Comparisons of Shark Catch Rates on Longlines Using Rope/Steel (Yankee) and Monofilament Gangions

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Introduction

In 1973, the Virginia Institute of Marine Science (VIMS) began a depth-stratified longline sampling program to examine the distribution, abundance, and biology of sharks from the lower Chesapeake Bay to the edge of continental shelf along the U.S. mid-Atlantic coast. To maintain the integrity of the survey design, the program has used the same gear configuration since its inception: A modified "Yankee" or "New England" longline rig, so named because of wide-spread use in the New England swordfish fishery in the 1960's (Berkeley et al., 1981). The VIMS gear consists of a buoyed hard-laid nylon mainline from which hang gangions composed of hard-laid nylon rope with a steel leader.

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ABSTRACT—During the months of June through September in 1991 and 1992, 71 shark longlines were fished in the Chesapeake Bight region of the U.S. mid-Atlantic coast with a combination of rope/steel (Yankee) and monofilament gangions. A total of 288 sharks were taken on 3,666 monofilament gangions, and 352 sharks were caught on 6,975 Yankee gangions. Catch rates between gear types differed by depth strata, by month, and by species. Analyses were divided between efforts in the nursery ground of the sandbar shark, Carcharhinus plumbeus, *in Chesapeake Bay and efforts outside the Bay. Mean catch per unit effort (CPUE) ± SE, as sharks caught per 100 hooks fished, was significantly (P<0.05) lower for Yankee gangions. Mean CPUE's for sandbar sharks in the nursery ground were 20.6 ± 3.8 for Yankee gangions and 26.0 ± 3.0 for monofilament gangions, and mean CPUE's for all species combined outside the Bay were 3.7 ± 0.7 for Yankee gangions, and 6.9 ± 1.2 for monofilament gangions.*

In addition to monitoring the status of the shark populations of the Chesapeake Bight, the VIMS program has been a source of specimens for related research projects. During the course of the program, the catch per unit effort (CPUE) has declined approximately 75% (Musick et al., 1993). The large-coastal shark stock of the northwest Atlantic has been overfished for almost a decade (NMFS, 1993), and the declining CPUE of the VIMS survey can be at least partially attributed to this. Because the longline program fishes a set number of hooks at specific sites during each survey, the declining catch rate has meant that a substantially reduced number of individuals have been collected for research purposes. Proportional increases in effort to offset such a large reduction in CPUE were logistically prohibitive; therefore we sought a more efficient, ancillary method of capturing sharks to supplement the catches of the traditional survey.

During the 1970's, the commercial fishing industry replaced "Yankee" gangions with monofilament gangions because catch rates for swordfish and tuna were much higher using the latter gear (Berkeley et al., 1981). A side-benefit for this fishery was that the unwanted shark by-catch could escape by biting through the monofilament (Graham, 1987; Berkeley and Campos, 1988); "bite-offs" averaged about 5% of the hooks per set. Even so, shark catch rates increased, often exceeding the catch rate of the targeted species (Branstetter, 1986; Berkeley and Campos, 1988). Additionally, fishermen in the current commercial directed shark fishery have told us[1] that they prefer monofilament longline gear because it is more efficient. Based on this information, we added monofilament gangions to the standard longline rig as a way to increase catches without a substantial increase in effort. Herein, we compare catch rates between these two gear types fished simultaneously in the Chesapeake Bight region during 1991 and 1992.

Methods and Materials

Longlines were fished monthly from June through September at specific stations from the lower Chesapeake Bay to the edge of the continental shelf (200 m contour); additional localities were fished on occasion to provide supplemental data on species distribution and abundance (Fig. 1). For analysis, efforts were stratified by depth: 1) Lower Chesapeake Bay, 2) coastal (<10 m depth), 3) nearshore (10-20 m depth), 4) mid-shelf (20-100 m depth), and 5) offshore (>100 m depth).

