# Overview of the U.S. East Coast Bottom Longline Shark Fishery, 1994–2003

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## Introduction

Shark exploitation in the U.S. Atlantic and Gulf of Mexico, sporadic throughout much of the twentieth century, has greatly increased over the last three decades. Shark stock assessments (NMFS[1, 2, 3]) have varied in their estimates of stock size, fishing mortality, and maximum sustainable yield (MSY). However, each assessment reached the same general conclusion: shark mortality from a combination of fishing efforts has exceeded the reproductive capacity of certain species to the detriment of overall stock size. These conclusions are corroborated by substantial declines in shark catch-per-unit-effort (CPUE) in commercial fishery samples, fishery-independent longline fishing experiments (NMFS[1, 2, 3]), and recreational fishing tournament data (Hueter[4]).

Sharks are argued to be highly susceptible to overfishing because of their *K*-selected life history characteristics (Heppell et al., 1999; Cortés, 1999, 2002). Many of the species important to commercial and recreational fisheries grow slowly, mature at larger sizes, and have limited reproductive capacity. Given the biological constraints on shark production, the intensive fishing of shark resources is believed to be unsustainable.

Various management agencies examined strategies for sustainable utilization of the resource in the early 1990's. Initially, Texas, North Carolina, Virginia, and Florida enacted regulations for shark fisheries within their state waters (NMFS[5]). A Federal Shark Fishery Management Plan (FMP) was implemented in 1993 by the National Marine Fisheries Service (NMFS) for 39 species in the U.S. Atlantic and Gulf of Mexico waters (NMFS[5]). Implementation of this plan, in development for nearly a decade, was hampered by a lack of adequate data.

Initial regulations in the FMP included seasonal commercial quotas, recreational bag limits, and prohibitions of "finning" and recreational catch sales which were all designed to enhance stock rebuilding. The FMP proposed a data collection plan, including utilization of at-sea observers to verify logbook information and gather pertinent data on shark discards and interactions with protected and endangered resources. Subsequent FMP modifications were implemented reflecting results of updated assessments and newly generated biological data (NMFS[6,7,8]).

[1]NMFS. 1994. Report of the shark evaluation workshop. March 1994. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Southeast Fish. Sci. Cent., Miami, Fla., 46 p.

[2]NMFS. 1998 report of the shark evaluation workshop. June 1998. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Southeast Fish. Sci. Cent., Miami, Fla., 109 p.

[3]NMFS. 2006. SEDAR 11 stock assessment report: Large coastal shark complex, blacktip and sandbar shark. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Silver Spring, MD 20910, 387 p.

[4]Hueter, R. E. 1991. Survey of the Florida recreational shark fishery utilizing shark tournament and selected longline data. Final report, Fla. Dep. Nat. Resour., Grant Agreement 6627, 74 p.

[5]NMFS. 1993. Fishery management plan for sharks of the Atlantic Ocean. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Highly Migratory Species Div., 1315 East-West Highway, Silver Spring, Md., 273 p.

[6, 7, 8]*See next page.*

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*ABSTRACT—The U.S. Atlantic coast and Gulf of Mexico commercial shark fisheries have greatly expanded over the last 30 years, yet fishery managers still lack much of the key information required to accurately assess many shark stocks. Fishery observer programs are one tool that can be utilized to acquire this information. The Commercial Shark Fishery Observer Program monitors the U.S. Atlantic coast and Gulf of Mexico commercial bottom longline (BLL) large coastal shark fishery. Data gathered by observers were summarized for the 10-year period, 1994 to 2003. A total of 1,165 BLL sets were observed aboard 96 vessels, with observers spending a total of 1,509 days at sea. Observers recorded data regarding the fishing gear and methods used, species composition, disposition of the catch, mortality rates, catch per unit of effort (sharks per 10,000 hook hours), and bycatch of this fishery. Fishing practices, species composition, and bycatch varied between regions, while catch rates, mortality rates, and catch disposition varied greatly between species.*

An onboard observer program is an effective means of rapidly gathering detailed information on: 1) species and size composition of the catch and landings, 2) catch-per-unit-effort (CPUE) (number of sharks caught per 10,000 hook hours), and 3) disposition (released alive, discarded dead, used for bait, etc.) of nonlanded catch. An observer program garners details otherwise not captured by mandatory vessel logbook data, and it simultaneously "ground truths" this information.

In 1994, the Commercial Shark Fishery Observer Program (CSFOP) initiated monitoring of bottom longline (BLL) vessels targeting sharks in the U.S. Atlantic and Gulf of Mexico; the principle U.S. directed commercial fishery for large coastal sharks. The CSFOP has generated one of the most extensive and detailed biological databases in existence for sharks of the western North Atlantic.

The FMP allocated northwest Atlantic shark species into five groupings for potential management purposes. The "large coastal" (LC) shark complex represents an assemblage of 11 species of carcharhinid, sphyrnid, and orectolobid sharks (Table 1), which have historically been the target of the BLL fishery and have been managed as a unit. The "small coastal" (SC) shark complex, another managed complex of three carcharhinids and one sphyrnid species (Table 1), are less frequently targeted by BLL fishermen but are commonly captured as bycatch within the LC-targeted fishery and inshore gillnet, trawl, and hook fisheries. "Prohibited sharks" (PH) are a diverse group of 19 sharks (odontaspid, carcharhinid, and lamnoid sharks) deemed especially vulnerable and banned from landing (Table 1). "Pelagic sharks" (PE) (five lamnoid and carcharhinid sharks) and "dogfish" ((DF) excluded from management through the FMP) (Table 1) are infrequently taken in the BLL fishery (NMFS[9]). This paper characterizes the BLL shark fishery as monitored by the CSFOP in Atlantic waters of the United States from 1994 through 2003.

## Materials and Methods

CSFOP observers were trained in the following areas: marine safety, sea turtle handling and resuscitation techniques, fishery and biological data collection, biological sampling, and shark and bycatch species identification. Observers were required to record catch and effort information from each longline set targeting coastal sharks during each sampled trip (a "trip" is defined as the time period between a fishing vessel's departure from port and its return to port with all deployed fishing gear fully retrieved). Data and biological samples were returned to the Florida Museum of Natural History (FLMNH) at the University of Florida for processing and further studies. Data were archived and analyzed using a customized Microsoft Access database.[10] Relevant specimens and biological samples were archived at FLMNH for further study.

Fishing vessel participation in the CSFOP was voluntary from 1994 to 2001. CSFOP personnel (Principal Investigators or observers) personally solicited individual longline vessel owners and/or captains for permission to monitor their fishing trips. Due to the voluntary nature of the program at this time, monitoring was nonrandom by nature and certain vessels were observed repetitively, particularly during the latter part of this period. Percent observer coverage was calculated by dividing the total number of LC sharks landed on observed trips by the total number of commercially landed LC sharks during the same time period according to National Marine Fisheries Service (NMFS) records (Cortes and Neer[11]). Sampled trips were responsible for approximately two percent of total recorded commercial landings.

As NMFS regulatory measures were enacted and implemented, it became increasingly difficult to identify vessels willing to voluntarily accept observers (Burgess[12]). Placement of observers was made mandatory by NMFS in 2002. Vessels were selected by NMFS from a pool developed after consulting data generated by mandatory NMFS landing logbooks (Rilling[13]). Vessels identified as actively landing sharks were matched with vessels holding valid Federal shark permits for the upcoming fishing season. Those vessels that documented sharks as more than 25% of their total landings from the same fishing season of the previous year were deemed eligible for selection. A pseudo-random number generator was used to select vessels within three subregions (Mid-Atlantic Bight, southeastern U.S. Atlantic, and Gulf of Mexico). The number of vessels selected for monitoring in a given season was based on the number of fishing days projected by NMFS for the fishery in that season.

Owners/captains of selected vessels were required to contact the observer coordinator at least 48 hr prior to departing port on any trip where LC sharks were targeted or caught incidentally using BLL fishing gear. Individual observers were then deployed to vessels by the observer coordinator. To carry an observer, the vessels were

[6]NMFS. 1993. Secretarial shark fishery management plan for the Atlantic Ocean. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Highly Migratory Species Div., 1315 East-West Highway, Silver Spring, Md., var. pagin.

[7]NMFS. 2003. Final Amendment 1 to the fishery management plan for Atlantic tunas, swordfish and sharks. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Highly Migratory Species Div., 1315 East-West Highway, Silver Spring, Md., var. pagin.

[8]NMFS. 2006. Final consolidated Atlantic highly migratory species Fishery Management Plan. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Highly Migratory Species Div., 1315 East-West Highway, Silver Spring, Md., var. pagin.

[9]NMFS. 2006. Final Consolidated Atlantic Highly Migratory Species Fishery Management Plan. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, Office of Sustainable Fish., Highly Migratory Species Manage. Div., Silver Spring, Md., 1,600 p.

[10]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[11]Cortés, E., and J. A. Neer. 2002. Updated catches of sharks. U.S. Dep. Commer., Natl. Mar. Fish. Serv., NOAA, SEFSC Panama City Lab. Doc. SB/02/15 of the 2002 Shark Evaluation Workshop. Panama City, Fla., June 24–28, 2002, 62 p.

[12]Burgess, George. Florida Program for Shark Research, Florida Museum of Natural History, Gainesville, FL 32611. Personal commun.

[13]Rilling, Chris. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Sustainable Fisheries Division, Highly Migratory Species, Silver Spring, Md. 20910. Personal commun.

Table 1.—Number of each shark species, categorized into their respective management units, observed caught in each of the three regions ((EGM = Eastern Gulf of Mexico, MAB = Mid Atlantic Bight, and SE US = Southeastern U.S. Atlantic), and the percentage of the total catch and management unit catch each species represented. "T" designates trace amounts (<0.01%).

