Evaluation of the potential effects of the Perth Metropolitan commercial fishing closure to the risks of shark attacks

Department of Fisheries, Science and Resource Assessment Division
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Introduction

Between September 2011 and July 2012 there were five fatal incidents involving white sharks (*Carcharodon carcharias*) off the lower west coast of Western Australia (WA), as well as a number of other highly-publicised non-fatal encounters with this species. In 2012, the State Government funded several new initiatives to better understand white sharks in WA and the likely effectiveness of any community safety interventions in WA waters. The four research studies have now been completed, including a correlation study of the potential risk factors associated with white shark attacks in WA (DoF, 2012); a study on the effectiveness of shark meshing and shark exclusion barriers as a shark hazard mitigation strategy in WA (McPhee, 2012), a study that investigated the movement patterns of white sharks and evaluated passive acoustic telemetry approaches for monitoring and mitigating shark hazards off the coast of WA (McAuley et al. 2016) and most recently, a study that examined historical catch levels and potential population trajectories for the entire south-western (SW) Australian population of white sharks (Taylor, et al., in press).

Following a further two fatal shark attacks within the metropolitan region during May 2016, the Department of Fisheries was requested to provide advice on one of the factors that may have affected the rate of shark attacks in this region, specifically the 2007 closure of the West Coast Demersal Gillnet and Demersal Longline Fishery ('west coast shark fishery') in the metropolitan region (Lancelin to Mandurah, the 'metropolitan shark fishery'). The main objective of this study was therefore to provide advice on the potential change in relative risks to ocean users that may be generated from this fishery being re-opened in this region. In providing the advice we have also assessed the potential impacts re-opening the fishery could have on meeting other fishery management objectives established within this and other regions.

To complete the examinations of the potential impacts we have accounted for a number of other potential contributing factors. These include the significant management changes that have been made to the other associated fisheries within the West Coast Bioregion and the management changes for fisheries in other regions that may also capture white sharks. Furthermore, as white sharks are highly mobile (Malcolm et al. 2001; McAuley et al. 2016) it is possible for the regional distribution, and therefore the relative abundance of white sharks in the Perth metropolitan area, to differ within/between years. This could affect encounter rates without there having been any material changes in the total population size. Similarly, other biotic and/or abiotic factors can influence the distribution and 'local abundance' of white sharks (DoF, 2012) which makes it more difficult to assess how an increased probability of capture through renewed fishing activity influences the risk posed to ocean users. A number of theories have been proposed which could, either individually or

collectively, play a role in influencing the rates of encounters between white sharks and humans. These are briefly described below as 'direct' and 'indirect' mechanisms.

Conceptual framework

To examine the potential changes to the rates of white shark encounters and attacks on ocean users within the metropolitan area required:
(A) Outlining the potential direct and indirect mechanisms by which these risk levels may have been altered by the closure of the gillnet fishery within the metropolitan region, and;
(B) Determining what other factors (including changes that have occurred to other fisheries in this and other regions) needed to be considered when predicting the impact of any recommencement of fishing activities within the metropolitan region.

A. Direct and Indirect mechanisms

The closure of the 'west coast shark fishery' in the metropolitan region may have potentially increased the risks to ocean users by directly affecting the overall and/or local abundance of white sharks and/or potentially by indirectly affecting sharks' behaviour. These are defined more precisely below:

Direct. The closure of the 'west coast shark fishery' could have resulted in a reduction in the level of capture and mortality of white sharks (noting that white sharks have been protected since 1997 under both State and Commonwealth legislation) within this region which could potentially have had:

(1) a material effect on the overall abundance of white sharks and therefore the likelihood of encounters in the metropolitan region.

(2) no material effect on overall abundance but the fishery may have previously 'removed' those sharks that otherwise might have had relatively long periods of residency in the metropolitan area.

Indirect: Potential indirect effects from closure of the fishery include:

(3) the reduced level of fishing on targeted shark species and demersal scalefish (many of which are potential white shark prey) may have generated an increase in the overall abundance of white sharks and therefore increased the likelihood of sharks frequenting this region and/or staying longer within this region.

B. Other Considerations

To ensure that the advice on the potential effects from the establishment of the existing closure and the potential for any re-commencement of commercial shark fishing (and/or other commercial or recreational fisheries) in the metropolitan region is robust requires appropriate consideration of the other factors that may affect white sharks abundance or behaviours. Furthermore, examination of the impacts on other management objectives from a re-opened metropolitan shark fishery must also be undertaken. These include:

(4) as there is strong evidence for two separate populations of white sharks in Australian waters, combined with the wide ranging movements of individual white sharks that form the SW Australian population (McAuley et al., 2016) any examination of the potential changes to their local abundance within the metropolitan region must also consider the effects generated from previous or proposed changes in commercial fishing effort within other shark fisheries located both south and north of the metropolitan region. These include changes in fishing effort plus the closures off Ningaloo and elsewhere in the Gascoyne, the whiskery shark pupping closures[1], plus the potential additional restrictions that may be required for the Commonwealth's Marine Bioregional Planning and their Australian Sea Lion (ASL) closures.

(5) the changes in commercial fishing effort by shark fisheries located outside of the metropolitan region could also have influenced the abundance of other species of sharks. This may also affect the level of sightings of all species of sharks within the metropolitan region and the levels of risk.

(6) the significant changes to the levels of fishing effort in other commercial and recreational fisheries within the metropolitan region that could also have affected the relative abundance of prey species of white sharks (e.g. reduced catch levels of demersal scalefish by commercial and recreational line fishing) plus the reduction in capture levels of white sharks through cessation of using hooks on pot lines and net floats in the rock lobster fishery (see Taylor et al, in press).

(7) the potential impacts a re-opened shark fishery in the metropolitan fishery could have on the stock status objectives for other species. This includes ensuring that this would not impact on the current management objectives for rebuilding both demersal finfish stocks (e.g. dhufish and snapper) and some shark stocks (e.g. sandbar and dusky sharks) within this region.

(8) the potential effects on previous sectoral allocation decisions (i.e. Integrated Fisheries Management (IFM) outcomes) made for West Coast Demersal Scalefish as the basis for closing the metropolitan shark fishery to allocate this region to the recreational sector.

(9) the strong possibility that commercial fishing effort would not return to previous levels even if re-opened (including current and likely future economic returns, community and social attitudes, impacts of Commonwealth marine zoning within the metropolitan region).

Data Sources and Assumptions

To provide advice on the questions outlined above we have examined the information available on each of the relevant commercial and recreational fisheries that have operated, or are still operating in the metropolitan region plus, where relevant, those that operate in other regions. This includes the catch and effort data available for the fisheries directly affected by the metropolitan closure and/or other management actions within this region including the West Coast Demersal Gillnet and Demersal Longline Fishery, the West Coast Demersal Scalefish Managed Fishery and the West Coast Demersal Scalefish Recreational fishery. Summaries of these data are available from the Department's annual publication - *Status Reports on the Fisheries and Aquatic Resources of WA* (Fletcher & Santoro, 2015).

[1] The whiskery pupping closures occurred for a two month period (August-October) from 2006-2011 and for a one month period (September) between 2012 – 2013, for all inshore waters to 200 m depth throughout all of the WCDGDLF and the waters of the South Coast west of 118° E (in the JASDGDLF) to assist in the recovery of the over-exploited whiskery shark stock.

As outlined above, an examination of the potential effects of the Perth metropolitan closure on the local and total abundance of the SW population of white sharks requires the consideration of all potential WA sources of mortality on this population. Consequently we also have examined the relevant catch and effort data from the Joint Authority Southern Demersal Gillnet and Demersal Longline Fishery and the Northern Shark Fisheries which are the commercial shark fisheries that operate to the south and north of the metropolitan region, respectively. Summaries of these data are also available within the annual status reports (Fletcher and Santoro, 2015).

The specific estimates of white shark captures used within this study were obtained from the comprehensive study by Taylor et al. (in press). This study examined the effects on the overall abundance of the SW Australian population of white sharks (which covers the area west of Bass Strait across SA and up to northern WA) by estimating the changes in annual catch levels that have resulted from the fishery management changes and other restrictions during the period 1939-2012 (Taylor et al., in press).

Similarly, relevant information generated from the studies completed by McPhee (2012) on the relative effectiveness of shark netting programs and the study by McAuley et al. (2016) on the movement of tagged white sharks off WA has also been incorporated within the analyses where relevant.

Finally, the assessments of the likelihood associated with each of the possible direct and indirect effects being generated from the metropolitan closure were made based on the use of ISO31000 risk analysis methodologies (see Fletcher, 2015 for details).