The traditional VIMS longline rig consists of 6.4 mm (1/4-inch) tarred hard-laid nylon mainline anchored at both ends with 3-5 m gangions spaced about 20 m apart. Buoys are placed on the mainline at 20-gangion intervals.

[1]E. Sanders, Daytona, Fla., and H. West, Madeira Beach, Fla., 1991. Personal commun.

"Yankee" gangions consist of a heavy-duty quick-snap with 8/0 swivel, 2-3 m of 3 mm (1/8-inch) tarred hard-laid nylon line, an 8/0 swivel connecting 1-2 m of 1.6 mm (1/16-inch) 7X7 stainless steel wire, and a 9/0 hook. Hereafter, these gangions are referred to as "steel" gangions.

The monofilament gangions consist of the same quick-snaps and hooks, and are of similar length to the steel gangions. Two diameters, 1.6 mm (1/16-inch) and 2.4 mm (3/32-inch), of monofilament are used, but the breaking strength of both is 227 kg (500 pounds).

During this survey period, a "standard" longline consisted of 100 steel gangions set as a continuous unit with 50 monofilament gangions placed at one end of the line. The number of gangions for both gears varied on occasion due to gear loss during a survey or in an attempt to maximize production. To compare catch rates, a more statistically acceptable gear configuration would have been to alternate the gangion types at some interval, or to set them randomly along the line. However, gear comparison was not the primary purpose of the monofilament effort; it was meant to provide additional specimens for research purposes. It was more important to maintain the 100 steel gangion integrity of the longline for comparison with archival data; thus, the monofilament gear was set separately, but contiguously.

Longlines were fished for 3-4 hours duration. Based on sonar scans of longlines set in deep water, the catenary of the mainline reached depths exceeding 80 m; thus, for most coastal stations the majority of hooks were on or near the bottom specifically targeting semi-demersal species. Hooks were baited with cut mackerel, *Scomber scombrus*, or whole menhaden, *Brevoortia tyrannus*; if both bait types were used on a set, they were used randomly on both gangion types. Bait pieces were 0.10-0.25 kg each in order not to exclude the capture of small fish.

Catch by species for each set was recorded according to gear type. Healthy sharks not needed for biological sampling were tagged with M-type dart tags supplied by the National Marine Fisheries Service and released after species, length, and sex were determined; lengths were estimated for those large sharks that could not be safely boarded. Sharks that broke the gangion or dislodged the hook after being brought alongside were counted as a catch and noted as a "lost" shark. Broken gangions and "bite-offs" retrieved during haul-back were not recorded as a lost shark, nor were records kept as to the numbers of broken gangions retrieved for either gear type.

