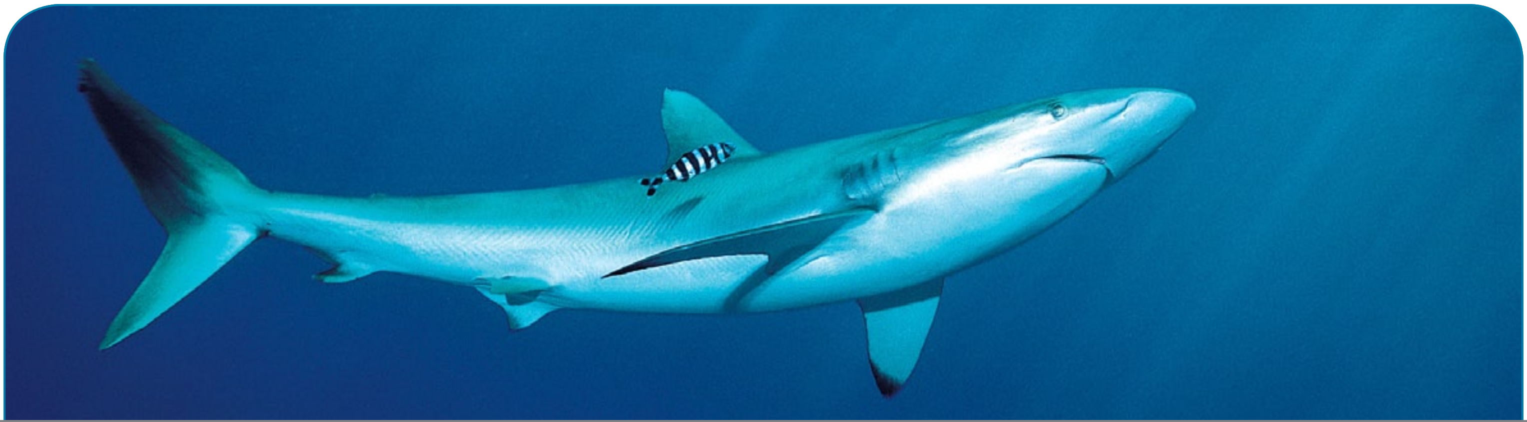

AN INTEGRATED APPROACH TO DETERMINING THE RISK OF OVER-EXPLOITATION FOR DATA-POOR PELAGIC ATLANTIC SHARKS

An Expert Working Group Report

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** The views expressed herein are solely those of the individuals and do not necessarily reflect the opinions of NOAA Fisheries Service.

SUMMARY

We assessed the risk of over-exploitation for pelagic shark species taken in Atlantic longline fisheries based on three main metrics: Ecological Risk Assessment, the inflection point of the population growth curve (a proxy for B_{MSY}) and IUCN *Red List* status. The results were analysed using multivariate statistics to provide an integrated measure of the risk of overexploitation. The integrated risk approach is not a substitute for stock assessment, but rather a method to aid in making science-based management recommendations in the face of data limitations. Findings for individual species were compared to that of the blue shark, a species that current stock assessments under the International Commission for the Conservation of Atlantic Tunas (ICCAT) indicate is not over-exploited. All examined pelagic shark and ray species had higher levels of risk than the blue shark. All species had substantially lower biological productivity than the blue shark and had inflection points above 50% of virgin biomass. According to our analyses, species at highest risk are the bigeye thresher, shortfin mako, longfin mako, and, to lesser extent, the silky shark. The porbeagle, oceanic whitetip and common thresher were grouped and identified as having the next greatest risk. The pelagic stingray and scalloped hammerhead ranked in line with the blue shark. Conclusions about the crocodile shark and smooth hammerhead could not be made due to a lack of data.

KEYWORDS

Integrated risk assessment, productivity, susceptibility, pelagic fisheries, sharks, bycatch

1. INTRODUCTION

Atlantic pelagic longline fisheries targeting primarily tuna and swordfish also take significant numbers of pelagic sharks and rays. The most commonly caught species are the blue shark (*Prionace glauca*) and the shortfin mako (*Isurus oxyrinchus*), with estimated annual catches of 40,000 t – 50,000 t and 6,000 t – 8,000 t, respectively, in the early 2000s (ICCAT 2005). Other species reported by fishery observers that are less commonly encountered include nine species of shark and one species of ray (Table 1). There are limited data on catches of these species, but fin trade data indicate that pelagic thresher, silky and oceanic whitetip sharks may be taken in similar amounts as shortfin makos (Clarke et al. 2006a, Clarke et al. 2006b, Camhi et al. 2008). Although pelagic shark species are still generally referred to as "bycatch" in tuna and swordfish fisheries, targeting of pelagic sharks is increasing due to declines in traditional target species, high value of fins for most species, and/or high or rising value of meat. For example, directed fisheries for porbeagles have taken place in both the western and eastern North Atlantic over several decades (Campana et al. 2002, ICES 2007).

