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A Proposal for a Research Plan to Determine the Status of the Key Shark Species

WCPFC-SC6-2010/EB-WP-01

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Abstract

The Fifth Regular Meeting of the Scientific Committee (SC5) of the Western and Central Pacific Fisheries Commission (WCPFC) in August 2009 considered the feasibility of quantitative stock assessments for sharks and recommended that preliminary assessments should proceed in parallel with development of a shark research plan to fill data gaps. This paper presents a proposed shark research plan in response to the Commission's approval in December 2009 of SC5's recommendation.

An introduction to the Commission's eight current key shark species is presented, including a brief review of the history of their designation and species profiles containing information on habitat, life history and ecological risk, conservation status, current catches in the WCPO, and existing assessments or management. A review of existing fishery and biological information is then presented and data gaps are summarised. Major difficulties in the use of logsheet data for shark assessment are anticipated due to lack of data provision, as well as issues of species mis-identification, under-reporting and changes in targeting strategies. Observer data coverage, especially for longline fleets, is low and may not be representative of all areas where sharks are caught. Other commercial, research and recreational fishery data sources have some potential to inform the analyses but will require further work. Fishery-specific biological data are available mainly in the form of observer data on shark lengths, sex, fate and condition, and through a limited number of studies on bycatch mitigation methods (i.e. post-release mortality rates). It is concluded that there is a reasonable amount of information available on the biology of most key shark species although studies are concentrated in a few geographic regions. The extent of shark tagging data is difficult to characterize but appears primarily available for blue and mako sharks. A number of proposed shark assessments by other organizations were noted, including silky and oceanic whitetip assessments for the eastern Pacific Ocean by IATTC; assessments of blue, mako and potentially bigeye and pelagic threshers by ISC; and data compilation for makos by CSIRO.

A research plan is proposed as three phases: assessment, research coordination and fishery statistics improvement. Progress in all three phases will be necessary to assist the Commission in meeting its responsibilities for ensuring the sustainability of shark stocks. Phase 1 consists of three assessment steps to be undertaken on the basis of existing data. The first step will involve constructing indicators of the degree of fishing pressure on the key shark species. The second step will involve plotting these indicators against various measures of shark species' productivity. The third step will involve stock assessments using simple surplus production and age structured models, if possible. However, without additional inputs from Phases 2 and 3, stock assessments for some species will be severely compromised and may not be able to provide a meaningful basis for Commission decision-making. For this reason CCMs are invited to consider potential activities identified under Phases 2 and 3 (i.e. research coordination and fishery statistics improvement) as collaborative work and in-kind contributions.

1. Introduction

The Western and Central Pacific Fisheries Commission's (WCPFC) responsibilities for managing and conserving sharks in the Western and Central Pacific Ocean (WCPO) derive from *inter alia* Articles 5(d) and 10.1(c) of the Convention which state that

> "[the members of the Commission shall] *assess the impacts of fishing, other human activities and environmental factors on target stocks, non-target species, and species belonging to the same ecosystem or dependent upon or associated with the target stocks*"

and

> "[the functions of the Commission shall be to] *adopt, where necessary, conservation and management measures (CMMs) and recommendations for nontarget species and species dependent on or associated with the target stocks, with a view to maintaining or restoring populations of such species above levels at which their reproduction may become seriously threatened*".

Other international conventions such as the Convention on International Trade in Endangered Species (CITES) and the Convention on Migratory Species (CMS) relevant to sharks have been acceded to by WCPFC members. These two international conventions have listed three[1] and seven[2] shark species, respectively, on their appendices, several of which are caught by fisheries in the WCPO. Several other non-binding international instruments, including the FAO International Plan of Action for the Conservation and Management of Sharks ("IPOA-Sharks"; FAO 1999) and United Nations General Assembly Resolutions 61/105 and 63/112 (UNGA 2006, 2008), underscore the responsibilities of fishing and coastal States for sustaining shark populations, ensuring full utilisation of retained shark catches and improving shark data collection and monitoring.

Current knowledge on sharks in the WCPO region was recently surveyed in the development of the Pacific Islands Regional Plan of Action (RPOA) for Sharks (Lack and Meere 2009). The RPOA noted that two species of shark occurring in the WCPO have been categorised by the IUCN Red List as globally endangered and another 16 categorised as globally vulnerable. While scientific stock status assessments remain unavailable, existing data demonstrate that sharks are caught in the WCPO in both directed fisheries, and as wanted and unwanted bycatch in fisheries which are not explicitly targeting them. Sharks comprise only a small portion of the catch in some fisheries managed by the WCPFC, for example sharks form <1% of the catch in WCPO observed purse seine sets (SPC 2010). However, in WCPO observed longline sets blue sharks (*Prionace glauca*) are more commonly caught than any of the individual target tuna species, and all shark species combined represent approximately 30% of the catch (SPC 2010).

The WCPFC first adopted a Conservation and Management Measure (CMM) specific to sharks in 2006 (CMM 2006-05). This CMM was subsequently amended in 2008 (CMM 2008-06) and 2009 (CMM 2009-

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[1] great white (*Carcharodon carcharias*), basking (*Cetorhinus maximus*) and whale (*Rhincodon typus*) sharks, all of which on are Appendix II (http://www.cites.org/eng/resources/species.html)

[2] the three CITES-listed species plus shortfin mako (*Isurus oxyrinchus*), longfin mako (*Isurus paucus*), porbeagle (*Lamna nasus*) and spiny dogfish (*Squalus acanthias*) (http://www.cms.int/pdf/en/CMS1_Species_5lng.pdf)

04). The current version of the measure 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.

In addition, CMM 2009-04 requires that "*in 2010, the Scientific Committee, 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.*"

The Scientific Committee (SC) has already taken some steps toward assessment of shark species through a multi-year project on ecological risk assessment conducted by the WCPFC Science Services Provider (the Secretariat of the Pacific Community (SPC)) in collaboration with the Forum Fisheries Agency (FFA), CCMs and non-governmental organizations (NGOs), and presented to the SC at each of its meetings beginning in 2006 (Kirby and Molony 2006). This project calculated a measure of the risk of adverse impacts from fishing activities for over 30 shark species on the basis of productivity and susceptibility. The index of productivity was based on factors such as reproductive strategy, length at maturity and maximum length, whereas the index of susceptibility was based on the likelihood of exposure to fishing gear, condition at capture and proportioned retained (Kirby and Hobday 2007). The analysis showed that while many of the sharks identified as high risk species were rarely observed in WCPO fisheries, others are both frequently observed and considered to be high risk species, and thus are highly vulnerable (Kirby and Molony 2006).

In preparing to provide preliminary advice on the stock status of key shark species in 2010 as required by CMM 2008-06 (and subsequently CMM 2009-04), in 2009 the SC considered the feasibility of quantitative stock assessments for sharks given the currently available data (Manning et al. 2009). It was recommended that preliminary assessments should proceed, on the understanding that this exercise would identify gaps in essential data that would need to be filled under a shark research plan which should be discussed at the Sixth Regular Meeting of the SC (SC6) in 2010 (WCPFC 2009). In December 2009, the Commission endorsed the recommendations by the SC regarding sharks but also requested SC6 consider whether several other sharks should be added to the list of key shark species (WCPFC 2010a). Due to the time required to obtain the Commission's approval for these SC recommendations, and to recruit for the position with the WCPFC Science Services Provider, CCMs were informed in February 2010 that the shark assessment work could first be presented in preliminary form at the Commission's meeting in December 2010, with a more complete analysis to be presented to the SC in 2011 (WCPFC 2010b).

This paper presents a proposed research plan in response to the Commission's requests as contained in CMM 2009-04. This proposed plan contains a brief introduction to the eight key shark species, a review of existing fishery and biological data (both available and known but not available), and a description of the proposed assessment work to be undertaken over a period of four years (July 2010 through June

2014). In parallel with the assessment work, activities to improve research coordination to fill data gaps, and to improve fishery statistics for sharks caught by fisheries managed by the Commission, are proposed.

2. Key Shark Species and Their Status

Under Article 1 of the Convention, the WCPFC is responsible for managing highly migratory fish stocks which are defined as those listed in Annex 1 of the United Nations Convention on the Law of the Sea (10 December 1982) as well as such other species of fish as the Commission may determine. UNCLOS Annex 1 specifies that oceanic sharks consisting of bluntnose sixgill (*Hexanchus griseus*); basking shark (*Cetorhinus maximus*); threshers (Family Alopiidae, three species); whale shark (*Rhincodon typus*); requiem sharks (Family Carcharhinidae, 52 species); hammerheads (Family Sphyrnidae, nine species) and lamnids (Family Isuridae (Lamnidae), five species) should be covered. While this list is thus extensive, it does not include non-shark species of chondrichthyan fishes such as skates, rays and chimaeras, even though these species are included in the IPOA-Sharks[3] (FAO 1999).

In order to focus and prioritize the list of 72 species covered by the Convention and the wider set of species covered by the IPOA-Sharks, the SC has developed a list of key shark species. This list is based on consideration of those species which were considered to be at high risk from fishing activities based on the Ecological Risk Assessment project; those species which are most readily identified (thereby most likely to appear in logbook and observer datasets); and those species which are frequently reported in annual catch data provided by CCMs. The first specification of key shark species (CMM 2008-06) included blue shark (*Prionace glauca*), oceanic whitetip shark (*Carcharhinus longimanus*), mako sharks (*Isurus* spp.) and thresher sharks (*Alopias* spp.). Silky sharks (*Carcharhinus falciformis*) were added to the list when the CMM was amended in 2009 (CMM 2009-04). The SC's list of key shark species is thus interpreted to include eight shark species: blue, oceanic whitetip, silky, shortfin mako (*Isurus oxyrinchus*), longfin mako (*Isurus paucus*), common thresher (*Alopias vulpinus*), pelagic thresher (*Alopias pelagicus*), and bigeye thresher (*Alopias superciliosus*). For the purposes of this document, the term "key shark species" refers to these eight species only, although it is acknowledged that the list of key shark species may be amended by the Commission at their discretion.

As mentioned above, in December 2009 the Commission requested SC6 consider designating other shark species, including porbeagle (*Lamna nasus*) and hammerhead (Family Sphyrnidae, nine species) sharks, as key shark species. These requests, unless otherwise specified, could add another 10 species to the list of key shark species. In addition, the Pacific Islands Regional Plan of Action for Sharks suggests six additional "high risk" species for consideration as key shark species: blacktip shark (*C. limbatus*), salmon shark (*Lamna ditropis*), pelagic stingray (*Pteroplatytrygon violacea*), silvertip shark (*C. albimarginatus*), sandbar shark (*C. plumbeus*) and Galapagos shark (*C. galapagensis*).

Profiles of the current key shark species are contained in Annex A. These profiles describe each species, in terms of existing information on habitat, ecological risk, conservation status, current catches in the WCPO, and existing assessments or management. Indicative life history parameters are also provided to allow a general comparison of productivity across species; the appropriateness of these values for use in

[3] The FAO IPOA-Sharks defines the term "shark" to include all species of sharks, skates, rays and chimaeras within the Class Chondrichthyes.

shark assessments has not been evaluated and their inclusion in this document does not imply endorsement. The salient features of each species are summarised as follows:

- **Blue shark** - A widely distributed, temperate and subtropical species with high productivity compared to other sharks, the blue shark is the most common species in WCPO observer records for longline fisheries. Assessments in the North Pacific and Atlantic indicate that the biomass of this species is probably above B_{MSY} and F (fishing mortality) is probably below F_{MSY}.
- **Silky shark** - This widely distributed, subtropical species is commonly observed in both longline and purse seine fisheries but is considerably less productive than the blue shark. Preliminary assessment work is underway by IATTC for the Eastern Pacific Ocean (EPO).
- **Oceanic whitetip shark** - This subtropical species is similar in productivity to the silky shark and is the second most commonly noted shark in longline observer records. Localized depletions have been reported in the Atlantic and this species was unsuccessfully proposed for CITES listing (Appendix II) in 2010.
- **Shortfin mako shark** - This shark is similar to the blue shark in distribution, and to the silky and oceanic whitetip sharks in productivity. It is commonly noted in longline observer records and is listed on CMS (Appendix II). Assessments conducted by ICCAT for the Atlantic have produced highly uncertain results but several scenarios indicated that the biomass of this species is below B_{MSY} and F is above F_{MSY}.
- **Longfin mako shark** - Little is known about this close relative of the shortfin mako except that it may be deeper dwelling. Many records do not distinguish between the two species. The longfin mako is also listed on CMS (Appendix II).
- **Bigeye thresher shark** - This species is believed to have the lowest productivity of the key shark species. Few estimates of catch are available due to a lack of species-specific reporting. ICCAT has prohibited catches of bigeye thresher since June 2010.
- **Common thresher shark** - Although information about this thresher shark is similarly limited, it is believed to be more productive than the bigeye thresher. ICCAT discourages directed fishing for this species.
- **Pelagic thresher shark** - Unlike the other threshers, the pelagic thresher is mainly distributed in tropical waters. Similar to the other threshers, productivity is low relative to other sharks and species-specific catch records are lacking.

3. Identification and Assessment of Available Data

At SC5 in 2009, the availability of data and the feasibility of conducting quantitative stock assessments for key shark species was discussed and it was proposed that sufficient biological and fishery data exist to support such assessments (Manning et al. 2009). The following section re-examines the available data in greater detail in order to document which data are immediately available for analysis, and to outline the limitations of these data. In parallel, this data description aims to identify potential opportunities to gather or generate better data in the near-term, which can then be incorporated into the ongoing assessment process as described in Section 5.

Three general types of potential shark data are described. First, catch and effort data provided through commercial logsheets, research cruise records, observer records, recreational catch records, landings or market data, and/or the CCM Annual Reports are introduced. Second, fishery-specific biological data in the form of length, weight and sex data, and/or condition and fate records, are described. Finally, non fishery-specific biological data for sharks, such as life history information databases, are identified.

As a preface it should be noted that under the rules for Scientific Data to be Provided to the Commission (WCPFC 2007), there are no requirements for CCMs to provide data on shark catch and effort in any form to the WCPFC. Furthermore, while CMM 2009-04 (and CMM 2008-06 and CMM 2006-05 before it) call for CCMs to include key shark species in their annual reporting of catch and fishing effort statistics in accordance with agreed Commission reporting procedures, these provisions are non-binding. As a result, much of the available data discussed below which can serve as the basis for shark stock assessment is not held by the Commission itself. While the quantity and quality of shark data submitted to the Commission appear to be increasing over the past few years, the sufficiency of Commission-held data for supporting Commission requests for shark assessment is an important consideration.

