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The feasibility of conducting quantitative stock assessments for key shark species and recommendations for providing preliminary advice on stock status in 2010

WCPFC-SC5-2009/EB-WP-08

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EXECUTIVE SUMMARY

This paper addresses a request made by the Fourth Regular Session of the Western and Central Pacific Fisheries Commission Scientific Committee (WCPFC-SC4) in Port Moresby, Papua New Guinea, in 2008 for the Oceanic Fisheries Programme of the Secretariat of the Pacific Committee (SPC-OFP) to review the general feasibility of undertaking single-species stock assessments of key shark species in the Western and Central Pacific Ocean (WCPO) in order to provide preliminary advice on stock status. We have also provided a recommended approach for undertaking these assessments and for developing a Shark Research Plan to meet the requirements of Western and Central Pacific Fisheries Commission (WCPFC) conservation and measurement measure CMM-2008-06.

Following our review, we conclude:

- Sufficient basic biological and fishery data exist to provide preliminary stock status advice of the key shark species (blue, oceanic whitetip, short- and longfin mako, silky, and bigeye, common, and oceanic thresher sharks). These will be almost entirely based on observer data held by SPC and member countries and territories, not the WCPFC.

- A hierarchical or stepwise approach to the development of preliminary stock status advice is recommended: (step one) beginning with a revised productivity-susceptibility and resilience analysis; (step two) followed by an evaluation of stock-status indicators outside a population model fit; and then by (step three) an evaluation of stock-status indicators calculated from the results of a series of simple population model fits.

- It is not expected that construction of simple population models (step three above) will be feasible for all species, in particular the rarer longfin mako and some or all of the three species of thresher sharks listed. The data available for these species may be too few and too patchy to proceed past steps one and two. However, it should be possible to identify the precise nature of the data gaps, any other information needs, and how these might be filled or met in the future.

- Construction of catch histories (i.e., total removals or the sum of the landed or retained catch and the dead discarded catch) will be a large and complex job and is likely to require a number of structural assumptions about the data that may not be immediately testable. The uncertainties in the data are likely to be heavily species-dependant, perhaps reflecting historic reporting practises. Calculation of several alternative catch histories for each species that are functions of different sets of structural assumptions is recommended.

- We expect that estimating biomass and yield with statistical confidence and providing a precise picture of stock status is unlikely to be possible without considerable investment in shark fishery data collection and reporting systems in the future. However, the process suggested here (i.e., the one-year preliminary assessment project), should produce sufficient information to guide the development of the WCPFC Shark Research Plan.

- Key tasks in the provision of preliminary advice include:

    i. developing collaboration, as appropriate, with the IATTC and other partners, including national scientists from WCPFC members, cooperating non-members, and participating territories (CCMs);

    ii. updating biological information where necessary and possible and identifying other potentially important data sets (e.g., data held by CCMs and not currently available to the WCPFC) that may be required;

iii. developing alternative catch histories;

iv. analysis of standardised CPUE and size data;

v. application of different stock assessment modelling methodologies; and

vi. developing a draft Shark Research Plan, in collaboration with CCMs and for approval by SC, based on the lessons learned in undertaking the preliminary assessments.

In order to undertake this task properly, we suggest that it would require the full-time work of one person starting as soon as possible after WCPFC-SC5.

1. INTRODUCTION

The relative low biological productivity of sharks compared to other fish species caught in oceanic fisheries of the Western and Central Pacific Ocean (WCPO) and the associated risks of overexploitation have been recognised by the WCPFC Scientific Committee (SC) through the results of the Ecological Risk Assessment (ERA) project. In 2006, the WCPFC adopted Conservation and Management Measure CMM-2006-05. Paragraph 14 of CMM-2006-05 encouraged WCPFC members, cooperating non-members, and participating territories (CCMs) to cooperate in the development of stock assessments for "key shark species" within the tropical West and Central Pacific Ocean Convention Area (WCPO-CA). Key shark species were not defined.

At SC4, based on earlier results from risk assessments presented by Kirby and Molony (2006) as well as subsequent multi-species analyses of both longline and purseseine fisheries for individual Pacific Island countries, silky shark (*Carcharhinus falciformis*) and oceanic whitetip shark (*Carcharhinus longimanus*) were identified as two species warranting greater attention (SC4 Summary Report, paragraph 220). In addition, blue shark (*Prionace glauca*), mako sharks (two species: *Isurus oxyrinchus* and *I. paucus*), oceanic whitetip shark, and thresher sharks (three species: *Alopias pelagicus*, *A. superciliosus*, and *A. vulpinus*) were recognised as species that can easily be identified by fishers, and, under the assumption that most other sharks caught are likely to be silky shark, that this should be the minimum list of shark species for which catches should be reported in the WCPO-CA (SC4 Summary Report, paragraph 218).

When CMM-2006-05 was superseded by CMM-2008-06 at WCPFC-5, the key shark species, both for the purposes of stock assessment and for catch reporting, were defined to be blue shark, mako sharks, oceanic whitetip shark, and thresher sharks, even though SC4 advised that the choice of shark species for stock assessment should be based on multi-species risk assessment. Furthermore, the list of key shark species should be expanded to include silky shark given its prevalence in the catch. CMM-2008-06 also stated that "*In 2010, the SC, and if possible in conjunction with the Inter-American Tropical Tuna Commission, provide preliminary advice on the stock status of key shark species and propose a research plan for the assessment of the status of these stocks*."

In response to the advice from WCPFC-SC4, SPC-OFP have been asked to "*Review data gaps on the necessary biological and fishery data and the general feasibility of single species stock assessment, with special attention on silky sharks and oceanic white tip sharks.*" Noting this direct request to SPC-OFP and the provisions contained in CMM-2008-06, the purpose of this paper is two-fold: (i) to assess the feasibility of undertaking stock assessments for all the "key shark species" based on a review of current biological and fishery information; and (ii) to provide a recommended approach for undertaking these assessments and for developing a Shark Research Plan to meet the requirements of CMM-2008-06.

We first briefly discuss the biological characteristics of the key shark species and how these are likely to influence any stock assessment work. We next discuss the likely data needs which will need to be met in order for any assessment to be successful and evaluate this against our current state of knowledge for the key shark species. We next describe the various stock assessment modelling approaches that should be considered in any shark stock assessments. Finally we outline a work plan to achieve the request for preliminary advice on stock status and a shark research plan.

2. BIOLOGICAL CHARACTERISTICS OF THE KEY SHARK SPECIES

2.1 General fisheries biology of sharks

Modern sharks (class Chondrichthyes, subclass Elasmobranchii, superorder Euselachii) are a group of approximately 500 cartilaginous fishes found in all the world's oceans and some intertidal and freshwater habitats, although their diversity and abundance is greatest in tropical and temperate marine waters (Compagno et al. 2005). Sharks as a group span a wide variety of life-history characteristics, strategies, and traits, but compared to modern bony fishes such as teleosts, they are typically larger, slower growing, less fecund, often longer lived, and reaching sexual maturity at a later age (reasonably up to date surveys of shark life history characteristics were compiled by Cortés 2000; Cortés 2004). It has long been realised that these life-history characteristics mean that the intrinsic rates of increase of shark populations are typically less than those of teleost populations of comparable size, and, consequently, shark populations tend to be less resilient to the effects of fisheries harvesting (e.g., Holden 1973; Hoenig and Gruber 1990; Musick 1999; Schindler et al. 2002; Walker 1998; Dulvy et al. 2008, among many others).

Given that the data available for stock assessments of the key shark species are likely to be incomplete or noisy or both (see discussion in Section 3 below), results of the preliminary stock assessments (e.g., biomass and yield estimates) are likely to be uncertain. One of the advantages from a stock assessment perspective of having a good understanding of the life histories of the key shark species is that productivity parameters and plausible population dynamics can be realistically constrained; e.g., populations can decrease quickly, but not increase quickly. This will be important for developing stock assessments in the face of uncertain data.

SC2 has previously considered the relative risk posed to sharks by the industrial fisheries in the WCPO. Results of a productivity-susceptibility analysis (PSA) from Kirby and Molony (2006) for several groups of large vertebrates in the WCPO are plotted in Figure 1. Here we see that sharks constitute a group of relatively low-productivity species that are often subject to fishing-induced mortality. Another important perspective is seen in Figure 2. Mean length-at-capture is plotted against mean length-at-maturity for sharks caught in the WCPO longline fisheries. Here we see that most sharks caught by longlines are juveniles, the life-history stage that is most important for population growth in sharks as shown by elasticity analysis (Heppell et al. 1999). Observed shark encounters and observer effort for the WCPO longline fisheries for the period 2002–2006 are plotted in Figure 3. Here we see that sharks are encountered wherever there is longline fishing effort, although the species composition of the shark catch does vary spatially. Nevertheless, with only a few exceptions such as the analysis presented by Kleiber et al (2009) for the stock status of blue shark in the North Pacific, quantitative estimates of the effect of the directed (e.g., Kumoru 2003) and non-directed fishery catch on shark populations in the WCPO are not available at this time[1].

2.2 Specific biological characteristics of the key shark species

A detailed understanding of the basic biological characteristics of each of the key shark species is clearly fundamental to any stock assessment of these species. With assistance from CSIRO (Australia) and NOAA-PIFSC (USA), SPC-OFP has developed and compiled a database of life-history characteristics of species from across a wide variety of taxa caught in the tuna fisheries in the WCPO.

[1] We are aware of a silky shark assessment for the Pacific Ocean by Shungo Oshitani, Tokai University, written as a post-graduate Thesis, but only have parts of the document.

