Australian Government
Department of Agriculture, Fisheries and Forestry
ABARES

Summary of the status of key shark species in tuna regional fisheries management organisations

S. Hansen and H. Patterson

Research by the Australian Bureau of Agricultural and Resource Economics and Sciences

August 2013

Working Paper CCSBT-ERS/1308/11 prepared for the 10th Meeting of the CCSBT Ecologically Related Species Working Group

28–31 August 2013, Canberra, Australia

Department of Agriculture, Fisheries and Forestry
Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)
Postal address GPO Box 1563 Canberra ACT 2601
Switchboard +61 2 6272 2010|
Facsimile +61 2 6272 2001
Email info.abares@daff.gov.au
Web daff.gov.au/abares

Acknowledgements
We thank Johnathon Davey, Ilona Stobutzki, Travis Bover and Mat Kertesz for their comments.

Contents

Summary

To date, the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) has not directly undertaken risk assessments for shark species. Fishing for southern bluefin tuna (SBT) using pelagic longline spatially overlaps with fishing for other tuna species, particularly in the Indian Ocean. As such, previous assessments from other regional fisheries management organisations (RFMOs) may be useful in determining which shark species are most at risk by SBT fishing and may provide guidance for the CCSBT in determining what further work on sharks needs to be undertaken.

In the face of increasing attention to the ecological implications of fishing operations on bycatch species, RFMOs have undertaken a series of ecological risk assessments (ERA) for bycatch species. These ecological risk assessments have identified sharks as one of the groups most at risk due to a combination of high catch rates and life history traits that make sharks particularly vulnerable to overfishing. Due to the current paucity of biological data for most shark species, these studies utilised productivity-susceptibility analysis (PSA) to identify vulnerability of different species of sharks to the different tuna fisheries. These studies identified shortfin mako (*Isurus oxyrinchus*), bigeye thresher (*Alopias supercilious*) and pelagic thresher (*Alopias pelagicus*) as the species most vulnerable to pelagic longline fisheries in the Indian Ocean (Murua et al. 2012). Shortfin mako, silky shark (*Carcharhinus falciformis*), porbeagle (*Lamna nasus*) and oceanic whitetip shark (*Carcharhinus longimanus*) were identified as the most vulnerable species to pelagic longline fisheries in the western and central Pacific Ocean (Kirby 2006). These species were typically identified as highly vulnerable due to their low productivity and high susceptibility to fishing gear. Conversely, blue shark *(Prionace glauca*) was found to be very susceptible to longline fisheries, but highly productive, and therefore is considered less intrinsically vulnerable to overfishing.

By using PSA it was possible to identify species that are most at risk to fishing operations. However, without biomass estimates and sound biological data, it is difficult to identify the true risk faced by different species. In order to assess the risk each species faces, inferences must be drawn from respective vulnerabilities and trends in catch rate and size.

SBT purse-seine operations present lower risk to sharks than longline fishing due to the higher susceptibility and higher mortality rates of sharks in relation to longline fisheries. Further, to date, PSA for sharks has only been completed for purse-seine operations in the Indian Ocean, which are very different operations, and as such, this review paper will focus on work completed in regards to longline fisheries.

1 Introduction

There has been increasing focus on the sustainable management and conservation of sharks, as reflected in the FAO International Plan of Action for the Conservation and Management of Sharks (FAO 1999). There is a need for the collection and analyses of species-specific catch and effort data and an assessment of shark status, particularly in tuna fisheries (Worm et al. 2013). However, given the current paucity of data, stock assessments of sharks are generally difficult to undertake. For example, in the Western and Central Pacific Fisheries Commission (WCPFC) there has been only one accepted quantitative shark stock assessment for oceanic whitetip shark (Rice & Harley 2012a). An assessment for blue shark and a revised assessment for silky shark are expected to be presented at the 2013 WCPFC Scientific Committee meeting.

To date, New Zealand has undertaken an assessment of the risk to seabirds from their commercial fisheries, including southern bluefin tuna (SBT; Richards et al. 2011), however there has not been an ecological risk assessment (ERA) for the total impacts of fishing for SBT on other ecologically related species. In contrast, some other regional fisheries management organisations (RFMOs) have undertaken such assessments and have identified sharks in particular as species of concern. The results of these studies may be useful for identifying future work for the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) and the shark species that are likely to be most at risk from SBT fishing.

The Ninth Meeting of the ERSWG discussed undertaking a stock assessment for porbeagles, and recommended Japan, New Zealand and Australia work towards this analysis (CCSBT 2012). At the same meeting it was acknowledged that work completed by other RFMOs will be relevant for the work of the ERSWG in relation to shark stock assessment and ERA. To that end, this paper summarises ERAs undertaken for shark species caught by tuna fisheries in the Indian, Pacific and Atlantic Oceans.

