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Assessment of the Status of the Atlantic Sharpnose Shark (*Rhizoprionodon terraenovae*) Using an Age-structured Population Model

(Elasmobranch Fisheries – Oral)

by

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Abstract

The status of the Atlantic sharpnose shark (*Rhizoprionodon terraenovae*) was assessed using a Bayesian age-structured population model. The results of the model indicated that the best estimate of the mature female biomass in 2000 was 69.6% of the 1972 biomass. Sensitivity tests indicated that changes in data on catches, catch rates and biology did not significantly change the estimates of biomass. The results of risk assessment indicated that the probability of depletion of the population to below 5% or 30% of the 1972 level by 2020 is low, even with substantial increases in future catches. The results show a high level of uncertainty, indicating a need to improve the quality of data collected if assessments are to be improved. The implications of the assessment results for fisheries management are discussed.

Introduction

The Atlantic sharpnose shark (*Rhizoprionodon terraenovae*) is an abundant member of the family Carcharhinidae that inhabits the coastal waters of the western North Atlantic. It is commonly taken as by-catch in a variety of commercial fisheries, including those utilizing longlines, gillnets and trawls. Within US waters this species is managed as part of a group of smaller carcharhinid species – the small coastal sharks. Several authors have produced demographic-style assessments based on life history of this species (e.g. Cortes, 1995; Cortes and Parsons, 1996; Marquez-Farias and Castillo-Geniz, 1998), but these have had limited utility in determining the status of populations and evaluating management options. Parrack (1990) provided the results of an assessment based on a production model for the group that used a limited time series of fisheries data (1986-89). He concluded that "the stock is likely stressed by fishing to the point that the risk of abundance decrease is significant" (p. 1). More recently, Cortes (2002) has produced an assessment of individual small coastal species based on a production model and a lagged recruitment, survival and growth (LRSG) model.

In this paper we describe the results of a stock assessment of Atlantic sharpnose sharks using an age-structured model within a Bayesian framework. Unlike production models or delay-difference models the age-structured modeling approach allowed for the inclusion of stochastic processes (e.g. recruitment variation), multiple gear types with different selectivities, and detailed biological information. The inclusion of these types of data allow more flexibility in evaluating management options for a population and have been used successfully in the past for a number of shark populations (e.g. Walker, 1992; Punt and Walker, 1998; Simpfendorfer *et al*., 2000).

Materials and Methods

An age-structured population model was developed for the Atlantic sharpnose population. Details of the model and the data used in the model can be found in Simpfendorfer and Burgess (2002). Catches from six fisheries were included in the model – Gulf of Mexico shrimp trawl, Atlantic shrimp trawl, shark longline, drift gillnet, recreational and Mexican inshore fishery (Fig. 1). Two fishery-independent surveys were used to provide indices of abundance of Atlantic sharpnose sharks (Fig. 2). The first was the Oregon II fall groundfish surveys carried out by the NMFS SEFSC at Pascagula. This survey has been conducted annually since 1972. The second survey was the Virginia Institute of Marine Science's (VIMS) shark longline survey (Enric Cortes, NMFS SEFSC Panama City, pers. comm) that has operated sporadically since 1974. To test the influence of changesin parameter values on the outcome of the model a series of sensitivity tests were performed (Table 1).

The catch data for small coastal sharks indicate that they are caught by a variety of fisheries, and are mostly taken as by-catch in fisheries. As such using risk assessment to evaluate harvest strategies of a single fishery is difficult. Thus the approach taken was to evaluate the risk relative to changes in the overall catch, assuming that the relative importance of each of the fisheries remained the same in the future. Risk was evaluated for three events: (1) the mature female biomass in 2020 is less than in 2000 ($B^M_{2020} < B^M_{2000}$), (2) the mature female biomass remains above 30% of the 1972 level ($\boldsymbol{B^M}$>0.3), and (3) the population remains above 5% of the 1972 level ($\boldsymbol{B^M}$ >0.05).