Background Information

Overview of the 'Metropolitan Shark Fishery'

Historically, most commercial shark fishing within the West Coast Bioregion was undertaken by licence holders within the West Coast Demersal Gillnet and Demersal Longline Fishery (WCDGDLF). This fishery extends from 33° S (just north of Bunbury) to 26° S longitude (the Shark Bay region) and therefore encompasses the Perth metropolitan region (Figure 1). The shark fishery that operates south of Bunbury and across to the WA/SA border is the Joint Authority Southern Demersal Gillnet and Demersal Longline Fishery (JASDGDLF; Figure 1). As these two fisheries have similarities in fishing methods, target stocks and management arrangements they are collectively known as the Western Australian Temperate Demersal Gillnet and Demersal Longline Fisheries (TDFGDLF). Fishers in the TDGDLF have traditionally targeted adult gummy and whiskery sharks plus juvenile dusky and sandbar sharks using bottom-set monofilament gillnets of typically 15.2 or 17.8 cm (stretched) mesh sizes, but they have also landed a wide range of other shark species and a variety of scalefish species (McAuley et al, 2015).

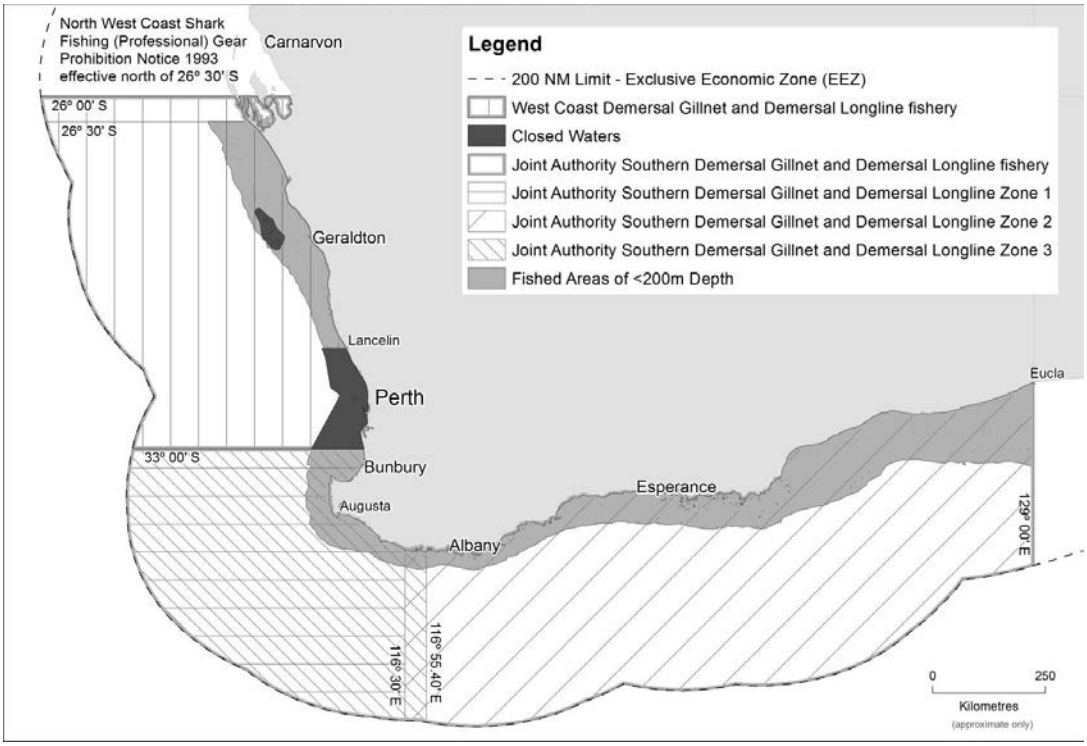

Figure 1. Management boundaries of the Joint Authority Southern Demersal Gillnet and Demersal Longline Fishery (JASDGDLF) and West Coast Demersal Gillnet and Demersal Longline Fishery (WCDGDLF). Grey shading represents fished areas of less than 200m depth.

Significant changes were implemented for the WCDGDLF after 2006 to deal with sustainability and sectoral issues associated with the west coast demersal scalefish resource (see next section for details). This package of management changes included the closure of the 'shark' gillnet fishery in metropolitan waters and significant effort reductions elsewhere. This precipitated a Government-funded Voluntary Fishery Adjustment Scheme that bought out 35% of WCDGDLF effort units (at a cost of approximately $5 million) which resulted in a large proportion of the remaining effort units changing hands to new operators.

These changes not only led to the end of all commercial shark captures within metropolitan waters but also to a significant decline of catch and effort across the entire WCDGDLF. The current levels of annual catch and effort levels are now <20% and only 10%, respectively, of the peak years (Figure 2). The remaining effort within the West Coast has mainly shifted to the areas of the fishery that are north of the Perth metropolitan region.

The future levels of effort for the WCDGDLF are likely to be further affected by a number of Commonwealth initiatives, including the Commonwealth Marine Bioregional Planning program plus a separate ASL closure initiative, both of which would exclude gillnetting from large areas (see below for more details).

Target Species: As this was a shark fishery, the main impact from the reductions in effort during 2006/07 resulted in reduced catches, especially of sandbar and dusky sharks. Given the life history of these species, full recovery to management targets is expected to take in the order of several decades. Nonetheless, with the reductions in effort and catches in the West Coast after 2006, (and the closure of areas of the Northern shark fisheries, starting in 2005 with full closure in 2009), these stocks have had some time to commence rebuilding and there has been an increasing trend in the catch per unit of effort (CPUE) for dusky sharks over the past 8 years (DoF, 2015).

Demersal scalefish are a byproduct species of demersal gillnet fisheries and therefore only comprised approximately 10-15% of catches of the TDGDLF sector, including the West Coast sector (WCDGDLF). The fisheries that captured the majority of demersal scalefish were the commercial wetline fleet and the recreational line sector which are covered in the West Coast Demersal Scalefish Fisheries section. The reductions in WCDGDLF effort due to the metropolitan closure reduced scalefish catches but by a much smaller amount than the declines in shark catches (Figure 2). This reduction, while relatively minor was still factored into the calculation of what overall reductions in catch levels were required by all sectors (see West Coast Demersal Scalefish Fisheries section for full details).

White Sharks: The TDGDLF is known to be the main source of white shark catches in Western Australia (Malcolm et al. 2001; McAuley & Simpfendorfer 2003). Detailed white shark catch reconstructions for the WCDGLF were completed by Taylor et al., (in press) but these estimates were for the entire WCDGDLF, not specifically for the Perth metropolitan region which would therefore have been only a subset of these totals. The values for current and historic levels of capture are presented in the analysis section.