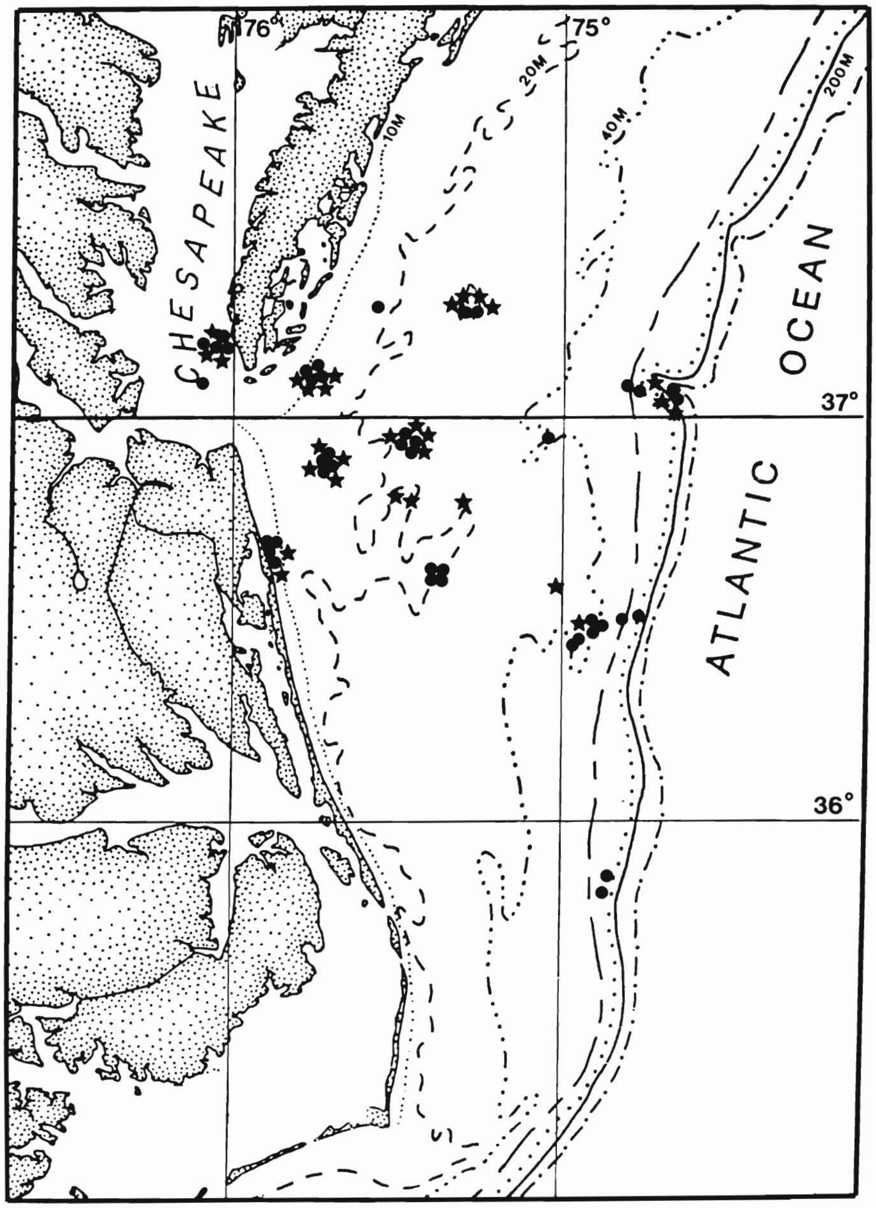

Figure 1.—Location of 71 longline sets in the Chesapeake Bight region that fished a combination of rope/steel and monofilament gangions during 1991 and 1992. Dots = 1991 sets, stars = 1992 sets.

Catch per unit of effort (CPUE) for each gear type per set was defined as sharks caught/100 hooks fished; a set that did not catch any sharks was not included in analyses. A mean CPUE over the 2-year period was calculated from the catch/set data, and a mean CPUE for each month and depth stratum was calculated from the catch/set data within each category. Calculations of mean CPUE's for each species were restricted to catch/set data where a given species was taken on either or both gear types. This was done because certain species occur more commonly, or entirely, within a specific depth range or during a particular time of year. The absence of a particular species on a given longline set provides no information concerning gear efficiency, and may simply reflect the absence of that species from the area at that time. Species were categorized according to their general depth of capture (coastal vs. offshore), and analyses were restricted to those species represented by 10 or more individuals; other species were grouped in "miscellaneous coastal" and "miscellaneous offshore" categories (Table 1).

Differences (P<0.05) between mean CPUE's for each gear type for each category were compared with paired *t*-tests (Snedecor and Cochran, 1980). Longlining as a sampling method is notorious for its variable catch rates (Branstetter, 1981a, b; Berkeley and Campos, 1988), and large sample sizes that would reduce variability were not available in some categories. Thus, some graphically distinct differences were not statistically different. This was especially true for species analyses where the number of longline sets that caught a given species, and the number of individuals of a given species, were relatively few.

Table 1.—Species of sharks taken on longlines fishing rope/steel and monofilament gangions. Categories and species codes are those used in Figures 2 and 3.

