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Progress Toward Shark Assessments

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1. Introduction

As part of its responsibilities under the Convention for managing non-target species the Western and Central Pacific Fisheries Commission (WCPFC) has called for the development of a Shark Research Plan and for advice on the stock status of key shark species in the Convention Area under Conservation and Management Measure (CMM) 2009-04. This measure also contains several operational provisions applicable to fisheries catching sharks which, *inter alia*:

- call for minimising waste and discards;
- encourage live release;
- define key shark species, and shark catch and discard reporting requirements for WCPFC CCMs;
- support research on avoidance of unwanted bycatch;
- prohibit retention on board, transhipment, landing or trading shark fins which total more than 5% of retained shark carcasses; and
- allow alternative measures for conserving and managing sharks within areas of coastal States' national jurisdiction.

The purpose of the Shark Research Plan is to inform future discussion by the Commission on the need for further management measures for sharks by providing a scientific basis for evaluating stock status. The current programme of shark analyses is limited to the key shark species designated by the Commission, i.e. blue shark (*Prionace glauca*), mako sharks (*Isurus* spp.), silky shark (*Carcharhinus falciformis*), oceanic whitetip shark (*Carcharhinus longimanus*) and thresher sharks (*Alopias* spp.). At SC6 in August 2010, the Scientific Committee (SC) considered the addition of other shark species to the Commission's key species list and tasked the Scientific Services Provider (the Secretariat of the Pacific Community (SPC)) with developing a process for key shark species' nominations.

This paper presents a brief summary of progress under the Shark Research Plan to support a decision by the Commission to formally approve the plan and to authorize continuation of work for 2011-2012.

2. Components of the Shark Research Plan and Program Implementation

The Shark Research Plan (SRP) was developed for the WCPFC by SPC and presented to SC6 where it was endorsed and forwarded to WCPFC7 for approval (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.

The SRP clearly states that progress under all three components will be necessary to assist the Commission in meeting its responsibilities for ensuring the sustainability of shark stocks. In particular, it was identified that without additional inputs from the second and third components, stock assessments for some species will be severely compromised and may not be able to provide a meaningful basis for Commission decision-making (Clarke and Harley 2010).

2.1 Progress with Research and Data Improvement

SPC is leading activities under the first component (i.e. assessments), but has also undertaken to initiate and coordinate work under the latter two components (i.e. research and data improvement) underpinning the assessments. As a result of preliminary efforts since SC6 some gains in research and data improvement have already been realised. Three papers containing biological and assessment – related shark information have been received from Korea, and Japan has agreed to make available an extensive bibliography of shark research conducted by Japanese scientists. Funding for development and internet posting of a meta-database of Pacific shark tagging studies is being finalised. Work toward obtaining better data from commercial fisheries is also progressing. Gaps in data provision were brought to the attention of three Commission members through correspondence and one has submitted data in response. Discussions are in progress with Japan regarding the provision of, or access to, shark data from commercial fisheries and research/training vessels which will be particularly important in filling data gaps in the North Pacific.

2.2 Progress with Assessments Using Existing Data

2.2.1 Step 1 – Shark Indicators

In parallel with research and data improvement coordination, SPC has begun, under SRP Phase 1-Step 1, a detailed exploration of the existing data available to support the stock assessments. Some examples of these analyses are given in the remainder of this paper. However, as will be described for specific analyses below, many of the existing datasets cannot be considered representative of the entire range of WCPO fisheries due to uneven coverage rates or changes in fishing operations, e.g. fishery closures, which bias the data. Furthermore, even in cases where the data can be considered representative of the fisheries, time will be required to determine the most appropriate model for standardizing the data to remove biases due to temporal and spatial changes in fishing operations and environmental interactions. As a result, not all of the parameters presented here can be considered unbiased indicators, and it is not advisable at this time to draw conclusions from these data regarding the overall impacts of the WCPO fisheries on sharks. Instead, these preliminary analyses are best viewed as a means of identifying issues that will need to be addressed before applying these fisheries datasets to stock status evaluations.

2.2.2 Step 2 – Shark Status Plots

Under Phase 1-Step 2 of the SRP it was proposed to build upon previous ecological risk assessment work, in the form of productivity-susceptibility analyses (PSA), by updating the PSA scores for the key shark species and combining them with indicators of fishing pressure from Step 1. In addition to the concerns with indicators identified above, in revisiting the PSA scores it was noted that input data are lacking or highly uncertain for several of the key shark species, as well as for many of the other non-key shark species. This situation has required, and is likely to continue to require, sharing or interpolation of data between species which are well-studied and those which are not. In the WCPO, the PSA approach has proved useful in characterizing risks to sharks relative to other target and non-target species and relative risks amongst sharks with widely divergent life history characteristics (Kirby and Molony 2006, Kirby and Hobday 2007).

It is noted, however, that an ecological risk assessment approach is not designed specifically to identify the amount of risk reduction required for stock sustainability. Ecological risk assessment results were used as the basis for a broadly-worded CMM for thresher sharks adopted by International Commission for the Conservation of Atlantic Tunas (no retention of bigeye thresher sharks and no directed fishing for any thresher sharks (ICCAT 2009)). The same type of measure could be considered for shark species by the WCPFC on the basis of the existing ecological risk results. However, the approach outlined under the SRP is to work toward refining our knowledge of the impacts of fishing on the key shark species in order to facilitate the development of focused measures for those species requiring management. Such focused measures would be based not only on the best available characterization of key shark species' productivity and susceptibility to fishing mortality, but also upon a detailed understanding of the existing levels of fishing pressure and the biological response of the stocks to these pressures.

The optimal approach for incorporating all of these types of information, i.e. life history characteristics, distribution and fate-upon-capture information as well as catch and effort data and biological information such as size and sex ratios, is stock assessment modeling. Stock assessment is in fact a risk assessment tool and in comparison to a PSA approach should provide a substantially reduced level of uncertainty regarding the risks of the fishery to shark populations. Unlike PSA, stock assessment modeling also allows for detailed comparison of alternative management options by evaluating the conservation benefits of various changes in fishing operations. For these reasons, it is proposed to incorporate information from the existing ecological risk assessment results directly into the Phase 1-Step 3 stock assessment activities rather than to produce further ecological risk assessment analyses as separate products.

2.2.3 Step 3 – Shark Stock Assessments

Stock assessment activities under Phase 1-Step 3 of the SRP are planned to begin in April 2011 with data preparation for a silky shark stock assessment which will be completed by the end of 2011. Assessment of the remaining key shark species, or groups of key species, are planned to run over similar 9-month timeframes, i.e. three months for data preparation and six months for stock assessment modeling and reporting, through the end of 2013. The data preparation work for each species will include refining the analyses begun under Step 1 with a specific focus on parameters necessary for the simple age-structured and/or surplus production model(s) considered most suitable for each species. Following silky shark, the order of assessment will be oceanic whitetip shark, blue shark, mako sharks and thresher sharks (see the SRP for details).

3. Examples of Exploratory Analyses Currently in Progress

Building upon the identification and assessment of available data presented in the SRP, activities since SC6 have focused on exploratory analysis of patterns in logsheet and observer datasets held by the SPC Oceanic Fisheries Programme (SCP-OFP). This has included preliminary graphical analysis of data availability and gaps; calculation of nominal catch per unit effort time series; initial models of catch rate and the factors which influence it; new methods for estimating total catches from observer data; investigation of patterns in biological parameters; and identification of operational factors influencing shark catches. As explained in Section 2.2.1 above, the analyses introduced below are preliminary in nature and will undergo further refinement before being applied in stock assessment models. They are presented here as examples of the work conducted to date and serve to highlight important issues and constraints inherent in the available data. As such, they should not be cited as “findings” of the shark assessment work until they have been finalised and presented in full to the Scientific Committee for review.

3.1 Logsheet Data Inventory and Gap Identification

In order to explore spatial patterns in data availability, the WCPFC Statistical Area was delineated into six regions based on the regions used in WCPFC bigeye tuna stock assessments (Harley et al. 2010). Although these boundaries are somewhat arbitrarily applied to sharks, longlines are the primary gear type catching sharks in the Convention Area (Clarke and Harley 2010) and the WCPO bigeye tuna-targeting fisheries are longline fisheries. Therefore, delineation of shark regions based on the current understanding of operational characteristics of the bigeye-tuna targeting longline fishery provides a reasonable starting point for further analysis (Figure 1).

