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EU project for the Provision of Scientific Advice for the Purpose of the implementation of the EUPOA sharks: a brief overview of the results for Indian Ocean.

by

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Abstract

The objective of this project was to obtain scientific advice for the purpose of implementing the EUPOA on sharks as regards the facilitation of monitoring fisheries and shark stock assessment on a species-specific level in the high seas. The study was focused on major elasmobranch species caught by both artisanal and industrial large pelagic fisheries on the High Seas of the Atlantic, Indian and Pacific area, which are currently monitored and potentially managed by respective Tuna RFMOs.

Estimated "potential" shark species catch in the Indian Ocean is around 160,000 t for 22,000 t. presently declared (7 times higher than declared). Considering all sharks that are not reported at species level, the total amount of shark declared was around 100,000 tons and, thus, the underreporting reduced to 1.6 times higher. 19 fisheries among the 195 fisheries found in IOTC database generate 86 % of potential investigated shark catches.

In the Indian Ocean, Gillnet (GN) and a composition of Gillnet and Longline (GN-LL) are the most impacting one with 61 % of the total estimated studied shark species catches (97,000 t). It is followed by longline (LL and LL-swo) with 18 % and other métiers (OTH) with 12 %, which precise gear composition is unknown. The blue shark is estimated to be the major shark catch in the Indian Ocean followed by silky shark, threshers, Oceanic whitetip, shortfin mako and hammerheads sharks.

The research framework to be proposed is organized in three steps: (i) estimation of shark catches by species using the method proposed here which allows identifying the most impacted shark species and the métier most affecting those species; (ii) a preliminary Ecological Risk Assessment (or other preliminary assessment based on fishery indicators) by fleets which allows to identify the most vulnerable species to focus the efforts in conjunction with point (i); and (iii) specific recommendations of how to apply possible management measures, to improve data collection and assessment of those fleets/species identified as priorities based on points (ii) and (iii). The implementation of the three steps is highly related.

Introduction

Sharks are particularly vulnerable to overexploitation because of their biological characteristics of maturing late, low reproductive capacity and being long-lived. This results in these species having a limited capacity to recover from periods of over-fishing or other negative impacts. Action on sharks by the Food and Agriculture Organization of the United Nations (FAO), international treaties such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Regional Fisheries Management Organizations (RFMOs) and shark catching countries and entities has been prompted by increasing international concern about shark stocks as a result of a growing body of evidence that many shark species are threatened and continuing to decline because of the fishing activity.

The purpose of the European Union Plan Of Action on Sharks (EUPOA) is to contribute to the general objectives outlined in the FAO IPOA Sharks by ensuring the rebuilding of many depleted stocks fished by the European Union fleet within and outside European Union waters. The Action Plan outlines what is already in place and what is still needed to do to ensure a comprehensive and coherent legislative policy and legislative framework for the conservation and management of sharks within and outside European Union waters.

The main objective of the European Union Action Plan is to contribute to the sustainability of shark populations fished by the European Union fleet within and outside European Union waters. The proposed Plan of Action covers any fishery activity in relation to sharks such as directed commercial, by-catch commercial, directed recreational, and by-catch recreational fishing of any shark within European Union waters but also of the European Union fleet fishing in high seas and managed by RFMOs.

The Action Plan pursues the following three specific objectives[1]:

- To broaden the knowledge both on shark fisheries and on shark species and their role in the ecosystem;
- To ensure that directed fisheries for shark are sustainable and that by-catches of shark resulting from other fisheries are properly regulated;
- To encourage a coherent approach between the internal and external European Union policy for sharks.

Thus, from a scientific point of view the operational objective of the EUPOA on sharks aims to efficiently monitor and assess shark stocks on a species-specific level and develop harvesting strategies in accordance with the principles of biological sustainability and rational long term economic use.

Scientific advice for the purpose of the management of shark species in the high seas is carried out mainly via the Scientific Committees of the relevant RFMOs, as well as through specific projects by national institutes, and other research organisms. However, the level of knowledge concerning many shark populations in the high seas of the

[1] On a European Union Action Plan for the Conservation and Management of Sharks. COM(2009) 40 final. SEC(2009) 103.

Atlantic, Indian and Pacific Oceans is far from satisfactory. It is therefore necessary to identify gaps in the current knowledge of biology and ecology of sharks which should be filled by undertaking studies in order to support advice on sustainable management of elasmobranches' fisheries.

In this context, the European Commission Directorate-General for Maritime Affairs and Fisheries (DG-MARE) promoted a project with the objective to obtain scientific advice for the purpose of implementing the EUPOA on sharks as regards the facilitation of monitoring fisheries and shark stock assessment on a species-specific level in the high seas. The study was focused on the large pelagic fisheries in the high seas of the Atlantic, Indian, Pacific Oceans and adjacent seas.

Specifically, the study provided scientific information and advice on issues relating to the management of shark fisheries. It collated and examined historical fisheries data especially on species composition of catches, realised catches and effort and identified gaps in the current knowledge of the biology and ecology of sharks.

More specifically, the project had two main phases each consisting of the following tasks:

- Phase 1: Data collection, analysis and management
  - ✓ Task 1.- Historical Catch/Effort data;
  - ✓ Task 2.- Estimation of discards levels;
  - ✓ Task 3.- Length frequencies from observers;
  - ✓ Task 4.- Biological information;
  - ✓ Task 5.- Fishery indicators (blue shark and shortfin mako).

- Phase 2: Data analysis and support to scientific advice
  - ✓ Task 6.- Design an observer program;
  - ✓ Task 7.- Formulation of scientific advice;
  - ✓ Task 8.- Integration of information to tuna RFMOs.

Where in the first phase a review of existing fishery, biological data, and assessments was carried out and, in a second step, a program for the developing the scientific advice identifying the data and research gaps and the need of coordination was formulated.

The project was focused on major elasmobranch species caught by large pelagic fisheries (especially longline fishery, purse seine fishery, but also other major fisheries depending on the areas) on the High Seas of the Atlantic, Indian and Pacific area, which are currently monitored and potentially managed by the respective tuna RFMOs (ICCAT, IOTC, IATTC, and WCPFC). Therefore, the following list of species was identified to be covered by the project (Figure 1).