In 2006, an ERA of species caught by tuna fisheries within the WCPFC Convention Area identified sharks as the group most at risk to the longline tuna fisheries (Kirby 2006). Following this work, Productivity-Susceptibility Analysis (PSA) of shark species have been completed for fisheries in the western and central Pacific, Atlantic and Indian Oceans (Kirby & Hobday 2007; Cortés et al. 2010; Murua et al. 2012). Further, Clarke (2011) reviewed these shark assessments as part of the WCPFC's Shark Research Plan.

Given the difficulty in completing quantitative stock assessments for shark species, risk level was investigated by contrasting species' productivity against susceptibility to the fishery, through PSA (Kirby 2006; Cortés et al. 2010; Murua et al. 2012). Productivity (intrinsic rate of population increase, r) is estimated using Leslie matrix approaches that incorporate uncertainty in age of maturation, lifespan, age-specific natural mortality and fecundity. Susceptibility estimates incorporate the likelihood of capture (dependant on the behaviour and distribution of shark species relative to the distribution and gear selectivity of each fishery) and direct or indirect mortality as a result of fishery encounters (Kirby 2006; Cortés et al. 2010; Murua et al. 2012).

2 General trends in shark bycatch of tuna fisheries

Commercial SBT vessels principally use longline and purse-seine to target the fish. Purse-seine is used by Australia and accounts for approximately 45 per cent of the global catch of SBT. Due to the very targeted nature of the fishery that employs spotter pilots to locate schools of SBT before the deployment of nets, the purse-seine fishery has a much lower bycatch rate than the longline fisheries. In addition, sharks that do become encircled by the purse-seine can be shepherded out of the net unharmed. For example, in the 2010–11 fishing season just two shark captures were recorded in the Australian SBT purse-seine fishery, and both sharks were released unharmed and alive (Patterson & Hormis 2012).

Shark bycatch rates are higher for pelagic tuna longline fisheries. For example, in the WCPFC, the longline fishing fleet is responsible for shark bycatch levels nine times greater than seen in the purse-seine fleet, despite having only 2.5 times the number of vessels (Clarke 2011; WCPFC 2011). Further, sharks are more often discarded alive by the purse-seine fishing vessels than the pelagic longliners fishing in the WCPFC Area (39 per cent in purse-seiners, as opposed to 31 per cent in longliners; Kirby 2006). Given the higher risk posed by longline operations, this study focuses on the impact of longline operations and the risk created to key shark species.

In 2001, the European Union (EU) instituted a mandatory observer program to assess the impact of their fisheries on both targeted stocks and discards (Data Collection Framework, Reg [EC] 1543/2000 and 199/2008; see Amandè et al. 2012). Further, in 2007, an assessment was undertaken of shark bycatch estimations of the EU purse-seine tuna fishery and the effectiveness of this observer program (Sánchez et al. 2007). Apart from this work undertaken by the EU, and fishing vessels acting under CCSBT jurisdiction, there is very little information available for other tuna fisheries in the Indian Ocean (Amandè et al. 2012). However, a recent study undertook PSA of shark species caught as part of the Indian Ocean Tuna Commission (IOTC; Murua et al. 2012). This study identified species that are most vulnerable to both longline and purse-seine fleets. However, it does not assess the current status of the stocks due to lack of biological data in regards to fishing mortality and current biomass levels. The study demonstrated that shark species are more vulnerable to the longline fleet due to higher susceptibility; even the most vulnerable species in the purse-seine fleet had lower vulnerability estimates than observed in longline fisheries (Murua et al. 2012).

In regards to the bycatch in the IOTC fishing fleet, Murua et al. (2012) identified the need for further study into the impact of gillnet fisheries, given that they account for about 30 per cent of total catches of tropical tunas, and are particularly damaging to shark species. However, drift gillnetting has not been used to target SBT since 1992, in part due to the UN ban on such techniques (Miyake et al. 2004).

Through the use of PSA, RFMOs have identified numerous shark species as vulnerable to their fishing operations; six key species of shark have been identified as high to intermediate risk in all major tuna fisheries: oceanic whitetip shark (*Carcharhinus longimanus*), silky shark (*Carcharhinus falciformis*), blue shark (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*), bigeye thresher (*Alopias superciliosus*), and porbeagle (*Lamna nasus*). The PSAs identified these species as higher risk largely due to their limited productivity (low rate of intrinsic population increase). Note that while blue shark was not identified as high risk (in part due to its relatively high fecundity), it was considered vulnerable in the IOTC, because of its high susceptibility to longline fishing (Murua et al. 2012). Further, while porbeagle was not considered vulnerable in the Atlantic Ocean it remains a species of concern in other RFMOs due to its low productivity.

