercial or recreational). Incidental catch and catch rate data from the demersal gillnet fishery, prior to their listing in the mid-late 1990s indicates that Grey Nurse Sharks were relatively abundant in temperate WA waters and that the population was stable (Cavanagh et al., 2003; Chidlow, et al . 2006). Given the subsequent reductions in effort that have occurred in the commercial fisheries that occasionally captured this species, including

the metropolitan closure to commercial net and line fishing, the level of annual catch of Grey Nurse sharks in WA will have significantly declined even from these low sustainable levels.

Anticipated Catch Levels

The number of captures of this species by the Program is anticipated to be very low. In the unlikely event this happens, their survival prior to release should be high given their ability to buccally ventilate and maintain neutral buoyancy. Consistent with the predictions, none of these sharks were captured during the trial program.

Risk Analysis/Evaluation

There is a **high likelihood** that no grey nurse sharks will be caught and, even if a few are caught they are most likely able to be released alive resulting in **no** or **negligible impacts** (Consequence Level 0) generating a **Risk Score of 0**. With these anticipated catch levels, the Program therefore represents **negligible risk** to grey nurse sharks.

This is an acceptable level of risk with no actions necessary.

Short Fin Mako

Background

Due to concerns for populations of shortfin mako (*Isurus oxyrinchus,* Rafinesque, 1810*)* elsewhere in the world this species was included in Appendix II of the *Convention on the Conservation of Migratory Species of Wild Animals* and therefore listed as a migratory species under the EPBC Act.

Anticipated Catch Levels

It is anticipated that the small number caught in the trial program (five) is likely to continue at similar levels in the proposed Program. Therefore, the annual capture rate is anticipated to be in the range of 5-20. This is a small amount compared to the historical captures of shortfin mako shark taken annually as bycatch by the commercial fisheries in WA (2-5t).

Risk Analysis

There are no particular concerns about anthropogenic impacts on shortfin-mako in Australian waters with continued recreational and commercial catches still being allowed by the Commonwealth despite their listing (CoA, 2010). The anticipated level of capture of this species by the program is small and this is likely to continue which would therefore likely to have only negligible impacts on this species' Australian population.

Risk Evaluation

There is a **high likelihood** that this program will have a **negligible impact** (Consequence Level 0) on shortfin mako shark population of Australia generating a **Risk Score of 0**. This therefore represents a **negligible risk**.

This is an acceptable level of risk with no actions necessary.

Other Listed elasmobranchs (sharks and rays)

Background

Both the Whale Shark (*Rhincodon typus*, Smith, 1828) and the Manta ray (*Manta birostris*, Walbaum, 1792) are listed migratory species that have distributions that extend to the West Coast Bioregion (Last & Stevens (2009). They are both plankton feeders and are mainly found in tropical waters, only occasionally being observed in more temperate waters.

Anticipated Catch Levels

Neither of these species is commonly observed in this area of the WA coast, and they are even less likely to be present within the inshore locations where the drum lines are to be deployed. The diet of both these species makes it implausible any individual whale shark or manta ray would be captured on a drum line hook. In terms of entanglement, with the single float arrangement used, this reduces the likelihood of this occurring even in the unlikely event that an individual of these species will pass through the areas where the drum lines are deployed. Finally, as the drum lines are monitored regularly any entanglement event is likely to be addressed in a timely manner.

None were captured in the trial program and this situation is likely to continue in the current proposed program.

Risk Analysis/Evaluation

With no captures anticipated to occur there is a high likelihood of no impact (Consequence Level 0) generating a **Risk Score of 0**. Therefore the program poses a **negligible risk** to whale sharks and manta rays.

This is an acceptable level of risk with no actions necessary.

Seals/Sealions

Background

There are no records of these species having been captured on large hooks off WA.

Anticipated Catch Levels

The size and design of the hooks make it a remote likelihood that any individual pinniped will become captured as part of this program. None were captured in the trial program and this situation is likely to continue in the current proposed program.

Risk Analysis/Evaluation

With no captures anticipated to occur there is a high likelihood of no impact (Consequence Level 0), the **Risk Score is 0** so program poses **no** or **negligible risk** to pinnipeds.

This is an acceptable level of risk with no actions necessary.

Turtles

Background

Turtles are not common in the more temperate like regions where the MMAs are located. Individuals of most turtle species are therefore highly unlikely to be in the vicinity of the

MMAs and therefore even interact with the drum lines. Furthermore, as the lines are monitored frequently, there is a likelihood of successfully releasing alive any turtles that are captured or entangled in the lines.

Anticipated Level of Capture

The size and 'circle like' design of the hooks make it a remote likelihood that any turtle will be captured on the drum lines. None were captured in the trial program and this situation is likely to continue in the current proposed program.