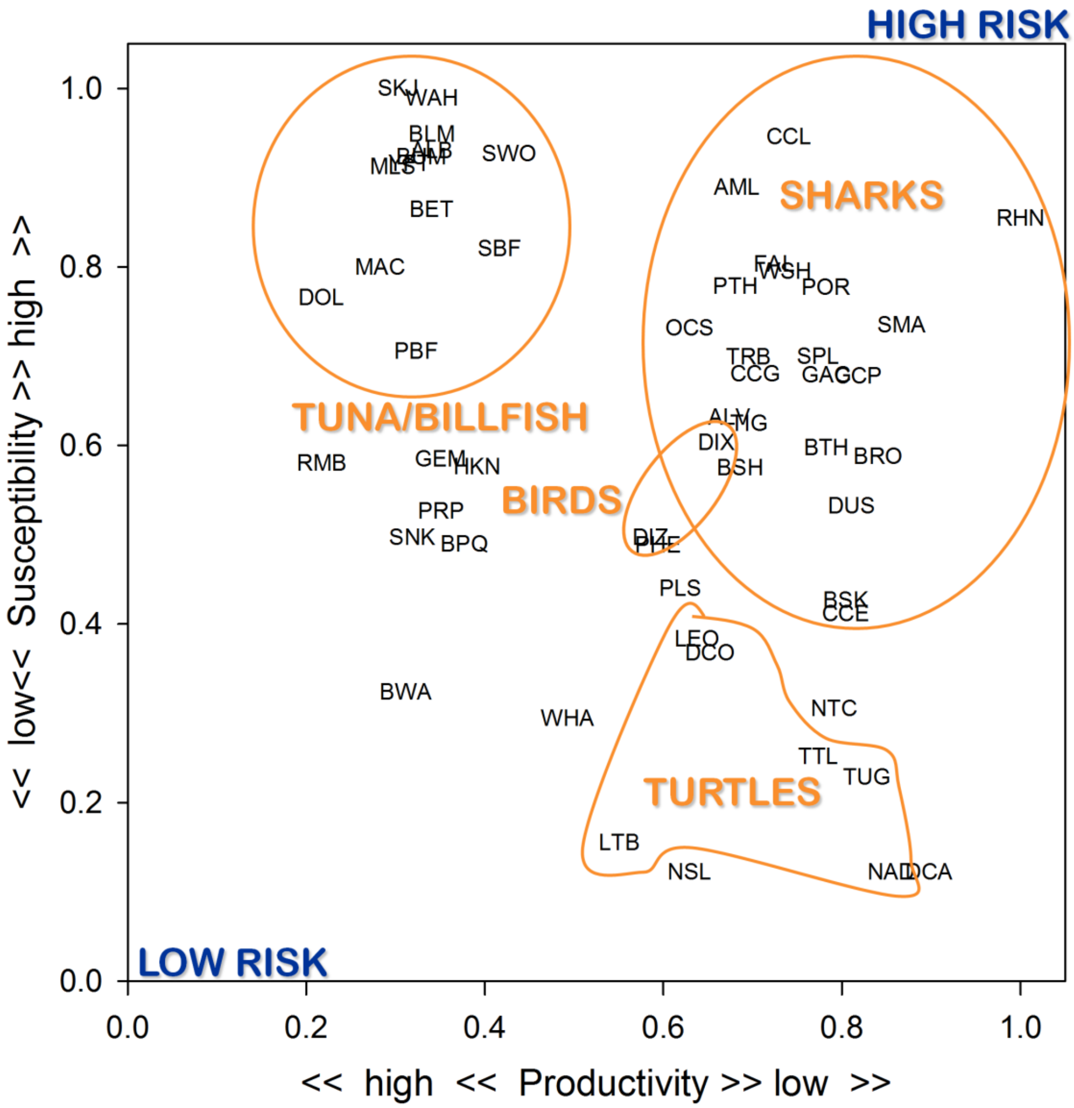


Figure 1: Productivity-susceptibility analysis for several groups of large vertebrates in the WCPO (Kirby and Molony 2006). The productivity risk score was based on age-at-maturity, longevity and reproductive strategy; the susceptibility risk score was based on an index of total mortality, i.e., encounters × condition × fate.

This database forms a component of the WCPFC Bycatch Information System developed by SPC-OFP for the WCPFC Secretariat during 2008 and 2009. The biological parameters were originally obtained from the primary and secondary or "grey" literature in order to support multi-species productivity-susceptibility analyses. Life-history characteristics for the key shark species from the WCPFC database are given in Table 1. Estimates of all critical biological parameters are therefore already available for the key shark species. However, as the parameters come from a variety of studies of variable quality and given the multitude of shark biological studies of sharks in recent years, an important early step in developing stock assessments would be to update this database based on the review in 2008 by PIFSC and incorporating any subsequent work.

Particular attention should be given in the preliminary assessments to assessing the reliability of existing estimates of relationships that are fundamental to stock assessment modelling such as weight-at-length, length-at-age, probability of sexual maturity at-length or at-age and so on for each of the key species. Unfortunately, given the short time remaining before preliminary advice on stock status of the

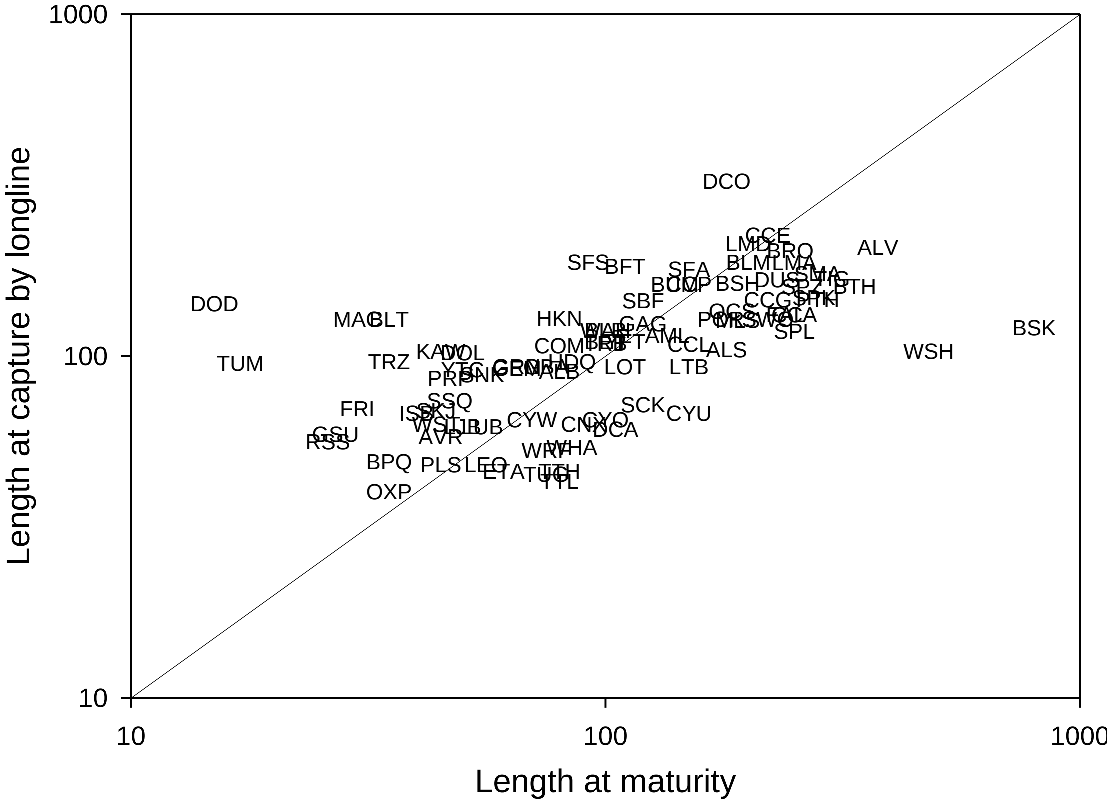


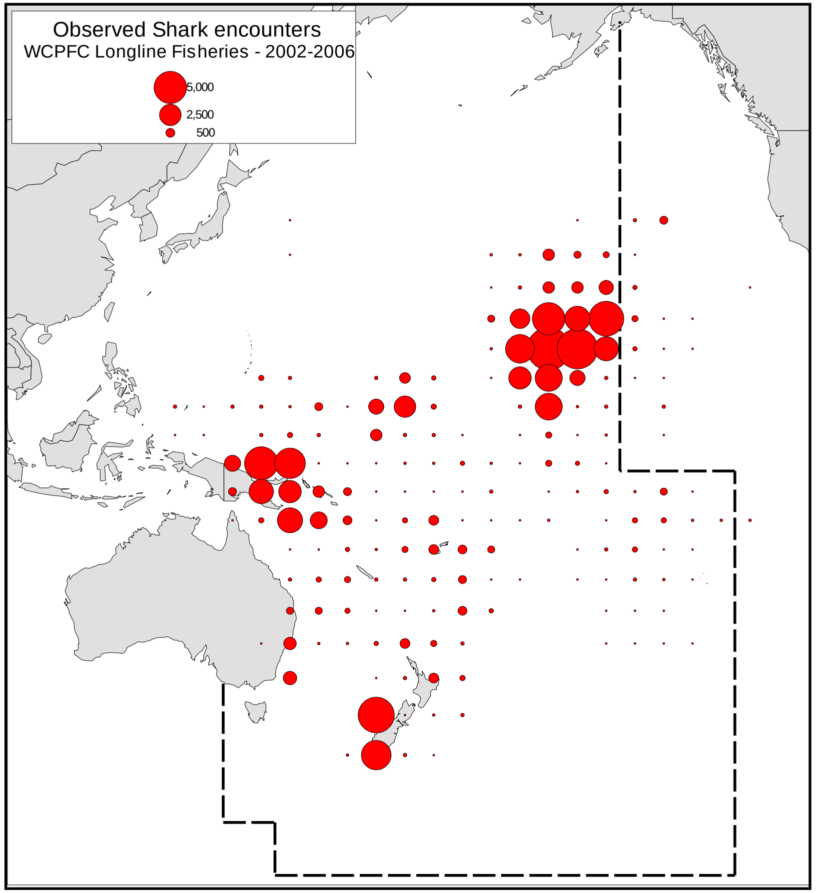
Figure 2: Mean length at capture as a function of mean length at maturity for shark species observed captured by longline gear in the WCPO (Kirby and Molony 2006). This shows that most sharks captured by the longline gear are juveniles, the life-history stage that is most important for population growth in sharks as shown by elasticity analysis (Heppell et al. 1999).

key shark species is expected by the WCPFC (12–18 months), it is unlikely that it will be possible to initiate new data collection programmes in time to support the preliminary assessments. However, further investigation of any inconsistencies and data gaps that are identified in the preliminary assessments should be addressed in the shark research plan to be pursued from 2010 onwards.

While it is obviously preferable to have parameter estimates derived from data collected from the WCPO, results from stocks from other regions, in particular the eastern Pacific, may also be informative when data from the WCPO does not exist or is found to be too difficult to collect. Parameter estimates from other stocks could be used, for example, to construct prior distributions for assessment model free parameters within a Bayesian analysis.