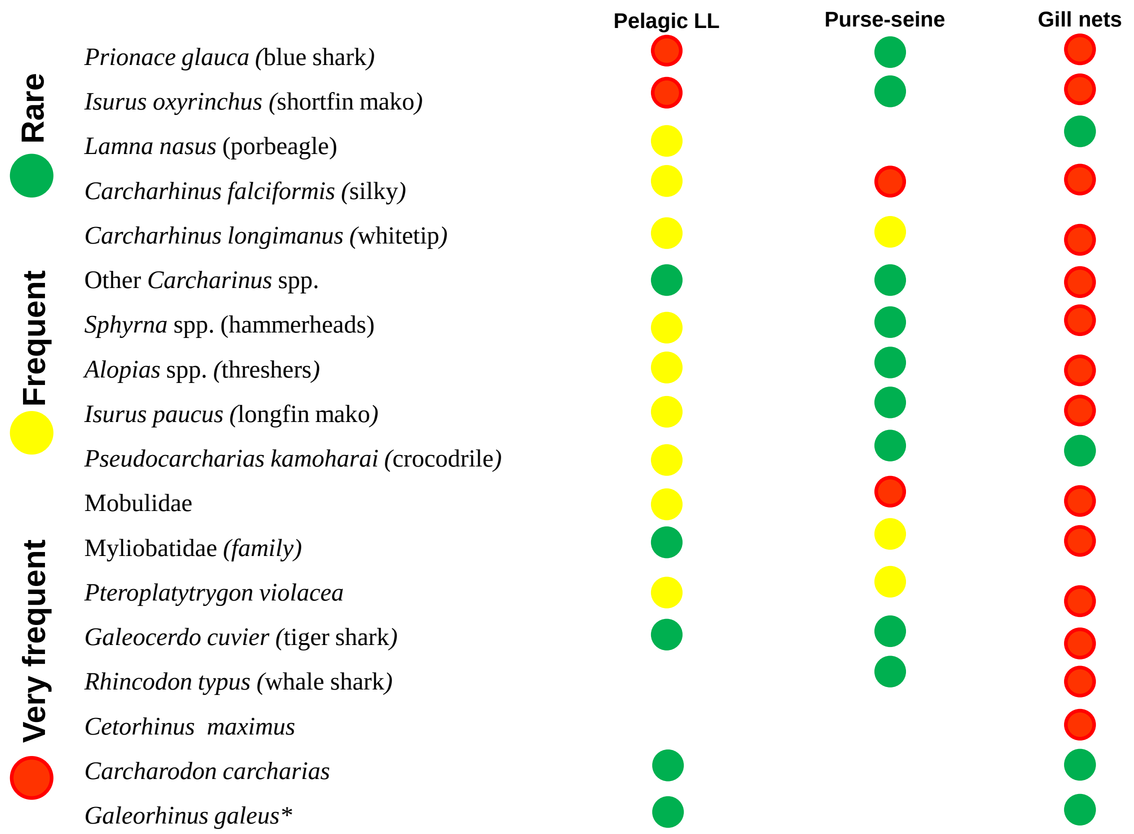

Figure 1.- Studied shark species through the project and their susceptibility to catch.

In this paper we present the main results of the project in relation to the estimation of shark catches in the Indian Ocean. The full report can be downloaded from: http://ec.europa.eu/fisheries/documentation/studies/sharks/index_en.htm

Methodology and data used

The Nominal Catch Information database which presents the nominal annual landing by shark species, region, gear and flag available on IOTC website was used. This database presents RFMO official shark landing data for major fleets and countries catching sharks based on current data available in the RFMO.

The Estimation of “possible” catch shark by major fleets and countries which are supposed to be catching shark was done based on the ratio of shark catch/bycatch over target species catch estimated through observers, literature or personnel communication. For this estimation, dataset available in IOTC was analyzed in order to identify fleets susceptible to generate important catch of sharks. Based on the assumption that target species quantities declared by flag/fleet to RFMO are correct estimation and that it is reliable to use these estimates to compute their potential shark catch knowing their métier (target species and their gear) and the corresponding ratio (shark bycatch/target species), we estimated the volume of sharks caught by fleets and ranked the main ones susceptible to impact sharks populations.

Based on the original database of RFMO which includes tuna and shark catch information by year, species, areas, gear, country, flag and fleet, we estimated the "potential" shark catches done by major fleets involved in shark fishery for the period 2000-2010.

In a first step a Ratio references table by métier (reference table of ratio shark bycatch/catch over target species catch by métier) was prepared. To do this a list of métiers (combination of gear and target species group) was identified, and for each of these métier the following parameters were defined:

1. a ratio of shark (all species together) catch to target species group (in weight); and
2. shark species composition in proportion (sum = 1; the project focuses on 18 major sharks species).

The ratio's reference table then is a summary including a list of métiers (see Table 1) and the ratio of shark catch (all species together) to target species group (in weight) as well as the shark species composition (in proportion) of the studied shark species.

So, this ratio reference table by métier incorporates the gear/target species information for each gear indicating the group of species targeted by the fishery. The ratio is the quantity (in tonnes) of sharks (all species included) caught for one ton of target species. For example, it is assumed in this study that baitboats (BB) generates zero (0) ton of sharks per ton of major tunas whereas gillnet combined (GN) generates 2 tons of shark per ton of target species (mostly tunas).

Table 1.- Ratio reference table by métierbased on literature available, expert knowledge and unpublished observer data. *In italic: an example to illustrate the species composition of shark catch.*

Gear name	Metier Studied Sharks	Target species	Ratio catch / Target_sp	BSH	BSK	FAL	…	ALL
Baitboat	BB	Major tunas	0.000	*0.75*	*0*	*0.25*	*0*	*1*
Gillnet combined	GN	Major tunas	2.000					
Gillnet Inshore	GN-in	Small tunas	1.000					
Gillnet Offshore	GN-off	Major tunas	1.000					
Gillnet for sharks	GN-shark	Sharks	2.000					
Handline	HL	Major tunas	0.002					
Longline (others)	LL	Major tunas	0.150					
Longline for sharks	LL-shark	Sharks	1.200					
Longline for swordfish	LL-swo	Swordfish	0.700					
Longline for tunas	LL-tuna	Major tunas	0.150					
Others	OTH	Major tunas	0.300					
Purse seine	PS	Major tunas	0.002					
Purse seine - BFT	PS-bft	Major tunas	0.000					
PS: Small scale	PSST	Major tunas	0.002					
Surface fisheries	SURF	Major tunas	0.500					
Trammel net	TN	Major tunas	0.002					
Trawl	TW	Major tunas	0.010					

In a second step the data was prepared. Data of task I (total nominal catches by flag and year) from RFMO were compiled by fishery i.e. a combination of flag, fleet and gear for the period 2000- 2010 (11 years). Mean nominal catches were calculated for target species groups (studied shark species, major tuna including billfishes but excluding swordfish, swordfish, other sharks, other species, small tunas). Two types of means were calculated:

1. a simple mean using all 11 years including 0. This means that if a country makes no declaration one year, this is used as 0 catch. It is assumed here that each 0 or blank (no declaration) corresponds to a year without catch. This method gave the **Low** estimate;
2. a simple mean considering only years with positive shark catches because we assumed that most zero declaration were not zero catches. This method gives the **High** estimate;

The number of positive years was compiled to see the effect of these two assumptions on the results.

