Report of the Indian Ocean Shark Year Program workshop (IO-ShYP01)

Olhão, Portugal, 14–16 May 2014

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Contact details:

Indian Ocean Tuna Commission
Le Chantier Mall
PO Box 1011
Victoria, Mahé, Seychelles
Ph: +248 4225 494
Fax: +248 4224 364
Email: secretariat@iotc.org
Website: http://www.iotc.org

ACRONYMS

ASPIC	A Stock Production Model Incorporating Covariates
ASPM	Age-Structured Production Model
B	Biomass (total)
B_{MSY}	Biomass which produces MSY
BSH	Blue shark (*Prionace glauca*)
BTH	Bigeye thresher sharks (*Alopias superciliosus*)
CMM	Conservation and Management Measure (of the IOTC; Resolutions and Recommendations)
CPCs	Contracting parties and cooperating non-contracting parties
CPUE	Catch per unit of effort
current	Current period/time, i.e. $F_{current}$ means fishing mortality for the current assessment year.
EEZ	Exclusive Economic Zone
ERA	Ecological Risk Assessment
F	Fishing mortality; F_{2011} is the fishing mortality estimated in the year 2011
FAD	Fish aggregating device
FAL	Silky shark (*Carcharhinus falciformis*)
F_{MSY}	Fishing mortality at MSY
GLM	Generalized linear model
GN	Gillnet
ICCAT	International Commission for the Conservation of Atlantic Tunas
ID	Identification
IO	Indian Ocean
IO-ShYP	Indian Ocean shark year plan
IOTC	Indian Ocean Tuna Commission
LL	Longline
LMA	Longfin mako shark
M	Natural mortality
MAK	Mako sharks (*Isurus* spp.)
MAN	Manta and devil rays (Mobulidae)
MOB	Mobulidae
MSY	Maximum sustainable yield
n.a.	Not applicable
OCS	Oceanic whitetip shark (*Carcharhinus longimanus*)
PLS	Pelagic stingray
POR	Porbeagle (*Lamna nasus*)
PS	Purse seine
PSK	Crocodile shark
PTH	Pelagic thresher sharks (*Alopias pelagicus*)
RFMO	Regional Fisheries Management Organization
RHN	Whale shark (*Rhincodon typus*)
ROS	Regional Observer Scheme
SC	Scientific Committee of the IOTC
SB	Spawning biomass (sometimes expressed as SSB)
SB_{MSY}	Spawning stock biomass which produces MSY
SKH	Other Sharks and rays
SMA	Shortfin mako sharks (*Isurus oxyrinchus*)
SPK	Great hammerhead shark
SPL	Scalloped hammerhead sharks (*Sphyrna lewini*)
SPY	Hammerhead shark (Sphyrnidae)
SPZ	Smooth hammerhead shark
SRA	Stock-reduction analysis
SS3	Stock Synthesis III
THR	Thresher sharks (*Alopias* spp.)
TIG	Tiger shark
WCPFC	Western and Central Pacific Fisheries Commission
WPEB	Working Party on Ecosystems and Bycatch (of the IOTC)
WWF	World Wide Fund for Nature (a.k.a World Wildlife Fund)

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Executive summary

The IO-ShYP01 **RECALLED** that prior to the workshop, participants to the IO-ShYP01 compiled the current information available, identified major gaps in knowledge, and established draft priorities for future research and cooperation among IOTC scientists and other groups. ***Readers of this report are encouraged to interpret it as a document with the sole aim of improving the information at the IOTC for future use in developing stock assessment and/or status indicators for shark species caught by IOTC fisheries and not as compliance issues with IOTC Conservation and Management Measures on provision of data for shark species.***

Data collection

(para. 51) The IO-ShYP01 **AGREED** that although there have been improvements in recent years, data collection on shark catches by IOTC fisheries remains limited. In many cases where data is being collected, it is being incorrectly recorded. A concerted action/effort to enhance data gathering abilities, database development and ongoing maintenance and verification in the following CPCs/fisheries would be needed if relevant stock status indicators for shark species could be developed in the future: Gillnet fleets from I.R. Iran, Pakistan, Oman, Sri Lanka.

Fisheries and data collection

(para. 59) The IO-ShYP01 **AGREED** that in general, there is a scarcity of data and limited data availability for major fleets and countries in IOTC for all shark species (although species such as blue shark can be considered a less data poor species). However, this is particularly evident for gillnet and/or coastal fishery, which accounted for around 68 % of the reported catch in IOTC database. Although some countries using gillnets (e.g. I.R. Iran and Oman) are providing the shark statistics to IOTC in aggregated level, the Resolution and stratification of the data is poor. This paucity of information of gillnet/coastal fisheries is basically due to the difficulties for coastal countries to cover all unloading places, identification of species and implementation of observer programs.

(para. 60) The IO-ShYP01 **AGREED** that the shark fishery data collection for gillnet/coastal fisheries as a high priority area, particularly for I.R. Iran, Sri Lanka, Pakistan, Yemen, India and Indonesia. Any work in this area should include all the components of data collection program including information of type of vessels, fleet characteristics and observer programs along with the implementation of a capacity building program. Although in general the longline fleet can be considered a fleet with a better shark fishery statistics (e.g. EU and Japanese longline fleets) there are still fishery data gaps in relation to some shark species and some LL fleet. Thus, the group considers as a matter of high priority to improve the data collection systems (i.e. through self-reporting, observers, electronic monitoring, etc.) for species that are caught by longline.

(para. 61) The IO-ShYP01 **AGREED** that the gaps in historical fishery statistics can be an important limiting factors for most of the fleets. Thus, any attempt for improving the data collection should be accompanied by a historical data mining exercise for the key species and fleets, such as artisanal gillnet and longline coastal fisheries. If it is not possible to obtain historical data, current observer programs can be used by each specific fleet to reconstruct species composition of sharks. Thus, the group considers as a matter of high priority a data mining process for major fleets/countries catching sharks and that an observer program is implemented in those countries/fleets.

(para. 64) The IO-ShYP01 **AGREED** that the implementation of the Regional Observe Schemes are necessary for the collection of basic information such as shark bycatch rates, shark species composition of the catch, correct species identification of shark, size frequency data, spatial/temporal shark catches, etc.

(para. 66) The IO-ShYP01 **RECOMMENDED** as high priority the implementation of Regional Observer Schemes in major IOTC fleets, including coastal artisanal fleet, and/or the collection of scientific data by all other means available including, pilot observer programmes, self-sampling (collection of data by trained crew) and electronic monitoring (sensors and video cameras).

Mitigation measures

(para. 70) The IO-ShYP01 **AGREED** that the list of mitigation measures summarised in Appendix V is **not** a ranking of potential measures, as the objective of this review was **just to highlight research needs** before any advice can be provided on their potential application and efficiency if introduced to IOTC managed pelagic fisheries. Additionally, the research needs took into consideration mostly their potential as shark mitigation measures, albeit the implications these might have on fisheries data collection and, consequently, on the shark stock assessment process. The listed management mitigation measures for major IOTC fisheries impacting sharks were split into two different categories: i) Operational and technological aspects, and ii) Best practices.

Identification of potential funding sources and application procedures

(para. 86) The IO-ShYP01 **RECOMMENDED** that the Chair of the SC and the Chair of the WPEB to liaise with the IOTC Secretariat for coordinate efforts on how funding can be achieved, and on how to use research funding in the most efficient, collaborative and transparent way, within the objectives of this research plan.

(para. 89) The IO-ShYP01 **AGREED** that interested participants should contact other relevant parties and develop short concept notes for each of the core topics requiring action from the workplan, and to circulate these among the IO-ShYP-01 participants for comment. The final concept notes should then be submitted to the IOTC Secretariat.

(para. 90) The IO-ShYP01 **RECOMMENDED** that the IO-ShYP working group continue its work inter-sessionally via electronic means to develop and refine a 5 year plan of work for the consideration and potential endorsement by the WPEB at its next session to be held in October, 2014, including the consolidated set of recommendations arising from the IO-ShYP01, provided at Appendix VII.

A summary of the stock status for some of the most commonly caught shark species caught in association with IOTC fisheries for tuna and tuna-like species is provided in Table 1, as adopted by the Scientific Committee in 2013 (IOTC–2013–SC16–R).

Table 1. Status summary for species of sharks impacted by IOTC fisheries (Source: IOTC–2013–SC16–R)

Stock	**Indicators**		**Prev[1]**	**2010**	**2011**	**2012**	**2013**	**Advice to the Commission**
Sharks: Although sharks are not part of the 16 species directly under the IOTC mandate, sharks are frequently caught in association with fisheries targeting IOTC species. Some fleets are known to actively target both sharks and IOTC species simultaneously. As such, IOTC Members and Cooperating non-Contracting Parties are required to report information at the same level of detail as for the 16 IOTC species. The following are the main species caught in IOTC fisheries, although the list is not exhaustive.								
Blue shark *Prionace glauca*	Reported catch 2012: Not elsewhere included (nei) sharks: Average reported catch 2008–2012: Not elsewhere included (nei) sharks: MSY (range):	21,901 t 42,793 t 24,204 t 48,708 t unknown						There is a paucity of information available for these species and this situation is not expected to improve in the short to medium term. There is no quantitative stock assessment and limited basic fishery indicators currently available. Therefore the stock status is highly uncertain. The available evidence indicates considerable risk to the stock status at current effort levels. The primary source of data that drive the assessment (total catches) is highly uncertain and should be investigated further as a priority.
Oceanic whitetip shark *Carcharhinus longimanus*	Reported catch 2012: Not elsewhere included (nei) sharks: Average reported catch 2008–2012: Not elsewhere included (nei) sharks: MSY (range):	412 t 42,793 t 292 t 48,708 t unknown						
Scalloped hammerhead shark *Sphyrna lewini*	Reported catch 2012: Not elsewhere included (nei) sharks: Average reported catch 2008–2012: Not elsewhere included (nei) sharks: MSY (range):	80 t 42,793 t 74 t 48,708 t unknown						
Shortfin mako *Isurus oxyrinchus*	Reported catch 2012: Not elsewhere included (nei) sharks: Average reported catch 2008–2012: Not elsewhere included (nei) sharks: MSY (range):	1,426 t 42,793 t 1,300 t 48,708 t unknown						
Silky shark *Carcharhinus falciformis*	Reported catch 2012: Not elsewhere included (nei) sharks: Average reported catch 2008–2012: Not elsewhere included (nei) sharks: MSY (range):	4,177 t 42,793 t 3,443 t 48,708 t unknown						
Bigeye thresher shark *Alopias superciliosus*	Reported catch 2012: Not elsewhere included (nei) sharks: Average reported catch 2008–2012: Not elsewhere included (nei) sharks: MSY (range):	465 t 42,793 t 98 t 48,708 t unknown						

Pelagic thresher shark *Alopias pelagicus*	Reported catch 2012: 328 t Not elsewhere included (nei) sharks: 42,793 t Average reported catch 2008–2012: 76 t Not elsewhere included (nei) sharks: 48,708 t MSY (range): unknown						

[1] This indicates the last year taken into account for assessments carried out before 2010

[2]The point estimate is the median of the plausible models investigated in the 2013 SS3 assessment

[3] most recent years data 2010; [4] most recent years data 2011

Colour key	Stock overfished($SB_{year}/SB_{MSY} < 1$)	Stock not overfished ($SB_{year}/SB_{MSY} \geq 1$)
Stock subject to overfishing($F_{year}/F_{MSY} > 1$)		
Stock not subject to overfishing ($F_{year}/F_{MSY} \leq 1$)		
Not assessed/Uncertain		

1. Opening of the Session

1. The Indian Ocean Shark Year Program workshop (IO-ShYP01) was held in Olhão, Portugal from 14 to 16 May 2014. A total of 12 invited experts attended the workshop (Appendix I). The meeting was opened by the Coordinators Dr. Miguel Neves dos Santos (EU,Portugal), Dr. Rui Coelho (Chair of the WPEB) and Dr. David Wilson (IOTC Secretariat). The IO-ShYP01 expressed its thanks to WWF for providing financial support to 4 national scientists from I.R. Iran, Oman and Pakistan, as well as the Vice-Chair of the WPEB, to attend the workshop.

2. The IO-ShYP01 **RECALLED** that in December 2013 the IOTC Scientific Committee recommended that a detailed multiyear shark research program be prepared by a small group of shark experts and the IOTC Secretariat, to further advance, detail and propose an Indian Ocean Shark multi-Year Program (IO–ShYP) for finalisation at the next WPEB meeting (see SC recommendation SC16.33).

3. The IO-ShYP01 **RECALLED** the main objective of the IO–ShYP will be to "*promote cooperation and coordination among IOTC researchers, to improve the quality of the scientific advice on sharks provided to the Commission, namely by conducting quantitative stock assessments for selected species by 2016, and to better assess the impact on shark stocks of the current IOTC Conservation and Management Measures*."

4. The IO-ShYP01 **RECALLED** that a great variety of sharks species are found within the IOTC area of competence, from coastal to oceanic species. Forty-four species or groups of shark species are currently present in the IOTC databases, which show very diverse biological strategies and as active predators occupy a very high position in the trophic chain. Although diverse, the biological characteristics of these species share some general patterns that make them potentially more susceptible to overfishing than other species, namely because they generally have a low reproductive potential, are slow growing and mature late compared to other species.

5. The IO-ShYP01 **RECALLED** that even though sharks have been impacted by commercial and recreational fisheries in the IOTC area of competence for many decades, there remains limited information and large gaps in the available catch, effort and discard data, as consistently noted in IOTC reports. These gaps currently preclude any robust stock assessment for sharks and the accurate estimation of fishery impacts on shark populations in the IOTC area of competence. Moreover, shark species life cycles, biological parameters, movement patterns and habitat utilisation are poorly understood due to the lack of specific studies on those aspects in the Indian Ocean. Therefore, the current state of knowledge on IOTC fisheries capturing sharks is a cause for concern, particularly on their conservation status and management.

6. The IO-ShYP01 **RECALLED** that the IOTC Working Party on Ecosystems and Bycatch (WPEB) has consistently recognised the urgent need to improve the collection of fisheries data and develop applied research to fill the major knowledge gaps that affect the provision of scientific advice to the Commission. Moreover, the Commission has recently established the scientific and management framework for the conservation of sharks (Resolution 13/06 *on a scientific and management framework on the conservation of shark species caught in association with IOTC managed fisheries*).

7. The IO-ShYP01 **RECALLED** that similar initiatives have been successfully developed by other fisheries and fisheries related organisations (i.e. ICCAT; WCPFC). Moreover, the ICCAT Shark Group (equivalent to the WPEB with regards to sharks), is currently working/preparing a Shark Research and Data Collection Program, to overcome similar data gaps and improve the provision of scientific advice for Atlantic pelagic shark stocks. Several researchers involved in this ICCAT Program have also been recently involved in the WPEB, which therefore represents an advantage to a future IOTC multi-year shark program.

8. The IO-ShYP01 **RECALLED** that prior to the workshop, participants to the IO-ShYP01 compiled the current information available, identified major gaps in knowledge, and established draft priorities for future research and cooperation among IOTC scientists and other groups. ***Readers of this report are encouraged to interpret it as a document with the sole aim of improving the information at the IOTC for future use in developing stock assessment and/or status indicators for shark species caught by IOTC fisheries and not as compliance issues with IOTC Conservation and Management Measures on provision of data for shark species***.

9. The IO-ShYP01 **ADOPTED** the Agenda provided at Appendix II.

2. CURRENT INFORMATION AVAILABLE (FISHERIES, DATA COLLECTION) AND IDENTIFY MAJOR GAPS

2.1 Fleet and gear characterization, and fleet dynamics

10. The IO-ShYP01 **NOTED** that knowledge on fleet/gear characteristics as well as fleet dynamics are necessary for a better knowledge of catch trends, CPUE and spatial/temporal dynamic of the fleets which will contribute to the stock assessment. Various fleets/gear types are identified as catching sharks in the Indian Ocean. Among them drifting gillnet vessels, gillnet/longline compound vessels, fresh-tuna longline vessels, deep-freezing longline vessels, coastal artisanal fisheries, and purse seine vessels, catch shark species.

11. The IO-ShYP01 **NOTED** that fleet/gear characterization and fleet dynamics are lacking for major fleets and coastal fisheries (Table 2). Additional supporting information for this section are provided in Appendix III).

2.2 Data needs [Catch (landings and discards), effort, CPUEs series; gear selectivity; catch-at-size/age; Data mining/recover of historical data sets for sharks]

12. The IO-ShYP01 **NOTED** that fishery statistics information necessary to carry out the assessment of shark species are required under a range of IOTC Conservation and Management Measures. There are various requirements in IOTC for the collection of fishery data for sharks (Table 2).

Table 2. Summary of current Conservation and Management Measurements for sharks in the IOTC area of competence.

Management Requirement	Target species group	IOTC Resolution
Reporting in logbooks	All bycatch	Res. 10/02 & Res. 13/03
Observers	All bycatch	Res. 11/04
Report catch	Sharks	Res. 05/05
Full utilisation of sharks	Sharks	Res. 05/05
No more fins than 5 % ratio	Sharks	Res. 05/05
Mitigation research	Sharks	Res. 05/05
Research Programme	Sharks	Res. 13/06
Prohibition of retention	Thresher and Oceanic whitetip sharks	Res. 12/09, 13/06
Conservation of thresher sharks	Thresher shark	Res. 12/09
Conservation of oceanic whitetip shark	Oceanic whitetip shark	Res. 13/06
Prohibition of setting on whale sharks	Whale shark	Res. 13/05

13. The IO-ShYP01 **NOTED** that to some extent, there are contradictions in the IOTC Resolutions adopted by the Commission and also in the SC reports with regard to the species to be covered under different Resolutions and research priorities (i.e. most common species, other terminology) (Table 3).

Table 3. Species or species groups identified by the Scientific Committee as either the most important for monitoring or the most commonly caught, and also those detailed by the Commission in Resolution 13/03 for data collection. (BTH: Bigeye thresher sharks *Alopias superciliosus*; BSH: Blue shark *Prionace glauca*; MAK: Mako sharks *Isurus* spp.; OCS: Oceanic whitetip shark *Carcharhinus longimanus*; FAL: Silky shark *Carcharhinus falciformis*; PTH: Pelagic thresher sharks *Alopias pelagicus*; SPL: Scalloped hammerhead sharks *Sphyrna lewini*; SPY: Hammerhead shark Sphyrnidae; SMA: Shortfin mako sharks *Isurus oxyrinchus*; THR: Thresher sharks *Alopias* spp.; RHN: Whale shark *Rhincodon typus*; MAN: Manta and devil rays Mobulidae; SKH: Other Sharks and rays; POR: porbeagle *Lamna nasus*)

Scientific Committee priority species	Most commonly caught species	Resolution 13/03			
		Gillnet	Longline	Purse seine	Pole-and-line
BSH	BSH	BSH	BSH		
SMA	MAK	MAK	MAK		
OCS	OCS	OCS	OCS	OCS	
FAL	FAL				
SPL	SPY	SPY	SPY	SPY	
BTH	THR	THR	THR	THR	
PTH	THR	THR	THR	THR	
	RHN	RHN		RHN	
	MAN				
	SKH	SKH	SKH		SKH

OPTIONAL			
	Tiger shark	Tiger shark	FAL
	Crocodile shark	Crocodile shark	Manta/rays
		Great white shark	SKH
	MAN	MAN	
	Pelagic stingray	Pelagic stingray	

15. The IO-ShYP01 **NOTED** that although there are some contradictions the species defined as “most common” and “less common” which are listed with different levels of priority in the SC work plan should be the target of the IO-ShYP (Table 4). Those shark species were listed by major fleet operating in the IOTC convention area. The Indian Ocean fleets were divided in five major fleets following the definition provided by WPDCS09 in its 2013 meeting. Then, for each of these fleets the catch of each shark species was categorised (target/bycatch/commercial) in order to understand the relative importance of each fleet for the catch of each species and to help for the priorisation of research.

Table 4. Categorization of the “most common” and “less common” shark species in terms of catch composition by five major fleets operating in the Indian Ocean. The categorization refers to whether the shark species are caught as a target, bycatch and/or have commercial interest (BTH: Bigeye thresher sharks *Alopias superciliosus*; BSH: Blue shark *Prionace glauca*; OCS: Oceanic whitetip shark *Carcharhinus longimanus*; FAL: Silky shark *Carcharhinus falciformis*; PTH: Pelagic thresher sharks *Alopias pelagicus*; SPL: Scalloped hammerhead sharks *Sphyrna lewini*; SMA: Shortfin mako sharks *Isurus oxyrinchus*; RHN: Whale shark *Rhincodon typus*; MAN: Manta and devil rays Mobulidae; POR: porbeagle *Lamna nasus*; SA: stock assessment)

Species	Coastal fisheries	Gillnet	Longline	Purse seine	Pole-and-Line	SC Consideration
BSH	Bycatch		Target/Bycatch			SA
SMA	Bycatch		Bycatch			Indicators
OCS	Bycatch	Target/Bycatch	Bycatch	Bycatch		SA
FAL	Target/Bycatch	Target/Bycatch	Bycatch	Bycatch		Indicators
SPL	Target/Bycatch	Target/Bycatch	Bycatch			Indicators
BTH	Target/Bycatch	Bycatch	Bycatch			Indicators
PTH	Target/Bycatch	Bycatch	Bycatch			Indicators
RHN	Bycatch/Commercial	Bycatch		Bycatch		
MAN	Bycatch/Commercial	Bycatch	Bycatch	Bycatch		
POR			Bycatch			
Pelagic stingray		Bycatch	Bycatch			
Tiger shark	Bycatch	Bycatch	Bycatch			
Crocodile shark		Bycatch	Bycatch			
Longfin mako	Bycatch	Bycatch	Bycatch			
Other hammerheads	Target/Bycatch	Target/Bycatch	Bycatch			

16. The IO-ShYP01 **NOTED** the data gaps for fishery indicators as well as fleet characteristics for each fleet and species as presented in Table 5. Overall, it is possible to see that there is major gaps of information for all species and fisheries. However, in the case of blue shark, these gaps are less important than for other species.