2.3 Stock boundaries of the key shark species in the WCPO

One of the first decisions to make in any stock assessment is the spatial definition of the stock or stocks to be assessed. We anticipate, given the large size, apparent mobility, and pelagic habitat of the key shark species, that the key tropical species (e.g., silky shark) are likely to consist of a single trans-Pacific stock while the key temperate shark species (e.g., mako shark) are likely to have separate stocks, north and south of the equator. The preliminary stock assessments should include a review of all available data (e.g., conventional and electronic mark-recapture data, other biological studies, catch-effort data, catch-composition data, etc.) to determine the most reasonable stock boundaries. If questions of stock identification and differentiation remain sufficiently ambiguous, it should be



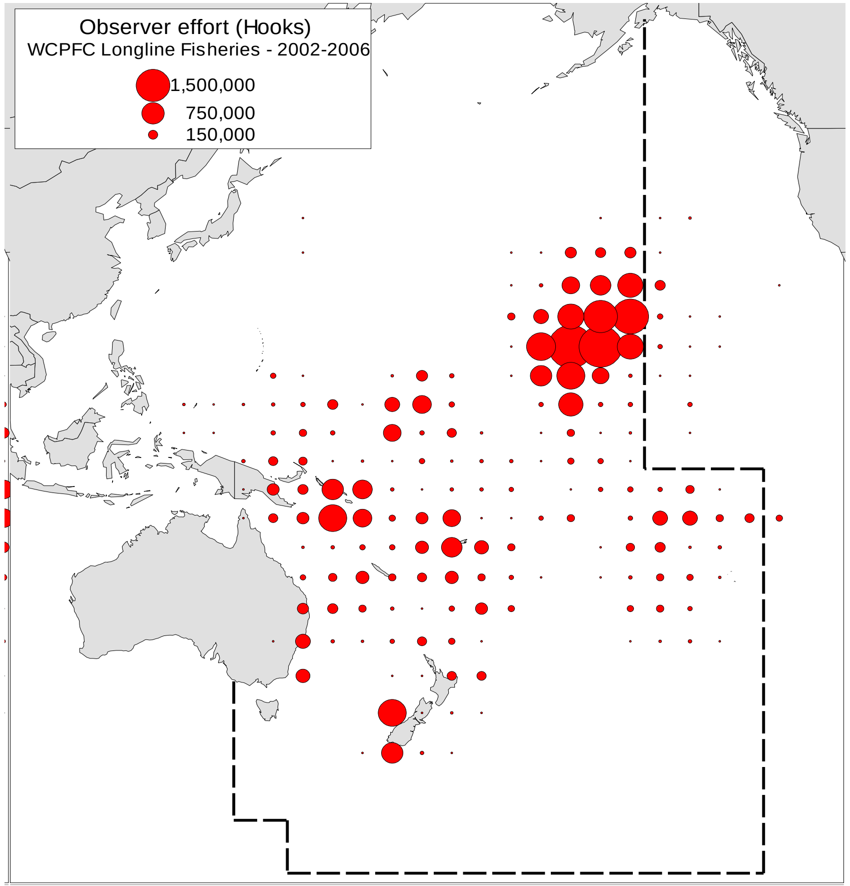


Figure 3: **Observed shark encounters (left) and observer effort (right) for the period 2002–2006 (source: SPC-OFP observer database, 2009). Unsurprisingly, sharks are encountered wherever there is longline fishing effort, although the species distribution changes spatially, most obviously with latitude.**

Table 1: Examples of life-history characteristics of blue shark, mako sharks, oceanic whitetip shark, silky shark, and thresher sharks compiled by SPC-OFP.

	Shark species							
	BSH	FAL	SMA	LMA	OCS	ALV	BTH	PTH
Characteristic	Blue shark	Silky shark	Shortfin mako	Longfin mako	Oceanic whitetip	Bigeye thresher	Common thresher	Pelagic thresher
Brody growth coefficient (*K*)	0.1571	0.0970	0.1790	0.1800	0.1010	0.1000	0.0890	0.1010
Max. size (lower bound) (cm)	383	258	394	368	300	450	460	330
Max. size (upper bound) (cm)	400	258	400	417	396	760	470	330
Age at maturity (min) (years)	5	6	6.5	6.5	4	5	7	7
Age at maturity (max) (years)	6	10	10	10	5	7	14.6	9.2
Size at maturity (min) (cm)	220	200	195	141	175	340	138	267
Size at maturity (max) (cm)	281	260	280	254	200	400	341	292
Reproductive strategy	LB	LB	DS	LB	LB	DS	DS	DS
Min. repro. periodicity (years)	1.2	1	2	2	1.3	–	–	–
Max. repro. periodicity (years)	2	2	3	3	2	–	–	–
Natural mortality	0.22	0.18	0.16	0.11	0.18	0.23	0.23	0.23
Min. lifespan (years)	20	15.75	25	25	15.75	–	–	–
Max. lifespan (years)	20	23	28	28	22	22	19	16
Min. depth (m)	0	0	0	0	0	0	0	0
Max. depth (m)	350	500	740	740	152	550	500	300
Water column position	PE	DE	DE	PE	DE	PE	PE	DE
Schooling behaviour	NS	–	SW	SC	–	–	–	–
L_∞	347	343.7	322.6	419.3	265	651	403.5	189.5
Min. litter size (pups)	4	2	4	4	1	2	2	2
Max. litter size (pups)	135	15	25	18	15	6	4	5
Mean litter size (pups)	35	7	12	2	6	2	2	2
Min. gestation time (months)	9	9	12	12	9	9	9	9
Max. gestation time (months)	12	12	18	18	12	–	–	–
Min. size at birth (cm)	35	70	60	60	60	114	64	100
Max. size at birth (cm)	50	87	74	74	65	150	106	190
Max. size (male) (cm)	310	299.66	–	–	299.66	760	553.5	347
Max. size (female) (cm)	312	260	–	–	260	549	466	383

Table 1: (continued)

								Shark species
	BSH	FAL	SMA	LMA	OCS	ALV	BTH	PTH
Characteristic	Blue shark	Silky shark	Shortfin mako	Longfin mako	Oceanic whitetip	Bigeye thresher	Common thresher	Pelagic thresher
Min. age at maturity (males) (years)	5	6	2	8	6	3	7	7
Max. age at maturity (males) (years)	7	10	3	10	7	7	13	8
Min. age at maturity (females) (years)	6	7	6	12	4	7	8.4	9
Max. age at maturity (females) (years)	7	9	8	8	5	11.9	14.6	9.2
Min. size at maturity (males) (cm)	180	210	195	195	175	260	270	267
Max. size at maturity (males) (cm)	281	220	330	330	195	340	300	276
Fifty percent size at maturity (males) (cm)	218	103	–	–	103	–	–	–
Min. size at maturity (females) (cm)	180	202	258	280	180	350	154	282
Max. size at maturity (females) (cm)	220	260	280	500	200	400	341	292
Fifty percent size at maturity (females) (cm)	225	120	–	–	120	287	287	287
Min. lifespan (males) (years)	13.75	20	4.5	4.5	16.17	–	–	–
Max. lifespan (males) (years)	16	21	10	4.5	17.88	10	12	14
Min. lifespan (females) (years)	18.31	22	12	12	22	19	23.75	28.5
Max. lifespan (females) (years)	15	25	28	28	22	22	23.75	28.5
Min. generation time (years)	5.12	7.9	7.75	9.41	7.38	8.18	8.75	7.1
Max. generation time (years)	10.31	15.91	7.75	9.41	14.78	16.77	17.7	14.16
Min trophic level	4.13	3.86	3.78	3.73	3.61	3.71	3.75	3.38
Max trophic level	4.87	5.14	5.22	5.27	4.71	5.29	5.25	4.62
Population resilience	Low	Low	Low	Low	Low	Very low	Very low	Very low
Rate of natural increase	–	–	0.24	–	–	–	–	–

considered within the context of the research plan requested under CMM-2008-06 whether additional research is required to inform future stock assessments of these species.

3. DATA NEEDS

The data used in stock assessments can be classified into several broad categories. These categories include fishing method, catch, effort, catch-rate, catch-composition (stratified by length, age, sex, or other covariates), growth and reproductive parameters, life status and condition at capture or release, and mark-recapture data. Here we give an overview of which data types we feel are particularly relevant to shark stock assessment in the WCPO and which are currently available from SPC, the WCPFC, or other sources. We also consider any particular properties of these data that are worth special consideration either during the preliminary or during any possible follow-on stock assessments.

We note here that:

- The methods used to provide preliminary advice on stock status of the key shark species in the WCPO in the short term will depend on the type and quality of the historical data that are available at this time.

- It is unknown to what extent the population dynamics modelling methods outlined below (Section 4 below) can be applied to all of the key shark species, in particular the rarer longfin mako and thresher species for which fewer data exist. Consequently, a stepwise process of assessment methods is recommended with the assessment of a species only proceeding from one step to the next if sufficient data exist.

- If more refined or complex assessments are required or desired in the future (i.e., past 2010), there may be a need to implement a data collection programme or programmes specifically designed to meet the data needs of the shark assessment approach chosen or desired.

- Collaboration in data collection, data provision, as well as in the carrying out of the stock assessment of the key shark species by the WCPFC and the IATTC will most likely be required in order to successfully complete stock assessments of these species. The extent of this collaboration will likely depend on the knowledge of or assumptions made regarding the stock structure of these species in the Pacific Ocean. We also note that the IATTC is planning a one-day shark stock assessment workshop in November 2009 and participation in this workshop by the WCPFC would provide a useful opportunity for the development of collaborations between the IATTC and the WCPFC.

- Stock assessment models range from the simple to the highly complex. With increasing complexity comes a requirement for collection of additional data to meet the greater information needs of the more complex models (e.g., collection of mark-recapture data to facilitate estimation of movement rates within an age and spatially-structured assessment model).

- Changes in fisher behaviour in response to management measures (e.g., Yokota et al. 2006; Gilman 2007; Ward et al. 2007) and the potential effects of these changes on catch and catch-rates should be considered.

In the remainder of this section, we consider aspects of the catch, catch-rate, size and sex composition, condition and fate, fishing method, mark-recapture, and other biological data requirements of the preliminary assessments.

3.1 Catch data

The accurate estimation of "total removals" from a stock and consequent calculation of fishing mortality statistics ideally require data on retained catch, discarded catch, condition-at-release (life status) and post-release mortality. Often, however, stock assessments are forced to focus on retained catches only, through a lack of data on discards, condition and post release mortality. Retained catch data from tuna fisheries operating within the WCPO can be derived from a number of sources including operational level logsheet data (provided mostly from within Exclusive Economic Zones or EEZs), aggregate logsheet data (provided by DWFNs), unloadings data, port sampling data (provided from regional port sampling programmes), observer data, and in some instances, market data (Table 2). With respect to shark catch data specifically, few CCMs provide operational logsheet data with species-specific records of shark catches. Many CCMs use logsheets that do not easily allow for the reporting of shark interactions at a species-specific level, and many members provide only grouped or aggregated shark catch data (non-species specific) shark catch data. SPC-OFP or the WCPFC or both agencies may not currently hold data from shark-targeting fisheries operating in some EEZs but these data could be requested for this study or accessed through the development of collaborations with national scientists.

Both retained and discarded shark catches, along with condition-at-capture and condition-at-release are collected through the national and regional observer programmes, with further limited sampling of landed catches collected by port sampling programmes. While the observer programmes typically cover only a small percentage of fishing operations (less than 1% for longline), their data still may be invaluable in constructing catch histories and abundance indices for bycatch species such as shark. A list of 49 shark species observed to be caught in the WCPO longline, purse-seine and pole and line fisheries is provided in Table 3. Observed catches by year are provided in Table 4 for the ten most commonly caught species.

Given the relatively limited nature of existing shark catch data, there is likely to be significant work required to construct a catch history for any of the pelagic shark species caught in the WCPO. This may involve exploring other data sources not currently held by either the WCPFC or the SPC-OFP, including commercial market and trade statistics (Clarke, Magnussen, et al. 2006; Clarke, McAllister, et al. 2006; Clarke 2008) and catch data from domestic fisheries targeting sharks. We conclude that sufficient information is available to attempt to compile catch histories for the key shark species, but note that these will likely be uncertain.