| | No. caught | | | | | |
|---|---|---|---|---|---|---|
| Region and species | EGM | MAB | SE US | Total | Percent of total | Percent mgt category |
| Large coastal | | | | | | |
| Sandbar, *Carcharhinus plumbeus* | 4,277 | 11,463 | 4,048 | 19,788 | 35.9 | 56.7 |
| Tiger, *Galeocerdo cuvier* | 945 | 1,789 | 2,873 | 5,607 | 10.2 | 16.1 |
| Blacktip, *Carcharhinus limbatus* | 3,087 | 355 | 1,586 | 5,028 | 9.1 | 14.4 |
| Nurse, *Ginglymostoma cirratum* | 846 | 7 | 302 | 1,155 | 2.1 | 3.3 |
| Scalloped hammerhead, *Sphyrna lewini* | 411 | 199 | 222 | 832 | 1.5 | 2.4 |
| Bull, *Carcharhinus leucas* | 564 | 45 | 70 | 679 | 1.2 | 1.9 |
| Spinner, *Carcharhinus brevipinna* | 432 | 34 | 102 | 568 | 1.0 | 1.6 |
| Silky, *Carcharhinus falciformis* | 282 | 8 | 199 | 489 | 0.9 | 1.4 |
| Great hammerhead, *Sphyrna mokarran* | 253 | 34 | 106 | 393 | 0.7 | 1.1 |
| Lemon, *Negaprion brevirostris* | 334 | 11 | 29 | 374 | 0.7 | 1.1 |
| Smooth hammerhead, *Sphyrna zygaena* | 0 | 0 | 6 | 6 | T | T |
| Subtotal | 11,431 | 13,945 | 9,543 | 34,919 | 63.4 | 100.0 |
| Small coastal | | | | | | |
| Atlantic sharpnose, *Rhizoprionodon terraenovae* | 2,123 | 2,236 | 10,501 | 14,860 | 27.0 | 85.9 |
| Blacknose, *Carcharhinus acronotus* | 1,332 | 38 | 997 | 2,367 | 4.3 | 13.7 |
| Bonnethead, *Sphyrna tiburo* | 15 | 0 | 52 | 67 | 0.1 | 0.4 |
| Finetooth, *Carcharhinus isodon* | 2 | 1 | 6 | 9 | T | 0.1 |
| Subtotal | 3,472 | 2,275 | 11,556 | 17,303 | 31.4 | 100.0 |
| Prohibited | | | | | | |
| Dusky, *Carcharhinus obscurus* | 41 | 1,440 | 170 | 1,651 | 3.0 | 76.6 |
| Sandtiger, *Carcharias taurus* | 0 | 342 | 26 | 368 | 0.7 | 17.1 |
| Night, *Carcharhinus signatus* | 41 | 0 | 8 | 49 | 0.1 | 2.3 |
| Bignose, *Carcharhinus altimus* | 13 | 11 | 5 | 29 | 0.1 | 1.3 |
| White, *Carcharodon carcharias* | 2 | 1 | 13 | 16 | T | 0.7 |
| Caribbean reef, *Carcharhinus perezii* | 10 | 3 | 2 | 15 | T | 0.7 |
| Sixgill, *Hexanchus griseus* | 7 | 0 | 1 | 8 | T | 0.4 |
| Bigeye thresher, *Alopias superciliosus* | 2 | 0 | 4 | 6 | T | 0.3 |
| Sevengill, *Heptranchias perlo* | 6 | 0 | 0 | 6 | T | 0.3 |
| Bigeye sixgill, *Hexanchus nakamurai* | 3 | 0 | 0 | 3 | T | 0.1 |
| Galapagos, *Carcharhinus galapagensis* | 0 | 0 | 2 | 2 | T | 0.1 |
| Angel, *Squantina dumeriil* | 0 | 1 | 0 | 1 | T | 0.0 |
| Subtotal | 125 | 1,798 | 231 | 2,154 | 3.9 | 100.0 |
| Dogfish | | | | | | |
| Smooth dogfish, *Mustelus canis* | 195 | 375 | 73 | 643 | 1.2 | 93.7 |
| Florida smoothhound, *Mustelus norrisi* | 29 | 0 | 2 | 31 | 0.1 | 4.5 |
| Roughskin spiny dogfish, *Cirrhigaleus asper* | 6 | 0 | 0 | 6 | T | 0.9 |
| Spiny dogfish, *Squalus acanthias* | 0 | 1 | 5 | 6 | T | 0.9 |
| Subtotal | 230 | 376 | 80 | 686 | 1.2 | 100.0 |
| Pelagic | | | | | | |
| Shortfin mako, *Isurus oxyrinchus* | 1 | 6 | 2 | 9 | T | 50.0 |
| Common thresher, *Alopias vulpinus* | 0 | 1 | 8 | 9 | T | 50.0 |
| Blue, *Prionace glauca* | 0 | 0 | 0 | 0 | T | 0.0 |
| Subtotal | 1 | 7 | 10 | 18 | T | 100.0 |
| Grand total | 15,259 | 18,401 | 21,420 | 55,080 | 100.0 | |

required to have a Commercial Fishing Vessel Safety Decal (CFVSD), issued by the U.S. Coast Guard, and be capable of providing room and board for the observer that was equivalent to that given to the crew. In addition to these NMFS mandated requirements, the CSFOP did not deploy observers aboard vessels smaller than 30 ft in length (because of space and safety considerations), vessels operated by a captain or crew known to abuse alcohol or drugs at sea, or other safety issues reported by observers and documented by the CSFOP.

When deployed on BLL vessels, observers recorded specific details regarding the fishing gear utilized and associated catch during each set for the duration of the trip. The term "set" refers to an individual BLL set, which includes the deployment and retrieval of fishing gear and associated catch. Recorded were the size and number of hooks, time and latitude and longitude coordinates when the first and last hooks entered and were removed from the water, bait utilized, and length of the deployed mainline. For analytical purposes, we divided the sampled area into three geographical subregions for our analysis: the Mid Atlantic Bight (MAB), the Atlantic coast of the southeastern U.S. (SE US), and the eastern Gulf of Mexico (EGM). The boundaries of these regions and the locations of observed BLL sets are identified in Figure 1.

Vessel captains calculated and provided the length of the mainline from their Global Positioning System (GPS) readings. GPS or Loran geographic positions were recorded. Loran coordinates were converted to latitude/longitude using the Coast Guard POSAID2 version 2.1a computer program. Water depth at the location of each set was measured with sonar, and bottom water temperature was recorded by a Stowaway XTI temperature recorder[14] fastened to one end of the longline. Air and sea surface water temperatures were recorded using a glass-stem thermometer.

Soak time was defined as the temporal interval between entry of the first hook and removal of the first hook from the water. CPUE for each set was calculated as the number of sharks caught per 10,000 hook hours (CPUE = catch × 10,000/(hooks x soak time)). CPUE calculations do not include or adjust for hook type and size, type of bait used, distance between hooks, gangion length and material (monofilament, steel), or the specific sharks targeted (SC or LC, sandbar or blacktip).

All catch was identified to the lowest possible taxon, and disposition of it was recorded. Disposition categories included: landed, used for bait, released alive, discarded dead, tagged (with a NMFS M-style dart tag), released, archived as museum specimens, or another category. To determine at-vessel mortality rates observers recorded the condition (alive or dead) of hooked animals when brought on board. Animals were deemed alive if there was any response to tactile stimuli (there were no varying degrees of alive) and dead if there was no response. Straight-line total (TL) and fork (FL) length measurements, to the nearest cm, were recorded for all sharks brought on board. For bycatch, TL was measured for fish, disc width (DW) for batoids, carapace length and width for sea turtles, and TL was estimated for cetaceans. The sex of elasmobranchs was noted and clasper lengths were measured to the nearest mm.

[14]Onset Computer Corporation, 470 MacArthur Blvd., Bourne, MA 02532.

## Results

### Observer Coverage

The geographic region sampled ranged from New Jersey to Louisiana. A total of 229 shark sets in the MAB, 507 sets in the SE US, and 403 sets in the EGM were observed during the study period (Fig. 1). Within each subregion there were core areas of highly observed fishing effort, namely waters off Cape Hatteras, NC (MAB), the waters off Daytona, Fla. (SE US), and waters north of the Florida Keys (EGM). The concentration of samples in these areas was, to some degree, due to increased utilization of these areas by participating vessels during the voluntary time period (1994–2001).

During 1994–2003, 434 trips were sampled including 1,165 BLL sets and 1,509 sea days aboard 96 vessels (Table 2). During the years that participation was voluntary, trips of 1–7 vessels per season were sampled. The percentage of landings sampled was extremely limited at times, due to insufficient funding. The least number of vessels observed (one in the winter and two in the summer) occurred during 2000, when funding restrictions limited observation to only the SE US region (Table 2). The greatest number of vessels observed (six in the winter and seven in the summer) occurred during 1995, the second year of the voluntary program (Table 2). There was a significant difference in the seasonal numbers of vessels observed in the voluntary 1994–2001 and mandatory 2002–03 periods (Table 2). The shift to mandatory observers resulted in increased seasonal totals of 9 (winter 2002), 10 (summer 2003), and 15 vessels (winter 2003) (Table 2).

Sampled trips caught 0.6–3.8% of large coastal shark commercial landings during 1994–2003 (Table 3). Sampled trips included only 0.6% of the landed catch during 2000 but 3.8% in 2003 (Table 3). On average, sampled trips observed 1.9% of the landed catch during the study period (Table 3).

Observers spent between 22 and 166 days at sea per fishing season during 1994–2003, most of it during the winter seasons ($n$=850 all years combined), compared to the summer seasons (659 all years combined) (Table 2). The highest and lowest numbers of days at sea occurred during the 2003 (166 sea days) and the 2000 (22 sea days) winter fishing seasons, respectively (Table 2). Days at

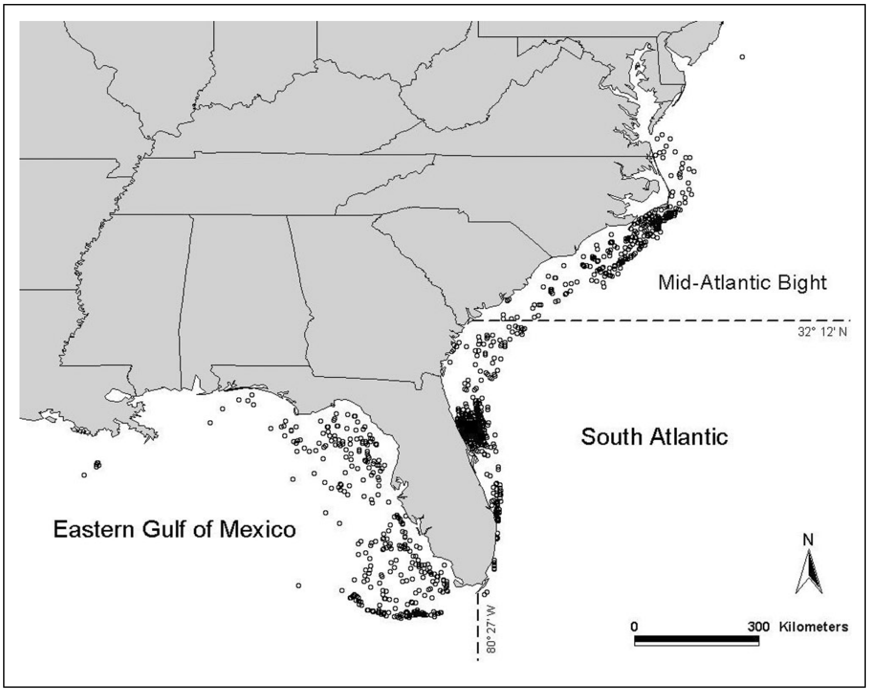


Figure 1.—The southeastern coast of the United States and the Gulf of Mexico with points representing individual BLL sets observed in each of the three regions (Mid Atlantic Bight, Southeastern U.S. Atlantic, and Gulf of Mexico). The solid line indicates the 100 m bathymetric contour.