Table 1. Pelagic shark and rays species reported by fishery observers on Atlantic pelagic longline vessels considered in this study.

Common name	Scientific name
Bigeye thresher	*Alopias superciliosus*
Common thresher	*Alopias vulpinus*
Silky shark	*Carcharhinus falciformis*
Oceanic whitetip	*Carcharhinus longimanus*
Shortfin mako	*Isurus oxyrinchus*
Longfin mako	*Isurus paucus*
Porbeagle	*Lamna nasus*
Blue shark	*Prionace glauca*
Crocodile shark	*Pseudocarcharias kamoharai*
Pelagic stingray	*Pteroplatytrygon violacea*
Scalloped hammerhead	*Sphyrna lewini*
Smooth hammerhead	*Sphyrna zygaena*

In recent years, there has been increasing concern about the deteriorating status of the world's pelagic shark and ray populations (Dulvy et al. 2008). Whereas there is some uncertainty about the precise status of these species (Baum et al. 2003, Baum & Myers 2004, Baum et al. 2005, Burgess et al. 2005), there is no doubt that populations have declined significantly as a result of the lack of shark fishing limits in the face of intensive pelagic fishing. Because most species of sharks have low reproductive potential (stemming from slow growth, late maturity, low reproductive rates), they are ill-equipped to sustain heavy fishing pressure and recovery times from overfishing are prolonged (Walker 1998, Cortes 2002, Cortes 2008, Smith et al. 2008). Sound, precautionary management of these species is required to ensure long-term, sustainable fisheries, prevent population collapse, and maintain ecosystem function.

The Subcommittee on Bycatch of the International Commission for the Conservation of Atlantic Tunas (ICCAT) carried out stock assessments for Atlantic shortfin mako and blue sharks in 2004 (ICCAT 2005). Through these assessments, scientists concluded that blue shark population biomasses in the North and South Atlantic were probably above that required to achieve maximum sustainable yield (ie $B_{2004} > B_{MSY}$). For shortfin mako, the Subcommittee found that the stock level in the North Atlantic had declined, possibly below that required to achieve *MSY*, and that the South Atlantic stock level had probably declined but not to the level of the North Atlantic. The results of the assessments were conditional on a range of assumptions used in the models and considered preliminary because of data limitations (ICCAT 2005). Based on these assessments, ICCAT adopted binding Recommendations for the reduction of North Atlantic shortfin mako shark mortality and improved reporting by Contracting Parties with respect to shark catches. Subsequent to the 2004 assessments, further biological research has improved the understanding of shortfin mako life history, in particular showing that the age at maturity was about 18 yr not 7 yr (Campana et al.

2005, Francis & Duffy 2005, Joung & Hsu 2005, Ribot-Carballal et al. 2005, Ardizzone et al. 2006, Bishop et al. 2006, Natanson et al. 2006, Maia et al. 2007, Wood et al. 2007, Stevens 2008). This work has shown that the parameters used in the 2004 shortfin mako assessment need updating and may have implications for associated conclusions.

With the exception of shortfin mako, blue shark, and porbeagle shark, a lack of fisheries data (e.g. abundance trends and catch series) has prevented stock assessment for Atlantic Ocean populations of pelagic sharks. Considering the inherent vulnerability and intense fishing pressure associated with these species, development of assessment methods based on the data that are available (usually life history and limited observer information) is warranted. In June 2008, the Lenfest Ocean Program convened an Expert Working Group to consider approaches to assessment of data-limited shark species and associated management strategies for achieving sustainable fisheries (Simpfendorfer & al. 2008). The Working Group used a range of metrics, including results from Ecological Risk Assessments (ERA, also known as Productivity and Susceptibility Analysis or PSA) (Braccini et al. 2006, Hobday et al. 2007, Rosenberg et al. 2007), the position of the inflection point of the population growth curve (Cortes 2008) and IUCN Red List assessments, then integrated and compared them with those populations for which full population assessments. While ERA has become a common tool for assessing the risks associated with shark catches in many fisheries (Stobutzki et al. 2001, Stobutzki et al. 2002, Griffiths et al. 2006, Rosenberg et al. 2007, Zhou & Griffiths 2008), it has limitations, particularly the fact that the method does not incorporate knowledge of population declines. The integration of multiple methods provides for the inclusion of a wider range of information than if ERA was used in isolation (e.g. the use of the inflection point of the population growth curve provides an indicator of the level at which B_{MSY} may be achieved, while IUCN assessments often incorporate some component of changes in abundance) (Simpfendorfer & al. 2008). The Expert Working Group also agreed that the level of precaution taken in management should be proportional to the level of uncertainty, thereby providing an incentive to improve fisheries data collection and initiate needed research. Such an approach has proved successful in improving data collection in Californian inshore fisheries (Kaufman et al. 2004) and has been recommended in the setting of catch limits for all US fisheries (Rosenberg et al. 2007). Given the progress of ICCAT contracting parties towards improved data collection on sharks, the use of incentives may be necessary to ensure the collection of the required data for more detailed assessments.