3.1 Catch and Effort Data

Catch and effort data usually provide the fundamental information for stock assessments. For the WCPO, available catch data can be broadly classified into:

- Logsheet data from commercial fisheries;
- Logsheet data from research or training cruises which generally conduct operations similar to commercial vessels;
- Observer data from national, sub-regional or regional observer programmes;
- Records from recreational fisheries;
- Landings or market samples in number or weight by species; and
- Other catch reporting, such as in CCM Annual Reports, Parts 1 or 2.

Each of the first four sources of catch data can usually be combined with a measure of effort to generate catch rate data. These data, either in nominal form or after standardising for operational, habitat and other variables, can be used per se to evaluate trends, or to provide indices of abundance for population dynamics-based stock assessment models. In contrast, landing or market samples and annual catch reports are usually decoupled from the fishing activity producing the fish and thus are only useful in understanding catch rather than catch rate. Most of these data types are unlikely to provide complete coverage of the fishery, therefore the sampled subset must be extrapolated to the entire fishery. In such cases the representativeness of the sample is an important underlying assumption. Annual catch reporting is often, but not always, adjusted (raised) according to sample coverage.

3.1.1 Logsheet Data from Commercial Fisheries

Logsheet data from commercial fisheries in the WCPO can be broadly classified into sources which are held by the SPC OFP and those which are not. These are described separately below.

Logsheet data held by the SPC OFP

Logsheet data held by the SPC OFP include data provided on SPC-FFA Regional Longline and Purse Seine Logsheet formats and other national data provided to SPC on an operational, i.e. set-by-set, basis. The SPC-FFA logsheet formats have until late 2009 recorded retained and discarded sharks in aggregate, i.e. as "sharks retained" and "sharks discarded", although species-specific shark information could optionally be recorded in a column titled "other species".

Longline logsheet data held by the SPC OFP indicate that in 2000-2006 approximately 814,000 sharks were recorded but only 14% of these were recorded as being one of the key shark species (blue, silky, oceanic whitetip, "mako", "thresher"). Of those which were identified, 77% were blue sharks and 10% were "mako" sharks. Table 1 shows the history of species-specific shark reporting in the longline logsheet data held by SPC-OFP. These data indicate that while blue and mako sharks have been reported separately by most CCMs in the database for many years, the majority of CCMs have not reported any silky, oceanic whitetip or thresher sharks in those specific categories (although they may have reported such sharks in a non species-specific category).

Table 1. Presence/absence of the key shark species (and first year of appearance) in the longline logsheet data, 1979-2010, held by the SPF OFP. (Note that some CCMs listed in this table may not be expected to encounter all of these sharks in their fisheries; also, some of these and other CCMs have longline logsheet data which are not held by SPC OFP -- see Table 2).

Country	**Blue**	**Silky**	**Oceanic Whitetip**	**"Makos"**	**"Threshers"**
American Samoa	yes (1996)	yes (2002)	yes (2001)	yes (1996)	yes (1996)
Australia	yes (1991)	yes (2001)	yes (1997)	yes (1998)	no
Cook Islands	yes (2002)	no	no	yes (2003)	no
China	no	no	no	yes (2006)	no
Fiji	yes (2006)	no	no	yes (2004)	yes (2002)
Japan	yes (1980)	no	no	yes (1980)	no
Korea	yes (1981)	no	no	yes (1981)	no
New Caledonia	yes (1996)	no	no	yes (1998)	no
New Zealand	yes (1989)	no	no	yes (1991)	no
French Polynesia	no	no	no	yes (1993)	no
Papua New Guinea	yes (1998)	no	no	yes (1997)	yes (1997)
Tonga	yes (2002)	no	yes (2007)	yes (2002)	no
Chinese Taipei	yes (1997)	no	no	no	no
Vanuatu	no	no	no	yes (2006)	no
Western Samoa	yes (2007)	yes (1998)	yes (2007)	yes (1998)	yes (1998)
Total number of sharks recorded	**1,394,468**	**542**	**13,981**	**89,844**	**3,722**

Much of the data shown in Table 1 is provided using the SPC-FFA Regional Longline Logsheet format. In late 2009 this format was amended to include separate columns for the number (and visually-estimated weight) of retained, and the number of discarded, key shark species (i.e. blue, silky, oceanic whitetip, mako and thresher). This "expanded format" logsheet is expected to be implemented gradually by CCMs as national regulations are amended (P. Williams, SPC, personal communication). It should be noted that there are other SPC-FFA logsheet formats, such as the SPC-FFA Regional Shark Longline Logsheet (used by one fishery only) and the SPC-FFA Regional Longline Logbook-Daily Form, which already provide for species-specific shark catch recording, but these formats are rarely utilised.

Species-specific shark catch records are more sparse in the purse seine logsheet data held by SPC OFP. In the period from 2000-2006, just over 19,000 sharks were recorded but only 6% of these were recorded in a species-specific category (blue, silky, oceanic whitetip, "mako", or "thresher", although these sharks may also have been reported in a non species-specific category). Of those which were identified, 88% were silky sharks. Table 2 shows the history of species-specific shark reporting in the purse seine logsheet data held by SPC OFP. These data illustrate that even the silky shark, which appears to be the most frequently encountered shark in this fishery, has in most cases only been recorded on a species-specific basis in recent years. The SPC-FFA Regional Purse Seine Logsheet has not yet been amended to include the key shark species individually.

Table 2. Presence/absence of the key shark species (and first year of appearance) in the purse seine logsheet data, 1988-2010, held by the SPC-OFP. (Note that some of the key shark species would not be expected to be commonly encountered to purse seine fisheries).

Country	**Blue**	**Silky**	**Oceanic Whitetip**	**"Makos"**	**"Threshers"**
China	No	No	No	No	No
FSM	No	Yes (2010)	Yes (1996)	No	No
Japan	No	Yes (2009)	No	No	No
Korea	No	Yes (2009)	Yes (2009)	No	No
Marshall Is.	Yes (2009)	Yes (2009)	No	No	No
New Zealand	No	Yes (2009)	Yes (2008)	No	No
Papua New Guinea	No	Yes (2002)	Yes (2004)	No	Yes (2007)
Philippines	No	Yes (1997)	No	Yes (2006)	Yes (2009)
Solomon Is.	No	No	No	No	No
Chinese Taipei	No	Yes (2004)	Yes (2007)	No	No
United States	No	Yes (2004)	Yes (2006)	No	Yes (2008)
Vanuatu	No	Yes (2004)	No	No	Yes (2006)
Total number of sharks recorded	**2**	**2,990**	**200**	**1**	**11**

Other Logsheet Data

WCPO distant water fishing vessels which do not operate under bi-lateral or multi-lateral agreements usually do not use the SPC-FFA Regional Longline and Purse Seine Logsheet formats and usually do not submit operational logsheet data to the Commission. Catch and effort data for these vessels is generally submitted to the Commission in aggregated form based on national logsheet formats. These data are aggregated by month and 5x5 degree square for longline fisheries, and by month and 1x1 degree square for purse seine fisheries. (Shark data may exist for other fisheries (e.g. drift net or troll fisheries (ISC 2010)) but these data sources are not currently available for assessment.) The extent to which the eight key shark species are included on these national logsheets varies. In addition, the extent to which the species-specific shark categories, if included on the logsheets, are used also varies. For example, Japan has implemented national longline logsheets with separate columns for recording blue, shortfin mako and porbeagle (referred to as salmon sharks (*Lamna ditropis*) in this context) since 1994, and for recording oceanic whitetip and "thresher" sharks since 1999, but 30-40% of Japanese longline logbooks for the North Pacific and 10-20% of longline logbooks for the South Pacific have not recorded any sharks using the species-specific format (Yokawa 2010a). As shown in Table 3, many CCMs submitting aggregated catch and effort logsheet data for longline fleets either do not compile species-specific shark data on logsheets, or do not submit species-specific shark data from logsheets to the WCPFC. Some of the CCMs which submit no shark logsheet data are among those which are reported in FAO databases as being the world's leading shark fishing nations (FishStat 2010). There is no information on shark catches provided within the aggregated catch and effort logsheet data for purse seines submitted to the Commission.

Table 3. Provision of shark catch data in the aggregated catch and effort logsheet data for longline fleets provided to the Commission as of 23 July 2010. Note that this list excludes those CCMs and fleets which are shown in Table 2, however, those CCMs and fleets may also provide logsheet catch and effort data to the Commission in aggregated form. (Please refer to Section 3.1.6 for a description of data provided by CCMs in Annual Reports)

Country	Shark Data Provision Situation
China	Data submitted for blue and mako shark since 2008 and for oceanic whitetip since 2009
European Union	No shark catch data provided
Japan	No shark catch data provided
Korea	Total (not species-specific) shark catches provided
Chinese Taipei	Total (not species-specific) shark catches provided
United States	Data provided for blue, silky, oceanic whitetip, mako, thresher (and several other shark species)
Belize	Total (not species-specific) shark catches provided for some years
Indonesia	No shark catch data provided
Philippines	No shark catch data provided
Senegal	Data provided for two categories: Moro (shortfin mako) and "shark"

While commercial logbooks are a potentially rich source of data for assessment, there are often critical data quality issues which must be overcome before they can be utilised. The first of these relates to shark species identification, either because of uncertainties in correct identification and/or due to reporting of sharks in undifferentiated "shark" categories. This issue can be partially addressed through more detailed reporting practices, but identifications for less distinct species (e.g. the two makos and the three threshers) are likely to remain a source of uncertainty.

Another major issue is under-reporting of sharks. This can manifest itself as false zeros in the data (Minami et al. 2007) or as sporadic and inconsistent recording of shark catches, for example, depending on the workload of the crew (Walsh et al. 2002). Some techniques have been developed to address this issue (Nakano and Clarke 2006), but the solutions are often fishery-specific and will require further development and testing. Due to such under-reporting biases it would not be expected that unadjusted catch reporting for sharks would accurately represent the true catches of these species. Substantial under-reporting biases were identified in a comparison of CCMs annual catch reports for sharks (based on logsheets) with observer records of shark catches conducted for the Pacific Islands Regional Plan of Action for Sharks (Lack and Meere 2009).

A third issue relates to whether vessels are targeting sharks. If there is a shift in the target species of a fleet over time, and if this is not recognized in the data analysis, catch rates for that fleet in different years cannot be directly compared and trends in catch rate will not provide an accurate index of abundance. Shifts in targeting may occur because of market fluctuations, regulatory changes, technological advances or other factors. Increased targeting of sharks is not always readily identifiable from patterns in the data but has been reported in some fisheries, including those relevant to the WCPO (Yokawa 2010b, Clarke and Mosqueira 2002), and has been cited as a cause for concern in Pacific Island Countries and Territories (PICTs; Lack and Meere 2009). In most cases, detailed knowledge of the fishery must be integrated into the assessment in order to properly interpret catch data.

3.1.2 Logsheet Data from Research and Training Cruises

Logsheet data from research or training cruises should not pose issues of commercial sensitivity and may thus be available at higher levels of spatial and operational resolution (i.e. set by set at specific coordinates). Unlike commercial logsheet data, under-reporting of sharks is not likely to be a major issue, and species identifications should be reliable, at least for the key shark species. The main drawbacks associated with research and training cruise data are the limited sample sizes and the temporal and spatial limits to their coverage in comparison to the entire fishery.

SPC does not hold any research or training cruise data. However, some useful data for sharks are known to exist in Japanese research or training cruise records. For example, Matsunaga et al. (2006) presented an analysis of research and training cruises fishing approximately 20 million hooks in the central north Pacific from 1992-2003 and recording catches of blue, silky and bigeye thresher sharks (Figure 1). There are also Japanese research or training vessel records for sharks from other time periods (1935-1945 (Matsunaga et al. 2005), 1967-1973 (Matsunaga et al. 2005) and 1978-1985 (Kleiber et al. 2009)) which have been used in analyses submitted to the SC. There may be other research and training cruise data on sharks held by other CCMs.

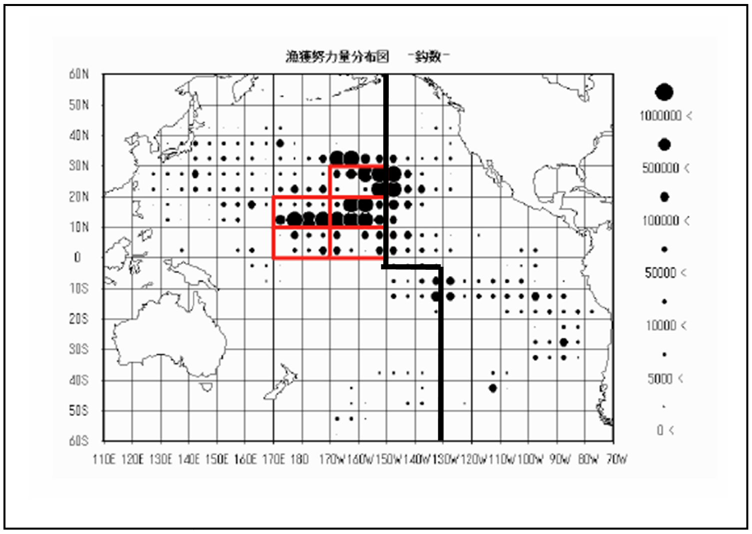

Figure 1. Distribution of longline effort in hooks for Japanese research and training vessel cruises recording blue, silky and bigeye thresher shark data, 1992-2003 (adapted from Figure 1 in Matsunaga et al. 2006; the thick black line shows an approximation of the eastern boundary of the WCPFC Convention Area).

3.1.3 Observer Data from Commercial Fisheries

Observer data are likely to provide the most reliable data on shark catches since observers are trained to identify and report all sharks to species level regardless of whether they are key shark species. The SPC OFP holds observer data from several sources:

- purse seine observer records collected under two sub-regional programmes (an agreement between the United States and members of the FFA, and the FSM Arrangement for Pacific Island-flagged vessels sponsored by members of the PNA);
- longline and purse seine observer data collected from foreign-flagged vessels operating under bilateral EEZ access agreements through national observer programmes; and
- longline and purse seine observer records for domestic fisheries collected under national observer programmes.

Under these arrangements observers have been deployed on longline vessels since 1992 and on purse seine vessels since 1988 and the total number of observed trips is approximately 3,200 for each gear type (SPC 2010; Table 4).

