CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES
OF WILD FAUNA AND FLORA

Twenty-sixth meeting of the Animals Committee
Geneva (Switzerland), 15-20 March 2012 and Dublin (Ireland), 22-24 March 2012

REPORT ON ASSESSING THE INTRINSIC VULNERABILITY OF HARVESTED SHARKS

1. This information document has been submitted by the United Kingdom in relation to agenda item 16[*].

2. The attached draft report was commissioned from TRAFFIC by JNCC (UK Scientific Authority – Fauna) to follow up work reported in AC26 Inf. 8 with a specific focus on sharks. It seeks to identify the most important variables in assessing the vulnerability risk of sharks as a basis for subsequently examining the risks of exposure to fisheries.

3. This work was referred to in the European Union submission (AC26 Doc. 16.2 Annex European Union p. 6) in response to Notification 2011/049.

4. A final version of this report will be published on the website of the Joint Nature Conservation Committee (the UK Scientific Authority – Fauna) in due course (www.jncc.defra.gov.uk).

[*] *The geographical designations employed in this document do not imply the expression of any opinion whatsoever on the part of the CITES Secretariat or the United Nations Environment Programme concerning the legal status of any country, territory, or area, or concerning the delimitation of its frontiers or boundaries. The responsibility for the contents of the document rests exclusively with its author.*

DRAFT REPORT

Assessing the intrinsic vulnerability of harvested sharks.

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Background

Over-exploitation of fish species has been identified as the dominant direct driver of biodiversity loss in the marine environment (Polidoro *et al*., 2009). Many commercially exploited aquatic organisms are subject to harvest levels that are in excess of what is likely to be sustainable. In 2008, 32% of fish stocks were considered to be over-exploited, depleted or recovering, an increase from around 10% in the 1970s (FAO, 2010). Fishing is conducted in a range of management environments; some fish stocks/species remain completely unmanaged, while others are managed by provincial or national governments, through bilateral agreements or through multilateral agreements for migratory species implemented through regional fisheries management organisations (RFMOs). However, the status of stocks indicates that, globally, the governance and management of fisheries is insufficient, in many cases, to achieve sustainable fish stocks. While there are examples of effective national management of target fish stocks and, to a lesser extent, non-target stocks, the experience at the international level, through RFMOs suggests very limited success in managing fish stocks.

The failure of fisheries management alone to protect fish stocks has led to increasing calls for the application of multilateral environmental agreements (MEAs), such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Convention on the Conservation of Migratory Species of Wild Animals (CMS), to commercially exploited fish species. As a result, a number of these species have been proposed for listing in the Appendices of these two MEAs. Although some species have now been listed, there has been strong opposition and contention regarding proposals to list commercially exploited aquatic species in the CITES Appendices and many have been unsuccessful. The Joint Nature Conservation Committee (JNCC) identified[1] the need for a systematic review of commercially exploited fish[2] species in order to identify those species for which additional management measures might make a tangible difference to their conservation and sustainable use (Sant *et al*., 2012). It was intended that this project should help to inform thinking on whether, or how, both Conventions might better complement fisheries management and fish conservation. It was not intended to identify a 'shopping list' of candidates for listing.

The original approach (Sant *et al*., 2012) developed stemmed from one suggested through an FAO appraisal of the suitability of the CITES criteria for listing commercially-exploited aquatic species, which considered that the risks faced by aquatic species can be characterised in terms of:

- vulnerability: related to the inability (for bio-ecological reasons) of a species to sustain the levels of exploitation that it may be subjected to, this factor could also be called 'bio-ecological risk'.
- value: related to the profitability of the species' exploitation, this factor could also be called 'economic risk'.
- violability: related to the extent to which conventional management measures may be circumvented, this factor could also be called 'compliance risk'.

