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A Status Snapshot of Key Shark Species in the Western and Central Pacific and Potential Management Options

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Abstract

This document synthesizes all of the shark assessment work completed to date under the Western and Central Pacific Fisheries Commission's Shark Research Plan and discusses existing and potential conservation and management measures for sharks. The current state of eight of the WCPFC's key shark species (blue; shortfin and longfin mako; oceanic whitetip; silky; and bigeye, common and pelagic thresher sharks) in the Western and Central Pacific Ocean is summarized. Various measures implemented to reduce shark mortality due to fishing are examined including the existing WCPFC shark measure and alternative measures applied by WCPFC members in national waters. Measures currently applied by other regional fisheries management organizations are evaluated using WCPO observer data. Conclusions regarding the status of the stocks and the effectiveness of current management measures are presented.

1. Introduction

In response to regional and global concerns about the status of shark populations, the Western and Central Pacific Fisheries Commission (WCPFC) at its Sixth Regular Session called for development of a Shark Research Plan (SRP) to fill data gaps and conduct quantitative stock assessments for key shark species. An SRP was developed by the Secretariat of the Pacific Community-Oceanic Fisheries Programme (SPC-OFP), endorsed by the WCPFC Scientific Committee's Sixth Regular Session (SC6) and approved by the Commission in December 2010 (WCPFC 2010).

The SRP has three main inter-related components:

- **assessments** to be undertaken with existing and available data;
- coordination of **research** efforts to supplement biological and other assessment-related information; and
- improvement of **data** from commercial fisheries.

Progress on the second and third components is discussed in Clarke et al. (2011a). For the assessment component, the initial work was agreed to consist of an indicator-based analysis of the consequences of fishing pressure on shark stock status. This work was designed to build on previous ecological risk analysis conducted by SPC-OFP and provide early input to the Commission's discussions of shark conservation and management measures. The next phase of the assessment work, to be conducted between mid-2011 and mid-2014, will involve quantitative stock assessments for the eight key shark species included in the SRP (Clarke et al. 2011a). A proposed process for the nomination of new key shark species and for determining whether such species should be designated for data provision and/or assessment will be considered separately by SC7 (Clarke 2011).

This document synthesizes all of the shark assessment work completed to date under the SRP and discusses various means of mitigating shark mortality due to fishing. It begins with a summary of what is known about the current state of key shark species in the Western Central Pacific Ocean (WCPO) based on analyses reported in detail in other papers presented to SC (Section 2). It also describes other available information on the status of key species, for example, in previous studies and/or from other oceans. To support consideration of existing and proposed conservation and management measures (CMMs) for sharks, the effectiveness of various measures in reducing shark mortality due to fishing are discussed (Section 3). These measures include the existing WCPFC shark CMM (Section 3.1), alternative measures applied by Commission members and cooperating non-members (CCMs) in national waters (Section 3.2), and CMMs currently applied by other regional fisheries management organizations (RFMOs; Section 3.3)). As a whole, this document supports discussion of the need for further mitigation of shark mortality due to fishing, and the options available, should this need be established.

2. Status Snapshots

The status snapshots provided below are summaries of scientific information concerning the current state of the key shark species in the WCPO. These status snapshots encapsulate findings from several papers presented to SC7 based on SPC (Clarke et al. 2011b, Lawson 2011), Japan (Clarke et al. 2011c) and United States (Walsh and Clarke 2011) data holdings, as well as information from previous papers presented to SC on ecological risk assessment (Kirby and Molony 2006, Kirby and Hobday 2007) and catch estimates based on shark fin trade records (Clarke 2009). As many of these papers do not provide species-specific information on makos or threshers, sharks in these genera (*Isurus* spp. and *Alopias* spp.) are often described as groups.

Each snapshot consists of a plot (Figures 1-5) and a brief description of the relevant findings; further details can be found in the original papers. To place this information in context, additional information on the status of the key species is also provided when available. As the purpose of the snapshots is to inform discussions on management measures for sharks under the WCPFC, the information is limited to scientific studies relevant to stock status (i.e. the full suite of oceanographic or biological studies is not presented). To provide a composite view, two status plots showing trends in catch rates and trends in size against a measure of productivity are shown for the key shark species as a group (Figures 6-7).

2.1 Blue Shark

2.1.1 Summary of Information Presented to WCPFC's Scientific Committee

Blue shark (Figure 1) is known as one of the most prolific shark species (Cortés 2002) and is distributed throughout the WCPO, including tropical waters (Clarke et al. 2011b; Clarke et al. 2011c). Reinforcing a pattern first described by Nakano (1994), adult blue sharks were generally found at lower latitudes with higher proportions of juveniles found at higher latitudes (Clarke et al. 2011b; Clarke et al. 2011c). Region-wide catch rate analysis identified areas off Japan and south of New Zealand as centers of abundance for blue shark (Lawson 2011). Standardized catch rate trends indicate continuous, substantial declines in abundance in the North Pacific (Clarke et al. 2011b, Clarke et al. 2011c) with the exception of the Japanese commercial longline catch rate series, which showed a strong trend of increase until 2005 as a result of blue shark targeting, followed by a decline (Clarke et al. 2011c). In the southern hemisphere, catch rate trends declined until 2003 and then increased to mid 1990s levels. Trends in median sizes were decreasing in some areas but increasing in others. Catch estimates in number based on observer data indicate removals have dropped by at least 50% in the past decade (Lawson 2011) with median estimates for 2006 ranging from 600,000 to 5 million individuals (Lawson 2011, Clarke 2009). The blue shark was categorized as being at “medium” ecological risk for deep longline sets and “medium-low” ecological risk for shallow longline sets (Kirby and Hobday 2007).

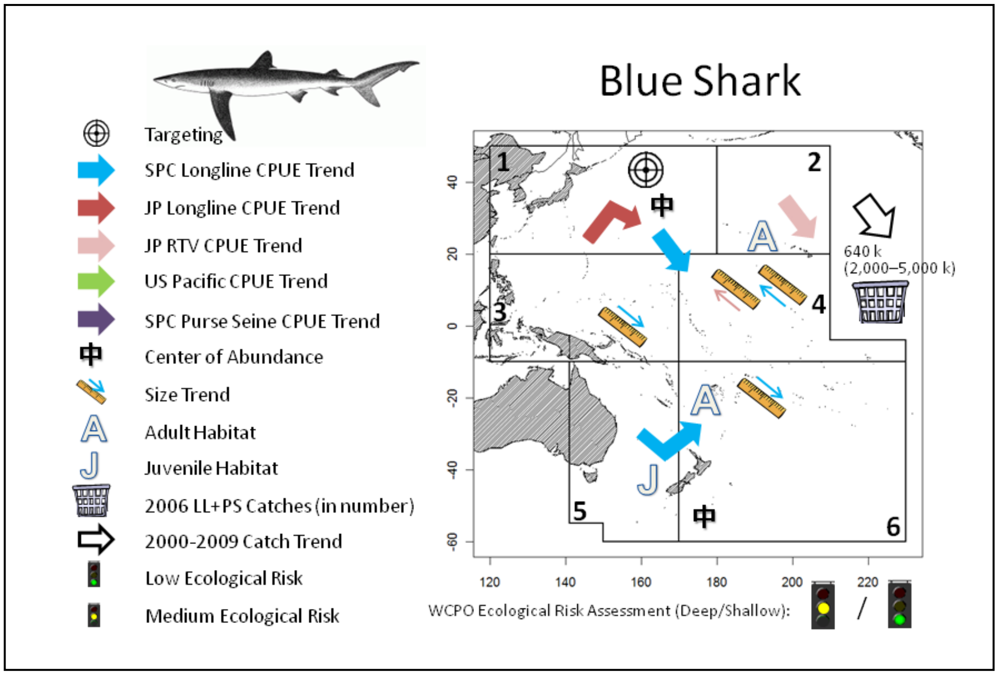

Figure 1. Status snapshot for blue shark (*Prionace glauca*) in the WCPFC Statistical Area. Targeting, JPLL CPUE Trend, JPRTV CPUE Trend and some Adult/Juvenile Habitat information is drawn from Clarke et al. (2011c). SPCLL CPUE Trend, Size Trend and some Adult/Juvenile Habitat information is drawn from Clarke et al. (2011b). SPC Purse Seine CPUE Trend, Center of Abundance, 2006 Catches (in number) and 2000-2009 Catch Trend (low end) are from Lawson (2011) and Catch Trend (high end) is from Clarke (2009). Ecological risk information is derived from Kirby and Hobday (2007).

2.1.2 Summary of Information from other Studies

Blue sharks are one of the few species for which several stock assessments have been conducted in both the Pacific and Atlantic oceans. Kleiber et al. (2009) presented an assessment of this species for the North Pacific based on data through 2002 which concluded that the population appeared close to the B_{MSY} reference point and fishing effort may be approaching F_{MSY}. Using a previous version of this stock assessment as a basis for comparison, Clarke et al. (2006) estimated based on shark fin trade quantities in 2000 that blue sharks globally were being harvested at levels close to or possibly exceeding their maximum sustainable yield. More recently, Polovina et al. (2009) identified a declining catch rate trend for blue sharks of 3% per year (1996-2006) in deep sets by the Hawaii-based longline fishery. Assessments conducted by ICCAT for the North and South Atlantic found that blue shark biomass and fishing mortality as of 2007 had not breached their MSY reference points (ICCAT 2005, 2008). Substantial declines in Atlantic catch rates were identified by Baum et al. (2003), which estimated a 60% decline in the Northwest Atlantic between 1986-2000, and Aires-da-Silva et al. (2008), which estimated a 30% decline in catch rates between 1957-2000. Two recent ecological risk assessments for longline fisheries in the Atlantic concluded that blue sharks' vulnerability to longline gear was moderate in comparison to other pelagic sharks (Cortés et al. 2010, Arrizabalaga et al. 2011). This species is classified by the IUCN Redlist as "Near Threatened" (IUCN 2011).

2.1.3 Synopsis

The blue shark is probably the most common, but not the most vulnerable, of pelagic sharks. Stock assessments to date, including those using Pacific data through 2002, have not indicated overfishing or an overfished state. However, in the recent WCPO analyses, substantial recent catch rate declines found in four different datasets for the North Pacific, in combination with demonstrated targeting of blue shark by a large commercial fleet operating in this area, are scientific grounds for concern and suggest further declines in abundance since 2002. Therefore, the conclusion of Kleiber et al. (2009) that this stock is above B_{MSY} may no longer hold.

2.2 Mako Sharks

2.2.1 Summary of Information Presented to WCPFC's Scientific Committee

The shortfin mako (Figure 2) is found over a similar range as the blue shark but at much lower abundances; the longfin mako is less well-studied but is believed to have a more tropical and offshore distribution (Compagno et al. 2005). The shortfin and longfin makos were categorized as being at "medium" ecological risk for both deep and shallow longline sets (Kirby and Hobday 2007). Few adult makos were identified in the North Pacific, and few adult females were identified in the South Pacific (Clarke et al. 2011b). High proportions of juveniles were found in the Tasman Sea (Clarke et al. 2011b) with a center of abundance for the species identified off northeast New Zealand (Lawson 2011). The only strongly increasing trend in standardized catch rates in the North Pacific was in the Japanese commercial longline series through 2006 for which there was some evidence of targeting bias, perhaps related to blue shark targeting (Clarke et al. 2011c). Other catch rate trends in the North Pacific were weak, and the only southern hemisphere series showed a nearly flat trend in recent years. Poor performance was noted for some of the standardization models, perhaps due to a lack of data, particularly in the North Pacific. There were no significant size trends identified for makos. Catch estimates in number based on observer data indicate removals have dropped by approximately 50% in the past decade (Lawson 2011) with median estimates for 2006 ranging from ~50,000 to 250,000 individuals (Lawson 2011; Clarke 2009).

2.2.2 Summary of Information from other Studies

Stock status information for makos is available in the form of two stock assessments for the shortfin mako. Consecutive assessments conducted by ICCAT failed to draw any conclusion about the North and South Atlantic stocks but considered that biomass and fishing mortality reference points may have been breached (ICCAT 2005, 2008). Declines in long-term catch rate series were identified by Baum et al. (2003) and Baum and Myers (2004) for shortfin makos but these declines were reportedly less than for other pelagic and coastal sharks. A Northwest Pacific stock assessment based on virtual population analysis found a downward trend in spawning potential ratio and concluded that the stock "might have been overexploited", recommending a reduction in current fishing effort of 32% (Chang and Liu, 2009). Recent ecological risk assessments for the Atlantic longline fisheries have ranked the shortfin mako, along with the silky shark, as among the most vulnerable pelagic sharks, and along with bigeye thresher the most vulnerable of the WCPFC key species (Cortés et al. 2010, Arrizabalaga et al. 2011). However, research from the North Pacific suggests that shortfin makos' productivity may be higher than previously thought (Semba et al. 2011). Both the shortfin and longfin makos are classified by the IUCN Redlist as "Vulnerable" (IUCN 2011).