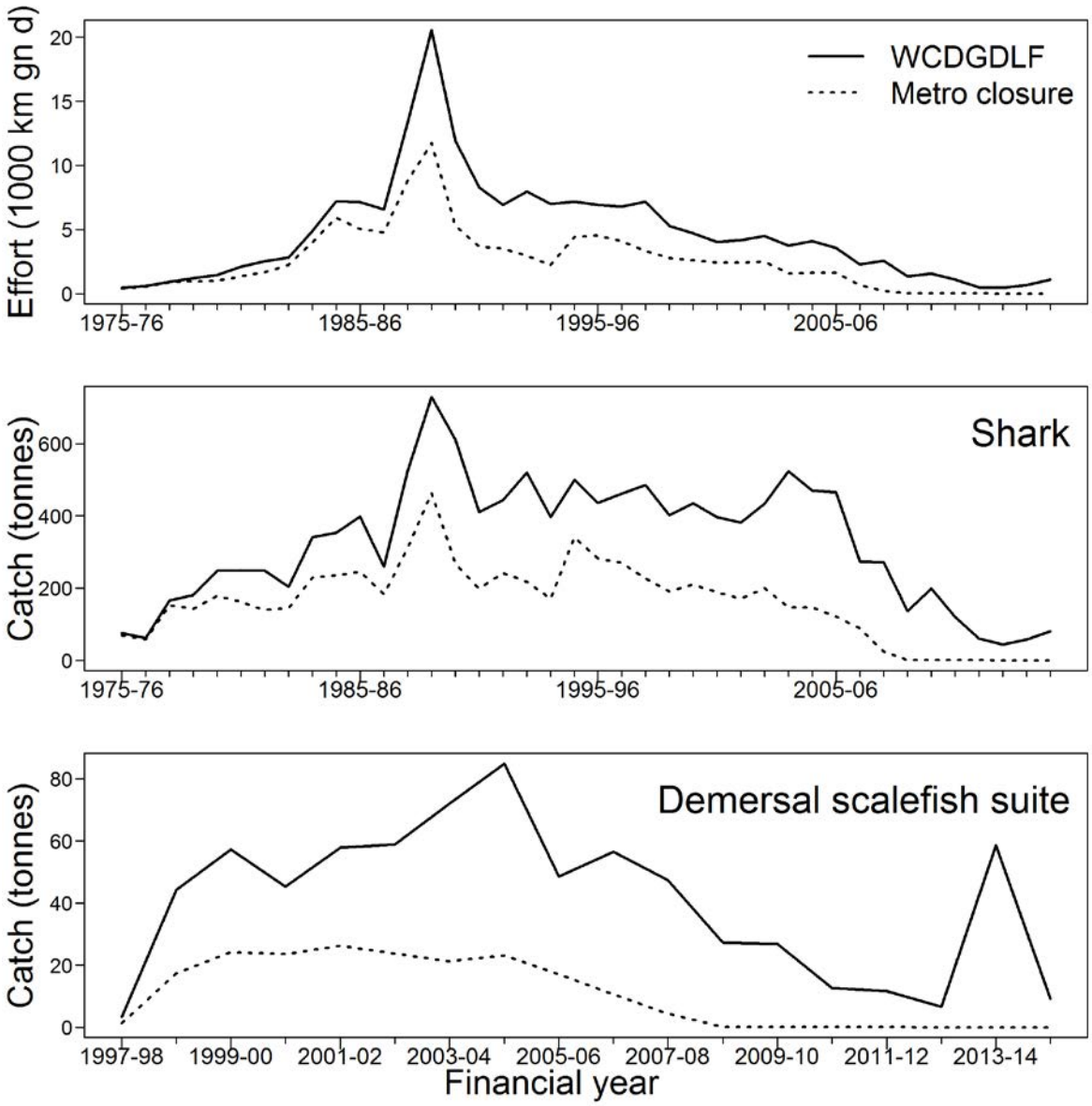

Figure 2. Fishing effort, shark and demersal scalefish suite component catch in the West Coast Demersal Gillnet and Demersal Longline Fishery and within the Metro closure.

Overview of the West Coast Demersal Scalefish Fisheries

Commercial line based catches of demersal scalefish (the 'wet line' fishery) in the West Coast Bioregion (WCB) increased during the 1990s to the mid-2000s (Figure 3) but even by the early 2000s, commercial and recreational fishers had reported increasing difficulties catching fish. A stock assessment of the indicator species for the demersal suite (West Australian dhufish, pink snapper and Baldchin groper) completed in 2007 identified that overfishing of this resource had been occurring (Wise et al., 2007). Significant management changes to all fisheries that captured demersal species in the WCB were made between late 2007 and early 2010 in order to initiate recovery of these stocks. The measures were designed to achieve a catch reduction of at least 50% of

2005/06 catches (the 'benchmark') by each sector which involved a reduction in effort in the commercial (WCDSF and TDGDLF) and recreational sectors. The catch benchmarks designed to allow these stocks to rebuild at an appropriate rate are still in place (Fairclough et al., 2014, 2015).

The main additional management measures implemented to achieve these catch benchmarks included the commencement of a limited entry/limited effort managed commercial line fishery which significantly reduced the overall level of effort in this fishery. For the recreational sector, changes introduced to their fishery between 2009-2010 included reductions to recreational bag and boat limits, a two month closure to fishing for demersal species each year (mid-October to mid-December) and the requirement to hold a recreational license to fish from a powered boat. In addition, largely to address sectoral allocation issues for demersal scalefish, at the end of 2007, the Metropolitan Area (31°–33°S) was closed to both commercial handline and gillnet/longline fishing.

Target Species: The 2007 package of management measures reduced catches by both the commercial and recreational line sectors below their respective benchmarks (Fairclough et al. 2015). The first assessment of the key species since management changes were introduced indicated that fishing mortality rates had stabilised in at least some management areas of the WCDSF resource (Fairclough et al. 2014). A subsequent assessment is due to be completed in 2016/17 which will identify the extent to which recovery is now occurring. Nonetheless, with the closure of the metropolitan area to commercial line and net fishing and the 50% reductions in catches throughout the West Coast from all sectors, it is likely that the stocks of at least some scalefish species have had increases in their abundances. However, given the biology of many demersal scalefish species, full recovery is expected to require at least 10 years of increased management restrictions.

As sharks are not allowed to be retained or targeted by the WCDSF fishery, the impacts on shark stocks by the WCDSF management is likely to be minimal.

White Sharks: Until the practice was prohibited in November 2002 (Reg. 56A), some West Coast Rock Lobster (WCRL) fishers attached large hooks and metal wire snoods/chains to their pot-floats to target large sharks, primarily for their fins (Borg & McAuley 2004). While droplines were only ever used by a minority of fishers in the WCRLF, the potential for white sharks to be caught using this 'wetline' method were included in the historical catch reconstruction (Taylor et al., in press).

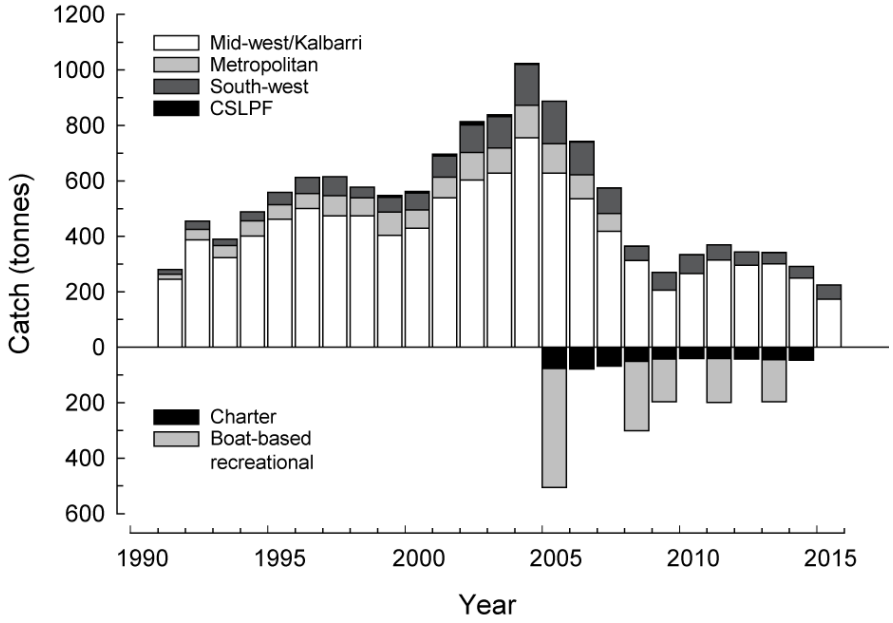

Figure 3. Commercial handline catches and recreational/charter catches of the top 15 demersal species (defined in Table 6, Ryan et al., 2015) in the West Coast Bioregion. Estimates of recreational and charter catches for the period before 2005 are not available.

Overview of the Joint Authority Southern Demersal Gillnet and Demersal Longline Fishery (JASDGDLF)

The JASDGDLF was formed in 1988, and was the State's first management plan for shark fishing off the south and southwest coasts. This management plan restricted the use of large-mesh demersal gillnets and longlines south of 33°S (Figure 2) to a limited number of fishers and specified the maximum effort that could be applied in two zones (McAuley & Simpfendorfer, 2003). The fishery is managed by input controls in the form of transferrable time/gear effort units, the value of which were reduced between 1992 and 2002 to address emerging sustainability risks to the fisheries' target stocks. In 2006/07, a more explicit hourly effort management system was introduced which removed excessive latent effort capacity and restricted effort within each management zone to 2001/02 levels. The future levels of effort for this fishery are likely to be affected by a number of Commonwealth initiatives (includes the Commonwealth Marine Bioregional Planning program plus a separate ASL closure initiative) as both of these would exclude gillnetting from large areas where this activity currently occurs.

Target Species: The main species targeted by this fishery are gummy and dusky sharks on the south coast, while dusky and sandbar sharks are targeted on the lower west coast with whiskery sharks also an important part of the catch. The current levels of effort for this fishery are significantly lower than in the late 1980s and early 1990s (Figure 4; McAuley et al. 2015). This reduction in effort has resulted in reduced catches, especially of gummy and whiskery sharks. In addition, a specific closure was put in place for whiskery sharks to protect 'pupping' females around the time of parturition (Whiskery pupping closure, WPC). The cumulative effects of these reductions in effort and the WPC were designed to allow stocks of this species to recover. Updated assessments for both these species are currently underway, and it is likely that the abundance of these stocks is

approaching management target levels. This suggests there are likely to be increased numbers of gummy and whiskery sharks on the south coast region.