3.2 Catch-rate data

The logsheet and observer data sources described above also provide effort data allowing the estimation of shark catch rates. The same limitations that apply to the logsheet-level catch data (i.e., few countries provide it at a species-specific level) and observer data (i.e., coverage is low) apply to the effort data as well. Molony (2008) presented some examples of logsheet and raw observer derived catches and nominal catch-per-unit-effort (CPUE) for commonly-caught shark. The spatial stratification in his analysis is plotted in Figure 4. The nominal observer-derived CPUE for silky, blue, and oceanic whitetip shark from his analysis are plotted in Figure 5 to Figure 7, respectively. Standardised catch-rates from observer data are available for silky shark caught in the eastern Pacific purseseine fisheries (Minami et al. 2007) and aboard Japanese training longline vessels in the North Pacific (Matsunaga et al. 2005, 2006; Shono 2008; see also the discussion of Shono's results by Dunn 2009 and Shono 2009). Standardised CPUE year effects were used as the abundance indices in the North Pacific blue shark assessment produced by Kleiber et al (2009). Standardised CPUE year effects are expected to provide the primary abundance indices used in both the preliminary and in any follow-on stock assessments of the key shark species. The existing standardised CPUE series should be carefully reviewed during the preliminary assessments.

Table 2: Categories and sources of data required for the assessment of pelagic shark stocks in the WCPO. "SPC", data held by SPC; "*", data available from other sources; "?", data availability possible, but acquisition for the purposes of stock assessment uncertain.

Data category		Data source: Catch-effort logsheet	Aggregate catch-effort	Unloadings	Port sampling	Observer sampling	Market activity
Total removals	Retained catch	SPC	SPC	?	SPC	SPC	?
	Discarded catch	–	–	–	–	SPC	–
	Life status	–	–	–	–	SPC	–
	Discard mortality	–	–	–	–	*	–
Abundance indices	CPUE	SPC	–	–	–	SPC	–
Composition data	Length	–	–	–	SPC	SPC	?
	Weight	–	–	–	–	?	?
	Conversion factors	–	–	–	–	–	–
Fishing practices	Gear parameters	SPC	–	–	–	SPC	–
Biological data	Age	–	–	–	–	–	–
	Growth	–	–	–	–	–	–
	Reproduction	–	–	–	–	SPC	–
	Movement	–	–	–	–	SPC	–
Environmental data	Oceanographic	SPC	–	–	–	SPC	–
	Climatic	–	–	–	–	–	–

Data category		Data source: Mark-recapture ("tagging")		Oceanographic or climate models or databases	Scientific studies
		Conventional	Electronic		
Total removals	Retained catch	–	–	–	–
	Discarded catch	–	–	–	–
	Life status	–	*	–	–
	Discard mortality	–	*	–	–
Abundance indices	CPUE	-	–	–	–
Composition data	Length	*	–	–	–
	Weight	*	–	–	–
	Conversion factors	–	–	–	–
Fishing practices	Gear parameters	–	–	–	SPC
Biological data	Age	–	–	–	*
	Growth	–	–	–	*
	Reproduction	–	–	–	*
	Movement	*	*	–	*
Environmental data	Oceanographic	–	*	SPC	–
	Climatic	–	–	SPC	–

Table 3: Shark and ray species observed to interact with longline, purseseine, and pole and line fisheries in the WCPO (data source: SPC-OFP observer database, July 2009). Species are given in alphabetical order by common name. Whether each species is listed in UNCLOS Annex 1 list of Highly Migratory Species ("HMS") is noted: Y, yes; –, no. IUCN Red List categories ("IUCN"; in increasing order of concern) are also noted: –, not evaluated; DD, data deficient; LC, least concern; NT, near threatened; VU, vulnerable; EN, endangered.

Common name	Scientific name	HMS	IUCN
Australian blacktip shark	*Carcharhinus tilstoni*	Y	–
Basking shark	*Cetorhinus maximus*	Y	VU-EN
Bigeye sand shark	*Odontaspis noronhai*	–	DD
Bigeye thresher	*Alopias superciliosus*	Y	VU
Bignose shark	*Carcharhinus altimus*	Y	DD
Blacktip reef shark	*Carcharhinus melanopterus*	Y	–
Blacktip shark	*Carcharhinus limbatus*	Y	NT
Blue shark	*Prionace glauca*	Y	NT
Broadsnouted sevengill shark	*Notorynchus cepedianus*	–	–
Bronze whaler shark	*Carcharhinus brachyurus*	Y	NT
Bull shark	*Carcharhinus leucas*	Y	NT
Carpet shark	*Cephaloscyllium isabellum*	–	–
Cookie cutter shark	*Isistius brasiliensis*	–	LC
Crocodile shark	*Pseudocarcharias kamoharai*	–	NT
Dusky shark	*Carcharhinus obscurus*	Y	–
Galapagos shark	*Carcharhinus galapagensis*	Y	NT
Great hammerhead	*Sphyrna mokarran*	Y	EN
Great white shark	*Carcharodon carcharias*	Y	VU
Greenback stingaree	*Urolophus viridis*	–	–
Grey reef shark	*Carcharhinus amblyrhynchos*	Y	–
Long finned mako	*Isurus paucus*	Y	VU
Megamouth shark	*Megachasma pelagios*	–	–
Oceanic whitetip shark	*Carcharhinus longimanus*	Y	VU
Pelagic sting-ray	*Dasyatis violacea*	–	–
Pelagic thresher	*Alopias pelagicus*	Y	VU
Plunket's shark	*Scymnodon plunketi*	–	–
Porbeagle shark	*Lamna nasus*	–	VU
Salmon shark	*Lamna ditropis*	–	LC
Sandbar shark	*Carcharhinus plumbeus*	Y	VU
Scalloped hammerhead	*Sphyrna lewini*	Y	EN
School shark	*Galeorhinus galeus*	–	VU
Seal shark	*Dalatias licha*	–	–
Sharpsnouted sevengill shark	*Heptranchias perlo*	–	–
Short finned mako	*Isurus oxyrhinchus*	Y	VU
Shovelnose dogfish	*Deania calcea*	–	–
Silky shark	*Carcharhinus falciformis*	Y	NT
Silvertip shark	*Carcharhinus albimarginatus*	Y	NT
Smooth hammerhead	*Sphyrna zygaena*	Y	VU
Spinner shark	*Carcharhinus brevipinna*	–	NT
Spiny dogfish	*Squalus acanthias*	–	–
Spurdog	*Squalus megalops*	–	–
Thresher	*Alopias vulpinus*	Y	VU
Tiger shark	*Galeocerdo cuvier*	Y	NT
Velvet dogfish	*Scymnodon squamulosus*	–	DD
Whale shark	*Rhincodon typus*	Y	VU
Whip stingray	*Dasyatis akajei*	–	–
Whitenose shark	*Nasolamia velox*	Y	–
Whitetip reef shark	*Triaenodon obesus*	Y	–
Zebra shark	*Stegostoma fasciatum*	–	–

Table 4: Total observed shark catches in numbers as recorded by observers on longline and purse-seine vessels within the WCPO, 1981 to 2008 (NB: 1981–1993 combined; 2008 incomplete). The percentages of the observed species catch in each fishery where condition and fate were recorded are provided. Only the top ten species in terms of total historical observed catch numbers are provided for each fishery (data source: SPC-OFP observer database, July 2009). PS, purse-seine; LL, longline.

											Year
Fishery	Species	1981–1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
PS	Silky shark	–	173	582	750	421	1979	2129	1588	3497	4631
	Oceanic whitetip	–	–	9	184	439	1289	1022	449	855	1423
	Shortfinned mako	–	–	36	–	–	234	133	205	25	–
	Silvertip shark	–	–	2	–	31	53	28	175	47	72
	Whale shark	–	1	2	1	11	2	2	26	14	64
	Blacktip shark	–	–	–	–	–	1	–	–	–	–
	Pelagic stingray	–	–	73	3	1	10	5	9	8	15
	Blue shark	–	–	–	4	–	5	23	1	1	3
	Crocodile shark	–	–	–	42	–	–	–	2	–	–
	Longfinned mako	–	–	23	–	–	–	–	4	–	–
LL	Blue shark	57490	17643	10327	14074	13553	11210	9975	6256	7139	6431
	Silky shark	–	–	629	362	545	2467	3644	1848	3576	7152
	Porbeagle shark	5571	1378	1184	964	1855	2468	2798	965	666	286
	Pelagic stingray	2051	559	461	472	725	696	224	292	350	497
	Oceanic whitetip	147	166	245	264	376	1139	1889	213	704	914
	Shortfinned mako	1468	123	236	239	463	614	420	167	493	604
	School shark	484	437	418	153	369	198	379	129	117	124
	Bigeye thresher	7	1	8	14	40	113	49	72	118	192
	Grey reef shark	131	6	37	10	–	87	178	60	1226	239
	Blacktip shark	–	–	3	–	–	115	444	28	677	79

								Year	Life-status observations (%)	
Fishery	Species	2003	2004	2005	2006	2007	2008	Total	Condition	Fate
PS	Silky shark	6464	13393	11660	10163	6267	1490	65187	–	99.96
	Oceanic whitetip	507	507	238	64	48	89	7123	–	99.93
	Shortfinned mako	1	–	–	1	3	2	640	–	100.00
	Silvertip shark	16	–	2	1	–	–	427	–	100.00
	Whale shark	25	38	76	65	18	–	345	–	99.13
	Blacktip shark	27	218	5	15	20	–	286	–	100.00
	Pelagic stingray	11	19	30	12	37	9	242	–	99.59
	Blue shark	2	12	105	5	2	–	163	–	100.00
	Crocodile shark	–	–	–	–	–	–	44	–	100.00
	Longfinned mako	–	1	–	1	1	–	30	–	100.00
LL	Blue shark	7239	9375	8349	9871	1618	259	190809	79.11	82.41
	Silky shark	2239	6146	8684	6003	3514	289	47098	99.23	99.95
	Porbeagle shark	422	2	7	1	–	–	18567	85.88	88.29
	Pelagic stingray	993	402	568	803	336	58	9487	86.68	97.20
	Oceanic whitetip	290	790	808	754	430	80	9209	91.12	98.98
	Shortfinned mako	721	740	815	588	72	30	7793	86.78	93.60
	School shark	113	257	274	53	–	–	3505	91.33	92.52
	Bigeye thresher	107	263	289	876	630	29	2808	97.47	99.79
	Grey reef shark	164	283	125	8	63	2	2619	69.07	93.74
	Blacktip shark	15	365	97	14	6	–	1843	99.45	100.00