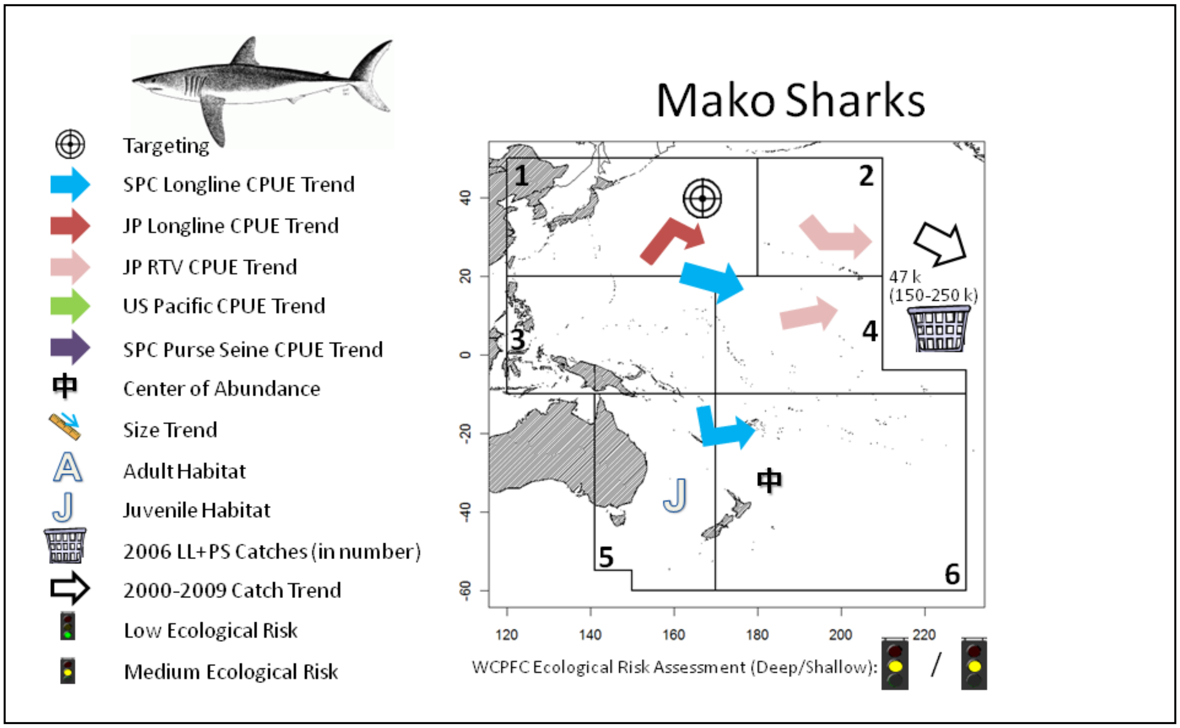

Figure 2. Status snapshot for mako sharks (*Isurus* spp.) in the WCPFC Statistical Area. Targeting, JPLL CPUE Trend, JPRTV CPUE Trend and some Adult/Juvenile Habitat information is drawn from Clarke et al. (2011c). SPCLL CPUE Trend, Size Trend and some Adult/Juvenile Habitat information is drawn from Clarke et al. (2011b). SPC Purse Seine CPUE Trend, Center of Abundance, 2006 Catches (in number) and 2000-2009 Catch Trend (low end) are from Lawson (2011) and Catch Trend (high end) is from Clarke (2009). Ecological risk information is derived from Kirby and Hobday (2007).

2.2.3 Synopsis

Recent abundance indices and median size analyses for shortfin mako in the WCPO have shown no clear trends; therefore there is no apparent evidence of the impact of fishing on this species in the WCPO. Most previously published stock status studies are also inconclusive. Ongoing issues of concern for the WCPO are: 1) a previously published study suggesting stock reduction in the Northwest Pacific using virtual population analysis; 2) the high vulnerability of shortfin makos to longline fishing; and 3) the potential for collateral targeting in directed fishing for blue sharks in the North Pacific. The status of longfin mako stocks is unknown for the WCPO and worldwide.

2.3 Oceanic Whitetip Shark

2.3.1 Summary of Information Presented to WCPFC's Scientific Committee

Oceanic whitetip sharks (Figure 3) were found to interact with fisheries between 30^{o} N and S latitude with larger individuals, near or at the length at maturity, taken by the longline fishery and mainly juveniles captured by purse seine gear (Clarke et al. 2011b, Clarke et al. 2011c). Juveniles were usually found in equatorial waters to the west; adults appear to predominate more to the southwest near the identified center of abundance (10^{o}S, 190^{o}E) (Clarke et al. 2011b, Lawson 2011). The oceanic whitetip shark was categorized as being at "medium" ecological risk for both deep and shallow longline sets (Kirby and Hobday 2007). All standardized catch rate trends from longline and purse seine fisheries were clear, steep and downward. Japan's research and training vessel (RTV) dataset and the SPC-held longline and purse seine observer datasets independently confirm that oceanic whitetip sharks were rarely recorded after 2005 (Clarke et al. 2011b, Clarke et al. 2011c). These datasets also agree that all median size trends were declining until samples became too scarce for analysis, and several of these size trends from more than one dataset were significant in the core habitat areas. Analysis of the United States (US) commercial longline series indicated that oceanic whitetip catch rates decreased by an order of magnitude between 1995-2010 (Walsh and Clarke 2011). Catch estimates in number based on observer data indicate removals have dropped by ~70% in the past decade (Lawson 2011) with median estimates for 2006 ranging from 48,000 to 320,000 individuals (Lawson 2011, Clarke 2009).

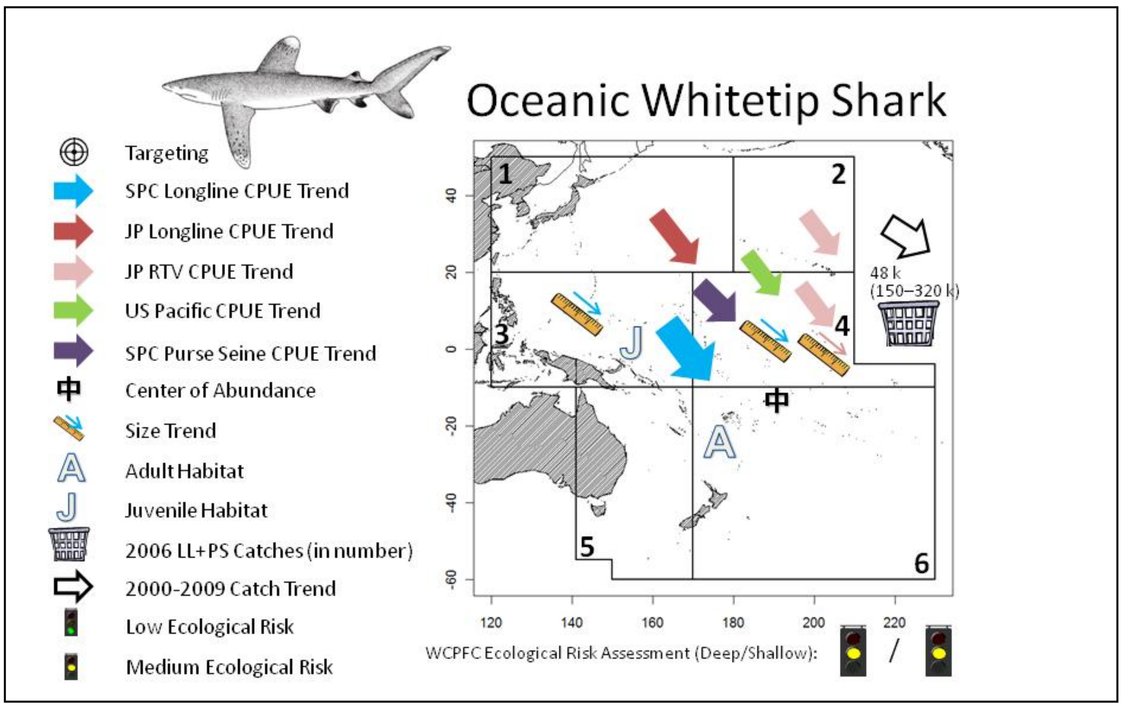

Figure 3. Status snapshot for oceanic whitetip shark (*Carcharhinus longimanus*) in the WCPFC Statistical Area. Targeting, JPLL CPUE Trend, JPRTV CPUE Trend and some Adult/Juvenile Habitat information is drawn from Clarke et al. (2011c). SPCLL CPUE Trend, Size Trend and some Adult/Juvenile Habitat information is drawn from Clarke et al. (2011b). US Pacific CPUE Trend information is from Walsh and Clarke (2011). SPC Purse Seine CPUE Trend, Center of Abundance, 2006 Catches (in number) and 2000-2009 Catch Trend (low end) are from Lawson (2011) and Catch Trend (high end) is from Clarke (2009). Ecological risk information is derived from Kirby and Hobday (2007).

2.3.2 Summary of Information from other Studies

To date, no stock assessments have been conducted for the oceanic whitetip shark. Available information from published catch rate analyses in the Atlantic suggest declines of 70-99% (Baum et al. 2003, Baum and Myers 2004) but operational changes over time and skewed sampling at the edge of the oceanic whitetip's range complicate interpretation of the magnitude of these trends (Burgess et al. 2005, Bonfil et al. 2008, Camhi et al. 2009). Previous analysis of Japanese research vessel data from the 1960s and the 1990s found significant differences in catch rates only in the central WCPO where the trend was increasing in one latitudinal band but decreasing in another (Matsunaga and Nakano 1999). IATTC reports that unstandardized catch rates for oceanic whitetip sharks in purse seine operations declined from 1994-2004 (IATTC 2010). The recent Atlantic ecological risk assessments found the oceanic whitetip to be similar in vulnerability to the blue shark and less vulnerable than the makos (Cortés et al. 2010, Arrizabalaga et al. 2011). However, the oceanic whitetip is classified with the makos as "Vulnerable" by the IUCN Redlist (IUCN 2011).

2.3.3 Synopsis

Although there has been no stock assessment conducted for this species to date, there is consensus that the oceanic whitetip population in the Atlantic is depleted. Recent analysis of four different datasets for the WCPO show clear, steep and declining trends in abundance indices for this species. Analysis of two of these datasets for median lengths confirmed that oceanic whitetip sizes decreased significantly until samples became too scarce for analysis. Given the strong existing evidence for the depleted state of the oceanic whitetip population in the WCPO, stock assessment studies may clarify but will not alter the case for further conservation and management action.

2.4 Silky Shark

2.4.1 Summary of Information Presented to WCPFC's Scientific Committee

Silky sharks (Figure 4) were the most narrowly distributed of the five key shark species groups, interacting with fisheries mainly between 20^{o} N and S latitude (Clarke et al. 2011b). Juveniles dominated the catches for both longline and purse seine gear (Clarke et al. 2011b, Clarke et al. 2011c). In contrast to oceanic whitetip sharks which also have core habitat in tropical waters, silky sharks' center of abundance is located more to the northwest (0^{o}S, 165^{o}E; Lawson 2011). Silky sharks were categorized as being at "medium" ecological risk for both deep and shallow longline sets (Kirby and Hobday 2007). Catch rates showed no strong trends in any of the SPC-, Japan- or US-held datasets, although slightly declining trends were noted in recent years in the SPC and Japan RTV series (Clarke et al. 2011b, Clarke et al. 2011c, Walsh and Clarke 2011). Lawson (2011) identified increasing catch rate trends in standardized purse seine catch rates through 2008. Despite the lack of clear trends in catch rates, median lengths were always decreasing and trends were often significant for both sexes in SPC-held longline and purse seine observer data from the core habitat areas (Clarke et al. 2011b). Decreasing size trends were also found in the Japan RTV data series (Clarke et al. 2011c). Catch estimates in number based on observer data indicate removals initially dropped but then increased beyond 2000 levels by 2010 (Lawson 2011). Median catch estimates for 2006 range from 200,000 to 500,000 individuals (Lawson 2011, Clarke 2009).