Table 2.—Total number of vessels, longline sets, trips, and sea days observed during each year of the Commercial Shark Fishery Observer Program (CSFOP).

| | | | Winter | | | Summer | | |
|---|---|---|---|---|---|---|---|---|
| Year | Vessels (winter) | Vessels (summer) | No. of trips | No. of sets | No. of sea days | No. of trips | No. of sets | No. of sea days |
| 1994 | 4 | 5 | 15 | 52 | 69 | 16 | 49 | 70 |
| 1995 | 6 | 7 | 40 | 87 | 110 | 24 | 88 | 103 |
| 1996 | 7 | 5 | 28 | 79 | 101 | 12 | 44 | 52 |
| 1997 | 4 | 5 | 24 | 66 | 73 | 12 | 21 | 33 |
| 1998 | 6 | 4 | 37 | 85 | 104 | 10 | 26 | 32 |
| 1999 | 4 | 4 | 18 | 51 | 51 | 21 | 56 | 71 |
| 2000 | 1 | 2 | 7 | 21 | 22 | 6 | 39 | 24 |
| 2001 | 4 | 3 | 31 | 63 | 95 | 11 | 21 | 30 |
| 2002 | 9 | 15 | 15 | 37 | 59 | 42 | 101 | 147 |
| 2003 | 15 | 10 | 42 | 102 | 166 | 23 | 77 | 97 |
| Total | 60 | 60 | 257 | 643 | 850 | 177 | 522 | 659 |

sea per season were similar between voluntary and mandatory coverage periods (Table 2), and variations in days at sea were due to funding, vessel availability, meteorological and oceanographic sea conditions, and the seasonal abundance of the target species.

The number of trips observed varied greatly depending on the species targeted, shark abundance, and the length of the legal open season. The number of trips per season was similar during the voluntary (6–40) and mandatory years (15–42) of the program (Table 2). The lowest number of trips (7 in the summer and 6 in the winter) were observed during 2000 (coinciding with a reduction in funding) and the largest number of trips were observed in 2002 summer (*n*=42) and 2003 winter seasons (*n*=42) (Table 2).

The total number of BLL sets observed per season ranged from 21–88 during the voluntary period and 37–102 during the mandatory period (Table 2). The highest number of sets was observed during the mandatory 2003 winter season (*n*=102), while the lowest number of sets occurred during the voluntary 1997 and 2001 summer, and 2000 winter seasons (*n*=21) (Table 2).

## Fishing Practices and Gear

Sixteen sizes of hooks were sampled during the duration of the study. Both circle and "J" style hooks were used but are not differentiated here because this information was not routinely collected during the duration of the study. More than one size of hook was frequently employed in individual sets; however, size 14/0 hooks were most commonly utilized in 6 out of 10 years (Table 4). In the other four years they were the second most frequently used after size 18/0 hooks (Table 4). Size 14/0 hooks were used in 86.1–94.2% of sets made during 1994–97 (Table 4). By contrast, during the 1999–2003 fishing seasons, 14/0 hooks were only used in 25.0–45.5% of sets, and were replaced by larger 18/0 hooks (Table 4). Size 3/0 and 3.5/0 hooks were also commonly used, most often for sets targeting SC sharks (Table 4).

There were regional preferences in the sizes of hooks used. In the MAB, 14/0 hooks and 3/0 hooks were used in 96.2% and 36.5% of the sets, respectively (Table 5). Fishermen in the EGM used 14/0 hooks on the majority (56.3%) of sets, while in the SE US fishermen used 18/0 hooks and 14/0 hooks in 37.0% and 26.6% of sets, respectively (Table 5). Data from the last year of the study provided the greatest range in size of hooks used in the fishery (Table 4).

The mean number of hooks used during individual sets annually ranged from 350 to 844, with a minimum of 53 and a maximum of 2,385 hooks recorded across all sets (Table 4). A greater number of hooks were used per set during 1994–97 than between 1998 and 2003 (Table 4). On average, twice as many hooks were used in sets in the EGM (mean = 843) compared to the MAB (mean = 412) (Table 5). The low number of hooks used in the year 2000 (mean = 350) is likely an artifact of reduced observer coverage (Table 4).

The majority of fishermen used monofilament mainline instead of steel cable. Mainline length deployed per set ranged from 1 to 24 nmi (1.9–44.5 km), but the most commonly used length was between 5 and 8 nmi (9.3–14.8 km) (*n*=447) (Fig. 2). Sets greater than 17 nmi (31.5 km) in length were rare (*n*=14) (Fig. 2). Analysis of yearly trends in the length of gear indicate that 8–12 nmi (14.8–22.2 km) of gear was commonly used during the early years

Table 3.—Total number of large coastal sharks observed caught in each of the three regions by the CSFOP, total number of commercial landings (Cortes and Neer[1]), and the total percent of large coastal shark catch observed by the CSFOP between 1994 and 2003.

| | No. of sharks | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Area/Item | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
| Southeastern U.S. Atlantic (CSFOP observed) | 149 | 1,022 | 677 | 335 | 386 | 843 | 658 | 477 | 896 | 987 |
| Eastern Gulf of Mexico (CSFOP observed) | 698 | 810 | 503 | 403 | 806 | 552 | 0 | 825 | 1,516 | 2,805 |
| Mid Atlantic Bight (CSFOP observed) | 1,275 | 1,893 | 1,507 | 1,063 | 2,634 | 979 | 0 | 1,815 | 517 | 885 |
| Total (CSFOP observed) | 2,122 | 3,725 | 2,687 | 1,801 | 3,826 | 2,374 | 658 | 3,117 | 2,929 | 4,677 |
| NMFS total | 228,000 | 222,400 | 160,600 | 130,600 | 174,900 | 111,500 | 111,200 | 95,700 | 123,400 | 122,100 |
| Percent observed CSFOP | 0.9% | 1.7% | 1.7% | 1.4% | 2.2% | 2.1% | 0.6% | 3.3% | 2.4% | 3.8% |
| Overall average observer coverage = 1.9% | | | | | | | | | | |

[1]Cortés, E., and J. Neer. 2005. Updated catches of sharks. NOAA Fisheries, SEFSC, Panama City Lab. Doc. LC05/06-DW-16 of the 2005 Shark Evaluation Workshop. Panama City, Fla., Oct. 31–Nov. 4, 2005, 112 p.

**Table 4.—Percentage of hook sizes observed used per year and the average, minimum, and maximum number of hooks observed used on individual sets during each year. Multiple hooks were sometimes used on an individual set; therefore, percentages can be over 100.**

| | Percentage of hooks observed | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Hook size | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
| 3/0 | 36.6 | 16.5 | 18.8 | 22.4 | 1.0 | 0.0 | 0.0 | 0.0 | 12.5 | 7.9 |
| 3.5/0 | 15.8 | 23.7 | 2.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.4 | 5.6 |
| 4/0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5/0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.6 |
| 6/0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 |
| 8/0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9/0 | 21.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10/0 | 0.0 | 4.1 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 1.5 | 6.2 |
| 12/0 | 0.0 | 1.0 | 0.0 | 37.9 | 0.0 | 0.0 | 0.0 | 0.0 | 8.1 | 11.8 |
| 13/0 | 0.0 | 0.0 | 0.0 | 3.4 | 15.0 | 2.0 | 15.6 | 0.0 | 0.0 | 7.9 |
| 14/0 | 86.1 | 93.8 | 94.2 | 89.7 | 0.0 | 45.5 | 31.3 | 42.9 | 25.0 | 33.1 |
| 15/0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 10.1 | 0.0 | 7.8 | 0.0 | 0.0 |
| 16/0 | 0.0 | 0.0 | 0.0 | 3.4 | 25.0 | 1.0 | 0.0 | 0.0 | 11.0 | 21.3 |
| 17/0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 0.0 |
| 18/0 | 0.0 | 0.0 | 0.0 | 5.2 | 33.0 | 41.4 | 57.8 | 50.6 | 26.5 | 6.2 |
| 20/0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.8 | 14.6 |
| Average no. of hooks | 844 | 825 | 755 | 653 | 577 | 508 | 350 | 594 | 484 | 587 |
| Minimum no. of hooks | 53 | 284 | 160 | 66 | 69 | 102 | 90 | 75 | 69 | 54 |
| Maximum no. of hooks | 1,181 | 1,218 | 1,054 | 1,142 | 1,154 | 1,153 | 538 | 1,080 | 1,250 | 2,385 |

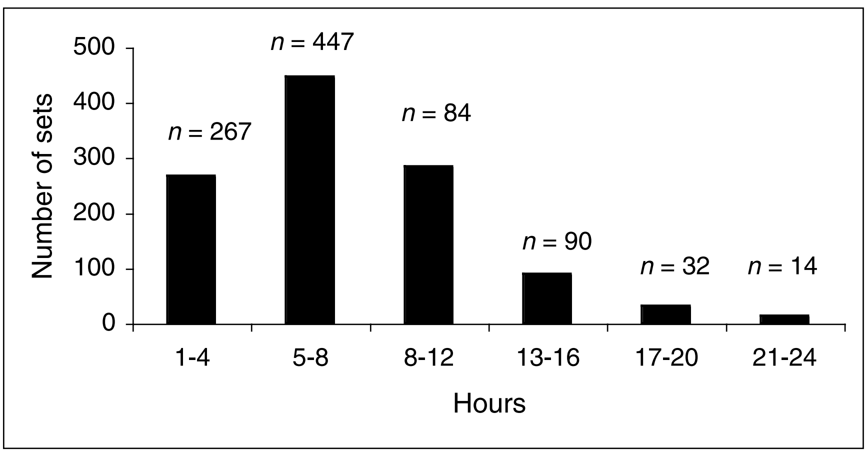


Figure 2.—Numbers of individual BLL sets observed by soak time.

**Table 5.—Percentage of hook sizes observed used in each of the three regions (EGM = Eastern Gulf of Mexico, MAB = Mid Atlantic Bight, and SE US = Southeastern U.S. Atlantic). Multiple sizes of hooks were used on some sets, therefore percentages do not always add up to 100.**

| | Percentage of hooks observed | | |
|---|---|---|---|
| Hook size | EGM | MAB | SE US |
| 3/0 | 5.0 | 36.5 | 3.8 |
| 3.5/0 | 0.0 | 11.8 | 9.0 |
| 4/0 | 0.0 | 0.0 | 0.0 |
| 5/0 | 0.0 | 0.0 | 0.3 |
| 6/0 | 1.0 | 0.0 | 0.0 |
| 8/0 | 1.3 | 0.0 | 0.0 |
| 9/0 | 0.0 | 12.3 | 0.0 |
| 10/0 | 0.0 | 0.0 | 5.2 |
| 12/0 | 8.0 | 2.4 | 4.9 |
| 13/0 | 2.0 | 1.9 | 11.2 |
| 14/0 | 56.3 | 96.2 | 26.6 |
| 15/0 | 6.5 | 0.0 | 0.0 |
| 16/0 | 13.0 | 0.9 | 4.7 |
| 17/0 | 0.0 | 0.0 | 0.0 |
| 18/0 | 16.3 | 0.5 | 37.0 |
| 20/0 | 0.0 | 0.0 | 10.4 |
| Average no. of hooks | 843 | 412 | 680 |
| Minimum no. of hooks | 53 | 54 | 75 |
| Maximum no. of hooks | 2,385 | 1,151 | 1,250 |

(1994–96), while 1–4 nmi (1.9–7.4 km) of gear was more commonly used in the later years (1999–2003) (Fig. 3). This reduction in length is most likely due to the implementation of trip limits in 1997 (NMFS[15]). Regional analysis shows that fishermen in both the EGM and SE US deployed 5–8 nmi (9.3–14.8 km) sets most frequently, followed by 9–12 nmi (16.7–22.2 km) in the EGM, and 1–4 nmi (1.9–7.4 km) in the SE US. In the MAB, sets of 9–12 nmi (14.8–22.2 km) were deployed most frequently, followed by 13–16 nmi (24.1–29.6 km) sets (Fig. 4).