Risk Analysis/Evaluation

With no captures anticipated to occur there is a high likelihood of no impact (Consequence Level 0) the **Risk Score is 0**, the program therefore poses **no** or **negligible risk** to turtles.

This is an acceptable level of risk with no actions necessary.

Whales

Background

The time period (November–April) of the Program occurs outside the typical migration and breeding seasons for the whale species that migrate along the WA coast reducing the likelihood of encountering drum line ropes. In addition, the positioning of these lines are inshore of where the majority of movements occur plus the use of single floats which reduces the likelihood of entanglements if they are encountered.

Although a small number of whales have become entangled in gillnets in south east Queensland (26 in 16 years) no whale entanglements have occurred on Queensland's drum lines. Should entanglement of one of these species occur, DPaW has considerable expertise in disentanglement procedures. Furthermore these whale populations are generally considered to have recovered significantly from their previously threatened status, consequently from a stock sustainability perspective even in the extremely remote likelihood that an entanglement occurs and causes a death, this would still represent a negligible risk to the stock (see Stoklosa, 2013).

Anticipated Level of Capture

None were captured or entangled during the trial program and this situation is likely to continue in the current proposed program.

Risk Analysis/Evaluation

With no captures anticipated to occur there is a high likelihood of no impact (Consequence Level 0) the **Risk Score is 0**. Therefore the program poses a **negligible risk** to whales.

This is an acceptable level of risk with no actions necessary.

Dolphins

Background

Dolphins are reported as scavenging off the hooks used in Queensland but even though their J shaped hooks are more likely to enable dolphins to be caught, very few have actually been captured in 16 years of drum line operations and all were released alive.

Anticipated Level of Capture

Given the size and shape of the hooks used by the Program, it is highly unlikely that dolphins will be captured by this gear. None were captured or entangled during the trial program and this situation is likely to continue in the current proposed program.

Risk Analysis/Evaluation

With no captures anticipated to occur there is a high likelihood of no impact (Consequence Level 0) therefore the **Risk Score is 0**. Therefore, the program poses **no** or **negligible risk** to dolphins.

This is an acceptable level of risk with no actions necessary.

Seabirds

Background

There are a number of listed seabirds that may occur within the marine areas where the drum lines are to be deployed (see http://www.environment.gov.au/topics/marine/marine-species).

Anticipated Level of Capture

Given the size and shape of the hooks used plus the size of the bait that is attached, it is highly unlikely that seabirds could be captured by this gear. Moreover the type of gear used and the method of deployment (a single drum line with a single large hook with large bait) that is dropped individually means that even if the birds are in the vicinity of the gear they are unlikely to be entangled when the gear is being deployed. None were captured or entangled during the trial program and this situation is likely to continue in the current proposed program.

Risk Analysis/Evaluation

With no captures anticipated to occur there is a high likelihood of no impact (Consequence Level 0) generating a **Risk Score is 0**. Therefore the program poses **no** or **negligible risk** to listed seabirds.

This is an acceptable level of risk with no actions necessary.

Ecosystem Effects

Habitat

Background

The drum lines are only to be operated within very small areas of the West Coast Bioregion (WCB) and only a maximum of 72 drum lines can be used. Each of the anchors are not substantially different in nature to those used by the tens of thousands of recreational boats

that operate in this region. Consideration was given to the location of drum line deployment through the development of the trial program with sandy substrates preferred and areas of reef substrate excluded from deployment locations. This work was originally done using ArcGIS spatial layers and later confirmed for the metropolitan region during a field verification trip through the MMA.

Anticipated Level of Impact

The precise footprint of these drum lines anchors will be in direct contact with << 1% of the coastal habitat. Even in the specific areas where they are deployed they are not anticipated to make a lasting effect on the habitat especially in areas where they are deployed on sandy substrates.

Risk Analysis/Evaluation

The extremely small footprint of the anchors used for the drum-lines and the high resilience of the sandy substrates where most are deployed results in **high likelihood** (Likelihood Level 5) of only **negligible impacts** (Consequence Level 0) which generates a **Risk Score of 0**. The Program therefore represents **a negligible risk** to the habitats within the West Coast Bioregion.

This is an acceptable level of risk with no actions necessary.

Community Structure

Background

Documented changes to community structure resulting from removals most likely arise either from general and widespread overfishing whereby the abundance of all species in a trophic level are significantly reduced resulting in 'trophic cascades' (*sensu* Pauly et al., 1998). For example, the loss of most large coastal sharks from the north-west Atlantic reduced overall predation on cownose rays which in turn preyed upon bay scallops, leading to the collapse of a commercial fishery (Myers et al 2007). This example resulted from the loss of an entire functional group of 11 species of large shark due to two decades of overexploitation (Baum et al. 2004). A similar functional group of large sharks exists in West Coast Bioregion (Table 2) these have not, however, been subjected to the same levels of overexploitation.