2.4.2 Summary of Information from other Studies

Preliminary work on a silky shark stock assessment has been undertaken by IATTC with a full stock assessment scheduled for completion in late 2011. Standardized catch rate analyses based on Eastern Pacific purse seine floating object set data for 1994-2004 demonstrated that catch rates had declined by 60-82% over the time series (Minami et al. 2007). Standardized catch rate analyses for Japanese research and training vessel data from the North Pacific have also showed a declining trend since 1992 (Shono 2008, SSKC 2011). In the Atlantic, standardized catch rates for the Gulf of Mexico were found to have declined by 91% for silky sharks (Baum and Myers 2004). The two Atlantic longline fishery-based ecological risk assessments agreed that the vulnerability of the silky shark is similar to the makos, and greater than that of blue and oceanic whitetip sharks. The IUCN Redlist ranks silky sharks as "Near Threatened" globally but "Vulnerable" in the eastern central and southeast Pacific.

2.4.3 Synopsis

Silky sharks have a restricted habitat range compared to the other WCPFC key species but within this range they dominate both longline and purse seine catches. Although silky sharks have been shown to have declining catch rate trends in past studies in the Pacific, no strong trends were found in recent (2011) WCPO analyses. Nevertheless, declining size trends in two datasets, declining catch rates in these two datasets for the most recent years of the time series, and increasing removals all indicate a need for close, ongoing monitoring of indicators. Further research may allow better definition of trends and a clearer depiction of stock status.

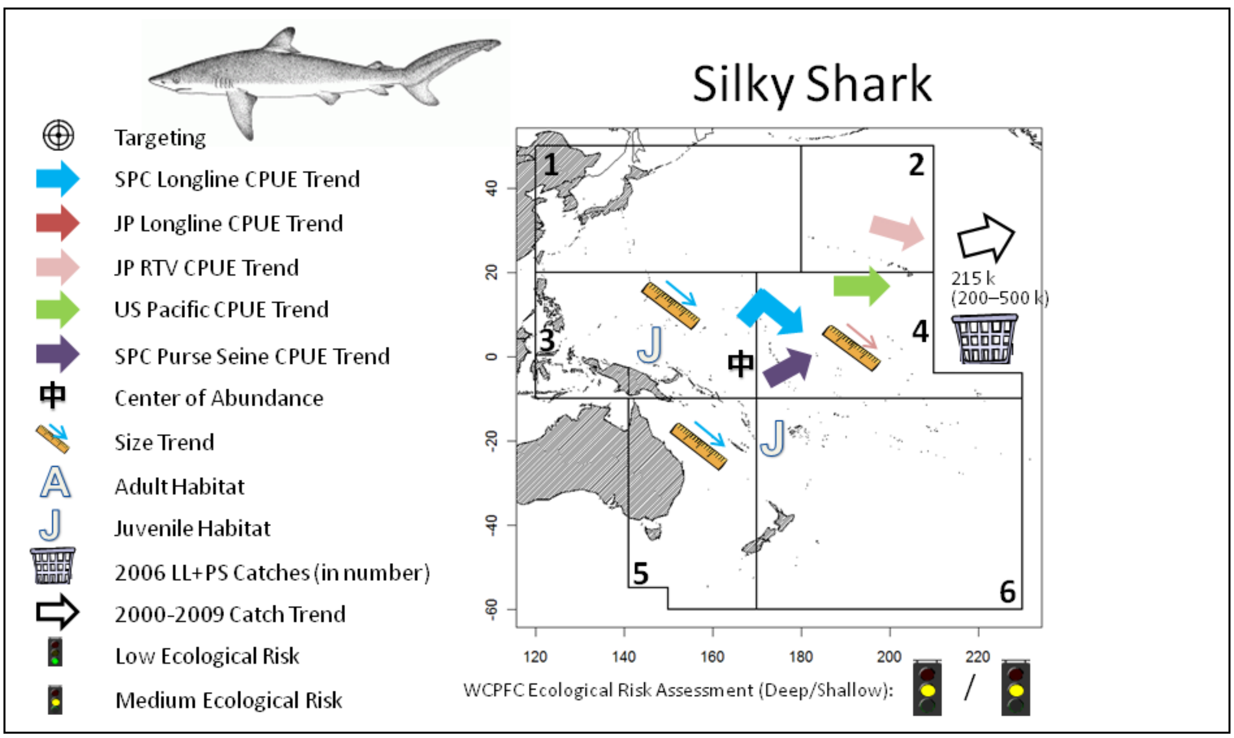

Figure 4. Status snapshot for silky shark (*Carcharhinus falciformis*) in the WCPFC Statistical Area. Targeting, JPLL CPUE Trend, JPRTV CPUE Trend, Size Trend and some Adult/Juvenile Habitat information is drawn from Clarke et al. (2011c). SPCLL CPUE Trend, Size Trend and some Adult/Juvenile Habitat information is drawn from Clarke et al. (2011b). US Pacific CPUE Trend information is from Walsh and Clarke (2011). SPC Purse Seine CPUE Trend, Center of Abundance, 2006 Catches (in number) and 2000-2009 Catch Trend (low end) are from Lawson (2011) and Catch Trend (high end) is from Clarke (2009). Ecological risk information is derived from Kirby and Hobday (2007).

2.5 Thresher Sharks

2.5.1 Summary of Information Presented to WCPFC's Scientific Committee

The three species in the thresher family have divergent, but not necessarily distinct, distributions (Compagno et al. 2005) and interact with longline fisheries throughout the WCPO (Clarke et al. 2011b). All three threshers were categorized as being at "medium" ecological risk for both deep and shallow longline sets (Kirby and Hobday 2007). Thresher sharks (Figure 5), mainly bigeye thresher, were most often observed from deep longline sets in east-central areas of the tropical WCPO (Clarke et al. 2011b, 2011c). High proportions of juveniles were found near the estimated center of abundance (15°N, 170°E) (Lawson 2011, Clarke et al. 2011b). Few adults were identified in tropical waters (Clarke et al. 2011b, 2011c) but in the Japan RTV dataset most bigeye threshers found north of 20°N exceeded the length at maturity. No strong trends in standardized catch rates were found for threshers analyzed as a group, although the Japan RTV dataset indicated a slight increase in catch rates in eastern waters (Clarke et al. 2011b, 2011c). Poor performance was noted for some of the standardization models, probably due to combining species with different ranges and trends. Decreasing size trends were identified in tropical regions by two studies, but while one attributed these to bigeye threshers (Clarke et al. 2011b), the other which analyzed both bigeye and pelagic threshers found that only pelagic thresher sizes declined (Clarke et al. 2011b). Catch estimates indicate removals have been stable in the past decade (Lawson 2011) with median estimates for 2006 ranging from ~65,000 to 750,000 individuals (Lawson 2011; Clarke 2009).

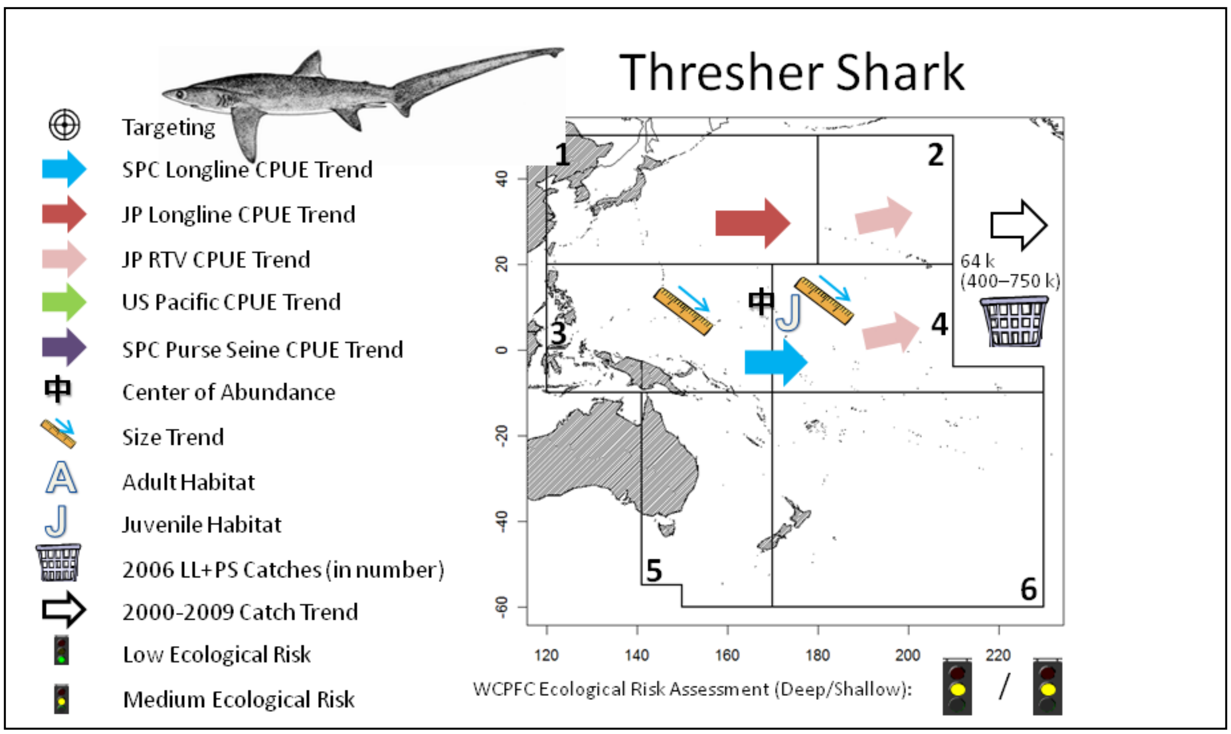

Figure 5. Status snapshot for thresher sharks (Alopias spp.) in the WCPFC Statistical Area. Targeting, JPLL CPUE Trend, JPRTV CPUE Trend and some Adult/Juvenile Habitat information is drawn from Clarke et al. (2011c). SPCLL CPUE Trend, Size Trend and some Adult/Juvenile Habitat information is drawn from Clarke et al. (2011b). SPC Purse Seine CPUE Trend, Center of Abundance, 2006 Catches (in number) and 2000-2009 Catch Trend (low end) are from Lawson (2011) and Catch Trend (high end) is from Clarke (2009). Ecological risk information is derived from Kirby and Hobday (2007).

2.5.2 Summary of Information from other Studies

Threshers are poorly studied as a group, and even more poorly known on a species-by-species basis. Two recent studies by researchers from Chinese Taipei present the first integration of thresher life history traits with measures of fishing pressure in the WCPO. The first study used a spawning per recruit analysis to assess pelagic threshers concluding that the stock was slightly over-exploited and a reduction in fishing effort was needed (Liu et al. 2006). An update to this study applied a stochastic stage-based model, concluded that the stock is over-exploited and recommended nursery closures and/or size limit management (Tsai et al. 2010). In the Atlantic, Baum et al. (2003) estimated declines in catch rate of 80% for bigeye and common threshers as a group. The two Atlantic longline-based ecological risk assessment studies disagreed on the relative risk associated with bigeye and common threshers. One study found bigeye thresher to be comparable in its vulnerability to the mako and silky sharks but common thresher to be relatively resilient (Cortés et al. 2010) whereas the other found both species to be similar to each other and to the blue and oceanic whitetip sharks (Arrizabalaga et al. 2011). The IUCN Redlist classifies all three thresher species as “Vulnerable” (IUCN 2011).

2.5.3 Synopsis

The relative vulnerability of thresher sharks to longline fisheries, and the appropriateness of assessing some or all thresher species as a group, are still under debate. Regardless, data limitations including problems with species identification led to grouping these species in recent (2011) WCPO thresher analyses. Declines in median sizes were identified but no strong catch rate trends were found in any data set. Further research into better analytical methods, in parallel with species-specific data improvement, is required for all three thresher species.

2.6 Shark Status Plots

Under the Shark Research Plan (Phase 1 – Step 2), shark status plots were proposed as a means of further integrating measures of productivity and susceptibility for the key shark species. These plots were designed to show a relatively static measure of productivity based on life history traits on one axis and a dynamic measure of susceptibility based on measurable indicators on the other axis. The two status plots presented below were produced from indicators presented in, or derived from, recent (2011) WCPO analyses. In addition to providing a composite view of the status of the key shark species in a single chart, these plots can be updated over time as a monitoring tool.

The first shark status plot is based on catch rates (Figure 6). Several studies produced standardized catch rate trends for different areas using different models. In total there were seven sets of results including the Japanese commercial longline analysis for Region 1 (JPLL1; Clarke et al. 2011c), the Japanese research and training vessel analysis for Regions 2 and 4 (JPRTV2 and JPRTV4; Clarke et al. 2011c), the analysis of SPC-held longline observer data for the north and south WCPO (SPC-N and SPC-S; Clarke et al. 2011b), and the analysis of Hawaii longline data using delta log normal and Poisson-based models (HWDLN and HWQP/ZIP; Walsh and Clarke 2011). Linear models were fit to the standardized year coefficients for the entire time series available for each of the seven analyses, and the slopes produced by these linear models are plotted on the y-axis of the status plot (Figure 6). Although all slopes are plotted, those that were statistically significant (p-value ≤ 0.05) are shaded in a darker hue. The x-axis represents values of “r”, the intrinsic rate of increase (a measure of productivity), from Cortés et al. (2010). It is important to note that linear models generalize the direction and magnitude of the trend over the entire time series and may obscure otherwise significant slopes occurring during a portion of the time series.