The assessment process developed drew heavily on the approach applied by the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO; Hobday *et al*. 2007), which has been modified and applied by others including National Oceanic & Atmospheric Administration (NOAA; e.g. Patrick *et al*., 2010). First, vulnerability and value risk was calculated for 500 commercially exploited species (fish and invertebrates) with management risk only assessed for a subset of the high risk species determined in those first steps. In undertaking the study, a number of difficulties were identified in undertaking a first iteration of the approach. Subsequently a workshop was held in Aberdeen, September 2011 (Fleming et al., 2012) to discuss the approach with a small group of fisheries and risk assessment experts in order to determine improvements to the approach. A number of recommendations were made for improving the method, including that that the life-history variables used to calculate the intrinsic vulnerability could be reduced in number and current factors were likely to be highly correlated. The workshop recommended that these

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[1] http://www.jncc.gov.uk/pdf/COMM_07D08.pdf

[2] "Fish' is used here to refer to fish and invertebrate species harvested commercially in marine waters and/or large freshwater bodies. This definition excludes aquatic amphibians, reptiles, birds, mammals and plants.

should be tested to determine the most important and minimal set of factors that could be applied to one taxonomic group. The present study discusses the results of a study to determine the most important variables in determining risk for sharks.

Amongst fish, sharks appear to be particularly vulnerable to the pressures of fishing due to their life-history traits, and are often lacking in comprehensive baseline data (Stevens *et al*., 2000). Additionally, many shark species are migratory which means making population estimates and management plans can be especially challenging (FAO, 1994).

Vulnerability

A number of studies have investigated the life history characteristics that make fish species vulnerable. A review of the evidence regarding the influence that life history traits had on fishing mortality was undertaken by Reynolds *et al*., (2005) who found that 10 of the 15 studies they looked at linked large size with vulnerability. A recent study by Le Quesne and Jennings (2011) suggested that body size (maximum length) was the only life history trait needed to give a reliable measure of sensitivity to fishing mortality, for both commercially-targeted and non-targeted species. If true, this approach would allow for the rapid assessment of species where only body size is known and may improve the statistical robustness of an assessment as body size is a trait that can be 'readily and accurately measured, giving it a practical advantage over other traits' (Reynolds *et al*., 2005).

Other traits (late maturity, longevity, reproductive output etc) were also found to determine vulnerability in some studies that did not assess body size, but these traits are often linked to maximum body size. It was assumed that vulnerability was also linked to fecundity (Dulvy *et al.*, 2003), however, others found no empirical evidence to suggest that species with high fecundity are more resilient to fishing mortality (Jennings *et al*., 1998; Jennings *et al*., 1999) and some have found that high fecundity correlates with a low recovery potential (Denney *et al*., 2002).

After the completion of IUCN Red List assessments for all scombrids (tunas, bonitos, mackerels) and billfish (swordfish and marlins), Collette *et al.* (2011) found that the species assessed as Threatened generally had relatively long generation length and high market price.

CSIRO's *Ecological Risk Assessment for the Effects of Fishing*[3] (ERAEF) (Hobday *et al.,* 2007) uses the following to score vulnerability:

- average age at maturity
- average size at maturity
- average maximum age
- average maximum size
- fecundity
- reproductive strategy
- trophic level

See Sant *et al*. (2012) for further details of scoring system used in original study.

Methods for determining most important factors

From FAO capture production data, sixty one shark species were identified as "harvested" i.e. data were available to species level. Other capture data were also available reported to a higher taxonomic level. This study did not seek to identify species that are harvested from these groups and, as such, "other shark species" may contain harvested species as well; this study did not seek to confirm from any other sources if harvesting of the species takes place. Further investigation of these groups could be considered in any further analysis. Data for each variable were complied for each shark species from (in order of availability) IUCN's Species

[3] *See http://www.csiro.au/science/fisheries-ecological-risk-assessment--ci_pageNo-3.html*

Information Service (SIS), FishBase and CSIRO. Variable information was not available for all species (see table 1).

Table 1: Number of species records for each of the Vulnerability scores

Variable	Harvested species	Other shark species	All species
Minimum Age Vulnerability	49	266	315
Size at maturity Vulnerability	61	373	434
Max age Vulnerability	46	263	309
Max size Vulnerability	61	386	447
Fecundity Vulnerability	47	120	167
Reproductive Strategy Vulnerability	61	145	202
Trophic level Vulnerability	61	205	266
Vulnerability average score	61	392	453

Mann-Whitney U-tests showed that harvested shark species scored more highly for all the Vulnerability scores, apart from the Fecundity Vulnerability, where every shark species had a score of 3.00 (Table 2).

Table 2: Mean Vulnerability values for harvested and other shark species and whether these values are significantly different.

