Review of a Small-scale Pelagic Longline Fishery off Northeastern Brazil

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Introduction

The pelagic longline fishery off northeast Brazil began in 1956 with several Japanese longliners (leased by a Brazilian company) mainly targeting tunas (*Thunnus* spp.). This fleet consisted of 12 boats in 1959 (Paiva and Le Gall, 1975), and although quite good catches were achieved, fishing operations were suspended in 1964 owing to economic and political reasons. During 1976 and 1977, the fishery experienced a brief revival through the leasing of two Korean longliners; however, there was no significant effort until 1983 when a Brazilian company, "Norte Pesca," began to operate from Natal (Fig. 1) using relatively small vessels to target tunas and other large pelagic species of fish. This fleet expanded throughout the following 10 years and by 1997 consisted of 10 boats ranging in size from about 16 to 26 m.

As part of management regulations governing the present fishery, operators have been required to complete logsheets for each fishing trip. Information requested include location of fishing grounds, number of hooks used on the longline, time of setting and retrieving the gear, and composition of catches. In addition, at the end of fishing trips, biological data on the various species captured have routinely been collected by researchers. Although some of these data have been used in studies examining biological aspects of the main species, including their relative distribution and abundance (Hazin et al., 1990; 1994a), reproductive biology (Hazin et al., 1994b), and feeding habits (Hazin et al., 1994c), no studies have been done describing temporal and spatial variabilities in composition of catches.

To provide a brief overview of the changes in fishing strategy and catches, including some analysis of relative abundance and distribution of the main species, our aims in this paper were to collate yearly catch data from four vessels that have operated in the fishery since 1983 and compare these across defined areas and locations.

Material and Methods

This study was done using data from the logsheets of four longliners, (*Alfa*, *Argus*, *Rio Turi*, and *Soloncy Moura*) operating off northeastern Brazil from 1983 to 1997 (Fig. 1). All vessels used similar configurations of Japanese-style multifilament longlines (Shapiro, 1950; Suzuki et al., 1977). Each longline consisted of a multifilament mainline (Fig. 2A) with secondary lines (Fig. 2B) attached in clusters of 6–7 (termed "baskets") over approx. 360 m. Styrofoam bouys, each attached to a 25 m line were tied to the mainline after every cluster of hooks (Fig. 2A). The types of hooks used varied among 3 main brands (depending on availability) however, relative sizes remained similar throughout the period examined (Fig. 2C). The mean number of hooks (± SE) set per vessel per day was 975 ± 7. Fishing methods and operations were similar across the fleet with the mainline-set begining at about 0200 h and ending at dawn. The gear was then left to fish for about 6 h, before retrieval began at noon and ended at dusk. The primary bait was the Brazilian sardine, *Sardinella brasiliensis*, although some other species, including flying fish, *Cypselurus cyanopterus*, and squid, *Loligo* sp., were occasionally used.

Due to different oceanographic and biological conditions (Paiva and Le Gall, 1975; Hazin[1]) and for the purposes of this study, the total area fished (Fig. 1) was divided into the following three subareas for analysis:

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ABSTRACT—The annual catches of four small longliners operating off northeast Brazil from 1983 to 1997 were examined across different areas and locations. The total catch comprised tunas (30%), sharks (54%), billfishes (12%), and other fish species (4%). Fishing strategy and annual composition of catches showed large spatial and temporal variabilities with the dominant catches alternating among yellowfin tuna, Thunnus albacares*; gray sharks,* Carcharhinus *spp.; and blue shark,* Prionace glauca*. Catches of blue and gray sharks showed a significant interaction among seamounts, with gray sharks occurring in maximum abundance around those seamounts that had relatively deep summits and low-sloping depth profiles. Results are discussed in terms of the various factors that may have influenced distribution of effort.*

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[1] Hazin, F. H. V. 1993. Fisheries-oceanographical study on tunas, billfishes and sharks in the southwest equatorial Atlantic Ocean. D. Sc. Thesis, Tokyo Univ. Fish., 286 p.

Subarea I (north of lat. 5°S and west of long. 35°W) contains several large seamounts comprising the North Brazilian Chain and is influenced by the North Brazil Current.

Subarea II (north of lat. 5°S and east of long. 35°W) contains Atol das Rocas, Fernando de Noronha, and the Archipelago of St. Peter and St. Paul and is influenced by the South Equatorial Current.

Subarea III (south of lat. 5°S) includes a deep oceanic area with no seamounts or islands and is influenced by the Brazil Current.