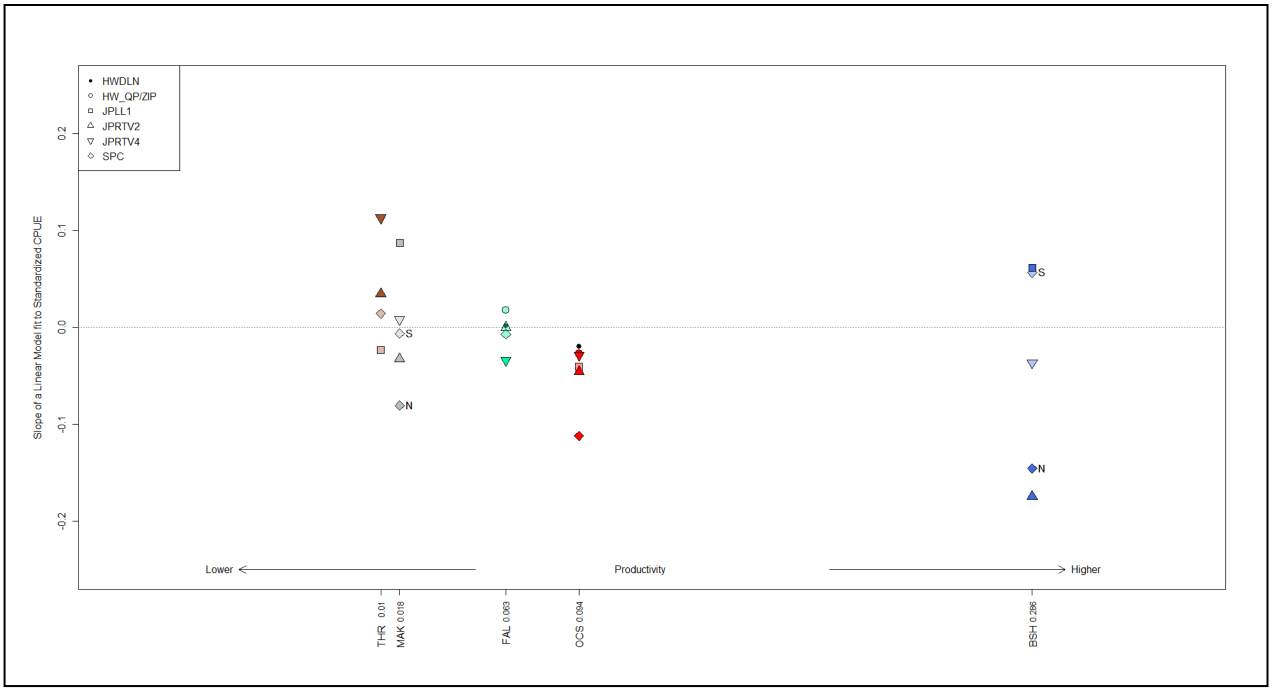

Figure 6. Status plot for catch rate trends showing the slopes of linear model fits to year coefficients produced by seven different standardization analyses (see text; SPC northern and southern hemisphere analyses are annotated with “N” and “S”, respectively) for blue (BSH), mako (MAK), oceanic whitetip (OCS), silky (FAL) and thresher (THR) sharks. Positive and negative slopes lie above and below the dotted line, respectively, with significant ($p \leq 0.05$) slopes shaded in a darker hue. Productivity values shown are the intrinsic rate of increase (r) from Cortés et al. (2010), with shortfin mako values applied to MAK and bigeye thresher values applies to THR.

The status plot for size trends (Figure 7) is based on three datasets: standardized SPC-held longline observer data for Regions 1-6 (Clarke et al. 2011b), unstandardized SPC-held purse seine observer data for Regions 3-4 (Clarke et al. 2011b), and standardized Japanese research and training vessel data for Regions 1-2 and 4 (Clarke et al. 2011c). Models for longline data were run for each sex separately but shark sex data were unavailable for purse seine fisheries. Also, purse seine length data are only available for oceanic whitetip and silky sharks. As for the catch rate status plot presented above, linear models were fit to the year coefficients or annual medians over the entire time series available and the slopes of these linear models were used to identify any significant trends in median lengths over time. The caveat above regarding summarization of a trend with a linear model applies to this analysis as well. A p-value of 0.05 was used to indicate a trend significantly different from zero and statistically significant results were shaded in darker hues.

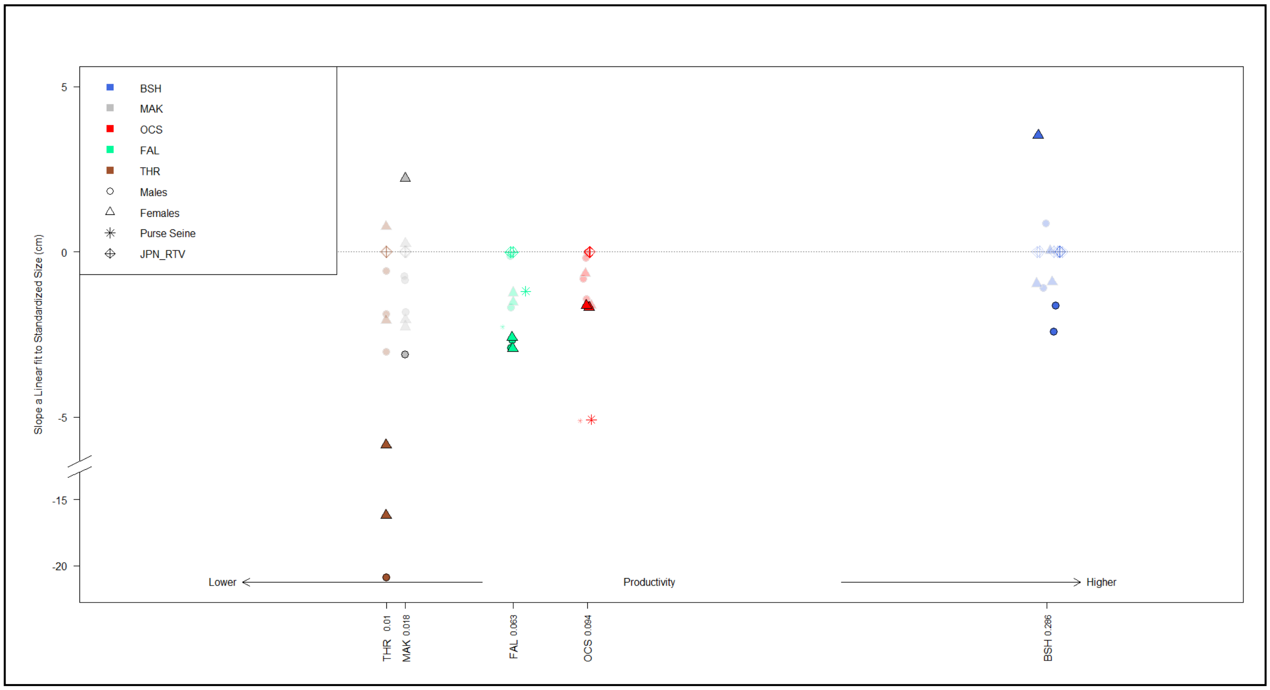

Figure 7. Status plot for median size trends showing the slopes of linear model fits to year coefficients (for standardized datasets) or to annual medians (for unstandardized datasets) of shark lengths recorded in SPC observer longline data (circles for males and triangles for females), SPC observer purse seine data (stars, no sex data available) and Japanese research and training vessel data (diamonds for males and females) for blue (BSH), mako (MAK), oceanic whitetip (OCS), silky (FAL) and thresher (THR) sharks. Positive and negative changes (i.e. larger and smaller size trends) lie above and below the dotted line, respectively, with significant ($p \leq 0.05$) slopes shaded in a darker hue. Productivity values shown are the intrinsic rate of increase (r) from Cortés et al. (2010), with shortfin mako values applied to MAK and bigeye thresher values applied to THR.

3. Scientific Information Relevant to Consideration of Potential Management Options

The previous section aimed to synthesize recent, relevant information on stock status of the WCPFC key shark species, and to briefly summarize the current levels of scientific concern. The next step is to evaluate conservation and management measures (CMMs) which can be applied to improve stock status. This section describes CMMs that have already been implemented, either in the WCPO or under other RFMOs, which may act to reduce shark mortality. The scope of this discussion is limited to existing measures in order to, where possible, provide scientific information about the effectiveness of these measures to facilitate management decision-making. It is therefore not intended that the following discussion represents a full list of potential conservation and management measures for sharks.

The remainder of this section presents the following analyses and summaries:

- An assessment of the WCPFC's existing shark CMM's prohibition on finning including historical and current levels of finning and changes since implementation of the CMM;
- A catalogue of shark-related measures applied by WCPFC members and cooperating non-members (CCMs) in national waters, either as "alternative measures" under the shark CMM or as separate measures; and

- An evaluation of the "no retention" and "prompt release unharmed" mitigation measures implemented by other RFMOs with regard to the expected reduction of shark mortality.

3.1 Existing Mitigation Measure: Prohibition of Finning (CMM 2010-07)

The only mitigation measure currently implemented for sharks in the WCPO is Conservation and Management Measure (CMM) 2010-07. This measure was first adopted in 2006 (CMM 2006-05, implemented in February 2007), and was subsequently amended in 2008 (CMM 2008-06) and 2009 (CMM 2009-04) before being revised in 2010 to the current version. Despite these amendments, the measure has remained substantively unchanged with regard to the following key provisions relating to the mitigation of fishing impacts to sharks:

- minimise waste and discards;
- encourage live release;
- prohibit retention on board, transhipment, landing or trading shark fins which total more than 5% of retained shark carcasses; and
- allow alternative measures within areas of coastal States' national jurisdiction.

Similar to the finning measures adopted by the four other tuna RFMOs (i.e. ICCAT (2004), IATTC (2005), IOTC (2005), and CCSBT (2008[2]), the WCPFC measure is based on a 5% fin to body ratio. However, the form of the fins (i.e. frozen or dried) and the form of the body (i.e. whole weight, dressed or partially dressed carcass) is not specified in any of the measures, and compliance standards are therefore unclear (Fowler and Séret 2010).

WCPFC's CMM 2010-07 is designed to apply to all waters of the Convention Area but allows coastal States to apply alternative measures and report those alternative measures to the Commission in their Annual Reports – Part 2. As of October 2010, of the 32 CCMs required to submit Annual Reports – Part 2, only half (16) had confirmed that they are fully implementing the CMM. Only eleven of these provided specific confirmation of either implementation of the 5% rule or an alternative measure in national waters (e.g. requiring fins to be attached, banning shark fishing or fin trade, or controlling shark mortality under a quota management system (see following section for further details)). More CCMs may be implementing the measure but have not reported this; conversely, where implementation is confirmed, the degree of compliance with the measure is often not reported. As a result, it is not always clear where and when controls on finning are applied.

It is possible, however, to examine the number of sharks which have been finned based on data collected by longline and purse seine observers (see Clarke et al. 2011b for a discussion of the representativeness of these data). Observers record the fate of sharks under a large number of codes (21 for purse seine fisheries and 26 for longline fisheries) which can be aggregated into six high-level categories (see Table 2): retained, finned (fins removed, but carcass discarded), cut free (not landed), discarded (excluding finned and cut free/not landed), escaped, and unknown. For the following analysis, sharks which were cut free or discarded were combined into one category, and sharks with unknown fate were excluded. When interpreting these data, it is important to bear in mind several points:

- The first WCPFC controls on finning were implemented in February 2007;

[2] A non-binding measure strongly encouraging compliance with IOTC and WCPFC finning measures.

- Some CCMs had finning or other shark regulations in place before this time (e.g. Australia, New Zealand and the United States);
- Some CCMs have not implemented the WCPFC finning controls in national waters;
- Observer coverage is higher for operations in national waters than operations on the high seas for both longline and purse seine fisheries (80% of observed longline sets and 85% of observed purse seine sets occurred in national waters in 1995-2009; 92-98% of observed longline sets and 83-89% of observed purse seine sets occurred in national waters in 2007-2009)[3] therefore observer data primarily reflect operations in national waters).