Historical purse seine coverage rates have varied depending on the Exclusive Economic Zone (EEZ) being fished with coverage exceeding 20% in Papua New Guinea but generally less than 10% in most other areas (Hampton 2009). Requirements for 100% purse seine coverage by observers from the WCPFC Regional Observer Programme (ROP) were implemented as of 1 January 2010 (except for vessels fishing exclusively in one EEZ). Under CMM 2007-01, required levels of ROP observer coverage in longline fisheries are set to rise to 5% in June 2012. Estimates prepared for the ROP indicate that 872 observer trips on longlines will be required to achieve this coverage rate suggesting that recent levels as shown in Table 3 have achieved only 1-2% coverage (WCPFC 2009b).

In addition to the limited historical observer coverage of the longline fishery in terms of sample size, the distribution of the samples over the spatial range of the fishery is also limited. The main areas from which data are available are the waters around Hawaii (but these data have not been provided since 2004), off the south island of New Zealand, the southeast coast of Australia, the area between Papua New Guinea and the Solomon Islands, and the Marshall Islands (Figure 2, top right). Given the distribution of reported longline effort and shark catch from logsheets (Figure 2, top left and bottom right) relying on the spatial and areal coverage of observer data to represent species composition and catch rates for other areas throughout the WCPO may be problematic.

Table 4. Number of trips by observers onboard longliners (classified by fishery) and purse seiners (classified by set type) covered by data held by the SPC Oceanic Fisheries Programme, 1992-2009 (from SPC 2010).

Fishery	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
Australia Domestic	0	0	0	0	0	0	0	0	0	0	0	6	34	11	51	19	0	0	121
Australia Japanese	59	86	62	41	34	31	2	0	0	0	0	0	0	0	0	0	0	0	315
Distant Water ALB[4]	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	4
Distant Water YFT and BET[5]	0	0	0	1	0	0	1	0	1	0	2	1	0	3	5	0	0	0	14
Hawaii	0	0	46	48	53	37	50	38	111	229	279	264	213	0	0	0	0	0	1,368
New Zealand Domestic	2	0	1	3	5	7	11	4	9	21	10	5	16	12	14	14	17	0	151
New Zealand Japanese	6	17	7	8	0	8	5	6	4	4	4	4	0	2	3	3	2	0	83
Offshore ALB[6]	1	1	1	7	13	10	6	12	5	5	32	48	52	53	74	49	70	90	529
Offshore Tropical Deep[7]	1	2	3	5	7	19	11	11	20	4	69	49	47	41	67	53	17	4	430
Offshore Tropical Shallow[8]	0	6	15	18	13	20	24	13	14	3	8	6	11	0	4	12	11	5	183
Shark	0	0	0	3	2	3	4	10	4	10	5	1	11	6	3	4	3	1	70
Longline Total	69	112	135	131	126	132	112	85	164	266	404	383	373	122	218	150	117	99	3,198
Unassociated Schools			14	32	52	47	78	21	35	56	84	91	141	164	191	169	151	53	1,379
Associated Schools			11	30	57	62	85	54	55	69	128	144	224	246	256	239	169	63	1,892
Purse Seine Total			25	62	109	109	163	75	90	125	212	235	365	410	447	408	320	116	3,271

4 Distant-water Taiwanese, Korean, Vanuatu and Japanese fleets operating in the sub-tropical and temperate waters of the south Pacific, primarily targeting albacore but also other temperate-water tuna species.

5 Distant-water Chinese, Taiwanese, Korean, Vanuatu and Japanese fleets operating in the eastern WCPFC Convention Area tropical waters (10°N-10°S, east of 180°) and temperate waters of the south Pacific, primarily targeting bigeye tuna.

6 Domestic Pacific Island fleets and chartered vessels operating in the sub-tropical and temperate waters of the south Pacific, primarily targeting albacore.

7 Domestic and foreign fleets and chartered vessels operating in the tropical waters of the WCPFC Convention Area (mainly 10°N-10°S, west of 180°) targeting bigeye and yellowfin tuna using a deep-gear setting strategy (> 10 hooks between floats).

8 Domestic and foreign fleets and chartered vessels operating in the tropical waters of the WCPFC Convention Area (mainly 10°N-10°S, west of 180°) targeting bigeye and yellowfin tuna using a shallow-gear setting strategy (< 10 hooks between floats)

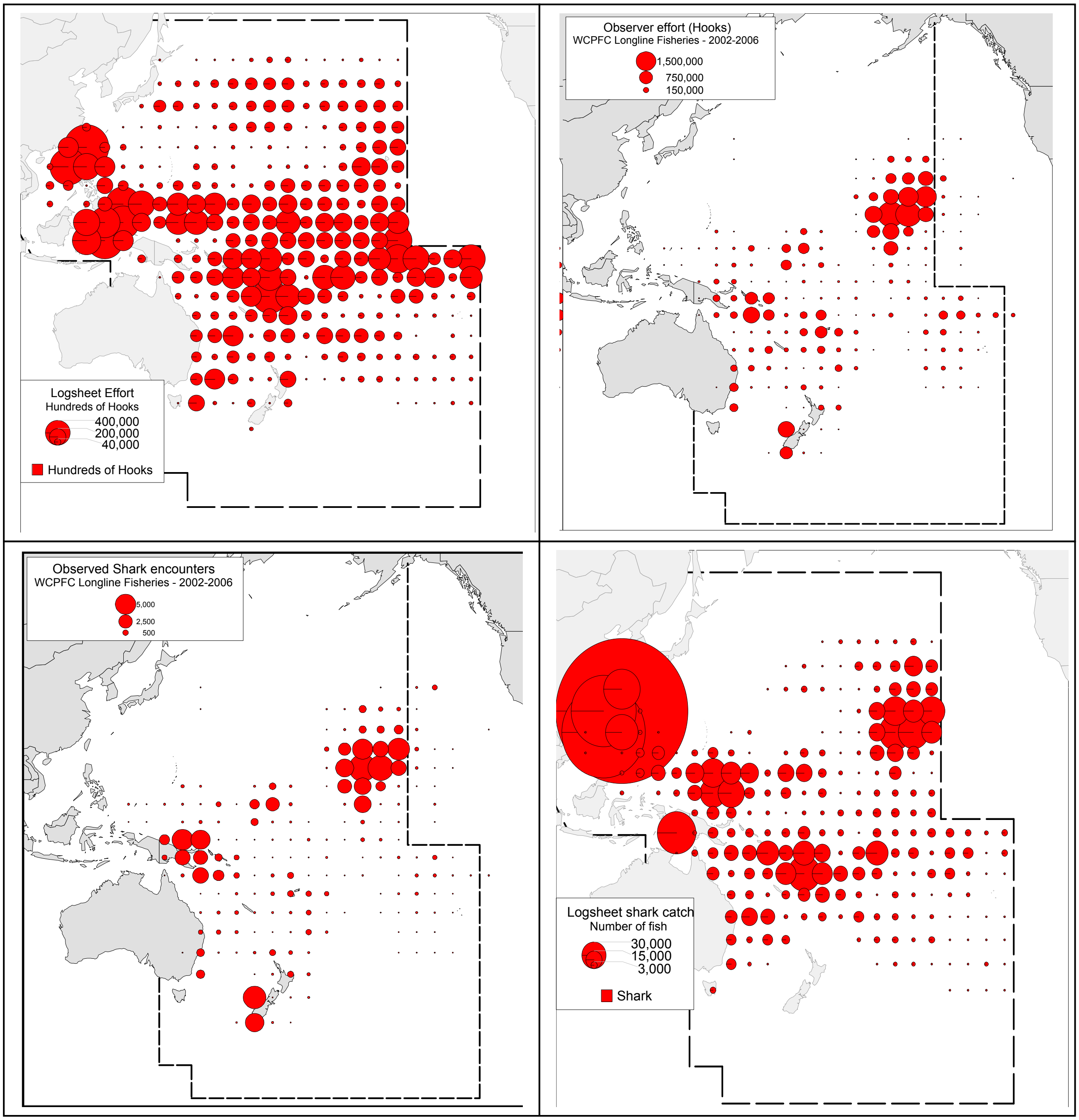

Figure 2. Longline effort from logsheets (top left), observed longline effort (top right), observed shark encounters (presence/absence, bottom left) and reported shark catch from logsheets (bottom right) for 2002–2006 (source: SPC-OFP observer database, 2010).

Estimates based on these available observer data indicate that approximately 30% of the observed longline catches and <0.2% of the purse seine catches between 1994-2009 are sharks and rays (SPC 2010). Major species comprising more than 0.2% of the total observed longline catch are blue (19.5%), silky (3.5%), mako (2.2%), oceanic whitetip (1.4%), porbeagle (1.0%), thresher (0.4%), and hammerhead (0.2%) sharks. Undifferentiated sharks and rays comprise another 1.5%. In purse seine fisheries the major species are silky shark (0.07%), oceanic whitetip (0.01%) and "other sharks and rays" (0.01%). A recent analysis of Pacific Island Countries and Territories (PICTs) identified that silky shark, blue shark, oceanic whitetip shark, pelagic stingray and bigeye thresher shark comprised more than 80% of the shark and ray catch in the PICT longline fisheries. For purse seine fisheries in the same area, silky shark, oceanic whitetip sharks and manta rays were found to be the most frequently encountered species (Lack and Meere 2009). Differences between these data for PICTs and the data in SPC (2010) for the WCPO as a whole illustrate how stratifying the observer data by area can influence the results.

As noted in SPC (2010), observer data for some or all of the fleets from China, Chinese Taipei, the European Union, Japan, Korea, and Vanuatu are lacking even though these fleets collectively account for 65-70% of the tuna catch in the WCPO. In order to assess where additional observer data for sharks could be sourced, Annual Reports: Part 1 submitted to SC5 were reviewed. Based on this review, the following CCMs conduct observer programmes in the WCPO but have not provided these data to the WCPFC[9]:

- China - There were three longline observer trips in the WCPO in 2008 and two observer trips between 10°N-10°S and 120°-160°W in 2009.
- European Union - Purse seine vessels operating in the EPO are required to carry observers under the Agreement on the International Dolphin Conservation Program (AIDCP), therefore when these vessels cross into the WCPO there is observer coverage in the WCPO.
- Japan - There were 38 observer trips for purse seiners between 1994-2008. Longline observer trips began in 2008 and consisted for four trips which reported a total of 424 blue sharks, 1 oceanic whitetip, 47 shortfin makos, 1 bigeye thresher and 11 "threshers".
- Korea - An observer programme was initiated in 2002 and in 2008 four purse seine/longline trips were observed. Shark catches were presented for one observed longline trip and consisted of 122 blue sharks, 10 oceanic whitetips, 2 "makos", 5 longfin makos and 47 bigeye threshers (An et al. 2009).
- Chinese Taipei - There were 43 observer trips on longliners between 2004-2007; in 2008, 32 longline and 28 purse seine trips had observers.
- United States (partial years only) - Coverage rates of 27% (n=380 trips) and 6% (n=9 trips) are reported for Hawaii-based and American Samoa-based longliners, respectively, but rules for the release of these data to WCPFC post 2004 are still being formulated.
- El Salvador - - Vessels operating in the EPO are required to carry observers under the AIDCP, therefore when these vessels cross into the WCPO there is observer coverage in the WCPO.

3.1.4 Data from Recreational Fisheries

Data on shark catches from recreational fisheries, including shark tournaments, have been used to compute catch rate indices for blue and shortfin mako sharks in the northwest Atlantic (Skomal et al. 2008). Such long-term and broad-coverage datasets can be useful indices of abundance, particularly

[9] It should be noted that the observer activities cited here from CCM Annual Reports submitted in 2009 are now subject to Regional Observer Programme coverage requirements.

when commercial data are lacking. The availability of recreational data worldwide was summarised in Babcock (2008) who found that most Pacific Ocean records are to be found off the east coast of Australia, around New Zealand and off southern California. Australian and New Zealand recreational fishers' catches are primarily blue and mako sharks, whereas threshers are reportedly the most common sharks caught off southern California. The availability and usefulness of these and other recreational data sets has not as yet been investigated in detail, however, a study of gamefish tournament records in New South Wales, Australia is reportedly underway with the objective of developing standardised catch and effort indices for use in formal stock assessment including those for sharks (I&I NSW 2009).

3.1.5 Landings and Market Data

Market data such as landings, imports, exports or other sources may be useful in providing alternative measures of catch. However, a common problem with such data sets for sharks is that the low value of shark meat provides a disincentive to transport the carcass to market. Available shark landings data, such as those available for the Japanese offshore longline fishery in the north Pacific (Japan Fisheries Research Agency 2010), are therefore likely to represent only a portion of total catches, even after adjusting for onboard processing.

One exception to this is the high-value shark fin trade which has provided the basis for back-calculated estimates of the number and biomass of five shark species in the WCPO (Clarke 2009). These estimates are extrapolated from shark fin trade records from 1999-2001 and assume that species composition and fin sizes have remained constant over time. Also, as the shark fin trade draws supplies from all world oceans, and the key shark species are circumglobally distributed, estimates need to be proportioned based on assumptions about the WPCO catch, effort or habitat area relative to the global total. While such alternative catch estimates can provide a valuable means of cross-checking total catches, and indeed suggest that catches are two to three times higher than estimated based on other methods (Clarke 2009), they cannot provide catch rate information. Also, like all of the catch and effort data sources described here, they are not necessarily reliable indicators of trends due to potential changes in targeting practices.

Other sources of landings and trade (import/export) data will be explored but these may be of limited value in estimating catches or catch rates due to a high, but unknown, proportion of at-sea discards, non species-specific reporting and/or lack of specification of product form (e.g. shark products not identified as fins or meat, or carcasses not specified as dressed or whole). Substantial improvement of the data applied by Clarke (2009) is also likely to prove impractical due to data access constraints.

3.1.6 Data from CCM Annual Reports

In addition to the sources of shark catch and effort data described above, additional information on sharks may be provided in CCMs Annual Reports-Parts 1 or 2. While this information may be helpful for purposes such as estimating total catches from the WCPO, or in estimating fleet-specific shark discard rates (i.e. if figures for retained and discarded sharks are provided), the aggregated nature of most data provided in the Annual Reports limits their usefulness for most assessment analyses.

The results of a review of CCM Annual Reports-Part 1 are provided in Table 5. Of the 32 CCMs required to submit Annual Reports-Part 1 in 2009 (for 2008), 20 provide data on total catches of sharks (either in aggregate or by species which can be summed to a total) and 15 provide at least some species-species shark catch data. Although it would not be expected that all CCMs would encounter all of the key shark species in their fisheries, it is noted that data for some of the key shark species (e.g. longfin mako and threshers) appears to be very sparse. Also, as is the case for submission of logsheet data (see Section 3.1.1), some CCMs which submit little or no shark data in their Annual Reports are among those which are reported in FAO databases as being the world's leading shark fishing nations (FishStat 2010).

