Ecological Risk Assessment (ERA) for species caught in fisheries managed by the Indian Ocean Tuna Commission (IOTC): a first attempt

by

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Abstract

ERA Level 2 Productivity Susceptibility Analysis for EU tropical tuna purse seiner, Soviet Union tuna purse seiner, Soviet Union longline research fleet, Taiwanese longline fleet, and La Reunion longline fleet was carried out. The productivity susceptibility analysis for all fleets showed somewhat similar results. In general, the analysis identified two main risk groups. The first one consists of pelagic and coastal sharks, characterized by relatively low productivities. The other group includes teleosts (both IOTC and non-IOTC species), characterized by higher productivities but high susceptibility to purse seine gear. Considering that sharks are beginning to receive the attention of the IOTC community, the analysis suggests that sharks at higher risk may deserve more detailed and thorough scientific monitoring and management actions.

Introduction

The Ecological Risk Assessment (ERA) for the effects of fishing framework involves a hierarchical approach that moves from a comprehensive but largely qualitative analysis of risk (level 1), through a more focused and semi-quantitative approach (level 2), to a highly focused and fully quantitative approach (level 3, (Hobday *et al.*, 2006)). Level 1 (Scale, Intensity, Consequence Analysis) evaluation of the risk is mostly based on perception from interaction with stakeholders, while a semi-quantitative approach which relies on good scientific investigation forms the basis of level two (Productivity Susceptibility Analsis, PSA), and level 3 is fully quantitative (full stock assessment and analysis of uncertainty).

Recently, there have been a few ERA applications to tuna and tuna like fisheries. For instance, a PSA analysis for species caught in WCPO tuna fisheries was conducted (Kirby, 2006). Cortés *et al.*, (2009) conducted a PSA analysis for eleven species of pelagic elasmobranchs to assess their vulnerability to pelagic longline fisheries in the Atlantic Ocean. Also, the seabird assessment which is being conducted within the ICCAT SubCommittee on Ecosystems, included an initial PSA analysis that allowed the identification of seabird species most at risk, and those for which a level 3 risk assessment might be pursued (Anon., 2008). The SubCommittee also identified the ERA framework as a potentially useful tool in order to identify species or species groups most at risk, so as to prioritize future assessment efforts.

The IOTC Working Party on Ecosystem and Bycatch (WPEB) expressed considerable interest in the application of ERA and recommended that "*such an analysis should be undertaken for the Indian Ocean in the near future*" because "*ERA would assist the Commission to identify, in the first instance, the key species of sharks and other species to be focused on by the Commission*". Therefore the Scientific Committee of IOTC in its meeting of 2008 recommended that "*a preliminary examination of the feasibility of undertaking an Ecological Risk Assessment process for IOTC fisheries be undertaken by the Secretariat, in collaboration with WCPFC and ICCAT, and to report on this to the working party in 2009*".

Thus, the purpose of this paper is to conduct a productivity susceptibility analysis, i.e. level 2 of an ERA analysis, for five example fleets for which observer data were available (namely EU purse seiner, Soviet Union purse seiner, Soviet Union research longline, Taiwanese longline, and La Reunion Island longline fleets) with the aim of ranking the species most at risk among the ones being caught in each of the fisheries.

Material and Methods

First we identified all the by-catch species from the observed data (including IOTC species (Scombridae and billfishes), other teleosts, skates and rays, sharks, marine mammals, sea turtles and seabirds) for each fleets considered. In several cases only the genera or family is specified (no full species name is available) and, thus, to avoid potential duplication, we worked only with records with full species names. Then, we used web based libraries (www.fishbase.org, www.sealifebase.org, www.iucn.org, www.searoundus.org, http://www.flmnh.ufl.edu/fish/), as well as published documents in IOTC or elsewhere in relation to Indian Ocean, to obtain additional biological and life history characteristic information about the species caught in IOTC fisheries.

The basic information collected included maximum length, length at maturity, reproductive strategy, intrinsic vulnerability (according to Cheung *et al.* (2005; 2007)), IUCN red list status. The intrinsic vulnerability index measures vulnerability to exploitation based on life history traits as opposed to total vulnerability that also takes into account environmental or fishing effects. The IUCN status also considers population trends to some extent. Not all the information was used for the productivity susceptibility analysis but it would be useful for further analysis and comparison.