Close to half of all sets (46.9%) had a soak time of 13–16 h in length. Soak times less than 13 h in length accounted for 38.1% of all sets and only 15.0% of all sets had a soak time greater than 16 h (Fig. 5). There were no regional differences in soak time.

The vast majority of all fishing effort (hook hours) occurred in water <50 m (75%), with peak effort (29.0%) in water 20–30 m deep (Fig. 6). Fishermen in the EGM and SE US set hooks in water >150 m in depth, while fishermen in the MAB only set to depths of 90 m. Fishing effort in the EGM was highest at depths of 10–20 m (19.5%) and at depths of 20–30 m for both the SE US (38.8%) and MAB (39.1%) regions (Fig. 7).

## Catch Composition and Disposition

During the study period, a total of 55,080 individual sharks were captured

[15]NMFS. 1997. Framework seasonal adjustment of management measures under the fishery management plan for sharks final environmental assessment and regulatory impact review/final regulatory flexibility analysis. March 1997. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Office of Sustainable Fisheries, Silver Spring, Md.

during observed BLL sets (Table 1). These included 34 species from 10 families, with the family Carcharhinidae representing 93.5% of all sharks encountered. Divided into their respective management groups, the catch comprised of 34,919 LC sharks (11 species), 17,303 SC sharks (4 species), 2,154 PH species (12 species), 686 DF (4 species), and 18 PE sharks (3 species) (Table 1). The sandbar shark is the primary target species and represented 35.9% of the total catch (TC) in the fishery, and 56.7% of the LC management group (Table 1). The sandbar was followed by the Atlantic sharpnose (27.0% TC, 85.9% SC) (Table 1), an SC species. Other substantial LC shark species found in the catch included the tiger (10.2% TC, 16.1% LC) and blacktip (9.1% TC, 14.4% LC) (Table 1). The dusky shark, a PH species, represented 3.0% of the total catch and 76.6% of its management unit (Table 1). Smooth dogfish was the largest component of the DF management group (73.1%) and represented 1.2% of the total catch (Table 1). PE sharks, including the common thresher, shortfin mako, and blue, represented the remaining <0.1% of the TC (Table 1).

Species compositions varied between the three regions. No species dominated the catch in the EGM (*n*=15,259) (Table 1). The sandbar (28.0%), blacktip (20.2%), Atlantic sharpnose (13.9%), and blacknose (8.7%) sharks represented the four most commonly caught species in the EGM (Fig. 8).

In the SE U.S. region (*n*=21,420), the Atlantic sharpnose comprised almost half the TC (49.0%) (Fig. 8). The two most commonly targeted species, sandbar and blacktip, represented only 18.9% and 7.4% of the TC, respectively (Fig. 8). The tiger shark, which is commonly a non-target species, represented 13.4% of the TC in this region (Fig. 8). Twenty-nine species of sharks were caught in this region, the most of all three regions (Table 1).

Sandbar sharks dominated the catch in the MAB, representing 62.3% of the TC in that region (*n*=18,401) (Fig. 8). The Atlantic sharpnose (12.2%), tiger (9.7%), and dusky (7.8%) sharks repre-

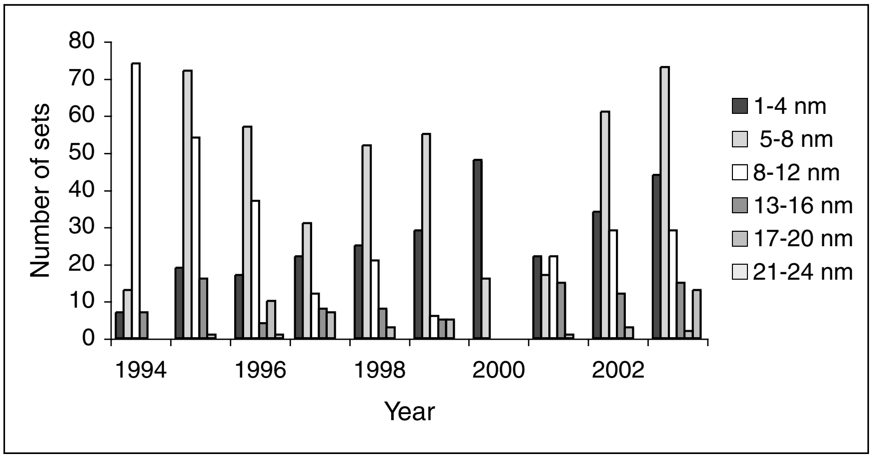


Figure 3.—Number of individual BLL sets observed per year by mainline length (nmi).

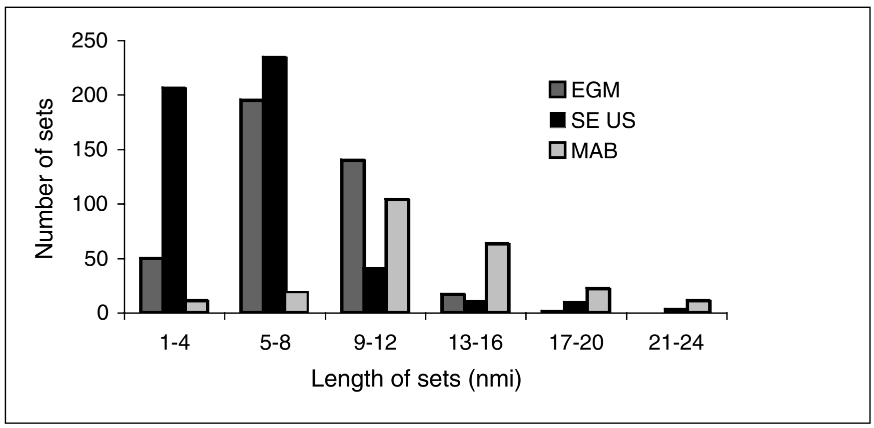


Figure 4.—Number of individual BLL sets observed in each of the three regions by mainline length (nmi).

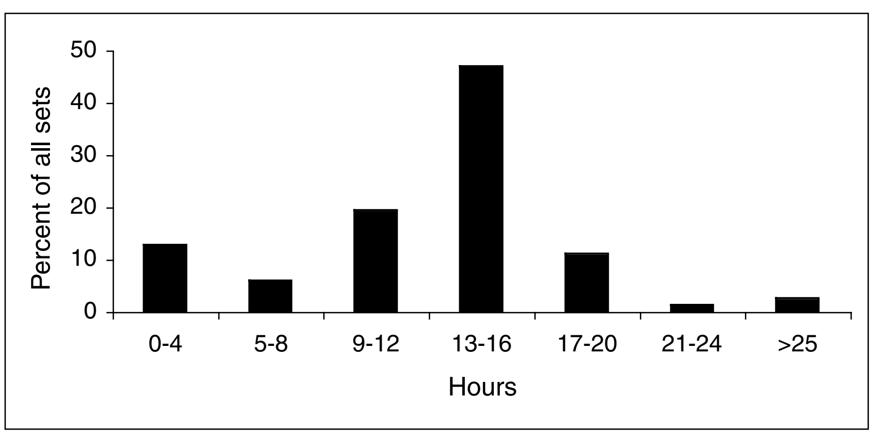


Figure 5.—Percent of all observed BLL sets by soak time.

sented the other most commonly caught species in this region (Fig. 8).

LC sharks caught on commercial BLL fishing gear had an 82.7% total mortality rate (Table 6). Total mortality includes sharks being landed, discarded dead, used for bait, or brought back to land for display or museum purposes. Seventy-five percent (75.9%) of all LC sharks were landed for commercial sale, 3.7% were discarded, 2.7% were used for bait, and 0.3% were used for display or museum specimens (Table 6). Of the 17.3% that survived the fishing process, 11.2% were released alive, 5.4% were tagged and released, and 0.7% were seen by an observer but escaped from the longline before being brought aboard (Table 6).

The sandbar and blacktip sharks were the most commonly targeted species in the fishery and were retained and landed 94.5% and 96.8% of the time, respectively (Table 7). The bull shark, although not traditionally targeted, was landed 94.6% of the time (Table 7). Sandbar, blacktip, and bull sharks suffered a total mortality rate of 95.4%, 99.6%, and 95.7%, respectively (Table 7). There were no yearly trends in disposition for any of these three species.

The dusky shark had total mortality rates ranging from 56.9–100% between 1994 and 2003 (Table 8). The average total mortality during the entire study period was 92.1% (Table 8). Regulations prohibiting the catch of dusky sharks in U.S. Federal waters went into effect in January 2001 (NMFS[16]). The total mortality rate for dusky sharks prior to 2001 was 94.1% and after 2001 was 78.2%. The dusky shark was most often retained and landed for sale during 1994–2001 (Table 7). Starting in 2002, shortly after being classified as a prohibited species, the majority of dusky sharks were discarded (Table 8).

The great hammerhead and scalloped hammerhead had very similar final dispositions. Both species had a total mortality rate >98.0%. For the great hammerhead, 62.3% were discarded, 26.5% were landed, 9.9% were used for bait, and 0.5% were retained for display or museum purposes, or had unknown disposition. For the scalloped hammerhead, 55.3% were discarded, 32.6% were landed, 9.9% were used for bait, and 0.6% were retained for display or museum purposes, or had unknown disposition (Table 7).

Tiger and nurse sharks were commonly caught nontarget species. Tiger shark disposition varied more than any other species in this fishery. They suffered a total mortality rate of only 30.9%, with 13.9% landed, 10.3% used for bait, 5.2% discarded, and 1.5% used for display, museum, or other purposes (Table 7). Of the 69.1% of tiger sharks caught alive, 42.8% were released, 25.4% were tagged, and 0.9% escaped (Table 7). Nurse sharks, rarely brought aboard or retained for sale, were released 95.8% of the time (Table 7).

SC sharks suffered 98.9% total mortality rate during the fishing process (Table 6). Over 60% of SC sharks (61.9%) were used for bait, 28.8% were landed for sale, 7.3% were discarded, and 1.0% were either retained for display or museum specimens (Table 6). SC sharks that survived the fishing process were either released (0.9%), tagged (0.2%), or escaped (0.1%) (Table 6).

Total mortality rates for Atlantic sharpnose were 96.3–100% during the entire study period (Table 8). There was a strong shift in the disposition of this species between the time periods 1994–97 and 1998–2003. During the first time period, Atlantic sharpnose sharks were landed most of the time (Table 8). After 1997, this species was landed very infrequently and was primarily used for bait (Table 8).