Species codes	Scientific name	Common name
Coastal species		
CP	*Carcharhinus plumbeus*	Sandbar shark
RT	*Rhizoprionodon terraenovae*	Atlantic sharpnose shark
OT	*Odontaspis taurus*	Sand tiger
CO	*Carcharhinus obscurus*	Dusky shark
GC	*Galeocerdo cuvier*	Tiger shark
SL	*Sphyrna lewini*	Scalloped hammerhead
Misc. coastal		
CM	*Carcharhinus brevipinna*	Spinner shark
CL	*Carcharhinus limbatus*	Blacktip shark
CB	*Carcharhinus leucas*	Bull shark
MC	*Mustelus canis*	Smooth dogfish
SZ	*Sphyrna zygaena*	Smooth hammerhead
Offshore species		
IO	*Isurus oxyrinchus*	Shortfin mako
Misc. offshore		
CA	*Carcharhinus altimus*	Bignose shark
CF	*Carcharhinus falciformis*	Silky shark
PG	*Prionace glauca*	Blue shark
AS	*Alopias superciliosus*	Bigeye thresher

Results and Discussion

A total of 6,975 steel gangions and 3,666 monofilament gangions were fished on 71 longline sets over the sampling period (Table 2). Excluding zero-catch sets, the data base for analyses included 58 longline sets that caught 352 sharks of 13 species on 5725 steel gangions, and 288 sharks of 13 species on 3038 monofilament gangions.

Table 2.—Catch and effort data by depth and month for 71 VIMS longlines fished in 1991-92 with a combination of steel/rope (S) and monofilament (M) gangions. Numbers equal sharks caught/hooks fished for each combination-gear longline set. Thirteen zero-catch sets {listed in brackets} are not included in totals or analyses; instead of providing information on gear efficiency, they probably only indicate a lack of sharks in the area at that particular time.

		June		July		August		September		Total	
Area or depth	Year	S	M	S	M	S	M	S	M	S	M
Bay	1991	No effort		29/100	14/40	37/100	16/50	6/100	8/50		
						15/100	12/52	6/60	17/84		
										161/760	108/426
	1992	30/100	20/50	21/100	10/50	17/100	11/50	No effort		8 sets	
<10 m	1991	2/100	7/46	2/100	5/47	0/100	3/48	9/100	6/50		
										20/500	23/241
	1992	7/100	2/50	No effort		{0/100	0/50}	No effort		5 sets	
10-20 m	1991	5/100	3/47	{0/100	0/40}	3/100	5/50	8/100	11/50		
		0/100	3/46	16/100	6/40	9/95	14/50	13/100	8/50		
								2/100	1/50		
										129/1795	109/883
	1992	7/100	7/50	3/100	1/50	2/100	5/50	1/100	1/50	18 sets	
		3/100	1/50	22/100	14/50	11/100	6/50	21/100	20/50		
		2/100	3/50			1/100	0/50				
20-100 m	1991	{0/100	0/47}	{0/100	0/47}	{0/100	0/50}	1/100	1/53		
		1/92	5/50	1/100	3/47	0/100	1/50	{0/100	0/50}		
		2/100	1/47	{0/100	0/47}	8/163	2/100	8/100	14/100		
		2/100	3/47	0/70	1/47	1/50	0/50	0/100	1/100		
						4/95	0/50				
										32/1870	44/1091
	1992	1/100	0/50	{0/100	0/50}	{0/100	0/50}	0/100	2/50	19 sets	
		1/100	0/50	{0/100	0/50}	0/100	3/50	{0/100	0/50}		
								1/100	5/50		
								0/100	2/50		
								1/100	0/50		
>100 m	1991	{0/100	0/47}	2/100	0/47	{0/50	0/50}	1/100	0/50		
		1/100	0/50			0/100	1/50				
		2/100	3/50								
										10/800	4/397
	1992	1/100	0/50	1/100	0/50	No effort		2/100	0/50	8 sets	
Totals											
Sharks/hooks		67/1592	58/783	97/970	54/468	108/1503	79/800	80/1660	97/987	352/5725	288/3038
No. of sets		16		10		15		17		58 sets	