Table 5. Summary of the data gaps identified for fishery indicators as well as fleet characteristics by fleet and species (Red = data gap; yellow = medium quality statistics; green = good statistics; 1 = High priority; 2 = Medium priority; and 3 = Low priority (BSH: Blue shark; SMA: Shortfin mako shark; OCS: Oceanic whitetip shark; FAL: Silky shark; SPL: Scalloped hammerhead shark; BTH: Bigeye thresher shark; PTH: Pelagic thresher shark; MOB: Mobulidae; POR: Porbeagle shark; PLS: Pelagic stingray; TIG: Tiger shark; PSK: Crocodile shark; LMA: Longfin mako shark; SPK: Great hammerhead shark; SPZ: Smooth hammerhead shark); (LL: longline; PS: purse seine; GN: gillnet; coastal: coastal fisheries); (Colour code: Red = data gap; yellow = medium data quality; green: good data quality; Priority: 1 = high; 2 = medium; 3 = low)

Fishery Statistics/ Species	Summary of available data																
	BSH	**SMA**	**OCS**	**FAL**	**SPL**	**BTH**	**PTH**	**MOB**	**POR**	**PLS**	**TIG**	**PSK**	**LMA**	**SPK**	**SPZ**	**FLEET**	**SUMMARY**
Data collection/needs																	
Nominal catch	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	LL	2
			2	2				2								PS	2
	2	2	1	1	1	1	1	1		1	1	1	1	1	1	GN	1
	2	2	2	1	1	1	1	1		2	1	2	1	1	2	Coastal	1
Catch and effort	1	1	3	3	2	2	2	2	2	2	2	2	2	2	2	LL	2
			1	1				2								PS	1
	3	3	1	1	1	3	3	1		1	1	1	1	1	1	GN	2
	3	3	3	1	1	1	1	1		2	1	2	1	1	2	Coastal	2
CPUE	1	1	3	3	2	2	2	2	2	2	2	2	2	2	2	LL	2
			1	1				2								PS	1
	3	3	1	1	1	3	3	1		1	1	1	1	1	1	GN	2
	3	3	3	1	1	1	1	1		2	1	2	1	1	2	Coastal	2
Size frequencies	1	1	3	3	2	2	2	2	2	2	2	2	2	2	2	LL	2
			3	3				2								PS	3
	3	3	1	1	1	3	3	1		1	1	1	1	1	1	GN	2
	3	3	3	1	1	1	1	1		2	1	2	1	1	2	Coastal	2
Spatial coverage	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	LL	2
			3	3				2								PS	3
	3	3	1	1	1	3	3	1		1	1	1	1	1	1	GN	2
	3	3	3	1	1	1	1	1		2	1	2	1	1	2	Coastal	2
Catch at size/length	1	1	3	3	2	2	2	2	2	2	2	2	2	2	2	LL	2
			3	3				2								PS	3
	3	3	1	1	1	3	3	1		1	1	1	1	1	1	GN	2
	3	3	3	1	1	1	1	1		2	1	2	1	1	2	Coastal	2
Observer data	1	1	3	3	2	2	2	2	2	2	2	2	2	2	2	LL	2
			3	3				2								PS	3
	3	3	1	1	1	3	3	1		1	1	1	1	1	1	GN	2

	3	3	3	1	1	1	1	1		2	1	2	1	1	2	Coastal	2
Bycatch data	2	2	2	2	**2**	**2**	**2**	2	2	2	2	2	2	2	2	LL	2
			3	3				2								PS	3
	1	1	1	1	1	1	1	1		1	1	1	1	1	1	GN	1
	1	1	1	1	1	1	1	1		2	1	2	1	1	2	Coastal	1
Data needs	2	2	2	2	**2**	**2**	**2**	2	2	2	2	2	2	2	2	LL	2
			3	3				2								PS	3
	1	1	1	1	1	1	1	1		1	1	1	1	1	1	GN	1
	1	1	1	1	1	1	1	1		2	1	2	1	1	2	Coastal	1
Fleet and gear characterisation																	
Gear characteristics	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	LL	2
			3	3												PS	3
	1	1	1	1	1	1	1	1		1	1	1	1	1	1	GN	1
	1	1	1	1	1	1	1	1		1	1	1	1	1	1	Coastal	1
Set characteristics	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	LL	2
			3	3												PS	3
	1	1	1	1	1	1	1	1		1	1	1	1	1	1	GN	1
	1	1	1	1	1	1	1	1		1	1	1	1	1	1	Coastal	1
Target species	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	LL	2
			3	3												PS	3
	1	1	1	1	1	1	1	1		1	1	1	1	1	1	GN	1
	1	1	1	1	1	1	1	1		1	1	1	1	1	1	Coastal	1
Fleet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	LL	2
			3	3												PS	3
	1	1	1	1	1	1	1	1		1	1	1	1	1	1	GN	1
	1	1	1	1	1	1	1	1		1	1	1	1	1	1	Coastal	1

17. The IO-ShYP01 **NOTED** Table 5 from which the following aspects can be noted:
   - Most of the shark species are taken as bycatch although there are fisheries targeting some shark species such as longline fleets targeting blue shark and coastal artisanal fisheries targeting some coastal shark species;
   - In general, shark catch data are not available - Several countries were not collecting fishery statistics, especially in years prior to the early 1970-s, and others have not reported catches of sharks to IOTC.
   - Poor resolution of catch data - The catches of sharks are usually not recorded by species and/or gear. The estimation of catches by species is highly compromised in these cases due to the paucity of the data available. Miss-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 and landed.
   - Underreporting in some instances of shark catches;
   - Deep-freezing tuna longliners and fresh-tuna longliners - Catches of sharks are thought to represent between 20-40% of the total combined catch for all species. However, the catches of sharks recorded in the IOTC database only make for a small proportion of the total catches of all species over longline fleets. Catches of sharks are, therefore, thought to be very incomplete. .
   - Gillnet fisheries - The species of sharks caught are thought to vary significantly depending on the area of operation of gillnets. The major problems may arise from:
     - Gillnets operated in areas having high concentrations of pelagic sharks - Gillnets operated in Sri Lanka, Indonesia and Yemen (waters around Socotra), in spite of being set in coastal areas, are likely to catch significant amounts of pelagic sharks.
     - Gillnets operated on the high seas - Vessels from Taiwan,China were using drifting gillnets (driftnets) from 1982 to 1992, the year in which the use of this gear was banned worldwide. The catches of pelagic sharks were very high during that period, representing around 25% of the total catch of all species. Driftnet vessels from Iran and Pakistan have been fishing on the high seas since the early-1990's, initially in waters of the Arabian Sea but covering a larger area in recent years, as they moved to operate also in tropical waters of the western Indian Ocean and Mozambique Channel.
     - Gillnet/longline fishery of Sri Lanka - Catches of sharks represent between 2% and 45% of the total combined catch for all species, depending on the year.

18. The IO-ShYP01 **AGREED** that generally, it is therefore possible to conclude that:
   1. Catch, catch and effort, and size frequency data for shark species from major gillnet fisheries are lacking;
   2. Catch, catch and effort, and size frequency data by species for some longline fleets are lacking. Historic data by species prior to 2006 are lacking for most of the longline fleets;
   3. Catch, catch and effort, and size frequency data by species from major countries are lacking;
   4. Discard data of shark from observer programs are generally lacking for all the fleets.

19. The IO-ShYP01 **NOTED** however, that besides this overall summary, the species-specific information available for stock assessment needs to be examined in more detail.

20. The IO-ShYP01 **NOTED** that Table 6 could be filled in before each assessment to detail the data available for each specific species. These tables are country specific because it is needed to identify the information that is available in each country for specific species in order to check the data available to carry out an assessment. This table is not targeted to identify non-compliance country just to contribute to know what data is available to carry out the assessment. It was agreed that an example would be provided in the report but that the input from a broader group of scientists is needed to complete accurately those tables. The chair of the WPEB will contact key scientist from each country to fill in those tables before the next meeting of WPEB depending on the target species in the yearly WPEB Program of Work.

Table 6. Template of species-specific and country-specific fishery statistics (metadatabase information for IOTC major fleets) that could be completed prior to undertaking a shark stock assessment (Red = data gap; yellow = medium quality statistics; green = good statistics); n.a. not applicable.

LONGLINE

	Summary of available data						
Fishery Statistics/Period	**1950**	**1960**	**1970**	**1980**	**1990**	**2000**	**2010**
Data collection/needs							
Nominal Catch	JPN	JPN	JPN	JPN	JPN	JPN	JPN
	n.a.	n.a.	n.a.	EU-SP	EU-SP	EU-SP	EU-SP
Catch and effort							
Standardised CPUE							
Size frequencies							
Spatial coverage							
Observer data/Discard info							
Set characteristic info							
Gear info							
Target species info							

Color code for this table:

Red = no data available; yellow = medium quality statistics; green = good statistics

-

GILLNET

	Summary of available data						
Fishery Statistics/Period	**1950**	**1960**	**1970**	**1980**	**1990**	**2000**	**2010**
Data collection/needs							
Nominal Catch	OMAN	OMAN	OMAN	OMAN	OMAN	OMAN	OMAN
Catch and effort							
Standardised CPUE							
Size frequencies							
Spatial coverage							
Observer data/Discard info							
Set characteristic info							
Gear info							
Target species info							

2.3 Observer programs (design and implementation)

21. The IO-ShYP01 **NOTED** that the Regional Observer Scheme coverage rates are low. Observer data coverage, for all major fleets, including coastal/artisanal fisheries, are low and may not be representative of all areas where sharks are caught. The data of observer programs is not available or accessible in most of the cases.

22. The IO-ShYP01 **NOTED** that the Regional Observer Scheme should be focused on the main fleets catching sharks and species most caught, using possible methodologies to increase the observer coverage such as self-sampling, pilot observer programs in artisanal gillnet fisheries, or electronic monitoring as well as observers onboard. Priorities in the Indian Ocean should be given to fleets that are considered to be responsible for most of the shark catches (i.e. driftnet gillnets, gillnets/longlines).

3. REVIEW OF THE CURRENT AVAILABLE INFORMATION IN TERMS OF BIOLOGICAL AND ECOLOGICAL KNOWLEDGE OF THE SEVEN MAJOR SHARK SPECIES (BSH, SMA, OCS, FAL, SPL, PTH AND BTH)

3.1 Life history traits (age and growth; reproduction; mortality)

23. The IO-ShYP01 **NOTED** that parameters that are needed for population dynamics studies include: age, growth and reproduction. These parameters can then be used to estimate mortalities and intrinsic population growth rates.

Age and growth

24. The IO-ShYP01 **NOTED** that knowledge on age structure and growth dynamics of a population is essential for age-structured stock assessment models. These parameters are often used to estimate natural or total mortality that are important for the calculation of important population and demographic parameters, such as population growth rates and generation times. Inaccurate age estimates can lead to serious errors in stock assessments and possibly to overexploitation. Because sharks lack otoliths and pelagic species are lacking fin spines: hard parts that are most commonly used for age estimation, information on age and growth is usually derived from counts of opaque and translucent bands on vertebral centre or spines. Goldman (2004) provides a revision on the more common techniques that have been used for age and growth studies on elasmobranchs. In terms of growth models, the von Bertalanffy growth function has been the model more commonly applied to elasmobranchs, even though alternative growth models have also been applied with success to some sharks in recent years. However, many of these models still lack age verification and/or validation, and often times suffer from small sample sizes for some age groups. To resolve these issues, collaborations among scientists is encouraged to collect samples and develop more complete models.

Reproduction

25. The IO-ShYP01 **NOTED** that knowledge on the reproductive biology is essential for stock assessment models that attempt to accurately capture the biology of a species, such as age- and sex-structured models. Size-at-maturity is usually set after consideration of the size at which most individuals (usually 50%) become sexually mature. This is particularly important for sharks, as females tend to mature at a later age and larger size, and reach a larger size and older age than their male counterparts. Other important reproductive parameters include fecundity, seasonality and periodicity, which are all needed to calculate fertility, an important parameter that is one of the main inputs into demographic analysis.

Mortality

26. The IO-ShYP01 **NOTED** that majority of population modelling studies for elasmobranchs relies on indirect estimates of mortality obtained through empirical methods based on predictive equations of life history traits. However, it is possible to estimate instantaneous natural mortality rates (M) or instantaneous total mortality rates (Z) for sharks based on mark-recapture techniques or catch curves. Simpfendorfer et al. (2004) provides a revision on some of those direct and indirect techniques to calculate mortalities.

Stock structure and delimitation

27. The IO-ShYP01 **NOTED** that to better understand the impact of fisheries on shark populations, it is important to determine the stock boundaries, existence of mixing areas and migration between geographic areas within and between Oceans. Different approaches can be used for identifying, delimiting and classifying the stocks, and one of the most used is to carry out population genetic studies using several types of molecular markers, such as allozymes, mitochondrial DNA and microsatellites. Other techniques are available and have been used mainly to complement population genetics studies. Those include biometric analysis including meristic and morphometric characters, comparison of population parameters, tagging, and parasites. However, the application of those techniques to pelagic sharks is still limited, and most studies were carried out on coastal sharks and bony fishes.

Habitat use and migrations

28. The IO-ShYP01 **NOTED** that knowledge on the movement patterns and on how the animals use the space for their activities is essential for understanding the behaviour and defining essential habitats for that species. Conventional tagging (based on mark-recapture) can provide patterns of movement, growth and mortality rates and assist in inferring the degree of mixing among stocks. On the other hand, the use of satellite tagging technology can provide insights on migration patterns, habitat use (both spatial and in terms of depth) and post-release mortality. The collection of oceanographic information (e.g., sea surface temperature, chlorophyll

concentration, current velocity, depth of the thermocline, oceanic fronts, and upwelling) is then necessary, and this information can either be collected *in situ* or through remote sensing techniques.

3.2. Review of the current biological knowledge

29. The IO-ShYP01 **NOTED** that the life history information, often required to help assess the status of the shark stocks, was compiled for the seven main species prioritized by IOTC. The Indian Ocean area was divided into the two major regions, specifically the eastern and western Indian Ocean, and the species-specific information compiled was grouped into major biological aspects, namely reproduction, age and growth, feeding, population genetics, tracking, habitat/environmental preferences, and other aspects.

30. The IO-ShYP01 **NOTED** that the available literature on the prioritized IOTC sharks biology and ecology was compiled and revised to the best extent possible. The information as compiled based on peer-reviewed papers, IOTC working documents and scientific report, and a total of 43 references were found and analysed.

31. The IO-ShYP01 **NOTED** Table 7 that presents a summary with collapsed life history and other parameters into five data categories (reproduction, age and growth, feeding, stock ID, and movements/migratory patterns), that are most relevant for stock assessments, and the two major Indian Ocean geographical areas. The following specific aspects are noted:
    - More studies have been carried out in the west than in the east Indian Ocean;
    - Reproduction is the only biological parameter for which there is already some information on most species, both in the east and west IO;
    - In the west region there is some information available in terms of feeding and movements for all species except the thresher sharks;
    - In the west region the research areas with more lack of data are age and growth and stock identification;
    - In the eastern area there is almost no information available for any species except some reproductive parameters for Lamnids, hammerhead and thresher sharks, age and growth for the silky shark, and stock ID for the scalloped hammerhead;
    - The most data-poor shark species in the IO are the thresher sharks, and in particularly the pelagic thresher; common misidentification is one of the major reasons for this situation.

32. The IO-ShYP01 **AGREED** that generally, it is therefore possible to conclude that:
    - The most data-poor biological parameters are age and growth and stock ID in the west IO, and age and growth, feeding, stock ID and movements in the east IO;
    - The more data-poor species are the two thresher sharks.

Table 7. Summary of the level of information available by research topic in the two main Indian Ocean geographical areas for the seven shark species. Color code: red = no studies available; yellow = 1 or 2 studies; green = 3+ studies. BSH = blue shark, SMA = shortfin mako, OCS = oceanic whitetip, FAL = silky shark, SPL = scalloped hammerhead, BTH = bigeye thresher and PTH = pelagic thresher.

Species	West Indian Ocean					East Indian Ocean				
	Reproduction	Age & growth	Feeding	Stock ID	Movements & migrations	Reproduction	Age & growth	Feeding	Stock ID	Movements & migrations
BSH	yellow	yellow	green	red	green	yellow	red	red	red	red
SMA	yellow	red	yellow	red	yellow	yellow	red	red	red	red
OCS	yellow	red	yellow	red	green	yellow	red	red	red	red
FAL	yellow	red	yellow	red	green	yellow	yellow	red	red	red
SPL	yellow	red	yellow	red	yellow	yellow	red	red	yellow	red
BTH	yellow	red	red	red	red	yellow	red	red	red	red
PTH	red	red	red	red	red	yellow	red	red	red	red

33. The IO-ShYP01 **NOTED** that besides this overall summary, the species-specific information available for each specific biological aspect was listed in more detail, as different assessment methods may require different life history parameters. That information is summarised in Table 8 and the detailed information on the references is listed in the Appendix IV. It is possible to see that the species where most studies have been carried out are the blue shark and silky shark, and that for the other species, particularly for the thresher sharks, there is considerably less information available for most of the specific biological parameters. In terms of research areas, more information is available regarding reproductive studies, while fewer studies have been conducted on age and growth and population genetics. Other research fields that have very little information available and that are very relevant for advice include information on post-release mortality that is lacking for all species in the Indian Ocean except the silky shark.

34. The IO-ShYP01 **AGREED** that it is important however, to look to the species and research specificities listed in Table 8, as there are exceptions to those overall and general conclusions. For example, even though the less data-poor species are the blue and silky sharks, there are still considerable biological parameters that are missing for those species and should be prioritized in terms of future research.

Table 8. Summary of the number of studies presenting life history parameters that are available for the seven main IOTC shark species. Color code: red = no studies available; yellow = 1 or 2 studies; green = 3+ studies. BSH = blue shark, SMA = shortfin mako, OCS = oceanic whitetip, FAL = silky shark, SPL = scalloped hammerhead, BTH = bigeye thresher and PTH = pelagic thresher.

	Summary (number of studies)						
Parameters	**BSH**	**SMA**	**OCS**	**FAL**	**SPL**	**BTH**	**PTH**
Reproduction							
Size-at-maturity (male)							
Age-at-maturity (male)							
Size-at-maturity (female)							
Age-at-maturity (female)							
Reproductive frequency							
Gestation period							
Size-at-birth							
Fecundity (litter size)							
Spawning period							
Mating period							
Age and growth							
L_{inf} (combined)							
k (combined)							
T_o / L_o (combined)							
Maximum obs. age (combined)							
Longevity estimate (combined)							
L_{inf} (male)							
k (male)							
T_o / L_o (male)							
Maximum obs. age (male)							
Longevity estimate (male)							
L_{inf} (female)							
k (female)							
T_o / L_o (female)							
Maximum obs. age (female)							
Longevity estimate (female)							
Feeding							
Traditional							
Isotopes							
Genetics							
mtDNA							
nDNA							
Tracking							

Traditional tagging							
Satellite telemetry							
Acoustic telemetry							
Habitat/Environ. preferences							
Temperature							
Depth							
Other aspects							
Haulback mortality							
Post-release mortality							
Size-size relationships							
Size-weight relationships							
Contaminants (e.g. heavy metals)							

4. REVIEW OF THE CURRENT AVAILABLE AND IMPLEMENTED MITIGATION MEASURES, INCLUDING BEST PRACTICE CODES/PROCEDURES, IN TERMS OF REDUCING SHARK BYCATCH AND INCIDENTAL MORTALITY

4.1 Operational and technological aspects (Gillnet; Longline; Purse seine)

35. The IO-ShYP01 **NOTED** that measures for mitigation of shark bycatch in IOTC managed pelagic fisheries have both major 'pros and cons'. These were highlighted for each method, based on best scientific knowledge currently available. Additionally, the level of research needs and financial implications were also considered (Table 9). Additional information for this Section are provided in Appendix V.

36. The IO-ShYP01 **AGREED** that the list of mitigation measures summarised in Table 9 is **not** a ranking of potential measures, as the objective of this review was just **to highlight research needs** before any advice can be provided on their potential application and efficiency if introduced to IOTC managed pelagic fisheries. Additionally, the research needs take into consideration mostly their potential as shark mitigation measures, albeit the implications these might have on fisheries data collection and, consequently, on the shark stock assessment process.

37. The IO-ShYP01 **AGREED** that the listed management mitigation measures for major IOTC fisheries impacting sharks were split into two different categories: i) Operational and technological aspects, and ii) Best practices.

Table 9. Summary of mitigation measures reviewed by the working group

Measure / Method	Approach	Research needs	Funding level
Longline			
Avoiding hotspots	Fleet communication program	No needs for research	No
Spatial and/or temporal closure	Spatial and/or temporal closure/MPAs	High research needs	Medium
Fishing time	Soaking time	Moderate research needs	Medium
Fishing depth	Deep setting - traditional	No needs for research	No
Fishing depth	Deep setting and elimination of shallow hooks	No needs for research	No
Decrease fishing mortality	Reduction of fishing effort	No needs for research	No
Decrease fishing mortality	Prohibition of retention	High research needs	Medium
Management of offal discharge	Reduction of offal discharge	No needs for research	No
Finning prohibitioin and other legal constrains in the fishery	Prohibition of shark finning	No needs for research	No
Bait modification	Bait type (squid vs. fish)	No needs for research	Medium
Bait modification	Blue/Green-dyed bait	No needs for research	No
Bait modification	Artificial bait	Moderate research needs	High
Attractant / Deterrent use	Restrictions on Light Attractors	No needs for research	No
Attractant / Deterrent use	Olfactory repellent/attractant	No needs for research	No
Attractant / Deterrent use	Magnetic, E+ metals	Moderate research needs	Medium
Catchability /Selectivty	Prohibition of wire/braided nylon trace use	High research needs	High
Catchability /Selectivty	Circle hooks + bait type	High research needs	High
Catchability /Selectivty	Corrodible hooks	Moderate research needs	Medium
Catchability /Selectivty	Weak hooks	Moderate research needs	Medium
Safe handling and release	Safe handling and release, promoting post-release survivorship	High research needs	High
Safe handling and release	Mandatory shark safe handling equipment	No needs for research	No
Awareness	Workshop/training information dissemination on good handling practices/fishing practices	No needs for research	Medium

Measure / Method	Approach	Research needs	Funding level
Gillnet			
Fishing time	Soaking time	Moderate research needs	Medium
Decrease fishing mortality	Reduction of fishing effort	No needs for research	No
Decrease fishing mortality	Prohibition of retention	High research needs	Medium
Gear configuration	Selectivity (mesh size, gear rigging/construction, net panel material)	High research needs	High
Turtle/shark lights for gillnest	LED lights, UV lights, nets constructed of photoluminescent materials.	No needs for research	No
Attractant / Deterrent use	Acoustic pingers	No needs for research	No
Attractant / Deterrent use	Olfactory repellent/attractant	No needs for research	No
Attractant / Deterrent use	Powered electric field ‘barrier’ Magnetic field ‘barrier’	No needs for research	Medium
Attractant / Deterrent use	Pre-net fence (tactile)	No needs for research	Medium
Safe handling and release	Safe handling and release, facilitation post-release survivorship	High research needs	High
Safe handling and release	Mandatory turtle/shark safe handling equipment	No needs for research	Moderate
Awareness	Workshop/training information dissemination on good handling practices/fishing practices	No needs for research	Medium
Purse Seine			
Decrease ratio bycatch/target catch	Setting on bigger aggregations	No needs for research	No
Avoiding protected/charismatic species	Prohibition of setting on whale sharks	Moderate research needs	Medium
Decrease fishing mortality	Reduction of fishing effort for certain types of schools	No needs for research	No
Non entangling FADs	Non entangling FADs	No needs for research	No
Release panels for shark	Release panel	Moderate to high research	High

Measure / Method	Approach	Research needs	Funding level
		needs	
Attractant / Deterrent use	Acoustic attractant	Moderate research needs	High
Safe handling and releases	Safe handling and release practice	No needs for research	No
Workshop/training information dissemination on good handling practices/fishing practices	Fisheirmen training / awareness	No needs for research	No

5. REVIEW OF THE MOST APPROPRIATE ASSESSMENT METHODS THAT COULD BE USED ON THE MAIN SHARK SPECIES, AS WELL AS THE POTENTIAL USE OF OTHER INDICATORS AS ALTERNATIVES TO TRADITIONAL STOCK ASSESSMENT APPROACHES

5.1 Stock status indicators

5.1.1 CPUE standardisation

38. The IO-ShYP01 **NOTED** the methods of CPUE standardization available. GLM (Catch or CPUE model) has been used to handle 0 (zero) catch data problems. This method was also suggested to apply to shark data as they have a large composition of 0 (zero) data. There is a rule of thumb to select GLM model by composition of 0 (zero) catch data, i.e., log normal GLM model if 0 (zero) catch composition is less than 30%, negative binominal (catch) model (30%~60%) and Delta-type two-step model (> 60%). The Tweedie model can handle any composition of 0 (zero) catch. It was also suggested to use 2 or more methods in CPUE standardization to evaluate the results.