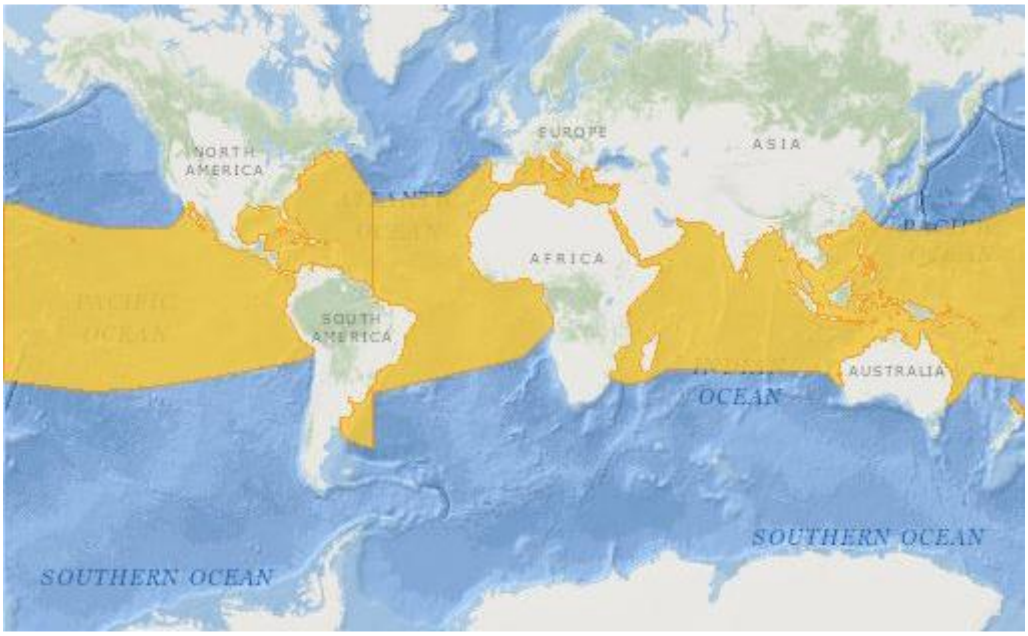
The International Union for the Conservation of Nature (IUCN) lists oceanic whitetip shark, blue shark, shortfin mako, bigeye thresher and porbeagle as "vulnerable" due to declines in population sizes. Both blue shark and silky shark are listed as "near threatened" (http://www.iucnredlist.org/). In addition, the Memorandum of Understanding on the Conservation of Migratory Sharks, which recognises the vulnerability of migratory sharks, covers several of the key species noted here, including the shortfin mako, longfin mako and porbeagle (http://sharksmou.org/).

3 Shark species summaries

Below is a summary of the risk assessments undertaken by the WCPFC, IOTC and International Commission for the Conservation of Atlantic Tuna (ICCAT). A review of shark status and management plans was completed by the WCPFC in 2011 (Clarke 2011), however since that time, stock assessments have been updated and an ecological risk assessment of sharks in the Indian Ocean has been completed (Murua et al. 2012). It is important to note that the assessments of shark status completed by the different RFMOs are not directly comparable due to varying techniques, assumptions and terminology, and often do not explicitly state whether a species is "high risk", "highly vulnerable" or "intermediate risk".

Oceanic Whitetip Shark

Figure 1 Distribution of oceanic whitetip



Source: iucnredlist.org

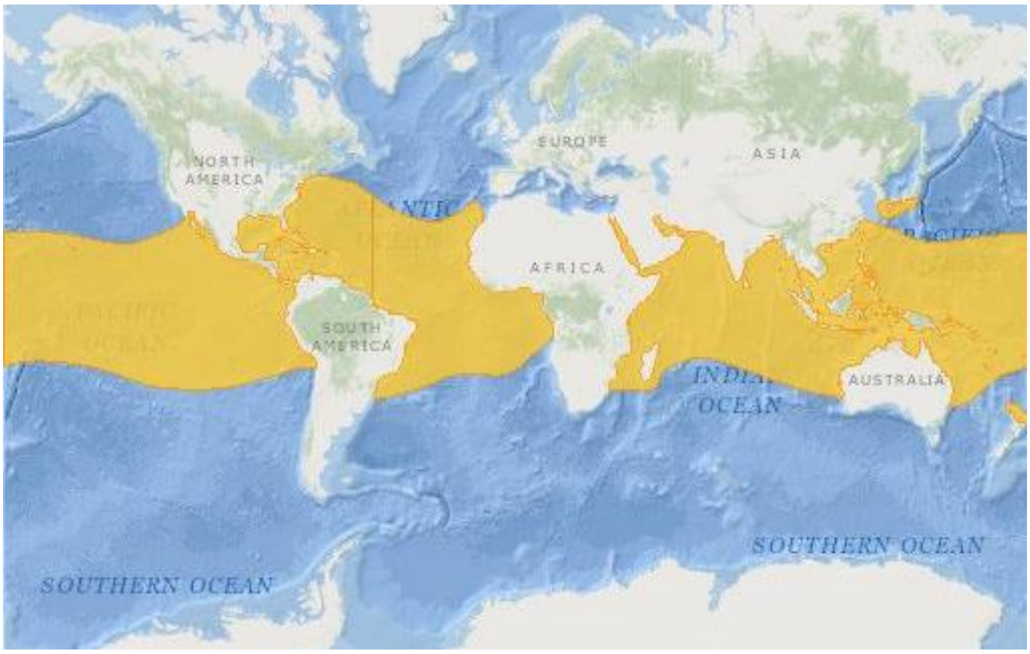
Oceanic whitetip sharks were identified as the fifth most vulnerable shark species to longline operations in the Indian Ocean (Murua et al. 2012). While considered to have low productivity, this species exhibits lower susceptibility to longline fishing gears, and therefore lower vulnerability.