Species composition and relative abundance of each species were similar for each gear type (Fig. 2). Eleven species occurred on both gear types. Overall, sandbar sharks, *Carcharhinus plumbeus*, comprised about 55% of the total catch on both gear types. Chesapeake Bay is a major nursery ground in the western North Atlantic for the sandbar shark (Colvocoresses and Musick, 1980; Musick et al., 1993), and except for three individuals, all sharks caught in the Bay were juvenile sandbar sharks (Fig. 2, inset boxes). Catch rates for sandbar sharks in the Chesapeake Bay nursery were much higher than the catch rates for all species combined outside the Bay. For this reason, analyses that included sandbar sharks were divided between efforts inside and outside the Bay. Sandbar sharks outside the Bay were the second-most abundant species taken on longlines fished in this area. The Atlantic sharpnose shark, *Rhizoprionodon terraenovae,* ranked second in overall abundance on both gear types; this small, schooling species was taken sporadically in large numbers at specific locations during each summer, and it was the most common species taken outside Chesapeake Bay. The remaining species occurred in low numbers throughout each summer.

Catch rates for five of the seven most common species were greater on monofilament gangions (Fig. 3). Overall, catch rates for the miscellaneous coastal species were higher on monofilament gangions, whereas catch rates for the miscellaneous offshore species were higher on steel gangions. Although mean CPUE's differed substantially between gears for several species, only the CPUE's for sandbar, Atlantic sharpnose, and sand tiger, *Odontaspis taurus*, sharks were statistically different (P>0.10 for all other species or species groups, probably reflective of the low sample sizes).

Catch rates were higher on monofilament gangions in all depth strata except outside the 100 m depth contour (Fig. 4a). Catch rates were significantly higher on monofilament gear in the Bay, nearshore (10-20 m), and mid-shelf (20-100 m) depth strata, and, although not statistically different, were 2.4 times higher on monofilament in the coastal (<10 m) depth stratum. Catch rates in offshore waters were slightly higher on steel gear. This was unexpected and in contrast to findings of Berkeley and

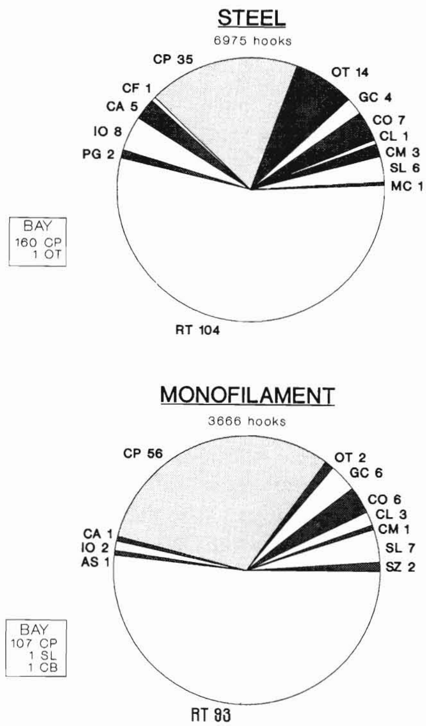

Figure 2.—Relative abundance of shark species taken on rope/steel and monofilament gangions on longline sets outside Chesapeake Bay. Catches for each gear type in the sandbar shark nursery ground inside Chesapeake Bay are noted in the boxes associated with each pie diagram. Species codes are listed in Table 1.