Table 2. List of large shark species captured in the West Coast Bioregion.

Common name	Scientific name
Dusky shark	*Carcharhinus obscurus*
Bronze whaler	*Carcharhinus brachyurus*
Spinner shark	*Carcharhinus brevipinna*
Common blacktip shark	*Carcharhinus limbatus*
Sandbar shark	*Carcharhinus plumbeus*
Tiger shark	*Galeocerdo cuvier*
Grey nurse shark	*Carcharhias taurus*
Shortfin mako	*Isurus oxyrichus*
White Shark	*Carcharodon carcharias*

Scalloped hammerhead	*Sphyrna lewini*
Great hammerhead	*Sphyrna mokarran*
Smooth hammerhead	*Sphyrna zygaena*

The other potential pathway for a significant change to occur to the community structure of a region is from significant reductions in the numbers of just one species where this species alone has the controlling influence over a major trophic pathway. Such species are described as a keystone species (*sensu* Paine, 1966). This is not the same as just being a higher order predator and they are relatively rare (Powers et al., 1996). A keystone species, by definition, cannot occur if there is a high level of redundancy in functional roles of other species across the same trophic level (ie other species occupy the same trophic level and there are clear overlaps in potential diets). This level of redundancy is the situation for the large suite of shark species that occur within the WCB, most of which, but especially tiger sharks, are noted to be generalists ('true scavengers') with a broad diet including white sharks (Malcolm, et al., 2001; Last & Stevens, 2009). Consequently, whilst these may operate as higher order predators, none would be considered keystone predators within the WCB system.

Anticipated Types of Impacts

The ecological footprint of this Program is relatively small within the context of the West Coast Bioregion. The individual assessments completed for each of the species and groups (outlined above) indicate only negligible impacts on each of these. This therefore is not consistent with the conditions that lead to a change in trophic levels.

The only species where the level of capture is close to having a measurable impact on their abundance at the population level are tiger sharks.

Based on the capture of 40 t of tiger sharks, five tonne of other shark species and a negligible catch of non-shark species, the cumulative total for all captures of all species is very small (i.e. 45 t/year) when compared to the total combined levels of commercial capture of sharks and other fish species that previously occurred within this bioregion (> 500 t/year). These removals are only going to occur within very small parts of the West Coast Bioregion (<5%) during less than six months per year and only for three years.

While tigers sharks are considered to potentially play a role in regulating the community structure of Shark Bay by their predation on turtles and dugongs (Heithaus et al 2008), this situation does not apply in the southern WCB where the Program is operating. In this part of the WCB region dugongs are extremely rare and turtles are significantly less abundant than in the Gascoyne Bioregion. Moreover, there are a higher number of other shark species present in the more temperate and open ocean habitats of the WCB region compared to those shark species commonly present within the embayment conditions present within Shark Bay.

Comparative Impact Levels

The historical level of shark catches by various commercial fisheries operating in the West Coast Bioregion were over 400 t per year up to 2005 (Figure 11). Since this time, a series of management changes have occurred in the WCB including large spatial closures off the

Metropolitan region (for sectoral allocation purposes), temporal closures, and effort reductions have resulted in the annual commercial catch of the suite of sharks in the WCB (including tiger sharks) falling by more than half from over 500t in 2005/06 to less than 250 t in 2011/12 (Figure 11).

The anticipated increase in the catch level of sharks in the WCB by the operation of the drum line program therefore represents only 5% of the historical level. Moreover, by adding the anticipated drum line catch to the current commercial catch level, the cumulative total is still about 50% below the historical average yearly cumulative catch.

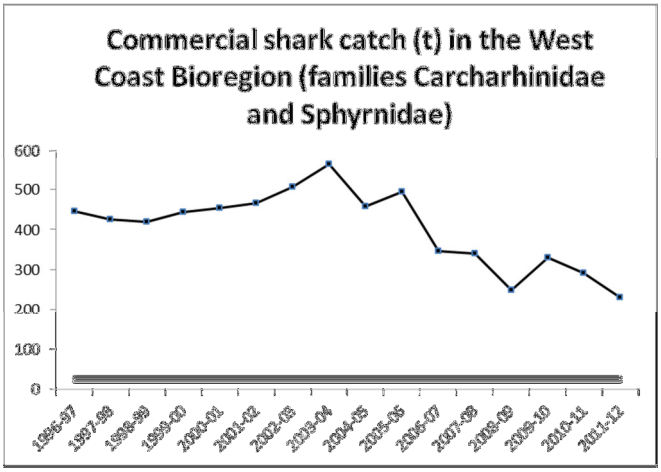

Figure 11. The total commercial catch of sharks in the West Coast Bioregion since 1996/97.