Besides, a métier was identified for each fishery according expert knowledge and species group profile declared.

Finally, the "potential" shark catches by métier based on the ratio by métier (step 1) and target species average nominal catch declared (step 2) was estimated as

$$\text{Studied Shark Species shark catch} = \text{Target species} * \text{Ratio}_{\text{studied shark species/target species}}$$

Results

Table 2 presents the nominal catch of shark species available in the IOTC database as by 25/05/2012. The information of catches until 1986 is given as total shark catch and since then the information is reported by species when possible (Table 2). Although the information is broken down by species, in all year the % of unidentified sharks is around or greater than 75 %.

Table 2.- Nominal catch of shark species by species 1950-2009 in the IOTC database.

Year/Code	Lamnidae MSK	Short fin SMA	Makos MAK	Longfin mako LMA	Oceanic whitetip OCS	Silky FAL	Carcharhinidae RSK	Cocodrile PSK	Tope GAG	Bigeye Thresher BTH	Thresher ALV	Threshers THR	Blueshark BSH	Smooth hammerhead SPZ	Hammerheads SPN	Unidentified Shark SHK	Minor sharks	TOTAL
1950																2,600		**2,600**
1951																4,155		**4,155**
1952																3,714		**3,714**
1953																2,852		**2,852**
1954																2,784		**2,784**
1955																2,737		**2,737**
1956																2,725		**2,725**
1957																2,967		**2,967**
1958																3,144		**3,144**
1959																3,422		**3,422**
1960																3,956		**3,956**
1961																4,627		**4,627**
1962																6,613		**6,613**
1963																8,503		**8,503**
1964																12,306		**12,306**
1965																10,433		**10,433**
1966																11,615		**11,615**
1967																14,317		**14,317**
1968																14,047		**14,047**
1969																15,504		**15,504**
1970																18,293		**18,293**
1971																19,406		**19,406**
1972																24,710		**24,710**
1973																18,846		**18,846**
1974																20,447		**20,447**
1975																17,811		**17,811**
1976																21,326		**21,326**
1977																21,674		**21,674**
1978																27,815		**27,815**
1979																25,766		**25,766**

1980																27,123		**27,123**
1981																19,410		**19,410**
1982																15,730		**15,730**
1983																19,693		**19,693**
1984																14,401		**14,401**
1985																17,587		**17,587**
1986	48	4			98	449	74					67	171		61	19,730		**20,701**
1987	60	5			122	562	92					83	214		77	29,667		**30,883**
1988	63	6			127	584	96					87	222		80	20,067		**21,331**
1989	116	10			234	1,076	177					160	409		147	34,977		**37,307**
1990	166	16			335	1,540	253					229	585		210	25,861		**29,194**
1991	214	19			433	1,991	327					296	757		271	38,302		**42,610**
1992	312	28			632	2,904	477					431	1,104		396	63,467		**69,751**
1993	468	52		2	947	4,356	723					647	1,656		595	63,980		**73,425**
1994	754	148		3	1,525	7,010	1,317					1,041	2,844		968	59,943	1	**75,554**
1995	793	75			1,604	7,376	1,216					1,095	2,834		1,007	53,757	0	**69,758**
1996	716	71			1,447	6,654	1,114					988	2,565		909	49,060	0	**63,524**
1997	1,141	224		0	2,313	10,619	1,763		25			1,577	4,359	6	1,448	65,268	23	**88,765**
1998	997	469		1	2,026	9,231	1,538		6			1,434	4,480	16	1,258	64,546	10	**86,012**
1999	1,481	736		30	3,050	13,740	2,356		20			2,057	8,341	11	1,876	81,115	70	**114,884**
2000	439	388		5	2,647	10,886	3,679		16			265	9,020		1,201	81,588	56	**110,191**
2001	175	278		0	1,323	5,529	3,846		2			470	4,072	1	178	82,020	1	**97,894**
2002	267	524		0	1,022	2,947	1,039					1,121	6,766	2	880	85,802	4	**100,375**
2003	231	1,079		2	1,141	3,505	3,504	0	1	1		2,000	9,324	2	594	83,621	71	**105,075**
2004	171	1,565		5	648	2,949	1,707		8	0		1,005	10,493	1	449	85,631	154	**104,784**
2005	46	2,089		15	271	666	845		2	8		398	11,335	4	181	68,837	106	**84,803**
2006	40	1,401		50	289	748	939	1	1	10		341	8,599	3	133	69,657	58	**82,271**
2007	101	1,200	311	10	166	461	540	0		1		588	9,051	2	121	64,170	469	**77,190**
2008	25	1,048	586	5	175	447	501			1		226	7,613	3	121	66,165	693	**77,611**
2009	29	564	1,160	407	245	543	616	0		5	1	252	9,978	0	128	65,312	938	**80,180**

The "potential" shark catches by métier and the main fleets that could be mainly responsible for the catch of the shark species included in the study during the period 2000-2010, based on the best assumption of the shark catch over target species catch ratios derived from the literature, were estimated and ranked by

(i) Studied shark species mostly impacted;
(ii) Métier most impacting studied sharks species altogether;
(iii) Métier most impacting studied sharks species by species.

Estimated "potential" studied shark species catch for the high estimation approach is around 160,000 t for 22,000 t. presently declared (7 time higher than declared) (Figure 2). Considering all sharks that are not reported at species level, the total amount of shark declared was around 100,000 tons and, thus, the underreporting reduced to 1.6 times higher. 19 fisheries among the 195 fisheries found in IOTC database generate 86 % of potential investigated shark catches. These fisheries are not those already declaring the bulk of studied shark catches and are those with the highest unreported catches of the species investigated in the project. The estimation of "potential" investigated shark species for the low estimation is around 152,000 tonnes which is similar in the case of Indian Ocean for the high estimation and, thus, to avoid repetition in the results only high estimation values will be showed in this paper.