Table 5. Shark information provided in CCM Annual Reports - Part 1 submitted in 2009 covering 2008.

Country	Reports Total Catches of Sharks?	Reports Total Catches for Key Species?	Other Shark Information
Australia	Yes (2004-2008)	Yes (some key species grouped)	
Canada	Yes (but reports zero sharks caught)	N/A	
China	Yes (2008 only)	Yes (blue and shortfin mako only)	
Cook Islands	Yes (2004-2008)	Yes (blue, oceanic whitetip and "shark unidentified")	Observer programme reports blue, silky, shortfin mako, longfin mako, oceanic whitetip and Galapagos
European Union	Yes (2007-2008)	Yes (silky, oceanic whitetip, and "shark nei" extrapolated from observer data for 2008 only)	Observers also recorded whale sharks
FSM	Yes (2004-2008)	No	
Fiji	Yes (2006-2008)	Yes (blue, silky, oceanic whitetip, mako and "other")	Reports catches of whale sharks; notes that total catch figures do not account for shark trunks discarded at sea
French Polynesia	Yes (2004-2008)	Yes (mako and "other" only)	Retention of sharks other than makos is prohibited, but total catches are reported.
Japan	No	No	Catches of thresher, bigeye thresher, shortfin mako, salmon, porbeagle, oceanic whitetip and blue sharks observed in four observer cruises in 2008 are reported.
Kiribati	Yes (2006-2008)	Yes (blue, silky, oceanic whitetip, makos and "other sharks and rays")	Catches of sharks by species reported as a percentage of total catch.
Korea	Yes (2004-2008)	No	Introduced in a new logsheet format to record sharks by species in 2008. Some species-specific shark data from observers presented separately.
Marshall Is.	Yes (2006-2008)	Yes (blue, silky, oceanic whitetip, makos and "other sharks and rays")	Unloadings data for "sharks" provided for 2007-2008. Whale shark catches provided for 2006-2008.
Nauru	No	No	
New Caledonia	Yes (mako only; 2008)	Yes (mako only; 2008)	The number of blue, silky, oceanic whitetip, shortfin mako, longfin mako, bigeye thresher, pelagic thresher and crocodile sharks encountered by observers is reported for 2008.
New Zealand	Yes (landed catches for 2003/04 to 2007/08; estimated catches for 2006-2008)	Yes (landed catches of blue, shortfin mako and porbeagle; estimated catches for blue, shortfin mako, porbeagle and thresher sharks)	Fate and condition also provided along with estimated catch by species.
Niue	No	No	
Palau	Yes (2004-2008)	Yes (blue, silky, oceanic whitetip, makos and "other sharks and rays")	Catches of sharks by species reported as a percentage of total catch.

Country	Reports Total Catches of Sharks?	Reports Total Catches for Key Species?	Other Shark Information
Papua New Guinea	No	No	It is reported that the directed shark longline fishery has an annual TAC of 2,000 t (dressed weight). Amounts of exported shark meat and fins are provided.
Philippines	No	No	
Samoa	Yes (2004-2008)	Yes (blue, silky, oceanic whitetip, bigeye thresher, blacktip reef, Galapagos, and unidentified sharks)	
Solomon Is.	No	No	Silky shark is noted as the most frequently caught species.
Chinese Taipei	Yes (2008)	Yes (blue, silky, oceanic whitetip, makos, threshers and "other")	Logsheet format for separate recording of blue, silky, shortfin mako and other sharks implemented in 2004.
Tokelau	No	No	
Tonga	Yes (2004-2008)	No	It is reported that >90% of sharks are finned before being discarded.
Tuvalu	No	No	
United States	Yes (2004-2008)	Yes (blue, mako, thresher and "other")	Landings data for these species also provided (2004-2008)
Vanuatu	No	No	
Wallis & Futuna	No	No	
Belize	Yes (2004-2008)	No	
El Salvador	No	No	
Indonesia	No	No	
Senegal	Yes (2005-2008)	Yes (blue, shortfin mako, *Carcharhinus* sp., *Sphyrna* spp.)	Some sharks reported as "fins" only.

A review of shark data contained in CCM Annual Reports-Part 2 submitted since 2007 was conducted by the WCPFC Secretariat. This review found that 25 of 32 CCMs submitted an Annual Report-Part 2 containing at least some shark-related information, and a small number of these contain information which could be useful for scientific assessment purposes. Voluntary reporting of annual retained and discarded shark catches under CMM 2008-06 and CMM 2009-04 has only appeared in one of the Annual Reports-Part 2.

3.2 Fishery-specific Biological Data

There are three potential sources of fishery-specific biological data on sharks in the WCPO: observer sampling, port sampling and bycatch mitigation trials. As described above in Section 3.1.3, there are likely to be relevant observer datasets which are not currently held by the SPC OFP which may provide additional sources of fishery-specific biological data.

Observer data held by the SPC OFP containing length and estimated weight data for the key shark species are shown in Figure 3. In the period 2000-2008, on average a total of about 30,000 sharks were recorded by observers in longline fisheries annually, slightly more than half of which were blue sharks. In the same period lengths were taken from on average about 12,000 sharks annually. Blue and silky

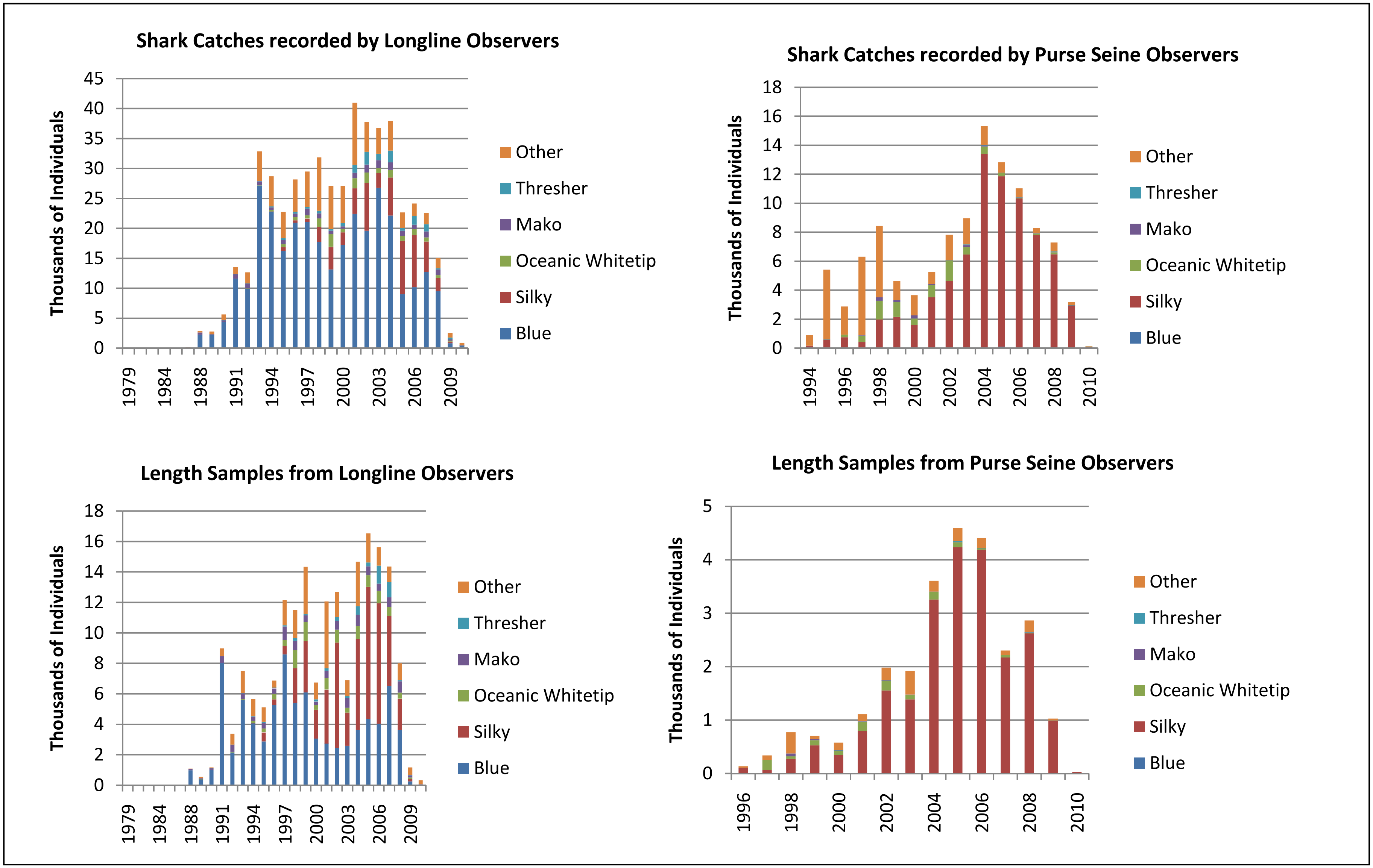

Figure 3. Annual number of sharks recorded by longline (1979-2010) and purse seine (1994-2010) observers and sample sizes of length measurements for the key shark species held by the SPC OFP. Note that data for recent years may be incomplete.

sharks together comprised about 70% of these samples, with the major sampled species shifting from blue to silky shark over time. All other longline caught sharks were sampled in numbers of less than 1,300 per year. Purse seine observers recorded total catches averaging approximately 9,000 sharks annually during 2000-2008, the majority of which were silky sharks. On average about 2,500 purse seine-caught sharks were measured by observers each year between 2000 and 2008 with over 80% of these being silky shark.

Data are also collected by observers on the sexes of captured sharks, their fate (retained, discarded, unknown) and condition (dead, alive, unknown). A summary of these data is given in Table 6 and indicates that sex is recorded for 52%, fate is recorded for 92%, and condition recorded for 75% of all observed key shark species. It should be noted that the same caveats which apply to the representativeness of catch and catch rate data based on these observer data also apply to biological data drawn from this data set.

Table 6. Sample sizes for sex, fate and condition data for the eight key shark species collected by longline observers and held by the SPC OFP, 1981-2010.

	Number (% of total) for which sexed is recorded	Number (% of total) for which fate is recorded	Number (% of total) for which condition is recorded
Blue shark	147,173 (46%)	286,343 (89%)	228,518 (71%)
Silky shark	48,217 (86%)	56,160 (100%)	54,377 (97%)
Oceanic whitetip	8,818 (59%)	14,712 (99%)	11,201 (76%)
Shortfin mako shark	6,986 (57%)	11,644 (96%)	9,536 (78%)
Longfin mako shark	634 (57%)	1,103 (99%)	978 (88%)
Bigeye thresher shark	2,524 (30%)	8,265 (100%)	5,825 (70%)
Common thresher shark	847 (38%)	2,170 (96%)	2,064 (91%)
Pelagic thresher shark	1,660 (61%)	2,707 (100%)	2,299 (85%)
Mako shark (unidentified)	2,399 (78%)	2,750 (89%)	2,891 (94%)
Thresher shark (unidentified)	259 (17%)	1,452 (98%)	997 (67%)

The second source of fishery-specific biological data is the various national port sampling programmes. Port sampling occurs in the Federated States of Micronesia, Fiji, French Polynesia, Kiribati, Marshall Islands, New Caledonia, Palau, PNG, Solomon Islands and Tonga. These programmes are designed primarily to collect additional biological information (e.g. species composition, length and weight data) for target tuna species caught by longline fisheries. Some biological data for sharks are also collected but these are often limited by the fact that the sharks are processed before landing, making species identification difficult. According to SPC OFP data holdings, between 2000 and 2009 data for approximately 4,200 sharks were collected, but half of these were identified only as "shark" and 44% were identified as "mako".

A final area of fishery-specific biological research relates to bycatch mitigation including trials of various hook types (e.g. Yokota et al. 2006), studies of post-release mortality (Moyes et al. 2006, Musyl et al. 2009, Campana et al. 2009a, 2009b), and methods for avoiding attracting sharks onto hooks (Gilman et al. 2008, Ward et al. 2008). Such studies can provide useful information for estimating catch rates and mortality for sharks in fisheries which do not report this information.

3.3 Non Fishery-specific Biological Data

Non fishery-specific biological data for many shark species can be sourced from published and unpublished scientific literature. Databases such as Fishbase (2010) and Moss Landing Marine Labs

(2010) provide compilations of life history parameters for all of the key shark species, although correct parameters must be selected and applied with care given the potential range of variation between studies and populations. With due regard to these caveats, a preliminary summary of some of the most important parameters for stock assessment is given for the key species in Annex A.

Ideally, data specific to the WCPO would be available for all of the key shark species. Biological and information known to be available based on Pacific studies is briefly summarised as follows:

- Blue shark biology has been extensively studied in the Pacific (e.g. Stevens 1984, Nakano and Seki 2003, Manning and Francis 2005, Nakano and Stevens 2008) and recent stock assessments in the north Pacific (Kleiber et al. 2009) and southwest Pacific (West et al. 2004) have compiled information which provides a useful starting point for further work.
- Silky shark biological information is available for the North Pacific (Oshitani et al. 2003, Bonfil 2008), and preliminary assessment work is underway for the EPO by IATTC (IATTC 2010).
- Oceanic whitetip life history is available for the Pacific through the work of Seki et al. (1998) and Bonfil et al. (2008).
- Shortfin makos have been studied by Semba (2005) and Semba et al. (2009) in the north Pacific and by Bishop et al. (2005) off New Zealand, and several studies have been conducted off California (Stevens 2008).
- Longfin mako biology is poorly understood as this species is often combined with, or confused with, the shortfin mako (IUCN 2010). The appropriateness of available biological data is therefore highly uncertain.
- Thresher biological data is primarily available from areas off California and Chinese Taipei (Smith et al. 2008; Liu et al. 1998, 1999).

Additional biological data for these species is being compiled through shark studies conducted by the United States National Marine Fisheries Service off southern California (ISC 2010) and by the New Zealand Ministry of Fisheries off New Zealand (New Zealand Ministry of Fisheries 2009b). Further data for the Pacific and other oceans are available through pelagic shark compendiums such as Camhi et al. (2008) and Camhi et al. (2009).

