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RECENT TRENDS IN CATCH RATES OF SOME ATLANTIC SHARKS

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SUMMARY

In the absence of time series of species-specific catch and by-catch, it is difficult to conduct evaluations of the potential risk to individual shark species stock increase under different harvest levels. It is unknown if the management system in place for the U.S. Atlantic fisheries (catch limits for groups of species with similar life history characteristics) is overly conservative for under-utilized shark species in the complex while still allowing for recovery of over-harvested shark species in the group. Inference based on trends in catch rates, in conjunction with knowledge about the general life history characteristics of sharks has been used to qualitatively evaluate the relative risks to recovery of increase in allowable harvest levels for the sharks grouped as "large coastal" species.

RÉSUMÉ

En l'absence de séries temporelles sur les captures principales et accessoires par espèce, il est difficile d'évaluer le risque potentiel qu'implique l'augmentation des captures de requins dans différentes hypothèses de production. On ne sait pas si le système de gestion mis en place pour les pêcheries américaines actives dans l'Atlantique (limites de capture pour les groupes d'espèces montrant des caractéristiques vitales similaires) s'avère trop strict pour des espèces sous-employées tout en permettant le rétablissement d'espèces de requins sur-pêchées. Le raisonnement basé sur les tendances des taux de capture, et les connaissances des caractéristiques vitales générales des requins ont été utilisés pour évaluer qualitativement les risques relatifs que font peser les augmentations de capture sur le processus de rétablissement à des niveaux de production autorisés pour les requins de la catégorie "grands côtiers".

RESUMEN

En ausencia de series temporales de captura y captura secundaria específica por especies, resulta difícil llevar a cabo evaluaciones del riesgo potencial, para los stock de las especies individuales de tiburones, del incremento a diferentes niveles de captura. Se desconoce si el sistema de ordenación en vigor para las pesquerías estadounidenses del Atlántico (límites de captura para grupos de especies con una historia vital de características similares) es principalmente conservadora para las especies de tiburones infrautilizadas en el conjunto, mientras que aún permite la captura de especies de tiburones que sufren sobrepesca en el grupo. Se ha aplicado la deducción basada en tendencias en las tasas de captura, junto con el conocimiento de las características del ciclo vital general de los tiburones, para evaluar cualitativamente el riesgo relativo de recuperar el incremento a niveles de captura permisibles para los tiburones agrupados como especies de "grandes costeros".

Background. U.S. Atlantic shark catches increased rapidly over the late 1980's and early 1990's to more than 9,500 mt, but have recently been limited because of concern over the sustainability of this catch level. Because species-specific catches of sharks are not well documented, they are grouped by similar life-history and habitat characteristics for the purpose of management. Most of the recent U.S. catch of sharks for the market are of species grouped as large coastal sharks (*e.g.* sandbar, blacktip, dusky, spinner sharks, *etc.*). Some pelagic sharks (*e.g.* mako, thresher, porbeagle) are also highly valued by U.S. fishers targeting tunas and swordfish.

The U.S. commercial shark fishery is primarily a southern coastal (Atlantic and Gulf of Mexico) fishery extending from North Carolina to Texas. About 75% of recent U.S. Atlantic shark landings came from the southeastern region. The most sought after species in this fishery are sandbar, blacktip, dusky, and spinner sharks. Recreational fishing for sharks has also increased recently and occurs all along the U.S. Atlantic and Gulf of Mexico coasts.

In 1993 the U.S. commercial landings of Atlantic large coastal sharks were 2,715 mt dressed weight (these included sharks identified as large coastal sharks landed in the northeastern US and those either identified as large coastal sharks or as unclassified sharks landed in the southeastern US and Gulf of Mexico). Additionally, 303 mt of fins of all shark groups were landed in the northeastern US in 1993 and 69 mt of fins were landed in the southeastern and US Gulf of Mexico coastal states. Prior to implementation of the FMP, sharks were frequently "finned" and the carcasses were discarded at sea. Thus, earlier fin landings represented only a small fraction of the biomass of sharks harvested.

Bycatch of sharks is also known to occur in trawl, set-net and hook and line fisheries. For instance, in the Gulf of Mexico, shark bycatch by the US shrimp trawl fleet consists mainly of sharks too small to be

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highly valued in the commercial market. Bycatch of sharks in trawl and other fisheries outside of the Gulf of Mexico also likely occurs with regularity. Pelagic fisheries targeting swordfish and tunas can, at times have shark bycatches which exceed the targeted species catch. A listing of species of sharks reported to ICCAT as bycatch in some of the Atlantic fisheries directed at tuna and tuna-like species is listed in Table 1 (adapted from ICCAT 1995, SCRS/95/19). In the US longline and drift gillnet fisheries, logbook and scientific observer reports indicate that the shark mortality associated with this bycatch varies with the species of concern, gear characteristics an fishing season.