Results

Current status

The median estimate of the B^M_{2000}/B^M_{1972} for the base case scenario (A) was 69.6% (Table 2). The 90% confidence interval (CI) was 37.1 – 100% indicating a high level of uncertainty about the amount of depletion in the stock (Fig. 3a). The trend in the mature biomass over time shows that maximum depletion rates probably occurred during the late-1970s and early 1980s (Fig. 3b). Subsequently, the decline in mature female biomass has been slow.

The specification of a more informative prior for z (scenario B) resulted in a smaller CI for this parameter, but did not change the CIs for any other parameters (Table 2). The estimate of the B^M_{2000}/B^M_{1972} was approximately 5% higher than for the base case scenario, but the high CIs made this difference insignificant. Scenarios that tested lower (C) and higher (D) values of natural mortality estimated median B^M_{2000}/B^M_{1972} levels 7 and 12.5% higher than the base-case scenario, respectively (Table 2). The higher value of natural mortality had substantially greater CIs for B^M_{2000}/B^M_{1972} than for any other scenario, with the upper CI reaching 115%. Removal of recruitment variation from the model (scenario E) produced the highest estimate of B^M_{2000}/B^M_{1972} (89.2%) and the smallest CI (Table 2). The post-model-pre-data distribution shows that the model produced many solutions that had little or no depletion, but application of the data produced a posterior distribution that had disproportionately more solutions with greater depletion (Fig. 3c). The biomass trend over time was much smoother without recruitment variation and showed only a slight decrease (Fig. 3d). Increasing s_r from 0.2 to 0.4 (scenario F) produced the lowest estimate of B^M_{2000}/B^M_{1972} of all the scenarios tested (62.7%). In addition this scenario had the highest median value of R^* (108,000,000) and the lowest median value of z (0.391), indicating that this solution considered the stock to be larger and less productive than any other.

Seven scenarios tested for the impact of different catch histories on the model outcomes. The first three of these (G, G.2 and G.3) tested the effect of including different proportions of the Mexican catch. Including all of the Mexican catch produced results similar to that of the base case except that the median value of R^* was almost doubled, indicating that the model compensated for these increased catches by increasing the size of the stock (Table 2, scenario G). The post-model-pre-data and posterior distributions of B^M_{2000}/B^M_{1972} were similar to those of the base case, as was the biomass trend over time. Including only a portion of the Mexican catches (scenarios G.2 and G.3) produced estimates of R^* similar to those of scenario G, but median values of B^M_{2000}/B^M_{1972} that were slightly higher

(4% of ½ catch and 6% for ¼ catch). The two scenarios that increased catches by US fisheries had similar results to those of the base case, except that the scenario that increased catches by 25% (H) had a higher median value of R^*. The scenarios that decreased catches by US fisheries had higher median values of z than the base case, and higher estimates of B^M_{2000}/B^M_{1972} (Table 2). The scenario that assumed no by-catch reduction devices in shrimp trawl fisheries (J) produced higher median values of z, R^* and B^M_{2000}/B^M_{1972} than the base case (Table 2). Assuming the by-catch reducation devices were half as effective as assumed in the base-case (scenario J.2) produced results very similar to that of the base case.

Three sensitivity tests examined the effect of using different combinations of CPUE data in the model (K – M). Inclusion of all of the data points from the Oregon II data set (scenario K) produced a higher median value of B^M_{2000}/B^M_{1972} (Table 2), indicating that the points excluded produced a higher level of depletion. Using only Oregon II CPUE data set (scenario L) produced results similar to those for the base case, but with a lower median value of z. Using only the VIMS longline CPUE data set (scenario M) produced higher median values of z, R^* and B^M_{2000}/B^M_{1972}, suggesting a larger and more productive stock than the base case. The final sensitivity test (scenario N) examined the performance of the model when applying data similar to that used by Cortes (2002) in an separate assessment of Atlantic sharpnose sharks. These data resulted in higher values of z, R^* and B^M_{2000}/B^M_{1972} (Table 2), suggesting that depletion of the stock was lower than in the base case of this study.

Risk analysis

The results of the base case and all of the sensitivity tests indicate that if catches remain near the status quo over the next twenty years there is unlikely to be any substantial reduction in the size of the stock (Table 2). In fact, many of the scenarios tested, including the base case, indicate the possibility of a slight increase in mature biomass. The scenarios that show the greatest continued decline (albeit very small) are the lower natural mortality (D), increased recruitment variation (F) and no by-catch reduction devices (J).