5.1.2 Demographic analysis

39. The IO-ShYP01 **NOTED** that demographic analyses are usually carried out using: 1) life tables based on the Euler-Lotka equation; 2) age-based Leslie matrix population models or 3) stage-based Lefkovitch matrices. These models are typically based on deterministic, density-independent population growth theory, whereby populations grow at an exponential rate r and converge to a stable age distribution. Data requirements include maximum age, survival from natural mortality, age-specific fecundity (the number of offspring produced per breeding female of age x), sex ratio at birth, frequency of parturition, proportion of mature or breeding females at age x, and some associated information such as growth function parameters and a length-mass relationship. Sensitivity and elasticity analysis are extensions of matrix analysis that allows the identification of which vital ages/stages influence population growth rate the most, and thus which life ages/stages are more important for population growth.

5.2 Stock assessment approaches

5.2.1 Data-poor assessment approaches

- Ecological Risk Assessment – Productivity Susceptibility Analysis

40. The IO-ShYP01 **NOTED** that the Ecological risk assessment (ERA), and specifically Productivity-Susceptibility Analysis (PSA), is a useful methodology to rank bycatch sustainability by contrasting the productivity (p) of the bycatch species and their susceptibility (s) to the fishery. The productivity and susceptibility scores are displayed graphically on an x-y scatter plot to visualize species with high productivity and low susceptibility, which are considered at low risk or vulnerability, and low productivity and high susceptibility or those at high risk. The PSA figure allows to estimate directly an overall vulnerability score (v), a measure of the resilience of the species to the impact of the fishery (Stobutzki et al., 2002; Cortés et al., 2010).

41. The IO-ShYP01 **NOTED** that productivity parameters can be estimated based on life history parameters using Leslie matrices analysis, in which the value of Lambda (λ), population finite growth rate, is calculated (Caswell 2001). Susceptibility, defined as the potential effect of the fisheries in the stock, can be assessed as the product of four parameters: availability, encounterability, selectivity and post-capture mortality. Availability is the proportion of the species habitat area harvested by a given fleet or the probability that the stock will be available for a given fleet on the horizontal plane. Encounterability is the probability to encounter the available stock by one unit of fishing gear. Selectivity is the proportion of the individuals captured by the fishing gear provided that they are encountered. And post-capture mortality, is the proportion of animals that die as a result of the interaction with the gear (for more details see Walker (2004) or Cortés (2010)).

- Stock Reduction Analysis (SRA)

42. The IO-ShYP01 **NOTED** that SRA uses a surplus production model and catch estimated to project population size over time. SRA is constrained with range of depletion values at different points (times) in the trajectory. A set of models can fit these depletion rates, and these models have an optimal yield target as well as an optimal F target, which can then be used to assess management quantities, and current stock status levels. A case study using Kawakawa was introduced. It was suggested to use another approach like ASPIC (if catch and effort data are available) in order to evaluate the results. One question was raised, i.e., frequency distributions of resultant r and

K were skewed, while the one of MSY was normally distributed. If informative Bayesian priors were used, this problem will be solved in some extent

- Catch free models

43. The IO-ShYP01 **NOTED** that most stock assessment methods commonly used for fisheries advice and management require catch data, which for many species, particularly by-catches such as most sharks, are not always available. Catch-free methods are techniques that can estimate some reference points, stock status, and recovery times in situations where catch data is not available or cannot be estimated. Catch free methods can be based mainly on life history parameters (Zhou et al., 2012), or can use a CPUE series, in which case they the estimator is essentially an age-structured production model recast in terms relative to pre-exploitation levels (Porch et al., 2006).

5.2.2 Weight-of-Evidence approach to stock status determination

44. The IO-ShYP01 **RECALLED** that the SC had requested that in 2012, due to growing interest and use of the Weight-of-Evidence approach to determine stock status for data poor fisheries, that the IOTC Secretariat facilitate a process to provide the necessary information to the SC so that it may consider the Weight-of-Evidence approach to determine species stock status, as an addition to the current approach of relying solely on fully quantitative stock assessment techniques. A Weight-of-Evidence approach is currently being used in a number of countries to routinely determine stock status for data poor fisheries. The approach involves developing and applying a decision-making framework by assembling an evidentiary base to support status determination. Specifically, the framework aims to provide a structured, scientific process for the assembly and review of indicators of biomass status and levels of fishing mortality. Arguments for status determination are based upon layers of partial evidence. Ideally there would be independence between these layers which will be developed with a mixture of quantitative and qualitative reasoning. The framework provides guidance with which to interpret those indicators, and aims to provide a transparent and repeatable process for status determination. The framework includes elements to describe attributes of the stock and fishery; documentation of lines of evidence; and documentation of status determination.
45. The IO-ShYP01 **NOTED** that for shark species, as well as billfish and neritic tuna stocks, particularly in smaller fisheries, only a subset of the types of evidence are likely to be available and/or useful. As a result, expert judgment has an important role in status determination, with an emphasis on documenting the key evidence and rationale for the decision.
46. The IO-ShYP01 **RECALLED** that in 2013, the SC encouraged further exploration and potential utilisation of the weight-of-evidence approach to determine stock status by its Working Parties in 2014 and future years.

5.2.3 Fully-quantitative approaches

47. The IO-ShYP01 **REVIEWED** a range of fully-quantitative approaches (traditional assessment methods i.e., Production model (ASPIC), Age based models (VPA, ASPM, SCAA and etc.) and integrated models (SS3, MUTIFAN-CL and etc.) for potential use on shark species. Data types needed for each method was also explained. A summary is provided in Table 10 and supporting information in Appendix VI.

Table 10. Stock assessment models, data requirements, Reference points, Management advice and Pros/Cons

Method	Data Requirements		Reference Points	Management Advice	Pros	Cons
	Biology	Fishery				
PSA	Qualitative	Qualitative	No	Qualitative	Easy to use if LH parameters available	Difficult to relate to current abundances a fishing mortality.
Demographic Models/Elasticity Analysis	Age & growth, Fecundity, Natural Mortality	Several fishery characteristics	No	Mostly qualitative (change of gear) and F	Easy to use if LH Parameters available. Can provide guidance on gear usage/ selectivity	Must assume that LH parameters are corr but uncertainties can be introduced. Diffic to relate to current abundances and fishi mortality.
Catch free LH Based	M, growth curve parameters, and Age at full Maturity or Max Age	Selectivity	Yes (F_{MSY})	F_{MSY}	Easy to get LH parameters if available. Zhou et. al. (2011) provides equations that are relevant to species. Could run a meta-analysis and run as well using a Bayesian Hierarchical Model Approach. Provides a Target F.	Guidelines provided for Fishing Mortality no specifics on current status. No idea wh current Biomass and F are. However som guidelines could be provided based on theoretical carrying capacity, current depletion levels, and whether current take meeting or exceeding targets.
Catch free CPUE Based	M, growth curve parameters, and Age at full Maturity or Max Age & recruitment	Selectivity and CPUE Series	Yes (F_{MSY} & B_{MSY})	F_{MSY} & B_{MSY}	Easy to parameterize with LH data. Estimate recruitment, F and selectivity to tune to the CPUE series. Provides target F, Yield levels and where we are with regards to these rates. Provides target B as well and where we are with regards to that.	LH based assumptions could be misleadi CPUE series may not be representative o abundance series if from a limited fleet a area. Catch at size should be estimated fr the viewpoint of the operational pattern
Catch Based SRA	r & K	Catch series	Yes (F_{MSY} & B_{MSY})	F_{MSY} & B_{MSY}	Set of data that currently exist (but may not be too good). Tried and tested approach in ICES, Walters, etc. Easy to run, provides Yield targets and FMSY & BMSY	Uncertainty in catch series can give misleading results. Based on assumptions depletion range in current years that may g misleading results. May not be very accur in terms of FMSY and BMSY
Surplus Production (Bayesian or Otherwise)	r & K	Catch series & CPUE series	Yes (F_{MSY} & B_{MSY})	F_{MSY} & B_{MSY}	Traditional approaches. Used extensively in literature. Provides yield targets and FMSY and BMSY	Length of time-series and uncertainty in ca series and CPUE series can bias results Models may have problems converging t solution if there is no contrasting informat
Integrated assessments	Recruitment, M by age, growth parameters, maturation schedule, fecundity, recruitment	Catch series, Length based samples, CPUE data (and or have tagging data), fishery selectivity	Yes (F_{MSY} & B_{MSY})	F_{MSY} & B_{MSY}	Most robust approach. Incorporates all information in a dynamic model. Provides most representative yield targets and FMSY and BMSY	Highly data dependent. Models can hav problems converging. Learning curve ste

6. IDENTIFY MAJOR NEEDS IN TERMS OF CAPACITY BUILDING, AIMING TO BRING THE QUALITY AND QUANTITY OF DATA UP TO MINIMUM IOTC STANDARDS

6.1 Data collection

48. The IO-ShYP01 **RECALLED** the range of IOTC Resolutions relevant to the collection of data on sharks:

- Resolution 13/03 *on the recording of catch and effort by fishing vessels in the IOTC area of competence* sets out the minimum logbook requirements for purse seine, longline, gillnet, pole and line, handline and trolling fishing vessels over 24 metres length overall and those under 24 metres if they fish outside the EEZs of their flag States within the IOTC area of competence. As per this Resolution, catch of all sharks must be recorded (retained and discarded).
- Resolution 13/06 *on a scientific and management framework on the conservation of shark species caught in association with IOTC managed fisheries* prohibits, as an interim pilot measure, the retention onboard, transhipment, landing or storing any part or whole carcass of oceanic whitetip sharks (*Carcharhinus longimanus*) (and requests for all other species) by all vessels on the IOTC record of authorised vessels or authorised to fish for tuna or tuna-like species, with the exception of observers who are permitted to collect biological samples (vertebrae, tissues, reproductive tracts, stomachs) from oceanic whitetip sharks that are dead at haulback and artisanal fisheries for the purpose of local consumption, and will conduct a review and an evaluation of the interim measure in 2016.
- Resolution 05/05 *Concerning the conservation of sharks caught in association with fisheries managed by IOTC* includes minimum reporting requirements for sharks, calls for full utilisation of sharks and includes a ratio of fin-to-body weight for shark fins retained onboard a vessel.

49. The IO-ShYP01 **RECALLED** that in 2013, the SC recommended a regional review of the current and historical data available for gillnet fleets operating in the Indian Ocean, as follows:

- *SC16.14 (para 38): The SC reiterated its previous* ***RECOMMENDATION*** *that the Commission considers allocating funds to support a regional review of the current and historical data available for gillnet fleets operating in the Indian Ocean. As an essential contribution to this review, scientists from all CPCs having gillnet fleets in the Indian Ocean, in particular those from I.R. Iran, Oman, Pakistan and Sri Lanka, should collate the known information on bycatch in their gillnet fisheries, including sharks, marine turtles and marine mammals, with estimates of the likely order of magnitude where more detailed data are not available. A consultant should be hired for 30 days to assist CPCs with this task (budget estimate: Table 3).*

TABLE 3*. Estimated costs for the hiring of a consultant to undertake a regional review of gillnet fleets.*

Description	***Unit price***	***Units required***	***Total***
Contract days	*$350*	*30*	*10,500*
Travel costs (field)	*$3,000*	*3*	*9,000*
Travel costs to attend WPEB	*$5,000*	*1*	*5,000*
Total estimate (US$)			***24,500***

50. The IO-ShYP01 **RECALLED** that in 2013, the SC also recommended training programs for CPCs having gillnet fleets on species identification, bycatch mitigation and data collection methods and also to identify other potential sources of assistance – Development of plans of action, as follows:

- *SC16.15 (para. 39): The SC* ***RECOMMENDED*** *that the Commission allocate funds in its 2014 and 2015 budgets for the IOTC Secretariat to facilitate training for CPCs having gillnet fleets on bycatch mitigation methods, species identification, and data collection methods (budget estimate: Table 4).*

TABLE 4*. Estimated costs for CPCs with large gillnet fleets on bycatch mitigation methods, species identification and data collection methods. Two training workshops: I.R. Iran/Oman and Sri Lanka.*

Description	***Unit price***	***Units required***	***Total***
Production of training material	*$1,000*	*1*	*1,000*
Travel costs (IOTC Staff) (I.R.Iran/Oman, Sri Lanka)	*$4,000*	*3*	*12,000*
Travel costs (Experts) (I.R.Iran/Oman, Sri Lanka)	*$4,000*	*3*	*12,000*
Workshop venue – to be paid by hosts	*$0*	*2*	*$0*
Total estimate (US$)			***25,000***

51. The IO-ShYP01 **AGREED** that although there have been improvements in recent years, data collection on shark catches by IOTC fisheries remains limited. In many cases where data is being collected, it is being incorrectly recorded. A concerted action/effort to enhance data gathering abilities, database development and ongoing maintenance and verification in the following CPCs/fisheries would be needed if relevant stock status indicators for shark species could be developed in the future: Gillnet fleets from I.R. Iran, Pakistan, Oman, Sri Lanka.

6.2 Verification / Regional Observer Scheme

52. The IO-ShYP01 **RECALLED** the IOTC Resolution on a regional observer scheme:

- Resolution 11/04 *on a Regional Observer Scheme* requires data on blue shark interactions to be recorded by observers and reported to the IOTC within 150 days. The Regional Observer Scheme (ROS) started on 1st July 2010.

53. The IO-ShYP01 **RECALLED** that in 2013, the SC also recommended observer scheme training programs, as follows:

- *The SC **RECOMMENDED** that the Commission considers funding of future activities under the Regional Observer Scheme, by allocating specific funds to the implementation of capacity building activities in developing coastal countries of the IOTC Region, as detailed in Table 17.*

***TABLE 17**. Estimated budget for IOTC consultants to be engaged in Regional Observer Program training in 2014–15*

Description	*Unit price*	*Units required*	*Total*
2014			
Regional Observer Scheme – training materials	*US$2,000*	*1*	*2,000*
Regional Observer Scheme – travel (5 trips)	*US$4,000*	*5*	*20,000*
2015			
Regional Observer Scheme – training materials	*US$2,000*	*1*	*2,000*
Regional Observer Scheme – travel (5 trips)	*US$4,000*	*5*	*20,000*
Total estimate (US$)			***44,000***

54. The IO-ShYP01 **AGREED** that, in addition to the implementation of the ROS which is likely to take time, the collection of scientific data by all other means available including, pilot observer schemes, self-sampling (collection of data by trained crew) and electronic monitoring (sensors and video cameras) be encouraged and developed, and for CPCs to report on progress at the next WPEB meeting.

55. The IO-ShYP01 **AGREED** on the need for a comprehensive, long term training program, should be developed to ensure the IOTC Regional Observer Scheme requirements (data verification, species identification, coverage levels) are met. As part of this program of training/capacity building, the IOTC Shark Identification cards must urgently be translated into the following language groups, with other languages as a secondary priority:

- Group 1: Persian(Farsi) + Arabic + Urdu(Pakistani)
- Group 2: Spanish + Portuguese + French

6.3 Reporting

56. The IO-ShYP01 **RECALLED** the IOTC Resolution relevant to the reporting of data on shark interactions/catches:

- Resolution 10/02 *Mandatory statistical requirements for IOTC Members and Cooperating Non-Contracting Parties (CPC's)* indicated that the provisions, applicable to tuna and tuna-like species, are applicable to shark species.

57. The IO-ShYP01 **AGREED** that capacity building activities related to the reporting of shark data by IOTC CPCs should occur in tandem with the data recording requirements, under Section 2 above.

6.4 Other capacity building activities

Research collaboration

58. The IO-ShYP01 **AGREED** that collaboration and cooperation are essential actions that build the base of any transnational research activity. In the case of pelagic sharks species occurring in the Indian Ocean any research plan and efficient data collection focused on these widely distributed species requires the enforcement of mechanisms to strengthen relations between the scientific teams involved in the process. The areas of collaboration that should be reinforced within this collective action that were identified include:

- capacity building and training in data collection and analysis
- elaboration of protocols for the collection, storage, preservation and exchange of biological samples
- protocols for the analysis of biological samples
- equitable distribution of the biological sampling effort framed in a predefined scientifically sampling scheme
- promotion of visiting and interchanges opportunities for scientists at national laboratories
- prioritise multilateral collaboration for specific studies, aimed at promoting collaboration among scientific teams involved in shark research within the Scientific Committee of IOTC and other t-RFMOs.

7. PRIORITISE DATA COLLECTION AND RESEARCH ON SHARK SPECIES

7.1 Fisheries and data collection

59. The IO-ShYP01 **AGREED** that in general, there is a scarcity of data and limited data availability for major fleets and countries in IOTC for all shark species (although species such as blue shark can be considered a less data poor species). However, this is particularly evident for gillnet and/or coastal fishery, which accounted for around 68 % of the reported catch in IOTC database. Although some countries using gillnets (e.g. I.R. Iran and Oman) are providing the shark statistics to IOTC in aggregated level, the Resolution and stratification of the data is poor. This paucity of information of gillnet/coastal fisheries is basically due to the difficulties for coastal countries to cover all unloading places, identification of species and implementation of observer programs.

60. The IO-ShYP01 **AGREED** that the shark fishery data collection for gillnet/coastal fisheries as a high priority area, particularly for I.R. Iran, Sri Lanka, Pakistan, Yemen, India and Indonesia. Any work in this area should include all the components of data collection program including information of type of vessels, fleet characteristics and observer programs along with the implementation of a capacity building program. Although in general the longline fleet can be considered a fleet with a better shark fishery statistics (e.g. EU and Japanese longline fleets) there are still fishery data gaps in relation to some shark species and some LL fleet. Thus, the group considers as a matter of high priority to improve the data collection systems (i.e. through self-reporting, observers, electronic monitoring, etc.) for species that are caught by longline.

61. The IO-ShYP01 **AGREED** that the gaps in historical fishery statistics can be an important limiting factors for most of the fleets. Thus, any attempt for improving the data collection should be accompanied by a historical data mining exercise for the key species and fleets, such as artisanal gillnet and longline coastal fisheries. If it is not possible to obtain historical data, current observer programs can be used by each specific fleet to reconstruct species composition of sharks. Thus, the group considers as a matter of high priority a data mining process for major fleets/countries catching sharks and that an observer program is implemented in those countries/fleets.

62. The IO-ShYP01 **NOTED** that catch and effort, and spatial distribution of catches statistics is available for major longline and purse seiner fleets, but is mostly absent for those fisheries which are believed to have large catches on pelagic catches (i.e. various longline fleet, gillnet and coastal fisheries). Thus, the group considers the collection of information about catch and effort and spatial distribution of those fleets with important shark catches as high priority.

63. The IO-ShYP01 **NOTED** that size frequency data from observer programs are available for major longline and purse seiner fleets, but is mostly absent for those fisheries which are believed to have large catches on pelagic catches (i.e. various longline fleet, gillnet and coastal fisheries). Thus, the group considers the collection of information about size frequency of catches and bycatches of those fleets with important shark catches as high priority.

64. The IO-ShYP01 **AGREED** that the implementation of the Regional Observe Schemes are necessary for the collection of basic information such as shark bycatch rates, shark species composition of the catch, correct species identification of shark, size frequency data, spatial/temporal shark catches, etc.

65. The IO-ShYP01 **NOTED** that the low progress in the implementation of observer programs (Resolution 11/04) is hindering the ability of IOTC WPEB to infer the status of shark populations

66. The IO-ShYP01 **RECOMMENDED** as high priority the implementation of Regional Observer Schemes in major IOTC fleets, including coastal artisanal fleet, and/or the collection of scientific data by all other means available including, pilot observer programmes, self-sampling (collection of data by trained crew) and electronic monitoring (sensors and video cameras).

7.2 Shark biology and ecology

67. The IO-ShYP01 **AGREED** to the following list of research priorities in terms of biology and ecology. A temporal scale was attributed to those recommendations, with the following notation: short-term is the period until the next assessment (usually < 2 years), medium-term refers to the period until the second next assessment (usually < 5years), and long-term refers to long-term research over a longer time period.
    - **Age and growth**: ***HIGH priority in the short/medium term*** - Age and growth studies have been conducted and published in the Indian Ocean only for the blue and silky shark, but not for the other species. Those parameters are used as inputs in several stock assessment methods, and as such should be highly prioritized in future scientific research.
    - **Stock ID**: ***HIGH priority in the short/medium term*** – Stock identification, usually carried out using genetics tools, is important for delimiting stocks when conducting stock assessments. However, there is still no information on stock identification and delimitation for most shark species in the Indian Ocean, and as such it is recommended as a high priority research area for the near future.
    - **Migrations and habitat use (satellite tagging)**: ***HIGH priority in the short/medium term*** – Tagging studies, particularly with satellite tags have been used in the Indian Ocean for blue and silky sharks. Satellite tags can be used to estimate spatial movements, as well as vertical depth/temperature behaviour, which are important to understand the species spatial dynamics, including Essential Fish Habitats (e.g. nursery and mating grounds). However, this important information is still missing for most species, and should be a priority area of research in the near future.
    - **Post-release mortality**: ***HIGH priority in the short term*** – Post-release mortality can be estimated from satellite tags. This information is important, for example, to estimate the efficiency of mitigation measures such as prohibition of retention, minimum landing sizes, and others that require mandatory discards or live release of the sharks.
    - **Conventional tagging**: ***MEDIUM priority in short-term, HIGH in long-term*** - Conventional tagging can be carried out opportunistically by fishery observers with little costs and can provide, over the long term, important information on movements, migrations, survivorships, and abundances of the populations.
    - **Reproduction**: ***MEDIUM priority in the short, medium and long term*** - Some level of information on reproduction already exists for most species. Reproductive studies, that can be used in some of assessment methods (especially data-poor approaches), should have a medium priority and be focused especially on the specific aspects and species for which information is still currently missing.
    - **Feeding**: ***LOW priority in the short-term, MEDIUM in the long term*** – Feeding information is available for some species. While feeding data is usually not used directly in most of the traditional stock assessment methods, it is important for ecosystem-based approaches. As such, a medium priority should be given those issues in the long-term, as they may be needed in the future for conducting ecosystem-based modelling approaches.

7.3 Indicators and assessment methods

68. The IO-ShYP01 **NOTED** that according to the currently available information, no stock indicator or stock assessment method (data-poor or traditional) could presently be completely implemented for any shark species in the Indian Ocean. However, some methods would be possible to implement with additional estimations of some parameters, or substitutions from other Oceans (Table 11). In terms of species, the blue shark is the species for which it would be possible to conduct a more detailed analysis, including stock indicators (CPUE standardisation), data-poor and traditional stock assessments. For the shortfin mako shark and oceanic whitetip shark it would be possible to carry out CPUE standardisation, data poor assessments and production models (assuming that the catch data series could be reconstructed). For the other species, and as even more limited information is presently available, only some data poor methods such as PSA/demographics and stock reduction analysis could be implemented.

Table 11. Provisional conclusions on feasible shark stock assessment methods and CPUE standardization (STD_CPUE) according to the currently available information (May, 2014).

Color legend	**Can be conducted using the available data**	**Can be conducted by available information with additional estimation works and/or substitutions from other waters**	**Cannot be conduced**

(NB) Careful examinations of available periods, coverage and data quality are needed for (a) CE data to be used for STD_CPUE and (b) Nominal catch, in advance, as evaluation of these two types information were roughly conducted using limited information during this meeting. It should be also well noted that good quality of these two types data may be available only in last 10 years or so.

	Stock indicator	**Data poor SA**			**Traditional SA**		
	STD_CPUE	**ERA+PSA (demography)**	**Catch-free CPUE based**	**SRA**	**Production model (PM)**	**Age based SA**	**Integrated models**
(1) BSH (Blue shark)							**(without spatial structure)**
(2) SMA (Shortfin mako shark)							
(3) OSC (Ocean whitetip shark)							
(4) SPL (Scalloped hammerhead shark)							
(5) FAL (Silky shark)							
(6) BTH (Bigeye thresher shark)							
(7) PTH (Pelagic thresher shark)							

7.4 Mitigation measures

69. The IO-ShYP01 **RECALLED** that under Agenda item 4 the working group reviewed and analysed more than 100 available peer-reviewed publications on potential mitigation measures for mitigation of shark bycatch in IOTC managed pelagic fisheries. Major 'pros and cons' of each method were highlighted, based on best scientific knowledge currently available. Additionally, the level of research needs and financial implications were also considered.