US Shark Fishery Management. In April 1993, the U.S. Fishery Management Plan for Sharks of the Atlantic Ocean (FMP) was put into effect. This plan aims at stabilizing and regulating the rapidly growing shark fishery. The plan includes management measures for 39 of the most frequently caught sharks and divides them into three groups: large coastal species (22 species) small coastal sharks (7 Species) and pelagic species (10 species). The objectives of the FMP are to: 1) prevent overfishing of shark resources; 2) encourage management of shark resources throughout their range; 3) establish a shark resource data collection, research, and monitoring program; and 4) increase the benefits from shark resources to the U.S. while reducing waste, consistent with the other objectives. During preparation of the FMP, it was determined that stocks of Atlantic large coastal sharks were below the level required to produce the maximum sustainable yield (MSY). Accordingly, the FMP included a recovery plan designed to rebuild the resource to the MSY level, with annual total allowable catch (TAC) increasing as the rebuilding plan progressed.

One shortcoming of the FMP, which could limit success in achieving the plan objective of preventing overfishing and promoting rebuilding of the large coastal shark resource, is in use for management purposes, multispecies aggregations (e.g. "large coastal, small coastal, and pelagic sharks") without consideration of species-specific population responses. The FMP was developed in this way out of necessity because of the lack of species-specific information and is in many ways, analogous of the early attempts by the International Whaling Commission (IWC) to limit fishing mortality on whale stocks using the Blue Whale Unit (BWU). The BWU method of management was abandoned by the IWC because it provided inadequate safeguards against overharvest of individual species stocks.

Trends in shark catch rates. An array of catch rate information for sharks was examined; a total of 31 time series of CPUE data were available for evaluation (SEFSC 1995, Table 2). The available CPUE series were of different quantity and quality, *i.e.* some were nominal, highly aggregated averages from very localized fishing operations while others were based on analysis designed to adjust for area, season, and fishing practices for set-by-set catch and effort from fisheries operating over a broad area of the ocean. With this in mind, the CPUE data were examined, in aggregate, for evidence of trend in catch rates.

The procedures used for evaluating trend in the data was to apply a generalized linear model to the available data to scale each independent time series into a single series representing an average species or species group catch rate trajectory. The model applied to the natural log-transformed data, controled for source of data, and was used to test for a significant tendency in modeled catch rates between years. Only CPUE in the form of numbers per unit effort were combined in this way since most of the available series were of this form. The annual CPUE values were weighted in the analysis by the inverse of the precision of the value (*i.e.* weight = 1/coefficient of variation). In cases where only nominal information was available, or where no measure of the uncertainty in the annual CPUE series was available, a coefficient of variation of 100% (weight of 1.0) was assumed. Figures 1 and 2 show the available CPUE observations, with estimated variance measures, when available, for the large coastal and pelagic sharks considered.

In most cases, the resulting linear fits to the log-transformed CPUE values over the species and species groups considered had significant negative slopes (indicating a negative trend in the catch rates over the time series; only one case - Atlantic sharpnose (a small coastal species) since 1986 - was the model slope positive). In every case but two (of 21) was there less than a 90% probability of a larger t-statistic due to chance in the test for significance of the model slope parameter (Table 3; *i.e.* tiger shark and Atlantic sharpnose, in the recent time period: 1986-1993).

Table 3 summarizes the results of these model fits in terms of the predicted ratios of catch rates in 1986 with respect to the beginning of the time series of observations and the predicted ratio of catch rates in the most recent year (either 1993 or 1994) with respect to 1986. These model predictions, considering the variability in the ratios (Table 3), indicate that the abundance of many of the species and species groups for which catch rate information is available, could have declined by about 40 to 75% from the early 1970's to the mid 1980's. However, there could also be factors, such as gear changes, not accounted for in these data, which could explain at least part of the modeled trends. For the large coastal sharks considered, the model predicted catch rates in 1986 are generally in the range of 15-35% of their levels in the mid- to late-1970's. In most cases (except as noted above), the available data also indicate negative trends in CPUE since 1986. US shark catches dramatically increased in 1986 and there was no quota until 1993, thus the downward trend in CPUE probably accurately reflects shark abundance decrease since 1986. However, although CPUE observations show relatively large declines from 1970's levels to the current levels, in the most recent years since 1991 the CPUE data are too few and variable to show statistically significant evidence that the stocks are either increasing or decreasing under the current US allowable catch level for Atlantic sharks. Thus, there is not strong evidence at hand to indicate that rebuilding has been initiated or that the stocks are declining further under the recent catch restrictions.

The US Atlantic fisheries landings of sharks have been regulated for only a few years and since the expected rates of change in shark abundance are low, and measures of stock abundance are uncertain, sufficient observations of relative abundance levels are not yet available to test, with high power, hypotheses about change in stock size after management measures were implemented. In fact, given reasonably precise measures of abundance (cv's in catch rate indices of 20%), doubling or halving in these indices could be statistically detected with high probability. However, under a catch limit that might allow for a 5-10% annual increase, a doubling would not be expected to occur before about 7-14 years. Given the information available, US fishery managers considered increases in a TAC for coastal sharks risk-prone with respect to promoting stock recovery. Because of, in part, the uncertainty about historical catch time series and given the relatively low potential rates of increase for many shark species, it has also been noted that any non-zero TAC could be considered risk-prone with respect to recovery of shark resources, especially for individual species stocks in the large coastal grouping. However, the degree to which the current TAC could be considered risk-prone has not been evaluated.