In the WCPFC, oceanic whitetips are among the most encountered shark species for both the longline and purse-seine fisheries (Kirby 2006). The first quantitative stock assessment of oceanic whitetips was recently completed by the WCPFC, and found that the population was dramatically overfished and that overfishing was still occurring (Rice & Harley 2012a). Spawning biomass is estimated to have declined by 86 per cent in the model period (1995–2009). Further, catch, CPUE and size composition were all seen to decline consistently over the same time frame (Rice & Harley 2012a). While the risk assessment for the WCPFC indicates the threat to oceanic whitetips as "intermediate", this PSA was completed before the current stock assessment was released and is therefore in need of reassessment.

Across multiple data sets there has been a long decline in the catch rates of oceanic whitetips, with catch rates falling by 70–99 per cent, to near zero-levels, in the last decade in the WCPFC and Atlantic. Further, there has been a substantial decline in median size across multiple data sets (Clarke 2011). These declines indicate the species is drastically overfished and that the stock is depleted in the Western and Central Pacific Ocean (WCPO) and Atlantic. No stock assessment exists for any shark species in the IOTC.

Silky Shark

Figure 2 Distribution of silky shark



Source: iucnredlist.org

Silky sharks were identified as highly vulnerable to both the purse-seine and the pelagic longline fleets in the IOTC (Murua et al. 2012). This was attributed to their high susceptibility and low reproductive output. There may also be large indirect impacts of fisheries in the Indian Ocean. Incidental catch of silky sharks by abandoned Fish Aggregating Devices (FADs) appear to be 5–10 times higher than incidental catches in the purse-seine fishing operations (Chanrachkij & Loog-on 2003; Filmalter et al. 2013) as silky sharks often become ensnared in the netting used in some FADs. This may be addressed by preventing the use of netting in future FADs design and prohibiting the abandonment of FADs after their use (Filmalter et al. 2012; IOTC 2012). A recently adopted IOTC resolution has made progress to this end (IOTC Resolution 13/08 *Procedures on a Fish Aggregating Devices (FADs) management plan, including more detailed specifications of catch reporting from FAD sets, and the development of improved FAD designs to reduce the incidence of entanglement of non-target species*).

In the WCPFC, encounter rates of silky sharks are higher in the purse-seine fishery than in the longline fisheries; silky sharks were the most encountered shark species in the WCPFC purse-seine fishery (based on annual catch data; see Kirby 2006). This high encounter rate (including large numbers of juveniles), has led to suggestions that fishing mortality associated with the WCPFC fisheries is above the maximum sustainable level.

A preliminary stock assessment of silky sharks in the WCPFC was conducted in 2012. The results were pessimistic and indicated the stock was overfished and subject to overfishing (Rice &

Harley 2012b). However, some technical issues were identified with the assessment and the Scientific Committee was unable to provide management advice based on the assessment, although they noted that basic fishery indicators had declined in recent years and therefore recommended no increase in the mortality of silky sharks. Indeed, despite inconsistent trends in regards to catch rates, there has been a consistent decline in median size in both longline and purse-seine fisheries in the South Pacific. A revised stock assessment is being presented at the WCPFC Scientific Committee meeting in 2013.

Of the 11 species of pelagic elasmobranchs assessed as part of an ERA of the Atlantic pelagic longline fishery, silky sharks were ranked most vulnerable to the fishery due to the high susceptibility to the fishery and low productivity of the species (Cortés et al. 2010).

Blue Shark

Figure 3 Distribution of blue shark

Source: iucnredlist.org

In all three of the RFMOs examined here, blue shark is one of the most encountered shark species in pelagic longline fisheries (Cortés et al. 2010; Clarke et al. 2011a; Murua et al. 2012). However, blue sharks are considered to be one of the most productive shark species, with each adult female capable of producing more than 60 pups per year (Kirby 2006). As such, this species may be considered to be lower risk than lower productivity species, despite its high encounter rate (Clarke 2011).

Despite the high fecundity of blue sharks, recent declines in catch rates in four areas of the North Pacific and targeting by commercial fleets indicate the species may be below B_{MSY} and management measures are needed in order to prevent further depletion (Clarke 2011). A stock assessment of blue shark in the North Pacific is expected to be presented at the 2013 WCPFC Scientific Committee meeting.