Data from the four boats were grouped together (to provide a larger dataset) and total catches were standardized to yearly catch per unit of effort (CPUE), defined as the number of fish caught per 100 hooks per year (no. of fish/100 hooks/year). Catch records included identification at the species level, with the exception of sharks, which were collectively grouped prior to 1986. Most fishermen included catches of individual species during subsequent trips, although it wasn't until 1990 that all provided these data. Consequently, while the CPUE of total sharks was calculated using all hooks set in each year (Table 1), the CPUE of individual species of sharks was derived using the number of hooks pooled across only those trips that included a complete tabulation of catches (Table 2). In addition, because of difficulties in distinguishing some of the species of the genus *Carcharhinus*, for the purposes of this study, these were grouped under the category of "gray sharks," with the exception of *C. maou*, due to its easily identifiable characteristics. Data for two species of mako sharks (*Isurus oxyrinchus* and *I. paucus*) were also combined.

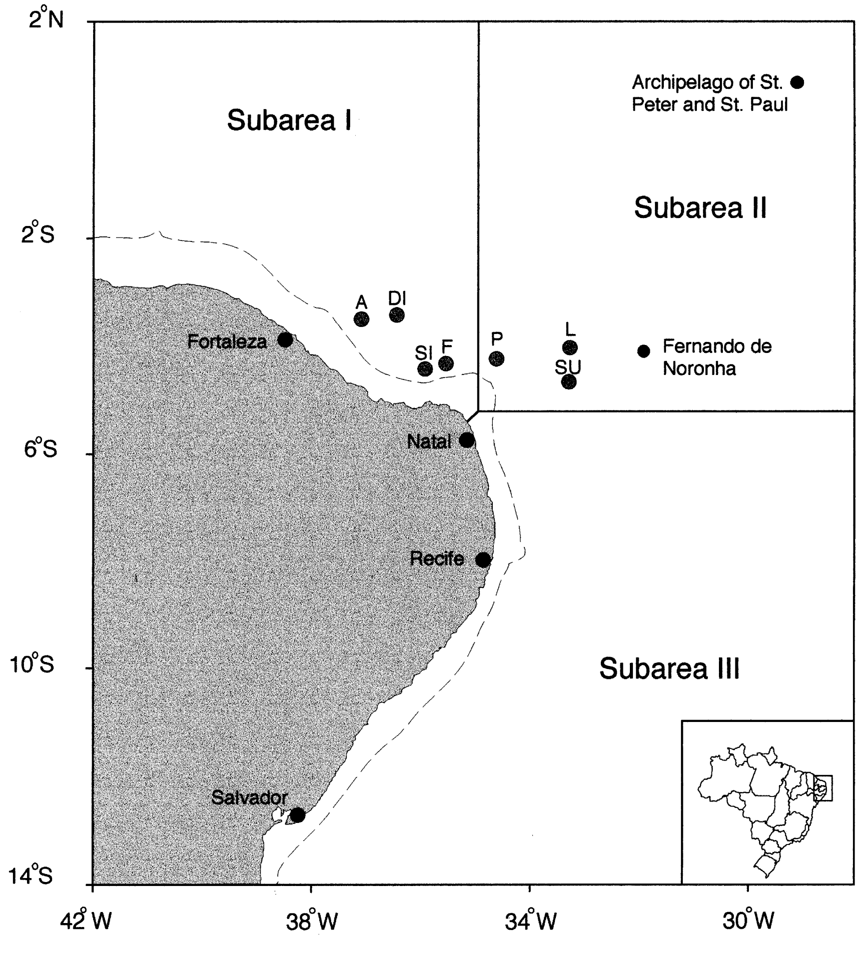

Figure 1.—Location of the area fished during the period examined, including the approximate position of seamounts: Aracati (A), Dois Irmãos (DI), Fundo (F), Sirus (SI), Pequeno (P), Leste (L), and Sueste (SU).

Analysis of Data

To examine temporal and spatial fluctuations in relative abundance and distribution throughout the fishery, yearly estimates of CPUE for groups of species were calculated for each of the three areas. Further, because significant differences were detected in the CPUE of sharks between areas (see Results and Discussion) the yearly CPUE's of gray and blue sharks, *Prionace glauca*, were calculated at seven seamounts located in subareas I and II (Fig. 1, Table 3). In deriving these data, longlines were considered to be in the vicinity of a seamount whenever they were located within 5 n.mi. of the 1,000 m isobath.