The aim of this study was to apply several different data-limited assessment techniques to Atlantic pelagic shark and ray species to aid in the development of management recommendations. The approach described by Simpfendorfer et al. (2008) was implemented using all available data to determine the level of risk of overexploitation associated with catches within the ICCAT area.

2. Methods

We used a number of quantitative and semi-qualitative approaches to define the risk of over-exploitation of the suite of species taken in Atlantic pelagic longline fisheries. These methods were employed for all species shown in Table 1 for which data were available. In addition, the shortfin mako life history data used in the 2004 ICCAT assessment (ICCAT 2005) were also used to enable a comparison of how improvements in knowledge can influence assessment results.

2.1 Ecological risk assessments

Ecological risk assessment (ERA) has become a popular tool for examining the potential effects of fisheries on a group of species. It can take several different forms, from purely qualitative to fully quantitative, depending on the amount of information available (Braccini et al. 2006). The general principles and means of implementing this technique were described by Hobday et al. (2007). Risk is considered on two axes – productivity (the biological ability of a species to sustain fishing or recovery from overfishing) and susceptibility (the level at which a species is likely to be affected by fishing).

We performed the quantitative assessment for pelagic sharks taken in Atlantic longline fisheries in order to provide detailed information and estimate risks for each species. Productivity was determined using stochastic demographic analyses (matrix population models) as described by Cortés (2002). These analyses yielded an estimate of intrinsic rate of population increase (r) for each species based on life history information available in the literature. We calculated susceptibility as the product of four attributes: availability (the proportion of a species' geographic range over which the fishery operates), encounterability (the proportion of the species' depth range over which they are likely to encounter the fishing gear), selectivity (the proportion of the population that encounters the gear that is captured) and post-capture mortality (the proportion of the individuals captured that were either retained or discarded dead). Data on the susceptibility attributes were gathered from a variety of sources:

1. Availability was calculated using GIS to determine the degree of overlap of pelagic longline fishing (based on ICCAT data) with a species' range in the Atlantic (based on data from the International Union for the Conservation of Nature (IUCN) Shark Specialist Group and the Global Marine Species Assessment (GMSA)).
2. Encounterability was determined using depth data from pop-up, satellite, archival tags deployed on pelagic sharks. These data were taken from the literature or obtained directly from researchers known to have deployed these tags. Depth utilisation data were compared to the depth at which longlines fished (based on U.S. fishing practices); probability of a species encountering the gear was determined using expert judgement. Where depth utilisation data were unavailable, a value of 1.0 was used.
3. Selectivity was calculated by a) determining the size range (minimum to maximum) of lengths of animals caught in the fishery based on data from U.S. longline observers, 2) transforming the stable age distribution obtained from matrix population models into a stable length distribution based on length-at-age data from the literature, and 3) summing the frequencies for each length distribution over the range determined in the first step.
4. Post-capture mortality was determined using fate data from U.S. pelagic fisheries provided by National Marine Fisheries Service (NMFS) observer studies (Lawrence Beerkircher pers. comm.). Post-capture mortality can also include post-release mortality (the proportion of individuals that are discarded alive that subsequently die as a result of capture and handling), but there were insufficient data for most of the pelagic shark species to enable consideration of post-capture mortality in this study.

In cases of unknown susceptibility attributes, species considered to have low risk were given a value of 0.33, those with medium risk, 0.66, and those with high risk, 1.0. Once productivity and susceptibility values were determined (see Appendix A for parameters), they were plotted on a scatter-plot to show their relative positions, and the Euclidean distance from a point of low risk (in this case, susceptibility = 0, productivity = 0.5) to determine the overall value of risk (higher Euclidean distance values indicate higher risk), thus enabling species to be ranked by level of risk.

2.2 Position of the inflection point of the population growth curve (R)

The value of this parameter for shark populations provides a measure of the level (relative to virgin biomass) at which B_{MSY} may be achieved. We stress that this is not an exact measure of B_{MSY}, but rather an indicator of where the level lies relative to other species and as such it should be interpreted cautiously (Cortes 2008). Values of R were calculated using the formula of Fowler (1988):

$$R = 0.633 - 0.187 \ln rT$$

where rT is the rate of population increase per generation. Median values of intrinsic rate of population increase (r) and generation time (T) were taken from the matrix population models used in the quantitative ERA (Cortes 2008). The values of B_{MSY} indicated a level of risk relative to the level of depletion in the stock, with higher values indicating greater risk of overexploitation.