The results of the risk analysis on the base case, no recruitment variation and the full Mexican catches included are shown in Fig. 4. The probability that the mature biomass is lower in 2020 than in 2000 increases with increasing catch. For the base case and the scenario with Mexican catches included there is an 80% chance if catches are 2.3 times current catch levels, and for the no recruitment variation scenario there is an 80% chance when catches are 1.7 times the current level. The probabilities of the stock declining to much lower levels (either 30% or 5% of the 1972 level) are relatively low, even at greatly increased levels of catch. In the base case, the probability of the mature biomass decreasing to less than 30% by 2020 was about 60% if catches are quadrupled from their 2000 level (Fig. 4).

Discussion

The results of the analysis indicate that since 1972 there is likely to have been a decrease in the abundance of Atlantic sharpnose sharks. The base case scenario indicates that in 2000 the population was most likely to be at a level of approximately 69% of that in 1972. There is a high level of uncertainty about the level of this decline, with 90% confidence intervals ranging from a decline to 37%, to no decline at all. Cortes (2002) has also undertaken assessment of the status of Atlantic sharpnose shark. Using a Bayesian surplus production model, and a lagged-recruitment survival and growth state-space model, he estimated the 2001 total biomass to be 79% of carrying capacity. This estimate of depletion is approximately 10% more than in the current study. However, a sensitivity test using similar data to that used by Cortes (2002) produced an estimate of median B^M_{2000}/B^M_{1972} of 81%. The greater level of depletion is likely to be a result of the current study using a model that included a full age structure, recruitment variability and gear selectivity. In addition, catch and catch rate data differed between the two analyses reflecting differences in the assumptions about catches made in fisheries for which little data was available.

The most likely level of depletion in the Atlantic sharpnose shark population suggests that the stock is in a healthy state and that the current level of catches are sustainable in the long term assuming that the future pattern of exploitation remains similar. In fact, the results of the risk analysis indicate that the stock could tolerate increased catches without a high probability of being reduced to levels where there were significant concerns about the stock. In other shark stocks for which similar analyses have been performed the levels of depletion have been much greater. For example, Punt and Walker (1998) estimated the southern Australian population of school sharks (*Galeorhinus galeus*) had been depleted to between 13 and 45% of its virgin level, and Simpfendorfer *et al*. (2000) estimated that the Western Australian population of whiskery sharks (*Furgaleus macki*) had been depleted to approximately 23% of virgin. These authors attributed the decline in these populations to sustained commercial shark fisheries that targeted these species at least part of the year. This is unlike the Atlantic sharpnose stock which is rarely targeted and is taken mostly as by-catch in a range of fisheries.

The sensitivity tests indicate that the results of the model are not substantially affected by changes in the input parameters of the model. There were changes in the median values of population status, but the high levels of uncertainty about all of the results meant that it was not possible to identify any factor that significantly changed the results. Cortes (2002) reported a similar result for the same population. Two factors need to be considered in relation to the uncertainty of the parameter estimates. Firstly, the actually uncertainty is a result of limited information on the trend in biomass of the stock included in the CPUE data sets which were assumed to represent abundance. Cortes (2002) included a larger number CPUE data sets in his analysis (up to 13), including the two used in the current study. His results indicate only minor changes (<10%) in the level of population depletion when different combinations of data sets were used, indicating that including more data series would be unlikely to significantly change the results in the current study. The results of the sensitivity analysis indicate that the Oregon II data set (excluding three data points) produces greater median levels of depletion in the stock than did the VIMS longline data set. One problem that all of the potential CPUE data sets are affected by is that they occur over only a limited proportion of the geographic range of this species, or for a short period relative to the length of the fishery. The Atlantic sharpnose shark population is highly sexually segregated and the segregation pattern changes over time (G. Burgess unpublished data), and as such spatially and temporally restricted data sets are less likely to accurately reflect the abundance of the stock. Thus a spatially-explicit model may eventually prove to provide a better assessment of the population (e.g. Punt *et al*., 2000). However, the increased data requirements (as opposed to a spatially-aggregated model as used in this assessment) may prove limiting, especially in relation to data on movement of individuals between spatial strata.