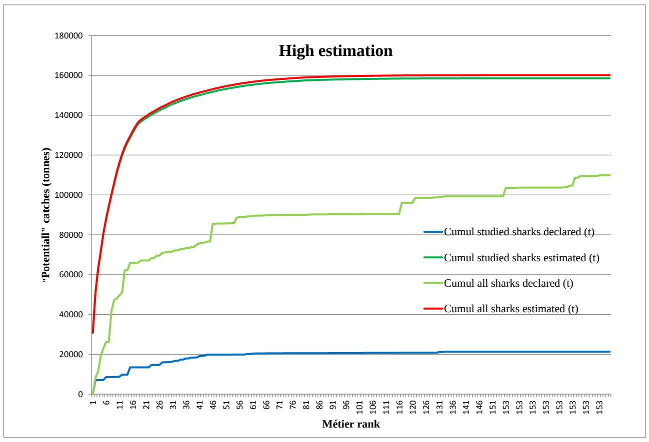

Figure 2.- Cumulative "potential" catch and declared catches of studied shark species as well as all shark together by fisheries ranked according their descending estimated of studied shark species catches.

Among the different métier identified, Gillnet (GN) and a composition of Gillnet and Longline (GN-LL) are the most impacting one with 61 % of the total estimated studied shark species catches (97,000 t) (Figure 3). It is followed by longline (LL and LL-swo) with 18 % and other métiers (OTH) with 12 %, which precise gear composition is unknown.

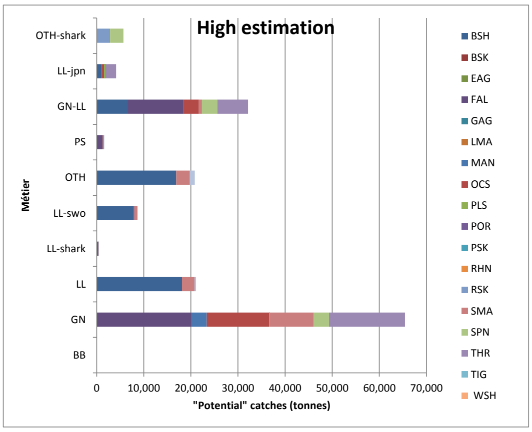

Figure 3.- Estimated Catch (tonnes) by Métiers and by studied shark species.

In the Indian Ocean, there are mainly two groups of métiers impacting the most important, in terms of total catch, two groups of shark species (Figure 4). Gillnet (GN - *sensu lato*) are impacting mainly silky (FAL), thresher (THR), Oceanic whitetip (OCS), and shortfin mako (SMA) sharks; whereas Longline (LL - *sensu lato*) impacts mainly blushark (BSH) and shortfin make (SMA) as well.

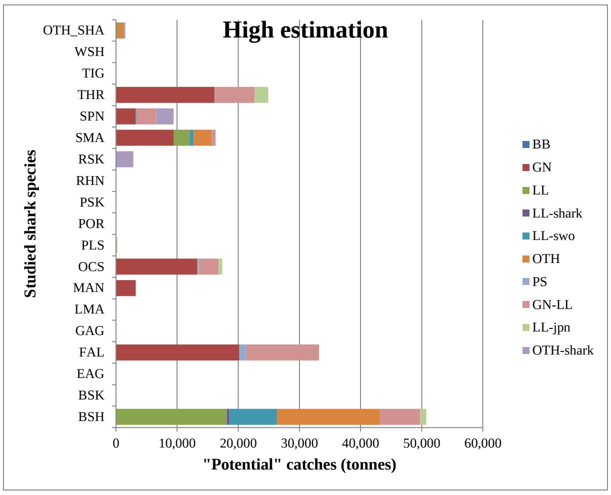

Figure 4.- Estimated Catch (tonnes) by studied shark pecies and by Métier.

17 fleets are identified as the major players in the Indian Ocean (Table 3). The main origin of underreporting is identified and relies on the difference between the declared value and the estimated value. The total average amount of sharks species studied estimated is 7 times higher than the average amount declared by species in the Indian Ocean based on our results.

Table 3.-Average yearly studied sharks species catch reported to the IOTC and the estimation carried out in the study (tons/year) by fleet; and the more accurate value considered (Retained value) between 2000 and 2010. Sharks estimated catch (tons) and % unreported by fleets. Na: data not available.

Fleet/Métier	Declared catch	Studied shark estimated catch	Cumulated Studied shark estimated	% Cumulated Studied shark estimated
IRN-GN	0	34,375	34,375	22.8
LKA-GN-LL	7076	32,141	66,516	44.1
IDN-GN	0	13,760	80,276	53.2
TWN-LL	547	9,075	89,352	59.2
YEM-OTH	0	6,074	95,426	63.2
IDN-OTH	0	6,039	101,464	67.2
PAK-GN	0	5,966	107,430	71.2
MDG-OTH-shark	0	5,690	113,120	75.0
IDN-LL	217	5,026	118,147	78.3
JPN-LL-jpn	466	4,116	122,263	81.0
OMN-GN	0	3,912	126,175	83.6
COM-OTH	0	2,952	129,127	85.6

IND-GN	0	2,870	131,997	87.5
ESP-LL-swo	3693	2,536	134,533	89.2
MDV-OTH	0	1,774	136,306	90.3
IND-LL	38	1,338	137,645	91.2
OMN-OTH	0	997	138,641	91.9

Table 4 compares the average yearly "potential" catch of studied shark species by species and métiers with the Ecological Risk Assessment (Murua *et al.*, 2012) carried out in the Indian Ocean in 2012.

Table 4.- Estimated (or range of estimated) annual catches of major species (MT) in the Indian Ocean tuna fisheries, for the period 2000-2011. Indication of ERA rank (top table, taking into consideration susceptibility for longline) and species productivity (as provided by Murua *et al.* (2012).