Yearly CPUE values for relevant groups and species from each area and for gray and blue sharks from each seamount were analyzed using Cochran's test for homogeneity of variances. Data were transformed if necessary and then analyzed in appropriate one and two-factor analyses of variance, respectively (Underwood, 1981). Significant differences detected in these analyses were investigated using Tukey's multiple comparisons of means test. The arithmetic mean yearly CPUE's used in these analyses are presented with their associated standard errors. Total yearly CPUE's combined across all areas, depths, and locations for all groups and species that showed sufficient catches were also calculated and graphed.

Results and Discussion

The yearly catch data collected during the period examined are provided in Tables 1 and 2. Tunas and sharks, and in particular, yellowfin tuna, *Thunnus albacares*, and gray and blue sharks were the dominant groups, accounting for almost 84% of the total catch.

There were no significant differences in the arithmetic mean yearly CPUE's of total tunas and billfishes across the three subareas examined (Fig. 3A, B, Table 4). While differences were de-

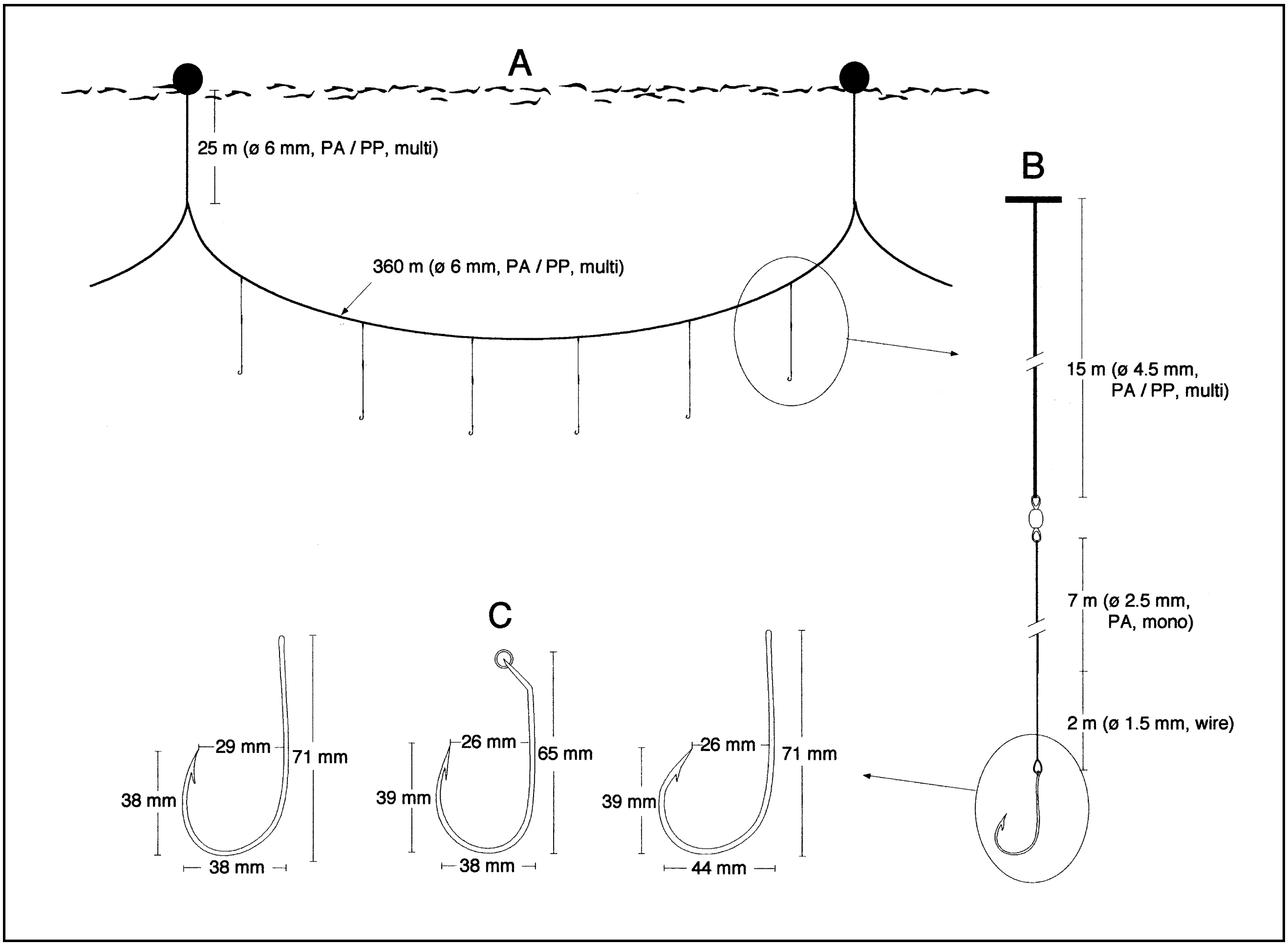

Figure 2.—Diagrammatic representation of typical (A) longline configuration; (B) secondary line; and (C) hooks used by the four vessels over the period examined. ø = diameter, mono = monofilament, multi = multifilament, PA = polyamide, PP = polypropylene.