The second factor to consider in relation to the uncertainty of the parameter estimates is that the results of the sensitivity tests show that refining the input parameters (other than the CPUE series) are unlikely to increase the precision of the stock assessments. This includes estimates of natural mortality, recruitment variability, catches and the impacts of by-catch reduction devices. While it will be important to refine estimates of all of these parameters (and others not considered in the sensitivity tests) greater refinement of stock assessments for the Atlantic sharpnose shark will be gained from improving estimates of abundance over time for this species.

The results of this research have a number of implications for the management of fisheries and shark populations in the Gulf of Mexico and the US Atlantic. The most notable of these is in relation to the setting of quotas for the small coastal shark group. It is clear from the data used in this research that the quotas set by NMFS represent only a fraction of the actual catch, with trawl fisheries in particular catching large amounts of a couple of these species. The use of quotas is thus of limited utility in managing these populations. In addition, the results indicate that the current catch levels are sustainable due to the large size and productive nature of these populations.

The high level of uncertainty about the status of the populations is also an indication that there needs to be improved data collection in fisheries that catch small coastal shark species. Probably the biggest need is for data that accurately represents the abundance of these populations over time. While there are large numbers of fishery-independent and fishery-dependent data sets available, none appear to be truly representative. A better understanding of how catch rate data sets relate to the abundance of small coastal sharks is likely to provide the most improvement in the estimation of the status of the populations. Initiatives such as the Shark Fishery Observer Program are beginning to provide some of these data, however, to fully understand the dynamics of the fishery and the population it may be necessary to introduce the collection of detailed catch and effort data from all vessels.

Acknowledgments

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Natural Resources provided data on the catch rates of small coastal sharks. Dr Gilmore Pelligrin provided data form the Gulf of Mexico trawl survey database. We also thank the participants of the Small Coastal Shark Assessment Workshop held at Mote Marine Laboratory in April 2000 for their time and input to the assessment process.

References

Cortes, E. 1995. Demographic analysis of the Atlantic sharpnose shark, *Rhizoprionodon terraenovae,* in the Gulf of Mexico. *Fishery Buletin.*, **93**: 57-66.

Cortes, E. 2002. Stock assessment of small coastal sharks in the US Atlantic and Gulf of Mexico. National Marine Fisheries Service Report, Sustainable Fisheries Divisi9on contribution SFD-01/02-152.

Cortes, E., and Parsons, G.R. 1996. Comparative demography of two populations of the bonnethead shark (*Sphyrna tiburo*). *Canadian Journal of Fisheries and Aquatic Sciences*, **53**: 709-717.

Marquez-Farias, J.F., and Castillo-Geniz, J.L. 1998. Fishery biology and demography of the Atlantic sharpnose shark, *Rhizoprionodon terraenovae,* in the southern Gulf of Mexico. *Fisheries Research,* **39**: 183-198.

Parrack, M.L. 1990. A study of shark exploitation in U.S. Atlantic coastal waters during 1986-1989. National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL, Contribution MIA-90/91-03, 14 pp.

Punt, A.E., and Walker, T.I. 1998. Stock assessment and risk analysis for the school shark (*Galeorhinus galeus*) off southern Australia. *Marine and Freshwater Research,* 719-731.

Punt, A.E., Pribac, F., Walker, T.I., Taylor, B.L. and Prince, J.D. 2000. Stock assessment of the school shark, *Galeorhinus galeus*, based on a spatially explicit dynamic model. *Marine and Freshwater Research,* **51**: 205-220.

Simpfendorfer, C.A., and Burgess, G. 2002. Assessment of the status of the Atlantic sharpnose shark in US waters using an age-structured model. Mote Marine Laboratory Technical Report, **836**: 58 pp.

Simpfendorfer, CA, Donohue, K, and Hall, N. 2000. Stock assessment and risk analysis for the whiskery

Walker, T.I. 1992. A fishery simulation model for sharks applied to the gummy shark, *Mustelus antarcticus* Gunther, from southern Australian waters. *Australian Journal of Marine and Freshwater Research*, **43**:195-212.