The blacknose shark, classified as an SC species, was commonly caught

**Table 6.—Final disposition in number of individuals and percentages of large coastal (LC) and small coastal (SC) sharks observed caught during 1994–2003 and the total number and percent alive and dead for each category.**

| | LC | | SC | |
|---|---|---|---|---|
| Disposition | No. of sharks | Percent | No. of sharks | Percent |
| Bait | 941 | 2.7 | 10,710 | 61.9 |
| Landed | 26,483 | 75.9 | 4,986 | 28.8 |
| Discard | 1,290 | 3.7 | 1,255 | 7.3 |
| Display | 107 | 0.3 | 26 | 0.2 |
| Museum | 27 | 0.1 | 12 | 0.1 |
| Other | 30 | 0.1 | 116 | 0.7 |
| Release | 3,912 | 11.2 | 154 | 0.9 |
| Tagged | 1,869 | 5.4 | 30 | 0.2 |
| Escape | 254 | 0.7 | 12 | 0.1 |
| Total | 34,913 | 100.0 | 17,301 | 100.0 |
| Alive | 6,035 | 17.3 | 196 | 1.1 |
| Dead | 28,878 | 82.7 | 17,105 | 98.9 |

[16]NMFS. 1999. Final fishery management plan for Atlantic tunas, swordfish and sharks. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Office of Sustainable Fisheries, Highly Migratory Species Division, Silver Spring, Md., var. pagin.

**Table 7.—Total number and percentage disposition by species for seven shark species during all years and regions combined.**

| | Great hammerhead | | Scalloped hammerhead | | Sandbar | | Blacktip | | Bull | | Tiger | | Blacknose | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Disposition | No. | % | No. | % | No. | %. | No. | % | No. | %. | No. | % | No. | % |
| Bait | 39 | 9.9 | 82 | 9.9 | 20 | 0.1 | 58 | 1.2 | 0 | 0.0 | 576 | 10.3 | 433 | 18.3 |
| Landed | 104 | 26.5 | 271 | 32.6 | 18,698 | 94.5 | 4,863 | 96.8 | 642 | 94.6 | 782 | 13.9 | 1,473 | 62.2 |
| Discard | 245 | 62.3 | 460 | 55.3 | 129 | 0.7 | 68 | 1.4 | 6 | 0.9 | 289 | 5.2 | 334 | 14.1 |
| Display | 0 | 0.0 | 3 | 0.4 | 18 | 0.1 | 15 | 0.3 | 1 | 0.1 | 58 | 1.0 | 23 | 1.0 |
| Escape | 2 | 0.5 | 1 | 0.1 | 138 | 0.7 | 5 | 0.1 | 19 | 2.8 | 50 | 0.9 | 8 | 0.3 |
| Museum | 0 | 0.0 | 2 | 0.2 | 2 | 0.0 | 0 | 0.0 | 0 | 0.0 | 18 | 0.3 | 9 | 0.4 |
| Other | 2 | 0.5 | 0 | 0.0 | 11 | 0.1 | 2 | 0.0 | 1 | 0.1 | 9 | 0.2 | 4 | 0.2 |
| Release | 0 | 0.0 | 7 | 0.8 | 360 | 1.8 | 7 | 0.1 | 8 | 1.2 | 2,401 | 42.8 | 64 | 2.7 |
| Tagged | 1 | 0.3 | 6 | 0.7 | 412 | 2.1 | 8 | 0.2 | 2 | 0.3 | 1,424 | 25.4 | 19 | 0.8 |
| Total | 393 | 100.0 | 832 | 100.0 | 19,788 | 100.0 | 5,026 | 100.0 | 679 | 100.0 | 5,607 | 100.0 | 2,367 | 100.0 |
| Alive | 3 | 0.8 | 14 | 1.7 | 910 | 4.6 | 20 | 0.4 | 29 | 4.3 | 3,875 | 69.1 | 91 | 3.8 |
| Dead | 390 | 99.2 | 818 | 98.3 | 18,878 | 95.4 | 5,006 | 99.6 | 650 | 95.7 | 1,732 | 30.9 | 2,276 | 96.2 |

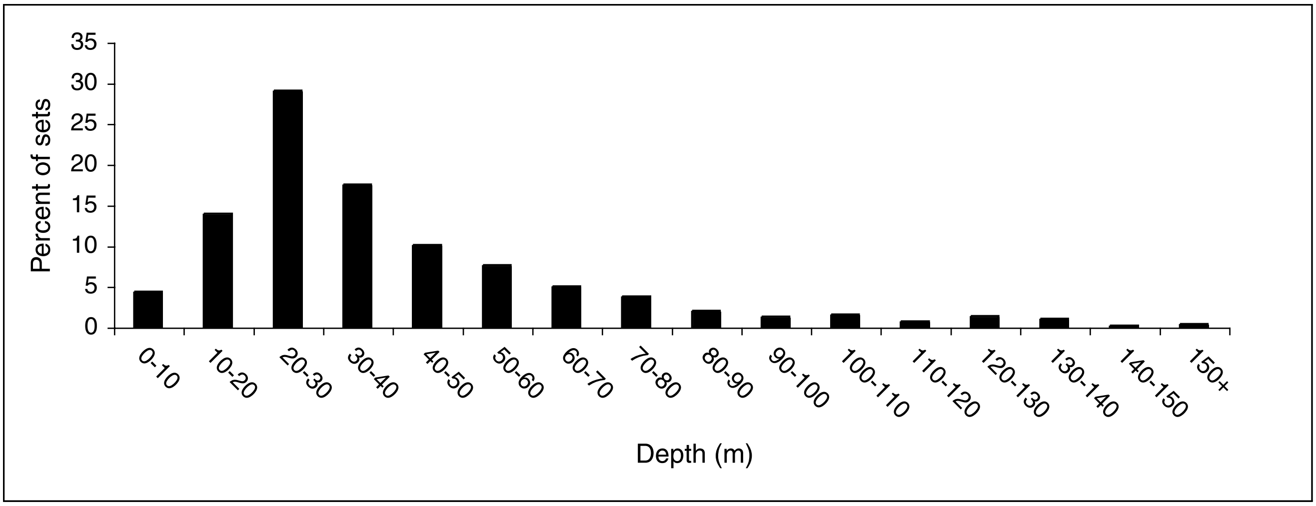


Figure 6.—Percent of all observed BLL sets by water depth.

and landed in this fishery. Of its 96.2% total fishing mortality rate, 62.2% were landed, 18.3% were used for bait, 14.1% were discarded, and 1.6% were retained for display, museum specimens, or other disposition (Table 7).

### At-Vessel Mortality and CPUE

We analyzed at-vessel mortality data for information on species-specific viability relating to the stress of longline capture. The most tolerant species were the nurse (100% alive), tiger (93.3% alive), lemon (92.1% alive), bull (69.9% alive), and sandbar (66.6% alive) sharks. Less hardy species were the great hammerhead (4.2% alive), scalloped hammerhead (8.0% alive), silky (11.5% alive), and blacktip (13.9% alive) sharks (Fig. 9).

To determine whether soak time affected mortality rates, we quantified the percentage of dead sharks observed after soak times broken down into 4 h bins, ranging from 0 to >24 h. The majority of data supported the hypothesis that as soak time increased mortality rates increased. Sandbar sharks caught during sets with <4 h soak times had a low mortality rate of 6.5% (Table 9). This doubled to 12.7% during soak times of 4–8 h and increased to a peak of 51.3% during soak times of 20–24 h (Table 9). Atlantic sharpnose and blacknose sharks showed large increases

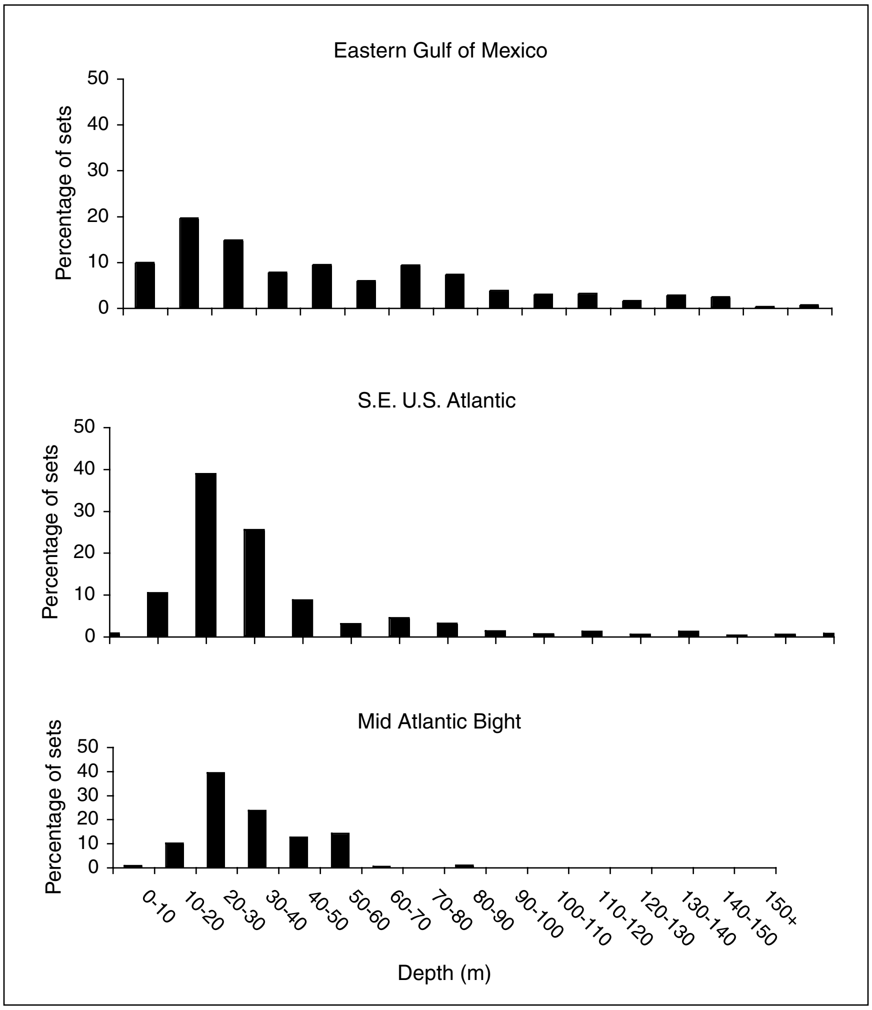


Figure 7.—Percent of all observed BLL sets by water depth and region.