Tagging studies can also provide valuable information for shark species stock assessments including movement, habitat area, growth and natural mortality. A comprehensive database of shark tags deployed and returned in the Pacific does not exist, and SPC OFP does not have any substantial tag data holdings for sharks. Known sources of tagging data for Pacific sharks include:

- Conventional tagging of blue and "mako" sharks in a New Zealand recreational tagging programme conducted between 1974 and 2007 occurred for 3,854 blue sharks and 11,476 mako sharks and resulted in recaptures of 63 and 93 sharks respectively (Holdsworth and Saul 2008 cited in Manning et al. 2009). This programme is ongoing (New Zealand Ministry of Fisheries 2009a).
- New Zealand's Highly Migratory Species Medium-Term Research Plan proposes to expand the existing shark tagging to the wider South West Pacific with regional partners, if possible, in 2011-2012 depending on approval of funds (New Zealand Ministry of Fisheries 2009a).
- Australia's New South Wales state fisheries agency coordinates a large recreational conventional tagging program which has tagged over 5,000 makos. These data are currently being analysed (B. Bruce, CSIRO, personal communication).

- Australia, through CSIRO, SARDI and other organizations, also conducts electronic (archival, PSAT, acoustic, direct satellite tracking) for shark species. This tagging is primarily aimed at makos but also includes blue, hammerhead and thresher sharks. Tagging with acoustic, long-life transmitters is likely to begin including pelagic shark species in the future (B. Bruce, CSIRO, personal communication).
- Japan reported conventional tagging of 1,394 blue, 82 bigeye thresher, 69 silky, 50 oceanic whitetip, 18 pelagic thresher, 14 "mako" and 19 "other" sharks in the North Pacific as of 2001 (Kohler and Turner 2001). The programme is ongoing and it was reported that in 2008 blue sharks (n=1,123), bigeye threshers (n=15), shortfin mako (n=60), and longfin makos (n=7) were tagged, and tags from blue shark (n=20) and shortfin makos (n=5) were recovered (Government of Japan 2009).
- A study conducted by the University of Hawaii investigated the behaviour of sharks after release from longline gear using pop-off satellite archival tags. A total of 55 sharks (7 bigeye thresher, 32 blue, 8 oceanic whitetip, 4 shortfin mako and 4 silky sharks) were tagged in the central north Pacific Ocean through 2004.
- The United States National Marine Fisheries Service conducts an annual juvenile shark survey off the coast of southern California which includes satellite tagging of blue and mako sharks. In 2008, nine "mako" sharks and three blue sharks were tagged (TOPP 2010). In addition, silky, thresher and oceanic whitetip sharks are also tagged with either conventional, electronic or oxytetracycline tags (ISC 2010). Data for five common thresher sharks tagged with satellite pop-up tags off southern California in 1999-2000 were retrieved (NMFS 2007).
- Acoustic tagging of two bigeye thresher sharks was reported for the eastern tropical Pacific (Nakano et al. 2003) as well as pop-up satellite archival tagging of one bigeye thresher off Hawaii (Weng and Block 2004).

3.4 Summary of Data and Data Gaps

After a review of available catch and effort data, and fishery-specific and non fishery-specific biological data, the following conclusions regarding the availability and sufficiency of existing information to support shark assessments for the WCPO are drawn:

- Major difficulties with the use of logsheet data for shark assessment are anticipated. Foremost among these is the lack of provision of operational (or even aggregated) shark data by species for most years by most CCMs. The use of logsheet data which are available is complicated by issues of species mis-identification, under-reporting and potential, unidentifiable changes in targeting strategies.
- Research and training cruise catch and effort data avoid many of the biases of logsheet data and could thus help to fill some of the critical data gaps, especially in the North Pacific. Data known to exist, however, are not currently available for use in the assessments.
- Observer data provide the best source of catch and effort data for shark assessment but coverage, especially for the longline fleets, is low and may not be representative of all areas where sharks are caught. Supplementing existing data holdings with known but unavailable observer data especially for the North Pacific can address this problem. Although less severe than for logsheet data, lack of species-specific reporting early in the time series may also be an issue for some shark species.

- Data from recreational fisheries may also provide important supplementary catch and effort data. Although they have not been explored in detail, these data are most likely to be available for Australia, New Zealand and United States waters.
- Market data for shark fin have been used to estimate total shark catches by species for the WCPO but are unlikely to provide additional useful information for shark assessments. Shark landings data appear very limited and are likely to be uninformative due to unknown rates of discarding at sea.
- Total shark catches were reported in 20 of 32 CCM's Annual Reports-Part 1 but many reports lack species-specific data and reports from some of the world's leading shark fishing nations lack even aggregated annual catch data.
- Fishery-specific biological data (length, weight, sex, fate and condition) drawn from observer programmes appear to be ample for blue and silky sharks but are limited for other species, and all samples will reflect any biases in the observer data.
- Port sampling could in theory provide additional fishery-specific biological data but this is hampered by the fact that most sharks are landed as processed carcasses (trunks) resulting in half of the samples collected so far not being identified to species.
- Bycatch mitigation research can provide useful information for estimating catch rates and mortality for sharks in fisheries which do not report this information.
- There is a reasonable amount of information available on the biology of most key shark species (with the exception of longfin mako) but this tends to be concentrated in temperate/sub-tropical waters off Japan, the United States, and Australia and New Zealand.
- It is difficult to characterize the extent of tagging data for sharks as there is no coordinated source of information and results have often not been published. Tag information is primarily available for blue and mako sharks, and to a lesser extent for threshers.

4. Relevant Past, Ongoing and Proposed Shark Research and Assessment

Despite the universal problem of insufficient data, stock assessments have been and are being attempted for sharks by several national and international organizations in response to growing concerns over the conservation status of these species. Other studies in the form of ecological risk assessment, demography, and analyses of catch and catch rate, also contain useful input for future assessment of the key shark species in the WCPO. As it is not possible to summarize the entire body of shark literature here, the following sections highlight only those assessment studies which are expected to be particularly relevant to those proposed under this plan.

4.1 Past Assessments and Existing Information

There are few existing shark stock assessments for the Pacific. Blue sharks have been assessed in the north Pacific by Kleiber et al. (2009, using data through 2002) which found that the population appears to be close to B_{MSY} and that fishing effort may be approaching F_{MSY}. West et al. (2004), after compiling all available data for blue sharks in the southwest Pacific, concluded that uncertainties in catch and life history data were too great to allow a formal stock assessment. Instead, a yield analysis was conducted and determined that removal rates of 4-12% of the unfished biomass would be sustainable.

Useful input to future stock assessments in the Pacific can be found in studies by Oshitani (2000) and Semba (2003) which estimated Pacific-wide catches and catch-rates for silky and shortfin mako sharks, respectively. Clarke (2009) provided total catch estimates in the WCPO for blue, silky, oceanic whitetip, shortfin mako and thresher sharks based on shark fin trade data. Analysis of shark catches by the Hawaii-based longline fleet by Walsh et al. (2001, 2002, 2009) and for purse seine fleets in the eastern Pacific Ocean by Minami et al. (2007) outline useful methods and/or data for use in future Pacific shark stock assessments. The ecological risk assessment conducted for WCPFC (Kirby and Hobday 2007) serves as a source of life history information and provides a useful basis for further productivity-susceptibility type analyses for shark species.

In addition to the above referenced studies for the Pacific, shark assessments have been conducted in the Atlantic for a number of species. Formal stock assessments have been limited to those concerning blue, shortfin mako and porbeagle sharks by ICCAT (2005, 2008, 2009) and assessments of a number of small and large coastal sharks (including silky sharks) by NMFS (2009). Additional information on stock assessment methods and life history parameters for sharks based on Atlantic data can be found in Harley (2002), Apostolaki et al. (2005) and Aires-da-Silva et al. (2008, 2009).

4.2 Planned Assessments and Research

IATTC is working toward stock assessments for two shark species, silky and oceanic whitetip, in the Eastern Pacific Ocean (IATTC 2010). There are tentative plans to complete the silky shark assessment in 2011 but this is subject to IATTC approval of the proposed stock assessment work plan (M. Maunder, IATTC, personal communication).

Australia's CSIRO has proposed a coordinated effort between relevant Australian and New Zealand shark research and management organizations, and with SPC, to compile and analyse data on the status and catch of shortfin and longfin mako and porbeagle sharks in Australasian waters. Tasks would include determining historical catches and catch rates, compiling tag data, examining mitigation measures for commercial bycatch and identifying critical data gaps. The project is awaiting funding but is currently anticipated to be completed as a first phase of work by June 2011 (B. Bruce, CSIRO, personal communication).

The ISC convened a Shark Task Force Group on 15 July 2010 to respond to a request from the Northern Committee of the WCPFC to consider conducting assessments for blue and mako sharks. The objectives of the Shark Task Force Group were to review available data for sharks, formulate a list of shark species for assessment in the North Pacific and classify the species in terms of which organization would be best placed to lead the assessments (ISC 2010). The ISC Shark Task Force Group produced assessment recommendations for eleven species including the key shark species (Table 7). These recommendations were not accompanied by timeframes and the lead organizations for assessments other than ISC were not specified. Boundaries for the proposed stock assessments were not defined. Species-specific data assessments were not provided, therefore details on the data gaps preventing the assessment of some species were not identified. Decisions by the ISC Plenary regarding these recommendations were not available at the time of writing.

Table 7. Recommendations by the ISC Shark Task Force Group regarding shark species and lead organizations for shark assessments (ISC 2010).

Species	**Recommendation (ISC 2010)**
Blue	The assessment should be conducted by ISC (ISC Category 1)
Silky	ISC should support an assessment led by another RFMO (ISC Category 2)
Oceanic whitetip	ISC should support an assessment led by another RFMO (ISC Category 2)
Shortfin mako	The assessment should be conducted by ISC (ISC Category 1)
Longfin mako	There is insufficient information to characterise this species (ISC Category 4)
Bigeye thresher	The assessment should either be conducted by ISC, or ISC should support an assessment led by another RFMO (ISC Categories 1 or 2)
Common thresher	The assessment should be conducted by another RFMO (ISC Category 3)
Pelagic thresher	The assessment should either be conducted by ISC, or ISC should support an assessment led by another RFMO (ISC Categories 1 or 2)
Other species considered:	
Hammerhead sharks (*Sphyrna* spp.)	The assessment should be conducted by another RFMO, potentially with the collaboration of ISC (ISC Categories 2 or 3)
Salmon shark (*Lamna ditropis*)	There is insufficient information to characterise this species (ISC Category 4)
Crocodile shark (*Pseudocarcharius kamoharai*)	There is insufficient information to characterise this species (ISC Category 4)

5. Proposed Assessment and Research Plan

The survey of existing information, as well as ongoing and planned research by other organizations, presented above provides the foundation for development of a research plan for the assessment of the status of sharks in the WCPO. The plan is proposed to consist of three phases: assessments to be undertaken with existing, available data; coordination of research efforts to obtain better data; and obtaining better data from commercial fisheries. Implementation of Phases 2 and 3 will lead to revisiting the assessments conducted under Phase 1 to update and improve their scientific rigour.

5.1 Phase 1 - Assessments to be Undertaken with Existing Data

The proposed assessment tasks to be undertaken with existing data are drawn from Manning et al. (2009) but have been modified slightly on the basis of further study. The original, progressive three-step approach is maintained such that simple assessments are conducted first followed by more complex assessments for those species with sufficient data. As the results of research coordination and improved data from fisheries become available, existing assessments can be updated and improved, and new types of assessments may become feasible for some species.

It is anticipated that results from Step 1 can be available for preliminary presentation at the annual meeting of the Commission in December 2010. A more complete and detailed presentation of results for Step 1 and Step 2 will be provided to the Scientific Committee in 2011. Step 3 is proposed to begin in 2011 and run for three years. Funding has been made available to support Steps 1 and 2 but additional funding will be necessary to support Step 3.

5.1.1 Step 1 - Shark Indicators

As described in Manning et al. (2009), simple indicators which can provide insight into the extent of fishing pressure will be developed for shark species on the basis of existing, available information. Indicators proposed for initial consideration include:

Catch: Trends in catch can sometimes be an indicator of stock status, but time series of catches will be difficult to generate for sharks due to the data gaps highlighted in Section 3. For those catch data which do exist care will need to be exercised to avoid biases arising from reporting practices (i.e. both in terms of species specificity and under-reporting). The extent of the time series to be computed for this indicator is potentially very long, but due to the influence of reporting biases it may be desirable to limit the time series to a shorter period for which data quality is consistent. This period may vary between species. Although a total catch indicator for all gear types is proposed, the utility of separate catch indicators by gear type will also be explored. Another indicator of catch may be based on market data as presented in Clarke (2009).

CPUE: Trends in catch per unit effort (CPUE) are probably the most common indicator of stock status in exploited fish populations. This indicator is fundamental for developing trends in relative abundance. It is proposed to compute CPUE based on logsheet and observer data sources separately, as well as by gear type. Both nominal and standardised CPUE indices will be developed and a range of statistical techniques will be considered, particularly those that account for the high proportion of zeros and/or misreporting that is common in shark catch and effort data.

Size: Declines in a standardised measure of fish size from an exploited population can be expected to be accompanied by changes in the age and size composition of the population. In particular, it is expected that a standardised measure of the sizes/ages of fish will decline in a population under exploitation (Goodyear 2003). Therefore an indicator based on size can, in theory, provide information on the level of exploitation that a fish stock is experiencing (Francis and Smith 1995). This indicator will be based on measured lengths of sharks compiled under the observer programme, therefore the time series will be limited to those periods of sufficient coverage and species-specific length recording. The time series will likely date at most, depending on species, from 1990 for longlines and from 1994 for purse seines (see Figure 3). Formulations based on the mean, median and 90th percentile lengths will be explored. Different versions of the indicator for different gear types and fishing operations (e.g. set depth for longlines, set type for purse seiners) will also be investigated.

Maturity: This indicator is proposed to be formulated on the basis of the proportion of the population which is sexually mature. Given that shark species often require a longer time to mature than many other fish, a reduction in the proportion of the population which is sexually mature could have important implications for stock production. As for the size indicator, the maturity indicator will also be based on measured lengths compiled by observers and so it will be computed for the same time series and strata. Since maturity will be inferred from length at maturity data in the scientific literature, it will be important to select the most appropriate value for each species from the relevant studies. If there is uncertainty in the maturity parameters this should also be taken into account.

Overlap: The level of interaction or overlap between fishing activities and a given shark species can provide information on the potential risks posed to the stock by fishing. Indicators such as Gulland's concentration index (Harley 2009) could be calculated as measure of where fishing effort occurs relative to areas of highest shark density. Habitat preferences based on electronic tagging also have the potential to allow the calculation of overlap indices as has previously been done with seabirds (Kirby et al. 2009).

Other: Indicators such as sex ratio and/or an index based on fate and condition data, will also be considered. Indicators such as these are likely to be based primarily on observer data.

Where possible these indicators will be calculated as annual values for all of the key shark species. However, it is clear from the review of existing data that there are insufficient data for the longfin mako and the three thresher species separately, therefore mako and thresher sharks will have to be assessed as groups.