70. The IO-ShYP01 **AGREED** that the list of mitigation measures summarised in Appendix V is **not** a ranking of potential measures, as the objective of this review was **just to highlight research needs** before any advice can be provided on their potential application and efficiency if introduced to IOTC managed pelagic fisheries. Additionally, the research needs took into consideration mostly their potential as shark mitigation measures, albeit the implications these might have on fisheries data collection and, consequently, on the shark stock assessment process. The listed management mitigation measures for major IOTC fisheries impacting sharks were split into two different categories: i) Operational and technological aspects, and ii) Best practices.

4.1 Operational and technological aspects

Prohibition of retention

71. The IO-ShYP01 **NOTED** that the prohibition from retaining on board, transhipping, landing, storing, selling or offering for sale any part or whole carcass of sharks, was already set in place by the IOTC for thresher sharks and oceanic whitetip shark (Resolutions 12/09, 13/03).
    - *Research priorities* – High. Assess efficiency for currently prohibited species. Moderate for major shark species.

4.1.1. Longlines – High priority

Circle hooks

72. The IO-ShYP01 **RECALLED** that circle hooks are a hook style distinguished for having a rounded shape with the point oriented perpendicular to the shank, as a means to reduce bycatch mortality. Most of the research involving circle hooks aimed at reducing interactions of longlines with marine turtles.
    - *Research priorities* – High. Additional work is required to assess efficiency of the combination of circle hooks and bait types in terms of catch rates of both targeted species and bycatch, at-haulback and post-release mortality, particularly for major shark fishing areas in the IO.

Spatial and/or temporal closure/MPAs

73. The IO-ShYP01 **RECALLED** that time and area closures is a common management measure in coastal fisheries, as a tool to reduce fishing effort and mortality, protect sensitive areas and/or specific species life stages. However, as regards highly migratory species, the implementation of such spatial-temporal areas closures has been limited to tropical tuna fisheries.
    - *Research priorities* – High. Identify major pelagic shark hotspots and investigate associated environmental conditions affecting shark distribution in the Indian Ocean.

Prohibition of wire/braided nylon trace use

74. The IO-ShYP01 **RECALLED** that the terminal part/section of the gangions used on longlines is usually made of monofilament nylon material. However, on fisheries targeting sharks and in areas of high abundance of sharks, wire or braided "multifilament" nylon leaders are regularly used by swordfish target longliners.
    - *Research priorities* – High. Need to carry out large scale experiments in the Indian Ocean to improve knowledge on this measure and assess economic implications.

4.1.2. Purse-seines – High priority

None

4.1.3. Gill nets – High priority

Selectivity (Mesh size, hanging ratio, etc…)

75. The IO-ShYP01 **RECALLED** that there are number of technical aspects of gillnet gear that affect selectivity including mesh size, hanging ratio, net twine material, etc.
    - *Research priorities* – High. All types of technical aspects of the gear affecting selectivity needs research by fleet, depends on target species.

4.2. Best practice

Safe handling and release

76. The IO-ShYP01 **RECALLED** that guidelines to handle and release sharks and other protected species in order to reduce the mortality without detrimental effect on safety of fishermen. This already was developed and approved for PS fisheries.
    - *Research priorities* – Developing guidelines and protocols for safe handling and release: High priority for longline and gillnet.

Prohibition of setting on whale sharks (PS)

77. The IO-ShYP01 **RECALLED** that corresponds to prohibition from intentionally setting a purse seine net around a whale shark in the IOTC area of competence, if it is sighted prior to the commencement of the set. Regulation was already set in place by IOTC for whale shark (Resolutions 13/05).
    - *Research priorities* – High. Post release mortality of whale sharks released from purse seine is unknown. Efficiency of the best practice currently set in place should be assessed.

4.1.1. Longlines **-** Moderate priority

Corrodible hooks

78. The IO-ShYP01 **RECALLED** that corrodible hooks are fishing hooks composed of material other than stainless steel. They may be made from different alloys, with different coatings, which all affect how long they last. The hook may dissolve quickly, within a couple of days, or more slowly over weeks or months. The premise behind the use of corrodible hooks is that they should improve the survival rate of by-catch released with a hook attached.
    - *Research priorities* – Moderate. Efficiency and economics impacts should be assessed.

Weak hooks

79. The IO-ShYP01 **RECALLED** that a weak hook is a hook that is constructed of round stock wire that is thinner-gauge than the traditional hooks currently used in a given fishery. The difference between the traditional hook and the weak hook is barely detectable to the naked eye; however, the weak hook is more likely to bend when a large fish or marine mammal is hooked.
    - *Research priorities* – Moderate. Efficiency and economics impacts should be assessed.

Magnetic, E+ metals, electrical deterrent

80. The IO-ShYP01 **RECALLED** that the use of permanent magnets, electropositive rare earth metals (EPREM) and other electrical measures has been tested as a means of deterring sharks from approaching baited hooks. Permanent magnets are made from magnetized material and create their own persistent magnetic field. EPREM react with seawater to create such fields. Sharks are able to detect the Earth's geomagnetic field using their ampullae of Lorenzini. Electropositive metals or magnets appear to generate an aversion response in some species of sharks through an overstimulation of their ampullae, which are sensitive electroreceptors.
    - *Research priorities* – Moderate. Need to assess efficiency to mitigate shark by-catch.

Soaking time

81. The IO-ShYP01 **RECALLED** that the pelagic longlines are often soaking for long periods, in some cases for more than 24 hours, depending on the vessels characteristics and sea conditions. Longer soaking time usually results in higher proportion of shark caught in relation to target species catch. The proportion of fish alive at-haulback is inversely related to time on the line (hooking duration), hence the mortality of fish caught increased as soak time increased. Of the pelagic species shown, sharks were most resistant to hooking mortality.

- *Research priorities* – Moderate. Optimal *soaking* duration to be assessed by target species. Impact on the target catch levels should be assessed for major fleets.

Artificial bait

82. The IO-ShYP01 **RECALLED** that artificial baits are an experimental technology in pelagic longline fisheries. Prototype artificial baits have relied upon olfactory attractants alone or in combination with a visual attractant (bait shape), each with different physical properties. Natural and/or synthetic ingredients have been used to fabricate the baits.
    - *Research priorities* – Moderate. Although they have the potential to reduce shark bycatch, considerable work remains to be done before artificial baits could be used as a viable alternative to natural baits.

4.1.2. Purse-seines – Moderate priority

Release panel

83. The IO-ShYP01 **RECALLED** that corresponds to part of purse seine wall, which could be opened to provide a 'window' for free escape of sharks from the gear.
    - *Research priorities* – Moderate to high. Efficiency of shark release procedure through the panel should be considerably improved. Experiments are being carried out by ISSF in other oceans.

Acoustic attractant

84. The IO-ShYP01 **RECALLED** that acoustic attractants are a device that produce low frequency sounds have strong attractive effect on sharks. Potentially attract sharks away from the fishing gear.
    - *Research priorities* – Moderate. Low frequency emitting device on another FAD or speedboat to attract sharks away from FAD going to be fished.

4.1.3. Gill nets – Moderate priority

Soaking time

85. The IO-ShYP01 **RECALLED** that the pelagic driftnets are often soaking for long periods, in some cases for more than 24 hours, depending on the vessels characteristics and sea conditions. The proportion of fish that still alive at-haulback is inversely related to time in the net, hence the mortality of fish caught increased as soak time increased.
    - *Research priorities* – Moderate. Optimal soaking duration to be assessed by target species. Impact on the target catch levels should be assessed for major fleets.

8. IDENTIFICATION OF POTENTIAL FUNDING SOURCES AND APPLICATION PROCEDURES

86. The IO-ShYP01 **RECOMMENDED** that the Chair of the SC and the Chair of the WPEB to liaise with the IOTC Secretariat for coordinate efforts on how funding can be achieved, and on how to use research funding in the most efficient, collaborative and transparent way, within the objectives of this research plan.

8.1 IOTC Membership

87. The IO-ShYP01 **NOTED** the following avenues for seeking funding with the IOTC membership:

Source	Time and $ limitations	Application process	Topic focus
IOTC annual budget	The IOTC budget is now estimated and approved on a two-yearly basis. Thus, the next budget cycle will cover 2014 and 2015. In exceptional circumstances, the Commission may approve additional budget items for 2015. There is no set maximum, however projects in excess of $30K are unlikely to be successful given the nature of the budget.	Proposals should come via the WPEB to the SC to the Commission.	Any approved by the WPEB and SC
Members	No specific timeframe, though most Members work at least one full year in advance.	Member specific. Suggest that once a workplan is developed	Member specific

		and approved by the WPEB, that TORs are developed for each element and submitted to the Membership.	

8.2 Non-Governmental Organisations (NGO) and Inter-Governmental Organisations (IGO)

88. The IO-ShYP01 **NOTED** the following avenues for seeking external funding:

Source	Time and $ limitations	Application process	Topic focus
WWF	Ad hoc concept notes <$50K	Once specific projects are agreed upon, a short concept note to be submitted for consideration. Additional information may be required.	• Data gaps, in particular for gillnet fisheries. • Travel assistance for relevant meetings. • Capacity building/ training workshops.
ISSF	$30–50K		
PEW; World Bank; Shark Alliance; GEF-ABNJ	Ad hoc concept notes. Funding variable.	Variable.	All listed

89. The IO-ShYP01 **AGREED** that interested participants should contact other relevant parties and develop short concept notes for each of the core topics requiring action from the workplan, and to circulate these among the IO-ShYP-01 participants for comment. The final concept notes should then be submitted to the IOTC Secretariat.

9. REVIEW OF THE DRAFT INDIAN OCEAN SHARK YEAR PROGRAM (IO-SHYP) FOR SUBMISSION TO THE WPEB IN 2014

90. The IO-ShYP01 **RECOMMENDED** that the IO-ShYP working group continue its work inter-sessionally via electronic means to develop and refine a 5 year plan of work for the consideration and potential endorsement by the WPEB at its next session to be held in October, 2014, including the consolidated set of recommendations arising from the IO-ShYP01, provided at Appendix VII.

91. The report of the Indian Ocean Shark Year Program (IO-ShYP01) (IOTC–2014–IO-ShYP01–R) was **ADOPTED** by correspondence on the 12 September 2014.

APPENDIX I
LIST OF PARTICIPANTS

Coordinators:

Dr Miguel **Neves dos Santos**
Portuguese Sea and Atmosphere Institute (IPMA), EU,Portugal
Email: mnsantos@ipma.pt

Dr Rui **Coelho** (Chair of the WPEB)
Portuguese Institute for the Ocean and Atmosphere (IPMA), EU,Portugal
Email: rpcoelho@ipma.pt

Dr David **Wilson**
Deputy Secretary / Science Manager, IOTC Secretariat
Email: david.wilson@iotc.org

Dr Evgeny **Romanov** (Vice-Chair WPEB)
CAP RUN – ARDA, EU,France
Email: evgeny.romanov@ird.fr

Dr Reza **Shahifar**
Iran Fisheries Organization
Iran, Islamic Rep. of
Email : r.shahifar@gmail.com

Mr Kotaro **Yokawa**
National Research Institute of Far Seas Fisheries, Japan
Email: yokawa@affrc.go.jp

Other participants:

Dr Juma Al-Mamry
Marine Science and Fisheries Center, Oman
Email: drjumabar@hotmail.com

Mr Ismail Al-Farsi
Ministry of Agriculture and Fisheries, Director of Fisheries Affairs, East Region, Oman
Email: iiialfarsi@yahoo.com

Dr Wetjens **Dimmlich**
World Wide Fund for Nature (WWF)
Email: wdimmlich@wwf.panda.org

Dr Hilario **Murua**
AZTI Tecnalia
Basque Country, Spain
Email: hmurua@azti.es

Dr Tom **Nishida** (SC Chair)
National Research Institute of Far Seas Fisheries (NRIFSF), Japan
Email: tnishida@affrc.go.jp

Mr Mohammad **Noor**
Department Balochistan, Pakistan
Director General Fisheries, Pakistan
Email: noorbfd@gmail.com

APPENDIX II
AGENDA FOR THE INDIAN OCEAN SHARK YEAR PROGRAM (IO-SHYP01) WORKSHOP

Date: 14–16 May 2014

Location: IPMA Building, Olhão Portugal

Time: 09:00 – 17:00 daily

Coordinators: Dr. Miguel Neves dos Santos; Dr. Rui Coelho; Dr David Wilson

In December 2013 the IOTC Scientific Committee recommended that a detailed multiyear shark research program be prepared by a small group of shark experts and the IOTC Secretariat, to further advance, detail and propose an Indian Ocean Shark multi-Year Program (IO–ShYP) for finalisation at the next WPEB meeting (see SC recommendation SC16.33). The main objective of the IO–ShYP will be to "*promote cooperation and coordination among IOTC researchers, to improve the quality of the scientific advice on sharks provided to the Commission, namely by conducting quantitative stock assessments for selected species by 2016, and to better assess the impact on shark stocks of the current IOTC Conservation and Management Measures*."

Participants to the meeting will compile the current information available, identify major gaps in knowledge, and establish priorities for future research and cooperation among IOTC scientists and other groups.

1. **OPENING OF THE SESSION** (Coordinators)
2. **REVIEW OF THE CURRENT INFORMATION AVAILABLE (FISHERIES, DATA COLLECTION) AND IDENTIFY MAJOR GAPS** [Task leader: Hilario Murua (AZTI); Support: Kotaro Yokawa (NRIFSF), IOTC Secretariat and all regional participants]
   - 2.1 Fleet and gear characterisation
   - 2.2 Fleet dynamics
   - 2.3 Data needs [Catch (landings and discards), effort, CPUEs series; gear selectivity; catch-at-size/age; Data mining/recover of historical data sets for sharks]
   - 2.4 Trade data
   - 2.5 Observer programs (design and implementation)
3. **REVIEW OF THE CURRENT AVAILABLE INFORMATION IN TERMS OF BIOLOGICAL AND ECOLOGICAL KNOWLEDGE OF THE SEVEN MAJOR SHARK SPECIES (BSH, SMA, OCS, FAL, SPL, PTH AND BTH)** [Task leader: Rui Coelho (IPMA); Support: Evgeny Romanov (CAP RUN - ARDA)]
   - 3.1 Life history traits (age and growth; reproduction; mortality)
   - 3.2 Stock structure, range and distribution (tagging and genetics)
   - 3.3 Habitat use and migrations
   - 3.4 Morphometrics and conversion factors for shark products
4. **REVIEW OF THE CURRENT AVAILABLE AND IMPLEMENTED MITIGATION MEASURES, INCLUDING BEST PRACTICE CODES/PROCEDURES, IN TERMS OF REDUCING SHARK BYCATCH AND INCIDENTAL MORTALITY** [Task leader: Evgeny Romanov (CAP RUN - ARDA); Support: Miguel N Santos (IPMA); David Wilson]
   - 4.1 Operational and technological aspects (Gillnet; Longline; Purse seine)
   - 4.2 Best practices
5. **REVIEW OF THE MOST APPROPRIATE ASSESSMENT METHODS THAT COULD BE USED ON THE MAIN SHARK SPECIES, AS WELL AS THE POTENTIAL USE OF OTHER INDICATORS AS ALTERNATIVES TO TRADITIONAL STOCK ASSESSMENT APPROACHES** [Task leader: Tom Nishida (SC Chair); Support: IOTC Secretariat; Rui Coelho (IPMA); other experts via correspondence]
   - 5.1 Stock status indicators
     - 5.1.1 CPUE standardisation
     - 5.1.2 Demographic analysis

5.2 Stock assessment approaches

5.2.1 Data-poor assessment approaches

- Ecological Risk Assessment – Productivity Susceptibility Analysis
- Stock Reduction Analysis
- Catch free models

5.2.2 Weight-of-Evidence approach to stock status determination

5.2.3 Fully-quantitative approaches

6. **IDENTIFY MAJOR NEEDS IN TERMS OF CAPACITY BUILDING, AIMING TO BRING THE QUALITY AND QUANTITY OF DATA UP TO MINIMUM IOTC STANDARDS** [Task leader: David Wilson; Support: Reza Shahifar (I.R. Iran); Juma Almamry & Ismail AlFarsi (Oman); Mohammad Noor (Pakistan); Wetjens Dimmlich (WWF)]

6.1 Data collection

6.2 Verification / Regional Observer Scheme

6.3 Reporting

7. **PRIORITISE DATA COLLECTION AND RESEARCH ON SHARK SPECIES, BEARING IN MIND THE SC SCHEDULE OF ASSESSMENT (BSH – INDICATORS IN 2014, FULL ASSESSMENT IN 2015; OCS - INDICATORS IN 2014, FULL ASSESSMENT IN 2016; SPL: - INDICATORS IN 2015; FAL - INDICATORS IN 2015; SMA – INDICATORS IN 2016; PTH – INDICATORS IN 2016; BTH – INDICATORS IN 2017)** [Task leader: Miguel N Santos (IPMA); Support: Tom Nishida (SC Chair); Rui Coelho (Chair WPEB); David Wilson (IOTC Secretariat)]

7.1 Fisheries and data collection

7.2 Shark biology and ecology

7.3 Indicators and assessment methods

7.4 Mitigation measures

7.5 Capacity building

8. **IDENTIFICATION OF POTENTIAL FUNDING SOURCES AND APPLICATION PROCEDURES** [Task leader: David Wilson; Support: Wetjens Dimmlich (WWF)]

9. **REVIEW OF THE DRAFT INDIAN OCEAN SHARK YEAR PROGRAM (IO-ShYP) FOR SUBMISSION TO THE WPEB IN 2014** (Coordinators)

APPENDIX III
AGENDA ITEM 2 SUPPORTING INFORMATION: REVIEW OF THE CURRENT INFORMATION AVAILABLE (FISHERIES, DATA COLLECTION) AND IDENTIFY MAJOR GAPS

Background

Numerous aspects of fishery statistics and biology of the shark species caught in association with tuna fisheries in the IOTC area of competence are still poorly understood or unknown. In general, there is a scarcity of data and even for major fleets and CPCs there is limited data being reported, and therefore available in the IOTC database. With regards to historical data, several countries have not collected and shark fishery statistics, especially in the years prior to the major development of tuna and tuna-like fisheries in the Indian Ocean, in the early 1970s. At present, most industrial fisheries provide limited data, while artisanal and small scale fisheries data is almost non-existent due to monitoring difficulties. Most CPCs are not reporting shark statistics to the IOTC Secretariat, despite the mandatory reporting requirements of the IOTC. 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). Although finning is prohibited, it still occurring but the catches of sharks for which only the fins are kept on board are rarely recorded. Therefore, the information on the catch of sharks provided by most CPCs is thought, for this reason, to be incomplete and/or inaccurate.

Moreover, 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 and fleet. Generally major sharks are better reported than other species but still there are inconsistencies. Misidentification 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.

There is scarce data on discards, incomplete and heterogeneous: some CPCs report discards in weight, while others provide discard numbers. Data from the IOTC regional observer scheme is not yet available or only available for a few fishing trips each year, and the observer coverage varies substantially by fishery, although it is generally considered very low in most of the fleets, while there are no observer schemes implemented in some coastal country fleets (i.e. gillnets fisheries).

Very little information about shark catches length frequencies is available both for landings and catches recorded by observers. There is a general lack of biological and ecological knowledge for pelagic sharks in the Indian Ocean. 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, resulting in half of the samples collected so far not being identified to species.

Information on the activities of fleets capturing sharks (by targeting or as an incidental bycatch), the reporting level of catch data (although improvements have been made in recent years), is still insufficient to permit the provision of quantitative advice on stock status with sufficient precision to guide fishery management toward optimal harvest levels for any of the species. Nominal catches from the IOTC database, as well as the estimations carried out by Murua et al. (2003), provides as comprehensive picture as possible of what are the main fleets capturing shark species in the IOTC area of competence (Table 1). These estimates also help to identify the different species for which greater focus is needed, as well as those for which resources should not be applied in the near future. However, a detailed analysis of the information available is needed, with the aim of prioritizing which fleets require immediate monitoring, so as to design specific and representative data collection programs, as well as scientific observer schemes for those fleets, to facilitate a comprehensive assessment of the status of the shark stocks impacted by IOTC fisheries for tuna and tuna-like species.

Table 1. Summary of the main fisheries catching shark species, and summary of the most commonly shark species caught in the IOTC area of competence according to IOTC database and to Murua et al. (2013).

IOTC	IOTC database	Murua et al. (2013)
Contribution of different fisheries to total	Gillnet (68%)	Gillnet (61%)

shark catch	LL (16 %) Other gears (12 %) Line (4 %) LinePS (< 1 %)	LL (18%) Other gears (12%) PS (1%)
Shark total catch by species		Blueshark (32%) Silky shark (21%) Threshers (16%) Oceanic whitetip (11%) Shortfin mako (10%) Hammerheads (6%)

Therefore, it is essential that CPCs urgently improve data collection and research on sharks, namely on life history traits and interactions with IOTC fisheries. The overall objective is to assess the status of the shark stocks and provide adequate scientific advice on sustainable management of elasmobranch fisheries in the IOTC area of competence to the Commission. This proposal is a step forward for the provision of scientific advice and the evaluation of the efficacy of the management measures adopted by the Commission in recent years (Table 2).

Table 2. Summary of current Conservation and Management Measurements for sharks in the IOTC area of competence.

Management Requirement	Target spp group	IOTC resolution
Reporting in logbooks	All bycatch	Res. 10/02 & Res. 13-03
Observers	All bycatch	Res. 11/04
Report catch	Sharks	Res. 05/05
Full utilisation of sharks	Sharks	Res. 05/05
No more fins than 5 % ratio	Sharks	Res. 05/05
Mitigation research	Sharks	Res. 05/05
Research Programme	Sharks	Res. 13/06
Prohibition of retention		
Thresher sharks	Thresher shark	Res. 12/09
Oceanic whitetip shark	Oceanic whitetip shark	Res. 13/06
Prohibition of setting on whale sharks	Whale shark	Res. 13/05

Following a summary of main requirements of those resolutions are described:

- IOTC Resolution 10/02: ***Mandatory statistical requirements*** *for IOTC Members and Cooperating Non-Contracting Parties (CPC's)*
  - *Paragraph 3(end): These* ***provisions***[1] ***applicable to*** *tuna and tuna-like species, shall also be applicable to the most commonly caught* ***shark species*** *and, where possible, to the less common shark species. CPC's are also* ***encouraged*** *to record and provide data on* ***species other than sharks*** *and tunas taken as bycatch.*

- IOTC Resolution 13/03: On the recording of catch and effort by fishing vessels in the IOTC area of competence
  - *Paragraph 1: Each flag CPC shall ensure that all* ***purse seine, longline, gillnet, pole and line, handline, and trolling*** *fishing vessels flying its flag and authorized to fish species managed by IOTC be* ***subject to a data recording system****.*
  - *Paragraph 10: The Flag State and the States which receive this information shall* ***provide all the data*** *for any given year to the* ***IOTC Secretariat*** *by June 30th of the following year* ***on an aggregated basis****. The confidentiality rules set out in Resolution 12/02 Data Confidentiality Policy and Procedures for fine–scale data shall apply.*

[1] Refers to nominal catch, catch-and-effort, and size frequency data for sharks

- IOTC Resolution 11/04: *On a **regional observer scheme***
  - *Paragraph 2: In order to improve the collection of scientific data, at least 5 % of the number of operations/sets for each gear type by the fleet of each CPC while fishing in the IOTC Area of competence of **24 meters overall** length and over, and **under 24 meters** if they fish **outside their EEZs** shall be covered by this observer scheme. For vessels under 24 meters if they fish outside their EEZ, the above mentioned coverage should be achieved progressively by January 2013.*
  - *Paragraph 4: The number of the **artisanal** fishing vessels landings shall also be monitored at the landing place by field samplers. The indicative level of the coverage of the artisanal fishing vessels should progressively increase towards 5% of the total levels of vessel activity (i.e. total number of vessel trips or total number of vessels active).*

- IOTC Resolution 05/05: *Concerning the conservation of **SHARKS** caught in association with fisheries managed by IOTC*
  - *Paragraph 1: Contracting Parties, Cooperating non-Contracting Parties (CPCs) shall annually report data for catches of sharks, in accordance with IOTC data reporting procedures, including available historical data.*

- IOTC Resolution 12/09: *On the conservation of **THRESHER SHARKS** (family Alopiidae) caught in association with fisheries in the IOTC Area of Competence*
  - *Paragraph 4: CPCs shall **encourage** their **fishers** to record and **report incidental catches** as well as **live releases**. These data will be then kept at the IOTC Secretariat.*
  - *Paragraph 8: The Contracting Parties, Co-operating non-Contracting **Parties**, especially those **directing fishing activities for sharks**, shall **submit data for sharks**, as required by IOTC data reporting procedures.*

- IOTC Resolution 13/06: *On a scientific and management framework on the conservation of **SHARK** species caught in association with IOTC managed fisheries*
  - *Paragraph 5: **CPCs** shall **encourage their fishers to record incidental catches as well as live releases of OCEANIC WHITETIP SHARKS**. These **data shall be kept at the IOTC Secretariat**.*
  - *Paragraph 8: The **CPCs, especially those targeting sharks**, shall **submit data for sharks**, as required by IOTC data reporting procedures.*

The list of “most commonly caught” (**O)** and “less common caught” (o) shark species agreed for IOTC is provided in Table 3.