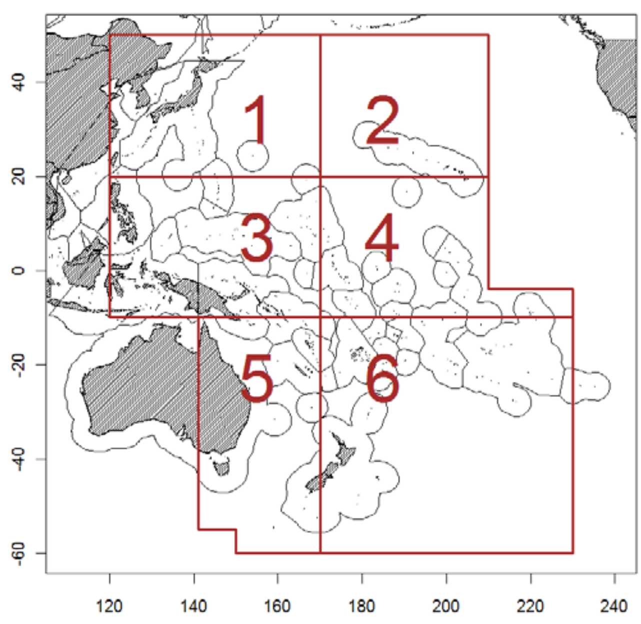

Figure 1. Area delineation for shark exploratory analysis based on regions used in the WCPO bigeye tuna stock assessments.

SPC-OFP data holdings for longline fisheries were plotted at the operational level of detail as this representation of the data provides the finest degree of spatial resolution available for analysis. The coverage of the longline fishery in the WCPFC Statistical Area during 1980-2009 by operational longline data held by SPC-OFP is 25.1%. As shown in Figure 2, there are very few operational-level data for the northwest Pacific. In most other areas, the spatial distribution of longline sets with at least one shark recorded on the logsheet (pink circles) overlies the location of logsheet-reported sets (green circles). However, this picture is somewhat misleading as only 25% of the total number of sets shown recorded any sharks (see Figure 3 below)[1]. Since only ~16% of the shark data contained in logsheet records held by SPC-OFP is recorded to species (Clarke and Harley 2010), this analysis included all sets for which sharks were recorded regardless of whether or not they were key shark species. With some notable exceptions (e.g. northeast and southwest of Hawaii), most observed sets (orange circles) occurred within Exclusive Economic Zones (EEZs) (see Section 3.2 for discussion of observer data).

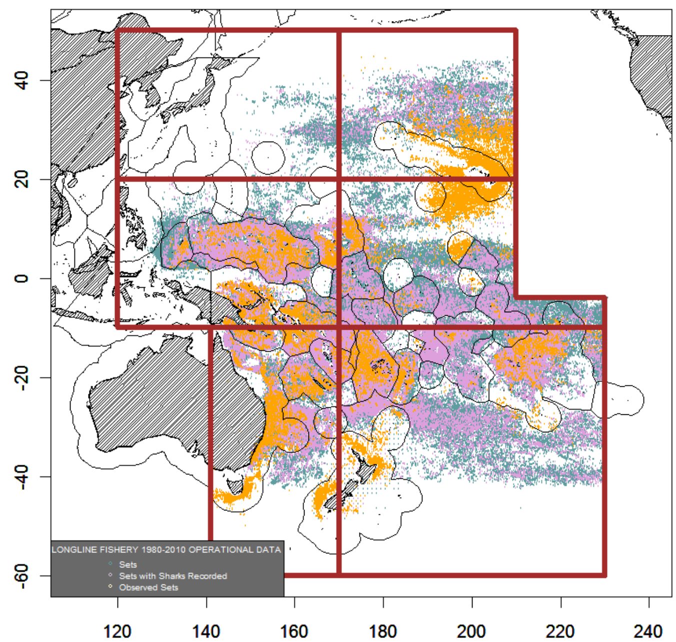

Figure 2. SPC-OFP logsheet data holdings for longline fisheries at the operational level, 1980-2010, showing location of logsheet-reported sets (green), sets for which at least one shark of any species was recorded on the logsheet (pink) and sets for which an observer was present (orange). Set locations in logsheet data for the New Zealand fleet are rounded to 1x1 degree.

A comparison by flag of longline effort and the number of sharks recorded is presented in Figure 3. This analysis used the aggregated (5x5 degree square) data, identifying the top ten flags in each panel and aggregating all remaining flags into an "Other" category. Once again, all instances in which a shark of any type was recorded in logsheet data in the SPC-OFP data holdings were included in the analysis. According to the WCPFC data provision rules, both retained and discarded fish should be recorded (WCPFC 2007). If shark catch is assumed to be proportional to longline effort, and if shark catches are accurately recorded in the logsheet data, it would be expected that the same proportions by flag would be observed in both left and right panels of Figure 3. However, as the comparison illustrates, there appear to be several major longline fishing countries which have not submitted data on shark catches to the database that will be used for the shark stock assessments. Among these major longline fishing countries there are both cases for which the data are known to exist but have not been provided, and cases for which the data may never have been collected.

[1] In contrast to these logsheet data, 87% of observed longline sets in the WCPFC Statistical Area reported shark catches.

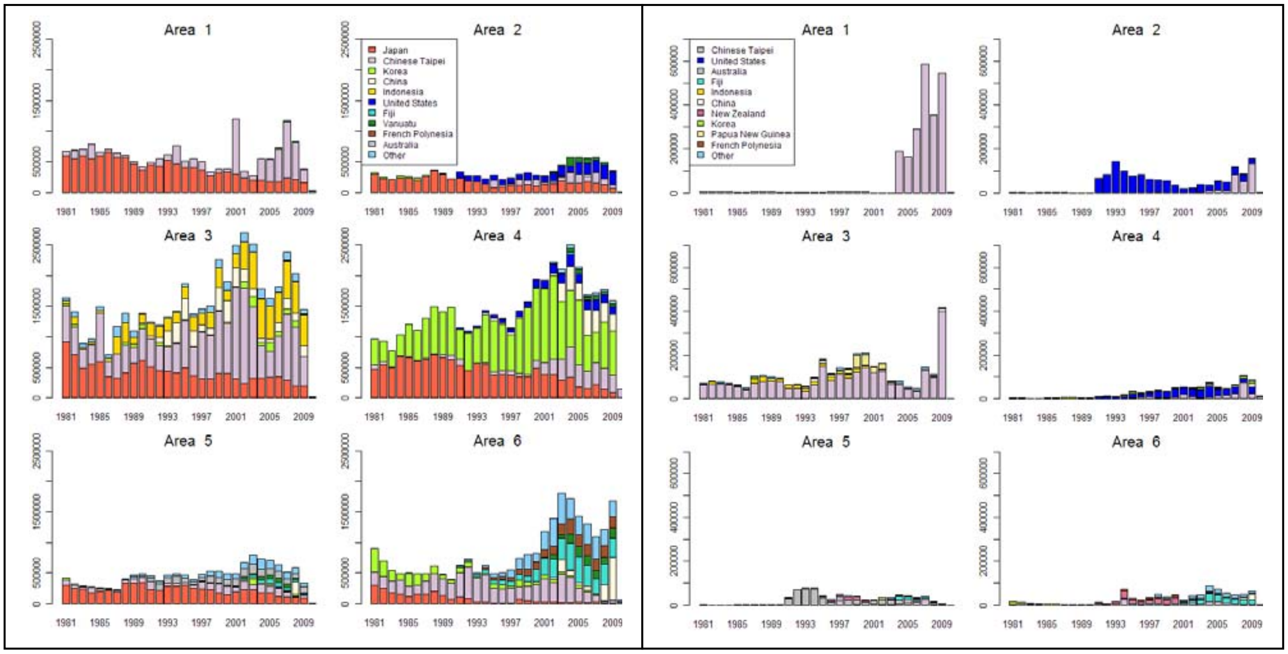

Figure 3. Comparison by flag of longline logsheet effort (left, in hundreds of hooks) and total sharks recorded on logsheets(right, in number of sharks), using aggregated (5x5 degree square)data, for six regions of the WCPFC Statistical Area.

Operational data held by SPC-OFP for purse seine fisheries in the WCPFC Statistical Area are shown in Figure 4. This purse seine fisheries plot is analogous to Figure 2 for longline fisheries except that due to the relatively higher observer coverage and the relatively lower catches of sharks in purse seine fisheries (Clarke and Harley 2010), logsheet-reported sets were plotted first (green circles), followed by observed sets (orange circles) and then logsheet sets with sharks (pink circles). The vast majority of logsheet-reported sets (98%), observed sets (99%), and logsheet sets with sharks recorded (99%) were located in Areas 3 and 4, thus these are the only areas for which purse seine fisheries data analyses will be meaningful.