Risk Analysis

The ecosystem impacts of the various fisheries in the West Coast Bioregion, including those generated by the historical levels of catch by the various shark fisheries, have already been investigated by Hall and Wise (2011). Their assessments of the community structure and trophic level of all commercially caught fish species in the West Coast Bioregion over the past 30 years found no evidence that there have been any systematic changes. Therefore, there is no indication that the fish faunas have been impacted by the historic levels of shark catch taken by the various commercial fisheries that operated in the WCB to the extent that ecosystem function was materially affected (Hall and Wise 2011).

As the expected annual cumulative total for all shark captures by the Program is relatively small (< 10% of historical levels) and even when combined with current commercial catches this still represents only 50% of historical levels of the total catch of the suite of sharks species. Given that the historical level of catch (>500t) was not found to have generated any measurable shift in the community structure for the broader fish community for this bioregion, the additional 45 t of sharks to be captured by this Program is **highly likely** (Likelihood 5) to have **no measurable effect** (Consequence Level 0) on community structure which generates a **Risk Score of 0**.

Risk Evaluation

Given the comparatively healthy status of populations of large coastal sharks in WA, the high level of functional redundancy in the ecosystem, the lack of any measurable changes observed when catch levels of this suite were much higher, it is not plausible that the removal of an additional 45 tonnes of common species of sharks per annum from limited areas over just three years would initiate material changes to the fish or other assemblages of the West Coast Bioregion.

The Program therefore represents **a negligible risk** to functioning of the community structure of the marine ecosystems within the West Coast bioregion.

This is an acceptable level of risk with no actions necessary.

Conclusions

The potential risks to targeted and non-targeted species arising from implementation of the set of activities listed within the proposed Marine Monitored Areas strategy were assessed using risk assessment methods that conform to international standards (ISO 31000, 2009; AS, 2012). These procedures used the information currently available which included, but was not limited to, the results obtained from the trial drum line program completed in Jan- April 2014.

The Program as proposed, which includes significant risk mitigation components, was assessed as posing only negligible risks to the population status of two of the three targeted species, the non-targeted species and the broader ecosystem (Table 3). It identified, however, that the Program represents a low level of risk to the tiger shark population off WA. This acceptable level of risk requires a higher level of monitoring and a specific assessment for tiger sharks to be completed at the end of the Program.

Prior to the trial Program, the potential catch of large dusky sharks was identified as an issue that may require additional management interventions (DoF 2014a). However, with only one individual caught during the trial program, this meant that no intervention was required. Additional acoustic tracking data now available on their more offshore migration routes suggests their rates of capture during the proposed Program are most likely to remain at the observed insignificant levels. The risk to this stock is therefore now considered to be negligible.

The rate of capture for other potential or actual bycatch species (including all relevant listed, threatened or migratory species) found during the trial program was, as predicted, low or non-existent. These rates of capture are expected to all remain at their very low or non-existent levels for the proposed Program. Consequently, for all of these non-target species, the risks of the Program are considered negligible.

In terms of potentially generating broader ecosystem effects, the Program is expected to generate negligible impacts on each of the species which is also consistent with no trophic impacts being generated. The cumulative total for all captures of all species is very small

(45t/year) when compared to the total combined levels of commercial capture of sharks and other fish species that previously occurred within this bioregion (> 500 t/year). This historical level was found to not have generated any measurable shift in the community structure for this region (Hall & Wise, 2011). Following a series of management interventions over the past decade (a major component being their removal from the metropolitan region for sectoral allocation purposes), the level of commercial shark capture in the WCB has been reduced from 500 t to less than 250 t annually, and is expected to operate at this lower level into the future. Consequently, the additional 45 t/year of sharks to be captured by this Program poses a negligible risk to the community structure of the Leeuwin-Naturaliste ecosystem.

A significant factor in determining these risk levels was the set of risk mitigation procedures that have been proposed. These include (1) the short duration of the proposed activities (15 November – 30 April), (2) the proposal is for just three years, (3) the very limited geographic extent of their operation compared to the broad distribution of the potentially affected species and (4) the gear configuration (including hook size and design) which has demonstrably kept the level of bycatch species to a minimum, especially non sharks species, (5) the high level of monitoring of the gear which enables release of non-targeted captures.

If this Program, or similar was to continue beyond the current three year proposal period (2017) or extended to other geographic areas, a further risk assessment may be necessary where this is considered to potential increase cumulative impacts.