Table 3. Listing of bycatch species of concern to IOTC and reporting requirements, by type of fishery. Fisheries: Purse seine (PS), Longline (LL), Gillnet (GN), Pole-and-line (BB), Hand line (HL), Trolling (TR)

Common name	**Scientific name**	Species Code	**Reporting requirements by fishery**					
			PS	**LL**	**GN**	**BB**	**HL**	**TR**
Blue shark	*Prionace glauca*	BSH		**O**	**o**			
Mako sharks	*Isurus spp.*	MAK		**O**	**o**			
Porbeagle	*Lamna nasus*	POR		**O**	**o**			
Hammerhead Sharks	*Sphyrnidae*	SPN		**o**	**o**			
Whale shark	*Rhincodon typus*	RHN	**o**		**o**			
Thresher sharks	*Alopias spp.*	THR	**o**	**o**	**o**			
Crocodile shark	*Pseudocarcharias kamoharai*	PSK		v	v			
Silky shark	*Carcharhinus falciformis*	FAL	v					
Oceanic whitetip shark	*Carcharhinus longimanus*	OCS	**o**	**o**	**o**			
Tiger shark	*Galeocerdo cuvier*	TIG		v	v			
Great White Shark	*Carcharodon carcharias*	WSH		v				
Pelagic stingray	*Pteroplatytrygon violacea*	PSL		v	v			
Mantas and devil rays	*Manta spp. (Mobulidae)*	MAN	v	v	v			
Other sharks nei		SKH	v	**O**	**o**	**o**	**o**	**o**
Other rays nei		SRX	v	v	v	**o**	**o**	**o**

Reporting requirements:
O: As from 2008 catch shall be recorded in logbooks and reported to the IOTC
o: As from 2013 catch shall be recorded in logbooks and reported to the IOTC
v: As from 2013 recording and reporting of catches to the IOTC is encouraged

Fisheries information (fleet and gear characterisation)

Although several countries have not collected shark fishery statistics in the early years of the time series, the shark nominal reported catches increased continuously from 1950 onwards but especially from around the beginning of the 90s (Fig. 1) to reach the historic highest catch levels of the time series in 1999 with around 115,000 tonnes of sharks. Since then, the total nominal reported catches have slightly decreased and it was around 80,000 tonnes in 2010. The Commission adopted Resolution 10/02 and 13/03 which make mandatory the reporting of shark catch data for various shark species; however, the collection and reporting of shark catches in IOTC fisheries has been very irregular over time but have improved in the most recent years (Herrera and Pierre, 2012). Thus, the information on shark catch and bycatch available in the IOTC database is thought to be very incomplete. In this sense, it is considered that not all shark catches are reported and, if they are reported, they are not usually reported by species and they represent the catches of these species that are retained on board (or nominal catches) dressed with no indication on the type of processing that the different specimens underwent; which make very difficult the estimation of total shark catches by species (Herrera and Pierre, 2012). Herrera et al. 2012 as well showed that most of the shark catches corresponds to pelagic sharks (around 60 %) while the coastal sharks amount around 30 % of the total shark catches.

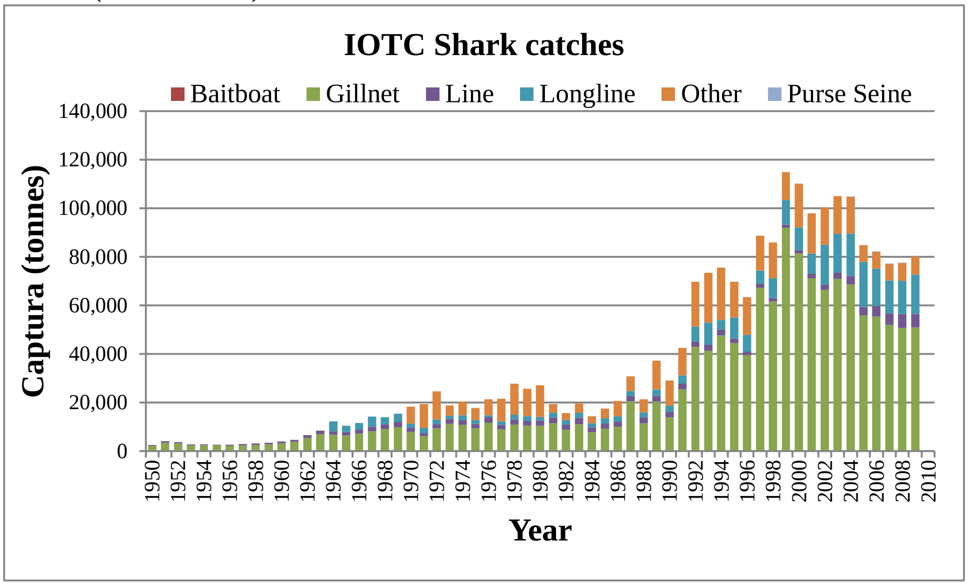
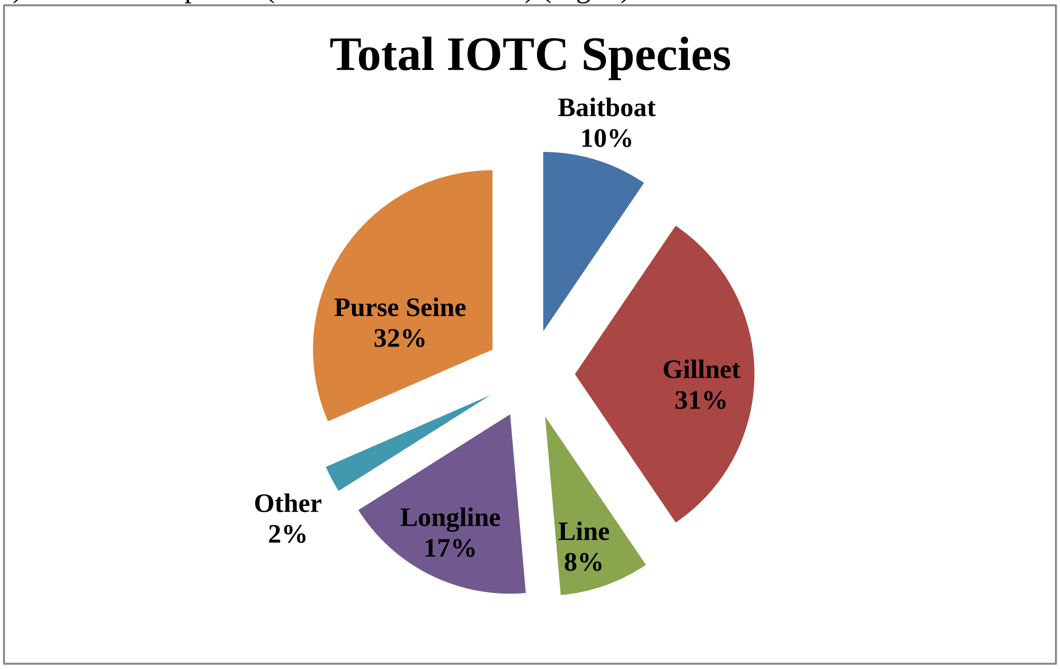


Fig. 1. Total nominal catch of IOTC Shark species for the period 1950-2010.

Various fleets/gear types are identified as catching shark in the Indian Ocean. Among then driftnet gillnets, gillnet/longline compounds, fresh-tuna longliners, deep-freezing longliners, coastal artisanal fishery, and in less extend the purse seiners as bycatch some shark species. **For those gears/fleets, accurate information about the gear characteristics and specifications at which species are captured is fundamental to understanding the impacts of fisheries. The fishing power, selectivity and catchability of fishing gears are variables that would help to understand the evolution of catches.**

As sharks are mostly caught as bycatch in IOTC fisheries (and are defined as bycatch by the Scientific Committee), any change in the dynamics of the fleets is likely to have implications on catches and subsequent landings. Such changes may be related to different aspects such as: technological development; shifts on target species as a result of their abundance; markets changes; management or piracy; fleet movement between fishing areas throughout the year.

The contribution of each gear to total IOTC species catch and shark catches is shown in Figure 2. It can be observed that while the gillnet fishery contributed with 31 % of the total IOTC species its contribution increased up to a 68 % of the total shark catches being the main gear catching sharks. The gillnet fishery is followed by the longline with 16 % of the total shark contribution (around 17 % of the total IOTC species without sharks), whereas other fleets contributes with 12 % (2 % of the total IOTC species), the line fleet with 4 % (8 % of total IOTC species) and the purse seiner and the baitboat fleet with less than 1 % (32 % and 10 % of the total IOTC species, respectively). The contribution of the different species in each fleet showed that most of the shark catches are reported as a group without identifying the species (Figure 3). For example, in the gillnet fishery most of the shark are reported as shark group (88 % SHK), Requiems nei (3%), Threshers (1%) and hammerheads (1%) whereas the main sharks reported by species are silky shark (4 %), blueshark (2%), and oceanic whitetip shark (1%). In the line and other fleets most of the sharks are reported as sharks altogether (99 % and 100 % respectively). However, in the longline around 35 % is reported as sharks in general and 65 % as species being blueshark (47 %) the main shark caught, followed by shortfin mako (7 %) and various species (9 % of the total catch) (Fig. 3).



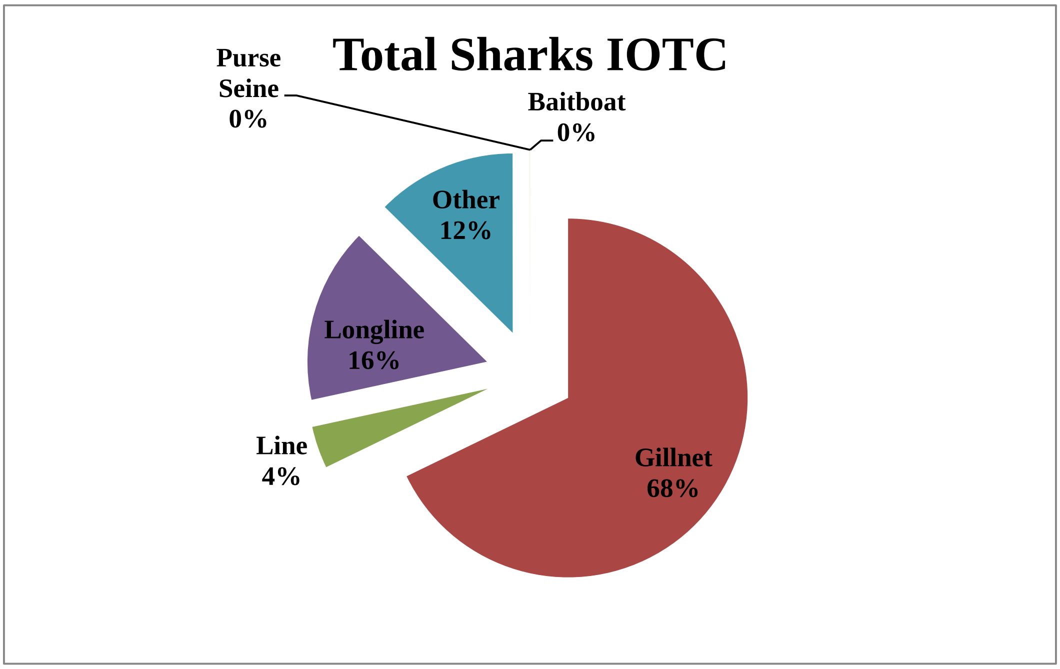


Fig. 2. Relative contribution to total IOTC species catch and total IOTC shark catch by different gears for the period 2000–09.

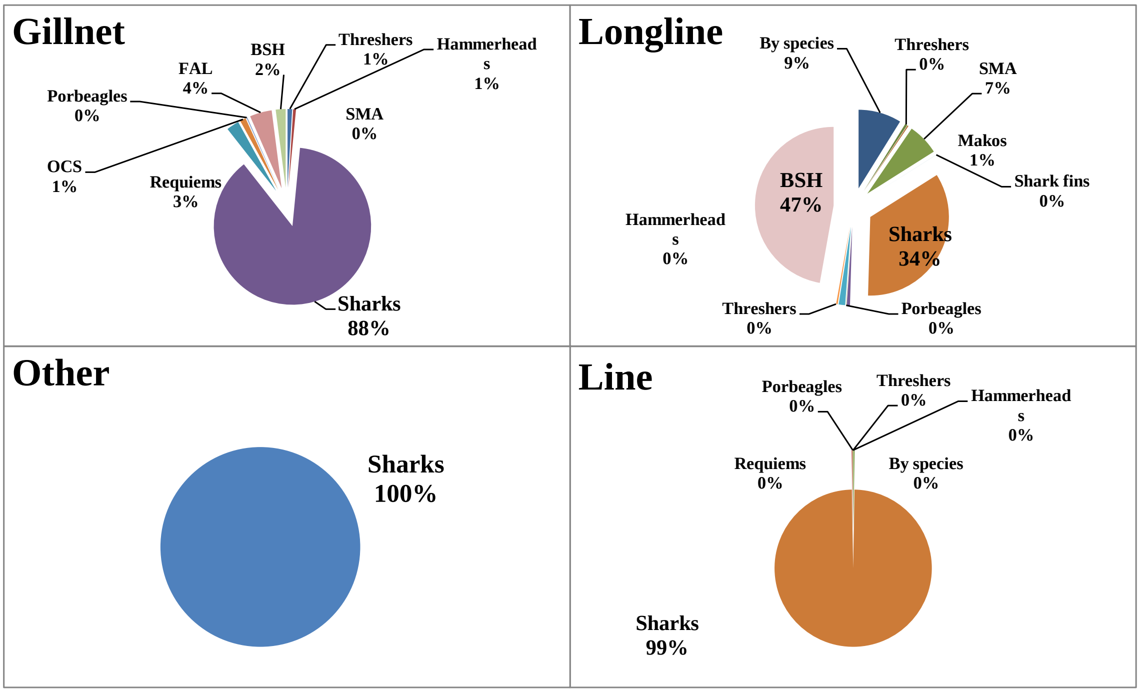


Fig. 3. Relative contribution of different species group and different species to total shark catches by gears for the period 2000–09.

At the WPEB09, participants agreed that the following list covers the main issues affecting the quality of the shark statistics available at the IOTC, by type of dataset and type of fishery.

1. **Catch-and-Effort data from gillnet fisheries:**

- **Drifting gillnet** fisheries of **Iran** and **Pakistan**: To date, Iran and Pakistan have not reported catches of sharks, by species, for their gillnet fisheries.
- **Gillnet/longline** fishery of **Sri Lanka**: Sri Lanka has not reported catch-and-effort data for sharks as per the IOTC standards.
- **Driftnet fishery of Taiwan,China** (1982–92): Catch-and-effort data does not include catches of sharks by species.

2. **Catch-and-Effort data from Longline Fisheries:**

- **Historical catches of sharks from major longline** fisheries: To date, **Japan**, **Taiwan,China**, **Indonesia** and **Rep. of Korea,** have not provided estimates of catches of sharks, by species, for years before 2006.
- **Fresh-tuna longline** fisheries of **Indonesia** and **Malaysia**: Indonesia and Malaysia have not reported catches of sharks by IOTC standards for longliners under their flag. In addition Indonesia has not reported catch-and-effort data for its longline fishery to date.
- **Freezing longline** fisheries of **EU-Spain**, **India**, **Indonesia**, **Malaysia**, and **Oman:** These countries have not reported catch-and-effort data of sharks by IOTC standards for longliners under their flag.

3. **Catch-and-Effort data from coastal fisheries:**

- **Coastal** fisheries of **India**, **Indonesia**, **Madagascar**, **Sri Lanka** and **Yemen**: To date, these countries have not provided detailed catches of sharks to the IOTC, in particular Thresher and other pelagic shark species caught by their coastal fisheries.

4. **Discard levels from surface and longline fisheries:**

- **Discard levels of sharks from major longline** fisheries: To date, **European Union**, **Japan**, **Indonesia** and **Rep. of Korea,** have not provided estimates of discards of sharks, by species, in particular Thresher sharks and oceanic whitetip shark.
- **Discard levels of sharks for industrial purse seine** fisheries: To date, the **European Union** (before 2003), **Iran**, **Japan**, **Seychelles**, and **Thailand**, have not provided estimates of discards of sharks, by species, for industrial purse seiners under their flag.

5. Size frequency data:

- **Gillnet** fisheries of **Iran** and **Pakistan:** To date, Iran and Pakistan have not reported size frequency data for their driftnet fisheries.
    - **Longline** fisheries of **China**, **Taiwan,China**, **India, Indonesia, Malaysia, Oman** and **Philippines:** To date, these countries have not reported size frequency data for their longline fisheries, including length frequency of discards of thresher sharks.
    - **Coastal** fisheries of **India, Indonesia, Madagascar, Sri Lanka** and **Yemen**: To date, these countries have not reported size frequency data for their coastal fisheries.

Moreover, IOTC Secretariat publishes a data catalogue in relation to shark fishery statistics gaps (i.e. nominal landings data, catch and effort, size frequency, etc…) that would be very valuable to identify research priorities.

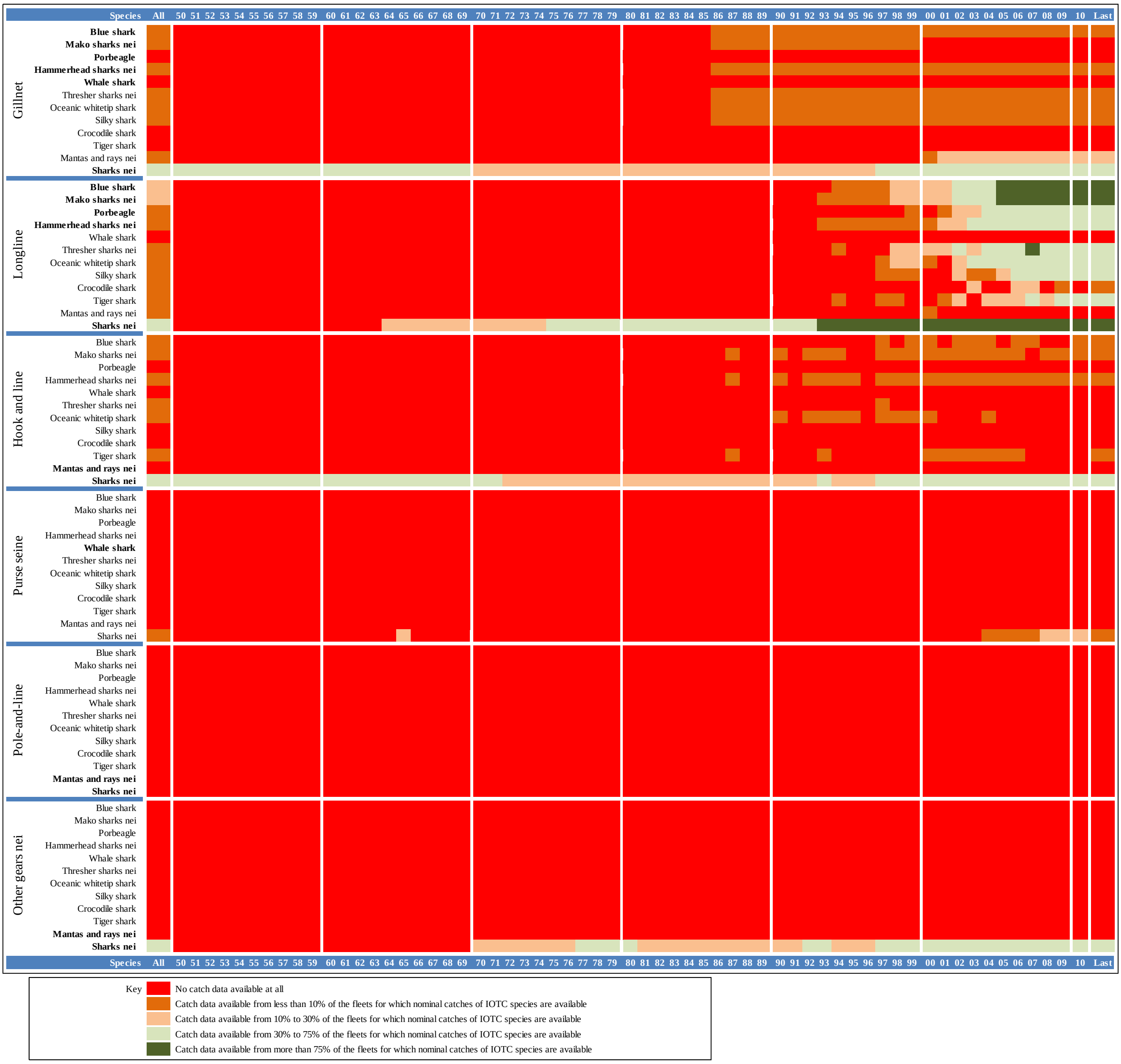
The information compiled in Table 4 corresponds to the data available at the IOTC website (which was last updated by the Secretariat on 25/05/2011 and consulted in 20/04/2012) and that from the last Scientific Committee meeting report (2011). However, we are aware that new information has been and/or will be provided to IOTC in the near future, which will be incorporated in the other reports of this project.

Table 4. Available information for the IOTC convention area in terms of shark nominal catches and catch and effort by country (fleet), fishing gear and period. *Historical* - general shark data that has been reported to the IOTC, corresponding to catches prior to 2006; *Common* - general shark data that has been reported to the IOTC, corresponding to catches for most common species from 2006 and thereafter; *Other* - general shark data that has been reported to the IOTC, corresponding to catches for other species from 2006 and thereafter.