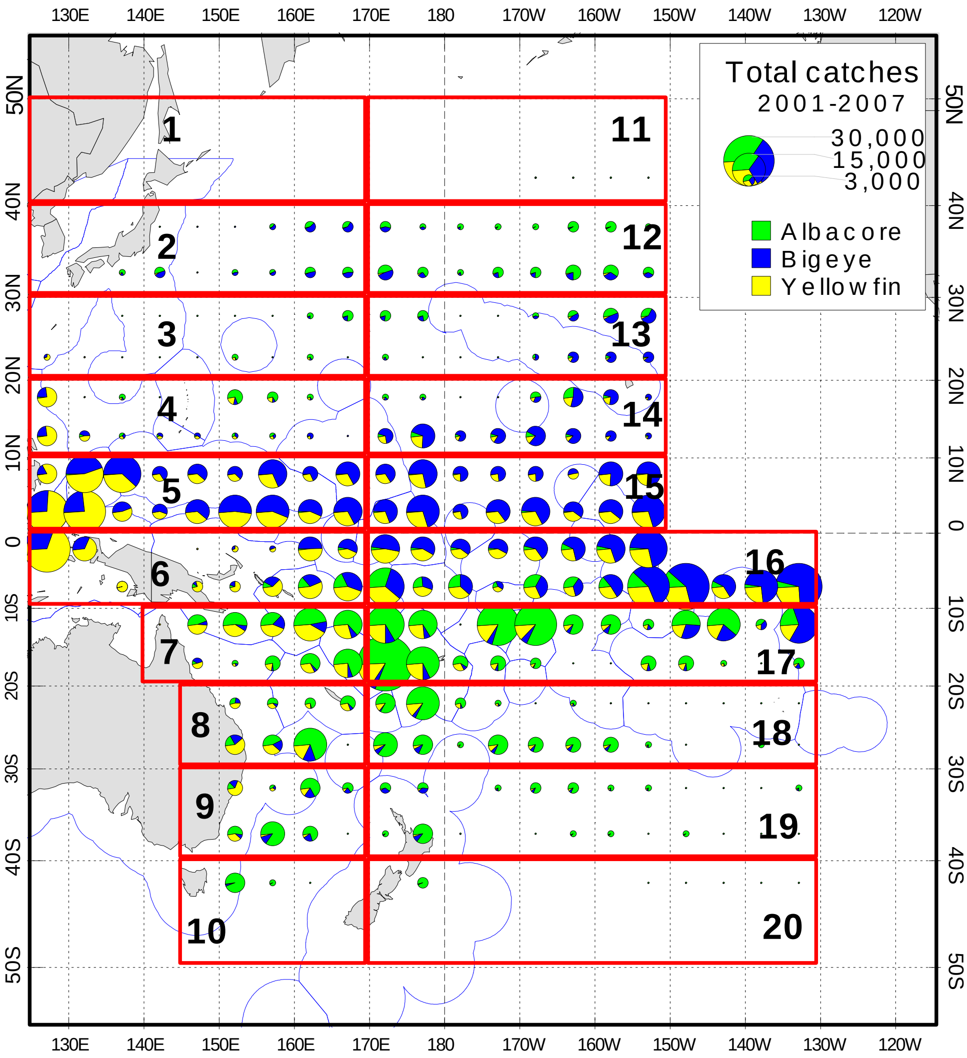


Figure 4: **Map of the WCPO displaying the longline catches of albacore, bigeye and yellowfin tuna, 2001–2007. Data source, SPC raised catch data base, July 2009. The red boxes define the twenty 10° latitude areas used for examining the catch rate and length data in Figure 8 to Figure 10.**

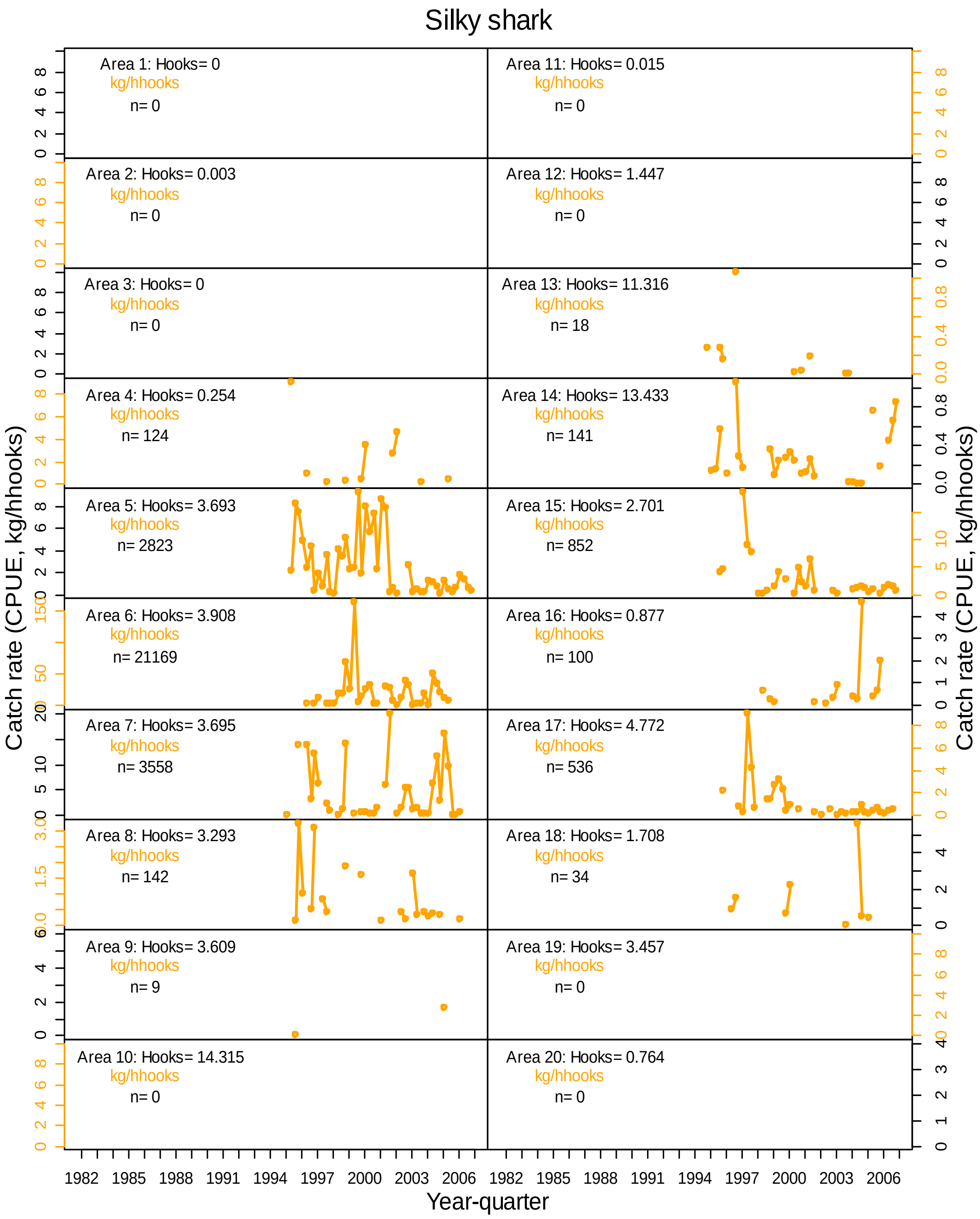


Figure 5: **Quarterly catch rates (kilogrammes caught per hundred hooks set) of silky shark reported by longline fishery observers pooled into 10º latitudinal bands (areas) in the WCPO, 1982–2006. See Figure 4 for area boundary definitions. Data source: SPC-OFP observer database, July 2009. Hooks, the total number of observed hooks (millions) in each area; n, represents the total number of individuals observed within each area. Scales of the y-axes vary among areas. Left-hand figures are west of 170ºE; right hand figures are east of 170ºE.**

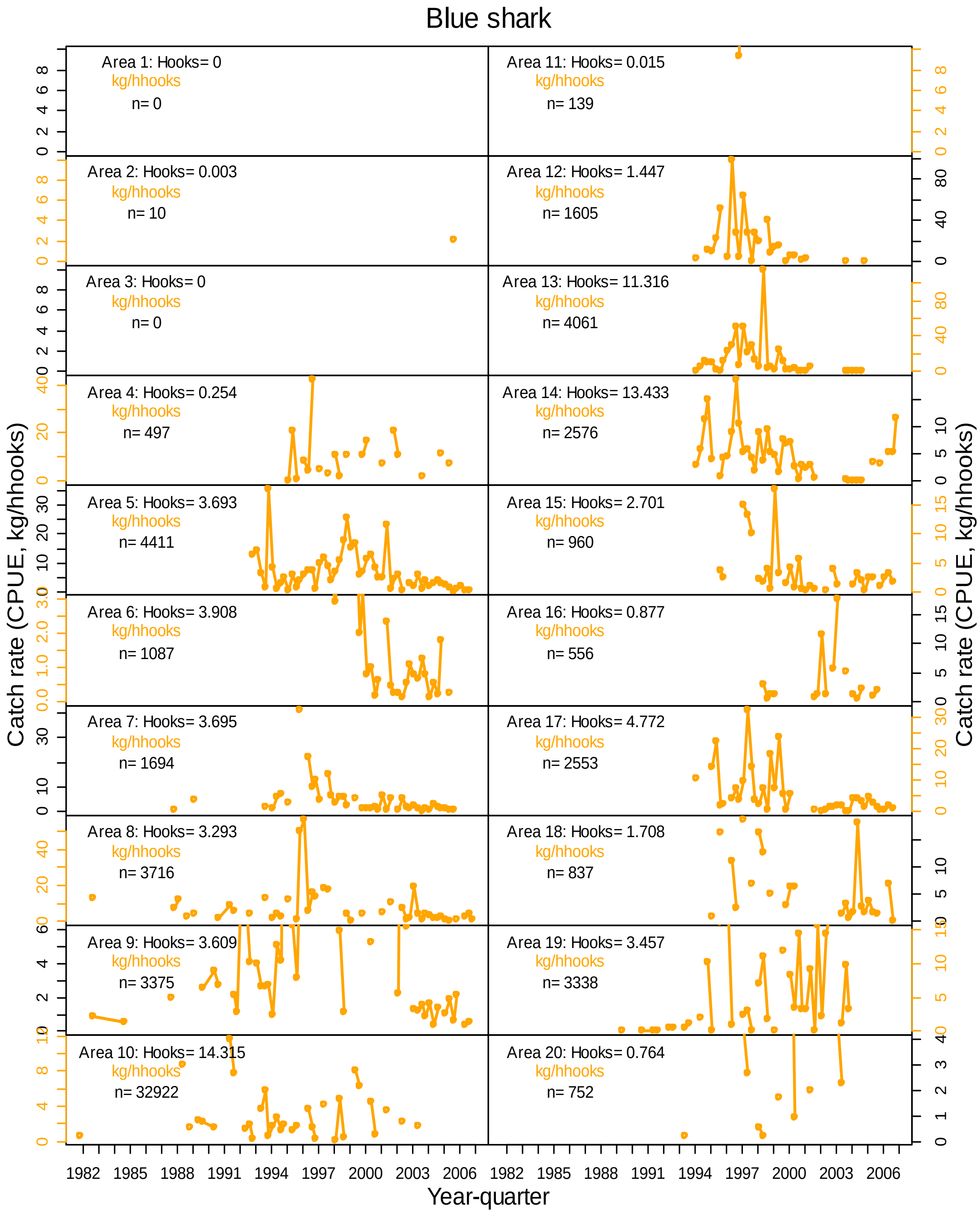


Figure 6: **Quarterly catch rates (kilogrammes caught per hundred hooks set) of blue shark reported by longline fishery observers pooled into 10º latitudinal bands (areas) in the WCPO, 1982–2006. See Figure 4 for area boundary definitions. Data source: SPC-OFP observer database, July 2009. Hooks, the total number of observed hooks (millions) in each area; n, represents the total number of individuals observed within each area. Scales of the y-axes vary among areas. Left-hand figures are west of 170ºE; right hand figures are east of 170ºE.**