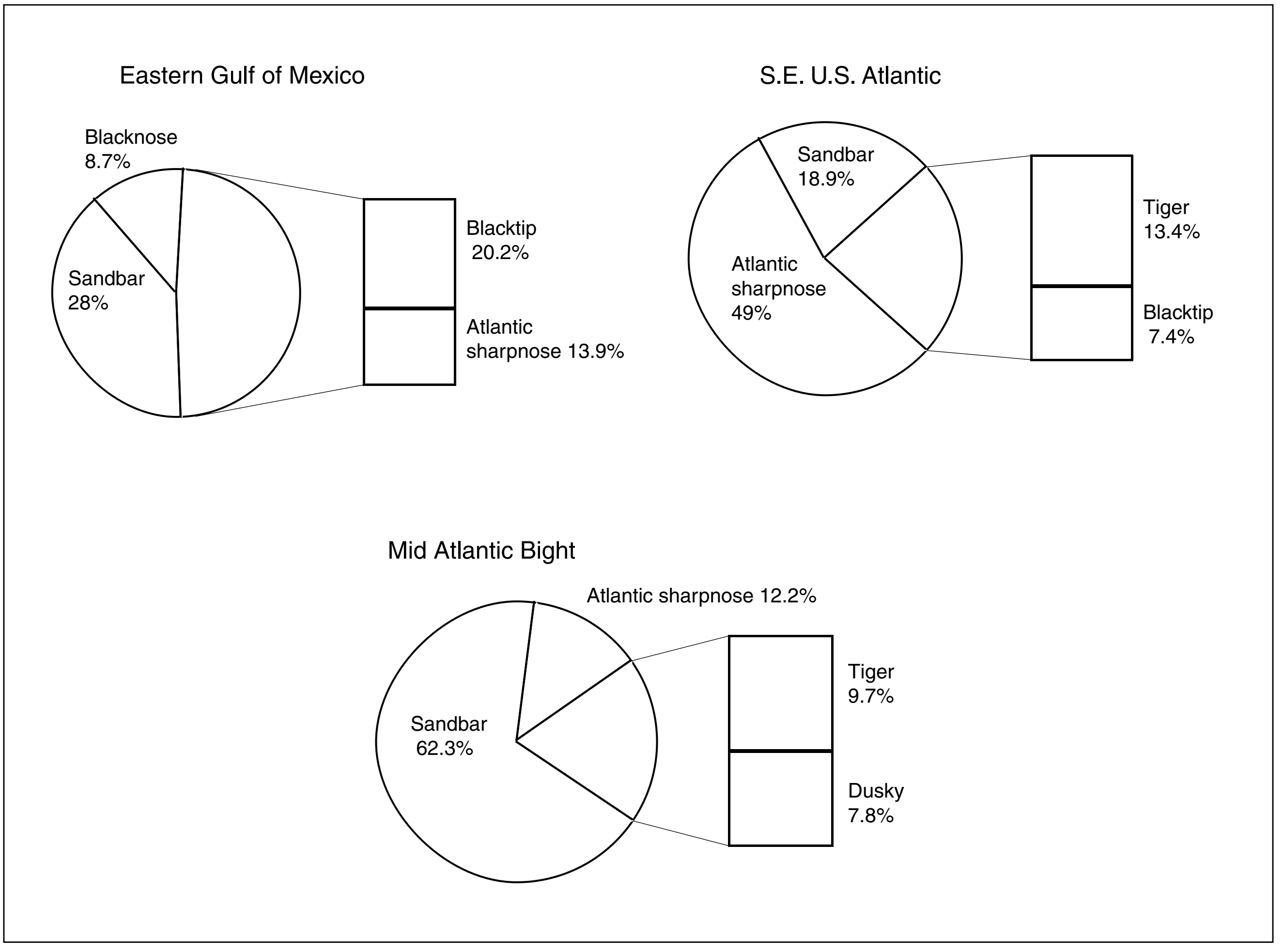


Figure 8.—Percent of individual shark species and management units represented in the total shark catch of each of the three regions.

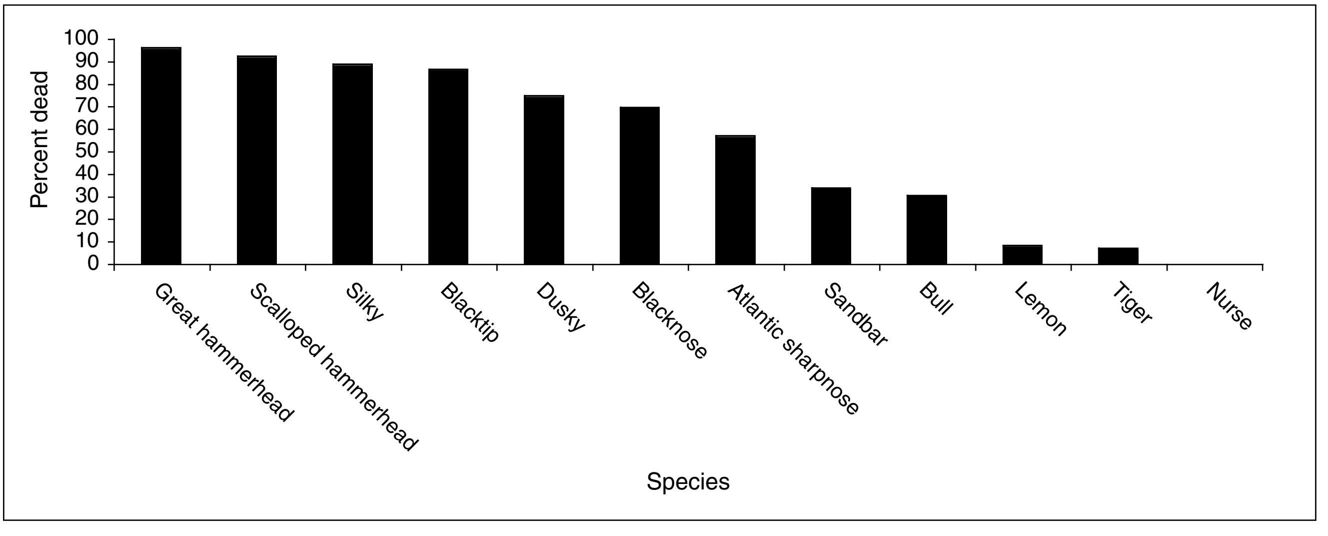


Figure 9.—Mortality rates for shark species (at the vessel) commonly observed caught in the BLL fishery.

Table 8.—Percent disposition for the dusky and Atlantic sharpnose sharks by year for all regions combined.

| Species and disposition | Percent | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | Total (all yrs) |
| Dusky | | | | | | | | | | | |
| Bait | 0.0 | 0.0 | 0.5 | 0.7 | 0.0 | 0.0 | 10.0 | 2.5 | 0.0 | 3.7 | 0.5 |
| Carcass | 91.7 | 96.6 | 94.2 | 91.6 | 85.4 | 93.7 | 90.0 | 63.3 | 0.0 | 35.2 | 84.3 |
| Discard | 8.3 | 2.1 | 0.0 | 0.0 | 0.6 | 2.5 | 0.0 | 27.8 | 56.9 | 38.0 | 7.0 |
| Display | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| Escape | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Museum | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| Other | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.3 | 0.0 | 0.0 | 0.1 |
| Release | 0.0 | 0.5 | 1.0 | 1.4 | 1.6 | 2.1 | 0.0 | 5.1 | 5.9 | 10.2 | 2.1 |
| Tagged | 0.0 | 0.8 | 3.9 | 6.3 | 12.3 | 1.4 | 0.0 | 0.0 | 37.3 | 13.0 | 5.8 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.4 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Alive | 0.0 | 1.3 | 4.8 | 7.7 | 13.9 | 3.5 | 0.0 | 5.1 | 43.1 | 23.1 | 7.9 |
| Dead | 100.0 | 98.7 | 95.2 | 92.3 | 86.1 | 96.8 | 100.0 | 94.9 | 56.9 | 76.9 | 92.1 |
| Atlantic sharpnose | | | | | | | | | | | |
| Bait | 36.0 | 40.3 | 36.2 | 32.7 | 83.5 | 89.6 | 99.9 | 93.5 | 70.1 | 76.5 | 69.0 |
| Carcass | 15.2 | 58.9 | 59.7 | 58.4 | 8.0 | 9.7 | 0.1 | 0.6 | 15.5 | 0.7 | 23.3 |
| Discard | 47.2 | 0.5 | 1.6 | 8.6 | 3.4 | 0.5 | 0.0 | 5.7 | 13.9 | 19.1 | 6.2 |
| Display | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Escape | 0.8 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| Museum | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Other | 0.0 | 0.1 | 1.5 | 0.0 | 4.8 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.8 |
| Release | 0.8 | 0.1 | 0.0 | 0.2 | 0.3 | 0.0 | 0.0 | 0.2 | 0.2 | 3.6 | 0.6 |
| Tagged | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Alive | 1.6 | 0.1 | 0.9 | 0.2 | 0.3 | 0.0 | 0.0 | 0.2 | 0.2 | 3.7 | 0.7 |
| Dead | 98.4 | 99.9 | 99.1 | 99.8 | 99.7 | 100.0 | 100.0 | 99.8 | 99.8 | 96.3 | 99.3 |

in at-vessel mortality when soak times exceeded 8 h. (Table 9). Mortality was <40% during sets <8 h and over 90% and 80% during sets >8 h for these species, respectively (Table 9). The blacktip, great hammerhead, and scalloped hammerhead sharks had mortality rates >67.0% during soak times longer than 4 h (Table 9).

Two species did not show increased at-vessel mortality rates with increased soak times: bull and dusky sharks. Bull shark mortality peaked at 52.3% with soak times of 16–20 h and had much lower mortality during soak times >20 h. (6.1%) (Table 9). Dusky sharks had a higher mortality rate (50.0%) during soak times <4 h compared with soak times of 4–8 h (15.4%). Overall, dusky sharks had a very high at-vessel mortality rate (Table 9). We believe that these contradictory patterns were the result of low sample sizes in certain soak time bins.

Table 9.—At-vessel mortality rates (% dead at vessel) by soak time for nine shark species observed caught during 1994–2003.

| Soak Time | Percent dead | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Blacknose | Bull | Blacktip | Dusky | Sandbar | Tiger | Atlantic sharpnose | Scalloped hammerhead | Great hammerhead |
| 0–4 | 11.3 | 0.0 | 48.6 | 50.0 | 6.5 | 0.0 | 14.3 | 60.0 | 100.0 |
| 4–8 | 34.8 | 31.3 | 79.6 | 15.4 | 12.7 | 0.0 | 35.3 | 67.9 | 90.9 |
| 8–12 | 84.9 | 35.1 | 89.4 | 65.8 | 18.9 | 6.4 | 90.9 | 85.0 | 96.6 |
| 12–16 | 84.4 | 28.3 | 85.4 | 68.1 | 21.8 | 7.1 | 94.1 | 92.6 | 94.9 |
| 16–20 | 78.3 | 52.3 | 87.4 | 81.8 | 38.5 | 9.6 | 97.1 | 96.1 | 96.8 |
| 20–24 | 75.0 | 6.1 | 90.0 | 75.0 | 51.3 | 8.6 | 98.6 | 98.0 | 100.0 |
| 24+ | 100.0 | 0.0 | 94.2 | 70.0 | 47.1 | 23.7 | 99.0 | 100.0 | 100.0 |

Variations appeared in the year-to-year CPUE of the major species caught in the fishery. Annual CPUE across all regions and seasons for sandbar sharks ranged from 14.3 to 41.7, but there was no significant overall CPUE change over the study period ($r^2$=0.04) (Fig. 10). Most of the commonly caught species showed increases in CPUE over the study period, especially the scalloped hammerhead ($r^2$ = 0.42), blacktip ($r^2$ = 0.30), and bull ($r^2$ = 0.28) sharks (Fig. 10). The only species with a CPUE decline was the dusky shark ($r^2$ = 0.07), while all other common species showed little to no change (Fig. 10).