			Nominal catches			Catch and Effort		
Country	**Flag**	**Gear Group**	**Common**	**Historical**	**Other**	**Common**	**Historical**	**Other**
CPC	Australia	LL	Post 2006	Prior to 2006	Post 2006			
CPC	Belize	LL	Post 2006	Prior to 2006	Post 2006			
CPC	China	LL	Post 2006	Prior to 2006	Post 2006			Post 2006
CPC	EU France	LL		Prior to 2006	Post 2006			Post 2006
		PS	Post 2006	Prior to 2006	Post 2006			
	EU Portugal	LL	Post 2006	Prior to 2006	Post 2006	Post 2006		Post 2006
	EU Spain	LL	Post 2006	Prior to 2006	Post 2006			
		PS	Post 2006	Prior to 2006	Post 2006			
	EU UK	LL	Post 2006	Prior to 2006	Post 2006	Post 2006		Post 2006
CPC	France	LL		Prior to 2006	Post 2006			
CPC	Guinea	LL		Prior to 2006				
CPC	Indonesia	LL	Post 2006	Prior to 2006	Post 2006			
CPC	Korea, Republic of	LL		Prior to 2006	Post 2006			Post 2006
CPC	Japan	LL	Post 2006		Post 2006	Post 2006		Post 2006
CPC	Kenya	LL	Post 2006		Post 2006			
CPC	Malaysia	LL		Prior to 2006	Post 2006			Post 2006
CPC	Mauritius	LL		Prior to 2006	Post 2006			Post 2006
CPC	Oman, Sultanate of	LL		Prior to 2006	Post 2006			Post 2006
CPC	Pakistan	GN		Prior to 2006	Post 2006			
CPC	Philippines	LL	Post 2006		Post 2006	Post 2006		
CPC	Seychelles	LL		Prior to 2006	Post 2006	Post 2006		Post 2006
CPC	Sri Lanka	LL	Post 2006					Post 2006
CPC	Thailand	LL	Post 2006	Prior to 2006	Post 2006			Post 2006
CNCP	Senegal	LL		Prior to 2006				
CNCP	South Africa	LL	Post 2006	Prior to 2006	Post 2006	Post 2006		Post 2006
Other	Taiwan	LL	Post 2006	Prior to 2006	Post 2006	Post 2006		Post 2006
Other	Uruguay	LL			Post 2006			Post 2006

Table 5 as recently been presented at the WPEB08 regarding the availability of catch data for the main shark species expressed as the amount of fleets (%) for which catch data are available out of the total number of fleets for which data on IOTC species are available, by fishery, species of shark, and year, for the period 1950–2010.

Table 5. Average levels of reporting for 1950–2010 and 2006–10 are shown column All and Last, respectively. Shark species in bold are those identified during the 2012 IOTC meeting, for which data shall be recorded in logbooks and reported to the IOTC Secretariat. Reporting of catch data for other species can be done in aggregated form (i.e. all species combined as sharks *nei* or mantas and rays *nei*). Hook and line refers to fisheries using handline and/or trolling and Other gears nei to other unidentified fisheries operated in coastal waters. Catch rates of sharks on pole-and-line fisheries are thought to be nil or negligible.



Murua et al., (2013) found that 17 fisheries amongst the 195 fisheries in IOTC database generate 92% of potential investigated shark catches (Table 6). Those authors identified that most of the shark catch may be impacted by 4 métiers, which generate more than 60 % of the estimated shark species: Gillnet from Iran, Sri Lanka, Indonesia and Taiwanese longliners. Gillnet (GN) and a composition of Gillnet and Longline (GN-LL) are the most important fleets for sharks with 61% of the total estimated shark catches (97,000 t); followed by longlines with 18% and other métiers with 12%, which precise gear composition is unknown.

Table 6. Estimated shark catches by fleet (tons/year), according to Murua et al. (2013).

Fleet/Métier	Studied shark estimated catch	Cumulated Studied shark estimated	% Cumulated Studied shark estimated
IRN-GN	34,375	34,375	22.8
LKA-GN-LL	32,141	66,516	44.1
IDN-GN	13,760	80,276	53.2
TWN-LL	9,075	89,352	59.2
YEM-OTH	6,074	95,426	63.2
IDN-OTH	6,039	101,464	67.2
PAK-GN	5,966	107,430	71.2
MDG-OTH-shark	5,690	113,120	75.0
IDN-LL	5,026	118,147	78.3
JPN-LL-jpn	4,116	122,263	81.0
OMN-GN	3,912	126,175	83.6
COM-OTH	2,952	129,127	85.6
IND-GN	2,870	131,997	87.5
ESP-LL-swo	2,536	134,533	89.2
MDV-OTH	1,774	136,306	90.3
IND-LL	1,338	137,645	91.2
OMN-OTH	997	138,641	91.9

Among the different métier identified, Gillnet (GN) and a composition of Gillnet and Longline (GN-LL) are the most important ones with 61 % of the total estimated studied shark species catches (97,000 t) (Figure 4). It is followed by longline (LL and LL-swo) with 18 % and other métiers (OTH) with 12 %, which precise gear composition is unknown.

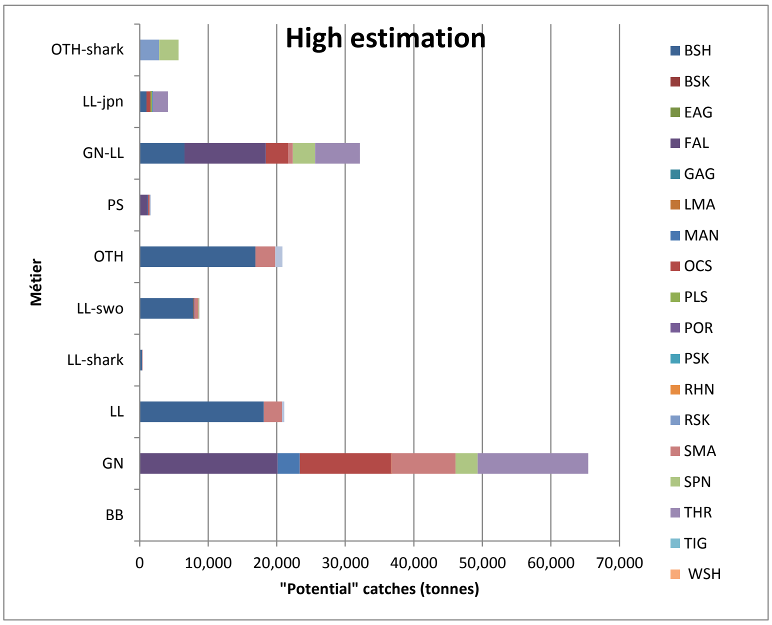


Fig. 4. Estimated Catch (tonnes) by Métiers (fleet/country) and by studied shark species.

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 5). Gillnet (GN - *sensu lato*) are catching 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.

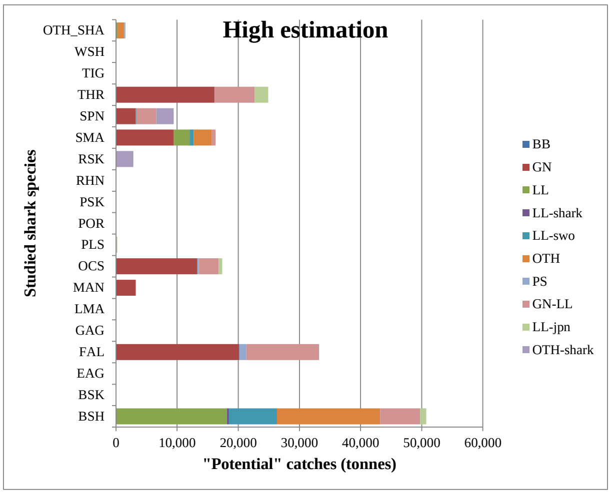


Fig. 5. Estimated Catch (tonnes) by studied shark species and by Métier.

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 (Fig. 6). Gillnet from from Iran, Sri Lanka, Indonesia are leading followed by Taiwanese longliners.

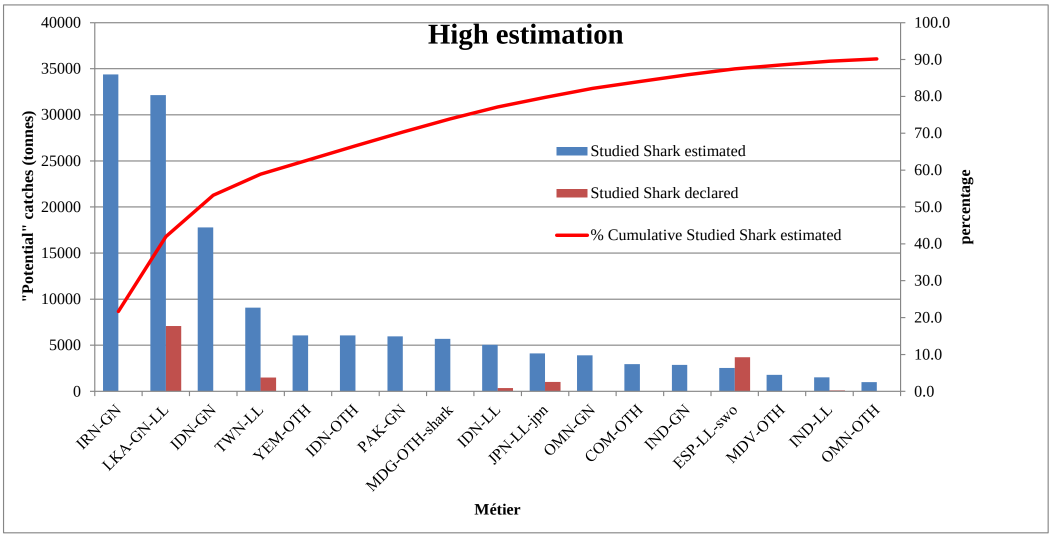


Fig. 6. Main fisheries (Flag and Métier) impacting studied shark species in the Atlantic Ocean.

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.

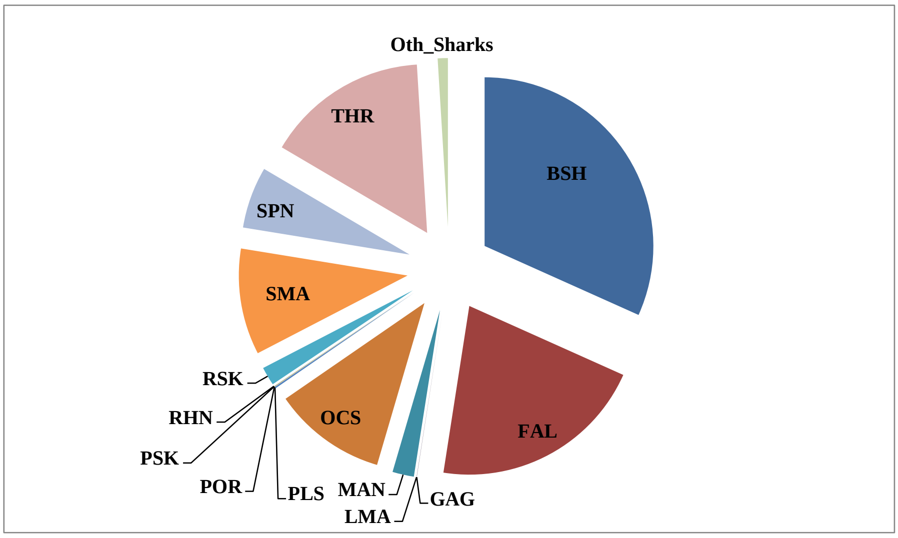


Fig. 7. Relative contribution of the total "potential" catch estimated for studied shark species in the Indian Ocean.

Particular emphasis should be dedicated to those fisheries which have the greatest catch of sharks in the Indian Ocean, namely gillnet and longline fisheries which catch an estimated 80% of the overall shark landings in the IOTC area of competence.

Catch at Size

There is not much public information on the catch at size of key shark species in the IOTC Statistical Area. Length frequencies for shark species bycaught in the IOTC convention area are scarce. According to the most recent information available on the IOTC database (by 10/07/2012) a limited a number of CPCs and Cooperative Non-CPCs (e.g. Japan, Republic of Korea, Seychelles and South Africa) have provided data for the major shark species caught on their fisheries [blue shark (BSH), bigeye thresher shark (BTH), silky shark (FAL), oceanic whitetip shark (OCS), porbeagle (POR), crocodile shark (PSK), and shortfin mako (SMA)]. However, it is worth noting that Portugal as recently provided size data for BSH and SMA for the most recent period. Moreover, Portugal is conducting an effort to provide further size data for these major shark species, based on the collection of historical skipper logbooks data and his onboard observer and self-sampling program.

Figure 8 shows length frequencies of blue shark as derived from the samples available from longliners flagged in Japan, Republic of Korea, Seychelles, and South Africa, for all periods and areas combined. Length frequency data of sharks are only available in recent years, for the fleets indicated in Table 2. To date no countries have reported shark length data for 2011 and 2012.

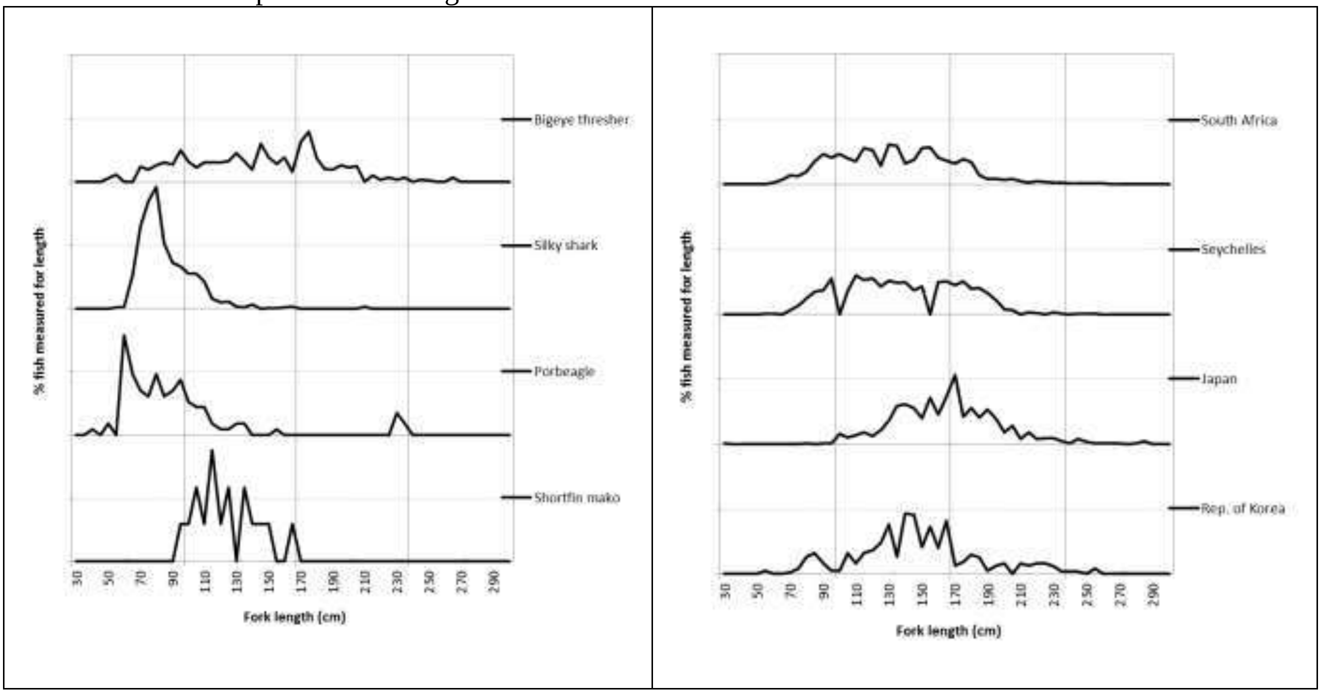


Fig. 8. (left) Length frequency distributions (%) of blue shark derived from the samples available for the longline fleets of South Africa, Seychelles, Japan, and Rep. of Korea (2005–10). Broken horizontal gridlines refer to 10% of the fish. (right) Length frequency distributions (%) of bigeye thresher, silky shark, porbeagle, and shortfin mako, as derived from the samples available from longline fleets (2005–10). Broken horizontal gridlines refer to 10% of the fish.

Observer information

The IOTC the observer coverage laid out in Resolution 11-04 is set at 5%. However, this is considered below the minimum level of 20 % required for a good level of precision.

There is no public database available of observers programs and/or on the level of discards in the IOTC yet. Although as from November 2012, eleven CPCs (Australia, Comoros, EU (France and Portugal), France (OT), Japan, Korea (Rep. of), Madagascar, Mozambique, Seychelles, South Africa and Taiwan,China) have submitted a list of accredited observers. To date thirty eight (38) observer trip reports have been submitted to the Secretariat by seven CPCs, i.e. Australia, China, EU (France and Portugal), France (OT), Japan, Korea and South Africa: 11 reports for 2010, 23 reports for 2011, 4 reports for 2012. In addition, South Africa has also submitted 13 and 10 observer reports, respectively for 2011 and 2012, for foreign flag fishing vessels operating in South African waters. Table 7 provides an estimation of the level of effort covered by observer's onboard longliners and purse seiners in 2010 and 2011, respectively.

Table 7. Summary of bycatch data available from Observer Programmes for Sharks

Fleet	**Gear**	**Time period**	**Sharks**		**Remarks**
			No. individual species	**% specimens by species**	
Australia	Longline	2004-10	17	100	
China	Longline	2006-10	2	100	
Taiwan,China	Longline	2006-10	11	99	
European Union	Purse seine	2003-07	2	90	
EU-France	Longline	2010			Report as 16.6 % of total bycatch (no number given)
EU-Spain	Longline	2007-10	16	99.9	
EU-Portugal	Longline	2006-10	7	100	
Japan	Longline	July 2010-Jan 2011	13	99	Sharks and stingrays
Korea Rep.	Longline	2007-10	3	98	
South Africa	Longline	2006-10	3	95	

According to Herrera and Pierre (2011) currently there are no estimates of discards levels of sharks in the IOTC convention area. Although being mandatory, namely for the thresher sharks (Res. 2010/12, Alopias spp.), the information will only be available during 2012. However, Australia has reported shark discard levels on its national reports (Anon, 2011) and other several countries also reported shark discards levels in various working documents presented to the IOTC WPEB. According to the observer data, in all fleets combined 22 shark species were recorded. However, in several cases only the genera or family was specified (no full species name is available) and, thus, it was difficult to identify fully the number of shark species recorded.

The observer programs should be focused on the main fleets catching sharks and species most caught, using possible methodologies to increase the observer coverage such as self-sampling, pilot observer programs in artisanal gillnet fisheries, or electronic monitoring as well as observers onboard. **Priorities in the Indian Ocean should be given to fleets that are considered to be responsible for most of the shark catches (i.e. driftnet gillnets, gillnets/longlines).**

Trade data

Trade data are a potentially useful complementary source of information for the management and assessment of shark species caught in association with IOTC fisheries. Identifying trends and changes in the trade of shark products (e.g., routes, volumes and products) may in turn help our understanding of the dynamics of fisheries capturing sharks. In the specific context of shark assessments, historical and current trade data may be used to identify potential gaps in reported catches and to develop proxy indices for estimating historical catches.

Data priorization

Data gaps are the main constraints to assess shark species population and the improvement of collected data for shark species should be the ultimate goal of the research program aiming to provide a sound formulation of scientific advice.

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;

The 3 step framework or process can described as follows:

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.

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 methods for observer programs (e.g. self-sampling, electronic monitoring);
  - o Biological research;
- ✓ Stock assessment and management;
- ✓ Application of some management measures (e.g. prohibition of retention);
- ✓ Identification of mitigation measures.

Appendix IV

Agenda Item 3 Supporting Information: Review of the current available information in terms of biological and ecological knowledge of the seven major shark species (BSH, SMA, OCS, FAL, SPL, PTH and BTH)

Table 1. Summary of the studies focusing on blue shark (BSH, *Prionace glauca*) life history parameters in the Indian Ocean. Each value refers to a particular study with the references provided as a footnote to the table.

BSH - *Prionace glauca*				
Parameters	**West IO**	**East IO**	**IO**	**Total**
Reproduction				
Size-at-maturity (male)		16, 18		2
Age-at-maturity (male)				0
Size-at-maturity (female)		16	5	2
Age-at-maturity (female)				0
Reproductive frequency				0
Gestation period				0
Size-at-birth	15	16		2
Fecundity (litter size)	6, 15		5	3
Spawning period				0
Mating period				0
Total	2	2	1	
Age and growth				
L_{inf} (combined)	1			1
k (combined)	1			1
T_o / L_o (combined)	1			1
Maximum obs. age (combined)	2			1
Longevity estimate (combined)	2			1
L_{inf} (male)	1			1
k (male)	1			1
T_o / L_o (male)	1			1
Maximum obs. age (male)	2			1
Longevity estimate (male)	2			1
L_{inf} (female)	1			1
k (female)	1			1
T_o / L_o (female)	1			1
Maximum obs. age (female)	1			1
Longevity estimate (female)	1			1
Total	2	0	0	
Feeding				
Traditional	5, 17			2
Isotopes	12			1
Total	3	0	0	
Genetics				
mtDNA				0
nDNA				0
Total	0	0	0	
Tracking				
Traditional tagging	7, 8, 14			3
Satellite telemetry	9			1
Acoustic telemetry	9			1
Total	4	0	0	
Habitat/Environ. preferences				
Temperature			5	1
Depth	9		5	2
Total	1	0	1	
Other aspects				
Haulback mortality	10, 13, 20			3
Post-release mortality				0
Size-size relationships	4, 19			2
Size-weight relationships	3, 19			2
Contaminants (e.g. heavy metals)				0
Total	6	0	0	

Table references: 1: Rabehagasoa et al (2009); 2: Romanov & Campana S (2011); 3: Romanov & Romanova (2009); 4: Romanov (2012, pers. Comm); 5: Gubanov & Gigor'ev (1975); 6: Mejuto & Garcia-Cortes (2005); Anonymous (2010); 8: Mejuto et al. (2005); 9: Filmalter et al. (2012a); 10: Coelho et al. (2011); 11: Petersen et al. (2008); 12: Rabehagasoa et al. (2012); 13:Petersen et al. (2009). 14: Dunlop et al. (2013); 15:

Bass et al. (1975a); 16: White et al. (2006); 17: Romanov et al. (2009); 18: White (2007a); 19: Ariz et al. (2007); 20: Poisson (2009).

Table 2. Summary of the studies focusing on shortfin mako (SMA, *Isurus oxyrinchus*) life history parameters in the Indian Ocean. Each value refers to a particular study with the references provided as a footnote to the table.

SMA - *Isurus oxyrinchus*				
Parameters	**West IO**	**East IO**	**IO**	**Total**
Reproduction				
Size-at-maturity (male)	1, 5	4, 11		4
Age-at-maturity (male)				0
Size-at-maturity (female)	1, 5	4, 11		4
Age-at-maturity (female)				0
Reproductive frequency				0
Gestation period				0
Size-at-birth	1			1
Fecundity (litter size)				0
Spawning period				0
Mating period				0
Total	2	2	0	
Age and growth				
L_{inf} (combined)				0
k (combined)				0
T_o / L_o (combined)				0
Maximum obs. age (combined)				0
Longevity estimate (combined)				0
L_{inf} (male)				0
k (male)				0
T_o / L_o (male)				0
Maximum obs. age (male)				0
Longevity estimate (male)				0
L_{inf} (female)				0
k (female)				0
T_o / L_o (female)				0
Maximum obs. age (female)	14			1
Longevity estimate (female)				0
Total	1	0	0	
Feeding				
Traditional	1, 10			2
Isotopes				0
Total	2	0	0	
Genetics				
mtDNA				0
nDNA				0
Total	0	0	0	
Tracking				
Traditional tagging	6, 9			2
Satellite telemetry				0
Acoustic telemetry				0
Total	2	0	0	
Habitat/Environ. preferences				
Temperature				0
Depth				0
Total	0	0	0	
Other aspects				
Haulback mortality	8			1
Post-release mortality				0
Size-size relationships	3, 13			2
Size-weight relationships	2, 5, 13			3
Contaminants (e.g. heavy metals)				0
Total	5	0	0	

1: Bass et al. (1975b); 2: Romanov & Romanova (2009); 3: Romanov (2012, pers. comm.); 4: White (2007b); 5: Cliff et al. (1990); 6: Mejuto et al. (2005); 7: Fourmanoir (1961); 8: Coelho et al. (2011); 9: Dunlop et al. (2013); 10: Romanov et al. (2009); 11: Stevens (1983); 12: Stevens (2008); 13: Ariz et al. (2007); 14: Romanov & Campana (2014, pers comm.).