FAO code		Species name	Common name	LL Rank ERA	Productivity (Lambda)	Iran (GN off-shore)	Sri Lanka (G/L)	Sri Lanka (GN)	Indonesia (GN)	Indonesia (GHLI)	Taiwan (LL)	Yemen (HAND)	Pakistan (GN)	Madagascar (TROL)	Indonesia (TROL)	Indonesia (FLL)	Japan (LL)	Iran (GN)	Indonesia (GN)	UE-Spain (LL)	Other métiers
	SMA	*Isurus oxyrinchus*	Shortfin mako	1	1.061	4432	417	243	1283	694	898	895	857	0	792	600	0	508	412	178	3171 - 3512
	FAL	*Carcharhinus falciformis*	Silky shark	4	1.075	9497	7510	4370	2749	1488	0	0	1837	0	0	0	0	1088	884	8	2396 - 2544
	OCS	*Carcharhinus longimanus*	Oceanic whitetip shark	5	1.162	6268	2065	1202	1814	982	0	0	1213	0	0	0	573	718	583	8	1102 - 1138
	POR	*Lamna nasus*	Porbeagle	7	1.041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	13 - 19
	LMA	*Isurus paucus*	Longfin mako	8	1.029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	13 - 19
	BSH	*Prionace glauca*	Blue shark	10	1.483	0	4130	2403	0	0	6149	5179	0	0	4581	4109	1007	0	0	2288	17874 - 20907
	PLS	*Pteroplatytrygon violacea*	Pelagic stingray	13	1.242	0	0	0	0	0	0	0	0	0	0	0	232	0	0	0	0
RSK	DUS	*Carcharhinus obscurus*	Dusky shark	12	1.027	0	0	0	0	0	0	0	0	2845	0	0	0	0	0	1	41306
	CCP	*Carcharhinus plumbeus*	Sandbar shark	15	0.978																
SPN	SPZ	*Sphyrna zygaena*	Smooth hammerhead	6	1.281	1520	2065	1202	440	238	0	0	294	2845	0	0	0	174	141	33	274 - 299
	SPM	*Sphyrna mokarran*	Great hammerhead	9	1.098																
	SPL	*Sphyrna lewini*	Scalloped hammerhead	14	1.062																
THR	BTH	*Alopias superciliosus*	Bigeye thresher	2	1.033	7598	4130	2403	2199	1191	0	0	1470	0	0	0	2239	871	707	3	1093 - 1101
	PTH	*Alopias pelagicus*	Pelagic thresher	3	1.098																
	ALV	*Alopias vulpinus*	Common thresher	16	1.148																
SKH	TIG	*Galeocerdo cuvier*	Tiger shark	11	1.147	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	WSH	*Carcharodon carcharias*	Great white shark			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	BSK	*Cetorhinus maximus*	Basking shark			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	GAG	*Galeorhinus galeus*	Tope shark			0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4 - 6
	EAG	Myliobatidae	Eagle rays nei			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	MAN	Mobulidae	Mantas, devil rays nei			1520	0	0	440	238	0	0	294	0	0	0	0	174	141	0	282 - 292
	PSK	*Psedocarcharias kamoharai*	Crocodile shark			0	0	0	0	0	0	0	0	0	0	0	65	0	0	0	0
	RHN	*Rhincodon typus*	Whale shark			6	0	0	2	1	0	0	1	0	0	0	0	1	1	0	1 - 1
	OTH_Sharks		Other sharks			0	0	0	0	0	112	320	0	0	283	75	0	0	0	0	710 - 765
Estimated total shark catches (MT)						30841	20318	11823	8928	7159	6394	5966	5690	5655	4833	4785	4116	3534	2870	2536	26935 - 30606

In the Indian Ocean, impact on studied shark species is highly concentrated in 4 métiers, which generate more than 60 % of the estimated studied shark species (Figure 5). GN from Iran, Sri Lanka, Indonesia are leading followed by Taiwanese longliners.

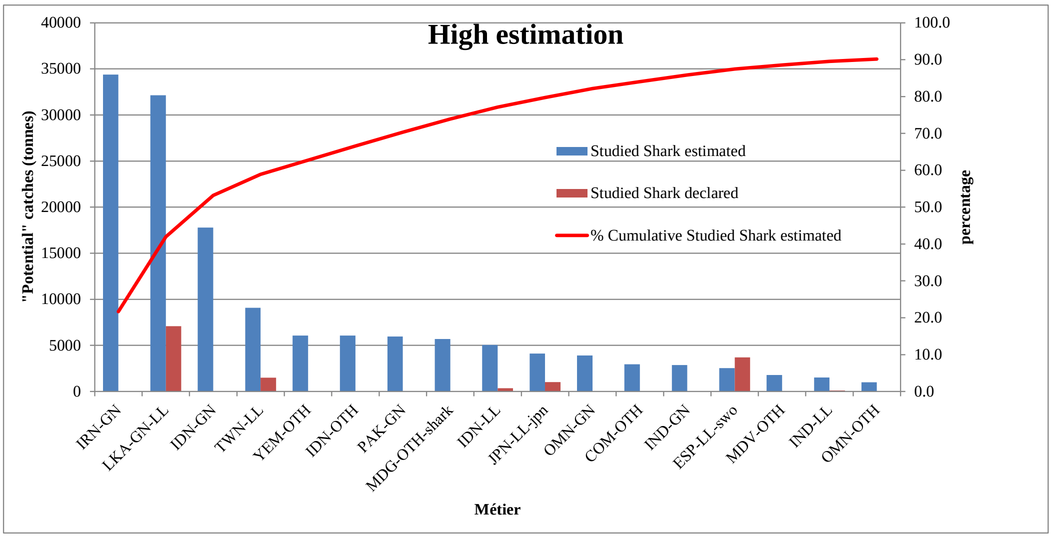

Figure 5.- Main fisheries (Flag and Métier) impacting studied shark species in the Indian Ocean.

Figure 6 shows the difference between the declared nominal catch of shark by species and our estimations by species. The underestimation is mainly related to the species with most catches such as blueshark, silky shark, oceanic whitetip shark, thresher shark and shortfin-mako shark for which our estimation are 3.9, 10.5, 19.4, 33.5, 10.6 higher respectively, than the declared estimation. Underestimation of studied shark species catches concerns all species at an extremely high level.