Variable	Harvested mean value	Other shark species mean value	Z value	P
Minimum Age Vulnerability	1.75	1.26	-5.985	< 0.001
Size Vulnerability	2.11	1.57	-6.885	< 0.001
Max age Vulnerability	2.48	1.67	-6.473	< 0.001
Max size Vulnerability	2.31	1.40	-9.454	< 0.001
Fecundity Vulnerability	3.00	3.00	†	†
Reproductive Strategy Vulnerability	2.98	2.68	-3.850	< 0.001
Trophic level Vulnerability	2.95	2.86	-1.864	0.062
Vulnerability average score	2.00	1.46	-7.461	< 0.001

† *Fecundity Vulnerability scores were all the same and so could not be analysed*

Further analysis using Spearman's Rank tests showed that most of the factors were highly correlated and so there was definitely scope for reducing the number of factors used in the vulnerability scoring system. Therefore principal component analysis (PCA) was applied to the variables used in the original scoring system for vulnerability. PCA is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. It can be used to identify which Vulnerability scores are most similar and which are most different from each other, thereby identifying which variables add the most information when in combination. PCAs can only analyse data for species that have values for each vulnerability score and so the analysis was based on 36 species. The fecundity and trophic level scores for this restricted set of species all had vulnerability scores of 3, so these two factors were excluded from the analysis as they would fail to distinguish between the species.

Based on the PCA analysis it appeared that:

a) if the Vulnerability Average score were to be be based on **one** factor then it should be based on **Minimum Age Vulnerability** (based on it having the strongest relationship between PCA band 1 and PCA band 2).

b) if the Vulnerability Average score were to be be based on **two** factors then it should be based on **Minimum Age Vulnerability** and **Reproductive Strategy Vulnerability**.

c) if the Vulnerability Average score were to be be based on **three** factors then it should be based on **Minimum Age Vulnerability**, **Maximum Size Vulnerability** and **Reproductive Strategy Vulnerability**.

Given the strong assertion in the literature that size is amongst the most important characteristics, we considered that a vulnerability score based on the three factors of minimum age at maturity, maximum size and reproductive strategy would be most appropriate. However, all but 5 species were live bearers and therefore it was considered that this variable added little to the scoring for these harvested species. The final vulnerability score was therefore based on minimum age at maturity and size (see Annex 1). All species of shark have been assessed against the IUCN Red List Categories and Criteria and each species' Red List category was compared with the final Vulnerability score (see Figure 1). Although the IUCN Red List considers all threats, for harvested species it is considered that the main threat comes from harvesting; therefore, this was considered a useful comparison to make.

Results

High, medium and low "risk" were defined on the basis of approximately a third of species in each category for the overall score (scoring for the individual variable was based on bands as used in the previous study), therefore, the results should be considered as a relative ranking rather than as high medium or low overall risk (see Annex 1). Annex 1 shows both the vulnerability scores according to minimum age at maturity and maximum size and the size rank due to this having been identified by other studies as the single most important variable (Le Quesne and Jennings, 2011). Sixteen species were ranked differently by these two scores, six of which had no data available for the minimum age at maturity. Notably *Centroscymnus coelolepis* (Portuguese dogfish) scored highly when age and size were considered together, due to it having one of the highest ages at maturity, but, when size alone was considered it ranked in the lowest group. Two of the larger species *Galeocerdo cuvier* (Tiger Shark) and *Carcharhinus longimanus* (Oceanic Whitetip Shark) ranked highly for size but their relatively low minimum age at maturity reduced them to a medium overall vulnerability category.

Twelve species had no data for the minimum age at maturity. CSIRO's ERAEF takes a precautionary approach where data are not available, automatically assuming the highest level of risk. This may result in 'false positives', which the Aberdeen workshop (Fleming *et al*., 2012) considered to be preferable to false negatives. If we follow this approach the overall vulnerability level of nine of these species would increase (see Precautionary Vulnerability Score Table 3) if the same bands are retained for high, medium and low. It may be more appropriate to redefine these bands; alternatively the scores for the individual variables could be scored according to quartiles.