Table 1.—Annual number of hooks used and catches (from 1983 to 1997) for various species and groups.

Year	Number of hooks	Tunas			Billfishes				Total sharks	Other fish combined
		Yellowfin	Albacore	Bigeye	Swordfish	Sailfish	White marlin	Blue marlin		
1983	34,719	129	194	16	23	10	42	9	156	228
1984	98,295	1,039	465	66	136	124	407	26	681	320
1985	222,738	1,827	666	158	276	142	240	83	1,381	379
1986	543,198	3,622	1,053	312	433	210	762	122	3,267	615
1987	513,427	1,906	418	347	443	243	452	84	5,835	448
1988	399,640	3,399	159	438	483	129	234	57	4,270	350
1889	275,526	3,973	182	207	361	76	217	74	2,054	143
1990	273,700	1,630	177	126	305	74	146	36	1,883	522
1991	101,670	868	51	40	135	11	37	21	970	53
1992	130,912	606	42	17	276	27	42	16	2,591	54
1993	89,222	93	0	1	169	8	16	10	3,371	35
1994	116,964	973	5	11	270	62	51	18	3,347	1
1995	172,100	597	21	4	555	18	25	18	8,394	12
1996	229,888	246	12	22	1,298	173	67	36	7,162	300
1997	74,060	72	6	9	280	20	21	13	1,738	17

tected between mean CPUE's of other fish combined (Fig. 3C, Table 4), Tukey's tests showed no definitive order of catches among the three subareas (Fig. 3C). In contrast, analyses showed that the mean CPUE of total sharks was significantly greater in subarea I than in subareas II and III (difference between means of up to 68%) (Fig.

Table 2.—Annual number of hooks used and catches (from 1986 to 1997) for individual species of sharks.

Year	Total no. of hooks	Blue (*Prionace glauca*)	Gray (*Carcharhinus* spp.)	Bigeye thresher (*Alopias superciliosus*)	Mako (*Isurus* spp.)	Ocean whitetip (*C. maou*)	Crocodile (*Pseudocarcharias kamoharai)*	Other shark species
1986	147,237	715	221	2	41	0	30	286
1987	338,704	1,345	973	18	74	18	21	41
1988	399,430	2,503	1,489	50	103	78	0	26
1889	274,126	945	934	11	56	63	0	37
1990	273,700	986	771	13	56	23	15	19
1991	101,670	360	577	6	9	15	1	2
1992	130,912	177	2,392	7	8	6	1	0
1993	89,222	105	3,212	5	8	0	0	41
1994	116,964	192	3,122	11	7	9	0	6
1995	172,100	238	8,082	15	24	5	0	30
1996	229,888	732	6,231	5	26	36	0	132
1997	74,060	263	1,455	0	8	7	0	5

Table 3.—The approximate location (midpoint) of seamounts examined, depth at the summit, and area contained within 5 n.mi. beyond the 1,000 m isobath. Seamounts in bold represent those located in subarea I.

	Seamount						
Item	**Aracati**	**Dois Irmãos**	**Fundo**	**Sirus**	Pequeno	Leste	Sueste
Location (lat.)	**3°20' S**	**3°20' S**	**3°52' S**	**4°00' S**	3°50' S	3°45' S	4°16' S
(long.)	**37°30' W**	**36°38' W**	**35°22' W**	**35°55' W**	34°44' W	33°12' W	33°15' W
Depth at summit (m)	**254**	**370**	**214**	**233**	124	176	38
Area (km^2)	**4,837**	**1,110**	**2,815**	**5,075**	833	952	833

Table 4.—Summaries of *F* ratios from analysis of variance to determine effects on CPUE due to different areas for total tunas, sharks, billfishes, and other fish combined between 1983 and 1997 and for blue and gray sharks between 1987 and 1997. Because 5 and 3 replicate CPUE data were missing from each analysis respectively, we substituted means of the remaining replicates and reduced the degrees of freedom accordingly. The transforms used to stabilize variances (if required) are also listed. *significant (*P* = 0.05); **significant (*P* = 0.01).