The number of sharks finned on longline trips with observers onboard decreased slightly in 2008, the first full year after the WCPFC shark CMM was implemented, compared to the two previous years (Figure 8, left panel). However, the number of sharks in the observer database for 2008 also decreased such that the proportion of sharks finned in 2008 (48%) was lower than 2007 (53%) but higher than 2006 (42%), the year before the measure was implemented. Data for 2009 are still incomplete. Plotting the same data by region reveals higher proportions of discarded sharks in Regions 2 and 4 through 2004 (Figure 8, right panel), most likely reflecting the shark finning prohibitions applied by the US to its vessels and national waters starting in 2000 (Walsh et al. 2009). The absence of the US observer data post-2004[4] reduces the number of discarded sharks in the database in recent years (Figure 8, left panel). Notably higher proportions of retained sharks were recorded in Region 3 where silky sharks dominate the catch (Figure 8, right panel). In Regions 5 and 6, the percentage of sharks finned has remained between 45-70% since 1998.

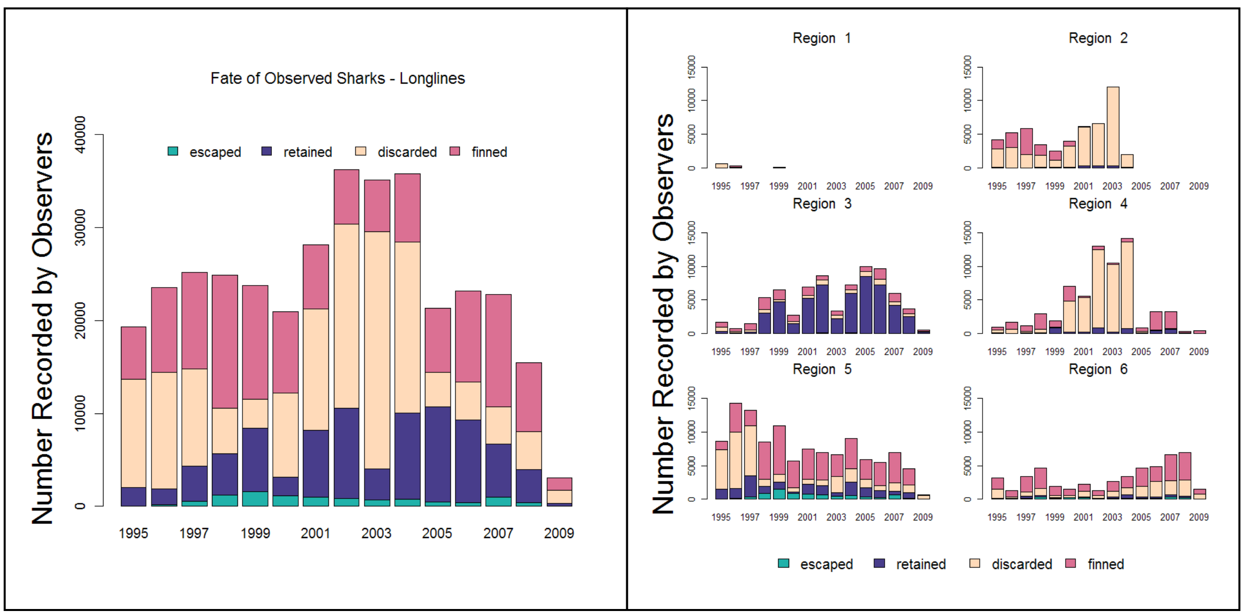

Figure 8. Fate of sharks (escaped, retained, discarded (including cut free), finned) as recorded by longline observers, 1995-2009 for the WCPO as a whole (left panel) and by region (right panel). Observer data submitted by Australia and New Zealand for 2009 is not shown.

Unlike longline observer data, purse seine observer data for 2009 is largely complete, therefore both 2008 and 2009 data (as well as 2007 data as a transition period) can be used to assess the number of

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[3] Observer data submitted by Australia and New Zealand for 2009-2010 have not yet been entered into the SPC database.

[4] Due to domestic legal constraints US observer data exist but have not been provided to the SPC-OFP database since 2004; it is understood that the US intends to provide longline observer data from April 2010.

sharks finned since implementation of the WCPFC shark CMM in February 2007. For the purse seine fishery, the proportion of sharks finned has decreased each year since 2006 (0.61, 0.51, 0.40, 0.18), and the proportion of sharks discarded has increased (Figure 9, left panel; 0.32, 0.37, 0.46, 0.76). It is possible that the adoption of CMM 2008-01, which was designed as a CMM for bigeye and yellowfin tuna and which included a two-month closure of fishing on fish aggregating devices (FAD), may have influenced the number of sharks caught in purse seine fisheries since most shark catch occurs in sets on FADs (see Clarke et al. 2011b, Figure 9). However, it is also noted that sets on FADs in 2009 reached the second highest level on record despite the closure (SPC-OFP 2010). Regional plots suggest that less finning is taking place in Region 4 than in Region 3 (Figure 9, right panel).

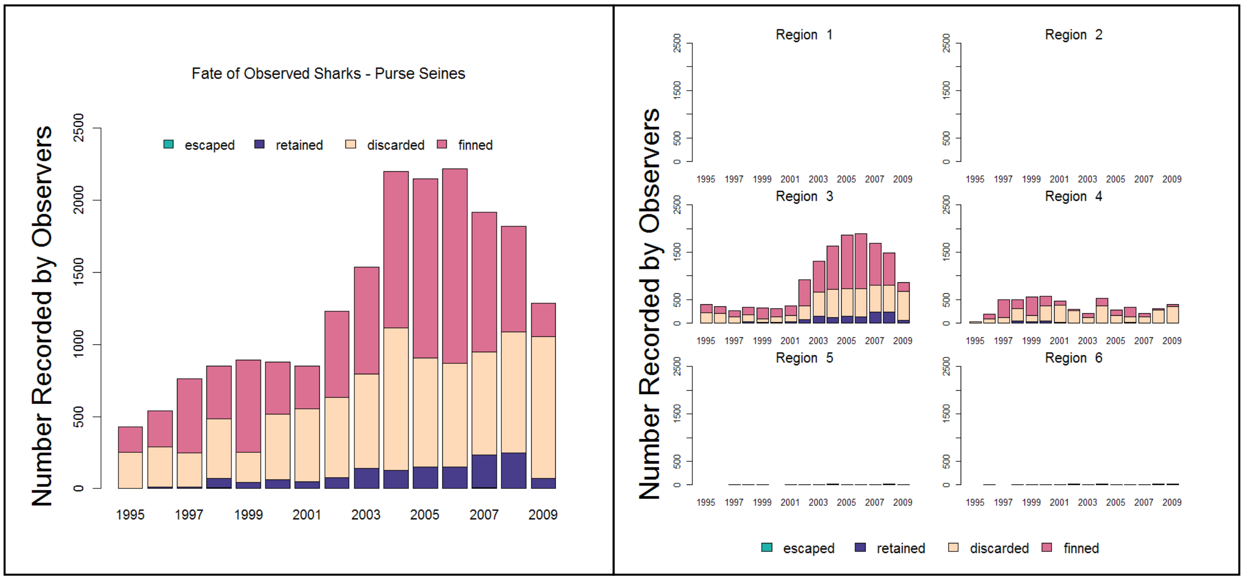

Figure 9. Fate of sharks (escaped, retained, discarded (including cut free), finned) as recorded by purse seine observers, 1995-2009 for the WCPO as a whole (left panel) and by region (right panel).

Shark fate by species over the period 1995-2009 indicates different disposition patterns by species within a fishery (e.g. blue versus silky sharks in the longline fishery) and between fisheries for a given species (e.g. silky sharks in the longline versus purse seine fisheries) (Figure 10). In the longline fishery silky sharks are usually retained, but in the purse seine fishery this species is usually finned and rarely retained[5]. Oceanic whitetip sharks show a similar but less pronounced pattern. Another species that is commonly retained is the shortfin mako, probably due to the value of its carcass (Vannuccini 1999). Species which are most commonly discarded (or cut free) are the blue shark, and the common and bigeye threshers. Pelagic thresher and longfin makos are most commonly finned. Due to expectations that only a small amount of the observer data reflects implementation of current finning prohibitions, it should be noted that these characterizations may show more finning, and less retention and discarding, than is currently occurring. On the other hand, if the presence of the observer discourages finning in favour of discarding or cutting free, the rates of finning recorded by observers would be underestimates.

[5] SPC-OFP queried the high retention rates of silky sharks in the longline fishery through observer programme contacts but was unable to identify the reason(s).

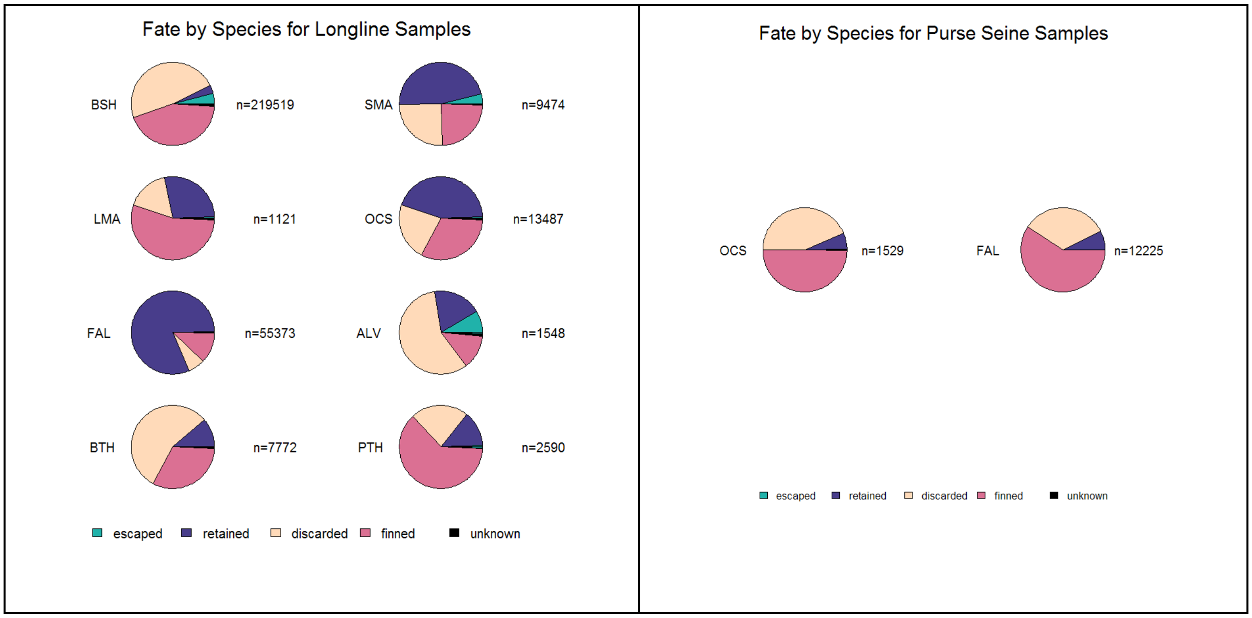

Figure 10. Fate of sharks (escaped, retained, discarded (including cut free), finned) by species as recorded by observers, 1995-2009, for the WCPO as a whole for longline (left panel) and purse seine (right panel) fisheries. BSH=blue, SMA=shortfin mako, LMA=longfin mako, OCS=oceanic whitetip, FAL=silky, ALV=common thresher, BTH=bigeye thresher, PTH=pelagic thresher.

3.2 Other Existing Mitigation Measures by CCMs

As referred to in the preceding discussion, some CCMs have implemented the WCPFC shark CMM in their national waters as is it specified for high seas regions (i.e. the 5% fin to body ratio), whereas as other CCMs have implemented alternative measures. This section provides a summary of existing alternative measures which can or do affect shark mortality in the WCPO. This discussion is focused on the WCPFC key species[6] and is not intended to catalog every measure in the WCPO, but rather to highlight the range of measures being applied. National and Regional Plans of Actions (POAs) for sharks (see Lack and Meere 2009, FAO 2009) are not considered in this section as they do not necessarily contain implemented mitigation measures.

An evaluation of the effectiveness of alternative measures applied in national waters is not presented here as such issues are better addressed by the CCMs which have implemented them. However, as some of these alternative national measures could be considered for broader application under the WCPFC, where there are scientific data held by SPC-OFP that can inform such considerations, these data are briefly presented.

3.2.1 Catch Controls for Sharks

Catch controls provide a limit to the number of sharks which can be removed. Depending on where the limit is set, catch controls can act to mitigate shark mortality. At least six CCMs are known to have implemented catch controls for sharks:

[6] Although not a key species, whale sharks are also included in this summary as they are the focus of an existing mitigation measure applied across a wide area of the WCPO (see Section 3.2.3).