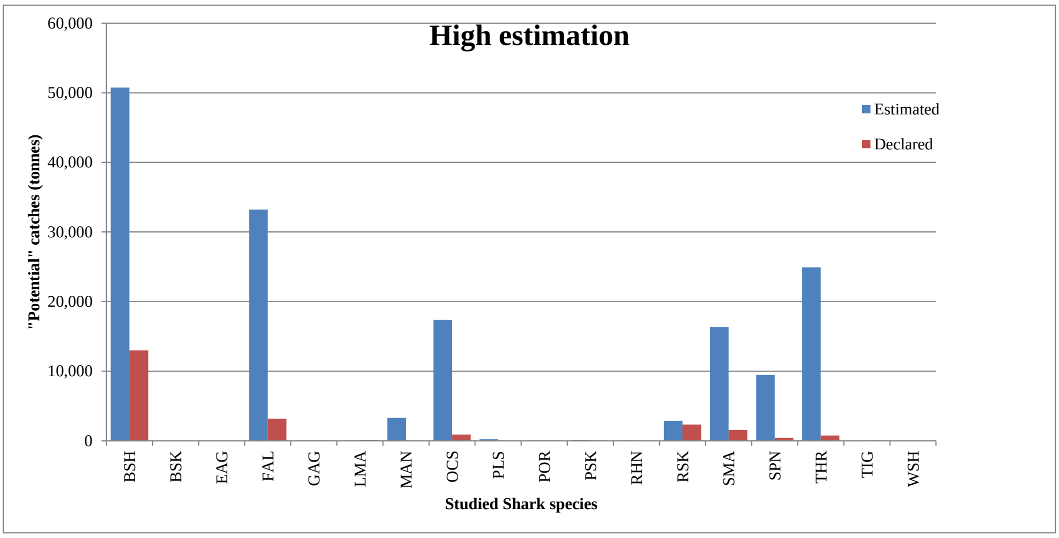

Figure 6.- Most impacted studied shark species (reported vs estimated) based on the difference between the declared nominal catch of shark by species and our estimations by species.

The relative proportion of the species on the estimated catches of sharks in the Indian Ocean is shown in the figure Figure 7. The blue shark is estimated to be the major shark catch in the Indian Ocean followed by silky shark, threshers, Oceanic whitetip, shortfin mako and hammerheads sharks. This is quite different from other Oceans but not unexpected due to the high catch of target species, and expected associated shark bycatch done by gillnets in the Indian Ocean.

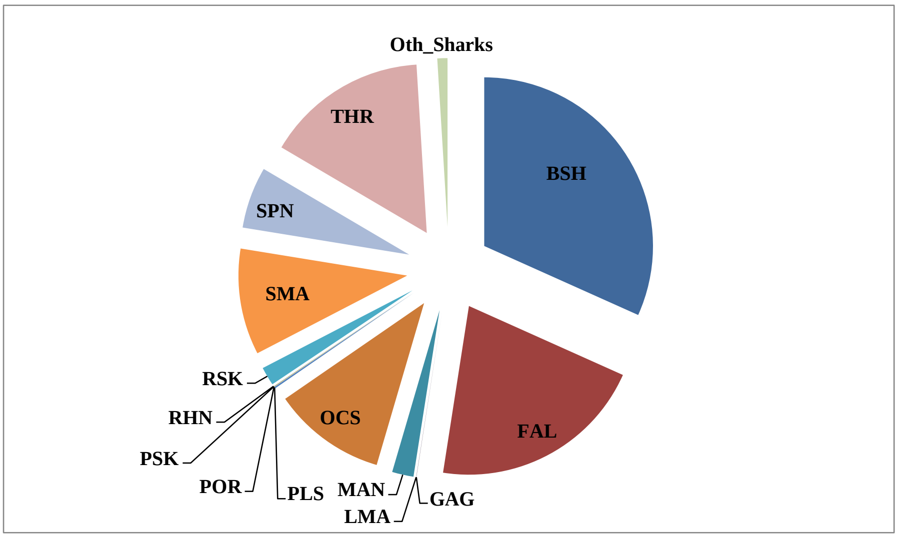

Figure 7.- Relative contribution of the total "potential" catch estimated for studied shark species in the Indian Ocean.

Discussion

<u>Methodological Approach</u>

Uncertainties in studied shark catches estimation may come from different sources: (i) from métier classification, (ii) from target species quantities declared and (iii) from the shark/target catch ratio used to estimate shark catches.

The fleets mainly responsible for the shark species studied were identified on the basis of tuna and tuna like catch reported to IOTC. IOTC data are based on reports from the national fisheries agencies which are affected by the limitations in reporting efficiency and problems of species identification and species breakdown. The estimates depend on the level of undereporting and non-reporting of tuna and tuna like catch by the countries.

The information on bycatch is scarce and the bycatch estimates found in the literature are not homogenous which made the raising and/or estimates of ratios uncertain due to various assumptions made (e.g. conversion of the estimates in number of individuals into weight without any information on the mean size per species).

For example, for other Oceans the total studied shark species catch is estimated to be 128,000 tons when a 0.15 ration is used for LL, whereas the catch is estimated as 175,000 when the ratio used is 0.5. Therefore, it is very important to have observer data to estimate those ratios. Moreover, ratios of studied sharks on target species have been considered homogeneous for the entire area exploited by the fishery. However, it is well known that ratios may vary according to fishing areas and this fact is sometime documented in literature. Further analysis would gain in precision by aggregating data by large fishing areas.

A global sensitivity analysis of results should be conducted according to these different sources of uncertainties. Monte Carlo simulation may be used after assigning confident intervals to these different input parameters.

Another assumption which could produce different estimations is the way in which undeclared catches are considered (i.e. as 0 catches or just not reported). Average catch estimates based on positive year declaration avoid considering undeclared catch as 0 catch but consider an average positive catch for years without catch declaration. In the case of Indian Ocean, this does not impact the global figure (+5%) but for other Oceans this method can generate important differences: 50 % of difference globally between the two methods in the Atlantic. This method may effectively correct undeclared catch (years undeclared) but may also consider non-active fisheries as active fisheries during the 11 years period studied. This assumption should be further explored. It is worth noting that the mean number of year declared is twice in the Indian Ocean than in the Atlantic Ocean.

At this step we considered the estimate calculated with positive mean as the high level estimate and the one calculated with the simple mean including zero as the low level one.

Shark Catch Estimation

In the Indian Ocean, the gillnet fleet is the most important métier catching sharks; which contributes with 61 % followed by the longliners with 18 % of the potential catch.

In general, the species composition of the sharks in different métiers is similar in all areas. For example, longline (LL - *sensu lato*) impacts mainly blueshark (BSH) and shortfin make (SMA) and in a minor extend hammerhead, threshers, silky and oceanic whitetip sharks; whereas Gillnet (GN - *sensu lato*) are impacting mainly silky (FAL), thresher (THR), oceanic whitetip (OCS), and shortfin mako (SMA) sharks. Although the contribution to the total catch of purse seiner is minor (less than 1 % of total catch in the Indian Ocean); the species composition of purse seiner catch is clearly dominated by silky and oceanic whitetip sharks.