Given the documented influences of environmental conditions on the spatial and temporal distribution of many species in the West Coast bioregion, it is recommended that annual reviews of the actual versus anticipated catches are undertaken. Furthermore, if the rates of capture of one or more listed species/groups begins to materially exceed the levels outlined above, a within season review of the risks would also be appropriate.

Table 3. Summary of the Risk Analysis, Risk Scores and Risk Evaluations (see text above for full details).

Component	Risk Analysis	Risk Scores	Risk Evaluation
TARGET SPECIES			
White Sharks	With annual catch levels anticipated to be < 10 per year there is only a remote likelihood (Likelihood Level 1) that this could have even a measurable level of impact (Consequence Level 1) on the total size of the southwestern Australian population of white sharks	1	Negligible
Tiger Sharks	If the levels of capture of tiger sharks remain within the anticipated levels and assuming high levels of release mortality rates this level of annual mortality (40t) for three years it would be **possible** (Likelihood Level 3) for the program to generate a **minor consequence**	3	Low

	(Consequence Level 1). This level of risk presents no concerns for their population viability.		
Bull Sharks	Anticipated capture rate is none to a few individuals each year. Therefore there is a high likelihood the Program will have no impact (Consequence Level 0).	0	Negligible
NON TARGET SPECIES			
Dusky Sharks	If the annual level of capture and mortality of large dusky sharks remains in revised anticipated range (< 10), there is now only a **remote likelihood** (Likelihood Level 1) of **a minor level of impact** (Consequence Level 1).	1	Negligible
Other Non-Listed Elasmobranchs	There is a **high likelihood** (Likelihood Level 5) few individuals from each of the other species of sharks and rays will be caught and the rays are likely to be released alive and survive and therefore generate **negligible impacts** (Consequence Level 0).	0	Negligible
Demersal Scalefish	There is a **high likelihood** (Likelihood Level 5) that **no demersal finfish** will be caught and also that few, if any, other finfish species will be caught (Consequence Level 0).	0	Negligible
PROTECTED OR LISTED SPECIES			
Grey Nurse	There is a **high likelihood** that no grey nurse sharks will be caught and, even if a few are caught they are most likely able to be released alive resulting in **no** or **negligible impacts** (Consequence Level 0).	0	Negligible
Shortfin Mako	There is a **high likelihood** that this program will have a **negligible impact** (Consequence Level 0) on shortfin mako shark population of Australia	0	Negligible
Other Listed Elasmobranchs	There is a **high likelihood** (Likelihood Level 5) that no whale sharks, manta rays or other listed species of sharks and rays will be caught resulting in **no** or n**egligible impacts** (Consequence Level 0)	0	Negligible
Pinnipeds	With no seal or sea lion captures anticipated to occur there is a high likelihood of no impact (Consequence Level 0),	0	Negligible
Turtles	With no captures of turtles anticipated to occur there is a high likelihood of no impact (Consequence Level 0)	0	Negligible
Whales	With no captures of whales anticipated to occur there is a high likelihood of no impact (Consequence Level 0)	0	Negligible
Dolphins	With no captures of dolphins anticipated to occur there is a high likelihood of no impact (Consequence Level 0)	0	Negligible
Seabirds	With no captures of seabirds anticipated to	0	Negligible

	occur there is a high likelihood of no impact (Consequence Level 0)		
ECOSYSTEM			
Habitat	The extremely small footprint of the anchors used for the drum-lines and the high resilience of the sandy substrates where most are deployed results in **high likelihood** (Likelihood Level 5) of only **negligible impacts** (Consequence Level 0)	0	Negligible
Community Structure	Given that the high historical level of commercial catch of sharks in this region (>500t) was not found to have generated any measurable shift in the community structure for the broader fish community. Now that this catch has been reduced by 250t, an additional 45 t of sharks to be captured by this Program is **highly likely** (Likelihood 5) to have **no measurable effect** (Consequence Level 0) on community structure of the West Coast Bioregion	0	Negligible

Key References consulted or cited.

Baum, J.K & Myers, R. (2004). Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. *Ecology Letters* 7:135–145

Braccini, M., McAuley, R. & F. Rowland (2013). Temperate Demersal Gillnet and Demersal Longline fisheries Status report. Pp 271-279 In: *Status Reports of the fisheries and aquatic resources of Western Australia 2012/13*. Department of Fisheries, Western Australia.

Blower, D. C., J. M. Pandolfi, B. D. Bruce, M. D. Gomez-Cabrera, and J. R. Ovenden. (2012). Population genetics of Australian white sharks reveals fine-scale spatial structure, transoceanic dispersal events and low effective population sizes. Marine Ecology-Progress Series **455**:229–244.