Source of variation	df	Total tunas	Total billfishes	Total sharks	Other fish combined	df	Blue shark	Gray shark
		ln(x+1)		ln(x+1)				ln(x+1)
Area	2	0.37	0.75	14.54**	4.482*	2	22.50**	36.60**
Residual	37					30		

3D, Table 4). This increase in CPUE may be attributed to the significant increase in catches of gray sharks in subarea I and the effects on total catches of sharks, since their mean CPUE was 9 times lower in subarea II and almost zero in subarea III (Fig. 3E, Table 4). Although much lower, the catches of blue sharks displayed the opposite trend and were significantly greater in subareas II and III than in subarea I (Fig. 3F, Table 4).

Possible explanations for the observed anomaly between the CPUE of gray and blue sharks may be the fishing location in subarea I and species-specific variabilities in habitat preference (Hazin et al., 1990). For example, unlike subareas II and III, which mainly comprise deep ocean, many of the sets in subarea I were done in the vicinity of seamounts that were relatively shallow over large areas (see Table 3). Because previous studies have shown that the blue shark typically is an oceanic species, its relative abundance might be expected to decline across these areas (Strassburg, 1958; Hazin, et al., 1990). In support of this, the mean CPUE of blue sharks was consistently low across individual seamounts (Fig. 4) and showed little variability since Tukey's test for a significant interaction detected between seamounts and groups of sharks (Table 5) failed to detect any significant differences in mean CPUE of this group among the seamounts examined (Fig. 4, Table 5).

Conversely, the CPUE of gray sharks did show an effect due to seamounts and was significantly greater (difference between means of up to 95%) at those seamounts that had relatively deep summits (e.g. 233–370 m) and were shallow over a large area (i.e. Aracati, Dois Irmãos, Fundo, and Sirus) than those characterized by shallow summits (38–176 m) and steep depth profiles (i.e. Pequeno, Leste, and Sueste). In the absence of any data describing oceanographic conditions and habitats at these different types of seamounts, it is difficult to determine possible causes for the observed increase in CPUE at the seamounts with deeper summits and low-sloping depth profiles. Previous studies have shown, however, that seamounts in this category may have more turbulence, due to the interaction between oceanic currents and the submarine relief, that results in the formation of upwellings and possibly "Taylor Columns" (Rogers, 1994; Travassos et al., In press). The extent to which these sorts of processes may facilitate primary production and consequent cascading effects throughout the trophic chain is unknown but, given the observations in the present study, they may have had some influence that contributed to the greater relative abundance of gray

Table 5.—Summaries of *F* ratios from analysis of variance to determine effects on yearly CPUE for two groups of sharks and different seamounts. Because 10 CPUE data were missing, we substituted means of the remaining replicates and reduced the degrees of freedom accordingly. The sqrt(x+1) transform was used to stabilize variances. **significant (*P* = 0.01).

Source of variation	df	CPUE
Seamount	6	6.38**
Shark group	1	97.57**
Interaction	6	14.36**
Residual	130	