In relation to the species composition, in the Indian Ocean the blueshark contribution to total shark catch is around 35 % followed by silky shark (21 %), thresher (16 %), oceanic whitetip (11 %), shortfin mako (10 %) and hammerheads (6 %).

The data above should be considered in the light of the different species productivity and susceptibility of a given species to a giving métier. This is important to take into account because in some cases a minor catch of one species of all fleets, or one fleet in particular, can have a great impact on a more vulnerable species with low productivity and high susceptibility. So, it is important to consider the results above in the framework of Ecological Risk Assessment which can help to identify priorities for observer programs/research efforts.

In that context, the exercise presented in this paper provided a complete picture of what are the main fleets targeting the more important shark species caught in the Indian Ocean as well as the extent of their volume (Table 5). The estimation also helps to identify the different species for which more focus is needed and those that are supposed to be caught in a lesser extent. This will help to focus the target or more important fleets to monitor and design specific representative observer and research programs for those fleets.

Table 5.- Summary of the main métiers impacting global catches of shark species in IOTC and summary of most impacted shark species in IOTC (based on our estimation).

	IOTC
Fisheries most impacting Studied Sharks (% of total catch)	1. Gillnet (61%) 2. LL (18 %) 3. Other gears (12 %) 4. PS (1 %)
Studied shark most impacted (the gear most impacting this species)	1. Blueshark (32 %) 2. Silky shark (21 %) 3. Thresher (16 %) 4. Oceanic whitetip (11 %) 5. Shortfin mako (10 %) 6. Hammerheads (6 %)

Research Recommendations

Within the framework of the Code of Conduct for Responsible Fisheries, the FAO adopted in 1999 the International Plan of action for the conservation and management of sharks (IPOA-Sharks). While the FAO plan of action is not binding, it aims to provide all concerned States with a reference point and guidelines for designing their own plans for the conservation, management and long-term sustainable exploitation of sharks. The FAO IPOA-Sharks applies to States in the waters of which sharks are caught by their own or foreign vessels and to States the vessels of which catch sharks on the high seas. States should adopt a national plan of action for conservation and management of shark stocks (Shark-plan) if their vessels conduct directed fisheries for sharks or if their vessels regularly catch sharks in non-directed fisheries. Each State is responsible for developing, implementing and monitoring its Shark-plan which mainly is focused, along with other provisions, to ensure that sharks populations are sustainable (FAO, 1999).

Having in mine the data gaps for major fisheries impacting pelagic sharks stocks in the different tuna RFMOs Conventions areas as well as the most important mètier catching sharks and most impacted shark species; the following is a brief overview of some possible solutions and recommendations for the implementation of research programmes on those fisheries, aiming to improve shark data collection, namely regarding shark catch and discards; species composition; vessel mortality; size and sex data.

The data collected in this project gave a complete picture of the current data availability of information about catch and effort, observer programs, size frequency information, biological information and fishery indicators that may support the assessment of major shark species in tuna RFMOs. Moreover, this revision has allowed also gathering information of other various issues currently addressing in tuna RFMO with regard to shark assessment and management, such as current management measures.

In general, there is a scarcity of data and limited data availability for major fleets and countries in tuna RFMOs. Attending to historical data, several countries were not collecting fishery statistics, especially in years prior to the development of tuna and tuna-like fisheries in early 1970s. At the moment, industrial fisheries provide limited data while artisanal and small scale fisheries data is almost non-existent due to monitoring difficulties. Many tuna RFMO countries are not reporting any catches or, in the case of few countries, only a small number of landings are declared. The information on the catch of sharks provided by the countries is thought, for this reason, to be incomplete in several countries. The catches recorded in other cases might not represent the total catches of sharks but simply the amounts retained on board (e.g. dressed weights instead of live weights). The catches of sharks for which only the fins are kept on board are rarely recorded.

Therefore catches of sharks might have gone unrecorded. The main consequence of this is that, at the moment, the catches of sharks available cannot be used to estimate reliably total catches of sharks. At this point, estimations of catch are made based on ratios published by literature. Then, the consistency of these estimations is conditioned to the levels of underreporting and non-reporting of tuna and tuna like species catches.

The catches of sharks are not recorded by gear and/or species. The catches of sharks are not disaggregated at the required level for each species by area or fleet. Generally major sharks are better reported that other species but still are inconsistencies. Mis-identification of shark species is also common. The identification of sharks in port is usually compromised by the way in which the different species of sharks are processed before landed. Generally, no indication is given on the type of processing that the different specimens underwent. Then, the identification of sharks unloaded as shark carcasses, shark fins or other shark products is difficult.

Although there are gaps of data, stock assessments for sharks have been and are being attempted in all tuna RFMOs in response to growing concerns over the conservation status of pelagic shark species. Those assessments can be based from simple fishery indicators, to more complex semi-quantitative Ecological Risk Assessment, to full stock assessments. However, as mentioned above, several gaps in data and information make difficult to obtain reliable and accurate stock status assessment to formulate sound scientific advice.

The review of existing information as well as the identification of information gaps, main shark species impacted and main métier responsible for major shark catch presented above provides the basis for development of a research program and priorities for the assessment of the status of sharks in tuna RFMOs. The following sections are structured (i) to offer a framework to identify the main species and fleets that needs to be prioritized for the collection of fishery data and information in order to assure the assessment of principal shark species regionally in the tuna RFMOs and (ii) to provide general recommendations for all tuna RFMOs to improve the data collection to fill the gaps identified.

Research Program Framework

The framework is proposed to organized in three steps (Figure 8): (i) estimation of shark catches by species using the method proposed here which will allow identifying the most impacted shark species and the métier most affecting those species; (ii) to carry out a preliminary Ecological Risk Assessment (or other preliminary assessment based on fishery indicators) by fleets which will allow to identify the most vulnerable species to focus the on in conjunction with point (i); and (iii) to propose specific recommendations of how to apply possible management measures, to improve data collection and assessment of those species/fleets identify as priorities in point (ii) and (iii).