Table 3. Summary of the studies focusing on oceanic whitetip shark (OCS, *Carcharhinus longimanus*) life history parameters in the Indian Ocean. Each value refers to a particular study with the references provided as a footnote to the table.

OCS - *Carcharhinus longimanus*				
Parameters	**West IO**	**East IO**	**IO**	**Total**
Reproduction				
Size-at-maturity (male)	1	3		2
Age-at-maturity (male)				0
Size-at-maturity (female)	1	6		2
Age-at-maturity (female)				0
Reproductive frequency				0
Gestation period				0
Size-at-birth	1	6		2
Fecundity (litter size)	1			1
Spawning period		3		1
Mating period				0
Total	1	2	0	
Age and growth				
L_{inf} (combined)				0
k (combined)				0
T_o / L_o (combined)				0
Maximum obs. age (combined)				0
Longevity estimate (combined)				0
L_{inf} (male)				0
k (male)				0
T_o / L_o (male)				0
Maximum obs. age (male)				0
Longevity estimate (male)				0
L_{inf} (female)				0
k (female)				0
T_o / L_o (female)				0
Maximum obs. age (female)				0
Longevity estimate (female)				0
Total	0	0	0	
Feeding				
Traditional	1, 8			2
Isotopes				0
Total	2	0	0	
Genetics				
mtDNA				0
nDNA				0
Total	0	0	0	
Tracking				
Traditional tagging	4, 7			2
Satellite telemetry	5			1
Acoustic telemetry	5			1
Total	3	0	0	
Habitat/Environ. preferences				
Temperature				0
Depth	5			1
Total	1	0	0	
Other aspects				
Haulback mortality	9, 11			2
Post-release mortality				0
Size-size relationships	10			1
Size-weight relationships	2, 10			2
Contaminants (e.g. heavy metals)				0
Total	4	0	0	

1: Bass et al. (1973); Romanov & Romanova (2009); 3:White (2007a); 4: Mejuto et al. (2005); 5: Filmalter et al. (2012a); 6: White et al. (2006); 7: Dunlop et al. (2013); 8: Romanov et al. (2009); 9: Poisson (2007); 10: Ariz et al. (2007); 11: Poisson (2009).

Table 4. Summary of the studies focusing on silky shark (FAL, *Carcharhinus falciformis*) life history parameters in the Indian Ocean. Each value refers to a particular study with the references provided as a footnote to the table.

FAL - *Carcharhinus flaciformis*				
Parameters	**West IO**	**East IO**	**IO**	**Total**
Reproduction				
Size-at-maturity (male)		3		1
Age-at-maturity (male)		3		1
Size-at-maturity (female)		3		1
Age-at-maturity (female)		3		1
Reproductive frequency				0
Gestation period		3(-)		1
Size-at-birth	1	3		2
Fecundity (litter size)	1	3		2
Spawning period		3		1
Mating period				0
Total	1	1	0	
Age and growth				
L_{inf} (combined)		3		1
k (combined)		3		1
T_o / L_o (combined)		3		1
Maximum obs. age (combined)		3		1
Longevity estimate (combined)		3		1
L_{inf} (male)		3		1
k (male)		3		1
T_o / L_o (male)		3		1
Maximum obs. age (male)		3		1
Longevity estimate (male)		3		1
L_{inf} (female)		3		1
k (female)		3		1
T_o / L_o (female)		3		1
Maximum obs. age (female)		3		1
Longevity estimate (female)		3		1
Total	0	1	0	
Feeding				
Traditional	10			1
Isotopes	8			1
Total	2	0	0	
Genetics				
mtDNA				0
nDNA				0
Total	0	0	0	
Tracking				
Traditional tagging	4, 9			2
Satellite telemetry	5			1
Acoustic telemetry	5, 11, 12			3
Total	5	0	0	
Habitat/Environ. preferences				
Temperature	11			1
Depth	5, 11, 12			3
Total	3	0	0	
Other aspects				
Haulback mortality	6, 15 (PS) 7 (LL)			3
Post-release mortality	6, 15 (PS)			2
Size-size relationships	13			1
Size-weight relationships	2, 13, 14	3		4
Contaminants (e.g. heavy metals)				0
Total	6	1	0	

1: Bass et al. (1973); 2: Romanov & Romanova (2009); 3: Hall et al. (2012); 4: Mejuto et al. (2005); 5: Filmalter et al. (2012a); 6: Poisson et al. (2014); 7: Coelho et al. (2011); 8: Rabehagasoa et al. (2012); 9: Dunlop et al. (2013); 10: Romanov et al. (2009); 11: Filmalter et al. (2011); 12: Filmalter et al. (2010); 13: Ariz et al. (2007); 14: Filmalter et al. (2012c); 15: Filmalter et al. (2012b).

Table 5. Summary of the studies focusing on the scalloped hammerhead (SPL, *Sphyrna lewini*) life history parameters in the Indian Ocean. Each value refers to a particular study with the references provided as a footnote to the table.

SPL - *Sphyrna lewini*				
Parameters	**West IO**	**East IO**	**IO**	**Total**
Reproduction				
Size-at-maturity (male)	1, 4	6, 10		4
Age-at-maturity (male)				0
Size-at-maturity (female)	4	6		2
Age-at-maturity (female)				0
Reproductive frequency				0
Gestation period				0
Size-at-birth	1	6		2
Fecundity (litter size)		6		1
Spawning period		6		1
Mating period				0
Total	2	2	0	
Age and growth				
L_{inf} (combined)				0
k (combined)				0
T_o / L_o (combined)				0
Maximum obs. age (combined)				0
Longevity estimate (combined)				0
L_{inf} (male)				0
k (male)				0
T_o / L_o (male)				0
Maximum obs. age (male)				0
Longevity estimate (male)				0
L_{inf} (female)				0
k (female)				0
T_o / L_o (female)				0
Maximum obs. age (female)				0
Longevity estimate (female)				0
Total	0	0	0	
Feeding				
Traditional	1, 4			2
Isotopes				0
Total	2	0	0	
Genetics				
mtDNA			3	1
nDNA				0
Total	0	0	1	
Tracking				
Traditional tagging	5, 7			2
Satellite telemetry				0
Acoustic telemetry				0
Total	2	0	0	
Habitat/Environ. preferences				
Temperature				0
Depth				0
Total	0	0	0	
Other aspects				
Haulback mortality				0
Post-release mortality				0
Size-size relationships	9			1
Size-weight relationships	2, 4, 9			3
Contaminants (e.g. heavy metals)				0
Total	3	0	0	

1: Bass et al. (1975a); 2: Romanov & Romanova (2012); 3: Duncan et al. (2006); 4:De Bruyn et al. (2005); 5: Diemer et al. (2011); 6: White et al. (2008); 7: Dunlop et al. (2013); 8: Stevens & Lyle (1989); 9: Ariz et al. (2007); 10: Kembaren et al. (2013).

Table 6. Summary of the studies focusing on the bigeye thresher (BTH, *Alopias superciliosus*) life history parameters in the Indian Ocean. Each value refers to a particular study with the references provided as a footnote to the table.

BTH - *Alopias superciliosus*				
Parameters	**West IO**	**East IO**	**IO**	**Total**
Reproduction				
Size-at-maturity (male)		5	3	2
Age-at-maturity (male)				0
Size-at-maturity (female)			3	1
Age-at-maturity (female)				0
Reproductive frequency				0
Gestation period				0
Size-at-birth	1			1
Fecundity (litter size)	1			1
Spawning period				0
Mating period				0
Total	1	1	1	
Age and growth				
L_{inf} (combined)				0
k (combined)				0
T_o / L_o (combined)				0
Maximum obs. age (combined)				0
Longevity estimate (combined)				0
L_{inf} (male)				0
k (male)				0
T_o / L_o (male)				0
Maximum obs. age (male)				0
Longevity estimate (male)				0
L_{inf} (female)				0
k (female)				0
T_o / L_o (female)				0
Maximum obs. age (female)				0
Longevity estimate (female)				0
Total	0	0	0	
Feeding				
Traditional				0
Isotopes				0
Total	0	0	0	
Genetics				
mtDNA				0
nDNA				0
Total	0	0	0	
Tracking				
Traditional tagging				0
Satellite telemetry				0
Acoustic telemetry				0
Total	0	0	0	
Habitat/Environ. preferences				
Temperature				0
Depth				0
Total	0	0	0	
Other aspects				
Haulback mortality	2			1
Post-release mortality				0
Size-size relationships				0
Size-weight relationships				0
Contaminants (e.g. heavy metals)				0
Total	1	0	0	

1: Bass et al. (1975b); 2: Coelho et al. (2011); 3: Gubanov (1978); 4: Romanov & Romanova (2012); 5: White (T. 2007).

Table 7. Summary of the studies focusing on the pelagic thresher (PTH, *Alopias pelagicus*) life history parameters in the Indian Ocean. Each value refers to a particular study with the references provided as a footnote to the table.

PTH - *Alopias pelagicus*				
Parameters	**West IO**	**East IO**	**IO**	**Total**
Reproduction				
Size-at-maturity (male)		1		1
Age-at-maturity (male)				0
Size-at-maturity (female)		1		1
Age-at-maturity (female)				0
Reproductive frequency				0
Gestation period				0
Size-at-birth		1		1
Fecundity (litter size)				0
Spawning period				0
Mating period				0
Total	0	1	0	
Age and growth				
L_{inf} (combined)				0
k (combined)				0
T_o / L_o (combined)				0
Maximum obs. age (combined)				0
Longevity estimate (combined)				0
L_{inf} (male)				0
k (male)				0
T_o / L_o (male)				0
Maximum obs. age (male)				0
Longevity estimate (male)				0
L_{inf} (female)				0
k (female)				0
T_o / L_o (female)				0
Maximum obs. age (female)				0
Longevity estimate (female)				0
Total	0	0	0	
Feeding				
Traditional				0
Isotopes				0
Total	0	0	0	
Genetics				
mtDNA				0
nDNA				0
Total	0	0	0	
Tracking				
Traditional tagging				0
Satellite telemetry				0
Acoustic telemetry				0
Total	0	0	0	
Habitat/Environ. preferences				
Temperature				0
Depth				0
Total	0	0	0	
Other aspects				
Haulback mortality				0
Post-release mortality				0
Size-size relationships				0
Size-weight relationships				0
Contaminants (e.g. heavy metals)				0
Total	0	0	0	

1: White (2007).

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APPENDIX V
AGENDA ITEM 4 SUPPORTING INFORMATION: REVIEW OF THE CURRENT AVAILABLE AND IMPLEMENTED MITIGATION MEASURES, INCLUDING BEST PRACTICE CODES/PROCEDURES, IN TERMS OF REDUCING SHARK BYCATCH AND INCIDENTAL MORTALITY

Under Agenda item 4 the working group reviewed and analyzed more than 100 available peer-reviewed publications on potential mitigation measures for mitigation of shark bycatch in IOTC managed pelagic fisheries. Major 'pros and cons' were highlighted of each method, based on best scientific knowledge currently available. Additionally, the level of research needs and financial implications were also considered.

The list of mitigation measures summarised in Table 1 is **not** a ranking of potential measures, as the objective of this review was just **to highlight research needs** before any advice can be provided on their potential application and efficiency if introduced to IOTC managed pelagic fisheries. Additionally, the research needs take into consideration mostly their potential as shark mitigation measures, albeit the implications these might have on fisheries data collection and, consequently, on the shark stock assessment process.

The listed management mitigation measures for major fisheries impacting sharks (LL, PS, GILL) were split into two different categories: i) Operational and technological aspects, and ii) Best practices.

4.1 Operational and technological aspects

Prohibition of retention – prohibition from retaining on board, transhipping, landing, storing, selling or offering for sale any part or whole carcass of sharks. Regulation was already set in place by IOTC for thresher sharks and oceanic whitetip shark (Resolutions 12/09, 13/03).

Major scientific work (see references section): not available.

Major results achieved (pros and cons) – Widely applied approach for protection of endangered species. Fishing mortality expected to decrease, but still can stay at a high level. Reduces the quality of reported data.

Research needs – High. Assess efficiency for currently prohibited species. Moderate for major shark species.

4.1.1. Longlines

Circle hooks – corresponds to a hook style distinguished for having a rounded shape with the point oriented perpendicular to the shank, as a means to reduce bycatch mortality. Most of the research involving circle hooks aimed at reducing interactions of longlines with marine turtles (see reviews by Read 2007; and Wallace et al., 2010).

Major scientific work (see references section): 18, 20, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 35, 36, 37, 38, 39, 40, 41, 42, 43, 76,78

Major results achieved (pros and cons) - Decrease deep-hooking of sharks and probably post-release mortality. Conflicting results in terms of catch rates, although most recent work suggesting an increase for sharks, namely when baited with fish. Other results are fisheries, species, specific and fishing area dependent.

Research needs – High. Additional work is required to assess efficiency of the combination of circle hooks and bait types in terms of catch rates of both targeted species and bycatch, at-haulback and post-release mortality, particularly for major shark fishing areas in the IO.

Corrodible hooks – Corrodible hooks are fishing hooks composed of material other than stainless steel. They may be made from different alloys, with different coatings, which all affect how long they last. The hook may dissolve quickly, within a couple of days, or more slowly over weeks or months. The premise behind the use of corrodible hooks is that they should improve the mortality rate of by-catch released with a hook attached.

Major scientific work (see references section): 50.

Major results achieved (pros and cons) – Can reduce the post-escape mortality of sharks. Need to be replaced more often than low-grade stainless hooks.

Research needs – Moderate. Efficiency and economics impacts should be assessed.

Weak hooks – A weak hook is a hook that is constructed of round stock wire that is thinner-gauge than the traditional hooks currently used in a given fishery. The difference between the traditional hook and the weak hook is barely detectable to the naked eye; however, the weak hook is more likely to bend when a large fish or marine mammal is hooked.

Major scientific work (see references section): 34, 49, and 53.

Major results achieved (pros and cons) – Can reduce the incidental catch of large fish. The ability of weak hooks to release large fish alive and in good condition is questionable. Need to be replaced more often than low-grade stainless hooks.

Research priorities – Moderate. Efficiency and economics impacts should be assessed.

Magnetic, E+ metals, electrical deterrent – The use of permanent magnets, electropositive rare earth metals (EPREM) and other electrical measures has been tested as a means of deterring sharks from approaching baited hooks. Permanent magnets are made from magnetized material and create their own persistent magnetic field. EPREM react with seawater to create such fields. Sharks are able to detect the Earth's geomagnetic field using their ampullae of Lorenzini. Electropositive metals or magnets appear to generate an aversion response in some species of sharks through an overstimulation of their ampullae, which are sensitive electroreceptors.

Major scientific work (see references section): 68, 69, 70, 74, 75 and 126.

Major results achieved (pros and cons) – Conflicting results concerning the efficiency of magnetic deterrents. Impact on the target species unknown. Little information on the effect that magnet and metal could have as repellent on pelagic sharks commonly caught by commercial longliners. Trials at large scale (in the Canadian longline) showed that rare-earth metal deterrent do not present a practical by-catch mitigation measure for this fishery. These devices are fragile, costly and the method can be difficult to implement.

Research needs – Moderate. Need to assess efficiency to mitigate shark by-catch.

Prohibition of wire/braided nylon trace use – The terminal part/section of the gangions used on longlines is usually made of monofilament nylon material. However, on fisheries targeting sharks and in areas of high abundance of sharks, wire or braided "multifilament" nylon leaders are regularly used by swordfish target longliners.

Major scientific work (see references section): 30, 42, 80, 81, 8 and 83.

Major results achieved (pros and cons) – Monofilament leaders do not decrease interactions, but promote bite-offs which may can lead to lower mortality rates. In contrast, wire and braided nylon traces produces higher shark catch rates and mortality, although it appears to vary by species.

Research needs – High. Need to carry out large scale experiments in the Indian Ocean to improve knowledge on this measure and assess economic implications.

Bait type (squid vs. fish) – Squid and fish are the most common baits used in pelagic longline fisheries. Traditionally squid is used on targeted swordfish and tuna fisheries.

Major scientific work (see references section): 43, 2, 40, 19, 78, 107

Major results achieved (pros and cons) **-** The use of squid bait, in preference to fish bait, has been shown to reduce the shark catch rates in longline fisheries. However, the effectiveness of this method may vary between species. Earlier studies demonstrate opposite results showing preference of sharks to squid bait.

Research needs – No needs for dedicated research. Only in combination with hook types/leaders.

Artificial bait – Artificial baits are an experimental technology in pelagic longline fisheries. Prototype artificial baits have relied upon olfactory attractants alone or in combination with a visual attractant (bait shape), each with different physical properties. Natural and/or synthetic ingredients have been used to fabricate the baits.

Major scientific work (see references section): 1, 54, 55, 56, 57, 58 and 59.

Major results achieved (pros and cons) **-** Research in the field has been very limited, with mixed success. However, artificial baits may reduce some types of bycatch under certain conditions. Although they have the potential to reduce shark bycatch, much work remains to be done before artificial baits are a viable alternative to natural baits.

Research needs – Moderate. Although they have the potential to reduce shark bycatch, much work remains to be done before artificial baits could be used as a viable alternative to natural baits.

Dyed bait – In the 1970s, fishermen experimented with dyed bait as a means of improving their target fish catch. More recently, experiments have been directed towards using blue-dyed bait to reduce seabird bycatch in pelagic longline fisheries. In theory, dyeing bait blue reduces the contrast between the bait and the surrounding seawater making it more difficult for foraging seabirds to detect. Alternative theories suggest that seabirds are simply less interested in blue-dyed bait compared with undyed controls.

Major scientific work (see references section): 19, 44, 45, 46, 47 and 48.

Major results achieved (pros and cons) **-** In the 1970s, fishermen experimented with dyed bait as a means of improving their target fish catch. More recently, experiments have been directed towards using blue-dyed bait to reduce seabird by-catch in pelagic longline fisheries. Not a promising measure as regards mitigating shark catches.

Research needs **–** No needs for research.

Restrictions on light attractors use – Light attractors, including chemical lightsticks and battery-powered light-emitting diodes (LEDs), are attached near baited hooks on branchlines to attract fish. In the Indian Ocean these light attractors are used by longliners targeting swordfish. Line is usually set in the late evening and soaked overnight. These include light sticks, flash batteries and other luminous beads or glowing loop protectors also rigged. Can have different colors, or a combination of two colors in the case of the flash batteries. The light attractors are mostly used on swordfish fisheries.

Major scientific work (see references section): 6, 11, 12, 13, and 15.

Major results achieved (pros and cons) **-** Little is known about how sharks respond to the types of light attractors used by longliners. Reduction of shark catch rates, good for the environment by reducing pollution (plastic containers, chemical component, batteries) and easy to implement. Opposition from the sector as also reduces the catch rates of target and by-catch commercial species. Difficult to control their use.

Research needs – No needs for research.

Olfactory repellent – Semiochemicals are chemical messengers or "clues" sharks may use to orient, survive and reproduce in their specific environments. Certain semiochemical extractions have the ability to trigger a fight reaction in sharks, but these trace chemicals present unique difficulties for isolation and detection.

Major scientific work (see references section): 64, 65, 66 and 67.

Major results achieved (pros and cons) – The existence of a putative chemical shark repellent (i.e. shark necromone) has been confirmed. The risk of repulsing target species not yet assessed.

Research needs – No needs for research.

Soaking time – The pelagic longlines are often soaking for long periods, in some cases for more than 24 hours, depending on the vessels characteristics and sea conditions. Longer soaking time usually results in higher proportion of shark caught in relation to target species catch. The proportion of fish alive at-haulback is inversely related to time on the line, hence the mortality of fish caught increased as soak time increased. Of the pelagic species shown, sharks were most resistant to hooking mortality.

Major scientific work (see references section): 3, 4, 5, 6 and 7.

Major results achieved (pros and cons) - Can reduce by-catch mortalities rates. Would not necessarily decrease swordfish catches but a reduction of total catch may occur. Optimal soaking duration varies by fishery.

Research needs – Moderate. Optimal soaking duration to be assessed for target species.

Deep setting – Deep setting is a longline fishing technique where hooks are set below a critical depth, out of range of most bycatch species, but within the range that target species are usually captured (i.e. tuna).

Major scientific work (see references section): 8, 9 and 10, 84.

Major results achieved (pros and cons) - Deeper setting reduces catch rates of pelagic sharks, but likely increases catches of deeper-dwelling shark species in some areas. Impossible to apply in swordfish targeting fisheries. Additional equipment (line-shooter) is required. More labour-costly, considerably increase duration of fishing operation.

Research needs – No needs for research.

Spatial and/or temporal closure/MPAs – Time and area closures is a common management tool in coastal fisheries, as a tool to reduce fishing effort and mortality, protect sensitive areas and/or specific species life stages. However, as regards highly migratory species, the implementation of such spatial-temporal areas closures has been limited to tropical tuna fisheries.

Major scientific work (see references section): 108, 109, 110, 111 and 112.

Major results achieved (pros and cons) - Time and area closures are effective at reducing by-catch only when target and non-target species segregate spatially, which is generally not the case for the pelagic sharks caught in longline fisheries targeting tunas.

Research needs – High. Identify major pelagic shark hotspots and investigate associated environmental conditions affecting shark distribution in the Indian Ocean.

Reduction of fishing effort – Limitation of fishing effort at certain (lower) level.

Major scientific work (see references section): 4, 5, 6, 7 and 79.

Major results achieved (pros and cons) – Reduction of shark catches and improvement of the overall at-haulback survival rates for by-catch species. May result in decrease catch rates of target and by-catch commercial species. Difficult to monitor and can result in an increase of non-reported fishing effort.

Research needs – No needs for research.

Prohibition of shark finning – prohibition of practice to keep fins discarding shark carcasses. Regulation of IOTC based on shark carcass/fins body ratio.

Major scientific work (see references section): 76.

Major results achieved (pros and cons) – Keeping shark with fins naturally attached to the body until first port of unloading further reduce capacity of finning practice.

Research needs – No needs for research.

Reduction of offal discharge – With regard to sharks, offal management includes the practices of chumming during setting or discarding of offal during hauling.

Major scientific work (see references section): 2.

Major results achieved (pros and cons) - Potential reduction of interactions with sharks. Little is known on the impact upon shark catch rates of these practices. Difficult to monitor.

Research needs – No needs for research.

4.1.2. Purse-seines

Release panel – corresponds to part of purse seine wall, which could opened to provide a 'window' for free escape of sharks form the gear.

Major scientific work (see references section): 119.

Major results achieved (pros and cons) - An experimental release panel was installed in a portion of the net that forms a "pocket" toward the end of net retrieval to determine their ability to release both silky sharks and non-target finfish. Dive surveys previously reported that silky sharks tend to segregate and collect in this section of the net. The release panel was tested during seven purse seine sets, but only two silky sharks (out of 105) exited through this panel. In net observations indicated that sharks and other non-target finfish did not appear to recognize the opening as an escape route out of the net. Despite this initial failure of the release panel, the authors feel refinement of the panel and additional testing is still warranted.

Research needs – Moderate to high. Efficiency of shark release procedure through the panel should be considerably improved. Experiments are carrying by ISSF in other oceans.