- Australia implemented a retention limit of 20 sharks per trip for its Eastern Tuna and Billfish (longline) fishery in 2000; any sharks caught in excess of the limit must be discarded whether alive or dead (AFMA 2008). For 2010, Australia's reported catch of sharks totaled approximately 92 t (Patterson and Sahlqvist 2011).
- New Zealand has included blue, shortfin mako and porbeagles in its Quota Management System since 2004 and reported 807 t, 82 t and 64 t catches for these three species in 2009 (New Zealand Ministry of Fisheries 2011a).
- Papua New Guinea has a small, directed shark fishery operating entirely within its national waters which is assigned a total allowable catch of 2,000 t (dressed weight; ~3,300 t assuming dressed weight is equivalent to 60% of whole weight (Fowler and Séret 2010)) per year (Kumoru 2010).
- Tonga's license conditions for longline fishing vessels require that shark bycatch must not exceed 10% of the total catch (from Tonga's WCPFC Annual Reports-Part 2); for 2009 Tonga reported a total shark catch of 10 t (Halafihi 2010).
- The Philippines and Chinese Taipei have banned catches of whale sharks in 1998 and 2008, respectively (Oposa 2008, TRO-UK 2007).

The most recent annual reported shark catches under catch limits for Australia, New Zealand, Papua New Guinea, and Tonga (4,355 t) compares to a total estimated shark catch in the WCPFC Statistical Area of 61,000 t (SPC-OFP 2008; 2006 estimate). This suggests that no more than 7% of the shark catch in the WCPO is controlled under catch limits.

Of the 3,775 observed longline trips in 1995-2010, 5% reported zero sharks, 39% reported 1-20 sharks, and 56% reported >20 sharks. When examined in terms of cumulative catch, 46% of the total shark catch recorded in the longline observer database was taken on trips which in total caught 20 or less sharks (Figure 11).

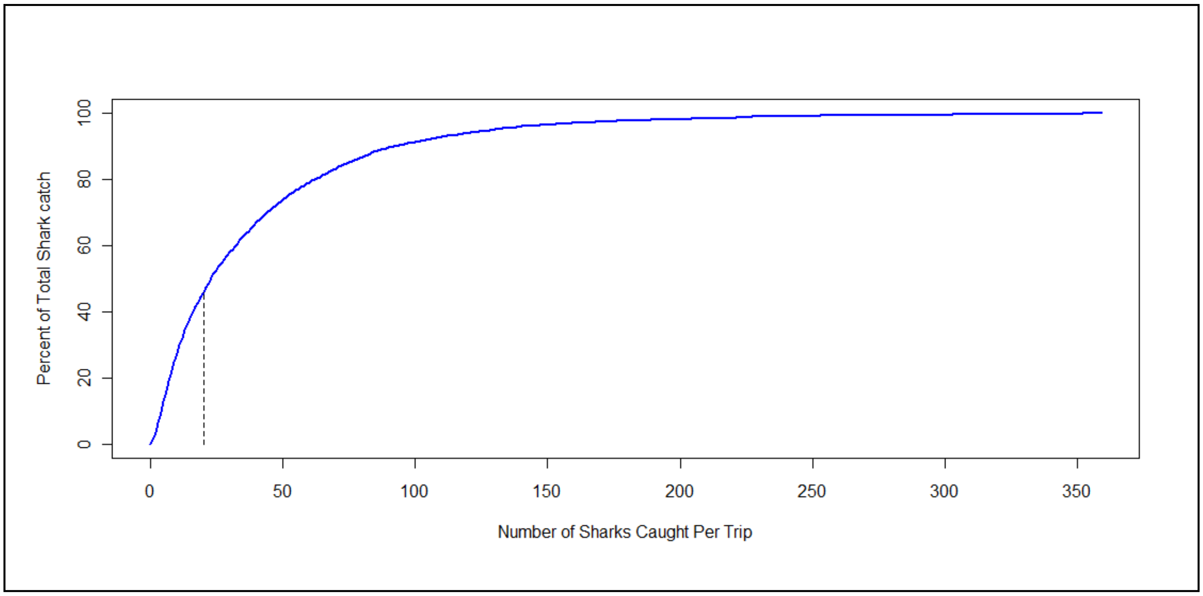

Figure 11. A cumulative catch curve showing the increase in the percentage of the total shark catch recorded in the longline observer data held by SPC-OFP, 1995-2010, as the number of sharks recorded per trip increases.

3.2.2 Finning Controls

Finning controls may take several forms including rules requiring fins be left attached, and various formulations of allowable weight ratios between fins and carcass onboard or at landing (e.g. the WCPFC shark CMM requires that fins onboard total no more than 5% of the weight of shark onboard up to the point of landing). Prohibitions on live finning, like those applied under New Zealand's Animal Welfare Act (New Zealand Ministry of Fisheries 2011b), are not considered a fisheries management measure and are not discussed here. Several CCMs have implemented finning controls:

- Australia banned finning in federal waters (3 to 200 miles offshore) for tuna and billfish longline fisheries in 2000 and now requires sharks to be landed with fins attached. Additional regulations apply in some territorial waters (out to 3 miles; Camhi et al. 2009).
- The State of Hawaii, followed by the United States nationally in the same year, enacted legislation banning finning in state/federal waters and by US vessels by requiring that the total wet weight of the shark fins does not exceed 5% of the total, dressed weight of shark carcasses landed or found on board the vessel (Walsh et al. 2009, Fowler and Séret 2010). These rules were superseded by the US Shark Conservation Act of 2010 which requires that sharks be landed with their fins attached (Eilperin 2010).
- French Polynesia banned shark finning in conjunction with a ban on fishing and retaining sharks except for mako sharks[7] in 2006 (Service de la Pêche 2011).
- Palau prohibited finning by foreign vessels, as well as all shark fishing, in 2003 (Camhi et al. 2009).
- The European Union (EU) implemented controls on finning in EU waters and by EU vessels worldwide in 2003 with a regulation that limits fin weights to 5% of the live (whole) weight of the shark catch. Onboard fin removal is allowed under Special Fishing Permits and fins may be landed and transhipped separately from other shark products (Fowler and Séret 2010).
- Since 2006, it is required in El Salvador waters and wherever Salvadorean vessels fish that fins be at least one-quarter attached to the carcass at landing (Camhi et al. 2009).

As discussed in Section 3.1, several other CCMs, have indicated in Annual Reports – Part 2 that they have implemented the WCPFC shark CMM but most do not provide details on how finning is prohibited. Other CCMs may be implementing, or partially implementing, finning controls but have not reported this to the WCPFC. Official sources quoted in the media have indicated that some CCMs, including the Marshall Islands (Marshall Islands Journal 2011) and Chinese Taipei (China Post 2011), will soon implement new controls on finning.

As discussed in Sections 3.1 and 3.3.1, the WCPFC has adopted finning controls using a 5% rule as part of its shark CMM, but the effectiveness of these controls remains unclear. Finning controls, and other full utilization policies (e.g. ISSF 2011), in the absence of other measures may not reduce shark mortality because these controls may lead to either an increase in retention (which like finning, also results in mortality) or an increase in discards (which unlike finning, may have some possibility of survival). Also, several problems with implementation of various forms of the 5% rule have been noted and this has led to regulations requiring fins attached in several countries including WCPFC CCMs (Fowler and Séret 2010).

[7] It is not clear whether fins are permitted to be removed from mako sharks, and if so how this is controlled.

3.2.3 Operational and Gear Controls

This section describes restrictions on methods used to catch sharks in order to reduce mortality or trauma. This type of mitigation measure is illustrated by a ban on setting purse seines on whale sharks and by a ban on wire leaders, i.e. the branch lines or traces, in longline fisheries. Examples of these practices currently implemented by WCPFC CCMs include:

- Under the Third Implementing Arrangement, the eight WCPFC CCMs which are also members of the Parties to the Nauru Agreement (PNA) adopted a ban on fishing or related activity in order to catch tuna associated with whale sharks; the exact date of implementation is subject to endorsement by each party (PNA 2011).
- Australia banned the use of wire leaders in its eastern tuna and billfish fishery in 2005 (AFMA 2008).
- Palau's Shark Protection Law of September 2003 prohibits having a steel leader onboard at any time (Islands Business 2009, Camhi et al. 2009).

Ban on Setting Purse Seines on Whale Sharks

Due to the recent implementation of this ban by PNA members, there are insufficient data available to assess whether interactions between whale shark and purse seine gear have decreased since implementation. The proportion of sets with whale shark interactions recorded over the period 2005-2009 was 1.24%. For sets where observers reported the set type as "whale shark associated", the proportion of all sets for the period 2005-2009 was 0.7% (Peter Williams, SPC-OFP, personal communication).

Ban on Wire Leaders

Australia's ban on wire leaders was adopted in response to a study which found that while the catch rates of many species, including eight of ten shark species, were significantly higher on wire leaders, the catches of the target species (bigeye tuna) were significantly lower, and that the five vessels involved in the study would take an additional 679 sharks per year if 100% wire leaders were used (Ward et al. 2008; AFMA 2008). One of the reasons nylon leaders show lower catch rates is believed to be the ease with which sharks can bite through the gear and escape (Ward et al. 2008). However, nylon leaders may also be severable by other species, including target species. Anecdotal evidence suggests that many longliners targeting bigeye tuna continue to use wire leaders to prevent bigeye biting through the line and thereby increase bigeye catch rates (S. Beverly, SPC Coastal Fisheries Programme, personal communication).

The effectiveness of a ban on wire leaders in reducing shark mortality would depend on at least three factors: 1) the extent to which wire leaders are currently used; 2) the degree of implementation and enforcement of a ban on wire leaders; and 3) the catch rate of sharks on the gear that replaces the banned wire leaders (e.g nylon, etc.). As there are no data available to inform the second or third components, this analysis, which was first presented to WCPFC7 (Clarke et al. 2010), is limited to investigating the current usage of wire traces based on available gear configuration information from observer records. The number of observer trips by flag and year for which the presence or absence of wire trace gear was confirmed totaled 637 trips for 17 flags from 1996-2009 (Table 1). One key limitation of the available data is the low number of samples available for the Japan and Korea distant water fleets, both of whom comprise a large portion of the total effort in the longline fishery.

Table 1. The number of observer trips by flag for which the presence or absence of wire leaders was recorded, 1996-2009.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
CK													6		6
CN									11	17	49	48	8	11	144
FJ								5	9	29	22	19	25	20	129
FM								1	4	5	11	6	2		29
JP			1						1	3	3	1			9
KI													4		4
KR			1							1	3				5
MH													1	1	2
NC	1		2	2					4	2	5	6	11	8	41
NZ										1		1			2
PF								1	1	12	18	12	15	47	106
PG								4	6	16	10	3	9		48
SB			2	1			1	2	12						18
TO					2				2	1	18	6	12	7	48
TW	1		4	2					7		3	2	14	9	42
VU														2	2
WS										1	1				2
Total	2	0	10	5	2	0	1	13	57	88	143	104	107	105	637

A model was constructed to extrapolate these samples to the entire fleet on the basis of total effort (in hooks) by estimating predictive factors for each year and flag within a Bayesian generalized linear model framework. Due to low and unevenly distributed sample sizes, the output of this extrapolation is characterized by wide probability intervals even in recent years with more data and better flag representation, probably reflecting diverse operations in the fisheries (Figure 12). Median estimates for the early years of the analysis (1996 to 2004) indicate that wire leaders were used in >90% of longline trips. Although this proportion had fallen to 66% by 2009, wire leaders are still likely to be the most common leader type used in longline fisheries within the WCPO. This continued high level of usage has implications for shark mortality as it suggests that sharks are handled by the crew during haulback (i.e. in order to recover the hooks and leaders) and thus have a higher probability of injury or mortality than would otherwise occur with bite-offs or if a nylon leader is cut at the rail.