5.1.2 Step 2 - Shark Status Plots

The ecological risk assessment prepared for the WCPO (Kirby and Molony 2006, Kirby and Hobday 2007) covered over 30 shark species including all of the key species. In that study each species was plotted on axes of productivity (based on factors such as reproductive strategy, length at maturity and maximum length) and susceptibility (based on the likelihood of exposure to fishing gear, condition at capture and proportioned retained; Figure 4). This approach, while useful, is not necessarily premised on any existing knowledge of the status of the stock and thus it is most often used to provide a relative assessment of species based on theoretical rather than empirical data.

Another approach to using plots as a snapshot tool for assessment is the stock trajectory diagram, often referred to as the "Kobe diagram". These diagrams show the value of a stock biomass reference point on one axis (often B/B_{MSY}) and the value of a fishing pressure reference point (often F/F_{MSY}) along another axis. Points are plotted to represent the condition of the fishery in each year. These diagrams have proved extremely useful for summarising and visualising status and trends but they require stock assessments to produce the reference points for plotting. Since such information is lacking for shark species at this time, Kobe diagrams are not practical.

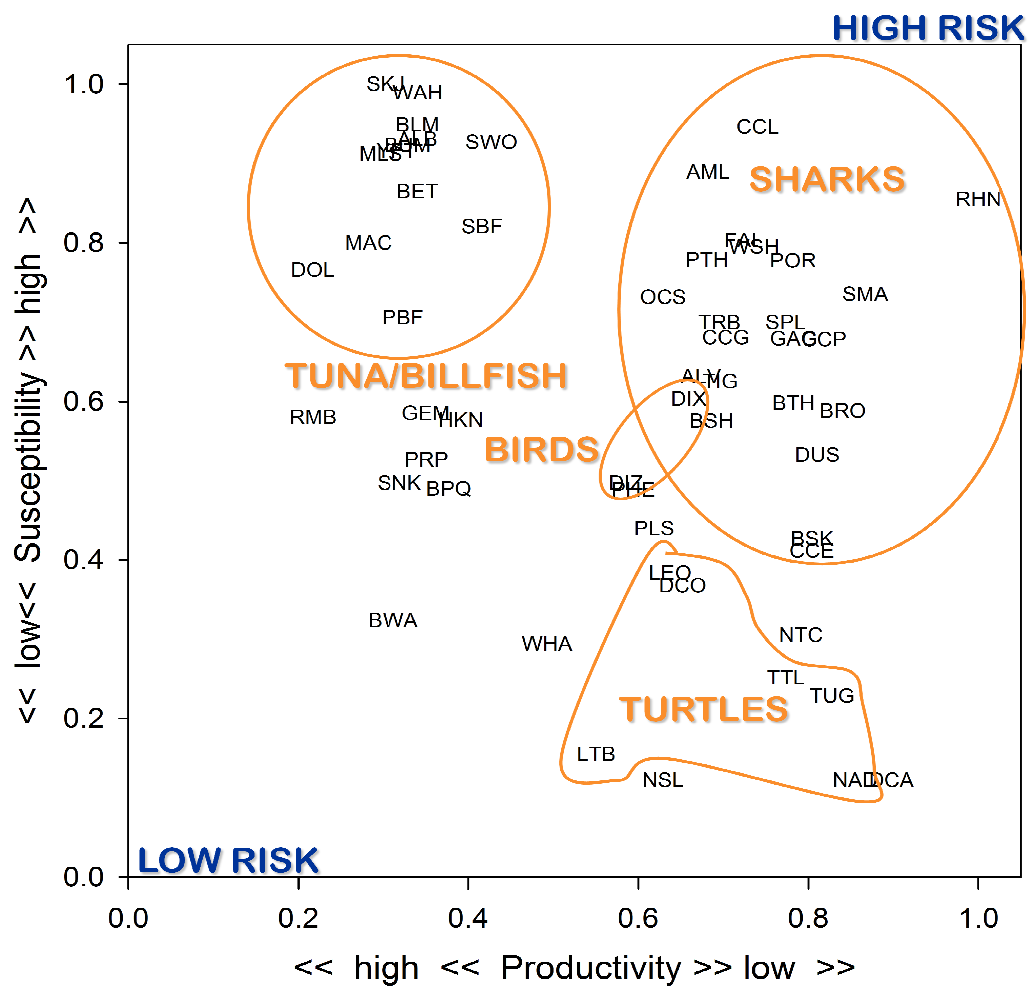

Figure 4. Results of the ecological risk assessment prepared for the WCPO (reproduced from Kirby and Molony 2006).

In finding a way to revise and enhance the ecological risk assessment for key shark species, Step 2 will seek to combine theoretical information on life history of shark species (e.g. improved measures of productivity) on one axis with a measure of the current threat to the population based on empirical data (e.g. the indicators from Step 1) on another axis. The productivity indices are unlikely to change over time, at least as far as they can be measured for this study, but there should be annual indicators for the other axis from Step 1 which can be plotted as a range to show the variance. It might also prove possible to investigate correlations between "input" and "output" indicators, e.g. changes in catch rates versus changes in size or maturity, or possibly between total catches and targeting indices.

Shark status plots such as these and potentially other correlation analyses will be attempted for all of the key shark species, although the limitations in the computed indicators for some species under Step 1 will necessarily limit the production of plots in Step 2.

The outcomes from these analyses will be useful in prioritising future activities under Phase 1, Step 3 (stock assessments) and Phase 2 (coordination of research efforts). Furthermore, methods developed here can be applied to other shark species in the future to facilitate periodic review of the Commission's key shark species list.

5.1.3 Step 3 - Shark Stock Assessments

Conducting shark stock assessments is the best method of determining the status of populations and exploring the technical basis of management options. Despite their importance, stock assessments have been proposed as the final step in this assessment methodology (Manning et al. 2009) because of the current limited availability of catch and effort data, and the associated uncertainties regarding species identification, under-reporting and targeting biases. For some species it may be possible to begin stock assessment work on the basis of existing data, whereas for other species the use of existing data alone is unlikely to produce meaningful results.

As outlined in Manning et al. (2009), simple surplus production models such as the Schaefer or Pella-Tomlinson formulations are recommended as a first alternative. Surplus production models have been criticised for disregarding the size or age structure of the population, and for ignoring time delays between reproduction and recruitment, but they have frequently been used to assess elasmobranch populations because of their appealingly low data requirements (see Bonfil 2004 for numerous examples). At a minimum, only a time series of total removals (i.e. catch) and an index of abundance (i.e. the year effects for standardized CPUE) are required. This does not however imply that surplus production models' data requirements will be easily met in the case of sharks because given the potential biases in existing WCPO catch data, constructing a time series of annual total removals will be challenging. On the other hand, the more demanding data requirements of age structured models need not be an insurmountable obstacle for shark stock assessment as illustrated by Harley (2002), Apostolaki et al. (2005), Kleiber et al. (2009) and others. In many cases sufficient information is known about shark population dynamics characteristics, in general if not on a species-specific basis, to realistically constrain parameters required in age structured models and thus allow these models to produce meaningful results. To the extent possible given the assessment schedule and the available data, both surplus production and simple age-structured models will be explored in order to compare and contrast results from the two model structures.

As also proposed in Manning et al. (2009), the use of Bayesian methods should be explored in order to better account for uncertainties in the data (Meyer and Millar 1999, McAllister et al. 2001, Cortés et al.

2002). These methods will not only explicitly incorporate uncertainties in existing data sets for the WCPO, they will allow, through specification of priors, the incorporation of existing knowledge about the key species, or similar species, in other oceans. Another advantage of Bayesian methods lies in their presentation of results, e.g. reference points, as probability distributions. This type of presentation will ensure that the results are properly considered in the context of the uncertainties which underlie the data and the analysis. These two aspects of Bayesian methods make them a particularly appropriate choice when grappling with the life history and catch history data gaps that often exist for sharks.

Ideally, stock assessments would be conducted for all of the key shark species but data requirements which are already foreseen to limit the assessments for some species under Steps 1 and 2 will also preclude stock assessment under Step 3. Furthermore, even for those species which may not be limited by available data in Steps 1 and 2, it will be difficult to construct realistic time series of catch based on existing data. Parameters to be used in the assessments, in particular the intrinsic rate of increase, will be reviewed and potentially re-estimated based on the best available data for the Pacific Ocean.

The blue and shortfin mako sharks have arguably the most extensive, species-specific catch and catch rate data sets, however, problems will be encountered even for these species. This is because several CCMs with major fisheries in the WCPO do not provide shark catch data by species, or any shark data at all, to the Commission (Table 3). As a result, catch and catch per unit effort parameters based on logsheets will also necessarily exclude the fisheries of these CCMs. The catches estimated by Clarke (2009) from market data could provide an alternative time series of catch but their usefulness will require further examination. In the absence of logsheet data, catch rate indices can be computed from existing observer data holdings for blue and mako sharks, but these data are likely to be representative only for the southern hemisphere portion of the WCPF Convention Area (Figure 2). On the basis of these considerations, stock assessments for blue and mako sharks in the southern hemisphere portion of the WCPF Convention Area are proposed but should be delayed until midway through the research period to allow the opportunity for compilation of better data (Table 8). The CSIRO porbeagle and mako project is one potential source of such data.

Existing data to support stock assessments is also limited for the other six key shark species. As discussed above under Step 1, it will probably be necessary to combine the longfin mako with the shortfin mako and all three thresher species into one group for stock assessment purposes due to the lack of sufficient data for the individual species. For those species whose distributions are thought to correspond to the coverage of the available observer data, assessments can rely heavily on this data source. Fortunately, these species include the silky, oceanic whitetip, and the bigeye and pelagic threshers, but unfortunately as indicated in Figure 3, with the exception of silky sharks the encounter rates for these species in the observer records are relatively low. This could result in sparse and discontinuous data series such as those shown in Manning et al. (2009) for these species. Nevertheless on the basis that silky and oceanic whitetip assessments have been proposed by IATTC for the eastern Pacific Ocean, it is proposed capitalise on those efforts by prioritising similar assessments for the WCPO. A combined thresher assessment can then be conducted as a final task after allowing the maximum amount of time for new data to become available (Table 8).

As this discussion indicates while some stock assessment work may be conducted on the basis of existing and available data such assessments will necessarily rely heavily on observer data which may or may not be representative of the entire area over which the shark species are fished. Reliance on other existing and available data sets such as available logsheet data and catch estimates based on market data will be more problematic. For these reasons, this research plan includes Phases 2 and 3 involving coordination of research efforts and strengthening shark data arising from commercial fisheries in order to improve the prospects for future stock assessments.

5.2 Phase 2 - Coordination of research efforts to obtain better data

The gaps in existing and available data identified above will come into sharper focus as the assessment work under Phase 1, Steps 1 and 2 proceeds. However, on the basis of this preliminary review the following research coordination and promotion activities should be incorporated into the research plan:

a. Obtain shark catch rate and biological data (length, weight, sex) from research and training vessel datasets, either in raw form for analysis or through collaborative analysis by national scientists. This will assist in filling historic data gaps, particularly for the North Pacific.
b. Explore and, if useful and practical, acquire shark catch rate data from recreational datasets *inter alia* in Australia, New Zealand and the United States. This will supplement catch rate indices based on observer records and could be very useful for game fish species, particularly makos.
c. Undertake a coordinated review of all Pacific shark tagging data (or tagging metadata). This will allow a more comprehensive understanding of the extent and usefulness of existing data and the need for further work.
d. Participate in a planned study of porbeagles and makos led by Australia including a coordinated compilation and analysis of data sources. This will help clarify the prospects for conducting a formal stock assessment of these species in the southern hemisphere portion of the WCPF Convention Area.
e. Cooperate with planned IATTC assessments of silky and oceanic whitetip sharks in the Eastern Pacific Ocean. This will allow a better understanding of the existing data sources and assessment techniques for these species, as well as identify opportunities to collaborate with the IATTC's assessment.
f. Review progress with shark bycatch mitigation techniques and identify opportunities for further studies. This will establish a scientific basis for evaluating mitigation measures for those fisheries which choose to avoid catching sharks.
g. Encourage further research into key shark species whose presence in fisheries and whose biology are less well understood, particularly longfin mako and the threshers. This will assist in deciding whether separate stock assessments are possible and/or worthwhile for these species.
h. Request CCMs to investigate their own data holdings for sharks and report to the Commission regarding the existence and availability of useful data. This may identify heretofore unknown sources of information.

At a minimum, annual reporting on these and any other research coordination efforts should be provided to the Commission and used to re-evaluate, and adjust if necessary, the shark research plan. It is anticipated that most of these items can be progressed through collaborative work and in-kind contributions from CCMs and other sources. However, if specific funding needs are identified, proposals can be developed to request funds from the Commission or from other funding sources.

5.3 Phase 3 - Obtaining better data from commercial fisheries

The review of existing data sources described above has highlighted that many of the fisheries in the WCPO do not provide sufficient data on shark catches to the Commission to allow assessment of the impacts of those fishing activities on shark stocks. While some of these data gaps can be compensated by creative use of existing data in the short term, and improved coordination of research activities in the mid-term, these strategies are no substitute for obtaining better data from the fisheries managed by the WCPFC. While it is not for this research plan to evaluate the mechanisms under which such data may be provided, on the basis of the data reviews conducted thus far the Commission is urged to consider whether the following critical data sources can be made available to support the proposed shark assessments:

a. Historic and current/future logsheet data for sharks, by species, for the key shark species for all CCM fleets catching sharks (see Sections 3.1.1 and 3.1.6);
b. Total catches (i.e. raised) of sharks by species for the key shark species for all CCM fleets catching sharks (see Section 3.1.6);
c. Shark catch rate and biological data from observer data sets which are known to exist but are not currently available for analysis by the Commission (see Section 3.1.3);
d. Ancillary sources of shark catch data such as landings, market or trade data that, in the absence of other catch records, may provide minimum proxy values for shark catches (see Section 3.1.5);
e. Fishery-specific biological data such as length, weight or sex by species to characterise the portion of the stock which is being selected by each fishery (see Section 3.2).

As work under the shark research plan progresses, ongoing assessment activities in Phase 1 can be revisited and strengthened through provision of new and improved data from commercial fisheries. In addition, the availability of additional data such as those identified above could make possible stock assessments for some species which do not currently appear to have sufficient data. While the data listed above will greatly enhance the ability to provide robust shark assessments for the consideration of the Commission, the cost of providing these data should be minimal since many of the data sources already exist. However, in addition to releasing data which already exist, CCMs may also wish to consider whether they can implement new procedures to collect more meaningful shark data in the future (e.g. new logsheet formats reflecting the key shark species; port sampling for species, size and sex data; rescue and/or mining of historical data sets to produce new data relevant to shark assessment). These activities could be undertaken as in-kind contributions by CCMs and would not represent a cost to the WCPFC.