2.3 IUCN Red List status

IUCN, the International Union for the Conservation of Nature, uses specialist groups within its Species Survival Commission to assess the conservation status of species on regional and global scales to determine and highlight which are under greatest threat and warrant conservation action. Experts determine species' relative risk of extinction and threat category under the IUCN *Red List of Threatened Species* using a detailed set of qualitative and quantitative criteria. Species or populations included in the high risk categories of *Critically Endangered, Endangered* or *Vulnerable* are considered *Threatened* with extinction. Species or populations classified as *Near Threatened* include those that may soon become *Threatened* if conservation action is not taken or maintained. The category of *Least Concern* is used to indicate species or populations with low risk of extinction. Species or populations for which data are insufficient to produce an assessment are classified as *Data Deficient.*

The Shark Specialist Group (SSG) has been assessing and updating the status of chondrichthyan fish species (sharks, rays and chimaeras) since 1991. Relevant subgroups of this international network of scientists and other experts evaluate individual species and/or populations on an ongoing basis. Those assessments are then evaluated by two additional experts, at least one of whom is trained as a Red List Authority. Red List assessors consider a range of information, including life history characteristics, abundance indices, fisheries data and expert opinion. Dulvy et al. (2005) demonstrated that the IUCN A categorisation (under which the pelagic shark species have been assessed) produced results consistent with population viability analysis and as such were good indicators of population status in the absence of full stock assessments.

We used the most recent IUCN SSG Red List assessments for twelve elasmobranch (shark and ray) species taken by pelagic longline fisheries in the ICCAT region (Dulvy et al. 2008). In order to use Red List assessment values quantitatively in assessing species' risk, we assigned a value between 0 and 1 to each threat category: *Critically Endangered* = 1, *Endangered* = 0.8, *Vulnerable* = 0.6, Data Deficient = 0.5, Near Threatened = 0.4 and Least Concern = 0.2. Data Deficient species were classified in the mid-range of values as a precautionary level since data were not available to fully classify these species.

2.4 Integration of results

To produce comprehensive assessments of risk for the pelagic shark and ray species taken in Atlantic pelagic longline fisheries, we conducted Multi-Dimensional Scaling (MDS) and Cluster Analysis (CA). This allowed grouping of species with similar risk levels as well as comparison with the blue shark,for which there is better information and a formal stock assessment,

3. Results and Discussion

3.1 Quantitative Ecological Risk Assessment

The plot produced by the quantitative ERA reveals a range of risk levels for the Atlantic pelagic shark species (Figure 1). Productivity values ranged from relatively high levels (0.3 yr^{-1} for the blue shark) to very low levels (0.010 to 0.014yr^{-1} for the shortfin mako, longfin mako and bigeye thresher). The lower levels of productivity are some of the lowest values reported for elasmobranchs (Cortes 2002) and have been classified by Musick et al. (2000) as very low. Values of susceptibility ranged from 0.06 (for the scalloped hammerhead) to 0.64 (for the shortfin mako), with most species falling within two groups: (1) those with susceptibility <0.3, and (2) those with susceptibility >0.43. The overall rankings based on Euclidean distance from the point of lowest risk showed that the shortfin mako, silky shark and longfin mako have the highest levels of risk of overexploitation by Atlantic pelagic longline fisheries, while the blue shark, pelagic stingray and common thresher have the lowest levels of risk (Table 2).

The results of the susceptibility estimations for the quantitative ERA were partially dependent on selectivity and post capture mortality data from observers on U.S. pelagic longline vessels. If practices related to species and size retention as well as fishing depth differs significantly in other fleets, susceptibility will vary. Other values used in the calculation of susceptibility were independent of the fleet and would not be expected to change. Further research may provide improved estimates of some parameters used in the ERA. For example, encounterability was determined based on records from satellite archival tagging, but could only be crudely assessed because of current studies' limitations in terms of detail and coverage of size classes.

Figure 1. Results of the quantitative Ecological Risk Assessment for Atlantic pelagic sharks. BTH, bigeye thresher; BSH, blue shark; LMA, longfin mako; SMA, shortfin mako; SMA*, shortfin mako with biological parameters used in 2004 ICCAT stock assessment; OCS, oceanic whitetip shark; POR, porbeagle; PSR, pelagic stingray; SPL, scalloped hammerhead; FAL, silky shark; ALV, common thresher.