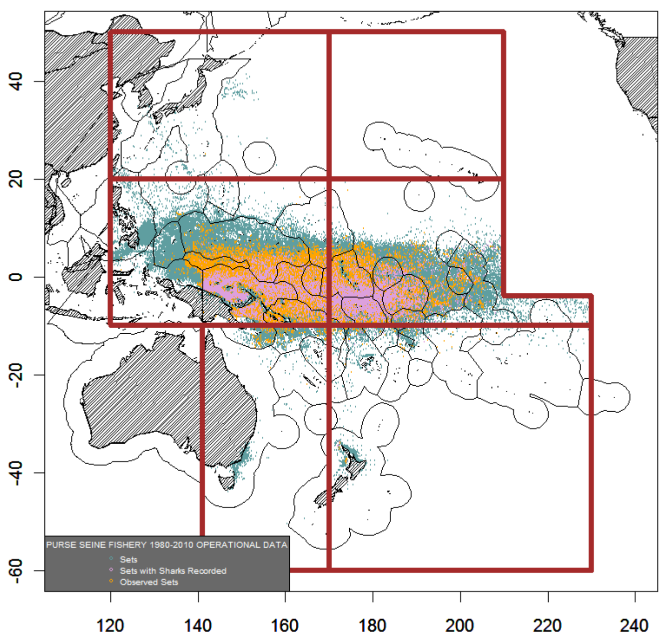

Figure 4. SPC-OFP logsheet data holdings for purse seine fisheries at the operational level (may be aggregated by 1x1 degree square), 1980-2010, showing location of logsheet-reported sets (green), sets for which an observer was present (orange), and sets for which at least one shark of any species was recorded on the logsheet (pink).

A comparison by flag of purse seine effort and the number of sharks recorded is presented in Figure 5. Unlike the analogous comparison for longline fisheries (Figure 3) this analysis used operational level data because of the dearth of shark records in the aggregated purse seine dataset. Nevertheless, even in the operational level logsheet data utilised, those sharks recorded in weight rather than number are not shown. Similar to the situation in the longline fisheries, there are some major fishing nations which have not submitted data on shark catches to the database that will be used for the shark stock assessments. Detailed shark reporting by the United States purse seine fishery contributes to the better overall match between effort and shark records as compared to longline fisheries.

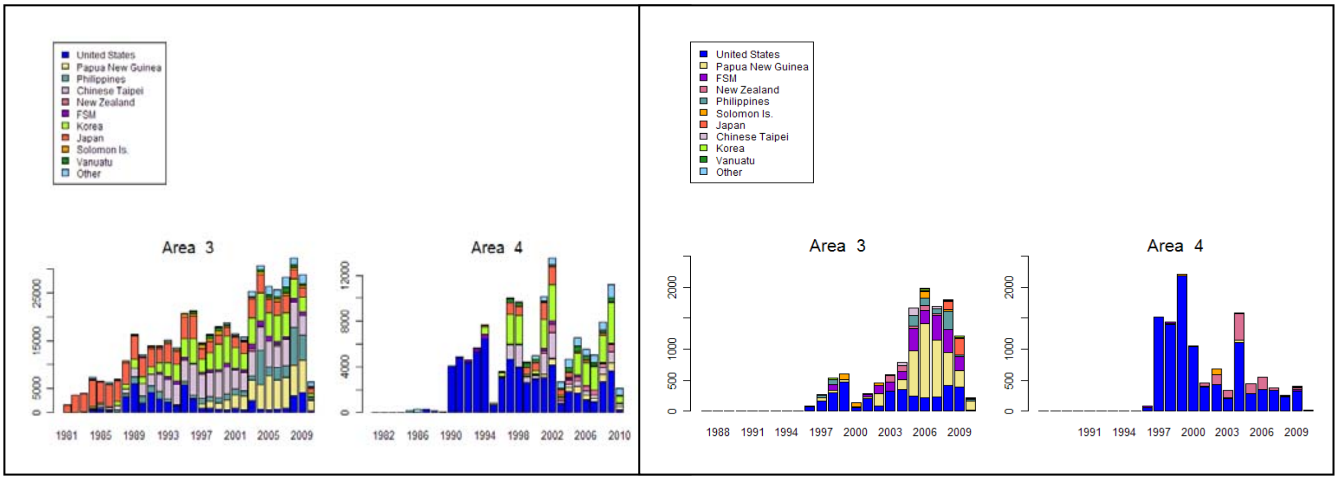

Figure 5. Comparison by flag of purse seine logsheet effort (left, in number of fished sets) and total sharks recorded on logsheets (right, in number of sharks), using operational level data, for six regions of the WCPFC Statistical Area.

This further exploration of the data inventory available for shark assessments has reinforced the concerns expressed in the SRP regarding data deficiencies in logsheet data. Coverage is lacking in some key areas (e.g. logsheet data in the northwest Pacific), available data do not represent the shark catch of several major fishing countries, and most available shark data are not species-specific. For these reasons, the further analyses of species composition, catch rate and catch introduced below necessarily rely on observer data.

3.2 Species Composition, Catch Rate and Catch Analyses based on Observer Data

Observer data provide the best source of information for shark assessment but coverage, especially for the longline fleets, is low and may not be representative of all areas where sharks are caught. In particular, areas fished by longlines in the northwest and southeast Pacific, and areas fished by purse seines west of 140°E, have scant observer coverage (Figure 6). Longline observer coverage is heavily skewed toward United States fisheries in Areas 2 and 4 and toward Japanese longline fishing in the Australian and New Zealand EEZs in Area 5. These three sources of data account for 52% of all longline observer records in the databases available to the SPC-OFP. Purse seine observer records from Papua New Guinea (30%) and the United States (24%) comprise the majority of records in the purse seine observer databases available to the SPC-OFP.

Gaps in spatial and flag coverage create considerable uncertainty when estimating catch rates and catches, and when exploring patterns in species composition and biological parameters such as size and sex ratio. In many cases, new analytical techniques will need to be developed to overcome these data deficiencies. Preliminary work toward this objective is presented below.