References Cited.

ICCAT 1995. SCRS/95/19. Report of the ad hoc Working Group on By-Catches. Appendix 10 of 1995 SCRS Report.

SEFSC 1995. 1995 Shark Evaluation Annual Report. Internal report, NMFS/SEFSC/April 1995, 23pp.

Table 1. Shark by-catch species list in the ICCAT area by major fisheries collected from ICCAT questionnaire on by-catch 1994-95

Longline Fishery:

Elasmobranchs	
Skates and rays	
Dasyatis centroura	Roughtail stingray
Dasyatis violacea	Pelagic stingray
Manta birostris	Manta ray
Raja straeleni	
Torpedo nobiliana	Torpedo ray
Coastal sharks	
Carchaias taurus	Sand tiger shark
Carcharhinus altimus	Bignose shark
Carcharhinus brevipinna	Spinner shark
Carcharhinus limbatus	Blacktip shark
Carcharhinus leucas	Bull shark
Carcharhinus obscurus	Dusky shark
Carcharhinus plumbeus	Sandbar shark
Carcharhinus signatus	Night shark
Carcharodon carcharias	White shark
Celorhinus maximus	Basking shark
Galeocerdo cuvieri	Tiger shark
Galeorhinus galeus	Tope shark
Negapnon brevirostris	Lemon shark
Rhizoprionodon terraenovae	Atlantic sharpnose shark
Sphyma lewini	Scalloped hammerhead
Sphyma mokarran	Great hammerhead
Sphyma zygaena	Smooth hammerhead
Pelagic sharks	
Alopias vulpinus	Thresher
Alopias superciliuosus	Bigeye thresher
Carcharhinus falciformis	Silky shark
Carcharhinus longimanus	Oceanic whitetip shark
Isurus oxyrinchus	Shortfin mako
Isurus paucus	Longfin mako
Lamna nasus	Porbeagle
Prionace glauca	Blue shark
Pseudocarchanas kamoharai	Crocodile shark

Gillnet Fishery

Elasmobranchs	
Skates and rays	
Dasyatis violacea	Pelagic stingray
Manta birostris	Manta ray
Myliobatis sp	Eagle ray
Torpedo nobiliana	Torpedo ray
Coastal sharks	
Carcharhinus obscurus	Dusky shark
Celorhinus maximus	Basking shark
Galeocerdo cuvieri	Tiger shark
Pelagic sharks	
Alopias vulpinus	Thresher
Alopias superciliuosus	Bigeye thresher
Isurus oxyrinchus	Shortfin mako
Isurus paucus	Longfin mako
Prionace glauca	Blue shark

Purse Seine Fishery:

Elasmobranchs	
Pelagic sharks	
Prionace glauca	Blue shark

Bait boat Fishery:

Elasmobranchs	
None Reported - limited information available	

Note: Shark classifications based on those adopted by the ICES Study Group on Elasmobranchs (distributed as addendum to SCRS/95/11) except that silky sharks (*Carcharhinus falciformis*) are classified as pelagic rather than coastal sharks in this Table. The species list is likely incomplete since detailed responses are not yet available from a full range of the Atlantic and Mediterranean tuna and tuna-like fisheries.

Table 2 The CPUE series for sharks considered in the 1995 shark evaluation report. Series are listed by species or species group with source of new information indicated. The index is the estimated mean CPUE and the CV is the estimated precision of the mean value.[1] Also indicated is if the series represents a number based or biomass based catch per unit effort. Observations with CV of 1.0 are nominal data for which no measure of precision of the estimate was available (in these cases, the CV was assumed to equal 100%). Sources of prior information listed in 1994 shark workshop report.