Bruce, B. D. (2008). White sharks: the biology and ecology of Carcharodon carcharias. Pages 69–81 in E. Pikitch and M. Camhi, editors. Sharks of the Open Ocean. Blackwell Scientific.

Bruce, B. D., and R. W. Bradford. (2012). Habitat use and spatial dynamics of juvenile white sharks, Carcharodon carcharias, in eastern Australia. Pages 225–254 in M. L. Domeier, editor. Global

Braccini, M., J. Van Rijn, and L. Frick. (2012). High post-capture survival for sharks, rays and chimaeras discarded in the main shark fishery of Australia? PloS one **7**:e32547.

Bruce, B. D., J. D. Stevens, and H. Malcolm. (2006). Movements and swimming behaviour of white sharks (Carcharodon carcharias) in Australian waters. Marine Biology **150**:161–172.

Caputi, N., Jackson, G. and Pearce, A. (2014). The marine heat wave off Western Australia during the summer of 2010/11 – 2 years on. Fisheries Research Report No. 250. Department of Fisheries, Western Australia.

Cavanagh et al., (2003). The conservation status of Australian chondrichthyans: report of the IUCN Shark Specialist Group Australia and Oceania Regional Red List Workshop, University of Queensland, Brisbane, p. 170.

Chidlow et al., (2006). Identification of Western Australian Grey Nurse Shark aggregation sites - Final Report to the Australian Government, Department of the Environment and Heritage, May 2006. *Fisheries Research Report* No. 155, Department of Fisheries, Western Australia, pp 48.

Cliff, G and Dudley, S. F. J. (2011). Reducing the environmental impact of shark-control programs: a case study from KwaZulu-Natal, South Africa. *Marine and Freshwater Research* 62: 700-709.

CoA (2006). A guide to the integrated marine and coastal regionalisation of Australia. V 4. Department of Environment and Heritage, Canberra.

CoA (2010). Legislative changes for recreational fishing of three shark species. Department of Environment, Water, Heritage and the Arts MAR 21.0810.

Cochrane, K. (2013). 10 Must-Be-Read Publications on the Ecosystem Approach to Fisheries. *Forum for Ocean Planning and Management*. http://openchannels.org/literature-library-top-lists/10-must-be-read-publications-ecosystem-approach-fisheries

Cochrane, K.L., Augustyn, C.J. and M.J. O'Toole. (2008). The implementation of the ecosystem approach to fisheries management in the Benguela Region: Experiences, advances and problems. In: Bianchi G. and Skoldal H.R. (eds.), *The Ecosystem Approach to Fisheries*. FAO CABI. 262-292

Department of Fisheries. (2006). Application to the Australian Government Department of Environment and Heritage on the Western Australian Tropical Shark Fisheries (covering the Western Australia North Coast Shark Fishery and the Joint Authority Northern Shark Fishery).

Department of Fisheries (2012). A correlation study of the potential risk factors associated with white shark attacks in Western Australian waters. *Fisheries Occasional Paper* 109. Department of Fisheries, WA.

Department of Fisheries (2013). *State of the Fisheries and Aquatic Resources of Western Australia 2012/13.* Department of Fisheries, Western Australia.

Department of Fisheries (2014a). Research Advice on the Proposed Shark Mitigation Strategy using drum lines for January to April 2014. Department of Fisheries, Western Australia, January 2014. Published on EPA website 12 February 2014. 8 pp.

Department of Fisheries (2014b). Review of the outcomes from the drum line component of the Shark Mitigation Strategy for the trial period January - April 2017. Report submitted to the Department of Premier and Cabinet, May 2014. Department of Fisheries, Western Australia.

Department of Fisheries (in prep). A risk-based, weight of evidence approach to determine the range of plausible estimates for the southwestern Australian population of white sharks. *Fisheries Research Report*, Department of Fisheries, Western Australia (in preparation).

Dudley, SFJ (1997). A comparison of the shark control programs of New South Wales and Queensland (Australia) and KwaZulu-Natal (South Africa). *Ocean Coastal Management* 34:1-27.

EPA, (2014a). EPA determines not to assess shark drum-line proposal. PUBLIC ADVICE UNDER SECTION 39A(7) *ENVIRONMENTAL PROTECTION ACT 1986* March 12 2014. 5pp. Environment Protection Authority, Perth, Western Australia. http://www.epa.wa.gov.au/News/mediaStmnts/Documents/Media%20Statement%20Shark%20Drum%20Line%20March%202014%20and%20public%20advice.pdf

EPA (2014b). Environmental Scoping Document. Western Australian Shark Hazard Mitigation Drum Line Program 2014-217 (Assessment No 2005).