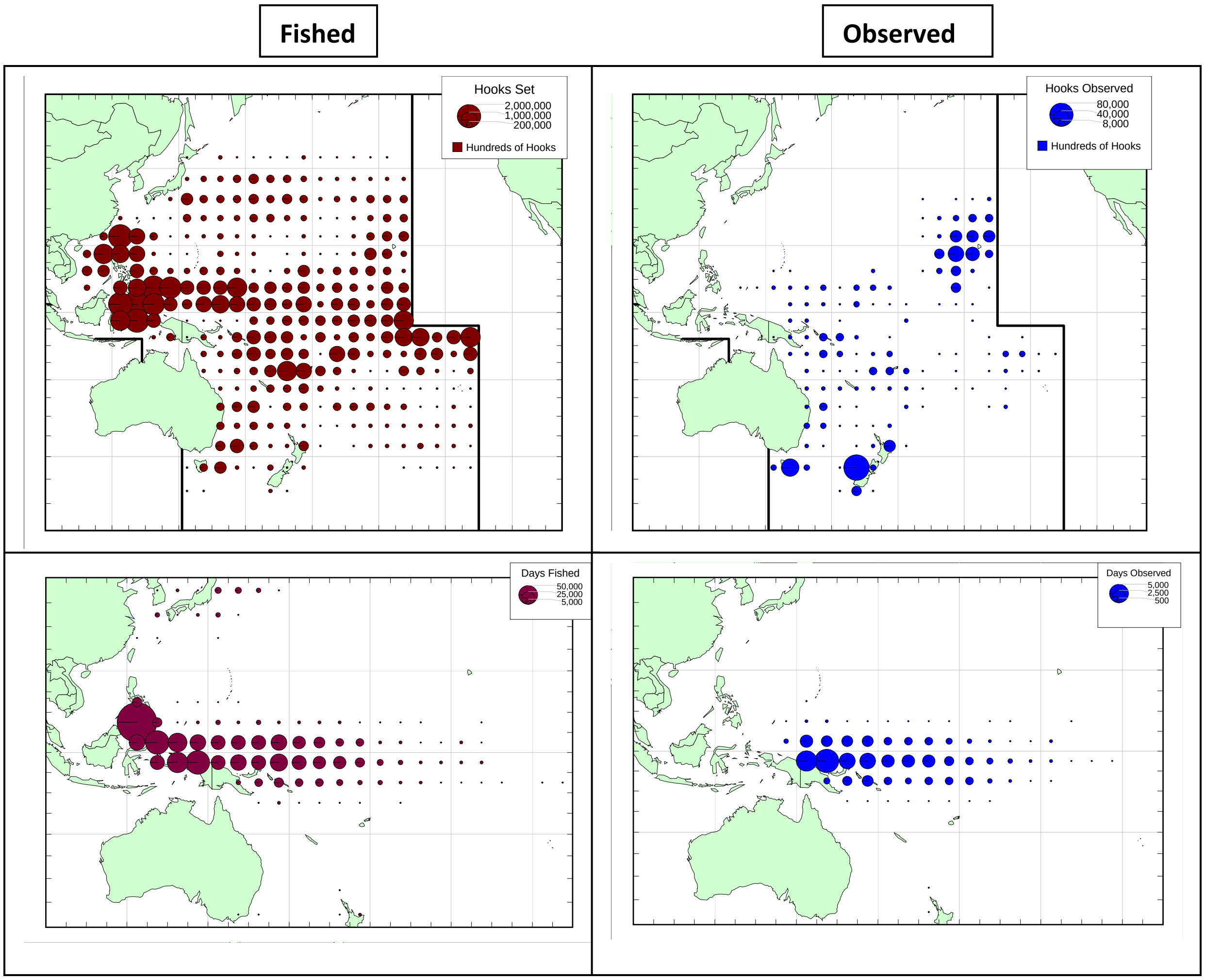

Figure 6. Distribution of longline hooks set and hooks observed (upper left and upper right), and purse seine days fished and days observed (lower left and lower right) in the WCPFC Statistical Area, 1992–2007.

Plots of the relative numbers of shark species recorded by longline and purse seine observers demonstrate the different vulnerability and spatial distribution of the key species with respect to the two gear types (Figure 7). The main species recorded by longline observers is blue shark whereas silky sharks dominate in purse seine observer records. The only exception to this pattern is in Area 3 for the longline fisheries dataset where the number of silky sharks observed consistently exceeds the number of blue sharks since 1998. Longline observer shark records are usually species-specific. In contrast, purse seine observers recorded large numbers of unidentified sharks early in the time series (i.e. through 1998) but then gradually began recording more sharks to species.

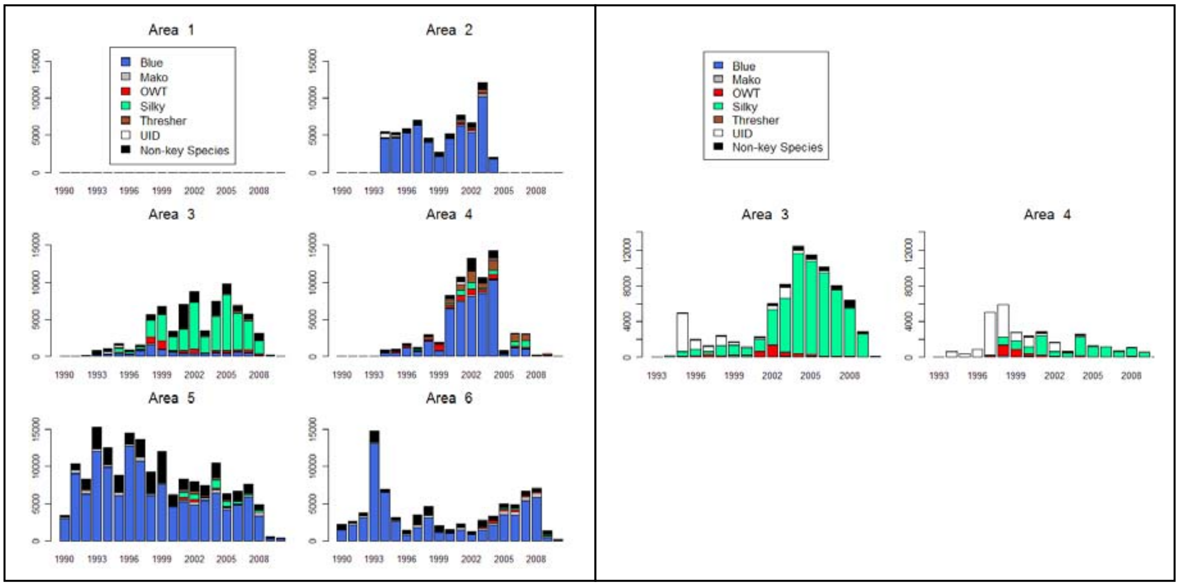

Figure 7. Key and non-key shark species recorded by longline (left) and purse seine (right) observers in number of sharks for the WCPFC Statistical Area, 1990-2010. "Mako" includes shortfin, longfin and unidentified makos; "Thresher" includes bigeye, common, pelagic and unidentified threshers. Unidentified sharks are represented by "UID".

Catch rates were plotted in the form of catch per unit effort (hooks or sets) to determine whether any apparent trends warranted further investigation. Such time series of nominal catch rates must be interpreted with caution as they are likely to be subject to biases which should be removed through the application of comprehensive standardization models. Nevertheless, the catch rates in Figure 8 can be considered partially standardized through partitioning by area (for both longline and purse seine) and by at least one operational characteristic (depth for longline and set type for purse seine). Full model-based standardizations will be developed as part of the data preparatory work for each shark species/group to be assessed.

The top two panels represent the nominal catch rates by area for the five key species/groups and for non-key species including unidentified sharks, for shallow (≤ nine hooks between baskets) and deep (≥ ten hooks between baskets) longline sets. Declining trends are apparent for blue shark in Areas 2 and 5 (shallow and deep) and Area 4 (deep only), and for silky shark in Area 3 (shallow only). It is likely that the observed trends in Areas 2, 4 and 5 are, at least in part, due to regulatory and operational changes affecting longline fisheries catch rates during this period, and thus may not reliably reflect trends in the abundance of the key shark species in these areas. For example, blue shark catch rates would be expected to decline in Area 5 with the suspension of the Japanese distant water longline fishery in the Australia EEZ in 1997, the imposition of a trip limit for sharks by Australia in 2000, and the banning of wire traces by Australia in 2005 (AFMA 2007). Regulatory changes affecting the Hawaii-based longline fishery in Areas 2 and 4 include the closure of the shallow set longline fishery for three years beginning in 2001 and a ban on shark finning imposed by state and later federal governments beginning in 2000 (Walsh et al. 2009). The declining catch rate trend for silky sharks in Area 3 shallow sets cannot be explained by any known changes in fishing operations, however, a slight but opposite trend in catch rates was observed in deep longline sets during the same time period.