5.4 Timeline

A timeline for the proposed shark research plan from the present through June 2014 is given in Table 8. Detail is provided on the proposed timing of activities in Phase 1 but this may need to be adjusted based on forthcoming decisions by ISC, IATTC and the Australian government regarding proposed complementary shark assessment and data preparation work. In addition, it is proposed to further investigate and explore opportunities for collaboration with the studies described above in Phase 2 with a view toward confirming when new information might become available for use in the Phase 1 assessments. These activities can then be specified and linked to the Phase 1 activities in a future revision to this plan. Activities under Phase 3 are not programmed in detail because it is for the Commission and/or individual CCMs to determine whether additional shark information can be made available from national sources to support the shark assessments. If so, similar to Phase 2, Phase 3 activities can be specified and linked to the Phase 1 assessments in a future revision to this plan.

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Table 8. Timeline for the proposed Phases (1-3) and assessment Steps (1-3) under the proposed shark research plan. Notes: * unless better data become available for the longfin mako, this species is proposed to be included in the shortfin mako assessment; ** unless better data become available for the three individual species, the thresher assessment is proposed to be conducted as a group; P=Data preparation; X=Assessment; R=Report; colours indicate when products are reported to the Commission.

	2010				2011				2012				2013				2014		
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	
TASKS PROPOSED UNDER THIS PLAN																			
Phase 1 - Assessments with Existing Data																			
Development of Shark Research Plan			XR																
Step 1 - Shark Indicators (all key species, if possible)			XXXX	XXXR															
Step 2 - Shark Status Profiles (all key species, if possible)				XXX	XXXXX	XXXRR													
Step 3 - Shark Stock Assessments																			
Silky - WCPO Convention Area (link to EPO)						PPPPP	XXXXX	XXXRR									PPPPP		
Oceanic whitetip - WCPO Convention Area (link to EPO)								PPPPP	XXXXX	XXXRR									
Blue - WCPO Convention Area, southern hemisphere										PPPPP	XXXXX	XXXRR							
Shortfin mako* - WCPO Convention Area, southern hemisphere												PPPPP	XXXXX	XXXRR					
Threshers** - WCPO Convention Area														PPPPP	XXXXX	XXXRR			
Final Report summarising Steps 1, 2 and 3 and providing scientific advice on shark stock status																	RRRRR	RRRRR	
Phase 2 - Coordination of research efforts (details to be developed)					X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	
Phase 3 - Obtain better data from commercial fisheries (details to be developed)					X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	
TASKS PROPOSED/UNDERWAY BY OTHERS																			
IATTC silky shark assessment			X	? ?	? ?	? ?													
IATTC oceanic whitetip assessment							? ?	? ?	? ?	? ?									
ISC blue shark assessment ?																			
ISC shortfin mako assessment ?																			
ISC bigeye thresher assessment ?																			
ISC pelagic thresher assessment ?																			
CSIRO mako and porbeagle data assessment			?	? ?	? ?	? ?	? ?												
REPORTING TO THE COMMISSION																			
SC Meetings			SC6				SC7				SC8				SC9				SC10
Commission Meetings				Com7				Com8				Com9				Com10			

6. Summary of Expected Outcomes

This proposed shark research plan describes an ambitious schedule of data compilation, indicator development, stock status plots and stock assessments for the current list of eight key shark species designated by the Commission. Initial work (Phase 1, Steps 1 and 2) can and will proceed on the basis of existing data and allocated funding through June 2011. Further work consisting of stock assessments (Phase 1, Step 3) will require additional funding from the Commission and will likely be constrained by the currently available data. Any addition of species to the Commission's key shark species list may have timing and funding implications.

Observer data is the only currently available data source which provides sufficient species-specific shark records for stock assessment but these data are disproportionately concentrated in areas which may not be representative of shark catches throughout the WCPO. Furthermore, observer data cannot provide the catch (total removals) time series needed for the simplest stock assessment models. For this reason, Phases 2 and 3 of the research plan will aim to explore, compile and better coordinate existing shark research and data, and to improve shark catch data from commercial fisheries managed by the WCPO, respectively. New and enhanced data arising from efforts under Phases 2 and 3 can be fed into the Phase 1 assessment work to strengthen the scientific rigour of the results. Without additional inputs from Phases 2 and 3, stock assessments for some species will be severely compromised and may not be able to provide a meaningful basis for Commission decision-making.

In aiming to provide advice on the stock status of key shark species to the Commission, this shark research plan thus proposes a joint programme of assessment, research coordination and fishery statistics improvement. Progress in all three areas will be necessary to assist the Commission in meeting its responsibilities for ensuring the sustainability of shark stocks.

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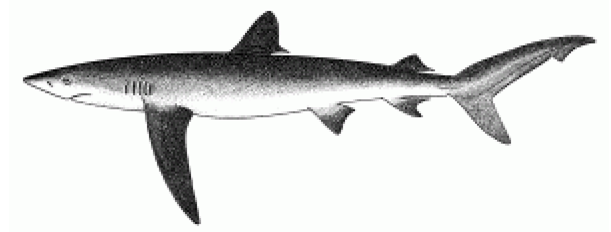
Annexes

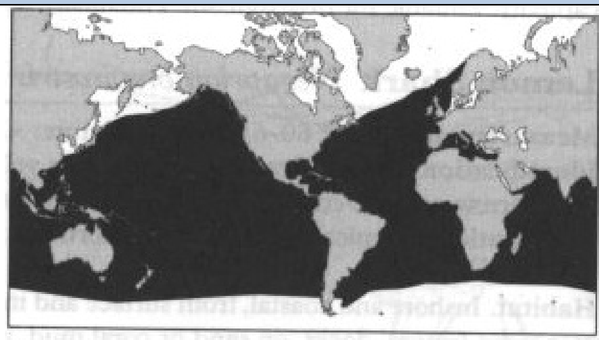
Notes:

a. Illustrations are from Compagno (1984). (This source authorises reproduction and dissemination for educational or other non-commercial purposes without any prior written permission from the copyright holders provided the source is fully acknowledged).
b. Habitat information is from Compagno et al. (2005)
c. Life history parameters shown in these annexes are indicative only and do not imply endorsement for use in assessments. These parameters (other than 'r') were compiled for Kirby and Hobday (2007) and drawn from Camhi et al. (1998), Cavanagh et al. (2003), Froese and Pauly (2010), Goldman and Caillet (2004), Hazin and Lessa (2005), Last and Stevens (1994) or Pratt and Casey (1990).
d. Intrinsic rates of increase ('r') were drawn from Cortés et al. (2010) except for the pelagic thresher which was drawn from Cortés (2002).
e. Ecological risk assessment results were drawn from Kirby and Hobday (2007).
f. International Conventions and Listings were taken from the websites of the cited organizations.
g. All other sources of information are as shown in the individual citations.

Blue Shark (*Prionace glauca*)



Habitat



Range: Circumglobal in temperate and tropical waters	
Depth: 0-350 m	

Life History Parameters

Length at First Maturity	220-281 cm	K (von Bertalanffy growth coefficient)	0.16
Age at First Maturity	5-6 years	M (natural mortality)	0.22
L_∞	347 cm	r (intrinsic rate of population increase)	0.29
Maximum Age (♀)	15 years		
Average Litter Size	35		
Reproductive Periodicity	1.2-2 years		

Ecological Risk Assessment Results

Risk from Deep Gear / Shallow Gear	Medium / Medium to Low

International Conventions and Listings

IUCN Redlist Status	Near Threatened
CITES	N/A
CMS	N/A

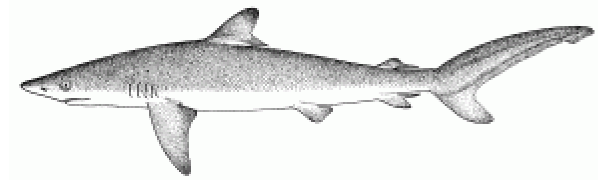
WCPO Fisheries

Estimated Catch in the WCPO (as of 2006 unless otherwise specified)	~40,000 t (SPC 2008) 90,000-180,000 t (Clarke 2009)
Identified by Observers in the LL fishery (as of 2006)	~10,000 recorded in 2006 (Manning et al. 2009) The mostly commonly identified shark by observers in 13 Pacific Island Country longline fisheries (Lack and Meere 2009)
Percentage of the WCPO LL catch (1994-2009)	19.5% (SPC 2010)
Identified by Observers in the PS fishery (as of 2006)	Yes, but observations are rare (Manning et al. 2009)
Percentage of the WCPO PS catch (1994-2009)	Negligible (SPC 2010)

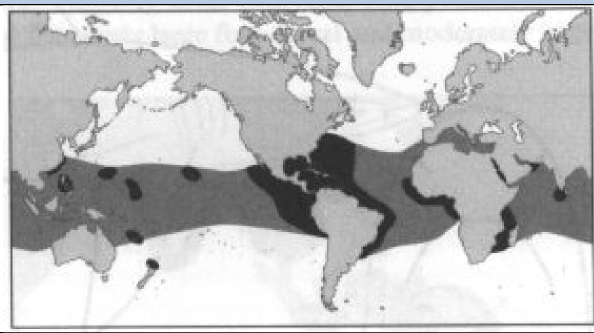
Existing Assessments or Management

In the WCPO	Kleiber et al. 2009 (North Pacific only): population appears close to B_{MSY} and fishing effort may be approaching F_{MSY} West et al. 2004 (mainly SW Pacific): did not present a finding on stock status but noted that maximum yield may be no more than 4% of unfished biomass. This species is managed under a quota management system in New Zealand (New Zealand Ministry of Fisheries 2009b).
In other oceans	ICCAT (2004, 2008): Biomass probably above B_{MSY} and F probably below F_{MSY} in both North and South Atlantic.

Silky Shark (*Carcharhinus falciformis*)



Habitat



Range: Oceanic and coastal, circumtropical	
Depth: 0-500 m	

Life History Parameters

Length at First Maturity	200-260 cm	K (von Bertalanffy growth coefficient)	0.10
Age at First Maturity	6-10 years	M (natural mortality)	0.18
L_∞	344 cm	r (intrinsic rate of population increase)	0.06
Maximum Age (♀)	25 years		
Average Litter Size	7		
Reproductive Periodicity	2 years		

Ecological Risk Assessment Results

Risk from Deep Gear / Shallow Gear	Medium / Medium

International Conventions and Listings

IUCN Redlist Status	Near Threatened, but Vulnerable in the eastern central and southeast Pacific
CITES	N/A
CMS	N/A

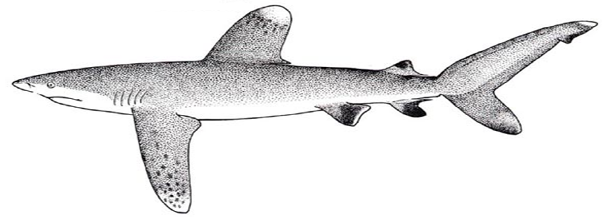
WCPO Fisheries

Estimated Catch in the WCPO (as of 2006 unless otherwise specified)	~6,000 t (SPC 2008) 11,000-24,000 t (Clarke 2009) ~900,000 taken as bycatch in tuna longline fisheries of the Pacific Ocean in 1989 (Bonfil et al. 2008)
Identified by Observers in the LL fishery (as of 2006)	~6,000 recorded in 2006 (Manning et al. 2009) One of the five most commonly identified sharks/rays; the most commonly identified shark in PNG & Tuvalu LL fisheries (Lack and Meere 2009)
Percentage of the WCPO LL catch (1994-2009)	3.5% (SPC 2010)
Identified by Observers in the PS fishery (as of 2006)	~10,000 recorded in 2006 (Manning et al. 2009). The most commonly identified shark in eight Pacific Island Countries purse seine fisheries (Lack and Meere 2009).
Percentage of the WCPO PS catch (1994-2009)	0.07% (SPC 2010)

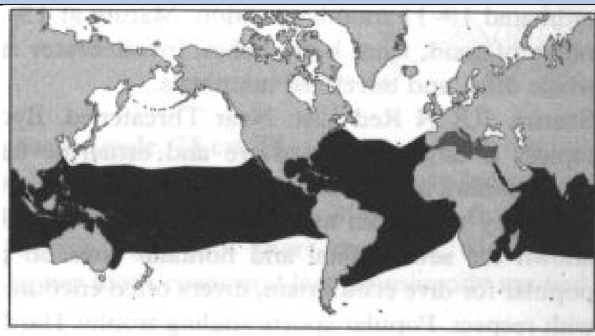
Existing Assessments or Management

In the WCPO	Oshitani (2000): Estimated annual catches of 400,000-600,000 by longlines, and 40,000 by sharks by purse seine over the entire Pacific for 1992-1998.
In other oceans	IATTC (2010): Preliminary assessment work underway for the EPO. NMFS (2009): Assessed for the U.S. Atlantic as part of a large coastal shark complex (not species-specific) but stock status "unknown". Catches prohibited in some fisheries since July 2008.