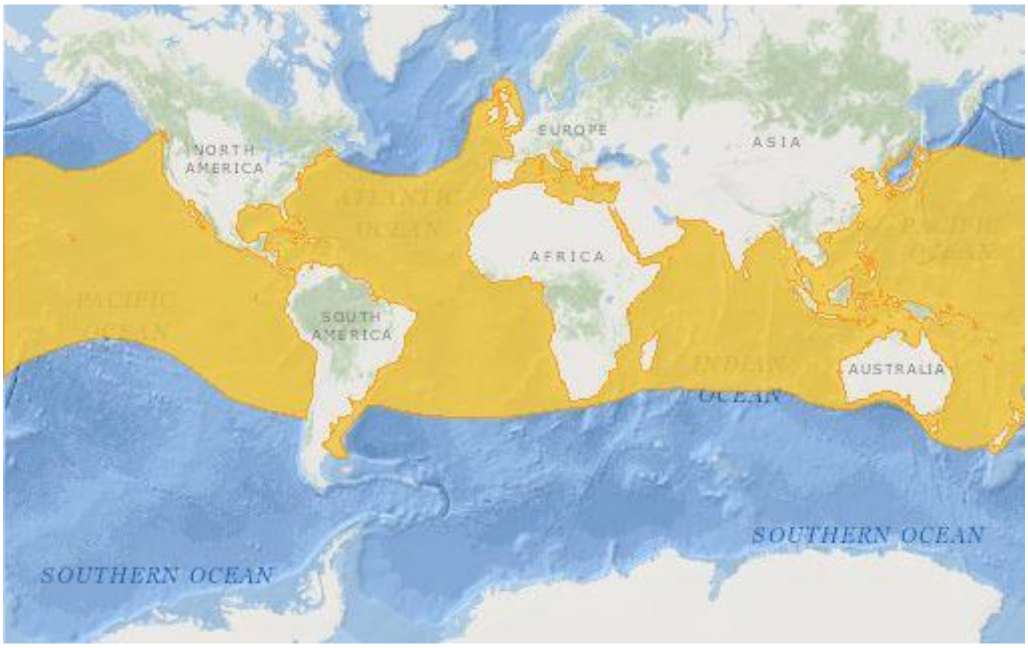
Makos

Observer data from the WCPO indicates an approximate 50 per cent drop in catch rates of makos in the WCPFC over the last decade (Clarke 2011; Lawson 2011). However, reported catch trends for makos in the North Pacific appear weak, while southern hemisphere catch rates have remained steady in recent years. Further, in the ICCAT Convention Area, there have been long-term declines in the catch rate of shortfin makos (Clarke 2011). Despite this, there has been a slight increase in the catch trends of the Japanese commercial long line fishery (in the North Pacific); however this may be due to some targeting bias (Clarke 2011).

Relative to other sharks, makos comprise a very small proportion of longline catch in the WCPFC and catch in purse-seine fisheries is even less common (Clarke et al. 2011a).

Shortfin Mako

Figure 4 Distribution of shortfin mako



Source: iucnredlist.org

Shortfin mako is considered to be highly vulnerable, or high risk to the IOTC and ICCAT longline fisheries due to low productivity, high susceptibility and high post-capture mortality (92 and 99 per cent, ICCAT and IOTC, respectively) associated with pelagic longline fisheries (Cortés et al. 2010; Murua et al. 2012). Shortfin mako is considered to be intermediate risk in the WCPFC due to low productivity and high susceptibility to pelagic longline fishing operations (Kirby & Hobday 2007; Clarke 2011).

There are varying catch rate trends for shortfin makos in the different regions of the WCPFC and ICCAT convention areas. Despite a slight increase in catch trends of the Japanese commercial longline fishery (although this may be due to some targeting bias), there has been up to a 50 per cent drop in the nominal catch of shortfin mako over the last decade in the WCPFC (Clarke 2011; Lawson 2011). Further, there has been long-term catch rate declines in the ICCAT area (Clarke et al. 2011a). These conflicting catch data trends may complicate the assessment of shortfin mako in the WCPFC. However, given the assessment of higher risk and vulnerability in other RFMOs, shortfin mako should be managed based on intermediate-high susceptibility to the pelagic longline fisheries.

Longfin Mako

Figure 5 Distribution of Longfin mako

Due to lower susceptibility to longline fishing gear, longfin mako is considered to be slightly lower risk than the shortfin makos in both the IOTC and ICCAT areas (Cortés et al. 2010; Murua et al. 2012). However, biological information about the species is lacking and analysis was made based on life history data for the shortfin species (Cortés et al. 2010). To increase confidence in the PSA of longfin mako requires information on reproductive potential and other biological characteristics.

Clarke (2011) emphasises the lack of conclusive data for longfin mako, and states that the status of the species is unknown in the WCPO and worldwide.