A productivity susceptibility analysis for the effects of fishing was conducted for the European purse seiner (2003-2007), Soviet Union purse seiner (1983-1995), Soviet Union research longline (1961-1989), Taiwanese longline (2002-2008), and La Reunion Island longline fleets (2003-2009), for which observer or research data were available. This analysis was conducted mainly following Kirby's (2006) approach, and allows the identification of species most at risk among the ones caught by each of the fleets.

The productivity index was defined as:

P= (REPRODUCTIVE STRATEGY)/3 + (LENGTH AT MATURITY/MAXIMUM LENGTH)

Where the reproductive strategy was scored as follows:

1.- Broadcast spawners-> external fertilization: Fish which release their gametes into the water, where fertilization may occur; without parental care.
2.- Egg layers-> internal fertilization: species that lay eggs (oviparity); species where the pups are protected by egg cases.
3.- Live bearers-> internal fertilization: ovoviviparity and viviparity; species where pups are born live.

High *P* values indicate low productivity and high risk. *P* values were scaled to the maximum value of the series.

The susceptibility index was defined as:

S= (LENGTH AT CAPTURE / MAXIMUM LENGTH + PROPORTION DEAD)/2

Note that the first term is proportional to susceptibility assuming that for the smaller sizes natural mortality is higher and that fishing mortality is a smaller component of total mortality than for larger sizes (Fonteneau and Pallares, 2004).

In the case of tropical purse seiners, the proportion of dead animals was calculated assuming that the categories "escaped from net (for cetaceans and whale shark)", "got out of the net (for cetaceans and whale shark)" and "discarded alive" had no associated mortality, which might mean that the proportion of dead animals might be somewhat underestimated. For Soviet Union PS and LL, it was assumed that all fishes captured were dead as they were caught in research surveys. For Taiwanese and La Reunion longliners, it was assumed that all finned animals died. The categories "lost at surface" and "depredation" were not considered to estimate the percentage of dead animals.

Results

Productivity Susceptibility Analysis:

According to the observer data, the EU tropical tuna purse seiner fleet has recorded catches for 103 different species (including target and bycatch species), but only 29 of those species were assigned productivity and susceptibility scores. The information needed to estimate P and S was not available for the other species. The species that were included in the PSA analysis were 17 teleosts (7 IOTC and 10 non IOTC), 8 coastal sharks, 1 ray, and 3 sea turtles.

Only 5 individuals of 2 species (4 individuals of *Balaenoptera physalus* and 1 of *Pseudorca crassidens*) of marine mammals have been observed to interact with tropical tuna purse seiners during the observer program, however, none of them died and there was no length estimate. Thus, it was not possible to compute a susceptibility score for any of the marine mammals and, correspondingly, they are not included in the PSA analysis.

The results of the PSA analysis for EU PS (2003-2007) indicate two main risk groups (Figure 1). The first one comprises of pelagic and coastal sharks, characterized by relatively low productivities. Another group includes of teleosts (both IOTC and non IOTC), characterized by higher productivities but also high susceptibility to purse seine gear. Some sharks (blue shark, dusty shark) are at the top of the risk rank. However, it should be stressed that only 2 individuals were observed to be caught in the entire observer program, so their total vulnerability to the purse seine gear might not be that high. This example highlights the need to consider the number of individuals caught when estimating risk. In spite of this, the broad PSA analysis is useful for comparing large numbers of species and identifying those most at risk. Sea turtles were not ranked high in terms of risk.