Oceanic Whitetip Shark (*Carcharhinus longimanus*)



Habitat



Range:	Oceanic and coastal, circumtropical
Depth:	0-500 m

Life History Parameters

Length at First Maturity	175-200 cm	K (von Bertalanffy growth coefficient)	0.10
Age at First Maturity	4-5 years	M (natural mortality)	0.18
L_∞	265 cm	r (intrinsic rate of population increase)	0.09
Maximum Age (♀)	22 years		
Average Litter Size	6		
Reproductive Periodicity	1.3-2 years		

Ecological Risk Assessment Results

Risk from Deep Gear / Shallow Gear	Medium / Medium

International Conventions and Listings

IUCN Redlist Status	Vulnerable
CITES	Proposed for Appendix II at COP 15 (2010) but not listed
CMS	N/A

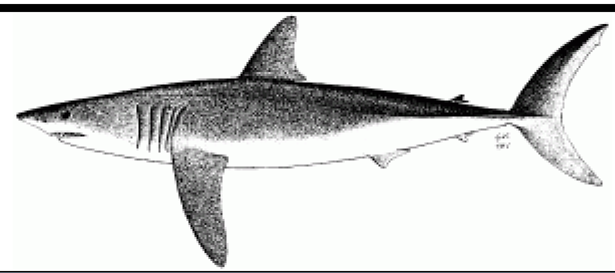
WCPO Fisheries

Estimated Catch in the WCPO (as of 2006 unless otherwise specified)	~3,500 t (SPC 2008) 6,000-12,000 t (Clarke 2009) ~550,000 taken as bycatch in tuna longline fisheries of the Pacific Ocean in 1989 (Bonfil et al. 2008)
Identified by Observers in the LL fishery (as of 2006)	~750 recorded in 2006 (Manning et al. 2009) The second most commonly identified shark in Pacific Island Countries' longline observer records (Lack and Meere 2009)
Percentage of the WCPO LL catch (1994-2009)	1.4% (SPC 2010)
Identified by Observers in the PS fishery (as of 2006)	<100 recorded in 2006 (Manning et al. 2009) Most commonly recorded in Fiji and Palau (Lack and Meere 2009).
Percentage of the WCPO PS catch (1994-2009)	0.01% (SPC 2010)

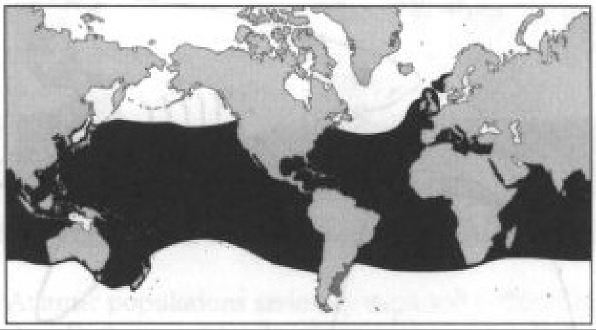
Existing Assessments or Management

In the WCPO	N/A
In other oceans	IATTC (2010): Preliminary assessment work underway for the eastern Pacific Ocean. Bonfil et al. (2008) notes localized depletions and/or very low catches in the Atlantic. This species is under quota management in the U.S. Atlantic and Gulf of Mexico (CITES 2010)

Shortfin Mako Shark (*Isurus oxyrinchus*)



Habitat



Range:	Coastal and oceanic, temperate and tropical
Depth:	0-740 m

Life History Parameters

Length at First Maturity	195-280 cm	K (von Bertalanffy growth coefficient)	0.18
Age at First Maturity	6.5-10 years	M (natural mortality)	0.16
L_∞	323 cm	r (intrinsic rate of population increase)	0.07
Maximum Age (♀)	28 years		
Average Litter Size	12		
Reproductive Periodicity	2-3 years		

Ecological Risk Assessment Results

Risk from Deep Gear / Shallow Gear	Medium / Medium

International Conventions and Listings

IUCN Redlist Status	Vulnerable
CITES	N/A
CMS	Yes, Appendix II

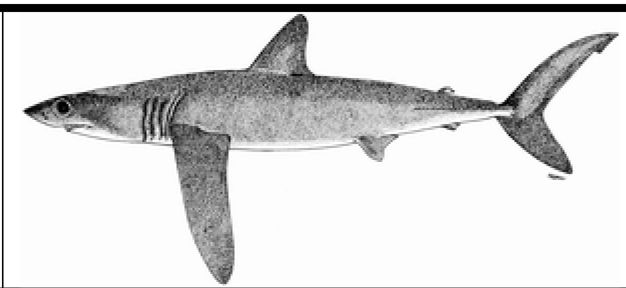
WCPO Fisheries

Estimated Catch in the WCPO (as of 2006 unless otherwise specified)	~5,400 t (SPC 2008) 9,000-18,000 t (Clarke 2009) Semba (2003) estimated annual catches of 15,000-30,000 sharks for the entire Pacific for 1994-1999.
Identified by Observers in the LL fishery (as of 2006)	~600 recorded in 2006 (Manning et al. 2009) The fifth most commonly identified shark/ray in Pacific Island Country observer records (Lack and Meere 2009)
Percentage of the WCPO LL catch (1994-2009)	2.2% (*Isurus* spp.) (SPC 2010)
Identified by Observers in the PS fishery (as of 2006)	Not commonly observed (Manning et al. 2009)
Percentage of the WCPO PS catch (1994-2009)	Negligible (SPC 2010)

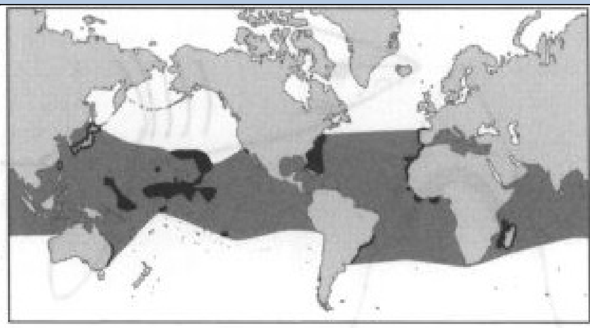
Existing Assessments or Management

In the WCPO	This species is managed under a quota management system in New Zealand (New Zealand Ministry of Fisheries 2009b).
In other oceans	ICCAT (2004, 2008): These assessment failed to draw any conclusion about the stocks but considered that biomass may be below B_{MSY} and fishing mortality may be above F_{MSY}. This species is under quota management in the U.S. Atlantic and Gulf of Mexico (CITES 2010).

Longfin Mako Shark (*Isurus paucus*)



Habitat



Range: A little-known epipelagic, tropical and warm-temperate shark, apparently common in the western Atlantic and possibly in the Central Pacific, but rare elsewhere. Said to be deep-dwelling.	
Depth: 0-740 m	

Life History Parameters[10]

Length at First Maturity	141-254 cm	K (von Bertalanffy growth coefficient)	0.18
Age at First Maturity	6.5-10 years	M (natural mortality)	0.11
L_∞	419 cm	r (intrinsic rate of population increase)	0.02
Maximum Age (♀)	28 years		
Average Litter Size	2		
Reproductive Periodicity	2-3 years		

Ecological Risk Assessment Results

Risk from Deep Gear / Shallow Gear	Medium / Medium

International Conventions and Listings

IUCN Redlist Status	Vulnerable
CITES	N/A
CMS	Yes, Appendix II

WCPO Fisheries

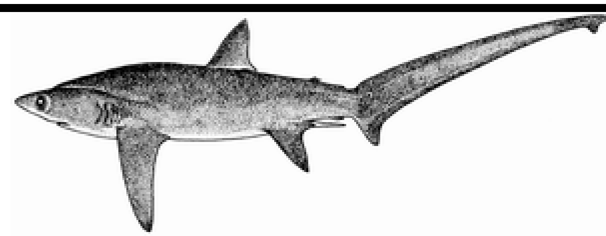
Estimated Catch in the WCPO (as of 2006 unless otherwise specified)	N/A
Identified by Observers in the LL fishery (as of 2006)	Yes (Lack and Meere 2009), but often not distinguished from its conspecific, the shortfin mako
Percentage of the WCPO LL catch (1994-2009)	2.2% (*Isurus* spp.) (SPC 2010)
Identified by Observers in the PS fishery (as of 2006)	Yes (Manning et al. 2009), but often not distinguished from its conspecific, the shortfin mako
Percentage of the WCPO PS catch (1994-2009)	Negligible (SPC 2010)

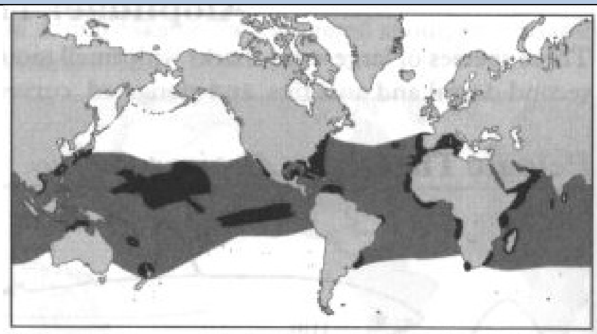
Existing Assessments or Management

In the WCPO	N/A
In other oceans	N/A

[10] Some parameters are species-specific while others have been drawn from the shortfin mako (*I. oxyrinchus*) due to data gaps.

Bigeye Thresher Shark (*Alopias superciliosus*)



Habitat	
	Range: Oceanic and coastal, virtually circumglobal in tropical and temperate seas Depth: 0-500 m

Life History Parameters			
Length at First Maturity	138-341 cm	K (von Bertalanffy growth coefficient)	0.09
Age at First Maturity	7-14.6 years	M (natural mortality)	0.23
L_∞	404 cm	r (intrinsic rate of population increase)	0.01
Maximum Age (♀)	24 years		
Average Litter Size	2		
Reproductive Periodicity	N/A		

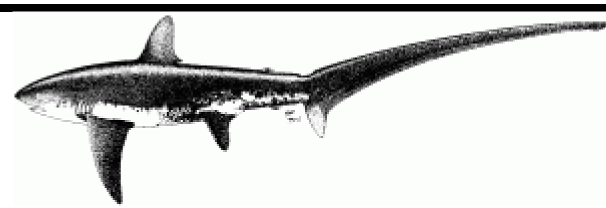
Ecological Risk Assessment Results	
Risk from Deep Gear / Shallow Gear	Medium / Medium

International Conventions and Listings	
IUCN Redlist Status	Vulnerable
CITES	N/A
CMS	N/A

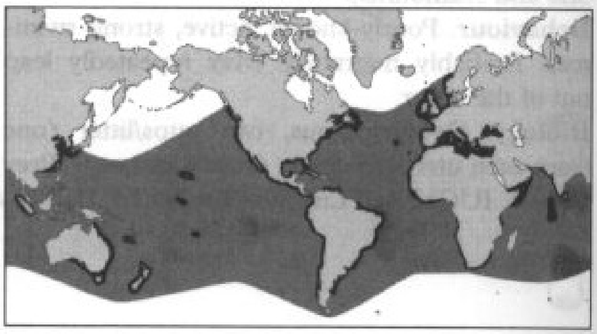
WCPO Fisheries	
Estimated Catch in the WCPO (as of 2006 unless otherwise specified)	10,000-25,000 t (all threshers combined; Clarke 2009)
Identified by Observers in the LL fishery (as of 2006)	~900 recorded in 2006 (Manning et al. 2009). Among the Pacific Island countries mostly observed in the Marshall Islands (Lack and Meere 2009).
Percentage of the WCPO LL catch (1994-2009)	0.4% (*Alopias* spp.) (SPC 2010)
Identified by Observers in the PS fishery (as of 2006)	Yes, but not common (Lack and Meere 2009)
Percentage of the WCPO PS catch (1994-2009)	Negligible (SPC 2010)

Existing Assessments or Management	
In the WCPO	N/A
In other oceans	ICCAT has prohibited catches of this species as of June 2010 with the exception of a Mexican small-scale coastal fishery (ICCAT 2009b).

Common Thresher Shark (*Alopias vulpinus*)



Habitat



Range:	Oceanic and coastal, virtually circumglobal in tropical to cold-temperate seas but commonest in temperate waters
Depth:	0-550 m

Life History Parameters

Length at First Maturity	340-400 cm	K (von Bertalanffy growth coefficient)	0.10
Age at First Maturity	5-7 years	M (natural mortality)	0.23
L_∞	651 cm	r (intrinsic rate of population increase)	0.13
Maximum Age (♀)	22 years		
Average Litter Size	2		
Reproductive Periodicity	N/A		

Ecological Risk Assessment Results

Risk from Deep Gear / Shallow Gear	Medium / Medium

International Conventions and Listings

IUCN Redlist Status	Vulnerable
CITES	N/A
CMS	N/A

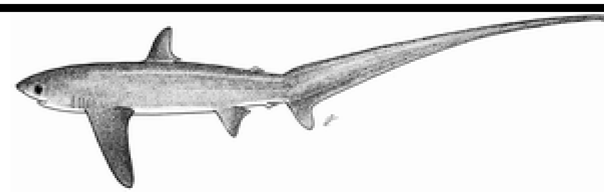
WCPO Fisheries

Estimated Catch in the WCPO (as of 2006 unless otherwise specified)	10,000-25,000 t (all threshers combined; Clarke 2009)
Identified by Observers in the LL fishery (as of 2006)	This species not recorded per se (Lack and Meere 2009)
Percentage of the WCPO LL catch (1994-2009)	0.4% (*Alopias* spp.) (SPC 2010)
Identified by Observers in the PS fishery (as of 2006)	This species not recorded per se (Lack and Meere 2009)
Percentage of the WCPO PS catch (1994-2009)	Negligible (SPC 2010)

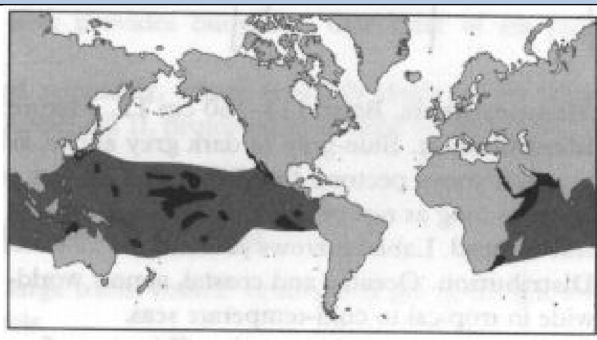
Existing Assessments or Management

In the WCPO	N/A
In other oceans	ICCAT discourages directed fishing for this species as of June 2010 (ICCAT 2009b). This species is under quota management in the U.S. Atlantic and Gulf of Mexico (CITES 2010)

Pelagic Thresher Shark (*Alopias pelagicus*)



Habitat



Range:	Primarily an oceanic, epipelagic, circumtropical species, but sometimes caught near shore
Depth:	0-300 m

Life History Parameters

Length at First Maturity	267-292 cm	K (von Bertalanffy growth coefficient)	0.10
Age at First Maturity	7-9.2 years	M (natural mortality)	0.23
L_∞	190 cm	r (intrinsic rate of population increase)	0.02
Maximum Age (♀)	29 years		
Average Litter Size	2		
Reproductive Periodicity	N/A		

Ecological Risk Assessment Results

Risk from Deep Gear / Shallow Gear	Medium / Medium

International Conventions and Listings

IUCN Redlist Status	Vulnerable
CITES	N/A
CMS	N/A

WCPO Fisheries

Estimated Catch in the WCPO (as of 2006 unless otherwise specified)	10,000-25,000 t (all threshers combined; Clarke 2009)
Identified by Observers in the LL fishery (as of 2006)	Yes, in the Marshall Islands (Lack and Meere 2009)
Percentage of the WCPO LL catch (1994-2009)	0.4% (*Alopias* spp.) (SPC 2010)
Identified by Observers in the PS fishery (as of 2006)	Yes, but not common (Lack and Meere 2009)
Percentage of the WCPO PS catch (1994-2009)	Negligible (SPC 2010)

Existing Assessments or Management

In the WCPO	N/A
In other oceans	N/A