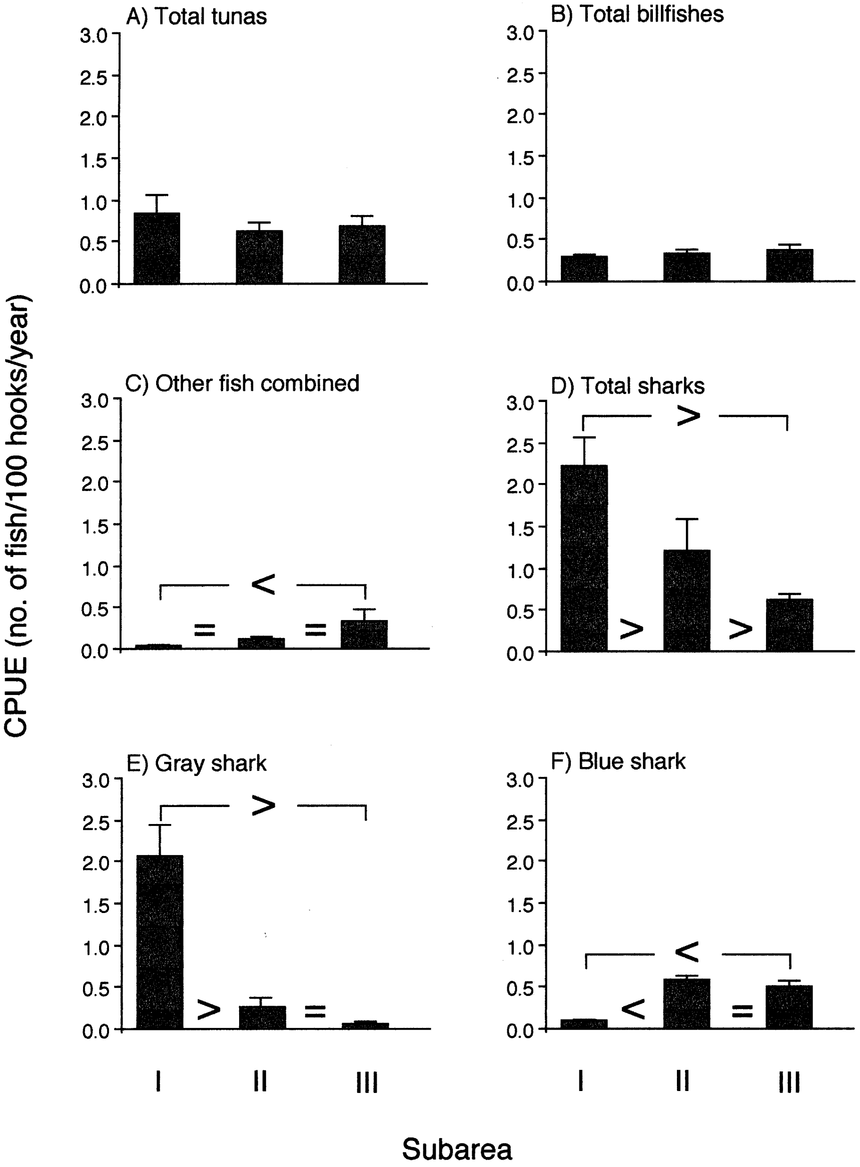

Figure 3.—Differences in arithmetic mean yearly CPUE (±SE) of (A) total tunas, (B) total billfishes, (C) other fish combined, (D) total sharks, (E) gray shark, and (F) blue shark across each of the three areas. <, >, and = indicate direction of differences detected in Tukey's comparison of means test.

sharks in subarea I and the significant increase in their CPUE.

The data presented in Figures 5, 6, 7, and 8 show quite large temporal fluctuations of total yearly CPUE (combined across all areas and depths) of most groups and species examined. For example, with the exception of the first year of the fishery, yellowfin tuna was always the most abundant species of tuna, with a yearly CPUE varying from 1.44 in 1989 to 0.10 in 1997 (Fig. 6). The CPUE of albacore, *Thunnus alalunga*, showed less variability but steadily decreased from 0.56 in 1983 to 0.001 in 1993, whilst the yearly CPUE of bigeye tuna, *T. obesus*, was always very low (Fig. 6). Catches of gray and blue sharks showed similar fluctuations with blue shark most abundant from 1986 until June 1991 before the CPUE of gray sharks began to increase, peaking in 1995 (Fig. 7). Although total catches of billfishes remained fairly stable (Fig. 5), individual catches of swordfish, *Xiphias gladius*, steadily increased from 1991 (Fig. 8).

Many of these temporal variabilities can be explained with respect to changes in overall fishing strategy over the past 14 years, summarized in 5 distinct periods:

Period 1 (July 1983–June 1986). Tunas (i.e. mainly yellowfin tuna) and

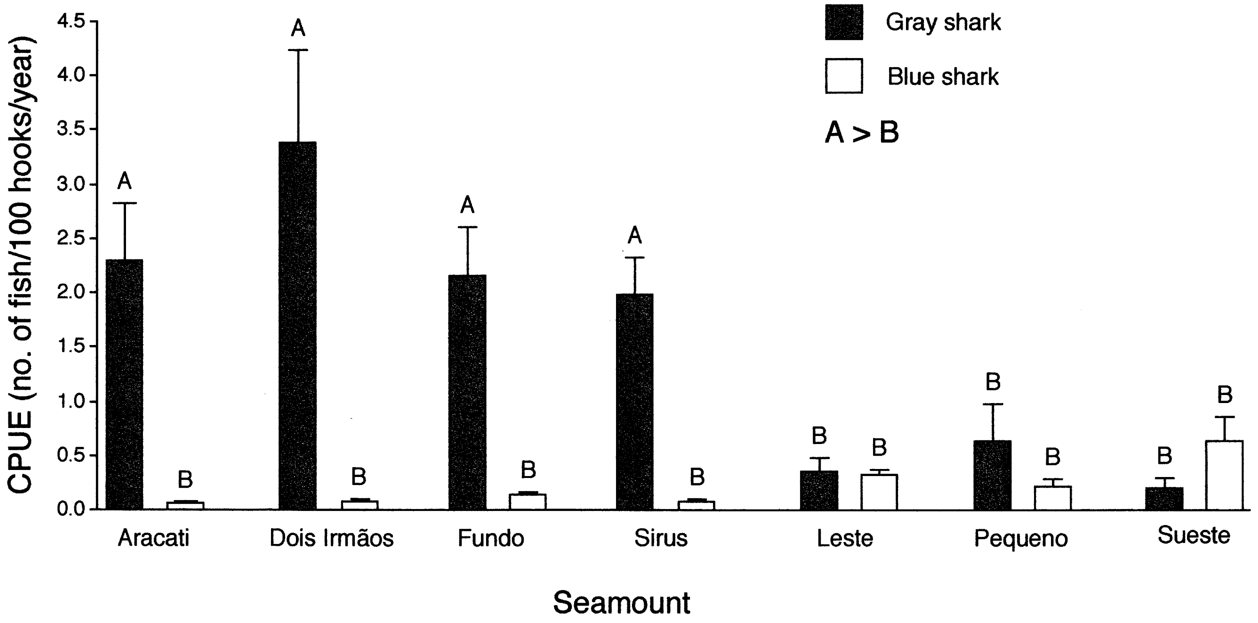

Figure 4.—Differences in arithmetic mean yearly CPUE (±SE) of (A) gray shark, and (B) blue shark across different seamounts. <, >, and = indicate direction of differences detected in Tukey's comparison of means test.

billfishes (swordfish, sailfish, *Istiophorus albicans*, white marlin, *Tetrapturus albidus*, and blue marlin, *Makaira nigricans*) were the main target groups whilst sharks were avoided.

Period 2 (July 1986–December 1987). Along with tunas and billfishes, sharks (mainly the blue) became a target group.

Period 3 (January 1988–June 1991). Fishing grounds were discovered off the Archipelago of St. Peter and St. Paul, with associated increases in catches of yellowfin tuna, shifting effort towards this species.

Period 4 (July 1991–June 1996). Fishing effort was concentrated over shallow seamounts, where species comprising gray sharks were abundant. Catches were mainly dominated by these sharks.

Period 5 (July 1996–June 1997). Although gray sharks were still the dominant group, the CPUE of swordfish rose sharply owing to a concentrated effort involving the use of light sticks above the hooks and squid as bait.

The initial diversification in effort that resulted in sharks being included as a target group (period 2) mainly occurred because of an increased awareness of their abundance and availability. In contrast to many international longline fisheries, which tend to remove the fins and discard the carcass at sea, in this fishery all shark carcasses are landed and sold at the local market. However, because of the low price of their meat, prior to June 1986 the return paid to fishermen was half that for tunas and billfishes. In July 1986, the fishing company standardized the return for all species caught after it realized that although sharks were worth less than other species, their abundance meant that production could be more than doubled. Facilitating this diversification of effort was an established local market for shark products, (e.g. frozen fillets) that had developed from the steady production of shark meat during the first 3 years of the fishery.

From January 1988 and during the first quarter of each consecutive year (period 3), vessels began to operate in the vicinity of the Archipelago of St. Peter and St. Paul to target yellowfin tuna that aggregate in large numbers to feed on dense schools of spawning flying fish (Hazin[1]). As a result, the CPUE of this species more than tripled in the first 2 years after the new fishing grounds were discovered (Fig. 6). This contributed to an overall rise in the CPUE of total tunas (Fig. 5) and also resulting in a slight drop in the CPUE of sharks (1988–90) due to a shift in effort away from their areas of maximum abundance (i.e. the seamounts in subarea I) (Fig. 5).

After 1992 (during period 4), vessels concentrated around the many seamounts mainly located in subarea I to target gray sharks (Fig. 7). Contributing factors towards the greater shift in effort on this group were 1) the discovery of large abundances of these individuals above those seamounts in subarea I that are shallow over a large area (see discussion above) and 2) an increase in the price of shark fins for international markets.

Prompted by the leasing of an American swordfish longliner, vessels began to shift fishing effort again during mid 1996 (period 5), using light sticks above the hooks and squid as bait to target swordfish. Recent modifications to gear, particularly the use of monofilament mainlines, should see this trend increase as fishermen adopt the latest technology and methods developed in other fisheries (Bjordal, 1989; Løkkeborg and Bjordal, 1992).