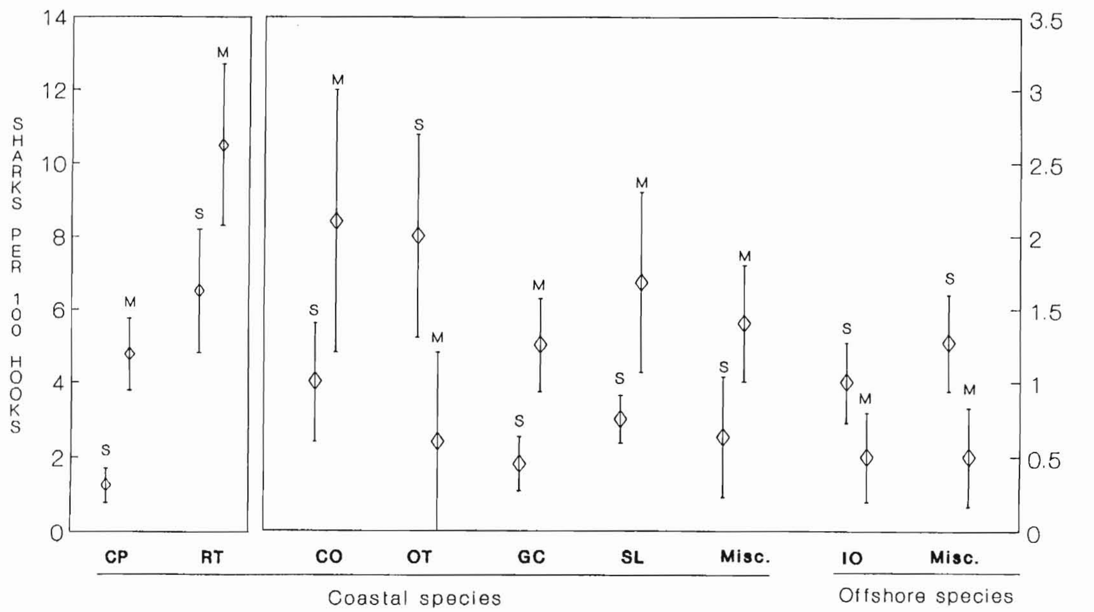

Figure 3.—Means ± one standard error for CPUE (sharks/100 hooks) on each gear type for the various shark species taken outside Chesapeake Bay. S = rope/steel gangions, M = monofilament. Species codes are listed in Table 1.

Campos (1988). They noted that shark catches in the offshore swordfish fishery were slightly higher on monofilament gangions (5.44 sharks/100 hooks) than on steel gangions (4.66 sharks/100 hooks), and that there was a mean loss of almost 5 hooks/100 monofilament gangions set. The species we took in the clearer waters of the offshore area are thought to be visually oriented predators; yet, although the monofilament is less visible in the water, when the "offshore species" listed in Figure 3 are pooled together, our catch rate on steel was more than 2:1 over that of monofilament.

The differences in CPUE between gear types was consistent throughout the sampling season, both inside (Fig. 4b) and outside the Bay (Fig. 4c). Although catch rates of juvenile sandbar sharks were more evenly distributed between gears in the Bay, mean CPUE's were always higher on monofilament gangions. Over the entire sampling period in the Bay the mean CPUE ± SE for monofilament gangions (26.0 ± 3.0) was significantly higher than that of steel gangions (20.6 ± 3.8). Mean CPUE's outside the Bay were higher on monofilament for every month and were significantly higher on monofilament during June and September. Over the survey period, mean CPUE's outside the Bay were significantly different between gears: Steel = 3.7 ± 0.7, monofilament = 6.9 ± 1.2.

Conclusions

The addition of monofilament gangions as an ancillary sampling effort of the VIMS shark longline program successfully increased the shark catch without a substantial increase in effort. The number of sharks collected for study nearly doubled, using only half again as many hooks. Over the 2-year period, catch rates were significantly higher on monofilament gangions. Monofilament has been a standard gear type for over a decade in the commercial fisheries, and our effort was initiated because of the success noted by commercial industry. Our results serve to highlight the widely divergent gear efficiencies. In the offshore swordfish fishery there is a general progres-