Demersal scalefish made up approximately 10-15% of catches by the JASDGDLF sector. Thus, the reduction in JASDGDLF effort has also reduced catches of scalefish. A recent stock assessment of south coast demersal scalefish (Norriss et al. in press) has concluded that the stocks of these species are at or above management targets.

White Sharks: The JASDGDLF is one of the main sources of white shark catches in Western Australia (Taylor et al., in press). The estimates of current and historical annual captures are presented below in the analysis section.

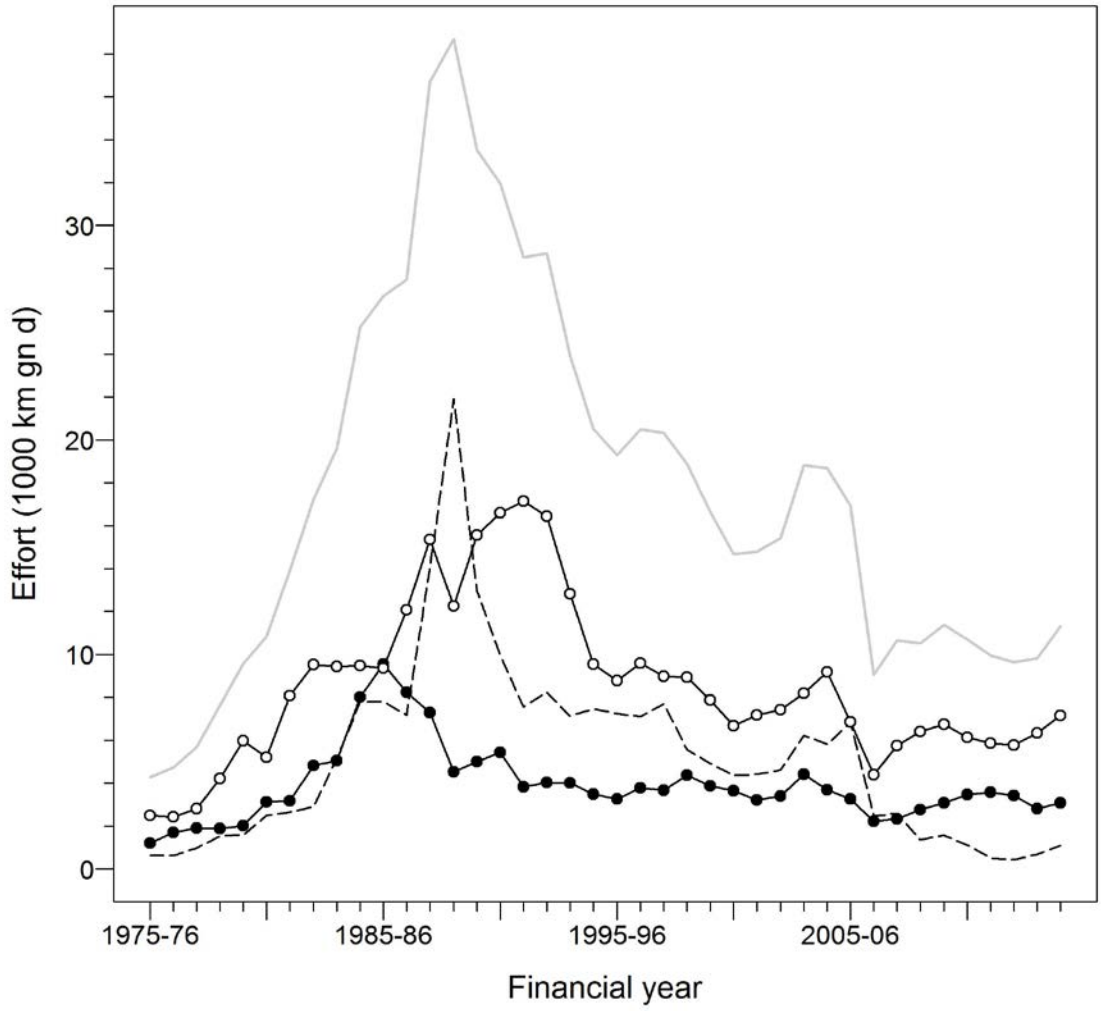

Figure 4. Standardised demersal gillnet and demersal longline effort. Black circles = JASDGDLF Zone 1; white circles = JASDGDLF Zone 2; dashed black line = WCDGDLF; plain grey line = total from the three management zones.

Overview of the North Coast Fishery

The WA Northern Shark Fishery (NSF), comprised of the WA North Coast Shark Fishery (WANCSF) and the Joint Authority Northern Shark Fishery (JANSF), operated between North West Cape and the WA/NT border from early 1988 until February 2009. Foreign fleets (particularly Taiwanese) and vessels operating under joint authority arrangements operated prior to this period targeting sharks and a range of other fishery species.

Both the WANCSF and the JANSF ceased operating after 2009 as a result of concerns about the ecological sustainability of the fisheries (including risks to the sandbar shark stocks, lack of management arrangements and risks of interactions with protected species) and loss of their Commonwealth export approvals (WTOs). The fishery has now either been closed (WACNSF) or has not operated (JANSF) for more than seven years.

Target Species: The Northern Shark Fisheries have variously targeted sandbar and blacktip sharks and have also caught relatively sizable quantities of tiger, lemon and hammerhead (family Sphyrnidae) sharks, plus some targeting of mackerel. Previously, the majority of these fisheries' income came from the sale of shark fins for export, which created a financial incentive for fishers to target larger sharks (DoF 2005; McAuley et al. 2005). During the period when no targeted shark fishing has occurred, it is likely that the abundance of a number of these shark species have increased, especially those species that are more productive and /or are not highly migratory (see Grubert et al. 2012, for example).

White Sharks: With respect to white sharks, only the southern part of this fishery (the western half of the WANCSF) is within the known species range of white sharks with the only known capture off North West Cape in 2002. No white shark captures were observed on WANCSF vessels between 2000 and 2005 by trained observers (Bensley et al. 2010). Consequently, as the majority of fishing effort in the Northern Shark Fisheries occurred outside of the known distribution of the south-western white shark population, this potential source of mortality was not considered in subsequent analyses by Taylor et al., (in press).

The cessation of shark fishing effort in this region may still have flow-on effects for the metropolitan region as a number of shark species migrate between these locations.

Recreational shark fisheries

Recreational shark fishing includes catches by game fishers who fish beyond the continental shelf in oceanic waters (Chesire et al .2013) and those that typically target finfish in coastal waters closer to regional centres (Ryan et al. 2013, 2015). Successive surveys have revealed that sharks have historically been a very small component of boat-based recreational catches in WA (Sumner & Williamson 1999; Ryan et al. 2013, 2015) and are insignificant relative to both current and previous commercial fisheries. Fishers are permitted to harvest sharks within the current bag and size limits. Importantly, approximately 80% of sharks caught by recreational fishers are released (Ryan et al. 2013, 2015). While the identification of closely-related whaler sharks (Family Carcharhinidae) is

difficult, and therefore accurate species-specific catches are not available for the recreational sector, their collective harvest of all sharks is considered to be minor.

Other Considerations

Gascoyne Region

Shark fishing previously occurred in the Gascoyne Bioregion with small numbers of larger species of shark (e.g. tiger sharks) being targeted. Significant management changes were implemented 30 years ago with the declaration of the Commonwealth and State Ningaloo marine parks which resulted in the closure to commercial fishing adjacent to the Ningaloo Marine Park out to the Economic Exclusive Zone (EEZ). Additionally, Shark Bay was inscribed as a World Heritage area in 1991 and there has been no significant shark fishing in the Gascoyne Bioregion for several decades. It is therefore likely that the abundance of a number of shark species have increased, especially those species that are more productive and /or are not highly migratory. This is consistent with the anecdotal reports of increased shark depredation by commercial and recreational line fishers in the Gascoyne Bioregion. Similar to the north coast, the lack of shark fishing in this area may have resulted in higher numbers of some shark species being present in the metropolitan region in different seasons or during certain environmental conditions (e.g. marine heat wave).

Other potential Impacts on Shark Fisheries

Potential effects of Commonwealth Requirements on current commercial shark fisheries

Recently, the Commonwealth Department of the Environment (DotE) recommended closures around Australian Sea Lion (ASL) breeding colonies in the West Coast (principally around the Abrolhos) and South Coast (mainly around the Recherche archipelago) Bioregions, to protect breeding colonies of ASLs. The sizes of the proposed closures are 20 km and 25 km radii around each breeding colony, respectively (Figure 5). The use of gillnets will be prohibited within these closures. These closures are due to come into effect in September 2016 and will affect approximately 30% of the areas where fishing for sharks and scalefish currently occurs both in the south coast and the west coast regions.