Several species showed similar high and low point patterns in annual CPUE. Dusky, blacktip, and bull sharks all showed peaks in catch rates in 1995, followed by 2 years of declining CPUE, and then a subsequent rise to a new peak in 1999 (Fig. 10). Nurse and blacknose shark CPUE trends also followed similar patterns with a rise in catch rates during 1994–96 and 1998–99, followed by drops in 1997 and 2001, and a distinct peak in 2002 followed by a drop in 2003 (Fig. 10).

The CPUE of the LC and SC management groups also varied from year to year, ranging from 20.9 to 52.7 for LC sharks and from 2.2 to 33.1 for SC sharks between 1994 and 2001 (Fig. 11). The CPUE for SC sharks in 2000 (65.0) is inflated due to observer coverage occurring only in the SA (Fig. 11). The CPUE for both management groups showed a rising trend during the study period ($r^2$ = 0.51 for LC, and $r^2$ = 0.11 for SC) (Fig. 11).

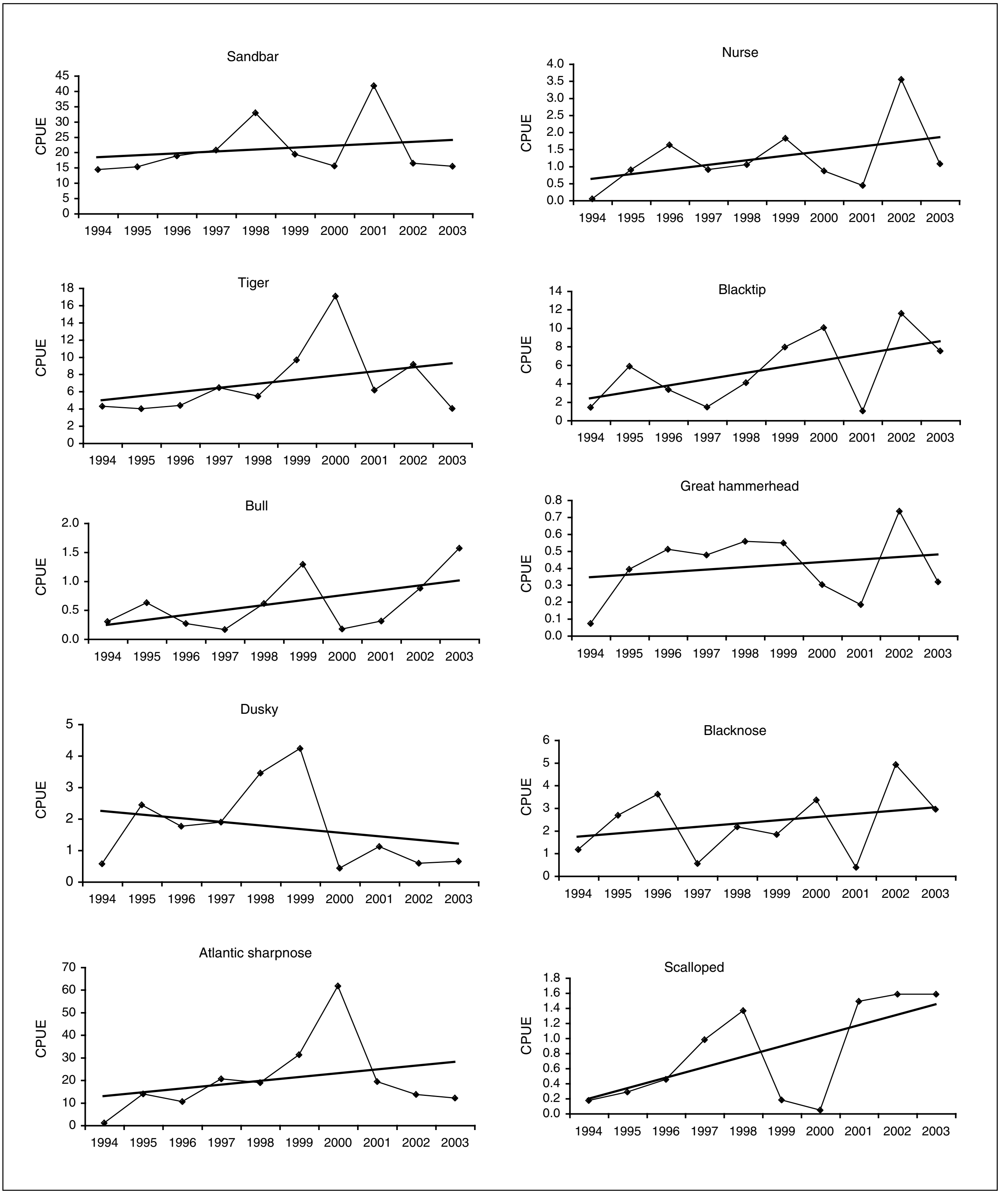


Figure 10.—Annual CPUE (sharks per 10,000 hook hours) by year for shark species commonly observed caught in the BLL fishery. The y-axis ranges are different for individual species.

## Bycatch

Bycatch of non-shark species numerically represented 4.8% of the TC in the fishery, with species composition varying between the three regions. Fishermen in the EGM caught the largest percentage (62.0%) of the total bycatch, while substantially less bycatch was caught in the SE US (27.2%) and MAB (10.8%) regions.

In the EGM, bycatch represented 10.2% of the TC. This area had the fewest sharks caught (15,259) (Table 1), but had three times as much bycatch as the SE US region (3.4% TC) and over six times the bycatch of the MAB (1.6% TC). Serranid fishes represented 44% of the bycatch in the EGM. The most frequently encountered serranid was the red grouper, *Epinephelus morio,* (68.1%), followed distantly by the yellowedge grouper, *E. flavolimbatus* (7.3%); black grouper, *Mycteroperca bonaci* (6.3%); and gag grouper, *M. microlepis*, (6.1%). Anguilliformes composed another large portion of the bycatch (23.9 %), represented primarily by unidentified eels (64.6%) and king snake eel, *Ophichthus rex* (19.0%) (Fig. 12).

Several protected species were caught in the EGM, including sea turtles (Dermochelyidae, Cheloniidae), bottlenose dolphins, *Tursiops truncates,* and smalltooth sawfish, *Pristis pectinata*. One pelican, *Pelecanus sp*., was caught (disposition not recorded), and 21 sea turtles were caught, including 15 loggerheads, *Caretta caretta* (1 discarded, 11 released alive, 3 unknown disposition); one leatherback, *Dermochelys coriacea*, of unknown disposition, and five unknown species (unknown disposition). Other protected species caught included two bottlenose dolphins (one released alive, one discarded dead), and seven smalltooth sawfish (six released alive, one unknown disposition). Unknown disposition usually meant that the gangion was cut prior to an observer being able to document whether the animal was alive or dead and whether it was released or discarded.

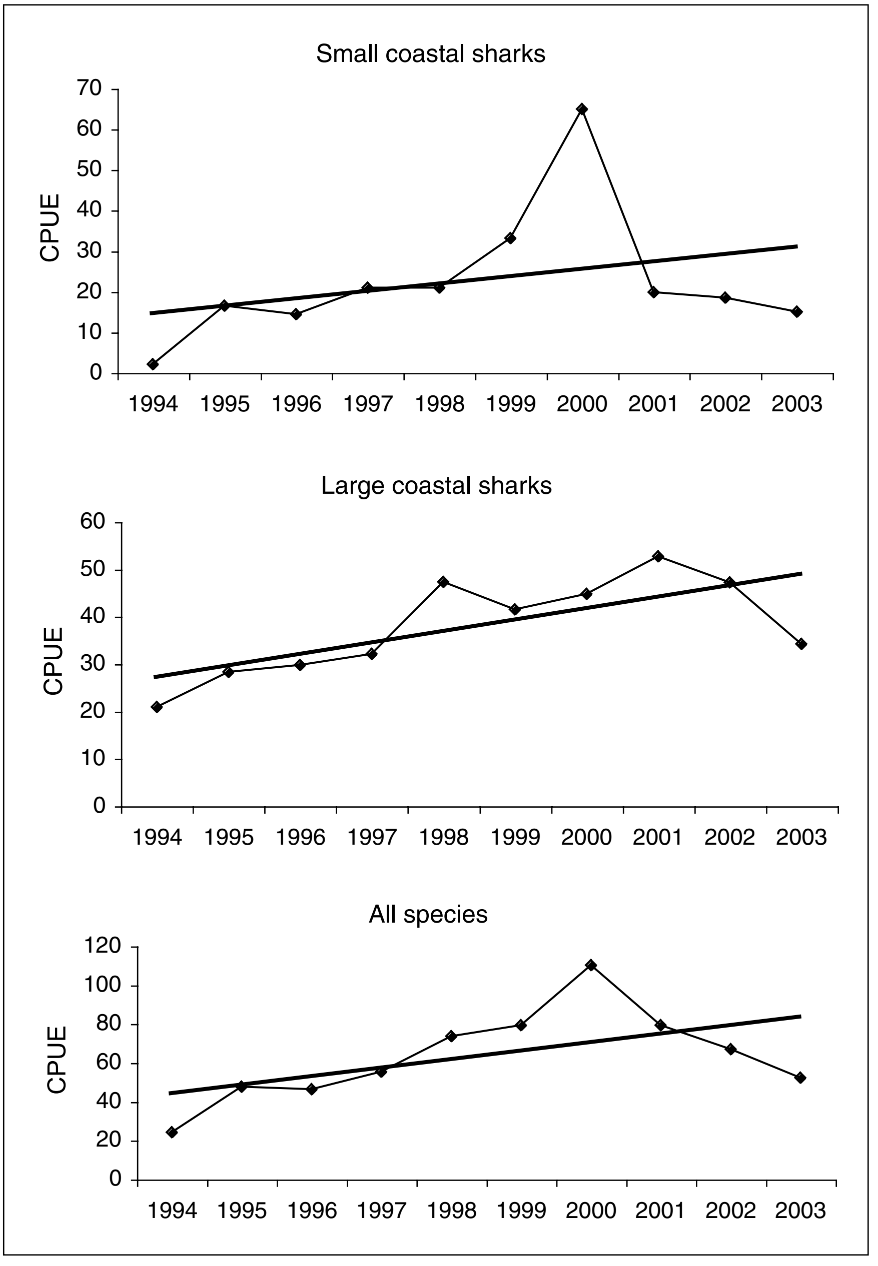


Figure 11.—Annual CPUE (sharks per 10,000 hook hours) for large coastal sharks, small coastal sharks, and all species combined.