FAO, (2012). EAF Toolbox: The ecosystem approach to fisheries. FAO Rome, 172 pp. www.fao.org/fishery/eaf-net/

Fletcher, W.J. (2005). Application of Qualitative Risk Assessment Methodology to Prioritise Issues for Fisheries Management. *ICES Journal of Marine Research* 62:1576-1587

Fletcher, W.J. (2008). Implementing an Ecosystem Approach to Fisheries Management: Lessons learned from applying a practical EAFM framework in Australia and the Pacific. In Bianchi, G. and Skjoldal, H.R. (Eds). 2008. The Ecosystem Approach to Fisheries. FAO-CABI Rome pp. 112-124

Fletcher, W.J., Chesson, J., Fisher M., Sainsbury, K.J., Hundloe, T., Smith, A.D.M. and B. Whitworth (2002). *National ESD Reporting Framework for Australian Fisheries: The* 'How To' *Guide for Wild Capture Fisheries*. FRDC Project 2000/145, Canberra, Australia. 120pp (http://www.fisheries-esd.com/a/pdf/WildCaptureFisheries_V1_01.pdf)

Fletcher, W.J., Chesson, J., Sainsbury, K.J., Fisher, M. & T. Hundloe (2005). A flexible and practical framework for reporting on ecologically sustainable development for wild capture fisheries. *Fisheries Research* 71:175-183

Fletcher, W.J., G. Bianchi (2014). The FAO – EAF toolbox: Making the ecosystem approach accessible to all fisheries. *Ocean. Coast. Manag*. 90:20-26.

Fletcher, W.J., Shaw, J., Metcalf S.J. & D.J. Gaughan. (2010). An Ecosystem Based Fisheries Management framework: the efficient, regional-level planning tool for management agencies. *Marine Policy* 34:1226–1238

Hall, N.G. and B.S, Wise. (2011). Development of an ecosystem approach to the monitoring and management of Western Australian fisheries. FRDC Final Report 2005/063 *Fisheries Research Report*, 215 Department of Fisheries,Western Australia.

Hazin, F.H.Z. and Afonso, A.S. (2013). A green strategy for shark attack mitigation off Recife, Brazil. *Animal Conservation*. In press.

Heithaus et al. (2008). Predicting ecological consequences of marine top predator declines. *Trends in Ecology and Evolution* 23:202-210.

Henry, G.W. & Lyle, J.M. (2001). National recreational and indigenous fishing survey. Final report FRDC project 99/158. DAFF Canberra, 188pp

Heupel, M and McAuley, R. (2007). Sharks and rays (Chondrichthyans) in the North-west Marine Region. *Final report to Department of the Environment and Water Resources*, National Oceans Office Branch, 123 pp.

IEC/ISO 31010. (2009). International Standard. Risk management – Risk assessment techniques. International Electrotechno Commission. Geneva, Switzerland. 90pp.

ISO (2009). Risk management – principles and guidelines. 31000. International Organisation of Standards, Geneva. Switzerland 24pp.

Jones, J.B. and Fletcher, W.J. (2012). Assessment of the risk associated with the release of abalone sourced from abalone hatcheries for enhancement or marine grow-out in the open ocean areas of WA. *Fisheries Research Report* No. 227, Department of Fisheries, Western Australia 20pp.

Last, P. R., and J. D. Stevens. (2009). Sharks and Rays of AustraliaSecond edi. Harvard University Press, Cambridge, Massachusetts. London, England.

Linkov I, Loney D, Cormier S, Satterstrom FK, Bridges T. (2009). Weight-of-evidence evaluation in environmental assessment: Review of qualitative and quantitative approaches. *Science of the Total Environment*. 407: 5199-5205.

McAuley, R et al. (2005). Biology and stock assessment of the thickskin (sandbar) shark, *Carcharhinus plumbeus*, in Western Australia and further refinement of the dusky shark, *Carcharhinus obscurus*, stock assessment, Final FRDC Report – Project 2000/134, *Fisheries Research Report* No. 151, Department of Fisheries, Western Australia, 132 pp.

McAuley, R. and Simpfendorfer C. (2003). Catch composition of the Western Australian temperate demersal gillnet and demersal longline fisheries, 1994 to 1999, *Fisheries Research Report* No. 146, Department of Fisheries, Western Australia, 78 pp.

McPhee, D (2012). Likely effectiveness of netting or other capture programs as a shark hazard mitigation strategy in Western Australia. *Fisheries Occasional Paper* 108. Department of Fisheries, WA.

Malcolm, H., B. D. Bruce, and J. D. S. September. (2001). A review of the biology and status of white sharks in Australian waters. 113pp. CSIRO Marine Research, Hobart.