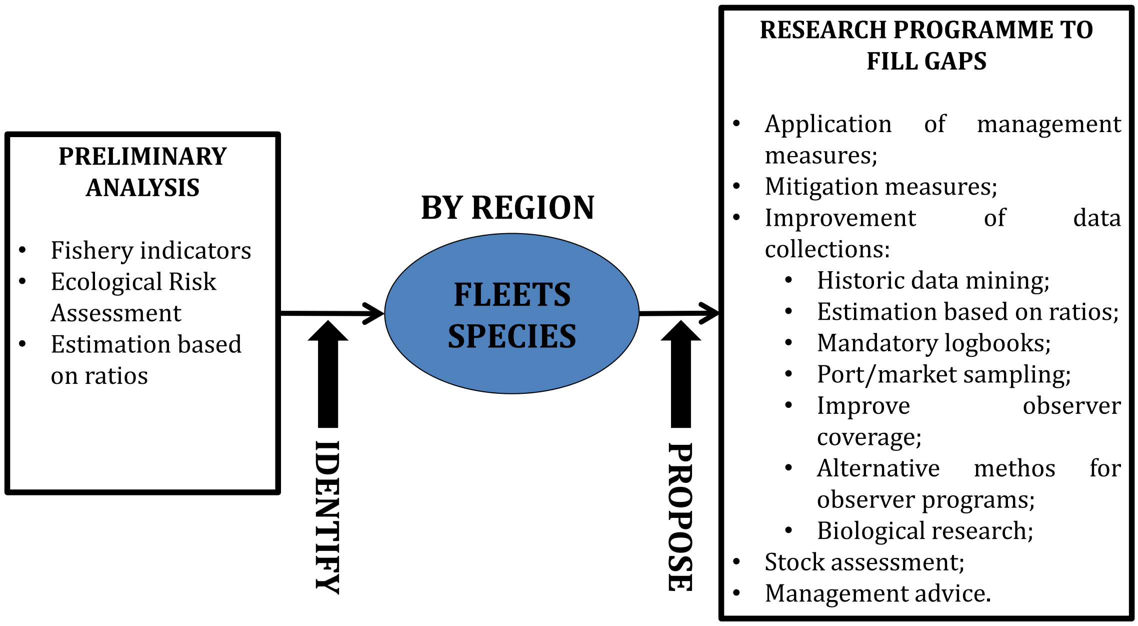

Figure 8.- Summary of the implementation of the research program into three steps.

Data gaps are the main constraints to assess shark species population and the improvement of collected data for shark species (point iii) should be the ultimate goal of the research program aiming to provide a sound formulation of scientific advice. Following the work conducted in the WCPFC (Clarke and Harley 2010, Clarke 2011), we propose hereafter a framework in order to improve data collection for main shark species/fleets. This process may be qualified as:

- **Species oriented** because at the end it is expected to have data with required level of precision on a particular shark species which will allow assessing fishing impact on its population;
- **Fishery/métier** based because the impact is different by métier, data collection has specific operational constraints and are set in place on a fishery/métier basis;
- **RFMO** based because situations are different regionally.

The 3 step framework or process can described as follows (see figure 8 above):

1. **Define the priority level for shark species/fleets.**

    ✓ Estimation of shark catch by species and fleets based on ratios: this will allow identifying highly impacted species and the fisheries impacting most the priority species by region.

2. **Identify most vulnerable species/métier impacting:**

    ✓ Status of the stock:

        i. Fishery indicators;

ii. Ecological Risk Assessment rank with high vulnerability to a given gear;
iii. Identified as at risk by other managing systems (CITES, etc.).

At the end of 2 first steps, a list of priorities for species and fleets is established.

- ✓ For species listed and for which data required for assessment are available, assessment should be conducted;
- ✓ For species suffering data gaps in specific and/or major fleets identified in step 1 the third step is proposed specifically to improve data collection.

3. The final step is **defining a research program for species by métier** to improve the data quality for the assessment. This research strategy would guarantee that data collection is adequate for the most priority sharks species impacted by the major fisheries/métier. The research program should be a combination of improvement of data collection through logbooks, observer programs including alternative method such as selfsampling and/or electronic monitoring, biological research, mitigation research, etc. This step does not preclude taking management actions based on the results of step 1 and 2. The research program should answer, for example, the questions below and try to take actions to improve the data collection:

- ✓ Is the information of the priority species included in the mandatory requirement for collection fishery data in the logbooks for the main fleets?
- ✓ Are logbook data presently collected appropriate? Which potential improvements and operationally feasible? How is the misidentification problem for the species in question? Are identification guides available in the regions?
- ✓ Are observer data appropriate in terms of precision at the coverage which is presently mandatory? Which coverage level would be required?
- ✓ How to insure adequate biological information availability (size, sex, weight)?

The species and fleets identified in step 1 and 2 should be the focus of the following actions:

- ✓ Improvement of data collections:
  - o Historic data mining;
  - o Estimation based on ratios from observer programs;
  - o Inclusion of the species in the mandatory requirements for the logbooks;
  - o Improve observer coverage including alternative methos for observer programs (e.g. selfsampling, electronic monitoring);
  - o Biological research;
- ✓ Stock assessment and management;
- ✓ Application of some management measures (e.g. prohibition of retention);
- ✓ Identification of mitigation measures.

As summary, the research Research Program Framework should include among other the following issues:

Data collection

1. Define key shark species based on empirical evidence of interaction between species and fisheries, e.g., observer records and other scientific records, ERAs, estimates of total catch, evidence of targeting, and listing on international instrument of conservation/management).
2. Enlarge observer coverage to be representative of all areas where sharks are caught and all gear that catch sharks.
3. Research and training cruise data to avoid many of the biases of logbooks data.
4. Data from recreational fisheries and market may provide important supplementary data.
5. Encourage CMMs to identify opportunities for rescue of historical shark data.
6. Request CCMs to investigate their own data holdings for sharks and report to the Commission regarding the existence and availability of useful data.
7. Implement new procedures to collect more meaningful shark data.

Data report:

8. Agreement on a data collection and reporting logsheet format.
9. Review logsheet formats to confirm they allow and facilitate the recoding of all key sharks.
10. Review procedures for hadling non-species specific shark logsheet data.

Data resolution:

11. Systematic revision for those species that is doubtful.
12. Cross checking the validity/discrepancies of the data reported.
13. Complete identification guides distributed among different agents dealing with shark issue, e.g., fishermen, scientist, managers, etc.
14. Encourage further research into key shark species whose presence in fisheries and whose biology are less well understood.
15. Coordinate information characterize tagging data for sharks.

Data access:

16. Continuing access to datasets pursued if possible.

Assessment:

17. Annual fishery indicators for species which do not currently appear to have sufficient data calculated as group.

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