The precise impacts on the catch and effort for the fishery and individual operators are unknown as it is possible some operators may switch to demersal longline gears within the ASL closures. However, it is likely that there will be at least some reduction in effort and catches, and some operators may potentially stop all fishing operations. There is also the potential for the actual reductions in effort to be significant which would not only affect the overall levels of sharks being captured off WA, but would also reduce the levels of incidental capture of white sharks.

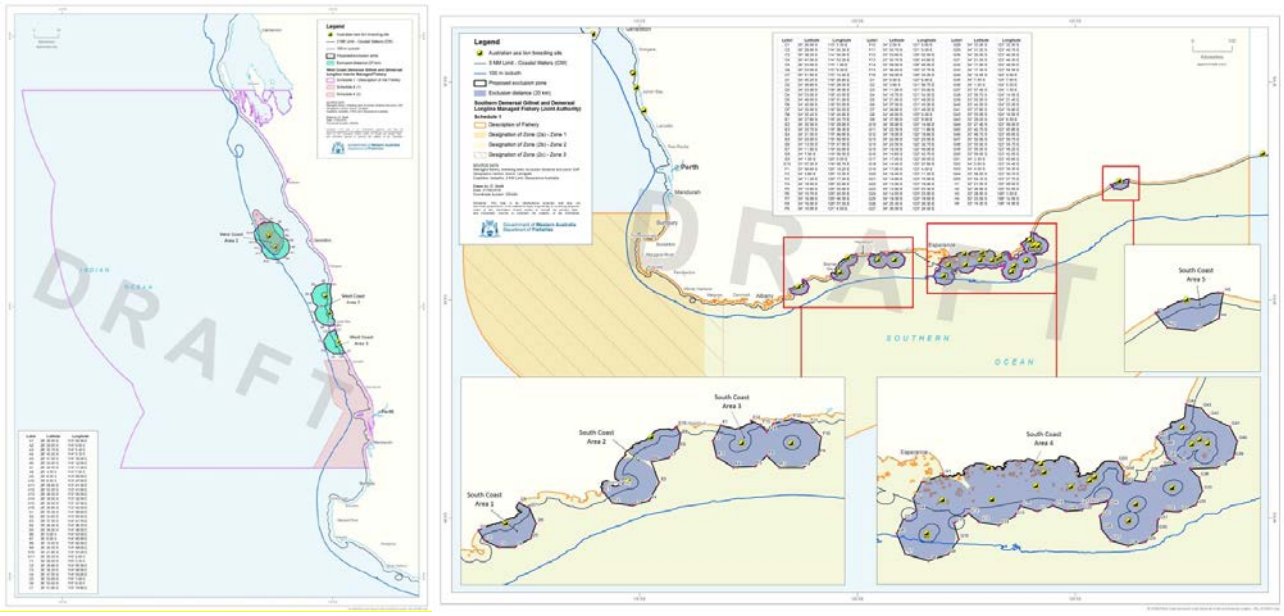

Figure 5. Currently proposed West Coast and South Coast gillnet closures (note the West Coast map currently assumes the metropolitan zone remains closed to gillnetting.

In addition to the ASL closures, the Commonwealth DotE is also leading a national Marine Bioregional Planning process. Although this process has slowed due to a review, the most recently available proposed planning scheme includes large areas that will, if implemented, exclude the use of fishing gears that contact the sea floor, including demersal gillnets and longlines. While the final size of the proposed areas that will exclude demersal gillnets and longlines are currently unknown, any reduction in areas of operation will further impact these fisheries and likely reduce effort and catches of all sharks, including the incidental captures of white sharks.

There is a significant risk that the sum of cumulative changes to spatial management as a result of these Commonwealth initiated closures may result in some or even most operators leaving these fisheries. This will reduce the level of catches of targeted sharks and teleosts in these regions, plus it will further reduce the annual levels of incidental captures of white sharks across their distribution in WA.

Commonwealth Requirements for a re-opened Metropolitan Shark Fishery – If the West Coast Shark fishery was to re-open in the metropolitan zone it may also be affected by the Commonwealth's marine reserve program. Specifically, the Two Rocks Marine reserve would not allow gillnetting (Figure 6). If these zones are enacted this would reduce the area where a re-opened fishery could operate, especially in the areas offshore of northern beaches.

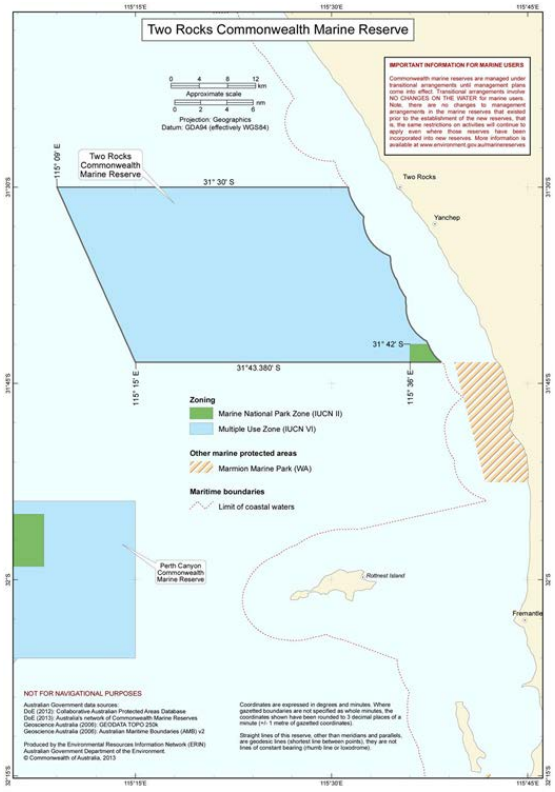

Figure 6. Indicative map of the proposed Two Rocks Marine Reserve within which gillnetting would be prohibited.

Analyses

Direct impact on the population of white sharks

(1) a material effect on the overall abundance of white sharks and therefore the likelihood of encounters.

As outlined above, the main sources of white shark captures in WA are the fisheries within the TDGDLF (Malcolm et al. 2001; McAuley & Simpfendorfer 2003). Using a combination of confidential interviews with commercial fishers matched with changes in historical levels of effort, the historical catches of white sharks within the TDGDLF were estimated by Taylor et al., (in press). These analyses included estimates for the entire WCDGDLF, though not specifically just for the Perth metropolitan region (Taylor et al, in press).

The estimated annual catches of white shark across the total gillnet fisheries in WA (TDGDLF) and for the entire West Coast shark fishery (WCDGDLF) are presented for three key periods 1988/89–1996/97 (before formal protection); 1997/98–2004/05 (after formal protection but before the metro closure); 2005/06–2012/13 (inclusive of the metro closure) (Table 1). Prior to their State and Commonwealth protection in 1997, it is likely most of these sharks would not have been released alive due to the high monetary value of (and market for) teeth and jaws. Post protection,

while the retention of incidentally-caught white sharks has declined, the level of post-capture mortality is currently unknown (Taylor et al., in press) but a proportion of the white sharks incidentally caught by gillnetters since this time are likely to have survived release.

The mean annual catch estimates for the West Coast fishery prior to protection between 1988/89 and 1996/97 was approximately 12 white sharks yr^{-1} whereas for the first period after protection (1997/98–2004/05), it was 6 yr^{-1}. For the most recent period (2005/06–2012/13) it was 5 yr^{-1} with all catches after 2007 having occurred outside of the Perth metropolitan area.

The estimates for the cumulative catches for both the total WA coast and the entire SW Australian population of white sharks (in waters west of Bass Strait, Victoria) for this population are higher (Table 1). Current total captures of white sharks are estimated using different assumptions to now be between 45–79 yr^{-1} (including the 35 yr^{-1} in WA) with an estimated peak in the late 1980s of 270–975 yr^{-1} (see Taylor et al., in press for details).

If gillnet fishing activities were regulated and maintained at or below the 2001/02 effort levels (the current management target for the TDGDLF), annual white shark catch levels in the metropolitan region would not be expected to substantially exceed those estimate for the entire west coast region during 1997/98–2004/05 (i.e. ~5-6 yr^{-1}). This is based on the assumption that fishing activities would be largely consistent with previous activities (i.e. same gear and targeting practices and same areas fished; no specific targeting of white sharks). An additional assumption is that fishers who have licences to fish both in Zone 1 of the JASDGDLF and the WCDGDLF do not simply substitute their effort in Zone 1 for the Perth metropolitan region.