Myers, R. et al. (2007) Cascading effects of the loss of apex predatory sharks from a coastal ocean. *Science* 315: 1846-1850

Paine, R.T. (1966). Food web complexity and species diversity. *Am. Nat*. 100:65-75

Pauly, D. et al., (1998). Fishing down marine food webs. *Science* 279:860-863.

Pearce, A. et al. (2011). The "marine heat wave" off Western Australia during the summer of 2010/11. *Fisheries Research Report* No. 222, Department of Fisheries, Western Australia.

Powers et al., (1996). Challenges in the quest for keystones. *Bioscience* 46:609-620.

Reid D. et al. (2011) Decadal trends in shark catches and effort from the New South Wales, Australia, shark meshing program 1950 – 2010. *Marine and Freshwater Research* 62: 676-693.

Ryan, K et al. (2013). An integrated system to survey boat-based recreational fishing in Western Australia 2011/2012. *Fisheries Research Report* No. 249, Department of Fisheries, Western Australia, 162 pp.

Standards Australia (2012). Risk management – guidelines on risk assessment techniques. HB 89; 92pp. Standards Australia Limited. Sydney, Australia.

Stevens, J.D. and McLoughlin, K.J. (1991). Distribution, Population Structure, Reproductive Biology and Diet of Sharks from Northern Australia. *Marine and Freshwater Research* 42, 151-99

Stoklosa, R. (2013). West Coast Lobster Fishery Ecological Risk Assessment 20 February 2013. *Fisheries Occasional Paper* 118. Department of Fisheries, Western Australia. 99pp.

Sumpton, W. et al., (2011) Gear selectivity of large-mesh nets and drumlins used to catch sharks in the Queensland Shark Control Program. *African Journal Marine Science* 33:37-43.

WA Govt. (2012) Shark Response Unit. http://www.fish.wa.gov.au/Education-and-Partnerships/Shark-Hazard/shark-response-unit/Pages/default.aspx

WA Govt. (2013) New measures to combat WA shark risks. http://www.fish.wa.gov.au/About-Us/Media-releases/Pages/New-measures-to-combat-WA-shark-risks.aspx Dec 12 2013.

Wetherbee et al., (1994). A review of shark control in Hawaii with recommendations for future research. *Pacific Science* 48, (2): 95-115.

Wise, B.S., St John, J., Lenanton, R.C.J. (2007). Spatial Scales of Exploitation among Populations of Demersal Scalefish: Implications for Management. Stock Status of the Key Indicator Species for the Demersal Scalefish Fishery in the West Coast Bioregion. *Fisheries Research Report* 163. Department of Fisheries.

Appendix 1 - RISK ASSESSMENT CATEGORIES AND LEVELS

LIKELIHOOD LEVELS

1. Remote - Never heard of but not impossible in situation and time frame. (<5% probability)
2. Unlikely - May occur here, but only in exceptional circumstances. (5 - 30%)
3. Possible - Clear evidence to suggest this is possible in this situation. (30- 50%)
4. Likely - It is likely, but not certain, to occur here. (50-90%)
5. High Likely -It is almost certain to occur here (>90%)

CONSEQUENCE LEVELS

STOCKS (target and non-target effective population viability)

0. No measurable decline
1. Measurable but minor levels of depletion to stocks with no effect on population viability.
2. Maximum acceptable level of depletion of stock with no effect population viability
3. Level of depletion unacceptable but still not significantly affecting recruitment levels or longer term population viability
4. Level of depletion of fish stocks are already (or will definitely if current arrangements continue) affect future recruitment potential/levels of stock and possibly longer term viability.
5. Permanent or widespread and long term depletion of stock, significantly reduced viability and/or close to extinction levels.

HABITAT

0. No measurable change.
1. Measurable impacts to habitats but still not considered to impact on habitat dynamics or system
2. Maximum acceptable level of impact to habitat with no long term impacts on region wide habitat dynamics
3. Above acceptable level of loss/impact with region wide dynamics or related systems may begin to be impacted
4. Level of habitat loss clearly generating region wide effects on dynamics and related systems
5. Total region wide loss of habitat and associated systems

ECOSYSTEMS

0. No measurable change.

1. Measurable but minor change in the environment or ecosystem structure but no measurable change to function
2. Maximum acceptable level of change in the environment/ecosystem structure with no material change in function.
3. Ecosystem function altered to an unacceptable level with some function or major components now missing &/or new species are prevalent.
4. Long term, significant impact with an extreme change to both ecosystem structure and function. Different dynamics now occur with different species/groups now the major targets of capture or surveys.
5. Permanent or widespread long term damage to the environment. Total collapse or complete shift of ecosystem processes.