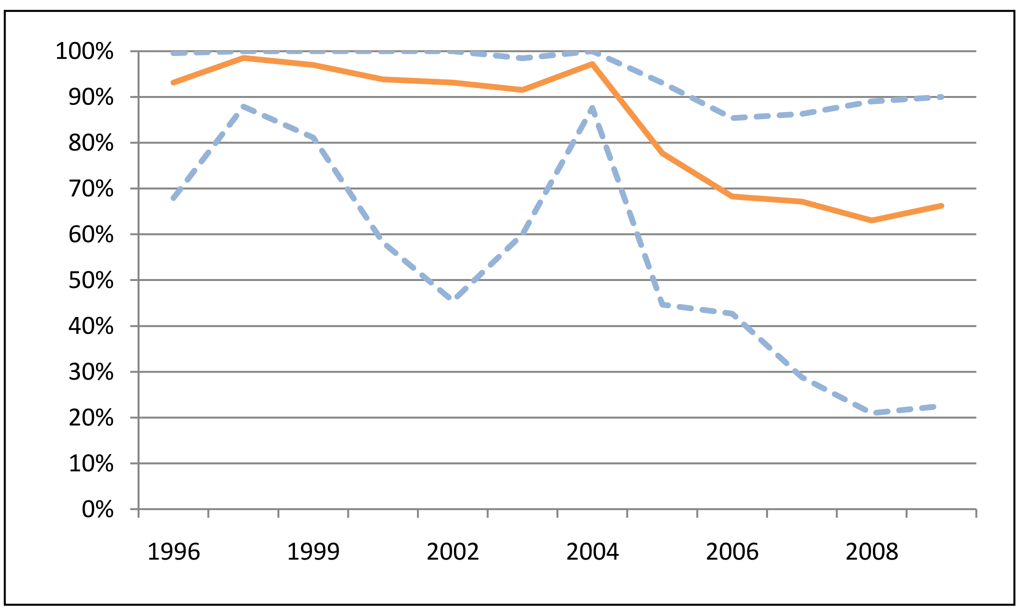

Figure 12. An extrapolated estimate of the proportion of longline effort in the WCPFC Statistical Area that employed wire leaders for 1996, 1998-2000, and 2002-2009 (estimation for other years is not supported by the available data).

3.2.4 Time/Area Closures

Time/area closures prohibit fishing, either permanently or for a fixed period of time (e.g. seasonal closures on a recurring annual basis). This mitigation measure may or may not be shark-specific. The following shark-specific and non shark-specific time/area closures are currently implemented within the WCPO:

- Palau, building on its previous shark fishing controls (see above), declared all of its national waters a shark sanctuary by banning all commercial fishing for sharks in September 2005; sharks caught as bycatch must be released whether dead or alive (Black 2009; Fowler and Séret 2010).
- French Polynesia has fully protected all sharks except for makos in its waters since 2006; there are currently plans to expand this protection to include makos (Service de la Pêche 2011).
- Under a conservation and management measure for bigeye and yellowfin tuna (CMM 2008-01), two high seas pockets were closed to all purse seine fishing on 1 January 2010.[8]

Palau last reported shark catches of 7.2 t in 2004 (SPC-OFP data). French Polynesia reported 25-26 t of mako catch annually from 2005-2006 and 10-21 t annual from 2007-2010 (Service de la Pêche 2011). Since the shark fishing ban in 2006, French Polynesia reports 116-200 t of shark are discarded annually (Service de la Pêche 2011). An evaluation of the effectiveness of CMM 2008-01 in reducing fishing mortality on bigeye and yellowfin tuna has been conducted and provides some insight into changes in fishing effort resulting from the high seas pocket closure (SPC-OFP 2010), but it does not examine potential effects on sharks as this was not the intention of the measure. As noted in Section 3.1, the two-month closure of fishing on FADs adopted under CMM 2008-01 might be expected to reduce the total catch of sharks by the purse seine fishery since most shark catch occurs in sets on FADs (see Clarke et al. 2011b, Figure 9). However, according to Lawson (2011) the total catch of sharks by the purse seine fishery comprises only 9% of the total catch of sharks by the purse seine and longline fisheries combined.

3.2.5 Shark Product Trade and Possession Controls

In an effort to curb shark fishing several CCMs have recently adopted bans on the trade and possession of shark fins. Most of these bans pertain to detached fins only and would not affect commercial or recreational landings of whole sharks. The following CCMs (or jurisdictions within a CCM) have implemented such bans since July 2010: Hawaii (ENS 2010), the Northern Mariana Islands (PR Newswire 2011a), Guam (PR Newswire 2011b), the Marshall Islands (Marianas Variety 2011), and the US States of Washington (Businessweek 2011) and Oregon (Learn 2011). Regulations are under active discussion in California (Hindery 2011) and Fiji (Radio Fiji 2011). The effect of these trade and possession bans on fishing activities in the WCPO cannot be evaluated on the basis of existing information.

3.3 Existing Mitigation Measures in other RFMOs: Prohibition of Retention and Requirements to Release Unharmed

One of the conservation and management measures for sharks adopted by IATTC (for oceanic whitetip sharks), by ICCAT (for bigeye thresher sharks, oceanic whitetip sharks and hammerhead sharks) and by

[8] High Seas Pocket 1 is located between the national waters of Indonesia, Palau, the Federated States of Micronesia and Papua New Guinea. High Seas Pocket 2 is located between the national waters of Papua New Guinea, the Federated States of Micronesia, the Marshall Islands, Nauru, Kiribati, Tuvalu, Fiji and the Solomon Islands.

IOTC (for all thresher sharks) is a prohibition on retaining any part or whole carcass of these species. Some of these conservation and management measures also specify that these sharks should promptly be released unharmed when caught[9]. In order to evaluate these potential mitigation measures for WCPFC fisheries, observer data held by the SPC-OFP were used to compute the expected mortality by species under various mitigation scenarios.

In addition to the shark fate data introduced in Section 3.1, longline observers record the condition of sharks when caught and when discarded in one of six codes: alive (not elsewhere indicated), alive and healthy, alive and injured, alive and dying, dead, and condition unknown (Table 2). Purse seine observers are instructed to use the same condition codes to record the shark's condition only once, but perhaps due to difficulties with actually observing the sharks' condition in the purse seine, the majority of purse seine condition records (98%) are "unknown". For the following analysis, longline (only) observer fate and condition codes were used.

Table 2. A summarized list of the fate and condition codes used in SPC/FFA Regional Longline and Purse Seine Observer Programmes.

Fate Codes (recorded once)	**Condition Codes** (recorded for initial and final condition by longline observers and initial condition only by purse seine observers)
Retained (all codes beginning with 'R')	Alive (not elsewhere indicated ('A0')
Finned (Discarded, Fins Retained – 'DFR')	Alive and healthy ('A1')
Cut Free (Discarded, not landed) – 'DDL', 'DSO' or 'DCF' (longline only)	Alive but injured/distressed ('A2')
Discarded (All other codes beginning with 'D')	Alive but dying ('A3')
Escaped ('ESC')	Dead ('D')
Unknown ('UUU')	Unknown ('U')

3.3.1 Baseline Scenario

It was first necessary to examine the baseline scenario. As discussed in Section 3.1, the current situation is one of recent, partial implementation of a prohibition on finning in WCPFC waters (CMM 2006-05, now revised to CMM 2010-06). This measure, in combination with a variety of other measures adopted unilaterally by CCMs in their own waters (Section 3.2), would be expected to reduce the number of sharks finned. The question for the baseline scenario is thus to define the level of mortality under existing measures as currently implemented so that the additional benefit (reduction in mortality) due to no retention and/or release unharmed can be assessed.

There are several issues which complicate delineation of a baseline dataset:

- Anti-finning measures have been implemented by various CCMs at various points in time;
- It is not clear when, or in some cases whether, these measures have affected finning practices;

[9] See IATTC (2011a); ICCAT Recommendations 09-07 (ICCAT 2009), 10-07 (ICCAT 2010a), 10-8 (ICCAT 2010b); IOTC Resolution 10/12 (IOTC 2010).

- The observer dataset is likely to be biased, and more so in recent years, toward national waters where the WCPFC finning prohibition may be replaced by alternative, national measures which may or may not allow finning[10];
- The observer dataset is awaiting, and currently lacking, observer data for recent years from two CCMs (Australia[11] and the US) which have implemented strong anti-finning measures in their own national waters.

As different baseline datasets could give widely varying estimates, particularly if defined such that sample sizes are small, this analysis was simplified by assuming that all available longline observer data since 1995 reflects the baseline. Although such a baseline tends to de-emphasize any reduction in finning that has occurred in recent years, it should be noted that such a reduction could lead to either an increase in retention (which like finning, also results in mortality) or an increase in discards (which unlike finning, may have some possibility of survival), and therefore the direction of the bias cannot be confirmed.

For the Baseline Scenario, all records with fate code "unknown" and initial condition code "unknown" were removed from the sample. Of the remaining records, the proportion of sharks which were recorded with fate "retained" or "finned", or were recorded in other fate categories but whose initial or final condition was "dead" or "alive but dying", were assumed dead[12]. The mortality under the Baseline Scenario is shown in the following equation and in Table 3:

$$\textbf{Baseline Mortality} = (\text{Fate} \neq \text{Unknown}) \cap (\text{Initial Condition} \neq \text{Unknown}) \cap \{\text{Fate} = \text{Retained or Finned} \cup [\text{Fate} = \text{Discarded or Cut Free or Escaped} \cap (\text{Initial Condition} = \text{Dead or Dying} \cup \text{Final Condition} = \text{Dead or Dying})]\}$$

Table 3. Categories of fate and condition codes used for the Baseline Scenario calculating the number of sharks which are presumed dead under current conditions. Codes which were removed from the sample are shaded in black. Codes which counted toward mortality are shaded in red and those which counted toward survival are shaded in green. To count toward survival the shark must be alive in its initial condition and not known to be dead or dying in its final condition.

	Initial Condition		
Fate:	Unknown (U)	Alive (A0, A1, A2)	Dead (A3, D)
Retained			
Finned			
Cut Free		Unless dead or dying in Final Condition	
Discarded		Unless dead or dying in Final Condition	
Escaped		Unless dead or dying in Final Condition	
Unknown			

The sample sizes remaining after removal of the "unknown" fate and condition codes (black in Table 3) are shown in Table 4, Column A. The proportion suffering mortality under the Baseline Scenario varied by species between 0.44 and 0.96 (Table 4, Column B). The lower observed mortalities for the common

[10] For example, under New Zealand's Quota Management System implemented in 2004, shark finning is legal in New Zealand waters as long as the number of sharks does not exceed the quota limit. However, live finning is banned and high seas permit conditions require fins to be attached.
[11] These data have been received but not yet loaded into the database.
[12] Injured sharks were assumed to survive.

and bigeye thresher (0.44-0.64) may be due to a higher preference for cutting free these species due to dangers inherent in landing them. However, this situation would also be expected, but was not observed, for the pelagic thresher (0.91). The lower observed mortality for blue sharks (0.56) may be due to a preference for cutting free this species due to its low value carcass (i.e. assuming implementation of a prohibition on finning). It should be noted for all species that if the presence of the observer discourages finning in favour of discarding or cutting free, the mortality proportions shown in Table 4, Column B would be underestimates.

Table 4. Sample size and proportion dead or dying by species for the Baseline Scenario, No Retention Scenarios 1 and 2, and Prompt Release Unharmed Scenario 3 based on observer data from longline fisheries, 1995-2010.

	A	B	C	D	E	F	G
Species	**Number in sample**	**Proportion dead under the Baseline Scenario**	**Number in sample for Scenario 1**	**Proportion dead under No Retention Scenario 1**	**Number in sample for Scenario 2**	**Proportion dead under No Retention Scenario 2**	**Proportion dead under Prompt Release Unharmed Scenario (Scenario 3)**
Blue	168,217	0.56	84,616	0.13	168,217	0.16	0.12
Shortfin mako	7,961	0.77	2,267	0.19	7,961	0.35	0.31
Longfin mako	995	0.90	135	0.30	995	0.54	0.37
Oceanic whitetip	10,047	0.87	1,667	0.21	10,047	0.42	0.31
Silky	53,594	0.96	2,769	0.31	53,594	0.40	0.34
Common thresher	1,474	0.44	993	0.16	1,474	0.28	0.25
Bigeye thresher	5,411	0.64	2,594	0.25	5,411	0.54	0.37
Pelagic thresher	2,245	0.91	347	0.41	2,245	0.81	0.59

3.3.2 No Retention – Scenarios 1 and 2

The second scenario examined was a prohibition on retention, similar to that adopted by ICCAT for oceanic whitetip sharks (ICCAT 2010a). The basis for this scenario was a computation of the number of sharks which would die even if they were not retained (or finned). Due to competing assumptions about the potential interaction between condition and fate, e.g. whether dead sharks more likely to be finned than live ones, two versions of this scenario were constructed.