Table 1: Details of sensitivity tests for the Atlantic sharpnose shark assessment.

Code	Scenario	Parameter change
A	Base-case	None
B	Normally distributed prior	Prior for $z \sim N(0.5,0.1)$
C	Low natural mortality	$M = 0.3$
D	High natural mortality	$M = 0.5$
E	No recruitment variation	$s_r = 0$
F	High recruitment variation	$s_r = 0.3$
G	Mexico included	Mexican catches included in the assessment
G.2	Half Mexico catch included	Half of the Mexican catch included
G.3	Quarter Mexico catch included	Quarter of the Mexican catch included
H	High US catch	Catches in US fisheries increased 25%
H.2	Very high US catch	Catches in US fisheries increased 50%
I	Low US catch	Catches in US fisheries decreased 25%
I.2	Very low US catch	Catches in US fisheries decreased 50%
J	No by-catch reduction devices	Catches by Atlantic and GOM shrimp trawl not reduced by 50% for BRDs
J.2	By-catch reduction devices less effective	Catches by Atlantic and GOM shrimp trawl fisheries reduced by 25% for BRDs
K	All Oregon II survey points	Data for 1972, 1973 and 1987 included
L	GOM CPUE only	Only GOM survey data used to fit model
M	VIMS CPUE only	Only VIMS survey data used to fit model
N	Cortes (2002) comparison	Catch history from Cortes (2002); uniform selectivity; $s_r = 0$

Table 2: Results of the base case assessment, and 18 sensitivity tests, for the Gulf of Mexico and US Atlantic population of Atlantic sharpnose sharks. Values in parentheses are 90% confidence intervals.

Scenario	R* ('000,000)	z	B_{2000}/B_{1972} (%)	B_{2020}/B_{2000}
A	41.4 (13.9–93.7)	0.416 (0.216–0.909)	69.6 (37.1–100)	1.04 (0.69-1.37)
B	70.2 (13.8-185)	0.479 (0.319-0.640)	74.3 (44.9-105)	1.06 (0.81-1.44)
C	65.2 (10.1–183)	0.484 (0.221-0.931)	76.5 (39.2-105)	1.03 (0.80-1.35)
D	67.9 (30.1-181)	0.508 (0.206-0.937)	82.2 (39.6-115)	0.98 (0.32-1.22)
E	59.6 (13.7-181)	0.466 (0.216-0.940)	89.2 (41.8-98.2)	1.02 (0.82-1.32)
F	108 (30.5-193)	0.391 (0.229-0.900)	62.7 (35.0-101)	0.97 (0.51-1.57)
G	83.3 (31.3-186)	0.447 (0.226-0.907)	68.7 (41.6-98.9)	0.99 (0.56-1.28)
G.2	81.7 (23.8-183)	0.442 (0.226-0.910)	72.4 (45.3-102)	1.00 (0.67-1.28)
G.3	76.7 (20.6-188)	0.447 (0.216-0.926)	74.2 (44.7-106)	1.01 (0.71-1.29)
H	72.2 (18.3-186)	0.413 (0.217-0.920)	72.5 (38.1-104)	1.01 (0.72-1.42)
H.2	41.4 (14.0-93.7)	0.416 (0.216-0.909)	69.6 (37.1-100)	1.04 (0.69-1.37)
I	73.2 (13.8-185)	0.449 (0.221-0.922)	79.5 (53.3-108)	1.02 (0.77-1.30)
I.2	37.2 (7.25-92.7)	0.450 (0.215-0.905)	77.3 (44.4-107)	1.03 (0.77-1.39)
J	76.1 (16.0-186)	0.469 (0.221-0.927)	77.0 (45.2-106.9)	0.96 (0.63-1.20)
J.2	43.2 (13.8-93.2)	0.418 (0.220-0.870)	70.2 (40.5-99.9)	1.00 (0.63-1.31)
K	88.5 (19.8-187)	0.475 (0.22-0.941)	81.9 (52.7-109)	1.03 (0.80-1.34)
L	56.7 (12.4-186)	0.377 (0.212-0.897)	72.1 (30.4-104)	1.01 (0.59-1.36)
M	102 (18.2-189)	0.587 (0.234-0.956)	85.2 (58.1-110)	1.02 (0.81-1.28)
N	90.4 (12.7-191)	0.494 (0.228-0.937)	81.0 (55.1-108)	1.01 (0.82-1.29)