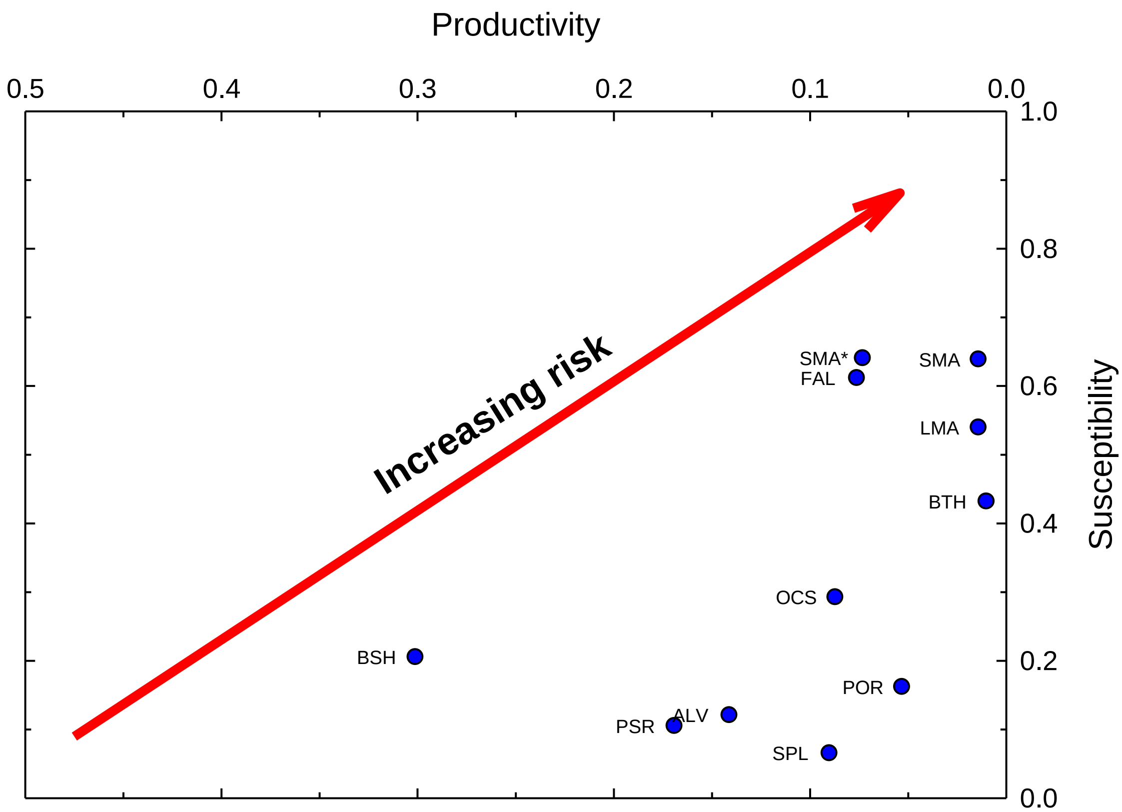


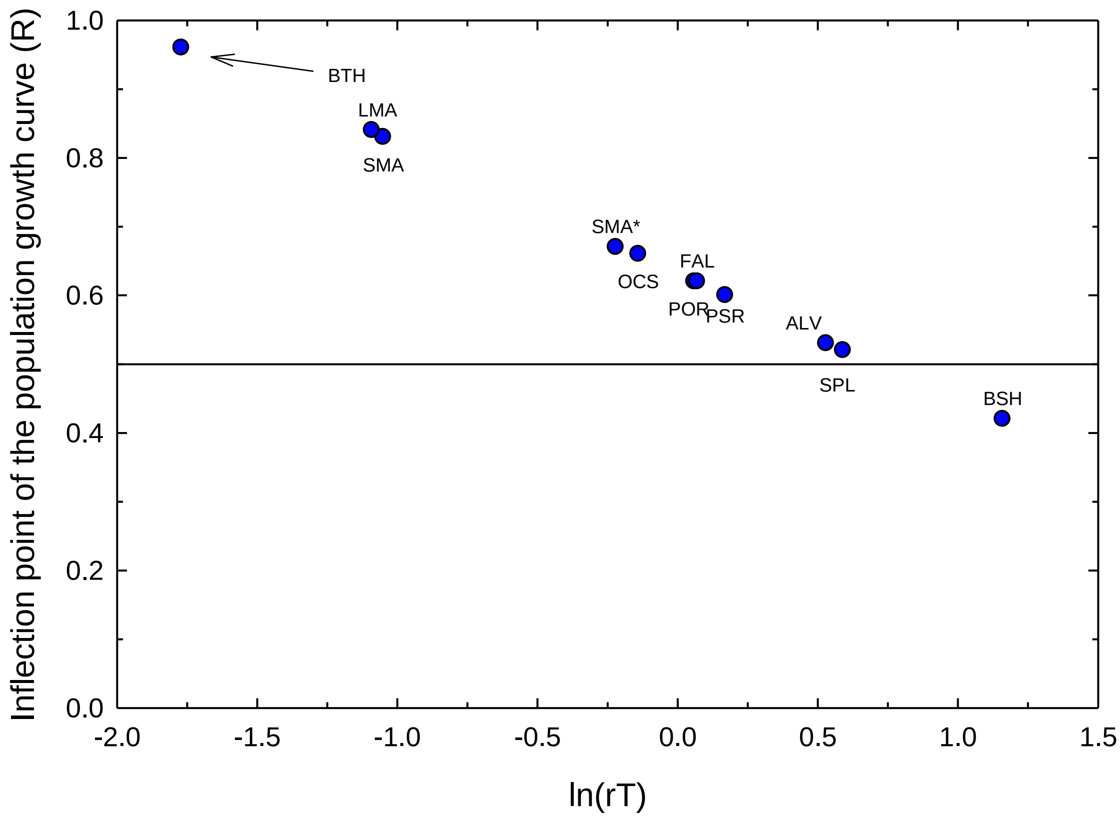
Table 2. Risk values expressed as Euclidean distance from the point of low risk (0.5,0) and each species risk rank. The shortfin mako was ranked only once – using the current biological data.