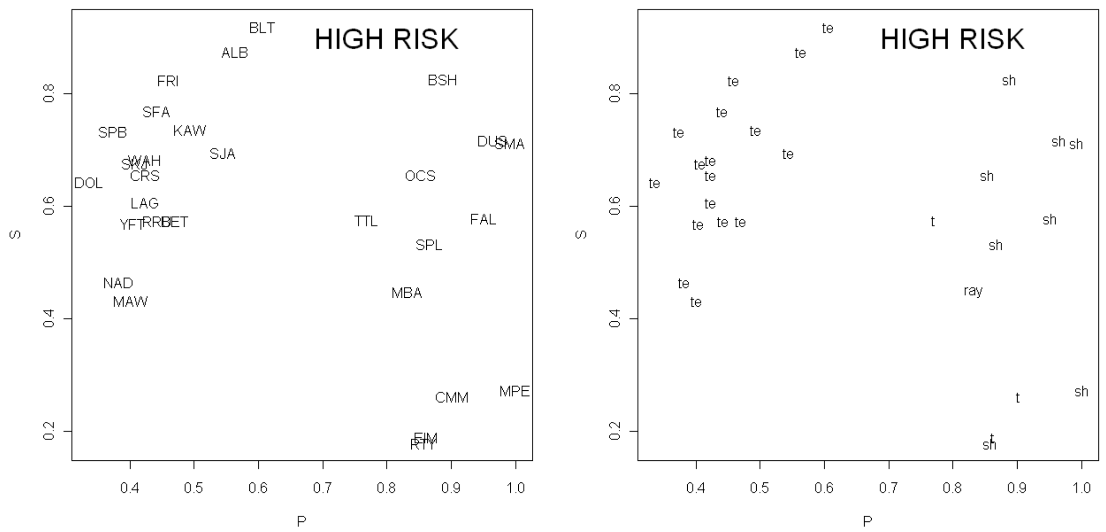

Figure 1.- Productivity susceptibility analysis for species caught by EU tropical tuna purse seiners. The species codes as well as the species groups are identified in the left and right panels, respectively. t: sea turtles; ray: skates and rays; sh: sharks; te: teleosts (IOTC and non-IOTC species). Codes for species are shown in Annex 1.

According to the observer data, the Soviet Union purse seiner surveys recorded catches for 76 different species (including target and bycatch species), but only 27 of those species were assigned productivity and susceptibility scores. The information needed to estimate P and S was not available for the rest of the species. The species that were included in the PSA analysis were 19 teleosts (8 IOTC and 11 non IOTC), 7 sharks, and 1 ray.

The results of the PSA analysis for Soviet Union PS for the period 1983-1995 showed similar results to the EU PS fleet, with two main risk groups (Figure 2). The first one consists of pelagic and coastal sharks, characterized by relatively low productivities index. The other group is comprised of teleosts (both IOTC and non IOTC), characterized by higher productivities index but also high susceptibility to purse seine gear. Scalloped hammerhead (*Sphyrna lewini*) and Blacktip reef shark (*Carcharhinus melanopterus*) are most at risk to Soviet Union PS. However, as before, it should be noted that only 1 individual scalloped hammerhead was observed in the catch of the entire observer program, so their total vulnerability to the purse seine gear might not be that high.

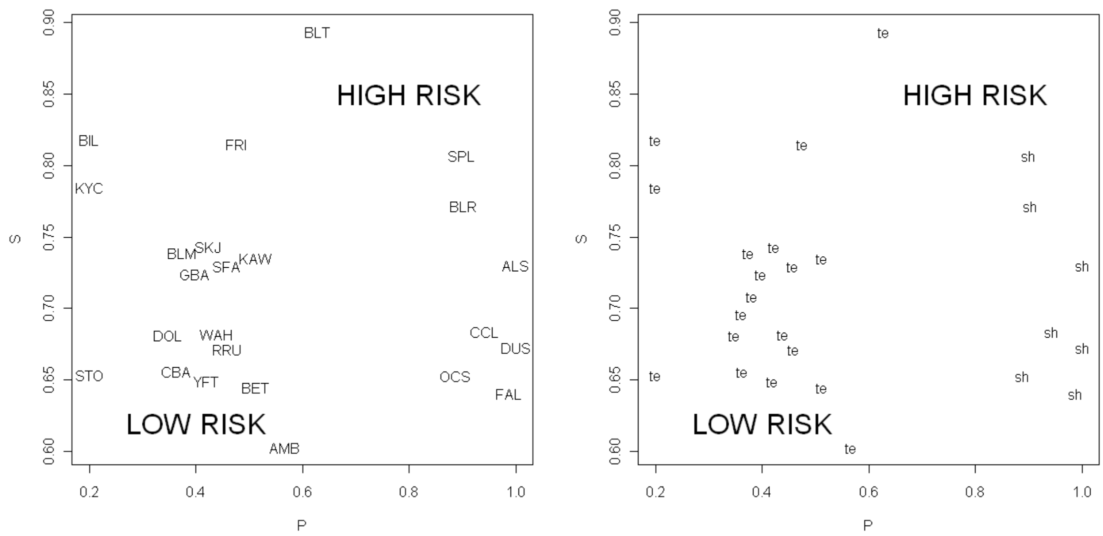

Figure 2.- Productivity susceptibility analysis for species caught by Soviet Union purse seiners (1983-1995). The species codes as well as the species groups are identified in the left and right pannels, respectively. t: sea turtles; ray: skates and rays; sh: sharks; te: teleosts (IOTC and non IOTC species). Codes for species are shown in Annex 1.