Bigeye Thresher

Figure 6 Distribution of bigeye thresher

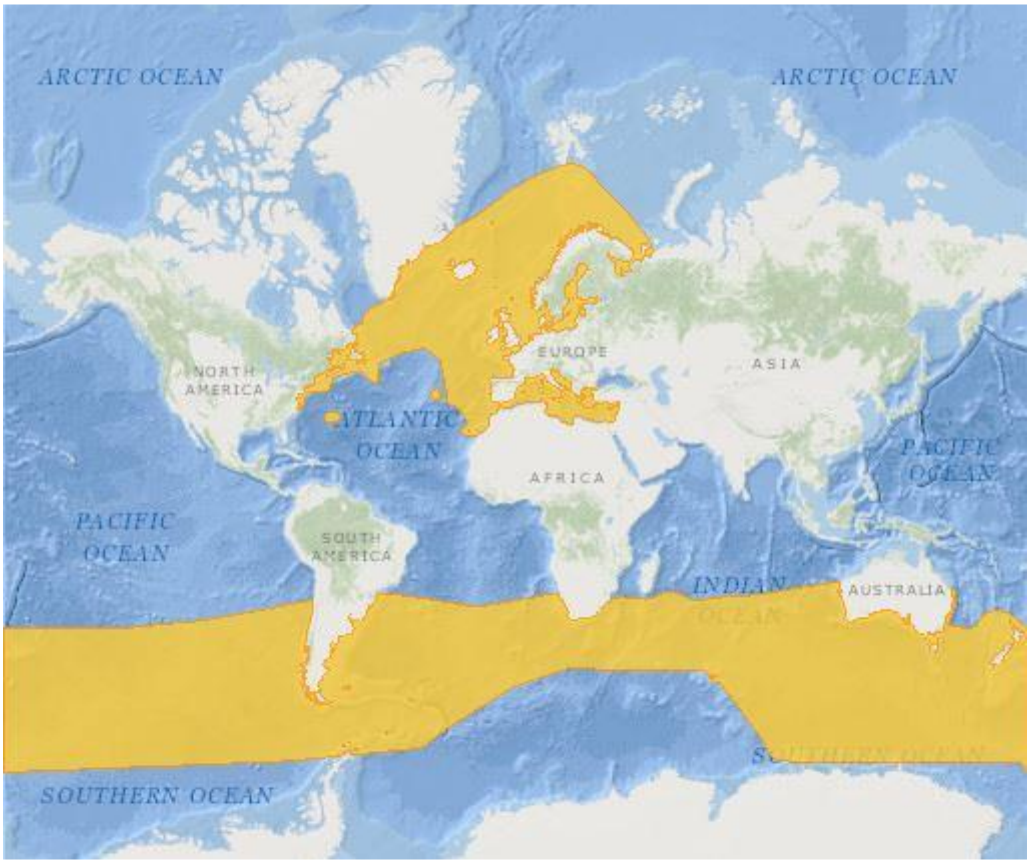
Source: iucnredlist.org

In all three of the RFMOs examined here, bigeye thresher has been identified as at high or intermediate risk to the pelagic longline fishery, however many studies are affected by a lack of species-specific data with some, or all, thresher species often studied as a single group. Longline catch rates of bigeye threshers have remained stable over the past decade in the WCPFC, while a decreasing size trend has been identified in the eastern Pacific (Clarke 2011). However, in ICCAT fisheries, catch rates are estimated to have declined by up to 80 per cent when bigeye and common threshers are studied as a group (Clarke 2011).

Catch and size trends in thresher sharks may be complicated due to the combining of the two species (bigeye and common) despite different ranges and trends. This has lead to decreasing size trends in tropical waters being attributed variously to either bigeye threshers (Clarke et al. 2011a) or pelagic threshers (Clarke et al. 2011b). This confusion highlights the need for species, or at least genus, specific study of catch and size trends.

Porbeagle

Figure 7 Distribution of porbeagle



Source: iucnredlist.org

In the IOTC, porbeagles are considered to be highly vulnerable to pelagic longline fisheries. The species has low productivity, but it is buffered from a higher risk level due to its lower availability to the fishing fleet and lower gear selectivity (Murua et al. 2012).

In the WCPFC, porbeagles face an intermediate risk to the pelagic longline fishing fleet due to a high level of encounters and low productivity (Kirby 2006).

Due to their low productivity, porbeagles are considered to be vulnerable to ICCAT tuna longline fisheries. However, the species is spatially buffered from higher risk due to fisheries effort focusing largely on areas outside the geographic range of the species (Cortés et al. 2010).

4 Conclusion

The PSA results summarised here, in conjunction with available quantitative stock assessments, indicate that shortfin mako, silky shark, bigeye thresher and oceanic whitetips appear to be the shark species most at risk to tuna longline operations in the IOTC, WCPFC and ICCAT areas (Appendix A and B[1]). However, there are uncertainties surrounding the biology and population levels of many shark species. In the case of the ICCAT longfin mako assessment, there is little species-specific data concerning breeding ecology and susceptibility to fishing gears; data from shortfin mako were used as a proxy (Cortés et al. 2010). These knowledge gaps need to be addressed in order to fully understand the impact of fishing operations on each species.