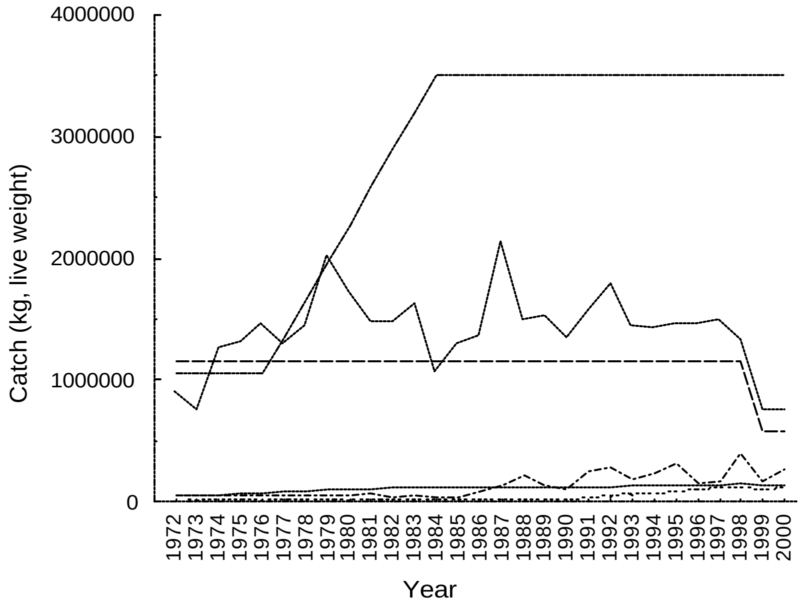

Fig. 1. Estimated catches of Atlantic sharpnose sharks since 1972. Drift gillnet fishery, short dashes; Atlantic shrimp trawl fishery, long dashes; shark longline fishery, dots; Gulf of Mexico shrimp trawl fishery, solid line; recreational fishery, dashes and single dots; Mexican inshore fisheries in the Gulf of Mexico, dashes and double dots.