SPECIES	SERIES	TYPE	YEAR	INDEX	CV
large coastal	[1]Gulf Reef	Biomass	90	4455.99	0.42200
large coastal	Gulf Reef	Biomass	91	4189.23	0.15312
large coastal	Gulf Reef	Biomass	92	5504.92	0.14045
large coastal	Gulf Reef	Biomass	93	5437.52	0.15080
large coastal	Gulf Reef	Biomass	94	6600.43	0.12883
large coastal	Hudson	Numbers	85	0.22	1.00000
large coastal	Hudson	Numbers	86	0.10	1.00000
large coastal	Hudson	Numbers	87	0.12	1.00000
large coastal	Hudson	Numbers	88	0.10	1.00000
large coastal	Hudson	Numbers	89	0.05	1.00000
large coastal	Hudson	Numbers	90	0.02	1.00000
large coastal	Hudson	Numbers	91	0.02	1.00000
large coastal	Crooke LL	Numbers	75	0.11	1.00000
large coastal	Crooke LL	Numbers	76	0.08	1.00000
large coastal	Crooke LL	Numbers	77	0.13	1.00000
large coastal	Crooke LL	Numbers	78	0.25	1.00000
large coastal	Crooke LL	Numbers	79	0.12	1.00000
large coastal	Crooke LL	Numbers	80	0.16	1.00000
large coastal	Crooke LL	Numbers	81	0.13	1.00000
large coastal	Crooke LL	Numbers	82	0.13	1.00000
large coastal	Crooke LL	Numbers	83	0.14	1.00000
large coastal	Crooke LL	Numbers	84	0.12	1.00000
large coastal	Crooke LL	Numbers	85	0.14	1.00000
large coastal	Crooke LL	Numbers	86	0.11	1.00000
large coastal	Crooke LL	Numbers	87	0.08	1.00000
large coastal	Crooke LL	Numbers	88	0.08	1.00000
large coastal	Crooke LL	Numbers	89	0.09	1.00000
large coastal	Jax	Numbers	79	0.59	1.00000
large coastal	Jax	Numbers	84	0.71	1.00000
large coastal	Jax	Numbers	90	0.16	1.00000
large coastal	NC #	Numbers	88	999.10	0.42199
large coastal	NC #	Numbers	89	1637.36	0.23219
large coastal	NC #	Numbers	90	549.10	0.13766
large coastal	NC #	Numbers	91	625.52	0.12714
large coastal	NC #	Numbers	92	721.60	0.17409
large coastal	NC KG	Biomass	88	837.85	0.50421
large coastal	NC KG	Biomass	89	2398.68	0.28493
large coastal	NC KG	Biomass	90	1121.99	0.16420
large coastal	NC KG	Biomass	91	1207.04	0.15886
large coastal	NC KG	Biomass	92	1163.71	0.16692
large coastal	Port Salerno	Numbers	76	0.18	1.00000
large coastal	Port Salerno	Numbers	77	0.81	1.00000
large coastal	Port Salerno	Numbers	79	0.89	1.00000
large coastal	Port Salerno	Numbers	80	0.82	1.00000
large coastal	Port Salerno	Numbers	81	0.39	1.00000
large coastal	Port Salerno	Numbers	82	0.50	1.00000
large coastal	Port Salerno	Numbers	83	0.12	1.00000
large coastal	Port Salerno	Numbers	84	0.10	1.00000
large coastal	Port Salerno	Numbers	85	0.15	1.00000
large coastal	Port Salerno	Numbers	86	0.50	1.00000
large coastal	Port Salerno	Numbers	87	0.32	1.00000
large coastal	Port Salerno	Numbers	88	0.20	1.00000
large coastal	Port Salerno	Numbers	89	0.12	1.00000
large coastal	Port Salerno	Numbers	90	0.20	1.00000
large coastal	Tampa Bay	Numbers	85	0.16	1.00000
large coastal	Tampa Bay	Numbers	86	0.09	1.00000
large coastal	Tampa Bay	Numbers	87	0.03	1.00000
large coastal	Tampa Bay	Numbers	88	0.14	1.00000
large coastal	Tampa Bay	Numbers	89	0.06	1.00000
large coastal	Tampa Bay	Numbers	90	0.05	1.00000
large coastal	Virginia LL	Numbers	76	7.14	0.25000
large coastal	Virginia LL	Numbers	80	8.26	0.22000
large coastal	Virginia LL	Numbers	81	4.65	0.31000