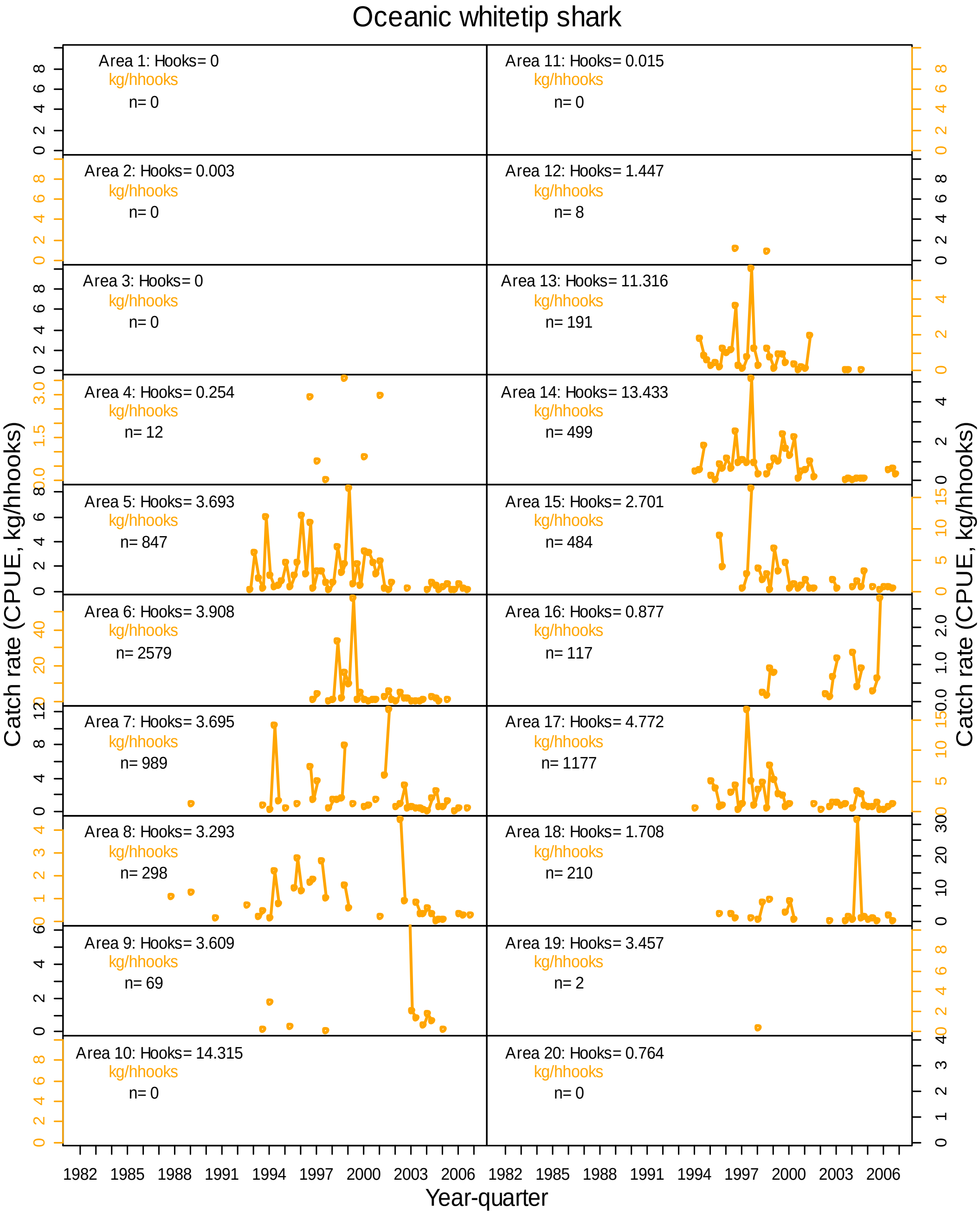


Figure 7: **Quarterly catch rates (kilogrammes caught per hundred hooks set) of oceanic whitetip shark reported by longline fishery observers pooled into 10º latitudinal bands (areas) in the WCPO, 1982–2006. See Figure 4 for area boundary definitions. Data source: SPC-OFP observer database, July 2009. Hooks, the total number of observed hooks (millions) in each area; n, represents the total number of individuals observed within each area. Scales of the y-axes vary among areas. Left-hand figures are west of 170ºE; right hand figures are east of 170ºE.**

While recognising concerns over observer coverage levels, we conclude that sufficient information is available to derive catch-rate time series for the key shark species. However, until these indices have been derived and compared to the catch histories, it is not possible to determine if they will be of sufficient quality to allow the development of population dynamics models.

3.3 Size- and sex-composition data

Size- and sex-composition data of the catch is a vital input in cohort dynamic stock assessment models for the estimation of fishery selectivity and other size- or age-dependant model functions. Size-composition data for tunas and other species held by SPC-OFP was collected mostly by national and regional observer and port-sampling programmes, but has been supplemented at different times by mark-recapture programmes, research cruise data, and other sources. However, for shark species, the majority of the size data is collected by regional observer programmes. Collectively, the shark size data held by SPC-OFP have already proven useful for the examination of size trends and fishery selectivity for commonly-caught species (Figure 8 to Figure 10) and continuing with the collection of these data into the future will be essential if cohort-structured stock assessment models are to be developed.

Data on the sex composition of the catch is collected by the regional observer programmes and is likely to be vital if sex-structured stock assessment models are to be developed. Knowledge of biases in the sex composition of the catch, along with spatial and temporal trends in the sex segregation of stocks, is potentially important for both assessment and management (e.g., Nakano 1994; Mucientes et al. 2009). Table 4 gives the total number of sharks observed and the proportion of those for which sex data was collected for the ten most commonly caught species in the WCPO.

We conclude that sufficient information on the composition of the catch of the key shark species exists to derive stock-status indicators. However, until these have been derived, and depending on the outcomes of the catch and catch-rate activities, it will not be known if it is possible to develop population dynamics models to estimate stock status incorporating these data.

3.4 Condition and fate data

Data on the condition-at-capture and at-release is also collected by national and regional observer programmes. Data on the discarded catch in particular can be especially important when estimating total removals (e.g., Bailey et al. 1996; Lawson 1997, 2001; Williams 1999; Bradford 2003; Moyes et al. 2006; Campana et al. 2009). Table 4 provides an indication of the proportion of observed shark catches for which condition data have been collected in the WCPO.

3.5 Fishing method data

Data describing how fishers use their fishing gear contains important information allowing catch rates to be standardised among diverse gear configurations and then used as indices of relative abundance. These indices are directly used to fit stock assessment models. Such data is collected on logsheets and by observer programmes in the WCPO and are held by SPC-OFP. For some fleets where logsheet level data are not available, data on important fishing gear configurations (e.g., hooks per basket for longlines) have sometimes been provided to SPC-OFP in aggregate form.

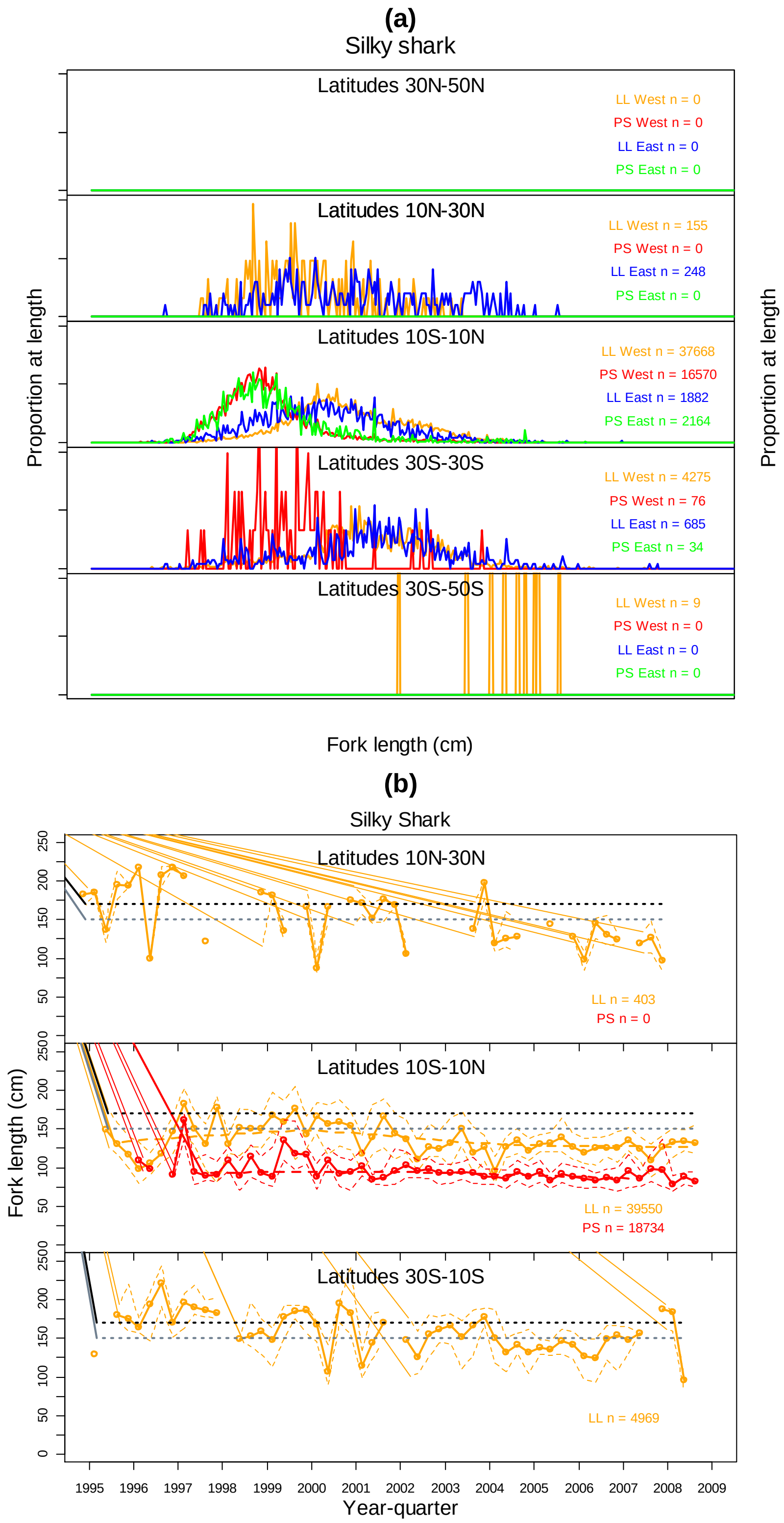
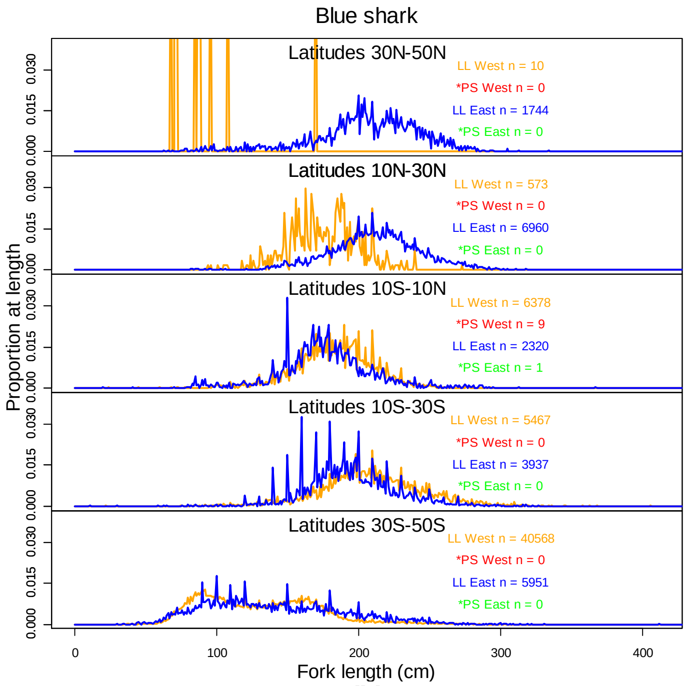