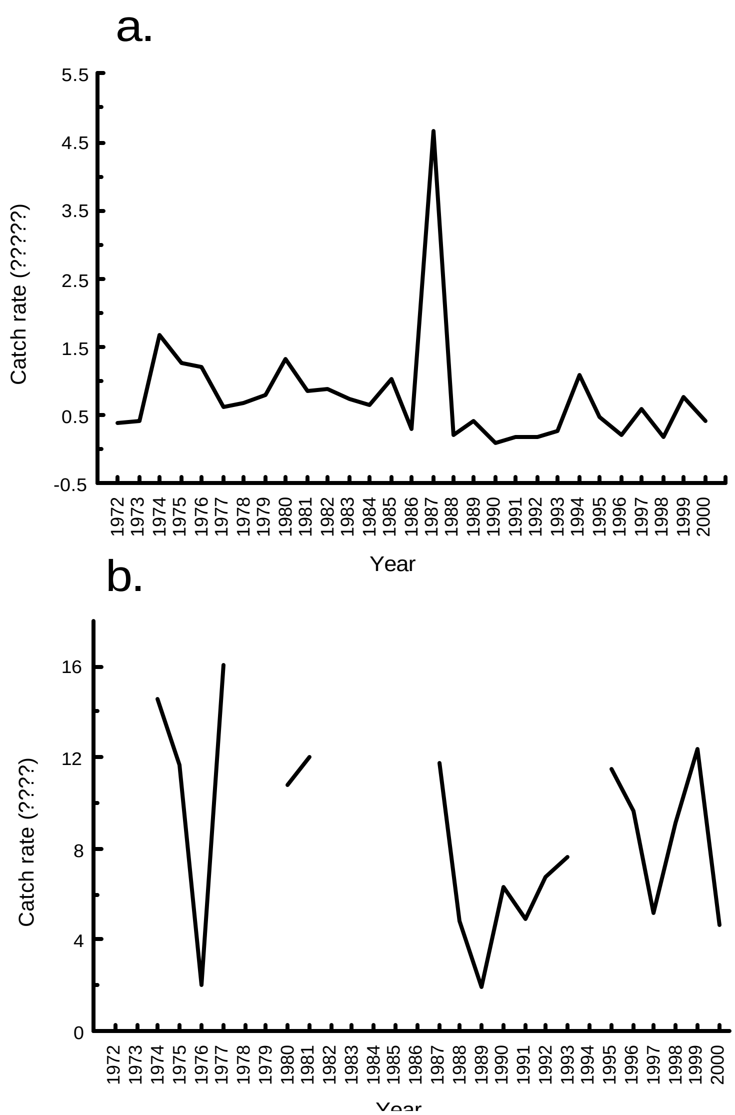

Fig. 2. Standardized catch rates for (a) the Oregon II groundfish survey and (b) the Virginia Institute of Marine Science shark longline survey