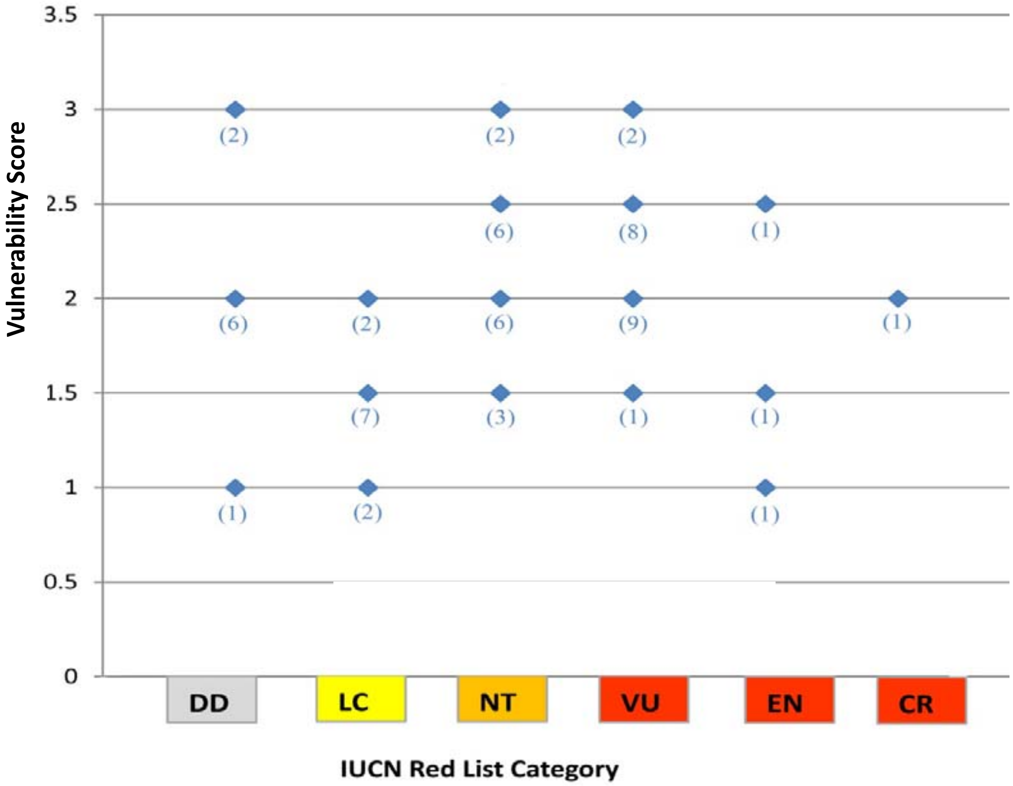
Table 3: Precautionary Vulnerability Scores for species with no information available for minimum age at maturity i.e. no original age score (See Annex 1 for details of the calculation of scores; high risk shown as pink; medium as orange and low as green)

Scientific Name	Common Name	Red List Status	Min age of maturity Vulnerability score	Max size (cms)	Vulnerabilit y ((age and[$]) size) score	Precautionary Vulnerability score	Rank based on Size
Scyliorhinus canicula	Small Spotted	LC	(3)	80	1	2	57
Scyliorhinus stellaris	Nursehound	NT	(3)	150	2	2.5	42
Scymnodon ringens	Knifetooth	DD	(3)	110	2	2.5	51
Centroscyllium fabricii	Black Dogfish	LC	(3)	107	2	2.5	53
Oxynotus centrina	Angular Rough	VU	(3)	150	2	2.5	39
Somniosus microcephalus	Large Sleeper	NT	(3)	640	3	3	3
Etmopterus princeps	Great	DD	(3)	75	1	2	58
Somniosus pacificus	Pacific Sleeper	DD	(3)	440	3	3	8
Pseudocarcharias kamoharai	Crocodile Shark	NT	(3)	110	2	2.5	50
Somniosus rostratus	Little Sleeper	DD	(3)	143	2	2.5	44
Echinorhinus brucus	Bramble Shark	DD	(3)	310	3	3	23
Oxynotus paradoxus	Sailfin	DD	(3)	120	2	2.5	48

In comparing the IUCN Red List and Vulnerability Score (see Figure 1), species that have been assessed by IUCN as Least Concern also had lower Vulnerability Scores. Species for which insufficient information is available to assess the extinction risk against the IUCN Red List Categories and Criteria, and have therefore been assigned a Category of Data Deficient, covered the range of Vulnerability Scores. It may therefore be useful to consider those species for which vulnerability has been scored high to assess the likely risk from actual fishing pressure and fisheries management.

Equally it would appear that two species *Mustelus schmitti* and *Squatina argentina* that have been assessed by IUCN as Endangered have a relatively low score for vulnerability; both species had catch levels in the top 12 according to the FAO catch data.