Based on these assumptions it is estimated that:

- following the closure of commercial fishing within the metropolitan region in 2007, the total number of white sharks captured per year within WA, and for the West Coast, either increased or remained at approximately the same levels, respectively, compared to the previous period (1997/98–2004/05).
- the catch of white sharks within the entire WCDGDLF was only a minor part of the total WA catch (<22%) and therefore the proportion of the white shark catch captured per year just within the metropolitan zone was likely to be smaller.
- compared to the total levels of captures across the SW population, estimated captures in the metropolitan region were negligible (< 5% of the peak in the late 1980s).
- It is not expected that captures by a reintroduced fishery would be significant at a stock level (5-6 yr^{-1}) and these would be required to be released alive.
- This level of capture may be lower if the areas available for gillnetting are reduced due to implementation of Commonwealth marine reserves (and/ or ASL closures). Moreover, the overall levels of capture of white sharks in WA (including the west coast) would decline from current levels if the Commonwealth initiatives to close large areas to gillnetting (and longlining) are implemented.

The analysis suggests that it is highly unlikely that reopening the metropolitan shark fishery would have a material effect on the <u>total abundance</u> of SW population of white sharks.

This likelihood would be even lower if the Commonwealth initiatives (e.g. imposition of ASL exclusion zones and Commonwealth Marine reserves) are implemented as these would significantly reduce the overall gillnet and longline effort across WA.

Table 1. Estimated annual catch of white sharks (number of sharks) in the TDGDLF, WCDGDLF and for the entire SW population by time period and region.

	Estimated annual catch (white sharks yr^{-1})		
Time period	Total (TDGDLF)	WCDGDLF	Total SW Population
1988/89–1996/97	59–81	12	270–975**
1997/98–2004/05*	28	6	
2005/06–2012/13	35	5	45–79***

*White sharks became protected under the WA Fisheries Resources Management Act (1994) in November 1997 and under the Commonwealth Protected Species Act in December 1997

** Annual catch estimate for 1988/89 (refer to Taylor et al (in press) for further explanation)

*** Annual catch estimate for 2012/13 (refer to Taylor et al (in press) for further explanation)

(2) no material effect on overall abundance but their capture may 'remove' those sharks that have longer periods of residency in the metropolitan area with a resultant increased likelihood of encounters.

As outlined in the previous section, the re-introduction of gillnet activities within the Perth Metropolitan area would likely result only in the incidental capture of a relatively small number of white sharks. Even assuming similar or plausibly higher levels of captures as previous, the number of captures by recommencing the metropolitan shark fishery is unlikely to impact on local abundance given that the studies of movement of tagged whites sharks detected off WA suggest that they are mostly only present for short periods (days to weeks) and there was minimal evidence of sharks spending extended periods in particular areas off the south-west of the State (McAuley et al. 2016).

The longer an individual shark continues to reside in netted areas, the higher probability of their being captured through fishing activities. Those that are captured may not survive post capture and/or they may be more likely to leave the area post capture. Hence, the reintroduction of the shark fishery could directly lower the risk to ocean users if this fishing activity was likely to capture those sharks that have longer residence times (>weeks) in areas relatively close to ocean users. This would operate using a similar concept to that used by dedicated shark control programs (Appendix A).

In considering this possible effect, it is important to note approximately half of the shark attacks within Western Australian waters during the past 15 years have occurred in areas where commercial

shark fishing still occurs, therefore having a commercial shark fishery operating offshore does not guarantee that attacks will not occur.

Second, the possibility that a recommenced metropolitan shark fishery would operate in a manner similar to shark control programs by lowering the risk to ocean users, is heavily influenced by the locations where their fishing operations occur. Commercial fishing for sharks off the west coast typically occurs in waters of between 30 and 100 m in depth which is generally several kilometres from the coast. This is in contrast to the dedicated shark control programs such as in NSW and southeast Queensland where shark control nets are set close to beaches in water between 5 and 12 m in depth (Taylor et al., 2011, McPhee 2012). Furthermore, because it is prohibited to sell large sharks for human consumption due to their (perceived) high mercury content, the gear set by commercial fishers in WA has smaller mesh sizes to target smaller sharks (< 3m), although larger sharks are captured, typically by becoming tangled in lead or float lines of gillnets. This reduces the likelihood that white sharks captured by this gear would be of the sizes normally associated with attacks (> 3m). Hence, the commercial gear and operations used in the TDGDLF vary to that of dedicated shark control programs (Appendix A).

Given the strong seasonality of white sharks relative abundance within the metropolitan region (McAuley, et al., 2016), the actual levels of capture of white sharks by the fishery would depend on the monthly distribution of fishing effort. This was also demonstrated in 2014 (January–April) when catches of tiger sharks caught using drum lines were higher than predicted but the lack of white sharks was not unexpected at this time of the year (DPC 2014).

Furthermore, the level of direct impact would depend upon whether fishing would be allowed across the entire metropolitan zone, or if the re-opened fishery would be restricted to the areas outside of Commonwealth Marine Reserves (see Figure 6) and any ASL closures . This could exclude all gillnetting activities within the main waters where the fishery would operate from Two Rocks down to Burns Beach which would significantly affect the potential efficacy of any fishing operations to reduce the levels of white shark encounters within the northern beaches.

Under historical levels and distribution of fishing effort, the incidental capture of white sharks by a metropolitan shark fishery could have a minor effect on reducing the local abundance of larger white sharks that exhibit longer residence times close to popular areas.

If Commonwealth marine reserves are implemented it would be less likely that the re-commenced fishery would have an impact on the rate of encounters with ocean users.

Potential indirect effects from the closure

(3) reduced levels of fishing on demersal scalefish and other shark species (many of which are potential prey of white sharks species) previously captured by this fishery

could have generated increased levels of prey, which may have increased the likelihood of white sharks frequenting this region and/or staying longer within this region.

The closure of the shark fishery off the Perth metropolitan coast may have led to an increase in the numbers of sharks of various species. As white sharks are known to prey upon other sharks, including those caught by commercial fishers (Malcolm et al. 2001), changes in the abundance of these smaller sharks could influence the distribution of white sharks.

The WCDGDLF previously captured 400-500 t of sharks per year but now only approximately 100 t are caught per year (Fig. 2). This suggests that the abundance of these previously targeted shark species are likely to now be higher than prior to the closure. This is supported by the anecdotal level of reports of shark bite-offs that are now being received by the Department from recreational and charter fishers in at least some areas. Consequently, a reintroduction of the shark fishery in this region would be expected to reduce the local abundance of these species of sharks which may result in a decline in the overall level of shark sightings (many of which are species of other sharks, not white sharks) and potentially the level of bite offs.

While the metropolitan shark fishery also captured demersal scalefish, their catch represented only a small proportion of the total catches. Assuming the fishery was required to remain within its allocation, its recommencement would be unlikely to impact the continued recovery of scalefish stocks within the Bioregion. Furthermore, the current management objective for this resource is for further increases in the abundance of all demersal scalefish species in this region.

As a metropolitan shark fishery would only reduce the local abundance of some targeted sharks, this makes it unlikely that the overall level of potential prey of white sharks would be reduced in the metropolitan region to a level that would significantly lower the 'attractiveness' of this region to white sharks and hence their rate of encounters with ocean users.

Other Considerations

(4) given the highly migratory nature of white sharks, changes in commercial fishing effort by other shark fisheries located both south and north of the metropolitan region could influence their total and local abundance in the metropolitan region.

The historical catch levels of white sharks within WA as estimated by Taylor et al. (in press) here largely a result of the fishing effort levels within the gillnet fisheries on the south and lower west coasts. As outlined above, the JASDGDLF has been actively managed to reduce levels of fishing effort to 2001/02 levels, equivalent of a 50% reduction from the peak of effort. Furthermore, to meet Commonwealth government requirements, the areas of the TDGDLF both south and north of the metropolitan zone are likely to have gillnet closures of 20 km around known ASL colonies. Moreover, the entire TDGDLF is likely to have additional areas closed to demersal gillnet and longline fishing from the proposed zoning generated from the Commonwealth Marine Bioregional planning process.

The combined reductions in effort generated by the proposed gear closures and marine park zoning would have a significant impact on the spatial distribution and effort levels of existing and potential shark fisheries throughout the State. This would reduce the catches of all sharks and scalefish captured by these method fisheries, including the number of incidental captures of white sharks. Given the overall scale of these potential closures, there is a risk that this loss of access may cause some shark fishers to cease all operations, further reducing effort and therefore catches of all these species.

This suggests that the levels of white shark captures in areas outside of the metropolitan region may decline further. Given the rates and extent of movement of white sharks (McAuley et al. 2016) this would have clear implications for the potential numbers of white sharks that may venture into this region on an annual basis.