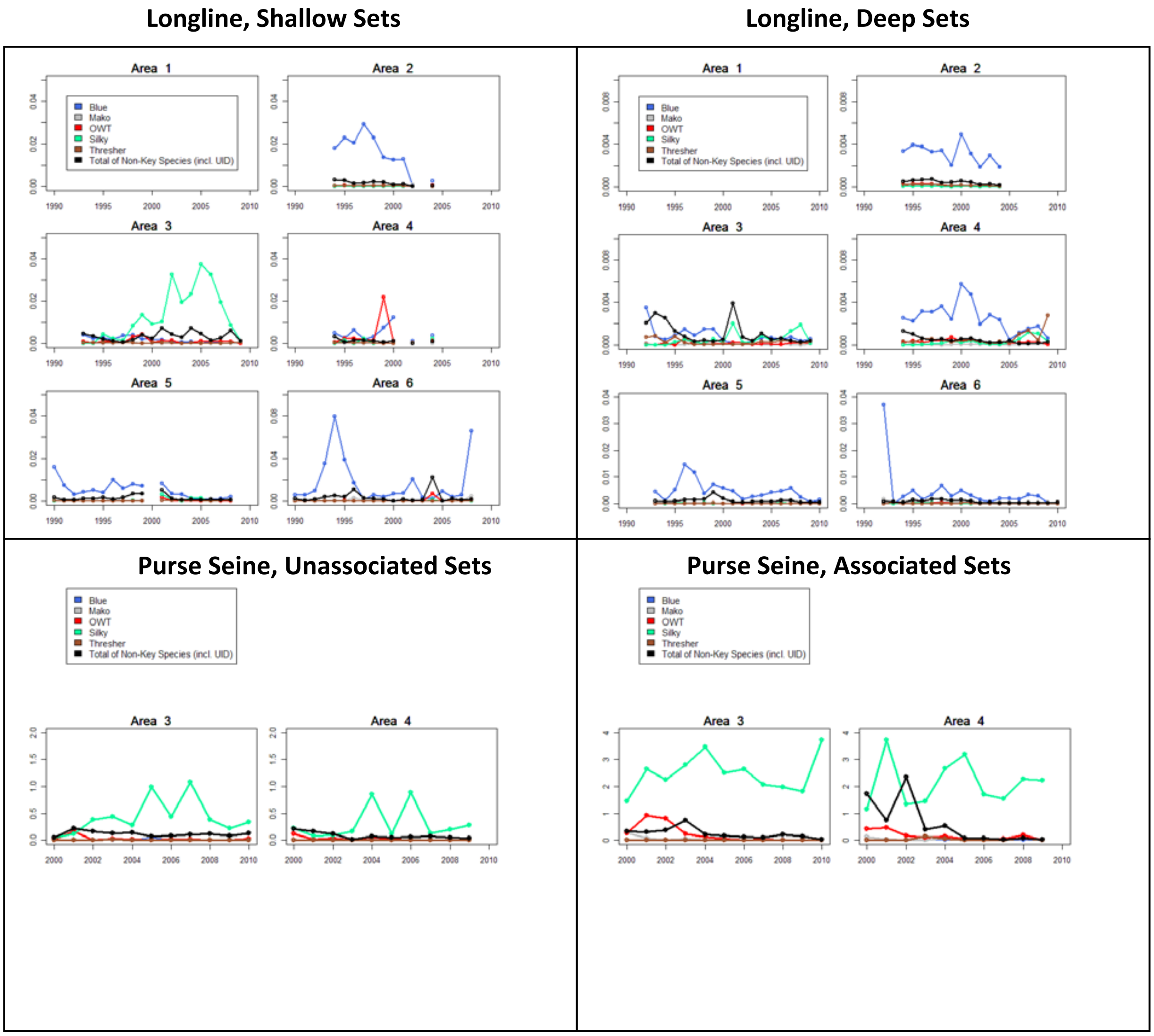

Figure 8. Nominal catch per unit effort time series for key and non-key shark species for longline and purse seine fisheries based on observer data, 1990-2010. The units of catch rate are number of sharks per hundred hooks for longline and number of sharks per set for purse seine. Unidentified sharks, which may have included key species, are grouped with the non-key species for presentation.

Prior to 2000 a large proportion of the sharks in the purse seine observer database are recorded only as unidentified sharks (Figure 7). For this reason, the nominal purse seine catch rates in Figure 8 were only presented from 2000 onward. In these series, a decline in catch rates is observed in Area 4 in 2000-2003 for non-key shark species. The only noteworthy trend in catch rates for key shark species is a decline in oceanic whitetip sharks in the period 2000-2002 in both Areas 3 and 4. This declining catch rate cannot be explained by any currently known changes in fishing operations. Aside from oceanic whitetip sharks, the only key species for which purse seine catch rates show major changes over time is the silky shark. However, there is no clear trend in either unassociated or associated purse seine sets. It is noted that nominal catch rates for the silky shark on associated sets are approximately four times greater than catch rates on unassociated sets.

Initial work on standardizing catch per unit effort (CPUE) data has also been undertaken in order to produce indices of abundance. A delta-log normal model has been applied to longline observer data to standardize for potential biases such as location (latitude and longitude), year, hook depth, flag and time of day. Gridded maps showing the estimated relative (within species/group) CPUE for each of the five key shark species/groups are shown in Figure 9. The darker areas on these maps indicate the areas of higher CPUE and provide a preliminary indication of the areas of highest abundance for each species/group. The patterns observed for blue shark correspond to existing information on the temperate distribution of this species (Nakano and Seki 2003). The patterns for mako would be expected to be similar to those for blue but lower abundances were observed in the northern hemisphere than in the southern hemisphere. The oceanic whitetip and silky sharks appear to be tropically distributed as expected. As little is known about the detailed distributions of these species, higher abundances in the west for silky sharks and in the east for oceanic whitetip sharks, and an eastern area of higher abundance for oceanic whitetip near -20^{o}S, will be further investigated in the literature and through further standardization modelling. Symptomatic of anticipated problems with thresher assessment, the gridded map for this species group shows a patchwork mosaic probably reflecting the different distributions of the three species combined, by necessity due to data deficiencies, into a single group.

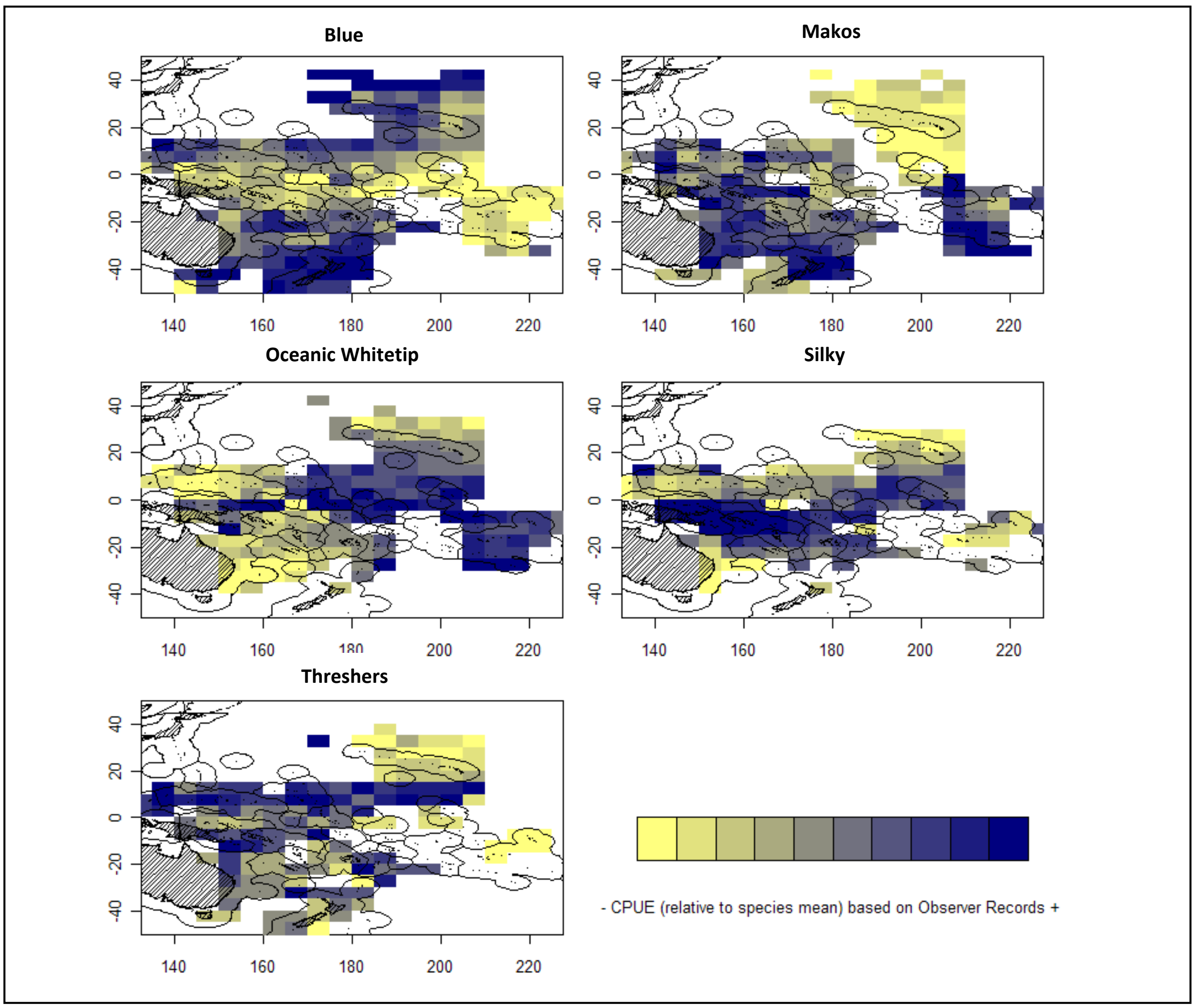

Figure 9. Relative estimates of standardized catch per unit effort produced using a delta-lognormal model applied to observer data, 1980-2010, for the five key shark species/groups.