large coastal	Virginia LL	Numbers	86	3.17	0.21000
large coastal	Virginia LL	Numbers	90	1.69	0.20000
large coastal	Virginia LL	Numbers	91	1.44	0.24000
large coastal	Virginia LL	Numbers	92	0.71	0.31000
large coastal	Virginia LL	Numbers	93	1.09	0.49000
large coastal	[2]charter boat	Numbers	89	394.93	0.15000
large coastal	charter boat	Numbers	90	414.51	0.14000
large coastal	charter boat	Numbers	91	399.91	0.14000
large coastal	charter boat	Numbers	92	331.37	0.15000
large coastal	charter boat	Numbers	93	334.20	0.20000
large coastal	charter boat	Numbers	94	407.41	0.17000
large coastal	[3]pelagic logbook	Numbers	86	8.84	0.09958
large coastal	pelagic logbook	Numbers	87	7.26	0.02896
large coastal	pelagic logbook	Numbers	88	7.40	0.02896
large coastal	pelagic logbook	Numbers	89	6.57	0.02827
large coastal	pelagic logbook	Numbers	90	6.64	0.02729
large coastal	pelagic logbook	Numbers	91	6.15	0.03030
large coastal	pelagic logbook	Numbers	92	5.96	0.02891
large coastal	pelagic logbook	Numbers	93	5.23	0.03009
large coastal	pelagic logbook	Numbers	94	3.57	0.03247
sandbar	Virginia LL	Numbers	76	3.92	0.25000
sandbar	Virginia LL	Numbers	80	4.45	0.22000
sandbar	Virginia LL	Numbers	81	3.49	0.32000
sandbar	Virginia LL	Numbers	86	1.50	0.28000
sandbar	Virginia LL	Numbers	90	0.79	0.28000
sandbar	Virginia LL	Numbers	91	0.82	0.32000
sandbar	Virginia LL	Numbers	92	0.34	0.42000
sandbar	Virginia LL	Numbers	93	0.75	0.60000
sandbar	[4]LPS	Numbers	86	16.20	0.44000
sandbar	LPS	Numbers	87	15.40	0.34000
sandbar	LPS	Numbers	88	29.83	0.23000
sandbar	LPS	Numbers	89	26.12	0.22000
sandbar	LPS	Numbers	90	8.15	0.52000
sandbar	LPS	Numbers	91	8.42	0.65000
sandbar	LPS	Numbers	92	14.80	0.34000
sandbar	LPS	Numbers	93	2.48	1.59000
sandbar	[5]NMFS LL	Numbers	86	447.74	0.13500
sandbar	NMFS LL	Numbers	89	214.25	0.17200
sandbar	NMFS LL	Numbers	91	107.41	0.23500
dusky	Virginia LL	Numbers	76	0.88	0.36000
dusky	Virginia LL	Numbers	80	1.24	0.46000
dusky	Virginia LL	Numbers	81	0.62	0.38000
dusky	Virginia LL	Numbers	86	0.22	0.48000
dusky	Virginia LL	Numbers	90	0.04	0.75000
dusky	Virginia LL	Numbers	91	0.08	0.57000
dusky	Virginia LL	Numbers	92	0.02	1.08000
dusky	Virginia LL	Numbers	93	0.18	0.75000
dusky	[4]LPS	Numbers	86	30.62	0.17500
dusky	LPS	Numbers	87	25.72	0.21600
dusky	LPS	Numbers	88	12.60	0.43000
dusky	LPS	Numbers	89	24.19	0.21900
dusky	LPS	Numbers	90	12.20	0.44300
dusky	LPS	Numbers	91	23.29	0.22000
dusky	LPS	Numbers	92	6.15	0.69800
dusky	LPS	Numbers	93	11.78	0.47600
hammerhead	[3]pelagic logbook	Numbers	86	2.95	0.14930
hammerhead	pelagic logbook	Numbers	87	1.80	0.06970
hammerhead	pelagic logbook	Numbers	88	1.90	0.06780
hammerhead	pelagic logbook	Numbers	89	1.63	0.06760
hammerhead	pelagic logbook	Numbers	90	1.44	0.07840
hammerhead	pelagic logbook	Numbers	91	1.19	0.08660
hammerhead	pelagic logbook	Numbers	92	1.04	0.08920
hammerhead	pelagic logbook	Numbers	93	0.87	0.09370
hammerhead	pelagic logbook	Numbers	94	0.73	0.09570
sc hammerh	[5]NMFS LL	Numbers	86	26.33	0.32300
sc hammerh	NMFS LL	Numbers	89	70.75	0.20100
sc hammerh	NMFS LL	Numbers	91	50.99	0.23500