According to the observer data, the Taiwanese Longline fleet recorded catch for 55 different species (including target and bycatch species), but only 24 of those species were assigned productivity and susceptibility scores. The information needed to estimate P and S was not available for the rest of the species. The species that were included in the PSA analysis were 14 teleosts (9 IOTC and 5 non IOTC), and 10 sharks.

The PSA analysis for Taiwanese Longline (2002-2008) revealed that some sharks are at the top of the risk rankings, with both low productivities and relatively high susceptibility to the fishing gear (Figure 3). Scalloped hammerhead sharks are most at risk to Taiwanese LL gear. Other sharks also share low productivity values but slightly lower susceptibility to capture. On the contrary, many teleosts also showed high risk scores, mainly because their high susceptibility to the fishing gear, despite their productivity being relatively high.

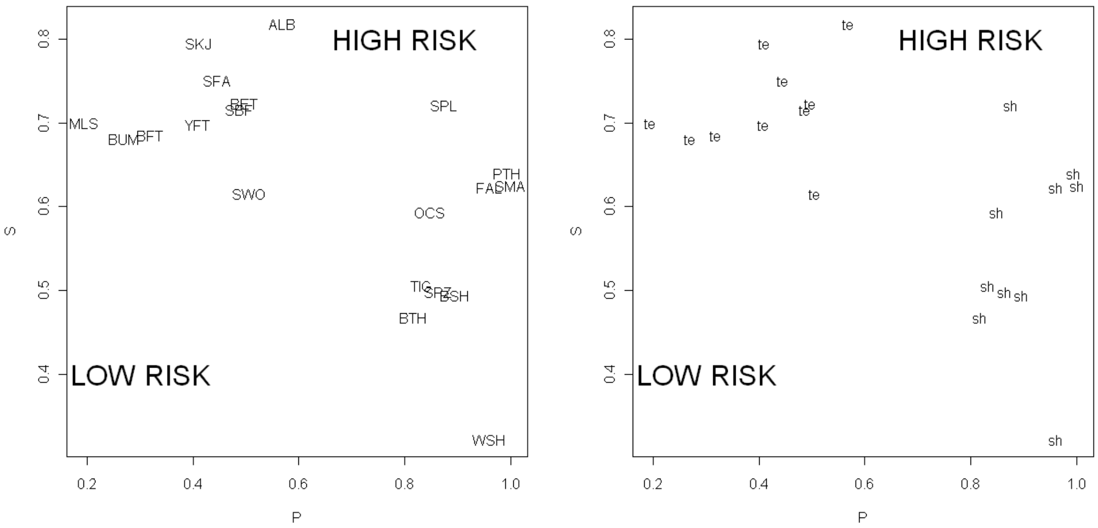

Figure 3.- Productivity susceptibility analysis for species caught by Taiwanese longline (2002-2008). The species codes as well as the species groups are identified in the left and right pannels, respectively. sh: sharks; and te: teleosts (IOTC and non-IOTC species). Codes for species are shown in Annex 1.

According to the observer data, La Reunion longline fleet recorded catch for 57 different species (including target and bycatch species), but only 38 of those species were assigned productivity and susceptibility scores. The information needed to estimate P and S was not available for the rest of the species. The species that were included in the PSA analysis were 18 teleosts (6 IOTC and 12 non IOTC), 15 sharks, 2 turtles, 2 rays, and 1 marine mammal.

The PSA analysis for La Reunion Longline (2003-2009) revealed that again, several sharks are at the top of the risk rankings, with both low productivities and relatively high susceptibility to the fishing gear (Figure 4). *Carcharhinus plumbeus* and *Pseudocarcharias kamoharai* are considered most at risk, however, it should be pointed out that only 1 individual *Carcharhinus plumbeus* was observed to be caught in the entire observer program, so their total vulnerability to the purse seine gear might not be that high. Other sharks also share low productivity values but slightly lower susceptibility to capture. On the contrary, some teleosts also showed high risk scores, mainly because of their high susceptibility to the fishing gear, despite their productivity being relatively high.