In addition to the three species noted above, bigeye thresher was identified as a species particularly vulnerable to longline fishing gears. However, gaps in species-specific biological data mean that thresher species are often studied together as a group, rather than as three distinct species (Clarke 2011). Species-specific data for the thresher group may be improved with better education of scientific observers and therefore identification as limitations on species analysis are created by poor species identification (Clarke 2011).

Blue sharks are among the most encountered shark species in the longline operations of the three RFMOs examined here. While it is often considered to be lower risk due to a particularly high reproductive output, declines in catch rates in the northern Pacific Ocean, in conjunction with active targeting of the species, indicate that the stock may be below sustainable levels (Clarke 2011). As such, blue shark has been identified as a species of concern given commercial fleets are still actively targeting the species (Clarke 2011).

The previous analyses done in other RFMOs can be used by CCSBT as a starting point in order to consider the impact of SBT fisheries on shark stocks. Given the information summarised in this paper, any work on shark species should initially focus on species identified as high risk or highly vulnerable to pelagic longline fisheries.

[1] The analysis for the WCPFC does not specifically rank the species identified as high risk, but indicates that silky shark, shortfin mako, porbeagle and oceanic whitetips are the most observed caught, and maintain low reproductive output, and therefore exhibit high apparent risk (Kirby 2006).

References

Amandè, M.J., Chassot, E., Chavance, P., Murua, H., de Molina, A.D. & Bez, N. 2012, 'Precision in bycatch estimates: the case of tuna purse-seine fisheries in the Indian Ocean', *ICES Journal of Marine Science: Journal du Conseil*, vol. 69, no. 8, pp. 1501-1510.

CCSBT 2012, *Report of the Ninth Meeting of the Ecologically Related Species Working Group*, Ecologically Related Species Working Group, Ninth Meeting, 27-30 March, Tokyo, Japan.

Chanrachkij, I. & Loog-on, A. 2003, *Preliminary report on ghostfishing phenomena by drifting FADs in the eastern Indian Ocean*, IOTC-2007-WPEB-INF06, Working Party on Ecosystems and Bycatch Third Session, 11-13 July 2007, Victoria, Seychelles.

Clarke, S. 2011, *A status snapshot of key shark species in the Western and Central Pacific and potential management options*, WCPFC-SC7-2011/EB-WP-04, Scientific Committee Seventh Regular Session, 9-17 August 2011, Pohnpei, Federated States of Micronesia.

Clarke, S., Harley, S., Hoyle, S. & Rice, J. 2011a, *An indicator-based analysis of key shark species based on data held by SPC-OFP*, WCPFC-SC7-2011/EB-WP-01, Scientific Committee Seventh Regular Session, 9-17 August 2011, Pohnpei, Federated States of Micronesia.

Clarke, S., Yokawa, K., Matsunaga, H. & Nakano, H. 2011b, *Analysis of North Pacific shark data from Japanese commercial longline and research/training vessel records*, WCPFC-SC7-2011/EB-WP-02, Scientific Committee Meeting Seventh Regular Session, 9-17 August 2011, Pohnpei, Federated States of Micronesia.

Cortés, E., Arocha, F., Beerkircher, L., Carvalho, F., Domingo, A., Heupel, M., Holtzhausen, H., Santos, M.N., Ribera, M. & Simpfendorfer, C. 2010, 'Ecological risk assessment of pelagic sharks caught in Atlantic pelagic longline fisheries', *Aquatic Living Resources*, vol. 23, no. 1, pp. 25-34.

FAO 1999, *International Plan of Action for the Conservation and Management of Sharks*, FAO, Rome, Italy.

Filmalter, J., Dagorn, L. & Capelo, M. 2012, *Ghost fishing of silky sharks by drifting FADs: highlighting the extent of the problem*, IOTC-2012-SC15-INF05, Scientific Committee 15th Session, 10-15 December 2012, Mahé, Seychelles.

Filmalter, J.D., Capello, M., Deneubourg, J.-L., Cowley, P.D. & Dagorn, L. 2013, 'Looking behind the curtain: quantifying massive shark mortality in fish aggregating devices', *Frontiers in Ecology and the Environment*.

IOTC 2012, *Report of the Fifteenth Session of the IOTC Scientific Committee*, IOTC-2012-SC15-R[E], Scientific Committee, Fifteenth Session, 10-15 December 2012, Mahé, Seychelles.

Kirby, D.S. 2006, *Ecological Risk Assessment for species caught in WCPO tuna fisheries: Inherent risk as determined by Productivity-Susceptibility Analysis*, WCPFC-SC2-2006/EB WP-1, Scientific Committe Second Regular Session, 7-18 August 2008, Manila, Philippines.