Figure 1: Vulnerability Score# compared with IUCN Red List category. # does not use the Precautionary Vulnerability score discussed above. Numbers in brackets indicates number of species.



Discussion

No attempt has been made in this analysis to combine the intrinsic vulnerability risk with an assessment of the risks from the exposure of the species to fishing. The next stage of the revised risk analysis would look at the exposure of each species to harvest, i.e. harvest pressure and the overlap of harvest area with range of a species . A measure of value might also be included in this risk measure.

It would appear that for sharks, vulnerability based on minimum age at maturity and size has produced a useful approach to ranking the relative intrinsic vulnerability of species to harvesting, which would be a good basis for investigating overall risk taking into account harvest pressure and management. Sixteen of the 61 species would have ranked differently for overall risk if size alone were considered, including the Portuguese dogfish, which was the only species to differ by two vulnerability categories but it is a small shark that is late to mature. Furthermore, where data were unavailable for age at maturity, taking a precautionary approach is likely to lead to false positives, which would then receive more detailed attention at a later stage in the risk assessment process, which was seen as preferable to potentially missing high risk species at this stage.

Acknowledgements

We thank the Joint Nature Conservation Committee for funding this work and the participants of the Aberdeen workshop for their guidance on further developing the approach for assessing vulnerability. In addition thanks go to Bob Smith for carrying out the statistical analysis. Thanks also to Nick Dulvy who was incredibly helpful in discussing the results and their validity.

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Annex 1: Vulnerability Scores for harvested shark species.

Scientific Name	Common Name	FAO Average catch per year 2000-2008 (tonnes)	Red List Status	Min age of maturity (Years)	Vulnerability score	Max size (cms)	Vulnerability score	Vulnerability (age and size) score[4]	Rank based on Size[5]
Alopias pelagicus	Pelagic Thresher	824.3	VU	7.5	2	330	3	2.5	21
Alopias superciliosus	Bigeye thresher shark	187.9	VU	11	2	461	3	2.5	7
Alopias vulpinus	Common Thresher Shark	458.4	VU	5.5	2	494	3	2.5	5
Carcharhinus brachyurus	Bronze Whaler	29.3	NT	17.75	3	350	3	3	17
Carcharhinus falciformis	Silky Shark	5574.3	NT	8.125	2	330	3	2.5	20
Carcharhinus leucas	Bull Shark	1.3	NT	13	2	400	3	2.5	10
Carcharhinus limbatus	Common Blacktip Shark	296.1	NT	2.1	1	275	2	1.5	26
Carcharhinus longimanus	Oceanic Whitetip Shark	238.7	VU	4.8	1	396	3	2	13
Carcharhinus obscurus	Dusky Shark	10.3	VU	19.8	3	360	3	3	16
Carcharhinus plumbeus	Sandbar shark	53.4	VU	11.75	2	250	2	2	27
Carcharhinus porosus	Smalltail Shark	83.6	DD	7.4	2	150	2	2	41
Carcharhinus sorrah	Spottail Shark	11212.6	NT	2.5	1	160	2	1.5	37
Carcharias taurus	Sand Tiger	3.3	VU	3.8	1	320	3	2	22
*Carcharodon carcharias**	Great White Shark	1.7	VU	11	2	640	3	2.5	4
Centrophorus granulosus	Gulper Shark	348.3	VU	11.5	2	160	2	2	34
Centrophorus lusitanicus	Lowfin Gulper Shark	60.3	VU	11.5	2	160	2	2	35
Centrophorus squamosus	Deepwater Spiny Dogfish	1741.6	VU	14.6	2	164	2	2	33
Centroscyllium fabricii	Black Dogfish	78.3	LC	-	-	107	2	2	53
Centroscymnus coelolepis	Portuguese dogfish	2465.2	NT	18	3	120	2	2.5	47
Cephaloscyllium isabellum	Draughtboard Shark	33.6	LC	2.7	1	100	2	1.5	56
*Cetorhinus maximus**	Basking shark	224.3	VU	16	3	900	3	3	1
Dalatias licha	Kitefin Shark	822.2	NT	6	2	182	2	2	30
Deania calcea	Shovelnose Spiny Dogfish	223.2	LC	14	2	120	2	2	49
Echinorhinus brucus	Bramble Shark	0.8	DD	-	-	310	3	3	23
Etmopterus princeps	Great Lanternshark	2.2	DD	-	-	75	1	1	58
Etmopterus spinax	Velvet Belly Lanternshark	11.2	LC	5	2	60	1	1.5	61
Galeocerdo cuvier	Tiger Shark	46.1	NT	2.9	1	750	3	2	2
Galeorhinus galeus	Whithound	4815.9	VU	3.4	1	193	2	1.5	28