SPECIES	SERIES	TYPE	YEAR	INDEX	CV
tiger	[3]pelagic logbook	Numbers	86	4.73	0.14790
tiger	pelagic logbook	Numbers	87	3.00	0.09540
tiger	pelagic logbook	Numbers	88	2.93	0.09630
tiger	pelagic logbook	Numbers	89	3.78	0.08180
tiger	pelagic logbook	Numbers	90	3.86	0.07560
tiger	pelagic logbook	Numbers	91	3.56	0.07760
tiger	pelagic logbook	Numbers	92	2.86	0.08430
tiger	pelagic logbook	Numbers	93	2.83	0.08270
tiger	pelagic logbook	Numbers	94	4.09	0.06420
tiger	[1]NMFS LL	Numbers	86	49.87	0.18900
tiger	NMFS LL	Numbers	89	30.28	0.25600
tiger	NMFS LL	Numbers	91	30.98	0.29800
blue	Japanese obs	Numbers	78	2.43	0.22000
blue	Japanese obs	Numbers	79	1.77	0.19000
blue	Japanese obs	Numbers	80	1.55	0.17000
blue	Japanese obs	Numbers	81	1.09	0.18000
blue	Japanese obs	Numbers	82	0.45	0.40000
blue	Japanese obs	Numbers	83	1.08	0.35000
blue	Japanese obs	Numbers	84	1.89	0.23000
blue	Japanese obs	Numbers	85	1.62	0.22000
blue	Japanese obs	Numbers	86	1.34	0.24000
blue	Japanese obs	Numbers	87	1.00	0.27000
blue	Japanese obs	Numbers	88	0.40	0.58000
blue	[3]pelagic logbook	Numbers	86	14.89	0.19200
blue	pelagic logbook	Numbers	87	10.12	0.04700
blue	pelagic logbook	Numbers	88	8.47	0.04500
blue	pelagic logbook	Numbers	89	5.91	0.04900
blue	pelagic logbook	Numbers	90	6.33	0.04800
blue	pelagic logbook	Numbers	91	6.28	0.04900
blue	pelagic logbook	Numbers	92	5.87	0.04800
blue	pelagic logbook	Numbers	93	5.61	0.05200
blue	pelagic logbook	Numbers	94	5.70	0.05000
blue	[4]LPS	Numbers	86	75.26	0.22500
blue	LPS	Numbers	87	43.89	0.37500
blue	LPS	Numbers	88	91.15	0.23800
blue	LPS	Numbers	89	48.16	0.31000
blue	LPS	Numbers	90	54.52	0.29400
blue	LPS	Numbers	91	113.86	0.19800
blue	LPS	Numbers	92	141.59	0.18500
blue	LPS	Numbers	93	129.37	0.22400
mako	Japanese obs	Numbers	78	0.60	0.19000
mako	Japanese obs	Numbers	79	0.42	0.19000
mako	Japanese obs	Numbers	80	0.36	0.18000
mako	Japanese obs	Numbers	81	0.30	0.19000
mako	Japanese obs	Numbers	82	0.16	0.44000
mako	Japanese obs	Numbers	83	0.22	0.40000
mako	Japanese obs	Numbers	84	0.30	0.25000
mako	Japanese obs	Numbers	85	0.23	0.25000
mako	Japanese obs	Numbers	86	0.27	0.27000
mako	Japanese obs	Numbers	87	0.26	0.30000
mako	Japanese obs	Numbers	88	0.17	0.65000
mako	[3]pelagic logbook	Numbers	86	1.11	0.13000
mako	pelagic logbook	Numbers	87	1.17	0.07000
mako	pelagic logbook	Numbers	88	0.95	0.07000
mako	pelagic logbook	Numbers	89	0.98	0.08000
mako	pelagic logbook	Numbers	90	0.85	0.08000
mako	pelagic logbook	Numbers	91	0.73	0.08000
mako	pelagic logbook	Numbers	92	0.86	0.08000
mako	pelagic logbook	Numbers	93	0.71	0.09000
mako	pelagic logbook	Numbers	94	0.58	0.07500
mako	[6]weighout	Biomass	85	60.84	0.11800
mako	weighout	Biomass	86	76.87	0.08800
mako	weighout	Biomass	87	55.63	0.06600
mako	weighout	Biomass	88	53.03	0.05900
mako	weighout	Biomass	89	49.57	0.06400
mako	weighout	Biomass	90	41.70	0.06400
mako	weighout	Biomass	91	38.12	0.05600
mako	weighout	Biomass	92	24.47	0.05300
mako	weighout	Biomass	93	32.73	0.04400
mako	[4]LPS	Numbers	86	40.92	0.18500
mako	LPS	Numbers	87	26.83	0.26400
mako	LPS	Numbers	88	11.31	0.50200
mako	LPS	Numbers	89	18.07	0.34800
mako	LPS	Numbers	90	20.78	0.31100
mako	LPS	Numbers	91	33.60	0.20900
mako	LPS	Numbers	92	32.09	0.22200
mako	LPS	Numbers	93	32.43	0.26700
thresher	[3]pelagic logbook	Numbers	86	4.27	0.22800
thresher	pelagic logbook	Numbers	87	4.92	0.09100
thresher	pelagic logbook	Numbers	88	5.40	0.08600
thresher	pelagic logbook	Numbers	89	4.20	0.09800
thresher	pelagic logbook	Numbers	90	3.79	0.10900
thresher	pelagic logbook	Numbers	91	2.67	0.14600
thresher	pelagic logbook	Numbers	92	2.84	0.14200
thresher	pelagic logbook	Numbers	93	2.95	0.11800
thresher	pelagic logbook	Numbers	94	2.29	0.14900
thresher	[6]weighout	Biomass	85	2.21	0.60200
thresher	weighout	Biomass	86	3.10	0.33300
thresher	weighout	Biomass	87	4.08	0.19700
thresher	weighout	Biomass	88	8.80	0.16600
thresher	weighout	Biomass	89	2.72	0.23800
thresher	weighout	Biomass	90	2.19	0.24400
thresher	weighout	Biomass	91	1.23	0.24500
thresher	weighout	Biomass	92	1.67	0.17500
thresher	weighout	Biomass	93	4.76	0.13500
sharpnose	[7]Oregon II	Numbers	72	0.40	0.34000
sharpnose	Oregon II	Numbers	73	0.41	0.26000
sharpnose	Oregon II	Numbers	74	1.69	0.19000
sharpnose	Oregon II	Numbers	75	1.28	0.18000
sharpnose	Oregon II	Numbers	76	1.21	0.15000
sharpnose	Oregon II	Numbers	77	0.63	0.21000
sharpnose	Oregon II	Numbers	78	0.69	0.21000
sharpnose	Oregon II	Numbers	79	0.80	0.21000
sharpnose	Oregon II	Numbers	80	1.33	0.22000
sharpnose	Oregon II	Numbers	81	0.85	0.20000
sharpnose	Oregon II	Numbers	82	0.89	0.20000
sharpnose	Oregon II	Numbers	83	0.73	0.28000
sharpnose	Oregon II	Numbers	84	0.66	0.23000
sharpnose	Oregon II	Numbers	85	1.03	0.39000
sharpnose	Oregon II	Numbers	86	0.30	0.59000
sharpnose	Oregon II	Numbers	87	4.65	0.90000
sharpnose	Oregon II	Numbers	88	0.27	0.50000
sharpnose	Oregon II	Numbers	89	0.41	0.53000
sharpnose	Oregon II	Numbers	90	0.11	0.67000
sharpnose	Oregon II	Numbers	91	0.19	0.47000
sharpnose	Oregon II	Numbers	92	0.19	0.50000
sharpnose	Oregon II	Numbers	93	0.28	0.50000
sharpnose	Oregon II	Numbers	94	1.08	0.42000
sharpnose	Virginia LL	Numbers	75	2.10	1.00000
sharpnose	Virginia LL	Numbers	76	2.10	1.00000
sharpnose	Virginia LL	Numbers	79	2.10	1.00000
sharpnose	Virginia LL	Numbers	80	2.50	1.00000
sharpnose	Virginia LL	Numbers	81	2.51	1.00000
sharpnose	Virginia LL	Numbers	86	1.40	1.00000
sharpnose	Virginia LL	Numbers	90	2.40	1.00000
sharpnose	Virginia LL	Numbers	91	2.00	1.00000
sharpnose	Virginia LL	Numbers	92	2.52	1.00000
sharpnose	Virginia LL	Numbers	93	2.90	1.00000