Another analysis of observer data is being conducted with the objective of producing estimates of catches of the key shark species in the WCPFC Statistical Area. The analytical approach involves fitting a predictive model of catch rates to observer data, and then applying this model to effort data to predict catch. A delta-lognormal model incorporating splines of the independent variables year, month, latitude, longitude and hooks between floats (a proxy for depth of the set) was constructed for this purpose. Preliminary estimates of the effect of latitude on shark catch rates are shown in Figure 10 below and provide for an interesting comparison to the spatial patterns of abundance illustrated in Figure 9. The hemispherically-symmetric pattern for blue shark appears in both figures, as does a peak in mako abundance around -30°S latitude. Uncertainty (i.e. wide confidence intervals) in the mako model in temperate waters of the northern hemisphere may explain the lack of an expected symmetrical distribution around the equator for this species. Despite the differences between the two models, oceanic whitetip, silky and thresher patterns from Figure 10 also resemble those in Figure 9.

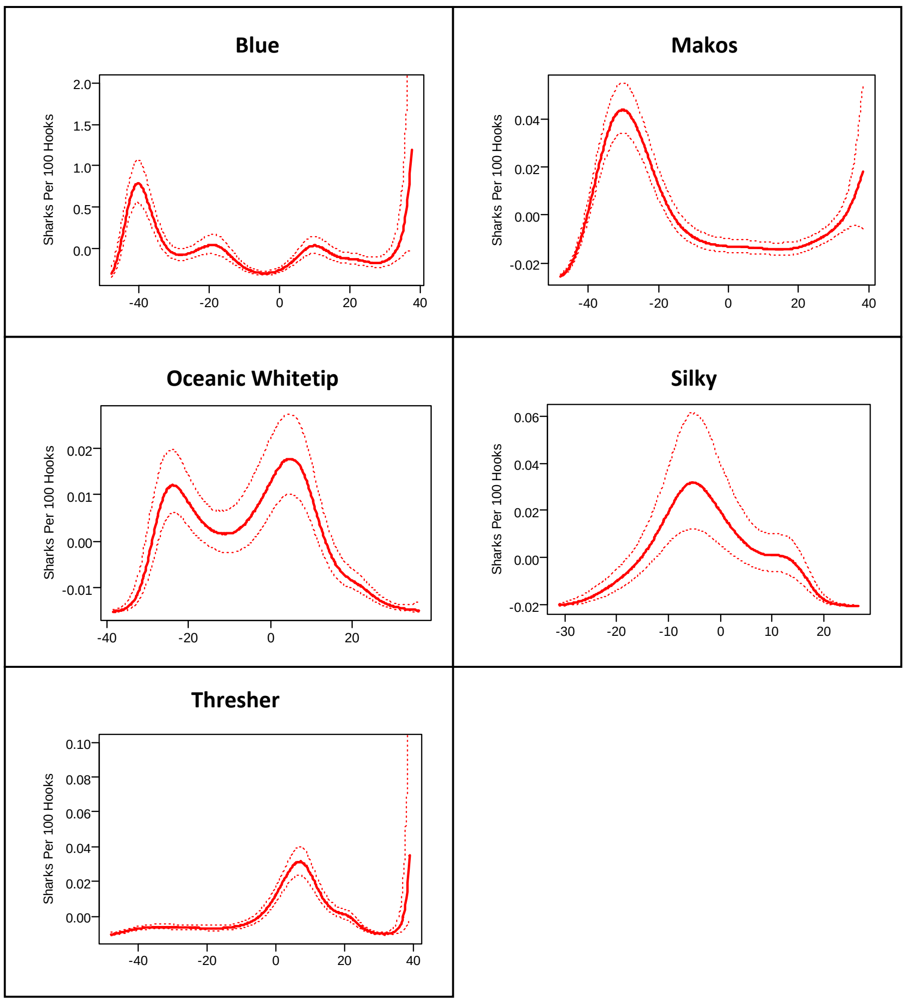

Figure 10. Effects of latitude in a delta-lognormal, spline-based model of longline CPUE for five key shark species/groups fitted to observer data, 1992-2010. The mean of each effect has been set to zero and the dotted lines represent 95% confidence intervals.

The primary purpose of the delta-lognormal model with splines is to predict shark catches in the WCPFC Statistical Area. Preliminary results for blue shark by area and year are shown in Figure 11. These results are similar to previous estimates of catches of blue shark which showed a peak in 1999 and declining catches thereafter (SPC 2008). The increasing trends in the 1990s may be attributed to observers in some programmes increasingly recording catches of non-target species during this period and possibly to an increase in shark targeting. The declining trends since the late 1990s may reflect operational changes in the fishery, discontinuities in observer coverage, and/or trends in fishing effort. These results contrast with estimates of shark catches in the WCPFC Statistical Area derived from the shark fin trade (Clarke 2009), and also with data from the North Pacific (Yokawa 2010), both of which show maximum catches occurring in 2001-2003 with only slight reductions in catches since then. The divergent results have likely arisen, at least in part, from the lack of data in the delta-lognormal, spline-based model to support robust estimates for the North Pacific (i.e. note the wide confidence intervals for Areas 1 and 2 relative to the other areas in Figure 11). This situation emphasizes both the need for better data to support the assessments, and the desirability of developing creative estimation techniques to fill remaining data gaps. One approach to the latter, involving the application of information from the southern hemisphere to northern hemisphere areas for those species which are believed to have hemispherically-symmetric distributions, is currently under consideration.

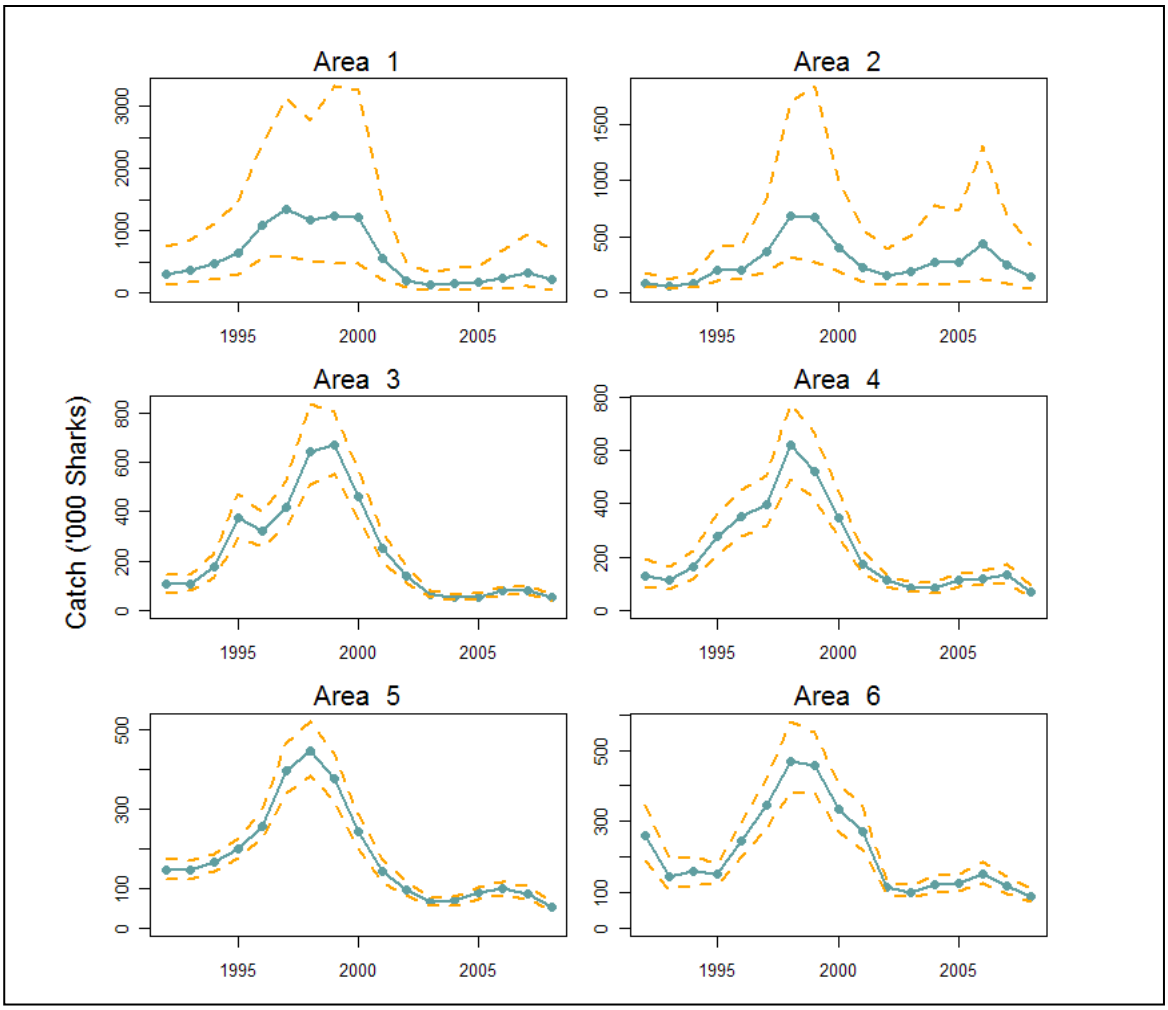

Figure 11. Total catch of blue sharks in the WCPFC Statistical Area, 1992-2008, estimated from a delta-lognormal, spline-based catch rate model of observer data. Solid lines represent the median; dotted lines represent the 95% confidence interval.