** Listed in CITES Appendices.*

[4] ***High* = 3 to 2.50, *Medium* = <2.50 to 2.00, *Low* = < 2.00.**

[5] ***High*= ≥320, *Medium* <320≥150, *Low* = <150**

Scientific Name	Common Name	FAO Average catch per year 2000-2008 (tonnes)	Red List Status	Min age of maturity (Years)	Vulnerability score	Max size (cms)	Vulnerability score	Vulnerability (age and size) score[4]	Rank based on Size[5]
Galeus melastomus	Blackmouth Catshark	212.8	LC	2.5	1	105	2	1.5	54
Galeus murinus	Mouse Catshark	0.6	LC	1.9	1	70	1	1	59
Ginglymostoma cirratum	Nurse Shark	177.1	DD	3.7	1	308	3	2	24
Hexanchus griseus	Bluntnose Sixgill Shark	9.4	NT	11	2	482	3	2.5	6
Isurus oxyrinchus	Shortfin Mako	7093.3	VU	13	2	400	3	2.5	11
Isurus paucus	Longfin Mako	2.4	VU	5.2	2	417	3	2.5	9
Lamna nasus	Porbeagle shark	928.7	VU	8.8	2	350	3	2.5	18
Mustelus asterias	Starry Smoothhound	8.9	LC	2	1	150	2	1.5	43
Mustelus canis	Dusky Smoothhound	367.9	NT	14.6	2	150	2	2	40
Mustelus henlei	Brown Smoothhound	3.4	LC	2.75	1	100	2	1.5	55
Mustelus lenticulatus	Spotted Smoothhound	1426.8	LC	2.6	-	125	2	2	46
Mustelus mustelus	Common Smoothhound	166.4	VU	9.925	2	173	2	2	31
Mustelus schmitti	Narrownose Smoothhound	9374.9	EN	2.7	1	69.5	1	1	60
Negaprion brevirostris	Lemon Shark	0.1	NT	12.5	2	368	3	2.5	15
Notorynchus cepedianus	Broadnose sevengill shark	6.4	DD	10.25	2	300	2	2	25
Oxynotus centrina	Angular Rough Shark	73.2	VU	-	-	150	2	2	39
Oxynotus paradoxus	Sailfin Roughshark	0.4	DD	-	-	120	2	2	48
Prionace glauca	Blue Shark	43958.6	NT	5.5	2	380	3	2.5	14
Pseudocarcharias kamoharai	Crocodile Shark	1.6	NT	-	-	110	2	2	50
Rhizoprionodon terraenovae	Atlantic Sharpnose Shark	76.3	LC	3.175	1	110	2	1.5	52
Scyliorhinus canicula	Small Spotted Catshark	6086.4	LC	-	-	80	1	1	57
Scyliorhinus stellaris	Nursehound	372.7	NT	-	-	150	2	2	42
Scymnodon ringens	Knifetooth Dogfish	83.1	DD	-	-	110	2	2	51
Somniosus microcephalus	Large Sleeper Shark	52.0	NT	-	-	640	3	3	3
Somniosus pacificus	Pacific Sleeper Shark	2.0	DD	-	-	440	3	3	8
Somniosus rostratus	Little Sleeper Shark	1.1	DD	-	-	143	2	2	44
Sphyrna lewini	Scalloped Hammerhead	378.1	EN	7.15	2	343	3	2.5	19
Sphyrna zygaena	Smooth hammerhead	179.4	VU	6.3	2	400	3	2.5	12
Squalus acanthias	Piked Dogfish	21849.7	VU	5.6	2	160	2	2	36
Squatina argentina	Argentine Angel Shark	4119.7	EN	4.8	1	170	2	1.5	32
Squatina californica	South Pacific Angel Shark	603.9	NT	13	2	152	2	2	38
Squatina squatina	Angel Shark	25.1	CR	7.1	2	183	2	2	29
Triakis megalopterus	Spotted Gully Shark	0.7	NT	4.5	1	142	2	1.5	45