Sources (see SEFSC 1995):1 - document SBII/95/06
2 - document SBII/95/08
3 - document SBII/95/02
4 - document SBII/95/07
5 - document SBII/95/05 (sc hammerh, scalloped hammerhead)
6 - document SBII/95/09
7 - document SBII/95/04

Table 3. Predicted catch rate ratios from log-linear model ($\ln(CPUE) = \beta_0 + \beta_1 Year + \beta_{2,i} Series_i + \epsilon$) fits to the available time series of CPUE (in numbers of sharks caught per effort unit). Values shown are approximate 95% confidence bounds and the model predicted mean ratio of catch rate (CR; $Lower_{95\ CI\ Bound}$, Mean, $Upper_{95\ CI\ Bound}$) in one year with respect to another, as indicated (note that I represents the initial year and E the ending year in the available time series of observations).

Species or Group	Years of CPUE Data	All Data CR_{86}/CR_I	All Data CR_E/CR_{86}	86-94 Data CR_E/CR_{86}
Large Coastal Sharks	1975-1994	***.28,.35,.43	***.36,.46, .59	***.39,.48, .60
Sandbar	1975-1993	***.12,.20,.32	***.26,.36, .49	***.10,.22, .48
Dusky	1975-1993	***.07,.15,.29	***.15,.25, .41	*.13,.34, .99
Hammerheads	1986-1994	N/A	***.23,.36, .56	***.23,.36, .56
Tiger	1986-1994	N/A	NS.63,.91,1.31	NS.63,.91,1.31
Pelagic Sharks				
Mako	1978-1994	***.45,.57,.73	***.45,.57, .73	***.46,.54, .63
Blue	1978-1994	**.44,.63,.91	**.44,.63, .91	***.45,.61, .82
Thresher	1986-1994	N/A	***.32,.43, .58	***.32,.43, .58
Small Coastal Sharks				
Atlantic Sharpnose	1973-1994	**.38,.58,.90	**.55,.72,.94	NS.23,1.1,5.01

Model Parameters: β_0, intercept; β_1, slope; $\beta_{2,i}$, scale effect adjustment for each of the I CPUE Series in the fit; ϵ, assumed normally distributed random error.

*** Model slope (β_1) parameter estimate negative and significantly different from 0 at α=0.01.
** Model slope (β_1) parameter estimate negative and significantly different from 0 at α=0.05.
* Model slope (β_1) parameter estimate negative and significantly different from 0 at α=0.1.
NS Model slope (β_1) parameter estimate **not** significantly different from 0 at α=0.25.