(5) changes in commercial fishing effort by other shark fisheries located both south and north of the metropolitan region could have influenced the abundance of other species of sharks.

There are a large number of shark species distributed along the WA coastline, many of which attain sizes greater than 3 m TL (e.g. Figure 7). With respect to level of shark sightings within the metropolitan region, as many of these species are highly mobile, significant changes to fisheries and marine management need to be considered well beyond the metropolitan area (Braccini and Taylor, 2016; - Figure 7).

As described above, no commercial shark fishing has occurred in the north coast of the State since April 2009. In addition, due to sustainability concerns around sandbar shark, no commercial shark fishing has occurred east of 120°E since 2005. Further south, the Ningaloo closure between Point Maud and Tantabiddi Wells out to the 200 nautical mile limit of the EEZ has been closed to commercial fishing since the early 1970s and only limited targeted shark fishing has occurred in the southern Gascoyne in subsequent and recent years.

While it is not possible to determine trends for the 100+ species of sharks in Western Australian waters (Last & Stevens 2009), anecdotal reports from some fishers suggest that the local abundance of some species, including tiger sharks, may have increased. The commercial catches of tiger sharks have declined significantly from levels of up to 80 t during 2004/05 down to current negligible levels due to reduced levels of fishing (Department of Fisheries, 2014). An increase in their abundance could be expected and this may affect the levels of sightings in metropolitan waters and potentially interactions with ocean users. The higher than expected drum line catches of tiger sharks experienced in 2014 may have been generated by this but this may have also been influenced by the warmer than normal water temperatures at that time (Pearce et al. 2011; Caputi et al. 2014). Ongoing analysis of standardised catch rates from fisheries-dependent and fisheries-independent sampling could assist in inferring trends in the (local) abundance of tiger sharks and other species of sharks.

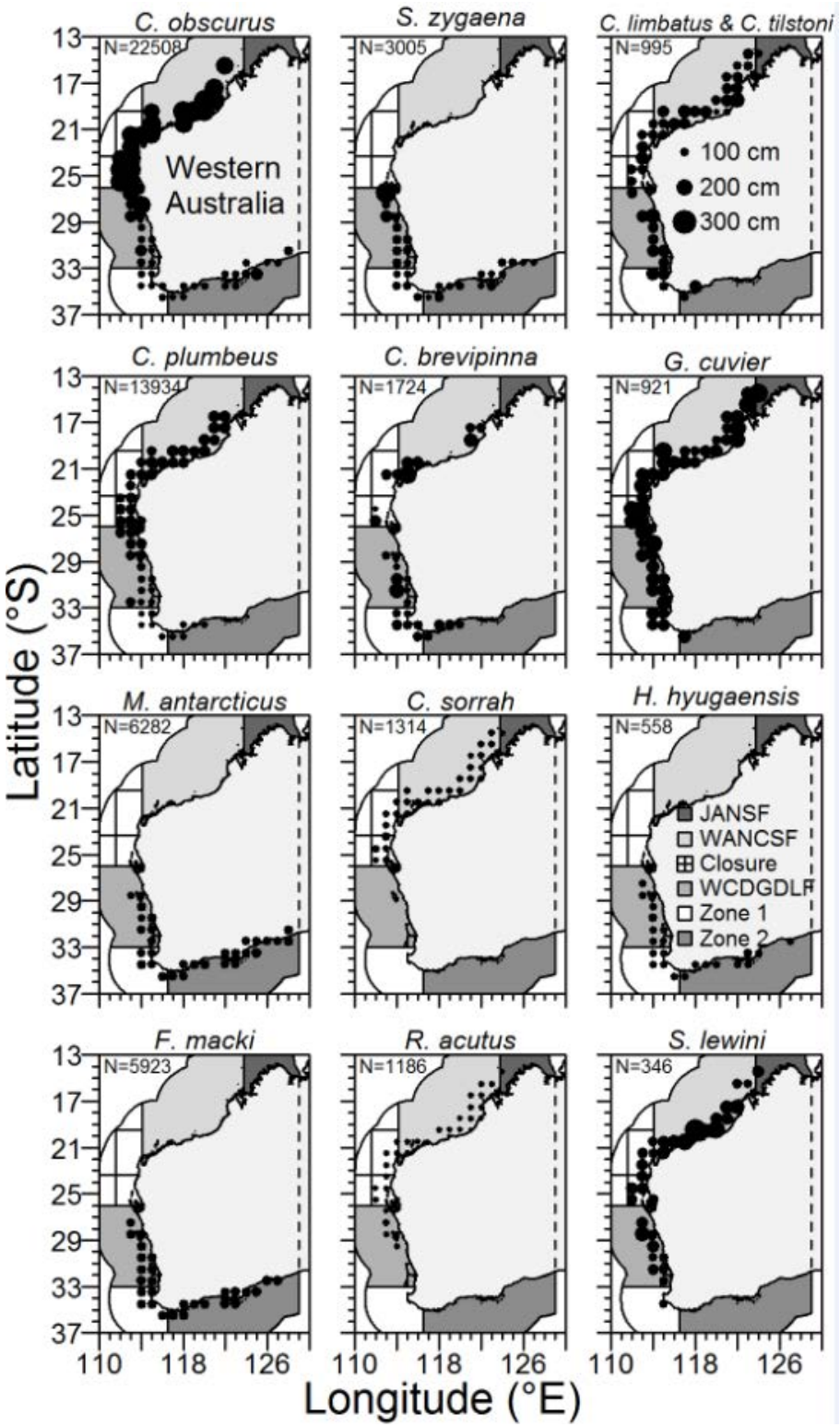

Figure 1. Spatial patterns in the observed fork length (FL) by management zone. Observations were grouped into spatial blocks of 1° latitude by 1° longitude. Dot size represents the mean size per block.

Figure 7 – Reprinted from Braccini and Taylor (2016).

(6) the changes to other commercial and recreational fishing activities within the metropolitan region that could have affected the relative abundance of prey species such as demersal scalefish.

Under current management arrangements, the stocks of WCDSF (including pink snapper) are in a rebuilding phase with the objective of increasing the abundance/biomass of these species. Teleosts such as pink snapper (*Pagrus auratus*) and West Australian salmon (*Arripis truttaceus*) are known prey items for white sharks (Malcolm et al. 2001). The high abundance of tagged white sharks detected by Cockburn Sound/Garden Island receivers in close proximity of annual pink snapper spawning aggregations (McAuley et al. 2016) and sightings of other shark species in the vicinity of pink snapper schools suggests that inter-annual fluctuations in the abundance and distribution of these and other species of teleosts may also influence the distribution of white sharks (and other shark species) and the risk these sharks pose to humans.

If there are more scalefish prey in the area this may increase the numbers of all sharks in the area, including white sharks, and also their retention times leading to increased probability of encounters with other ocean users.

(7) the potential impacts on the stock status of species, especially other shark species, that would be captured in a re-opened metropolitan area (with the objective of rebuilding fish stocks (WCDSF) and rebuilding shark stocks (sandbar and dusky)

The impacts of reopening the metropolitan WCDGDLF on shark and teleosts stocks would be dependent on the management settings. For example, if effort across the WCDGDLF remained stable but shifted to the metropolitan area, total catches of sharks and scalefish may not increase significantly enough to impact ongoing recovery of sandbar and dusky sharks and demersal scalefish.

If total effort increased (noting the current level of latent effort in the WCDGDLF), then the total shark and scalefish catch by this fishery would likely increase, assuming there is a market for additional catches. These increased catches may also not impact the recovery of shark and scalefish species if the total catches of the stocks are maintained below the levels estimated by McAuley et al. (2005). Maintaining catches of sandbar and dusky sharks below the levels that allow continued recovery may be possible noting that the NSF (which landed significant catches of sandbar sharks) are currently closed.

The catches and landings of all shark and teleosts in all fisheries and the status of these stocks would need to be closely monitored to manage risks around their continued recovery.

(8) the effect on sectoral allocation (IFM resource sharing decisions for west coast demersal scalefish if the gillnet fishery were to be reopened in the metropolitan region.

As part of the WCDSF resource management process, an allocation process was undertaken to assign commercial and recreational catch shares (IFAAC 2013). This allocation included the removal of all WCDGDLF and wet line effort from the metropolitan region in its final allocation of 64% to the commercial sector and 36% to the recreational sector (with additional consideration of several high profile teleost species). Moreover, the entire metropolitan zone was allocated to the recreational sector to enable its priority access in this region.

If consideration is given to reopening the metropolitan area to WCDGDLF and /or commercial line fishers in the WCDSIMF, a 're-allocation' process may be needed. As the majority of the State's recreational fishers reside in the metropolitan area (Ryan et al., 2015) the waters between Lancelin and Mandurah are very important for recreational fishing. Having any resumption of commercial fishing in this region that may catch demersal scalefish is likely be a contentious issue.