For No Retention Scenario 1, the observer dataset was further reduced to exclude all those sharks whose fates were recorded as “retained” or “finned”. The reasoning underlying this scenario is that under a no retention scenario the fate of all sharks would be either discarded, cut free or escaped, and thus the mortality to sharks in these “released” fate categories would represent the residual mortality after implementation of a no retention policy (i.e. residual mortality due to trauma incurred during hooking, hauling and/or handling only). As in the Baseline Scenario, mortality at either the initial or final observation of condition was counted. The mortality under No Retention Scenario 1 is shown in the following equation and in Table 5:

No Retention Scenario 1 Mortality = (Fate ≠ Unknown) ∩ (Initial Condition ≠ Unknown) ∩ [Fate = Discarded or Cut Free or Escaped ∩ (Initial Condition = Dead or Dying ∪ Final Condition = Dead or Dying)]

Table 5. Categories of fate and condition codes used for No Retention Scenario 1 calculating the number of sharks which are presumed dead under a no retention measure approximated by excluding retained and finned sharks (see text). Codes which were removed from the sample are shaded in black. Codes which counted toward mortality are shaded in red and those which counted toward survival are shaded in green. To count toward survival the shark must be alive in its initial condition and not known to be dead or dying in its final condition.

	Initial Condition		
Fate:	Unknown (U)	Alive (A0, A1, A2)	Dead (A3, D)
Retained			
Finned			
Cut Free		Unless dead or dying in Final Condition	
Discarded		Unless dead or dying in Final Condition	
Escaped		Unless dead or dying in Final Condition	
Unknown			

Given the high mortality levels observed under the current scenario (Table 4, Column B), those sharks observed to be discarded, cut free or escaped were considerably fewer in number (Table 4, Column C). Of this sample, the proportions which were observed dead or dying ranged from 0.13 to 0.41 for the eight key species (Table 4, Column D). Comparison to the Baseline Scenario (Table 4, Column B) indicates that a no retention policy as represented by this scenario would reduce overall mortality to 23-45% of its current levels.

It could be argued, however, that sharks which are alive are more likely to be released and conversely that sharks which are dead are more likely to be retained or finned. In contrast to No Retention Scenario 1, No Retention Scenario 2 includes all shark fates (except "unknown") in the calculation of mortality (Table 6):

No Retention Scenario 2 Mortality = (Fate ≠ Unknown) ∩ (Initial Condition ≠ Unknown) ∩ (Initial Condition = Dead or Dying ∪ Final Condition = Dead or Dying)

Table 6. Categories of fate and condition codes used for No Retention Scenario 2 calculating the number of sharks which are presumed dead under a no retention measure approximated by including retained and finned sharks (see text). Codes which were removed from the sample are shaded in black. Codes which counted toward mortality are shaded in red and those which counted toward survival are shaded in green. To count toward survival the shark must be alive in its initial condition and not known to be dead or dying in its final condition.

	Initial Condition		
Fate:	Unknown (U)	Alive (A0, A1, A2)	Dead (A3, D)
Retained		Unless dead or dying in Final Condition	
Finned		Unless dead or dying in Final Condition	
Cut Free		Unless dead or dying in Final Condition	
Discarded		Unless dead or dying in Final Condition	
Escaped		Unless dead or dying in Final Condition	
Unknown			

If sharks which are already dead are more likely to be retained or finned, mortality rates would be higher under No Retention Scenario 2 than under No Retention Scenario 1. The proportion of sharks that was recorded as “dead” or “dying” in the initial condition observation was compared between fate categories “retained”, “finned” and “discarded/cut free/escaped”. This comparison showed that for every key species, sharks whose fates were “retained” or “finned” were more likely to be recorded with condition “dead” or “dying”. However, this could be because the shark was handled normally but was dead; because it was roughly handled (e.g. gaffed, long soak time) specifically in order to weaken it before on-deck processing; or because the observer recorded the fate and condition codes at the same time (e.g. during hook retrieval on deck).

Under No Retention Scenario 2 the mortalities are reduced by less compared to the baseline than they are in No Retention Scenario 1, but the range of reductions is wider (proportion dead 0.16 to 0.81). Under No Retention Scenario 2, at one end of the range, blue shark mortality would be expected to be reduced to 0.16 or 29% of its baseline mortality (0.56), but at the other end of the range, bigeye and pelagic thresher mortality would only be reduced to 0.81 or 84-89% of their baseline mortality (0.91). Averaging across species, and comparing to a species-wide average baseline mortality of 0.76, no retention policies, as modeled by Scenarios 1 and 2, would be expected to result in mortalities ranging from 0.24-0.44, i.e. a 32-58% reduction.

3.3.3 Promptly Release Unharmed - Scenario 3

The final scenario evaluated the mortality which would result from requiring no retention as well as prompt release unharmed (Scenario 3). This requirement was adopted by ICCAT for hammerheads and threshers, by IOTC for threshers (ICCAT 2009, 2010b; IOTC 2010) and by IATTC for oceanic whitetip sharks (IATTC 2011a). Since this scenario would in theory have to be combined with a no retention scenario (either Scenario 1 or 2), it represents additional mortality reduction over the range identified above for the two scenarios. It was decided to base this scenario (Scenario 3) on No Retention Scenario 2, therefore sharks with fate codes “retained” or “finned” were included. Scenario 3 assumes that with both no retention and release unharmed policies in place, only those sharks which are already dead when brought to the vessel contribute to mortalities (Table 7):

Prompt Release without Harm Mortality = (Fate ≠ Unknown) ∩ (Initial Condition ≠ Unknown) ∩ (Initial Condition = Dead or Dying)

Table 7. Categories of fate and condition codes used for Scenario 3 (see text). Codes which were removed from the sample are shaded in black. Codes which counted toward mortality are shaded in red and those which counted toward survival are shaded in green. To count toward survival the shark must be alive in its initial condition.

	Initial Condition		
Fate:	Unknown (U)	Alive (A0, A1, A2)	Dead (A3, D)
Retained			
Finned			
Cut Free			
Discarded			
Escaped			
Unknown			

The differences in expected mortality between the no retention and prompt release unharmed scenarios (Table 4, Columns F and G) are small (3-6%) for common thresher, blue, shortfin mako and silky sharks and moderate (11-22%) for oceanic whitetip, longfin mako, bigeye thresher, and pelagic thresher. Similar percentage reductions for the prompt release unharmed scenario would be expected in combination with No Retention Scenario 1.

The mortalities associated with no retention and prompt release unharmed (Table 4, Column G) can be compared, with caveats, to pre-release mortality rates from other datasets (Table 8). In most cases the sample sizes are very much smaller in the other studies. Furthermore, as illustrated by the recent debate over blue shark mortality rates in the Atlantic and Pacific (Moyes et al. 2006, Campana et al. 2009a, Musyl et al. 2009, Campana et al. 2009b), comparison of pre-release mortality rates between studies can be complicated by differences in hook types, soak times, hook numbers and handling practices. As demonstrated by Campana et al. (2009a), when post-release mortality is taken into account, overall mortalities may be much higher. Therefore, while a direct comparison between studies is not likely to be appropriate, Table 8 suggests that under varying conditions, pre-release mortality rates may be more than double those observed in this study (e.g. silky and blue sharks) and total mortality figures would be expected to be even higher.

Table 8. Pre-release mortality rates for key species documented in other fisheries and research studies. Sample sizes are shown in parentheses.

	from Table 4, Column G (this study)	**Semba et al. (2009)**	**Griggs et al. (2008)**	**Yokota et al. (2006)**	**Campana et al. (2009a)**	**Beerkircher et al. (2008)**
Location/Fishery	WCPO Longline Fishery	Japanese Longline Fishery in the Atlantic	New Zealand Longline Fishery	Japanese Research and Fishing Vessel in the North Pacific	Canadian Atlantic Longline Fishery	US Atlantic Longline Fishery
Mortality Calculation	Proportion dead (see text for formulae)	Proportion dead (1-"Number alive") / Sample Size	Proportion dead (1-Percent "alive on recovery")	Number "dead"/Sample Size	Hooking mortality	Proportion dead at gear retrieval
Blue	0.12 (168,217)	0.36 (3,443)	0.08 (6,688)	0.09 (3,353)	0.13* (12,404)	0.13 (236)
Shortfin mako	0.31 (7,961)	0.29 (111)	0.25 (237)	0.26 (19)	-	0.34 (56)
Longfin mako	0.37 (995)	-	-	-	-	-
Oceanic whitetip	0.31 (10,047)	0 (8)	-	-	-	0.26 (93)
Silky	0.34 (53,594)	0 (5)	-	-	-	0.69 (911)
Common thresher	0.25 (1,474)	-	-	-	-	-
Bigeye thresher	0.37 (5,411)	0.32 (22)	-	-	-	0.59 (58)
Pelagic thresher	0.59 (2,245)	-	-	-	-	-

*Overall mortality, i.e. including both hooking and post-release mortality was estimated at 0.35 in this study.

Due to the lack of information in the purse seine observer condition codes (i.e. 98% of the records used condition code "U" for unknown), it was not possible to conduct a similar analysis for purse seine fisheries. However, using only the fate codes, the data show that 66% of the silky sharks (n=12,215) and 56% of the oceanic whitetip sharks (n=1,525) were either finned or retained. Of the remaining sharks, almost all of which are discarded[13], condition codes were only recorded for 223 silky sharks and 48

[13] Of the sample of 14,098 sharks, only eight were recorded as having escaped (fate code="E").

oceanic whitetip sharks, of which 99% and 100%, respectively, were dead. These figures may result from purse seine observers only being able to clearly identify the condition of the shark if it is dead.

Ongoing studies in the Eastern Pacific are expected to provide more useful data on the mortality rates for sharks discarded from purse seine operations (IATTC 2011b). This information would assist in evaluating the potential effectiveness of “no retention” and/or “promptly release unharmed” mitigation measures for WCPO purse seine fisheries.

4. Conclusions

There is sufficient scientific evidence to conclude that the status of some of the WCPFC key shark species is worsening over time. Foremost among these is the oceanic whitetip shark, for which catch rates have shown consistent declines to near-zero levels across multiple datasets. Size trends for oceanic whitetip shark also indicate significantly smaller sizes across multiple datasets. This strong existing evidence for the depleted state of the oceanic whitetip population in the WCPO, substantiates the need for immediate conservation and management action. While some indicators for blue shark produced variable results, marked recent catch rate declines found in four different datasets for the North Pacific, in combination with demonstrated targeting of blue shark by a large commercial fleet operating in this area, warrant management consideration. The status of silky sharks is at present ambiguous: despite significantly decreasing sizes, catch rate trends usually indicate only slight decreases. However, the predominance of this species in both longline and purse seine fisheries within its habitat range and an estimated increasing trend of removals suggest that these and other indicators should be closely monitored. Other key shark species (two makos and three threshers), are among the least productive pelagic sharks and appear to require further research and/or data improvement to identify and clarify stock status trends.

The WCPFC has taken one conservation and management measure for sharks in the form of a prohibition on finning first implemented in early 2007. As of 2010, half of the WCPFC CCMs had not yet confirmed that this measure is being fully implemented in their national waters, and even fewer have provided details on whether the 5% rule or an alternative measure is being applied and complied with. As a result, it is difficult to draw conclusions about the theoretical degree to which finning may be constrained by existing regulations. There is currently no evidence from observer data that the WCPFC finning prohibition has reduced the proportion of sharks finned in longline fisheries, although the proportion of sharks finned in purse seine fisheries is decreasing. Furthermore, some species, such as silky, oceanic whitetip and shortfin mako sharks, are more frequently retained than they are finned and thus even full implementation of a finning ban may not result in substantially reduced mortality for these species.

Given the concerns raised for the status of some of the key shark species, and the minor demonstrable effects of the existing shark CMM on shark mortality, the Scientific Committee may wish to consider formulating a recommendation with regard to the need for management action. Some CCMs have already implemented alternative or supplemental measures in national waters, including several examples of simple shark catch controls (e.g. license conditions which preclude targeting) that can directly reduce mortality. Measures adopted by other RFMOs involving “no retention” and/or “prompt release unharmed” were evaluated on the basis of existing observer data on shark fate and condition. This analysis showed that “no retention” policies would reduce mortality to 30-60% of its current levels (depending on species) and that requirements for prompt release unharmed may secure an additional 10-20% reduction in mortality for certain species such as oceanic whitetip and threshers.

A measure involving "no retention" with "prompt release unharmed" for oceanic whitetip would appear to be an appropriate and effective response to recent findings on the depleted status of this stock. Existing information does not, however, allow a conclusion regarding the sufficiency of this measure for stock recovery. For other species with less clear but potentially similar depletion trajectories, such as blue sharks in the North Pacific and silky sharks, simple catch limits in combination with improved finning controls, would serve as a useful first step toward reducing mortality. With regard to blue sharks in particular, it is not clear the extent to which North Pacific catches in 2011 may have declined due to the tsunami disaster in northeast Japan. Nevertheless, the potential for the stock to no longer be above B_{MSY} argues for management measures to prevent further depletion.

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