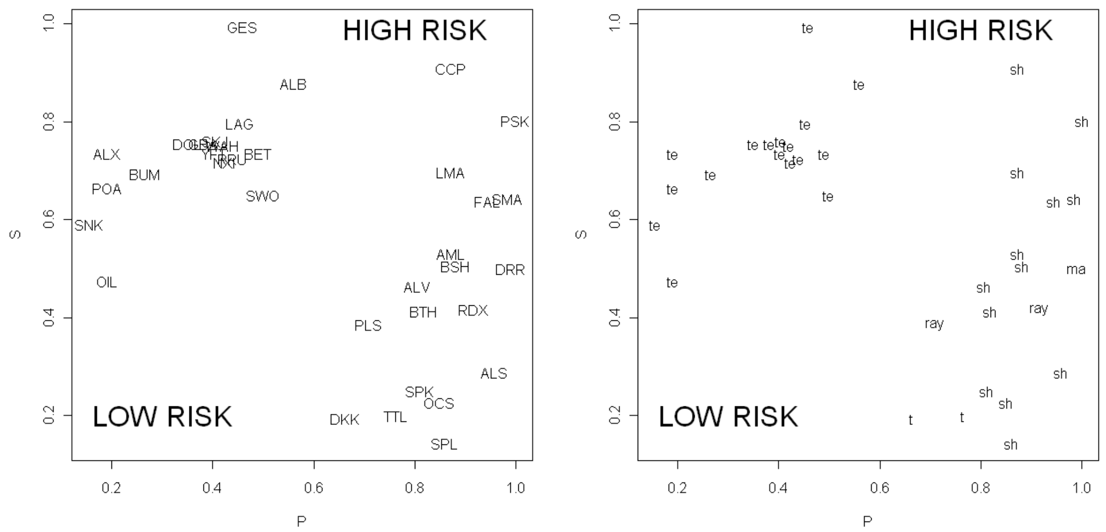

Figure 4.- Productivity susceptibility analysis for species caught by La Reunion longline (2003 2009). The species codes as well as the species groups are identified in the left and right pannels, respectively. sh: sharks; t: turtles; and te: teleosts (IOTC and non-IOTC species). Codes for species are shown in Annex 1.

Similarly, the Soviet Union Longline research survey from the period 1961 to 1989 recorded catch for 147 different species (including target and bycatch species), but only 62 of those species were assigned productivity and susceptibility scores. The information needed to estimate P and S was not available for the rest of the species. The species that were included in the PSA analysis were 32 teleosts (9 IOTC and 23 non IOTC), and 30 sharks.

The PSA analysis for Soviet Union longline showed that mostly shark species are at the top of the risk rankings, with both low productivities and relatively high susceptibility to the fishing gear (Figure 5). *Pseudocarcharias kamoharai, Carcharhinus amblyrhynchoides, Carcharhinus isodon, Carcharhinus plumbeus* are most at risk to Soviet Union LL gear. Other sharks also share low productivity values but slightly lower susceptibility to capture. On the contrary, some teleosts also showed high risk scores, mainly because of their high susceptibility to the fishing gear, despite their productivity being relatively high.