Common name	Species name	Euclidean distance	Risk rank
Bigeye thresher	*Alopias superciliosus*	0.65	4
Common thresher	*Alopias vulpinus*	0.38	8
Silky shark	*Carcharhinus falciformis*	0.74	2
Oceanic whitetip	*Carcharhinus longimanus*	0.51	5
Shortfin mako*	*Isurus oxyrinchus*	0.80	1
Shortfin mako (ICCAT '04)*	*Isurus oxyrinchus*	0.77	-
Longfin mako	*Isurus paucus*	0.73	3
Porbeagle	*Lamna nasus*	0.48	6
Blue shark*	*Prionace glauca*	0.29	10
Pelagic stingray	*Pteroplatytrygon violacea*	0.35	9
Scalloped hammerhead	*Sphyrna lewini*	0.42	7

3.2 Inflection point of the population growth curve

The inflection points of the population growth curves ($R \sim B_{MSY}$) to occur between 0.42 (blue shark) and 0.96 (bigeye thresher) (Figure 2). The only species with a value below 0.5 was the blue shark. We formed two other groupings based on the results: (1) those with values between 0.52 and 0.67 that probably achieve *MSY* at levels of virgin biomass at or above 0.5, and (2) those with values above 0.83 that probably achieve *MSY* at levels of depletion at virgin biomass levels much greater than 0.5.

Figure 2. Estimates of the inflection point of population growth curves (~B_{MSY}) for Atlantic pelagic shark species. Horizontal line indicates B_{MSY} ~ 0.5 virgin biomass. Labels are as for Figure 1.



3.3 IUCN Red List status

The SSG completed Red List assessments for all pelagic shark and ray species between 2000 and 2008. Classifications ranged from *Least Concern* (pelagic stingray) to *Vulnerable* (oceanic whitetip shark, common and bigeye threshers, short and longfin makos, and porbeagle) on an Atlantic-wide basis (Table 3). For some species (e.g. oceanic whitetip and porbeagle), however, level of risk varies across the Atlantic. Detailed information on the Red List assessments for pelagic species can be found in Dulvy et al. (2008).

3.4 Integrated results

The data we used in the integrated analysis are shown in Table 3 . We integrated the results of the ecological risk assessment, population growth curve inflection point, and the IUCN Red List status. The results of the MDS analysis revealed several groupings of species. Two broad groups were identified by the 80% similarity contour:

1. A group of species that have high levels of similarity with blue sharks, suggesting a lower risk of overexploitation. This group consists of the blue shark, scalloped hammerhead and pelagic stingray.
2. All other species grouped together in a higher risk cluster.

Within the higher risk cluster, three subgroups were identified (Figure 3):

1. The common thresher, oceanic whitetip and porbeagle had mid-range levels of risk from the ERA and inflection point analysis and were categorized as *Vulnerable* on the IUCN Red List. These species have moderately high levels of risk.
2. The silky shark had similar levels of risk to the above group, but had an IUCN Red List status of Near Threatened, suggesting experts were of the opinion that it is at lower risk than suggested by the biological data.
3. The shortfin mako (both new and old biological data), longfin mako and bigeye thresher had the highest levels of risk combined with IUCN Red List *Threatened* status. We consider these species to have the greatest degree of risk among Atlantic pelagic sharks.