(9) the likelihood that commercial fishing effort would return to previous levels even if re-opened.

In the WCDGDLF, the metropolitan closures and buyout reduced effort by 35% and effectively moved most remaining operations to north of Lancelin. In addition to the metropolitan closures, closures around the Abrolhos and limits to demersal scalefish catches also impact the fishery, limiting catches and spatial areas of operations. With the pending 20 km exclusion zones around ASL colonies at the Abrolhos, additional areas will likely be closed to gillnetting for sharks.

Even before the ASL closures come into force, the size and economic viability of the remaining WCDGDLF appeared to be marginal, with at least one operator stating that the ASL closures around the Abrolhos will result in this fishery becoming economically unviable. While spatial closures and demersal scalefish limits are significant impacts on fishery economics, the beach price of small sharks is also low at approximately $1/kg, (comparable with ~$0.50/kg in the Northern Territory, Simpfendorfer 2014) further impacting on viability.

It is therefore possible that even if the metropolitan zone is reopened there may be minimal interest in re-establishing fishing operations within this region both for economic reasons and potentially because of the fears of significant negative public concerns around gillnetting activities.

Conclusions

Providing advice on the potential impacts of re-opening the 'metropolitan shark fishery' is complicated by key factors which make separating the specific impacts that may be generated from a re-opened metropolitan shark fishery difficult. These factors include:

(1) There is uncertainty about whether the overall population trajectory for white sharks in WA is increasing, stable or declining (Taylor, et al., in press).

(2) The potential for wide ranging movements of white sharks across their distribution from SA to WA which may be affected by a variety of seasonal and inter-annual changes in biotic and abiotic conditions (DoF, 2012; McAuley et al., 2016).

(3) The metropolitan shark fishery was only one of a number of commercial and recreational fisheries that captured shark and finfish resources within the metropolitan region or shark resources more generally across the State. In addition to the closure of the metropolitan area of the west coast shark fishery, each of these other west and south coast fisheries also had significant changes to their specific arrangements over the past decade, and in some cases (e.g. the remaining west coast and south coast shark fisheries) further changes are underway that may reduce effort and therefore the number of white sharks that will be captured.

(4) Assessing the degree to which changing a management measure will reduce the incidence of rare but catastrophic events is inherently difficult (e.g. Crighton & Towl, 2008). The paucity of data as a result of rare species or events, such as those associated with white shark attacks, will always mean that the available statistics will be unable to forecast accurately where rare species and rare events are likely to happen in the future.

Recognising these difficulties we assessed each of the potential direct and indirect effects from re-opening the metropolitan shark fishery both at historical levels and by including appropriate consideration of other relevant factors. The results were:

Direct Effects on Total Abundance- It is highly unlikely the low levels of incidental capture and release of white sharks within the metropolitan area would materially affect the total abundance of the SW population even if the reopened fishery operated at historical levels. Furthermore, the levels of shark fishing in other areas of WA are likely to decline to deal with new and proposed Commonwealth requirements (e.g. imposition of Australian sea lion (ASL) exclusion zones and likely Commonwealth Marine Park closures) which will further reduce the total levels of fishing effort (gillnet and longline) in WA and therefore the total level of incidental captures of white sharks.

The cumulative effects on fishing effort from all proposed gillnet closures across the distribution of the SW population makes it more likely that increases in white shark abundance will occur into the future, even if the metropolitan fishery was to be re-opened.

Direct Effects on Local Abundance

Given the apparent seasonality of their presence within the metropolitan region (McAuley et al., 2016) and therefore the lower relative abundance compared to south coast regions (Taylor et al., in press), only low levels of incidental capture (and release) of white sharks are expected by a re-opened metropolitan shark fishery. This is likely to only have a minor effect on the local abundance of white sharks and, given the gear used, even lower impacts on larger (> 3m) individuals. Furthermore, as commercial shark fishing operations typically occur in relatively deeper and more offshore locations than shark (netting) control programs, this would reduce the potential for these captures to directly affect the rates of encounters with shore-based ocean users compared to those captures made by dedicated (inshore) shark control programs (see Appendix A).

A further consideration is that if the proposed zoning for the Commonwealth's Two Rocks Marine Reserve progresses, this would prohibit operations by this fishery across a large stretch of northern metropolitan beaches.

Indirect Effects on Residence

If historical levels of fishing effort were reintroduced into the metropolitan region, it would be possible that the local abundance of targeted shark species (e.g. dusky whalers) would decline. This could, in turn, reduce the overall level of shark sightings and shark bite offs within the region. However, given the level of latent (unused) effort in the rest of the WCDGDLF, it is unlikely that the historical levels of effort would return to this region. Consequently, the actual declines in the local abundance of smaller sharks may not be sufficient to affect these levels or their contribution as an attractant to white sharks as potential prey.

In addition, the current management measures in place for other fisheries in the region are all designed to further increase the abundance of scalefish and even some shark species (e.g. sandbar, dusky). It is, therefore, not likely that reintroducing the metropolitan shark fishery would reduce the overall level of potential prey within this region to a degree that would significantly lower the areas 'attractiveness' to white sharks and hence their visiting frequency or residence time.

Overall Assessment

Based on the individual assessments and consideration of all the other relevant factors that may either affect the operations of a reopened metropolitan shark fishery, the total population of white sharks or the total populations of other sharks in WA, our overall assessment is that a re-opened metropolitan shark fishery will be of limited benefit in reducing the rate of encounters with ocean users within this region.

It is noted that a high proportion of attacks by white sharks have occurred outside the metropolitan region which are within the areas where the TDGDLF is currently still operating. Thus, the presence of a shark fishery in a region does not guarantee that there will be no white shark encounters with ocean users within that area.

Given the cumulative impacts generated from current fishery management strategies designed to rebuild scalefish and some shark stocks, plus the various fishing closures already in place combined with the significant additional areas currently proposed by the Commonwealth, it is possible that there will be increasing numbers of sharks, including white sharks, present within the metropolitan region (and other areas of WA) in coming years, even if the metropolitan shark fishery is reopened.

Additional implications if re-opening supported

If the proposal to reopen the metropolitan shark fishery was supported, this may require flow-on changes to the management of a number of other commercial fisheries to ensure that there were no potential increases in the commercial catches of the west coast demersal scalefish resource which is still in a rebuilding phase.

Reopening of this fishery is likely to generate significant reactions from recreational fishing groups. These reactions could include anger at reversing the 2007 decision to allocate access to the demersal finfish resource within the metropolitan region to the recreational sector. Some of the recreational sector may, however, support the move if they consider this could potentially reduce the incidence of "bite-offs".

There will almost certainly be strong reactions from the conservation sector and the general community who may interpret this as a reintroduction of the drum line program, noting the general perception (e.g. Worm et al 2013) that shark stocks are at threat of collapse worldwide.

The re-opening of the fishery in this region may also generate the requirement to undergo a new Part 13a EPBC assessment as it would be seen as a major change to the operations of the WCDGDL Fishery.

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Appendix A. Comparison of gillnet operations used with Western Australian Temperate Demersal Gillnet and Demersal Longline Fisheries (TDGDLF) and those used in shark control measures elsewhere. For comparability with the TDGDLF, only existing shark control measures using gillnets are included. 1=Taylor et al. in press; 2= Sumpton et al. (2011); 3 = Reid et al. (2011); 4 = Cliff and Dudley (2011)

Location	Fishery	Target species	Time scale	Gear used	Average number of white sharks caught per year
Western Australia[1]	TDGDLF	Juvenile dusky and bronze whaler sharks, adult gummy sharks	Ongoing from the 1940s	Gillnets – monofilament gillnets of typically 15.2 or 17.8 cm (stretched) mesh sizes.	35 yr^{-1} (entire fishery)
Queensland[2]	Shark Control Measure	Bull shark, tiger shark, white shark	Ongoing from 1962	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. 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.	2 yr^{-1} (1992–2008, southern Queensland; net only) 2 yr^{-1} (1992–2008, southern Queensland; drumline only)
New South Wales[3]	Shark Control Measure	White shark,bull shark	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.	Currently approximately 6 yr^{-1} but significantly higher in the 1950s
South Africa[4]	Shark Control Measure	Bull Shark, white Shark	Ongoing from 1952	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). Drum lines – 79 hooks (14/0 Mustad J design) baited with Southern Rover or Jacobever species.	42 yr^{-1} (1978–1989; net only) 33 yr^{-1} (1990–1999; net only) 25 yr^{-1} (2000–2009; net only)