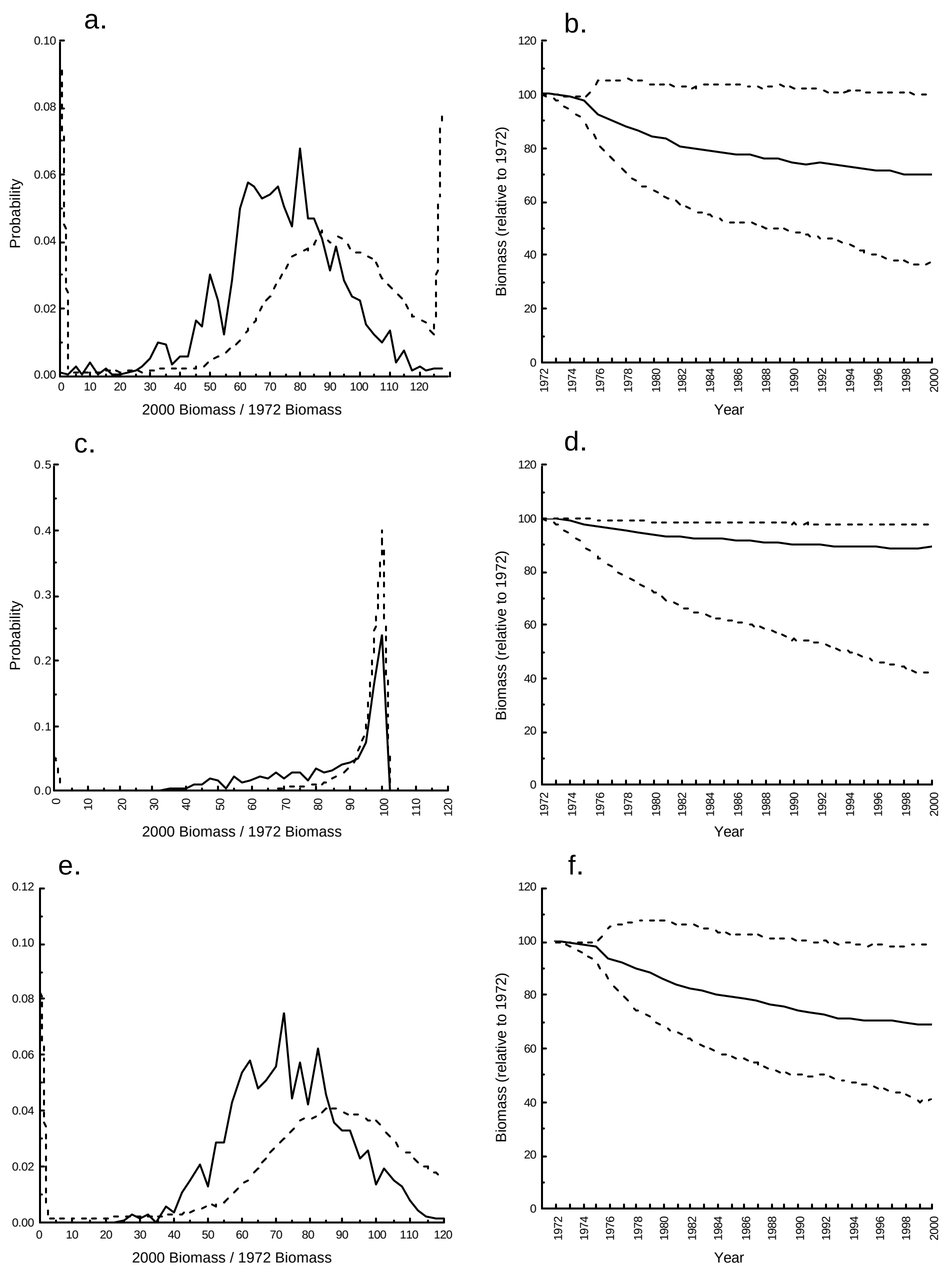

Fig. 3. Biomass depletion estimates of Atlantic sharpnose sharks in the Gulf of Mexico and Atlantic for three scenarios (base case, no recruitment variation and Mexican catches included) in the year 2000 (a, c, e) and biomass trend (b, d, f) 1972 - 2000. Dashed lines in a, c and e are post-model-pre-data distributions; solid lines in a, c and e are posterior distributions; dashed lines in b, d and f are 90% confidence intervals; solid lines in b, d and f are median values.

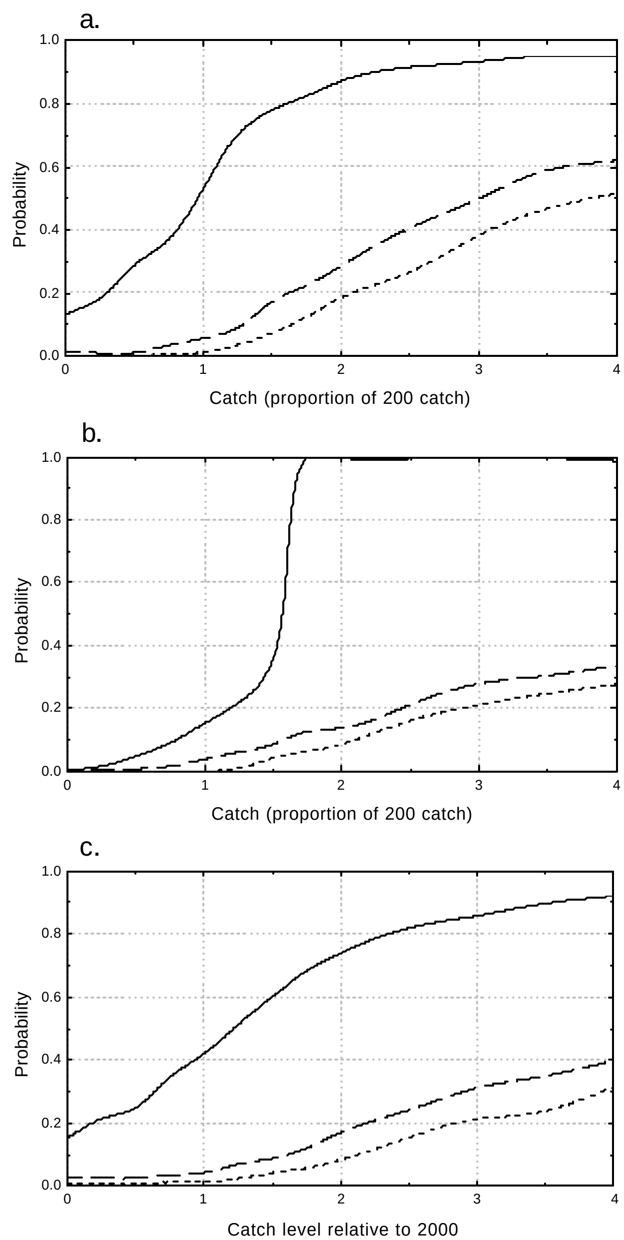

Fig. 4. Risk analysis for Atlantic sharpnose sharks based on three scenarios (a) base case (b) no recruitment variation and (c) Mexican catches included. Solid lines, $B^M_{2020} < B^M_{2000}$; long dashed lines, $\boldsymbol{B}^M$ >0.3; short dashed lines, $\boldsymbol{B}^M$ <0.05.