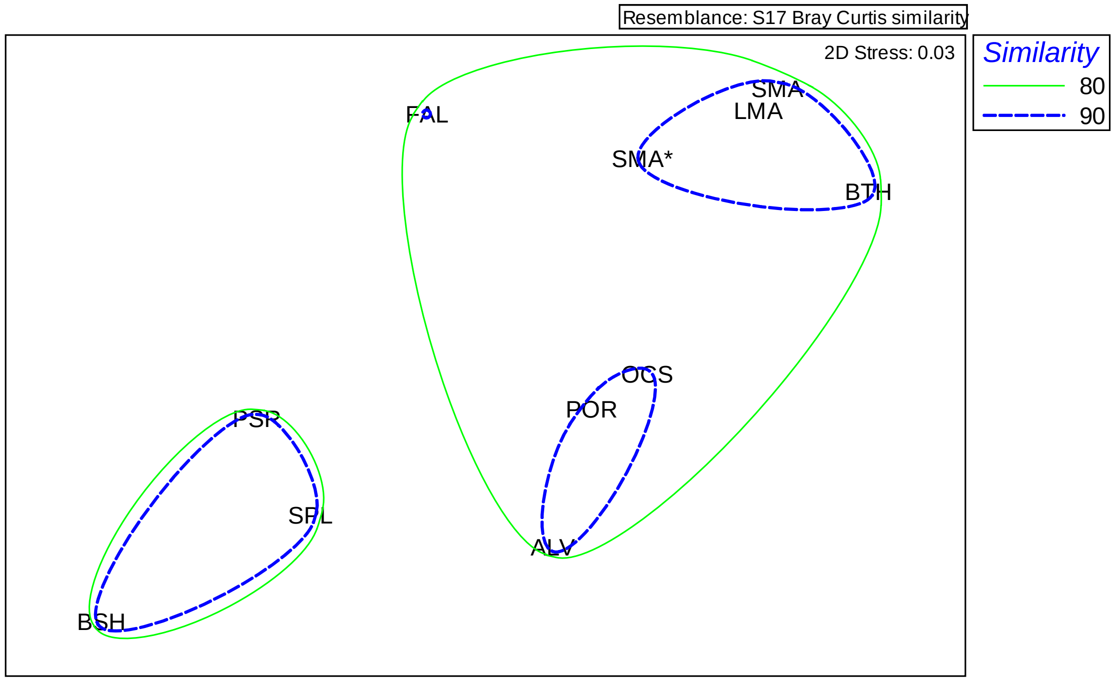
By comparing the results of these analyses to those of the blue shark, currently considered above B_{MSY} by ICCAT scientists, we gained a good understanding of the relative risks faced by other Atlantic pelagic shark species.

Table 3. Assessments of elasmobranch species caught within the ICCAT Convention Area. ERA, Ecological Risk Analysis; R, position of the inflection point of the population growth curve; IUCN classification includes year assessment was completed. Species indicated (*) are those assessed under ICCAT to date.

Common name	Species name	ERA[1]	R[2]	Global IUCN status	IUCN value
Bigeye thresher	*Alopias superciliosus*	0.65	0.96	Vulnerable (2008)	0.6
Common thresher	*Alopias vulpinus*	0.38	0.53	Vulnerable (2008)	0.6
Silky shark	*Carcharhinus falciformis*	0.74	0.62	Near Threatened (2008)	0.4
Oceanic whitetip	*Carcharhinus longimanus*	0.51	0.66	Vulnerable (2006)	0.6
Shortfin mako	*Isurus oxyrinchus*	0.80	0.84	Vulnerable (2008)	0.6
Shortfin mako (old)*	*Isurus oxyrinchus*	0.77	0.67	Vulnerable (2008)	0.6
Longfin mako	*Isurus paucus*	0.73	0.83	Vulnerable (2005)	0.6
Porbeagle	*Lamna nasus*	0.48	0.62	Vulnerable (2006)	0.6
Blue shark*	*Prionace glauca*	0.29	0.42	Near Threatened (2000)	0.4
Crocodile shark	*Pseudocarcharias kamoharai*	-	-	Near Threatened (2000)	0.4
Pelagic stingray	*Pteroplatytrygon violacea*	0.35	0.60	Least Concern (2008)	0.2
Scalloped hammerhead	*Sphyrna lewini*	0.42	0.52	Near Threatened (2000)	0.4
Smooth hammerhead	*Sphyrna zygaena*	-	-	Near Threatened (2000)	0.4

[1] ERA result based on Euclidean distance from lowest level of risk, with potential range from 0 to 1.12
[2] Potential range of R from 0.to 1

Figure 3. Results of the MDS analysis of the integrated risk results for Atlantic pelagic sharks. Levels of risk increase from lower left to upper right (as in Figure 1). Labels as for Figure 1.



Appendix A

Table A1. Life history parameters used in the ecological risk assessment. S_0, survival of 0+ age class; S_{1+}, survival range of all subsequent age classes; T, generation time, R_0, reproductive rate; r, intrinsic rate of population increase.