The SE US and MAB regions had much lower bycatch rates, which were dominated by batoids (32.9% and 59.8%, respectively). In the MAB, the butterfly ray, *Gymnura micrura* (21.4%); roughtail stingray, *Dasyatis centroura* (15.4%); and stingrays, *Dasyatis* spp. (20.3%), were commonly caught (Fig. 12), while stingrays (36.7%) dominated the batoid catch in the SE US (Fig. 12). Protected species taken in these two regions consisted of sea turtles and smalltooth sawfish. Sixteen loggerheads (nine released, four discarded, three unknown disposition), one leatherback (discarded), three unknown sea turtles (two released, one unknown disposition) and one smalltooth sawfish were caught in the SE US, and five loggerheads (one discarded, one

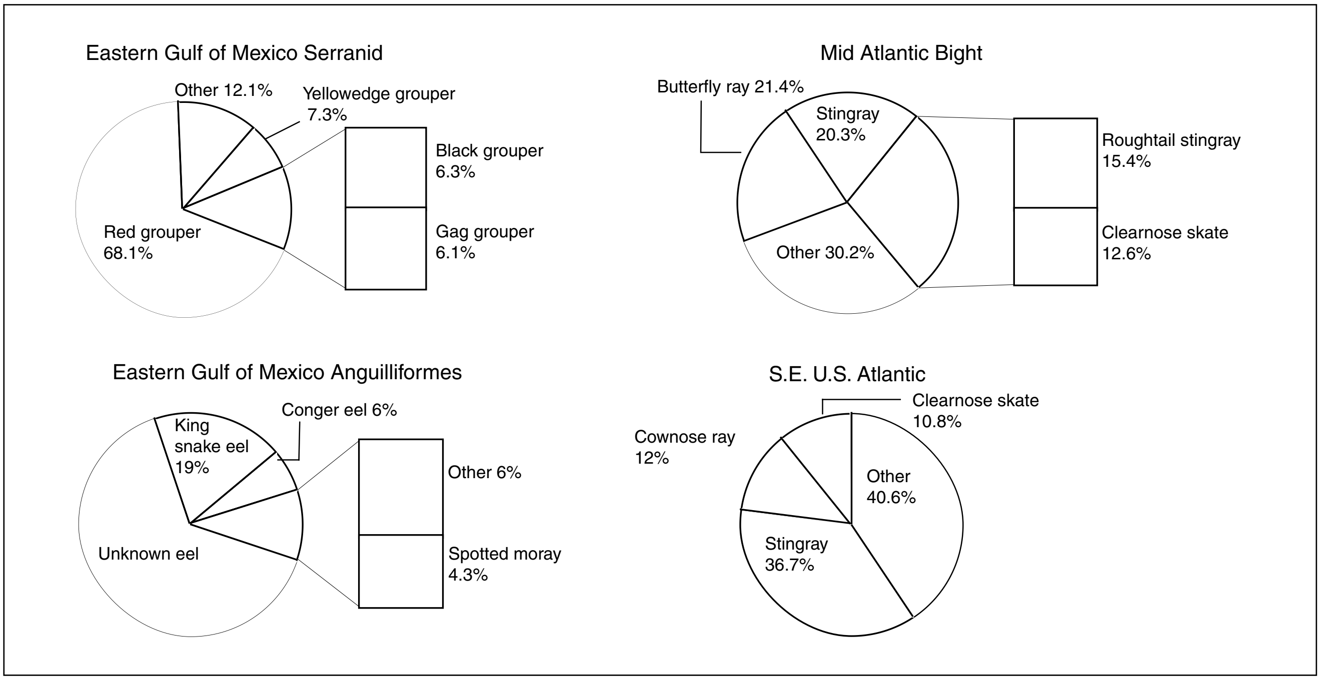


Figure 12.—Composition of bycatch by region.

released, three unknown) were caught in the MAB.

## Discussion

Fishery observer programs are an important fisheries management tool, and they allow the collection of valuable high-resolution data on fishery practices, effort, catch, discards, and bycatch. These data have become increasingly important in the stock assessments used to make management decisions. As northwest Atlantic shark fisheries rapidly expanded during the 1980's and 1990's, it became clear that more information was necessary to accurately characterize the fishery and the species comprising the catch. The CSFOP was established in 1994 to help acquire this information, and it has since become one of the largest sources of data available on northwest Atlantic coastal shark resources.

The number of vessels observed during an individual season and within a year varied greatly between the voluntary and mandatory years. During voluntary years, the same vessels were generally observed during each season and over several years. This is not an ideal way to sample commercial fisheries, but was the best available option during that time period. Once the program became mandatory, the pool of vessels available for observer coverage significantly increased, although failure of some fishermen to comply with the observer program requirements (including refusing women observers, failure to notify the CSFOP prior to a BLL trip, and failure to obtain the required vessel safety inspections) kept the number of available vessels at a suboptimal level. In the future, better communication between fishermen, managers, and observer program coordinators will help to improve coverage of the fishery.

During the voluntary years, the number of sets and sea days observed depended on the observer's ability to obtain rides on BLL fishing trips. The number of sea days and sets observed varied greatly between the voluntary and mandatory years and within the two time periods. These variations could be due to factors such as weather, length of the fishing season, market price, and catch rates. Often when the market price for sharks declined, fishermen would participate in other fisheries until the price increased. In addition, a trip limit of 4,000 lb (1,814 kg) for large coastal sharks required that vessels return to port and unload once the limit is reached (NMFS[15]). Observers on vessels that caught the trip limit quickly logged fewer sea days per trip.

During the 10 years analyzed, observers recorded a wide variety of hook sizes, although only three sizes were used frequently. The different sized hooks were selected based primarily on the targeted species and also on fisherman preference. Smaller hooks were used to target smaller species (Atlantic sharpnose, blacknose), and larger hooks were used to target larger shark species (sandbar, dusky, bull). Large fluctuations in the number of hooks used per set most likely relates to vessel size, fisherman preference, and prior fishing success. Smaller vessels generally set less gear, and fishermen in areas where fishing grounds are located far from shore (i.e. North Carolina) generally set more fishing gear. Reductions in the average number of hooks used per set between 1994–97 and 1998–2003 may have been influenced by changes in regulations, such as trip limits, which lead to a reduction in the size of vessels and therefore the amount of gear used.

Fishing gear was typically set at night and hauled back in the morning. This common fishing method was reflected in soak time and is why approximately 85% of sets had soak times less than 16 h. Sets lasting more than 16 h were typically an indirect result of the 4,000 lb trip limit implemented in 1993 (NMFS[5]). If the limit was reached before all the gear was hauled, fishermen were required to leave the remaining gear in the water while they returned to port to unload their catch. The remainder of the gear was hauled on subsequent trips. The large number of observed shallow-water sets was also a result of fishing methods, because most targeted species are located in waters <50 m deep (Compagno, 1984).

Knowledge of catch composition in multi-species fisheries is important for effective management. Observer programs help fishery managers better understand the scope of the catch composition within a fishery. While fishermen may only target one or two species, a number of species may be caught, and the mortality of each needs to be considered in the management plan. This is particularly true if species in the complex exhibit variation in their life histories and population dynamics.

Changes in catch composition can occur over time, which may indicate changes within the fishery or in the population status of particular species (Kirkwood et al., 1994; Greenstreet and Hall, 1996). The commercial BLL fishery targets LC sharks; however, a number of small coastal, dogfish, pelagic, and prohibited shark species are also caught. The fishery began by targeting sandbar and blacktip sharks for their fins and meat, but over time the Atlantic sharpnose shark also became a target for use as bait in longline sets. Regional differences in catch composition were very pronounced and were primarily due to individual species distributions, migration patterns, and fisherman preference.

Observer programs offer detailed information about the final disposition of the catch, which can be utilized to estimate total mortality in a fishery. Most catch statistics used in fisheries management are based on logbook data and landing reports, which often do not include this valuable information (Morgan and Burgess, 2005; NMFS[3]). Sharks that are caught and discarded or used for bait may never be recorded and therefore will not be counted against the quota or incorporated into fishing mortality estimates. Some species, such as dusky and white sharks, are prohibited from being landed but are often caught incidentally and discarded dead. Observer data are, therefore, the only indicator of the frequency of interactions with various protected species in this fishery.

Fishery managers must be made aware of these sources of undocumented mortalities, because they may have a major impact on the accuracy of stock assessments and the success of current and future management plans. Our results show that SC sharks have an extremely high fishing mortality rate (at-vessel mortality and disposition); however, only a small percentage of these sharks are landed for sale. This cryptic mortality illustrates the fact that a large number of sharks may not be accounted for and may never be incorporated into assessments of the fishery. The rates of mortality documented by observers can, therefore, be used by assessment scientists to extrapolate total mortality for non-landed species in the fishery.

Mortality estimates for species involved in commercial fisheries are a main component of population assessments (Simpfendorfer et al., 2005). Typically, fishing mortality is associated with those animals that are landed for sale. However, a large number of nontargeted species mortalities are not accounted for in population assessments because they are discarded at sea. As a consequence, any catch-and-release measures enacted for species with high at-vessel mortality rates will probably have little positive effect on reducing fishing mortality.

Species such as nurse, tiger, and bull sharks possibly suffer lower at-vessel mortality rates because they are not obligate ram ventilators and may not become greatly stressed when hooked (Manire and Hueter, 2001). Hammerhead species, on the other hand, are obligate ram ventilators and suffer a very high at-vessel mortality rate (Carlson et al., 2004). Fisheries observers are able to document such fishing mortality, and this provides valuable information to fisheries managers. Alternative management measures, such as reducing soak time or gear modifications, may be more helpful to species that have high at-vessel fishing mortality rates.

CPUE is a commonly used indicator of how commercial fish stock size fluctuates over time (Morgan and Burgess, 2005). It can be influenced by changes within the fishery, such as gear improvements, and changes in the targeted species and fishing areas. While CPUE is usually standardized to account for possible changes due to time constraints; this was not done for this report. Increases in CPUE for most of the targeted species in our data set maybe a result of fishermen becoming more adept at targeting and catching specific species. The results also mimic those found in the 2002 LC stock assessment (Cortes[17]), indicating an upward trend since the early 1990's.

The majority of the bycatch was represented by stingrays, groupers, and eels, which are all common inhabitants of the areas fished by the BLL fleet (McEachran and Fechhelm, 2005). There was minimal protected species bycatch compared with other fisheries (Poiner and Harris, 1996; Julian and Beeson, 1998; Witzell, 1999), most likely due to the use of BLL gear instead of PLL gear and setting fishing gear at night. While sea turtles were occasionally caught, only a few interactions with leatherback turtles were recorded, and most sea turtles were returned to sea alive. The high incidence of protected species interactions in the EGM, when

[17]Cortés, E., L. Brooks, and G. Scott. 2002. Stock assessment of large coastal sharks in the U.S. Atlantic and Gulf of Mexico. September, 2002. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Panama City Lab., Sustainable Fish. Div. Contrib. SFD-02/03-177.

compared to the SE US and MAB regions, was most likely due to heavy fishing in the Florida Key's region, where smalltooth sawfish and sea turtles more commonly occur. Overall, our data does not indicate that the shark BLL fishery is a large source of mortality for protected resources off the southeastern U.S. coast.

The CSFOP has collected a large amount of information pertaining to the shark BLL fishery over the 10 years documented in this report. Based on the observations collected during this time frame, we suggest that fishery managers consider single species monitoring and management options for this fishery. There are significant differences in the life history traits of species commonly represented in the catch, making it impossible to provide all species with the same levels of protection. The use of alternative management measures, such as limiting the soak time and/or length of gear or implementing larger time/area closures, may be beneficial to many species represented in this fishery (in particular the dusky, great hammerhead, and scalloped hammerhead sharks). The expansion of species-based monitoring efforts, both in port and at sea, in northwest Atlantic shark fisheries will help to provide much needed data for robust stock assessments. Fishery managers must continue to utilize an observer program as a tool to monitor the commercial BLL shark fishery to ensure that the resource may be sustainably managed in the future.

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