Figure 8: **Combined (a) length-frequency distributions and (b) trends in quarterly median size of silky shark reported by observers in longline and purse-seine vessels in the WCPO, 1984–2006. Data source: SPC-OFP observer database, July 2009. "n", total number of individuals from each method-fishery; "East" and "West", data from areas either side of 170° E longitude. The thin dashed lines are the 25th and 75th quartiles of the size data. Dashed lines represent loess fits to the median size data. Dotted lines represent estimates of size at first maturity for females (black) and males (grey).**

(a)



(b)

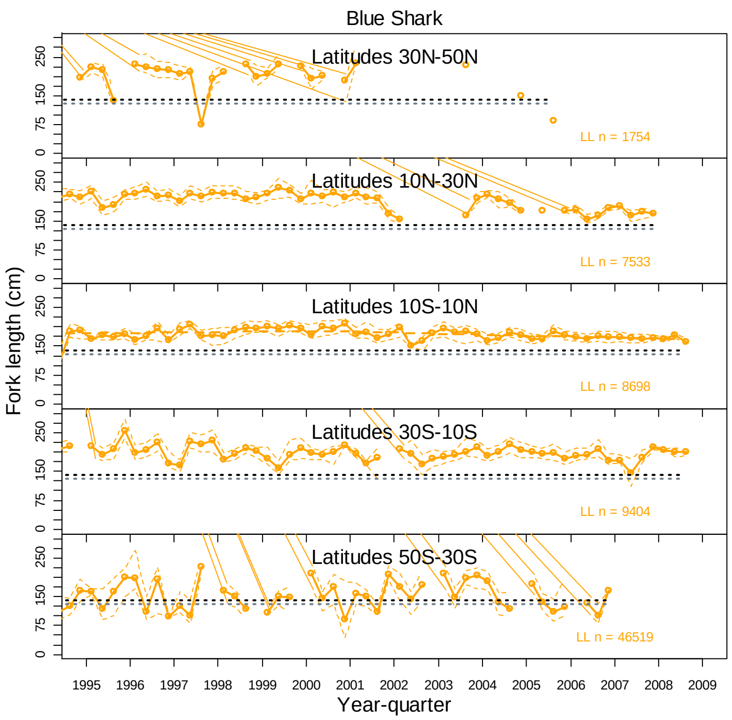
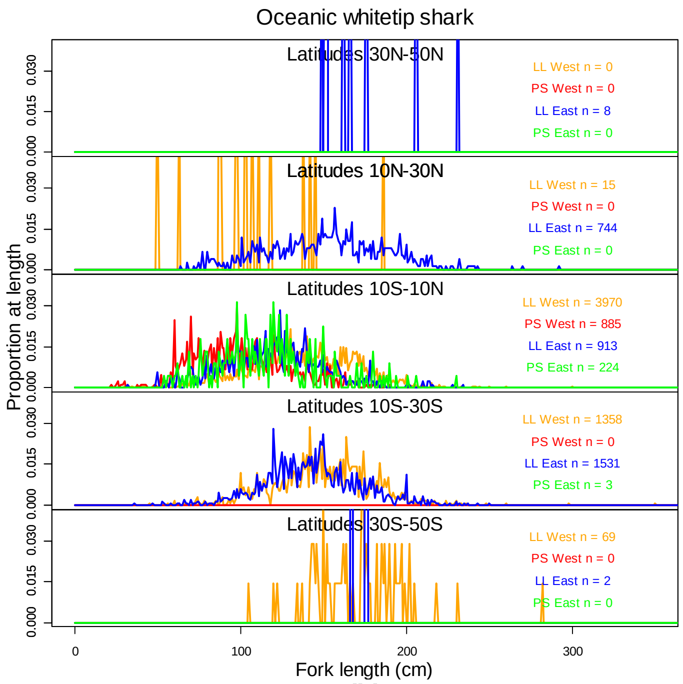


Figure 9: **Combined (a) length-frequency distributions and (b) trends in quarterly median size of blue shark reported by observers in longline and purse-seine vessels in the WCPO, 1984–2006. Data source: SPC-OFP observer database, July 2009. "n", total number of individuals from each method-fishery; "East" and "West", data from areas either side of 170° E longitude. The thin dashed lines are the 25th and 75th quartiles of the size data. Dashed lines represent loess fits to the median size data. Dotted lines represent estimates of size at first maturity for females (black) and males (grey).**

(a)



(b)

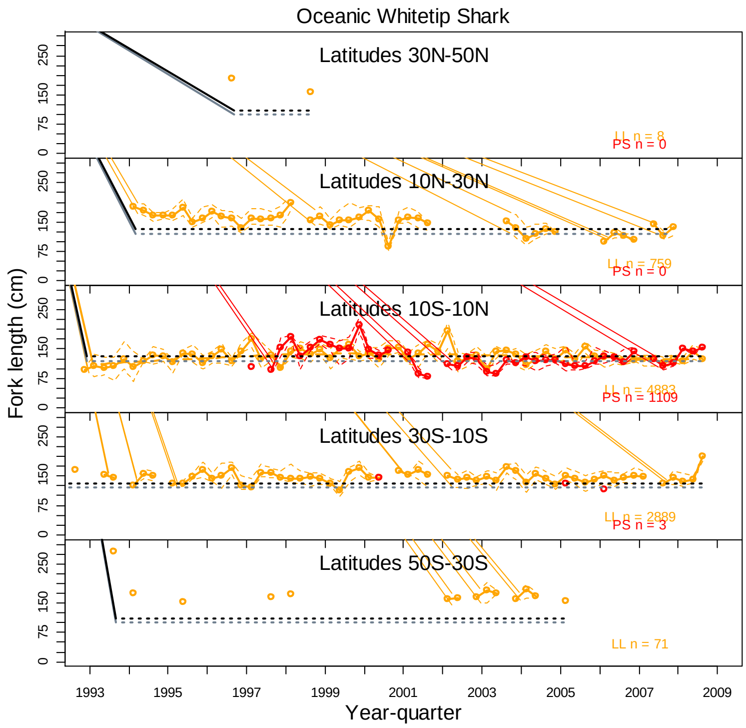


Figure 10: Combined (a) length-frequency distributions and (b) trends in quarterly median size of oceanic whitetip shark reported by observers in longline and purse-seine vessels in the WCPO, 1984–2006. Data source: SPC-OFP observer database, July 2009. "n", total number of individuals from each method-fishery; "East" and "West", data from areas either side of 170° E longitude. The thin dashed lines are the 25th and 75th quartiles of the size data. Dashed lines represent loess fits to the median size data. Dotted lines represent estimates of size at first maturity for females (black) and males (grey).

3.6 Tagging data

Tagging data—both conventional and electronic—have the potential to inform the estimates of many parameters critical to stock assessments of the key shark species, such as movement, growth, natural mortality, habitat use, etc. SPC-OFP does not hold any mark-recapture data for any shark species in the WCPO, but it is possible that existing conventional mark-recapture data might be sought through collaboration with regional recreational mark-recapture programmes (e.g., in Australia, Japan, New Zealand, and the USA) as well as from relevant scientific studies into shark movements conducted by scientists from member countries around the Pacific. For example, an analysis of recreational billfish and gamefish tagging effort and returns in the New Zealand region during the 2006–07 austral summer season was produced by Holdsworth and Saul (2008). From their records, totals of 3854 blue sharks and 11 476 mako sharks were marked with conventional tags and released since the start of the New Zealand recreational tagging programme during the 1974–75 summer season through to the end of the 2006–07 summer season. Sixty-three blue sharks and 316 makos had been recaptured, mostly from within the New Zealand EEZ, but one-third of blue shark and 93 mako recaptures have been made outside the New Zealand EEZ in the South Pacific and beyond. Although such recreational mark-

recapture data tend to be noisy and often have many associated issues which confound their easy interpretation, not the least of which is typically the absence of anything approaching an experimental design, such programmes may be the only source of mark-recapture data for some shark species and therefore of great value regardless of the noise they contain (see Kohler and Turner 2001 and the references cited therein for a list of possibly relevant conventional mark-recapture studies)

Electronic mark-recapture data, such as the data produced by implanted archival or Popup Archival Transmitting (PAT) tags, also have the potential to provide much information of direct relevance to either the preliminary or any follow-on stock assessments of the key shark species. For example, Moyes et al (2006). modelled the post-release survival of blue shark captured in the central Pacific Ocean near the Hawaiian archipelago using the data recorded by PAT tags attached to a sample of 23 blue sharks, although only 11 of the 23 PAT tags deployed reported in successfully. More recently, to support a quantitative stock assessment of North West Atlantic (NWA) blue shark, Campana et al (2009)[1] used the information recorded by PAT tags attached to a random sample of 40 blue sharks caught and later released in the NWA longline swordfish fishery to directly estimate the discard mortality and post-release survival functions of the discarded sharks and thus the total removals of sharks from the NWA blue shark stock by the fishery.

4. PROPOSED STOCK ASSESSMENT METHODS

4.1 Aims

The aims of producing preliminary advice on stock-status of the key shark species should be two-fold. Firstly, to produce preliminary estimates of current and historical biomass and yield and fishing mortality for stocks of key shark species stocks in the WCPO from which we may be able to calculate preliminary estimates of the current and historical status of these stocks. The SC should expect *a priori* that the uncertainty surrounding the biomass and yield and fishing mortality estimates will be moderate to high. However, the process of carrying out the preliminary assessments will help to identify any inconsistencies in the input data and other model quantities. Hence, the second aim should be to use these results to inform the development of data collection and research programmes to reduce or eliminate these sources of error in future stock assessments.