Species	Litter Size	Repro. period (yr)	Female K (yr^{-1})	Female maturity (yr)	Female longevity (yr)	S_0	S_{1+}	T	R_0	r
Alopias superciliosus	2	1	0.092	12-13	20	0.75	0.79-0.91	17	0.93	0.010
Alopias vulpinus	4	1	0.160	5.8	24	0.77	0.80-0.93	12	5.56	0.141
Carcharhinus falciformis	2-15	2	0.098	7-12	22	0.70	0.75-0.91	14	2.91	0.076
Carcharhinus longimanus	4-14	2	0.099	4-7	17	0.66	0.72-0.93	10	2.46	0.087
Isurus oxyrinchus	12.5	3	0.125	18.5	32	0.75	0.79-0.94	24	19.18	0.014
Isurus oxyrinchus (old)	12.75	3	0.084	7	16	0.69	0.75-0.93	11	2.28	0.073
Isurus paucus	2-4	2?	?	14	?	?	?	25	?	0.014
Lamna nasus	4	1	0.061	13	24	0.81	0.82-0.93	20	2.83	0.053
Prionace glauca	4-75	1	0.130	5.5	15	0.70	0.78-0.86	11	18.2	0.301
Pteroplatytrygon violacea	6	0.5	0.200	3	12	0.47	0.68-0.88	7	3.02	0.169
Sphyrna lewini	35	1	0.130	15	31	0.61	0.70-0.91	20	6.20	0.090

Table A2. Susceptibility data used in the ecological risk assessment of Atlantic pelagic sharks. See text for sources of information for each of the parameters

Species	Availability	Encounterability	Selectivity	Post capture mortality	Susceptibility
Alopias superciliosus	0.98	1.00	1.00	0.44	0.43
Alopias vulpinus	0.91	1.00	0.33	0.40	0.12
Carcharhinus falciformis	0.97	1.00	1.00	0.63	0.61
Carcharhinus longimanus	0.97	1.00	0.86	0.35	0.29
Isurus oxyrinchus	0.95	1.00	0.92	0.73	0.64
Isurus oxyrinchus (2004)	0.95	1.00	0.92	0.73	0.64
Isurus paucus	0.98	1.00	1.00	0.55	0.54
Lamna nasus	0.72	1.00	0.70	0.32	0.16
Prionace glauca	0.93	1.00	1.00	0.22	0.20
Pteroplatytrygon violacea	1.00	1.00	0.58	0.18	0.10
Sphyrna lewini	0.95	1.00	0.11	0.62	0.06

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MANAGEMENT RECOMMENDATIONS BASED ON INTEGRATED RISK ASSESSMENT OF DATA-POOR PELAGIC ATLANTIC SHARKS

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In developing management recommendations from the results of the Integrated Risk Assessment (SCRS/2008/140), we took the approach that the level of precaution should be determined by the levels of risk and uncertainty. Thus, management action for species for which there is insufficient data to perform stock assessments should be more cautious than that for species which have been subject to stock assessment and determination of biological reference points. This approach is recommended to minimize risk of population overexploitation (i.e. that the population would, or has already fallen, below B_{MSY}) and to provide incentive to improve data. Based on this approach and our analyses, we offer the following conclusions and recommendations for management under ICCAT:

1. ***That bigeye thresher and longfin mako be made no-take by ICCAT to ensure that populations levels do not fall below B_{MSY} levels, or are rebuilt to above B_{MSY} levels***. Through our integrated analysis, we determined that the bigeye thresher and longfin mako (along with shortfin mako) are at the highest risk of all the Atlantic pelagic sharks. Bigeye thresher and longfin mako, in particular, have extremely limited ability to sustain fishing pressure because of their biological parameters. Indeed, in these cases, MSY can be reached or exceeded at relatively low levels of exploitation. In addition, data needed for proper assessment of these two species are currently very limited.
2. ***That oceanic whitetip, porbeagle, common thresher and silky shark be made no-take species by ICCAT until such time that there is sufficient data to enable the determination of enforceable fishing limits for the entire ICCAT fleet that maintain the populations above B_{MSY}, or rebuild them to above B_{MSY}.*** The integrated analysis identified this group of species as having a moderately high levels of risk. There are also very limited amounts of data available for these species that restrict the ability to undertake any additional assessment.
3. ***Current assessments for blue and shortfin mako sharks should be updated and improved with the most up-to-date data, and strict management measures that ensure that populations remain above B_{MSY}, or are rebuilt to above B_{MSY}, be implemented. In addition, an assessment for the porbeagle should be a priority given the targeted fishing for this species in the North Atlantic and the existence of sufficient data***. For species were there is sufficient biological and fisheries data stock assessment should be carried out and management recommendations developed that ensure long-term sustainable catches can be achieved with low levels of risk.
4. ***That ICCAT encourage research related to smooth hammerheads, longfin makos and crocodile shark, and that ICCAT prohibit take of these species while more information is gathered. This status should be revisited once sufficient data have been collected and used to determine reliable reference points as well as fishing limits that rebuild and/or maintain populations above B_{MSY} levels.*** The status of information on these species is particularly poor. There is a critical need for both basic life history information and fisheries data in order to conduct sound assessments.

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