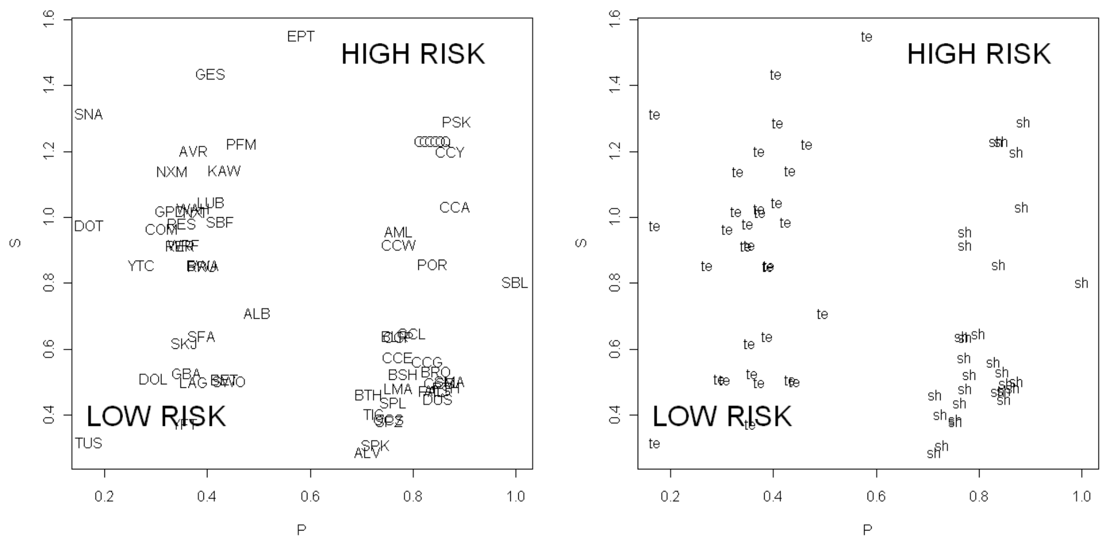

Figure 5. Productivity susceptibility analysis for species caught by Soviet Union longliners. The species codes as well as the species groups are identified in the left and right pannels, respectively. sh : sharks; and; te: teleosts (IOTC and non-IOTC). Codes for species are shown in Annex 1.

Discussion

Although it was planned to review the list of IOTC bycatch species, which includes all species ever reported by the different fishing gears, due to time constrains and lack of reported data it was not possible to carry out that task. A planned revision of this study will allow the identification of the contribution of each of the main fishing gears operating in the Indian Ocean (i.e. hand and pole line, gillnets, longline, purse seiner, and others.) to the total bycatch and the bycatch by species groups (including IOTC species, other teleosts, skates and rays, sharks, marine mammals, sea turtles and seabirds) in the Convention Area. Therefore, it should be an important exercise for the immediate future since this will provide very useful information to investigate the relative contribution of each gear to the bycatch.

The PSA analysis carried out in this study can be considered quantitative but restricted to species caught by two gear types, and five fleets, for which there was enough data available. This kind of global analysis, followed by more concentrated analyses could correspond to different levels within the ERA framework (Hobday *et al.*, 2006), can be regarded as a way to triage or rapidly assess large numbers of species to identify potentially vulnerable species that can then be subject to more detailed and rigorous analyses (Dulvy et al., 2004).

The PSA analysis for all fleets showed somewhat similar results. Overall, two high risk groups were identified, one consisting of coastal and pelagic sharks, characterized by low productivity values, and the other one including teleosts (both IOTC and non-IOTC species). Considering that sharks are starting to receive serious attention from the IOTC community, the analysis suggests that sharks at higher risk may deserve more detailed and thorough scientific monitoring and management actions. However, it should be considered that the risk ranking is likely to change under different definitions of *P* and *S*. For instance, according to this analysis four species of sea turtles (*Caretta caretta*, *Dermochelys coriacea, Chelonia mydas and Eretmochelys imbricate*) do not appear to be at high risk, while the IUCN lists 2 of those sea turtle species as endangered and the other 2 as critically endangered.

Alternative risk scores could be produced considering the total catch of each of the species (i.e. the likelihood of being caught). The risk score would be the one determined by PSA analysis multiplied by the likelihood of being caught. This would avoid cases such as for blue and dusky shark, and Scalloped hammerhead, which appears to be at highest risk in the PSA analysis for the EU and Soviet Union purse seine fishery, respectively, even though only one single individual was caught.

On the other hand, it would also be interesting to expand the analysis to observer data on gillnet fisheries, because they are also reported to catch many bycatch species, with a high proportion of marine mammals (that showed highest intrinsic vulnerability indices), and also a high proportion of critically endangered and vulnerable species.

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Annex 1.- Species scientific names, common names as well as FAO three-letter species codes.