3.3 Biological Parameters and Patterns based on Observer Data

In addition to forming the primary basis for analyses of species composition, catch rate and catch, observer records also provide the main source of biological data such as size and sex. These data can inform stock assessment modeling through providing the basis for assumptions or parameter estimates involving sex ratios, percentage of mature individuals, and distributional patterns by sex and life stage. It is important to note, however, that if there are strong subregional spatial patterns in the distribution of males and females, any spatial shifts in sampling effort over time may bias temporal trends in regionally aggregated sex ratios. Taking these objectives and issues into account, exploratory analyses are underway for each of the key shark species/groups. Two examples for silky shark based on longline observer data are presented below. Purse seine observer data contain no information on shark sexes and, due to the relatively lower shark catch rates as compared to longline fisheries, only small sample sizes of lengths.

To allow for the maximum possible coverage over the WCPFC Statistical Area, it is necessary to convert shark length measurements in total length (TL) from some observer programmes to fork length (FL) or to remove them from the analysis (e.g. if the length was outside the range of data used to create the conversion factor). For this purpose, male and female lengths at maturity were obtained from the scientific literature for the North and South Pacific separately where possible. Medians and confidence intervals for silky sharks derived from at least 20 measurements are shown in Figure 12.

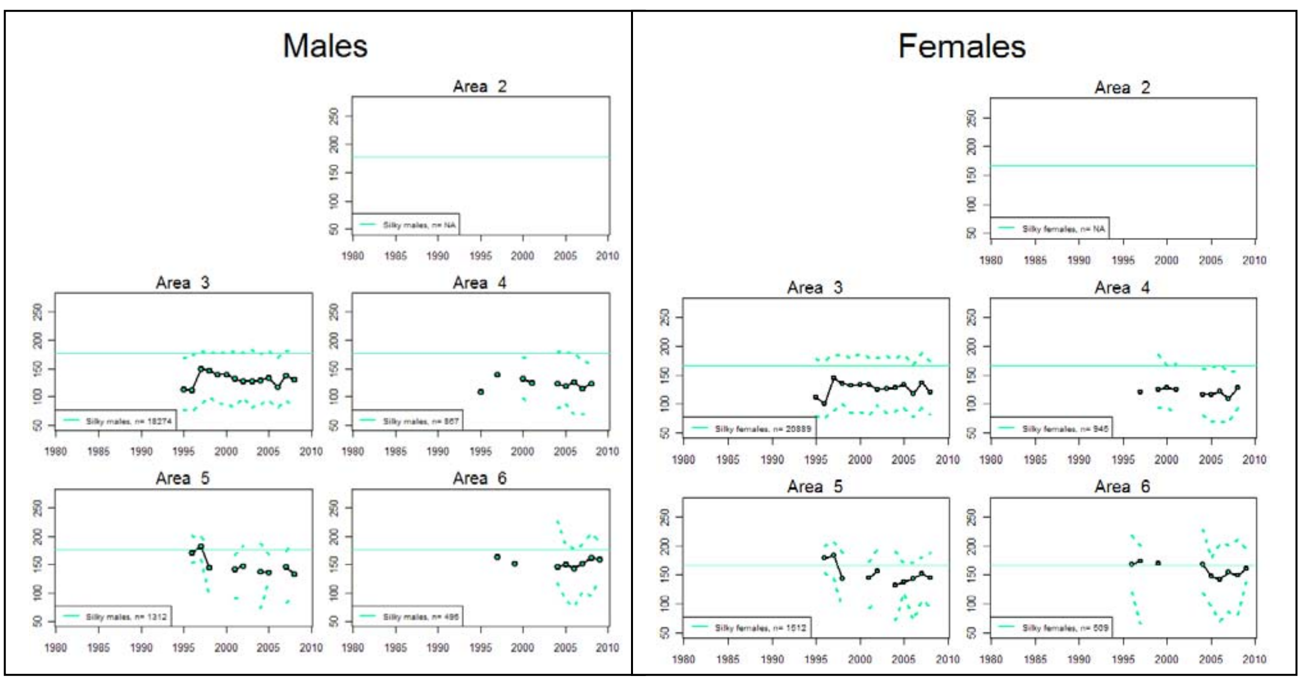

Figure 12. Median length (in fork length in cm) for male (left panel) and female (right panel) silky sharks for six areas within the WCPFC Statistical Area compiled from observer data, 1980-2010. The 5th and 95th percentiles of the data are shown with dashed lines.

As these example plots for silky shark illustrate, for all key shark species/groups there are no observer records for Area 1 and length samples in other areas for some or all of the years examined are insufficient for analysis. According to this analysis, in Area 3, the primary area of interest for silky sharks, nearly all of the male and a majority of the female silky sharks caught by longlines are immature[2]. The number of purse seine fishery-based length measurements for silky shark is very limited, even in Area 3 (n=353 for all years combined), but the available data indicate that approximately 92% of these unsexed individuals were below the smallest (i.e. female) length at maturity.

Many pelagic shark species are known to exhibit sex- and age- specific distribution patterns (Camhi et al. 2008, Sims 2009). Observer data on sex, life stage and location of catch were used to explore such patterns for the key shark species/groups. The gridded maps shown in Figure 13 were produced by partitioning the observer records for each key shark species/group into four subsets: adult females, adult males, juvenile females and juvenile males. The number in each subset in each cell was plotted as a proportion of the total number of that key species/group observed in that cell with darker colours indicating higher proportions. In order to account for seasonal changes, both year-end (November through January) and mid-year (May through July) plots are shown. The example shown for silky shark reinforces the indications from the previous analyses that adult silky sharks are infrequently recorded by observers and that there are locations within Area 3 which are particularly important habitats for both male and female juveniles.