Non entangling FADs – corresponds to fish aggregation devices both drifting and anchored that made from the material that prevent entanglement of associated species.

Major scientific work (see references section): 118, 124

Major results achieved (pros and cons) - To reduce entanglement of turtles on the FAD itself, the surface structure should not be covered or only covered with non-meshed material. If a sub-surface component is used, to reduce entanglement of turtles and sharks it should not be made from netting but from non-meshed materials such as ropes or canvas sheets. To reduce the amount of synthetic marine debris, and to promote environmentally friendly FADs, the use of natural or biodegradable materials should be promoted.

Research needs – No needs for research.

Acoustic attractant – Device that produce low frequency sounds have strong attractive effect on sharks. Potentially attract sharks away from the fishing gear.

Major scientific work (see references section): 60, 61, 62, 63, 64.

Major results achieved (pros and cons) – Mostly considered as a theoretical concept. Never tested in real or experimental environment in relation with fishing gear protection.

Research needs – Moderate. Low frequency emitting device on another FAD or speedboat to attract sharks away from FAD going to be fished.

Reduction of fishing effort – Limitation of fishing effort on certain at certain (lower) level for certain types of schools.

Major scientific work (see references section): Not available.

Major results achieved (pros and cons) – Reduction of shark bycatch especially FAL/OCS. Will result in decrease catch rates of target commercial species. Difficult to monitor and can result in an increase of non-reported fishing effort.

Research needs – No needs for research.

4.1.3. Gill nets

Selectivity (Mesh size, hanging ratio, net panel material, etc…) – corresponds to length of the mesh. There are three approaches to measure mesh size: is length of mesh side (bar length), length of mesh, and opening of mesh (ICES, 2004). The latter is most commonly used measurement, accepted by EU Regulation (Anon., 1997). A net may be rigged with varying degrees of slack, which is primarily regulated by the ***hanging ratio***. The hanging ratio measures how tightly the net is stretched along the head and foot rope. The hanging ratio may theoretically vary between the value 0 and a value of 1.0. In commercial fisheries hanging ratios are normally between 0.25 and 0.65 (Hovgård, Lassen, 2000). ***Net panel material*** – corresponds to characteristic of twine (braided line or monofilament, twine diameter) and method of netting (knotted or knotless).

Major scientific work (see references section): 85, 86, 87, 88, 104, 105, 106.

Major results achieved (pros and cons) – Selectivity curves are species-specific. Therefore selection of particular mesh sizes may reduce catchability of certain shark species. However shark species demonstrate relatively wide selectivity curves that can overlap with selectivity curves of target species. It was found also that increased tension in a gillnet (using larger floats on the head-rope and increasing the lead-core lead-line weigh) may reduce shark entanglement in the net.

Research needs – High. All types of technical aspects of the gear affecting selectivity needs research by fleet, depends on target species.

Illuminated nets/net lights – corresponds to lights (mostly battery-powered light-emitting diodes (LEDs)) attached to the net or nets constructed of photoluminescent materials in order to make net visible for bycatch species. May emit light in various spectral areas: visible lights, UV lights.

Major scientific work (see references section): 89, 90, 91, 92, 93.

Major results achieved (pros and cons) – visible spectrum LED lights and UV lights demonstrate decrease of seaturtle bycatch in gillnets without any effect on CPUE of target species. Apparently light might decrease bycath of marine mammals also. No published information on efficiency of such measure on sharks: only theoretical conclusions (93).

Research needs – No needs for research. Apparently not as appropriate mitigation measure for sharks.

Acoustic pingers – corresponds to devices that produce high intensity acoustic signals on constant or variable frequencies in order to scare unwanted species.

Major scientific work (see references section): 93, 94.

Major results achieved (pros and cons) – Proved to be effective to decrease bycatch of marine mammals. No any evidence of potential efficiency to mitigate shark bycatch.

Research needs – No needs for research.

Olfactory repellent/attractant – corresponds to chemical compound that provide repulsive/attractive stimuli for shark species.

Major scientific work (see references section): 91, 93, 97, 98.

Major results achieved (pros and cons) – Researches are not passed beyond experimental stage. The existence of a putative chemical shark repellent like shark necromone has been confirmed.

Research needs – No needs for research.

Powered electric field 'barrier' Magnetic field 'barrier' – corresponds to devices that produce magnetic or electric filed to repulse shark species.

Major scientific work (see references section): 93, 99, 100, 101, 102, 103, 125.

Major results achieved (pros and cons) – Some prototypes tested on experimental beach nets. It was demonstrated that bull sharks and great white sharks can be deterred by permanent magnets. Magnet efficacy can vary based on situational context. Study shows the potential for permanent magnets as devices that may reduce sharks encounters with nets. However research on magnet exclusion properties should be conducted prior to applying this concept to future shark exclusion technologies. There are also some ongoing studies of electrically-powered magnetic shark repulsion devices. 'Sharkshield'.

Research needs – No needs for research.

Pre-net fence (tactile) – corresponds to mechanical barrier from vertically positioned ropes (twines) with spaces that allow free passage of target species, positioned at some distance from the main net. Tactile contact should repulse shark species.

Major scientific work (see references section): 93.

Major results achieved (pros and cons) – A theoretical idea provided in the reference 93. Have been never tested in the field.

Research needs – No needs for research.

Soaking time – The pelagic driftnets are often soaking for long periods, in some cases for more than 24 hours, depending on the vessels characteristics and sea conditions. The proportion of fish that still alive at-haulback is inversely related to time in the net, hence the mortality of fish caught increased as soak time increased. Of the pelagic species shown, sharks were most resistant to hooking mortality.

Major scientific work (see references section): unknown for pelagic gillnet fisheries.

Major results achieved (pros and cons) – Can reduce by-catch mortalities rates. No information if decreased soaking time will decrease catch of target species. Optimal soaking duration may vary by fishery.

Research needs – Moderate. Optimal soaking duration to be assessed by target species. Impact on the target catch levels should be assessed for major fleets.

<u>Reduction of fishing effort</u> – Limitation of fishing effort at certain (lower) level.

Major scientific work (see references section): not available.

Major results achieved (pros and cons) – Reduction of shark bycatch. Will result in decrease catch rates of target commercial species. Difficult to monitor and can result in an increase of non-reported fishing effort.

Research needs – No needs for research.

4.2. Best practices

<u>Communication program</u> – direct communication between fishing vessels aimed to avoid areas with high level of bycatch.

Major scientific work (see references section): 1, 2, 14.

Major results achieved (pros and cons) – Mostly depends on fishermen incentive to mitigate bycatch. Efficiency depends on distribution patterns of target/bycatch species. Bycatch limitation regulation apparently might facilitate mitigation based on fleet communication.

Research needs – No needs for research.

<u>Safe handling and release</u> – guidelines to handle and release sharks and other protected species in order to reduce the mortality without detrimental effect on safety of fishermen. For some gears kits of specific equipment (e.g. de-hooking or leader cutting devices for LL are necessary).

Major scientific work (see references section): LL: 71, 72, 73; PS: 120, 121; GILL: not available

Major results achieved (pros and cons) – A preliminary study indicated that, depending from gear and release practice used, from 20 to 50% of sharks died after release. It is therefore important to inform fishermen what practices can cause a delayed mortality and which ones minimize physical trauma and stress to the animals.

Research needs – Developing guidelines and protocols for safe handling and release: High priority for longline and gillnet.

<u>Setting on bigger aggregations (PS)</u> – corresponds to the purse seine fishing tactics of avoiding setting on small schools given preferences to big schools of tuna.

Major scientific work (see references section): 113.

Major results achieved (pros and cons) – Such fishing tactics will reduce the number of fishing sets (a part of the total effort) while maintaining the same total yield. Such tactics will improve bycatch/target catch ratio. Ratios were always highest when catches were small, with the smallest class of catches responsible for the highest total portion of bycatch (23%–43%) while only contributing negligibly to the total target catch (3%–10%).

Research needs – No needs for research.

<u>Prohibition of setting on whale sharks (PS)</u> – corresponds to prohibition from intentionally setting a purse seine net around a whale shark in the IOTC area of competence, if it is sighted prior to the commencement of the set. Regulation was already set in place by IOTC for whale shark (Resolutions 13/05).

Major scientific work (see references section): 115, 116, 117.

Major results achieved (pros and cons) – Decrease encircling/entanglement and potentially fishing mortality. Decrease data quality: non-reporting of whale-shark sets occurs.

Research needs – High. Post release mortality of whale sharks released from purse seine is unknown. Efficiency of the best practice currently set in place should be assessed.

Table 1. Mitigation measures reviewed by the working group

Direction	Measure / Method	Approach	Comment	References	Research needs	Regulation IOTC in place
Longline	**LL**					
Fishing technique/practices/strategy modification	**Avoiding hotspots**	Fleet communication program		1, 2, 14	Not a priority.	No
	Spatial and/or temporal closure	Spatial and/or temporal closure/MPAs	Time and area closures are effective at reducing by-catch only when target and non-target species segregate spatially, which is generally not the case for the pelagic sharks caught in longline fisheries targeting tunas.	108, 109, 110, 111, 112	High. Identify major pelagic shark hotspots and investigate associated environmental conditions affecting shark distribution in the Indian Ocean.	No
	Fishing time	Soaking time	Can reduce by-catch mortalities rates. Would not necessarily decrease swordfish catches but a reduction of total catch may occur. Optimal soaking duration varies by fishery.	3, 4, 5, 6, 7	Moderate. Optimal soaking duration to be assessed for target species.	No
	Fishing depth	Deep setting - traditional	Deeper setting reduces catch rates of pelagic sharks, but likely increases catches of deeper-dwelling shark species in some areas. Impossible to apply in swordfish targeting fisheries. Additional equipment (line-shooter) is required. More labour-costly, considerably increase duration of fishing operation.	10	Not a priority.	No
	Fishing depth	Deep setting and elimination of shallow hooks	Deeper setting reduces catch rates of pelagic sharks, but likely increases catches of deeper-dwelling shark species in some areas. Impossible to apply in swordfish targeting fisheries. Additional equipment (line-shooter) is required. More labour-costly, considerably increase duration of fishing operation.	8, 9	No needs for research.	No

Direction	Measure / Method	Approach	Comment	References	Research needs	Regulation IOTC in place
	Decrease fishing mortality	Reduction of fishing effort	Reduction of shark catches and improvement of the overall at-haulback survival rates for by-catch species. May result in decrease catch rates of target and by-catch commercial species. Difficult to monitor and can result in an increase of non-reported fishing effort.	4, 5, 6, 7 and 79	No needs for research.	No
	Decrease fishing mortality	Prohibition of retention	Widely applied approach for protection of endangered species. Fishing mortality expected to decrease, but still can stay at a high level. Reduces the quality of reported data.		High. Assess efficiency for currently prohibited species. Moderate for major shark species.	Yes. Species: OCS, Resolution 13/03; BTH, PTH, ALV, Resolution 12/09
	Management of offal discharge	Reduction of offal discharge.	Potential reduction of interactions with sharks. Little is known on the impact upon shark catch rates of these practices. Difficult to monitor.	2	No needs for research.	No
	Finning prohibition and other legal constrains in the fishery	Prohibition of shark finning	Fishers argue with increasing labour costs, decrease storing capacity and deterioration of shark meat as defrost is required for removing the fins.	76,	No needs for research.	Yes. Partially. Carcass-fin weight ratio is applied. Species: all shark species, Resolution 05/05
Gear and bait modification	**Bait modification**	Bait type (squid vs. fish)	The use of squid bait, in preference to fish bait, has been shown to reduce the shark catch rates in longline fisheries. However, the effectiveness of this method may vary between species. Earlier studies demonstrate opposite results showing preference of sharks to squid bait.	43, 2, 40, 19,	No needs for dedicated research. Only in combination with hook types/leaders.	No

Direction	Measure / Method	Approach	Comment	References	Research needs	Regulation IOTC in place
	Bait modification	Blue/Green-dyed bait	In the 1970s, fishermen experimented with dyed bait as a means of improving their target fish catch. More recently, experiments have been directed towards using blue-dyed bait to reduce seabird by-catch in pelagic longline fisheries. Not a promising measure as regards mitigating shark catches.	19, 44, 45, 46, 47, 48	No needs for research.	No
	Bait modification	Artificial bait	Research in the field has been very limited, with mixed success. However, artificial baits may reduce some types of bycatch under certain conditions. Although they have the potential to reduce shark bycatch, much work remains to be done before artificial baits are a viable alternative to natural baits.	1, 54, 55, 56, 57, 58, 59	Moderate. Although they have the potential to reduce shark bycatch, much work remains to be done before artificial baits could be used as a viable alternative to natural baits.	No
	Attractant / Deterrent use	Restrictions on Light Attractors	Little is known about how sharks respond to the types of light attractors used by longliners. Reduction of shark catch rates, good for the environment by reducing pollution (plastic containers, chemical component, batteries) and easy to implement. Opposition from the sector as also reduces the catch rates of target and by-catch commercial species. Difficult to control their use.	6, 11, 12, 13, 15	No needs for research.	No
	Attractant / Deterrent use	Olfactory repellent/attractant	The existence of a putative chemical shark repellent (i.e. shark necromone) has been confirmed. The risk of repulsing target species not yet assessed.	64, 65, 66, 67	No needs for research.	No

Direction	Measure / Method	Approach	Comment	References	Research needs	Regulation IOTC in place
	Attractant / Deterrent use	Magnetic, E+ metals	Conflicting results concerning the efficiency of magnetic deterrents. Impact on the target species unknown. Little information on the effect that magnet and metal could have as repellent on pelagic sharks commonly caught by commercial longliners. Trials at large scale (in the Canadian longline) showed that rare-earth metal deterrent do not present a practical by-catch mitigation measure for this fishery. These devices are fragile, costly and the method can be difficult to implement.	68, 69, 70, 74, 75, 126	Moderate research needs. Need to assess efficiency to mitigate shark by-catch.	No
	Catchability /Selectivity	Prohibition of wire/braided nylon trace use	Monofilament leaders do not decrease interactions, but promote bite-offs which may can lead to lower mortality rates. In contrast, wire and braided nylon traces produces higher shark catch rates and mortality, although it appears to vary by species.	30, 42, 80, 81, 8, 83	High research needs. Need to carry out large scale experiments in the Indian Ocean to improve knowledge on this measure and assess economic implications.	No
	Catchability /Selectivity	Circle hooks	Decrease deep-hooking of sharks and probably post-release mortality. Conflicting results in terms of catch rates, although most recent work suggesting an increase for sharks, namely when baited with fish. Other results are fisheries, species, specific and fishing area dependent.	18, 20, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 35, 36, 37, 38, 39, 40, 41, 42, 43	High research needs. Additional work is required to assess efficiency of the combination of circle hooks and bait types in terms of catch rates of both targeted species and bycatch, at-haulback and post-release mortality, particularly for major shark fishing areas in the IO.	No

Direction	Measure / Method	Approach	Comment	References	Research needs	Regulation IOTC in place
	Catchability /Selectivity	Corrodible hooks	Corrodible hooks are fishing hooks composed of material other than stainless steel. The hook may dissolve quickly, within a couple of days, or more slowly over weeks or months. The premise behind the use of corrodible hooks is that they should improve the mortality rate of by-catch released with a hook attached.	50	Moderate research needs. Efficiency and economics impacts should be assessed.	No
	Catchability /Selectivity	Weak hooks	Can reduce the incidental catch of large fish. The ability of weak hooks to release large fish alive and in good condition is questionable. Need to be replaced more often than low-grade stainless hooks.	34, 49, 53	Moderate research needs. Efficiency and economics impacts should be assessed.	No
Practices to increase survival rates	**Safe handling and release**	Safe handling and release, facilitation post-release survivorship	The objectives provide fishers with the skills to reduce the mortality of protected species and sharks. Species identification could be taught in an effort to improve reporting. Fishers would be generally supportive of these measures as they would be easy to implement with relatively little expense. Such measures could also have positive effects on other species and could thus improve handling of other sensitive species.	71, 72, 73	High priority to develop best practice guidelines and effect of such practice on post-release survival.	No
	Safe handling and release	Mandatory Turtle/shark safe handling equipment	Fishers would be generally supportive of these measures.		Not a priority. Like cutter from turtle release kits could be used to cut monofilament leaders during shark release.	No for sharks, Yes for turtles, Resolution 12/04
	Awareness	Workshop/training information dissemination on good handling practices/fishing practices	Fishers would be generally supportive of these measures if they receive some subsidies in return.		No needs for research.	No

Direction	Measure / Method	Approach	Comment	References	Research needs	Regulation IOTC in place
Purse seine	**PS**					
Fishing technique/practices/strategy modification	**Decrease ratio bycatch/target catch**	Setting on bigger aggregations	Avoiding setting on small schools will improve catch/bycatch ratio	1,	No needs for research.	No
	Avoiding protected/charismatic species	Prohibition of setting on whale sharks	Decrease encircling/entanglement and potentially fishing mortality. Decrease data quality: non-reporting of whale-shark sets occurs.	115, 116, 117	High. Post release mortality of whale sharks released from purse seine is unknown. Efficiency of the best practice currently set in place should be assessed.	Yes. Species: whale shark, cetaceans, Resolutions 13/04, 13/05.
	Decrease fishing mortality	Reduction of fishing effort. Limitation of fishing effort on certain at certain (lower) level for certain types of schools	Reduction of shark bycatch especially FAL/OCS. Will result in decrease catch rates of target commercial species. Difficult to monitor and can result in an increase of non-reported fishing effort.	N/A	No needs for research.	No
Fishing gear modification	**Non entangling FADs**	Non entangling FADs	Reduction of shark interactions. Considerably decrease ghost fishing by FADs.	118, 124	No needs for research.	Yes. Resolution 13/08.
	Release panels for shark	Release panel	Results are highly uncertain due to shark behaviour issues.	119	Moderate to high. Efficiency of shark release procedure through the panel should be considerably improved. Experiments are carrying by ISSF in other oceans.	No
	Attractant / Deterrent use	Acoustic attractant	Mostly considered as a theoretical concept. Never tested in real or experimental environment in relation with fishing gear protection.	60, 61, 62, 63, 64	Moderate. Low frequency emitting device on another FAD or speedboat to attract sharks away from FAD going to be fished.	No
Practices to increase survival rates	**Safe handling and releases**	Safe handling and release practice	Appropriate documents available	120, 121	No further research needed. Probably will further studies will be warranted after whale shark post-release survival studies.	No

Direction	Measure / Method	Approach	Comment	References	Research needs	Regulation IOTC in place
	Workshop/training information dissemination on good handling practices/fishing practices	Fishers training / awareness	Already Implemented in some countries	122	No needs for research.	No
Gillnets	**GILL**					
Fishing technique/practices/strategy modification	Fishing time	Controlling soaking time	Shorter soak times would likely increase the survivorship but could increase the number of interactions if the effort is not limited. Optimal soaking duration likely varies by fishery.	N/A	Moderate. Optimal soaking duration to be assessed for target species.	No
	Decrease fishing mortality	Reduction of fishing effort	Reduction of shark bycatch. Will result in decrease catch rates of target commercial species. Difficult to monitor and can result in an increase of non-reported fishing effort.	N/A	No needs for research.	No
Fishing gear modification	Gear configuration	Selective mesh size, gear rigging/construction	Selectivity curves are species-specific. Therefore selection of particular mesh sizes may reduce catchability of certain shark species. However shark species demonstrate relatively wide selectivity curves that can overlap with selectivity curves of target species. It was found also that increased tension in a gillnet (using larger floats on the head-rope and increasing the lead-core lead-line weigh) may reduce shark entanglement in the net.	1, 85, 86, 87, 88	High. All types of technical aspects of the gear affecting selectivity needs research by fleet, depends on target species.	No

Direction	Measure / Method	Approach	Comment	References	Research needs	Regulation IOTC in place
	Turtle/shark lights for gillnets	LED lights, UV lights, nets constructed of photoluminescent materials.	Visible spectrum LED lights and UV lights demonstrate decrease of marine turtle bycatch in gillnets without any effect on CPUE of target species. Apparently light might decrease bycatch of marine mammals also. No published information on efficiency of such measure on sharks: only theoretical conclusions.	89, 90, 91?, 92, 93	No needs for research. Apparently not as appropriate mitigation measure for sharks.	No
	Attractant / Deterrent use	Acoustic pingers	Proved to be effective to decrease bycatch of marine mammals. No any evidence of potential efficiency to mitigate shark bycatch.	93, 94	No needs for research.	No
	Attractant / Deterrent use	Olfactory repellent/attractant	Research has not passed beyond experimental stage. The existence of a putative chemical shark repellent like shark necromone has been confirmed.	91, 93, 97, 98	No needs for research.	No
	Attractant / Deterrent use	Powered electric field 'barrier' Magnetic field 'barrier'	Some prototypes tested on experimental beach nets. It was demonstrated that bull sharks and great white sharks can be deterred by permanent magnets. Magnet efficacy can vary based on situational context. Study shows a the potential for permanent magnets as devices that may reduce sharks encounters with nets. Further research should be conducted prior to applying this concept to technologies. There are also some ongoing studies of electrically-powered magnetic shark repulsion devices. 'Sharkshield'.	93, 99, 100, 101, 102, 103, 125	No needs for research.	No
	Attractant / Deterrent use	Pre-net fence (tactile)	A theoretical idea provided in the reference 93. Have been never tested in the field.	93	No needs for research.	No

Direction	Measure / Method	Approach	Comment	References	Research needs	Regulation IOTC in place
Practices to increase survival rates	**Safe handling and release**	Safe handling and release, facilitation post-release survivorship	The objectives provide fishers with the skills to reduce the mortality of protected species and sharks. Species identification could be taught in an effort to improve reporting. Fishers would be generally supportive of these measures as they would be easy to implement with relatively little expense. Such measures could also have positive effects on other species and could thus improve handling of other sensitive species.		High priority. No any guidelines available at present.	No
	Safe handling and release	Mandatory Turtle/shark safe handling equipment	Fishers would be generally supportive of these measures.		No needs for research.	No for sharks, Yes for turtles, Resolution 12/04 but for LL only
	Awareness	Workshop/training information dissemination on good handling practices/fishing practices	Fishers would be generally supportive of these measures if they receive some subsidies in return.		No needs for research.	No

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APPENDIX VI
AGENDA ITEM 5: SUPPORTING INFORMATION

References:

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APPENDIX VII
CONSOLIDATED RECOMMENDATIONS OF THE FIRST SESSION OF THE INDIAN OCEAN SHARK YEAR PROGRAM WORKSHOP (IO-SHYP01)

Note: Appendix references refer to the Report of the First Session of the Indian Ocean Shark Year Program Workshops (IOTC–2014–IO-ShYP01–R)

IO-ShYP01.01 (para. 66) **RECOMMENDED** as high priority the implementation of Regional Observer Schemes in major IOTC fleets, including coastal artisanal fleet, and/or the collection of scientific data by all other means available including, pilot observer programmes, self-sampling (collection of data by trained crew) and electronic monitoring (sensors and video cameras).

Identification of potential funding sources and application procedures

IO-ShYP01.02 (para. 86) **RECOMMENDED** that the Chair of the SC and the Chair of the WPEB to liaise with the IOTC Secretariat for coordinate efforts on how funding can be achieved, and on how to use research funding in the most efficient, collaborative and transparent way, within the objectives of this research plan.

Review of the draft Indian Ocean shark year program (IO-ShYP) for submission to the WPEB in 2014

IO-ShYP01.03 (para. 90) **RECOMMENDED** that the IO-ShYP working group continue its work inter-sessionally via electronic means to develop and refine a 5 year plan of work for the consideration and potential endorsement by the WPEB at its next session to be held in October, 2014, including the consolidated set of recommendations arising from the IO-ShYP01, provided at Appendix VII.

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