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[1] Submitted to SC5 as EB-IP-07

4.2 Proposed methods

4.2.1 Overview

We recommend the use of a stepwise approach, beginning with the application of simpler stock assessment methods before advancing to more complex methods if the data and other information that are required to implement the more complex methods exist and are available and permit it. There is a trade-off between method complexity and data requirements on the one hand and ease of implementation on the other. Simpler stock assessment methods tend to be less data-hungry than more complex methods, but are typically more assumption-driven although less heavily parameterised (Hilborn and Walters 1992; Quinn II and Deriso 1999). The peril of applying simpler stock assessment methods such as surplus production models is that the assumptions made in the method may not reflect reality closely enough for the method to adequately describe—by whatever standard—the stock to which it is being applied. This is especially so if the ability to test the applicability of the method assumptions is difficult or lacking. The value of any management advice derived from the results is then limited. In theory, more complex models such as sex- and age-structured cohort dynamic population models by virtue of their greater complexity may provide a more realistic description of the stock population dynamics. However, in practice, their data and other information requirements are typically much greater than simpler methods due to the greater number of free or estimable parameters they contain and the cost of collecting the data required to fit the model adequately may be too great to be practical (for explorations of this issue see Ludwig and Walters 1985; Ludwig and Walters 1989; Punt 1992; Butterworth and Punt 1999; and the discussion by Hilborn 2003)

A stock assessment method or model should therefore only be as complex as it needs to be to produce the management advice and other output quantities that are desired from its results, given the required precision and resources that are available. Given the uncertainties and other issues that are likely to be associated with much of the available data for the key shark species in the WCPO, it is therefore sensible to begin with the circumspect application of simpler stock assessment methods before proceeding warily to the application of more complex, more highly-parameterised stock assessment methods, with higher anticipated data collection costs in the future, even though such models may be more realistic in their structural assumptions.

4.2.2 Step one: enhanced productivity-susceptibility and resilience analysis

The process that we recommend has three broad steps. Following reviews of stock boundaries and biological characteristics discussed in Sections 2 and 3 above, we recommend that revised productivity-susceptibility analyses that incorporate more sophisticated indicators for both productivity and susceptibility be carried out. The new indicators may include, where available, trends in catch, changes in unstandardised and standardised CPUE, as well as changes in the size or other composition of the catch (e.g., the 90th percentile of the scaled length-frequency distribution for each sex). Other indicators may be used, if appropriate. The results of the enhanced productivity-susceptibility analysis can then be compared with the results of ranking each of the key shark species in terms of their "resiliency" to fisheries harvesting using demographic methods similar to those presented in Hoenig and Gruber's (1990), Au and Smith's (1997), Smith et al.'s (1998), Frisk et al.'s (2001)[1], Cortés's (2004), Au et al.'s (2008) and Smith et al.'s (2008) analyses of the life-history characteristics and patterns of elasmobranchs and the implications of these for their ability to support

[1] Compare Frisk et al.'s (2001) analysis with that presented by Mollet and Cailliet (2003) and note the subsequent discussion by Miller et al. (2003) and Mollet and Cailliet (2003).

fishery exploitation. The sensitivity of the results to the choice of input variables should be explored. Comparison could also be made with IUCN Red List rankings, most of which have recently been updated for oceanic sharks.

4.2.3 Step two: stock-status indicators calculated outside a population model fit

Once the enhanced productivity-susceptibility and resilience analysis and the data adequacy review and the input data calculations discussed in Section 2 above are complete, the next step consists of a detailed analysis of trends in stock status indicators outside a population or stock assessment model fit. These indicators will include trends in nominal and standardised CPUE as well as trends in time series of functions of whatever catch-composition distributions (e.g., catch-at-length) are available for a given stock. Composition indicators that we recommend include trends in mean size, trends in quantiles such as the median and 90th percentiles of the corresponding length- or age-frequency distributions as well as trends in the estimated proportion of the population that is sexually mature. Downward or decreasing trends in all of these quantities are potential indicators that a stock is receiving substantial fishing pressure. Long-term changes in mean size, given that it is easy to calculate if the data exist and permit it, may be of particular value as an indicator of gross change (Francis and Jellyman 1999). It is also worth noting here that the “success” of the proposed stock assessments described in the next step depends, not entirely, but certainly greatly, on the information content of the abundance indices proposed for use in the stock assessments. As noted above, these will likely be the standardised CPUE year effects calculated here. Without sufficient contrast in the abundance indices, it will be very difficult to estimate any of the stock assessment model outputs with any certainty (Hilborn and Walters 1992).

4.2.4 Step three: stock-status indicators calculated following population model fits

The third step we recommend is an analysis of trends in stock status indicators that are derived from the results of a series of simple population model fits. Assuming that the catch history and standardised CPUE calculations in the previous steps were successful, we recommend fitting non-equilibrium aggregated Schaefer (Schaefer 1954; Schaefer 1957) and Pella-Tomlinson surplus production models (Pella and Tomlinson 1969) to the catch-history and standardised CPUE year effects calculated for each stock. The models are referred to as “aggregated” in the sense that stock biomass is modelled as a single term rather than as smaller groups such as cohorts in a statistical catch-at-age model (e.g., the model presented by Fournier and Archibald 1982 and later derivatives). Surplus production models (SPMs) have a long but not always distinguished history of use in fisheries assessment. Advantageously, the data requirements for SPMs are low, namely a time series of total removals from the stock and a time series of indices of relative abundance (the role fulfilled by the standardised CPUE year effects). However, if the model’s biomass production function does not adequately describe the stock’s biomass production, then the results may be biased.

The Schaefer surplus production model is based on classical logistic population theory and therefore assumes that the stock’s maximum production occurs at exactly half its mean unfished biomass. The Pella-Tomlinson model offers additional flexibility by introducing a parameter within its specification that allows the point at which the biomass that supports the maximum sustainable yield occurs to be shifted to the left or to the right of the 50% point of mean unfished biomass. This comes at a cost, namely the extra parameter to estimate, but the development of modern statistical model-fitting methods and tools make this far less of a problem than it may once have been, provided the data are adequate (Hilborn 1979).

Early criticism of SPMs as unsuitable for application to elasmobranches (e.g., by Holden 1977) was, as pointed out by Bonfil (1996; 2004), misplaced, and appears to have been driven by shortcomings associated with making the equilibrium approximation necessary to find analytical solutions to SPM model parameters. The development of modern non-linear search algorithms facilitating the fit of statistical, non-equilibrium SPM models (e.g., those presented by Punt 1992; "observation error" models sensu Polacheck et al. 1993) makes this irrelevant. Furthermore, if Schaeffer and Pella-Tomlinson model fits are successful and the additional information required exists, fitting partially age-structured models such as Deriso's (1980) delay-difference model or an Age-Structured Production Model (ASPM) such as the "PMOD" stock-reduction model developed by Francis (1992; 1993) to the data would be warranted.

We recommend that model fits be implemented using Bayesian methods (Meyer and Millar 1999a; Meyer and Millar 1999b; McAllister et al. 2001; Cortés 2002; Cortés et al. 2002). The advantages of adopting a Bayesian approach are well known (Punt and Hilborn 1997): (i) it facilitates representing and taking account of the full range of uncertainties related to models and parameter values; and (ii) provides a mechanism by which knowledge gained about the status of stocks of the key shark species in other oceans can be formally and rigorously incorporated in these assessments, which, given the existing information needs for sharks in the WCPO, may prove to be extremely useful. Construction of catch histories (i.e., total removals or the sum of the landed and dead discarded catch) will be a large job and is likely to require making a number of structural assumptions about the catch and other associated data available in order to complete successfully, which will need to be accounted for appropriately within the model fits. Regardless of model type, stock-status indicators we will likely use include the time series of annual biomass produced from each fit as a proportion of estimated mean unfished biomass, current biomass as a proportion of the biomass that produces the maximum sustainable yield, etc. (e.g., the reference points used by Polacheck et al. 1993).

The SC should recognise that it may not be possible to obtain precise estimates of stock-status indicators from the model fits due to the uncertainty in the data noted above, but in combination with the results of the earlier analyses recommended, hopefully it will be possible to develop a more precise idea of the true stock status than is otherwise available (e.g., from the IUCN Red List status) and this should be of some value to fishery managers in the Pacific. However, reducing the uncertainty in the model results is unlikely to be easy without considerable investment in shark data collection and reporting systems in the WCPO. However, carrying out the preliminary assessments described here during 2010, with either ongoing or periodic revisions to the assessments thereafter, should provide a good idea of where the worst data gaps are and where money and effort is best invested in order to produce the best possible gains in information on stock status. This should satisfy the Commission's immediate need for preliminary advice on stock status and should provide a framework for developing the future Shark Research Plan.

5. CONCLUSIONS

- Sufficient basic biological and fishery data exist to provide preliminary stock status advice of the key shark species (blue, oceanic whitetip, short- and longfin mako, silky, and bigeye, common, and oceanic thresher sharks). These will be almost entirely based on observer data held by SPC and member countries and territories, not the WCPFC.

- A hierarchical or stepwise approach to the development of preliminary stock status advice is recommended: (step one) beginning with a revised productivity-susceptibility and resilience analysis; (step two) followed by an evaluation of stock-status indicators outside a population model fit; and then by (step three) an evaluation of stock-status indicators calculated following a series of simple population model fits.

- It is not expected that construction of simple population models (step three above) will be feasible for all species, in particular the rarer longfin mako and some or all of the three species of thresher sharks listed. The data available for these species may be too few and too patchy to proceed past steps one and two. However, it should be possible to identify the precise nature of the data gaps, any other information needs, and how these might be filled or met in the future.

- Construction of catch histories (i.e., total removals or the sum of the landed or retained catch and the dead discarded catch) will be a large and complex job and is likely to require a number of structural assumptions about the data that may not be immediately testable. The uncertainties in the data are likely to be heavily species-dependant, perhaps reflecting historic reporting practises. Calculation of several alternative catch histories for each species that are functions of different sets of structural assumptions is recommended.

- We expect that estimating biomass and yield with statistical confidence and providing a precise picture of stock status is unlikely to be possible without considerable investment in shark fishery data collection and reporting systems in the future. However, the process suggested here (i.e., the one-year preliminary assessment project), should produce sufficient information to guide the development of the WCPFC Shark Research Plan.

- Key tasks in the provision of preliminary advice include:

    vii. developing collaboration, as appropriate, with the IATTC and other partners, including national scientists from CCMs;

    viii. updating biological information where necessary and possible and identifying other potentially important data sets (e.g., data held by CCMs and not currently available to the WCPFC) that may be required;

    ix. developing alternative catch histories;

    x. analysis of standardised CPUE and size data;

    xi. application of different stock assessment modelling methodologies; and

    xii. developing a draft Shark Research Plan, in collaboration with CCMs and for approval by SC, based on the lessons learned in undertaking the preliminary assessments.

In order to undertake this task properly, we suggest that it would require the full-time work of one person starting as soon as possible after WCPFC-SC5.

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