Scientific name	Common name	FAO code	Group
Alopias pelagicus	Thresher shark	PTH	sh
Alopias superciliosus	Bigeye thresher	BTH	sh
Alopias vulpinus	Common thresher	ALV	sh
Carcharhinus albimarginatus	Silvertip shark	ALS	sh
Carcharhinus altimus	Bignose shark	CCA	sh
Carcharhinus amblyrhynchoide	Graceful shark	CCY	sh
Carcharhinus amblyrhynchos	Grey reef shark	AML	sh
Carcharhinus brachyurus	Copper shark	BRO	sh
Carcharhinus brevipinna	Spinner shark	CCB	sh
Carcharhinus falciformis	Silky shark	FAL	sh
Carcharhinus galapagensis	Galapagos shark	CCG	sh
Carcharhinus isodon	Finetooth shark	CCO	sh
Carcharhinus leucas	Bull shark	CCE	sh
Carcharhinus limbatus	Blacktip shark	CCL	sh
Carcharhinus longimanus	Oceanic whitetip shark	OCS	sh
Carcharhinus melanopterus	Blacktip reef shark	BLR	sh
Carcharhinus obscurus	Dusky shark	DUS	sh
Carcharhinus plumbeus	Sandbar shark	CCP	sh
Carcharhinus sorrah	Spot-tail shark	CCQ	sh
Carcharhinus wheeleri	Blacktail reef shark	CCW	sh
Carcharodon carcharias	Great white shark	WSH	sh
Galeocerdo cuvier	Tiger shark	TIG	sh
Hexanchus griseus	Bluntnose sixgill shark	SBL	sh
Isurus oxyrinchus	Shortfin mako	SMA	sh
Isurus paucus	Longfin mako	LMA	sh
Lamna nasus	Porbeagle	POR	sh
Prionace glauca	Blue shark	BSH	sh
Pseudocarcharias kamoharai	Crocodile shark	PSK	sh
Rhincodon typus	Whale shark	RTY	sh
Sphyrna lewini	Scalloped hammerhead	SPL	sh
Sphyrna mokarran	Great hammerhead	SPK	sh
Sphyrna zygaena	Smooth hammerhead	SPZ	sh
Acanthocybium solandri	Wahoo	WAH	te
Alepisaurus ferox	Longnose lancetfish	ALX	te
Aprion virescens	Green jobfish	AVR	te
Auxis rochei	Bullet tuna	BLT	te
Auxis thazard	Frigate tuna	FRI	te
Balistes capriscus	Grey triggerfish		te
Brama brama	Atlantic pomfret	POA	te
Caranx ignobilis	Giant trevally	NXI	te
Caranx melampygus	Bluefin trevally	NXM	te
Caranx sexfasciatus		CRS	te
Coryphaena hippurus	Common dolphinfish	DOL	te
Elagatis bipinnulata	Rainbow runner	RRU	te
Epinephelus marginatus	Dusky grouper	GPD	te
Epinephelus tauvina	Greasy grouper	EPT	te
Euthynnus affinis	Kawakawa	KAW	te
Gempylus serpens	Snake mackerel	GES	te
Gymnosarda unicolor	Dogtooth tuna	DOT	te
Hyperoglyphe antarctica	Bluenose warehou	BWA	te

Scientific name	Common name	FAO code	Group
Istiophorus platypterus	Sailfish	SFA	te
Katsuwonus pelamis	Skipjack	SKJ	te
Kyphosus cinerascens	Blue sea chub	KYC	te
Lampris guttatus	Opah	LAG	te
Lutjanus argentimaculatus	Mangrove red snapper	RES	te
Lutjanus sanguineus	Humphead snapper		te
Lutjanus sebae	Emperor red snapper	LUB	te
Makaira indica	Black marlin	BLM	te
Makaira mazara	Indo-Pacific blue marlin		te
Makaira nigricans	Blue marlins	BUM	te
Naucrates ductor		NAD	te
Petrus rupestris	Red steenbras	RER	te
Polyprion americanus	Wreckfish	WRF	te
Pristipomoides filamentosus	Crimson jobfish	PFM	te
Rachycentron canadum	Cobia	CBA	te
Ruvettus pretiosus	Oilfish	OIL	te
Scomber japonicus	Chub mackerel	SJA	te
Scomberomorus commerson	Narrow-barred Spanish mackerel	COM	te
Scomberomorus tritor		MAW	te
Seriola dumerili	Greater amberjack	AMB	te
Seriola lalandi	Yellowtail amberjack	YTC	te
Sphyraena barracuda	Great barracuda	GBA	te
Stolephorus spp	Stolephorus anchovies	STO	te
Tetrapturus audax	Striped marlins	MLS	te
Thunnus alalunga	Albacore	ALB	te
Thunnus albacares	Yellowfin	YFT	te
Thunnus maccoyii	Southern bluefin tuna	SBF	te
Thunnus obesus	Bigeye	BET	te
Thyrsites atun	Snoek	SNK	te
Xiphias gladius	Swordfish	SWO	te
Caretta caretta	Loggerhead turtle	TTL	t
Chelonia mydas	Green turtle	CMM	t
Dermochelys coriacea	Leatherback turtle	DKK	t
Eretmochelys imbricata	Hawksbill turtle	EIM	t
Dasyatis ushiei		RDX	ray
Dasyatis violacea	Pelagic stingray	PLS	ray
Manta birostris		MBA	ray
Grampus griseus	Risso's dolphin	DRR	ma