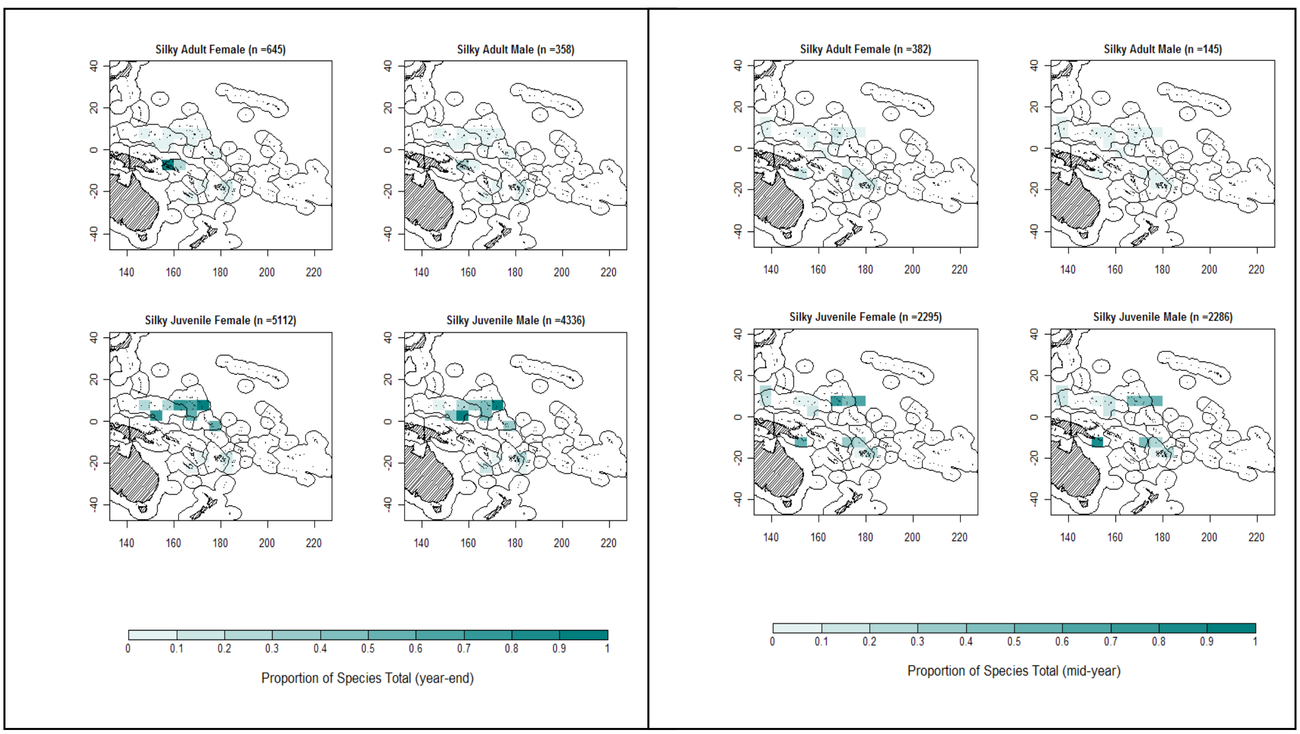

Figure 13. The proportion of silky sharks in each locational cell of the WCPFC Statistical Area which were adult females, adult males, juvenile females and juvenile males for year-end (left panel) and mid-year (right panel) timeframes based on observer data, 1980-2010.

[2] Smallest age at maturity of 214 TL for males and 202 TL for females (converted to 177 FL and 167 FL, respectively, using conversion factors from Kohler et al. 1996) from a study by Stevens in eastern Australia (Stevens 1984 cited in Bonfil (2008)).

3.4 Operational Factors Influencing Shark Catches

As discussed above in connection with the catch rate analysis, one of the factors expected to have influenced shark catch rates in longline fisheries in Australian waters is the banning of wire traces in 2005. Wire traces have been shown to have higher catch rates for sharks and lower catches for bigeye tuna than nylon leaders (Ward et al. 2008), but anecdotal evidence suggests that many longliners targeting bigeye tuna continue to use wire traces to prevent bigeye biting through the line and thereby increase bigeye catch rates (S. Beverly, SPC Coastal Fisheries Programme, personal communication). A ban on wire traces is one of several conservation and management measures for sharks proposed under the Pacific Islands Regional Plan of Action for Sharks (Lack and Meere 2009). Assuming implementation and full enforcement, the impact of such a measure on shark populations will depend largely on the extent to which wire traces are currently used and the catchability of sharks by other materials (e.g nylon, etc.).

This issue was investigated on the basis of the limited information on gear configuration available 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 665 trips for 17 flags from 1996-2010 (Table 1).

Table 1. The number of observer trips for which the presence or absence of wire trace 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 framework. Due to low and unevenly distributed sample sizes, the output of this extrapolation is characterized by wide probability intervals but suggests that the usage of wire traces has fallen over time (Figure 14). Median estimates indicate that in the early years of the analysis (1996 to 2004) wire traces were used in >90% of longline trips. Although this proportion had fallen to 66% by 2009, wire traces still appear to be the most common leader type used in longline fisheries within the WCPFC Convention Area. This 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 biteoffs or if a nylon leader is cut at the rail.

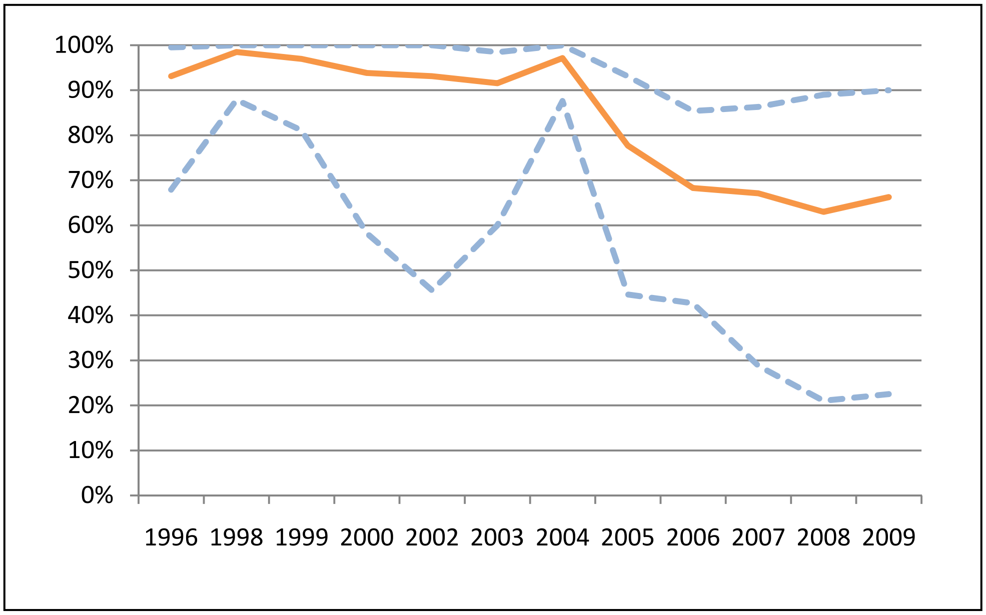

Figure 14. An extrapolated estimate of the proportion of longline effort in the WCPFC Statistical Area that employed wire traces for 1996, 1998-2000, and 2002-2009 (estimation for other years is not supported by the available data).

As a complement to the focused shark analyses being undertaken within the SRP and described above, ongoing analysis of regional observer data under the national-level tuna fisheries advisory programme of the SPC-OFP is assisting in identifying factors which influence the catch rates of the key shark species/groups. These analyses are designed to firstly, identify components of the fishery which might be targeting sharks, and secondly, identify key operational and environmental factors which influence catch rates of sharks. These analyses will provide a better understanding of where, when and how shark interactions occur. This work will therefore inform the shark stock assessments under the SRP, most directly by insuring that key fishery characterization factors are accounted for when standardizing catch rate data for use as indices of abundance and in estimating total catches. Factors currently being examined include, *inter alia*, operational factors (e.g. depth of fishing, hook size, time of day of setting, bait type, gear type and many others), environmental factors (e.g. sea surface temperature, thermocline depth, current speeds) and human factors (e.g. fishers experience). As information from these studies becomes available, it will be incorporated into the catch rate standardization and other data preparatory work for each key shark species' assessment.

4. Summary and Issues for the Commission's Consideration

The Shark Research Plan (SRP) is designed to lay a scientific foundation for further consideration by the WCPFC of stock status and sustainability of key shark species within the Convention Area. Following endorsement of the SRP by SC6 in August 2010, exploratory analyses of available data have been initiated as preliminary steps toward stock assessments. As this paper has highlighted, while some interesting trends have been identified, ongoing data gaps and biases have yet to be fully addressed and therefore conclusions about stock status would be premature. While analyses will continue to progress with existing data, and while innovative techniques will be applied to compensate for data shortcomings, it is becoming increasingly clear that better information is required. Without additional research and data contributions, it is likely that stock assessments for some species will be severely compromised.

To operationalize its commitment to managing and conserving sharks, WCPFC7 will take a decision on approval of the Shark Research Plan and on re-allocation of existing funds within the Scientific Services Provider's budget to support shark assessment through 2012. Positive steps on these decision points will enable shark stock assessment work to get underway in early 2011 and will provide for three shark stock assessments (silky, oceanic whitetip and blue) by the end of 2012. The WCPFC SRP comprises the most progressive shark assessment programme of any of the tuna regional fisheries management organizations and will facilitate directly addressing fisheries impacts through fisheries management.

Beyond approval and funding for the SRP, another shark-related decision before WCPFC7 is equally critical to the success of the shark programme. SC6 recommended that the key shark species listed in CMM 2009-04 be included in catch reporting to the Commission, including annual catches, operational level data (where applicable), and recreational catch and effort data (where possible). WCPFC7's decision to adopt this recommendation would greatly expand the logsheet data available for the shark assessments and ensure that the Commission's concern in designating these key shark species is matched by its data provision requirements. It is noted that expanding longline and purse seine observer coverage, to 5% by 2012 and to 100% in 2010 respectively, will also generate additional vital data to bolster the shark stock assessments.

The support provided thus far by Commission members and stakeholders to the WCPFC shark programme is greatly appreciated. Continuing support for all three components of the Shark Research Plan – technical advice on assessments, shark research contributions, and data provision and improvement—will be essential in ensuring the sustainability of western and central Pacific shark stocks.

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