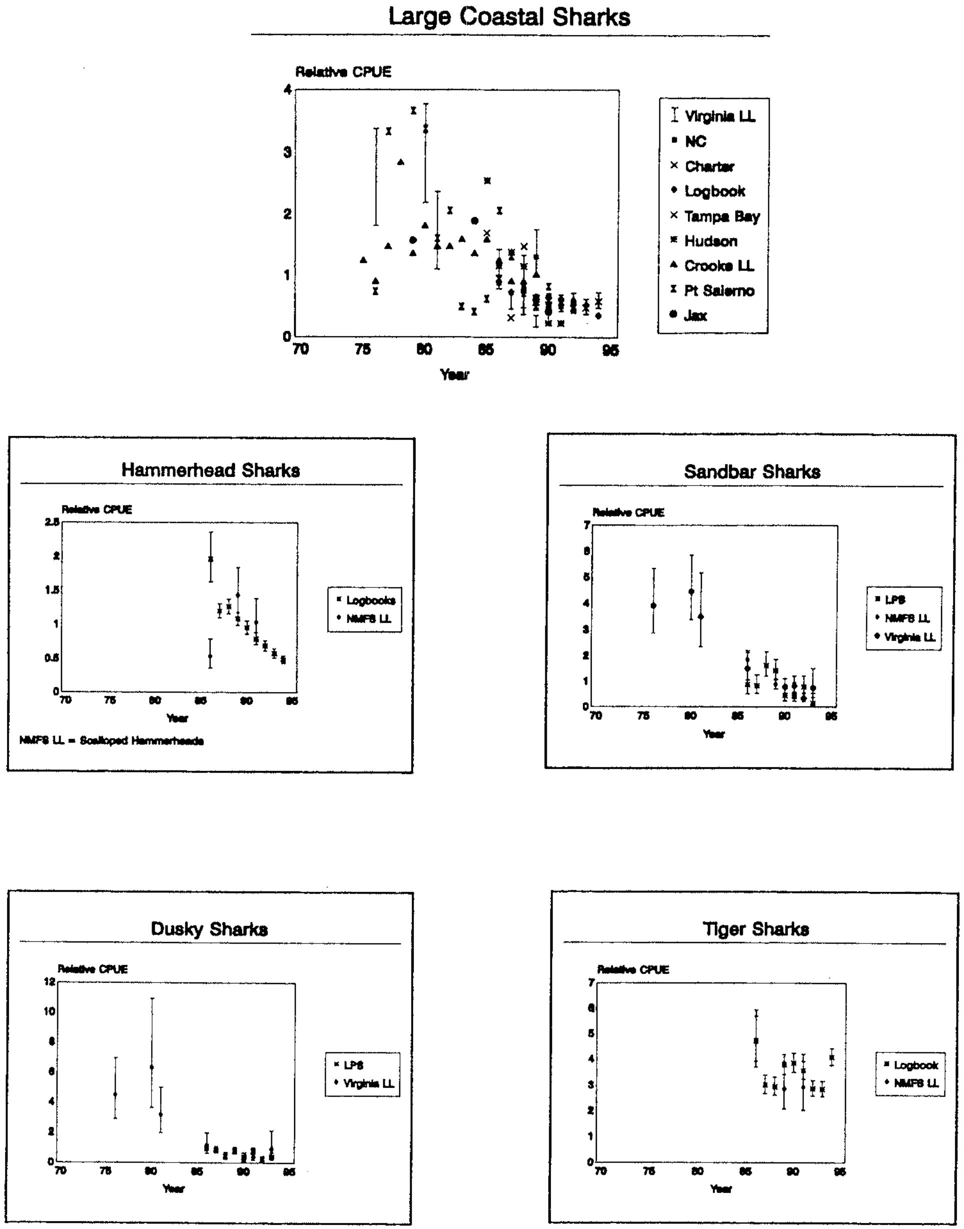

Figure 1. CPUE observations, adjusted for difference in scale, for species in the large coastal shark grouping. Error bars (approximate 80% confidence ranges) are shown for those CPUE series for which variability in CPUE was estimated. Sources of data are indicated (also see Table 2).

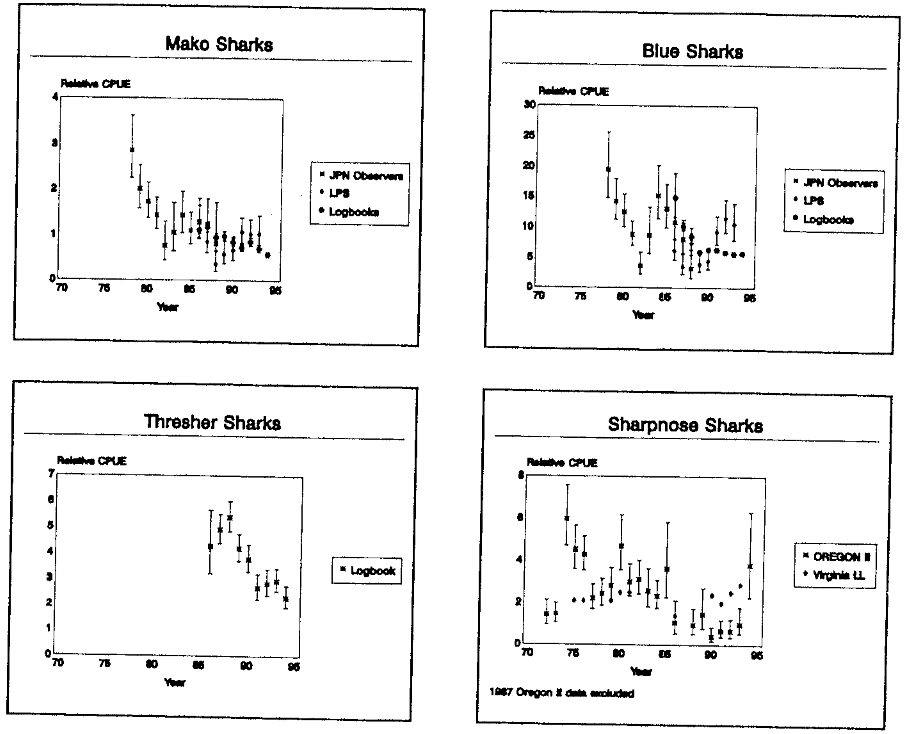

Figure 2. CPUE observations, adjusted for difference in scale, for species in the pelagic and small coastal shark groupings. Error bars (approximate 80% confidence ranges) are shown for those CPUE series for which variability in CPUE was estimated. Sources of data are indicated (also see Table 2).