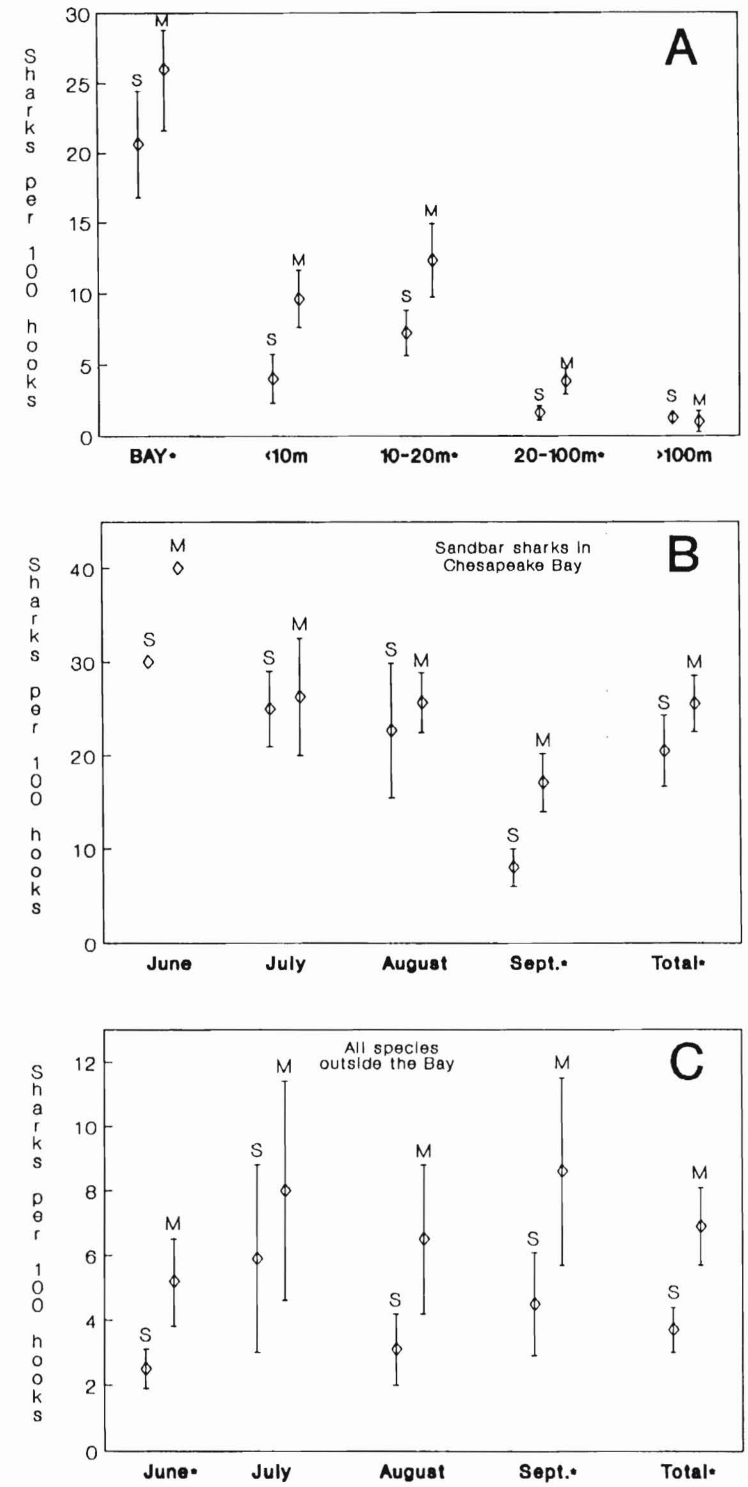

Figure 4.—Means ± one standard error for CPUE (sharks/100 hooks) on each gear type for designated depth strata and months. S = rope/steel catches, M = monofilament catches. Asterisks (*) indicate significant ($P<0.05$) differences between the means. A = catch rates by depth strata, B = catch rates of sandbar sharks in the Chespeake Bay nursery area, and C = catch rates for all species taken outside Chesapeake Bay.

sion in gear efficiency for both swordfish and pelagic sharks from "Yankee" gear to a monofilament/steel combination to monofilament (Berkeley et al., 1981; Berkeley and Campos, 1988), and our results of gear efficiency for coastal sharks are similarly divergent between gears.

Acknowledgments

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