Kirby, D.S. & Hobday, A. 2007, *Ecological Risk Assesment for the effects of fishing in the Western & Central Pacific Ocean: Productivity-Susceptibility Analysis*, WCPFC-SC3-EB SWG/WP-1, Scientific Committee Third Regular Session, 13-24 August 2007, Honolulu, United States of America.

Lawson, T. 2011, *Estimation of catch rates and catches of key shark species in tuna fisheries of the Western and Central Pacific Ocean using observer data*, WCPFC-SC7-2011/EB-IP-02, Scientific Committee Seventh Regular Session, 9-17 August 2011, Pohnpei, Federated States of Micronesia.

Miyake, M.P., Naozumi, M. & Nakano, H. 2004, *Historical trends of tuna catches in the world*, Food and Agricultural Organisation of the United Nations, Rome.

Murua, H., Coelho, R., Santos, M.N., Arrizabalaga, H., Yokawa, K., Romanov, E., Zhu, J.F., Kim, Z.G., Bach, P., Chavance, P., A. Delgado de Molina & Ruiz, J. 2012, *Preliminary Ecological Risk Assessment (ERA for shark species caught in fisheries managed by the Indian Ocean Tuna Commission (IOTC)*, IOTC-2012-SC15-INF10, Scientific Committee 15, Cape Town, South Africa.

Patterson, H. & Hormis, M. 2012, 'Southern Bluefin Tuna Fishery', in J Woodhams, S Viera & I Stobutzki (eds), *Fishery Status Reports 2011*, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

Rice, J. & Harley, S. 2012a, *Stock assessment of oceanic whitetip sharks in the western and central Pacific Ocean*, WCPFC-SC8-2012/SA-WP-06 Rev 1, Scientific Committee Eighth Regular Session, 7-15 August 2012, Busan, Republic of Korea.

—— 2012b, *Stock assessment of silky sharks in the Western and Central Pacific Ocean*, WCPFC-SC8-2012/SA-WP-07 Rev 1, Scientific Committee Eighth Regular Session, 7-15 August 2012, Busan, Republic of Korea.

Richard, Y., Abraham, E.R. & Filippi, D. 2011, *Assessment of the risk to seabird populations from New Zealand commercial fisheries*, Unpublished report held by the Ministry of Fisheries, Wellington. Final Research Report for Ministry of Fisheries projects IPA2009/19 and IPA2009/20

Sánchez, S., Murua, H., González, I. & Ruiz, J. 2007, *Optimum sample number for estimating shark by-catch in the Spanish Purse Seiners in the Western Indian Ocean*, IOTC-2007-WPTT-26, IOTC Working Party on Tropical Tunas, 16-20 July 2007, Seycelles.

WCPFC 2011, *Western and Central Pacific Fisheries Commission: Tuna Fishery Yearbook 2011*, WCPFC, Pohnpei, Federated States of Micronesia.

Worm, B., Davis, B., Kettemer, L., Ward-Paige, C.A., Chapman, D., Heithaus, M.R., Kessel, S.T. & Gruber, S.H. 2013, 'Global catches, exploitation rates, and rebuilding options for sharks', *Marine Policy*, vol. 40, pp. 194-204.

Appendix A

Table 1 Top ten shark species from the PSA vulnerability rankings in the ecological risk assessment for the IOTC fisheries.

PSA Ranking	Longline species
1	Shortfin mako (*Isurus oxyrinchus*)
2	Bigeye thresher (*Alopias superciliosus*)
3	Pelagic thresher (*Alopias pelagicus*)
4	Silky shark (*Carcharhinus falciformis*)
5	Oceanic whitetip shark (*Carcharhinus longimanus*)
6	Smooth hammerhead (*Sphyrna zygaena*)
7	Porbeagle (*Lamna nasus*)
8	Longfin mako[1] (*Isurus paucus*)
9	Great hammerhead (*Sphyrna mokarran*)
10	Blue shark (*Prionace glauca*)

[1]All biological information, expect for litter size and reproductive frequency, as for shortfin mako

Source: Murua et al. (2012)

Appendix B

Table 2 Top ten shark species from the PSA vulnerability rankings in the ecological risk assessment for the ICCAT fisheries.

PSA Ranking	Longline species
1	Silky shark (*Carcharhinus falciformis*)
2	Shortfin mako (*Isurus oxyrinchus*)
3	Shortfin mako (*Isurus oxyrinchus*)[1]
4	Bigeye thresher (*Alopias superciliosus*)
5	Oceanic whitetip shark (*Carcharhinus longimanus*)
6	Longfin mako (*Isurus paucus*)[2]
7	Blue shark (*Prionace glauca*)
8	Smooth hammerhead (*Sphyrna zygaena*)
9	Scalloped hammerhead (*Sphyrna lewini*)
10	Porbeagle (*Lamna nasus*)

[1] Based on productivity and susceptibility values for shortfin mako used in the 2004 ICCAT shark stock assessment

[2] Productivity and susceptibly values of longfin mako are those for shortfin mako

Source: Cortés (2010)