It is apparent that a number of factors have contributed to changes in fishing strategy during the past 14 years. Many of the shifts in effort appear to

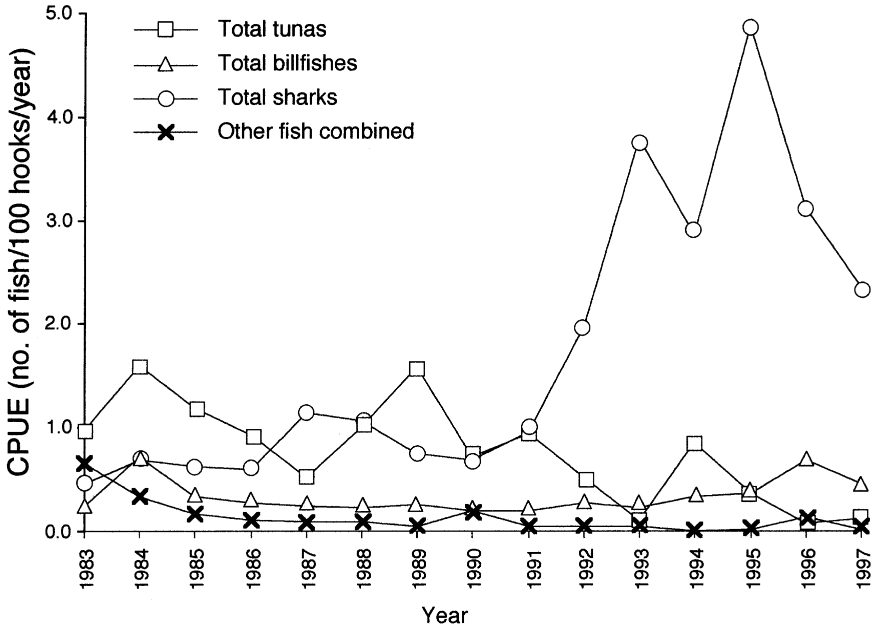

Figure 5.—Yearly CPUE estimates of total tunas, billfishes, sharks, and other species combined throughout the period examined.

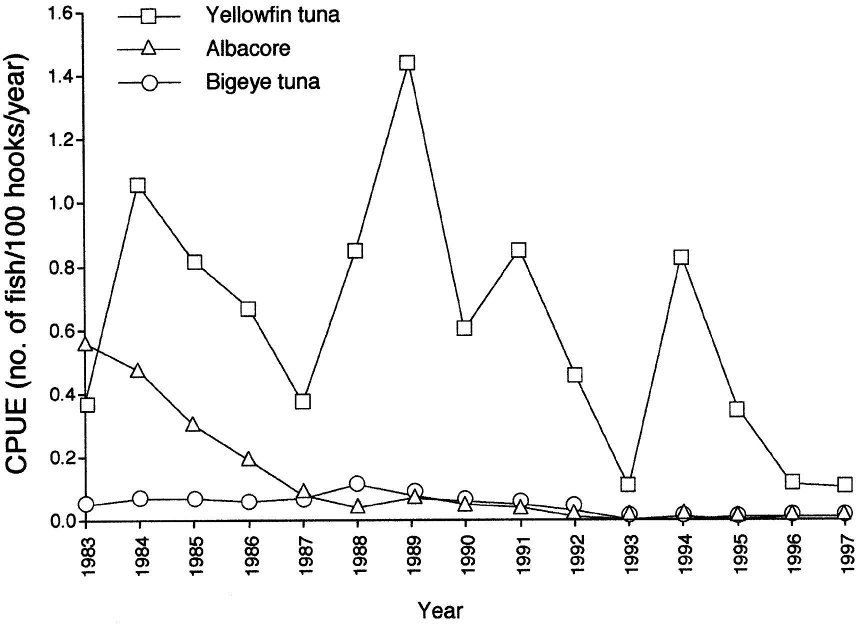

Figure 6.—Yearly CPUE estimates of yellowfin tuna, albacore, and bigeye tuna throughout the period examined.

have been either market orientated, reflecting variabilities in consumer demand for various species, or as a result of the discovery of new fishing grounds and stocks. While few, if any, of the changes in the first 13 years are gear related, given some of the more recent developments (e.g. use of monofilament) and that most of the fishing areas have been fully explored, these sorts of changes are likely to affect CPUE in the future. It is important, therefore, for the continued sustainability of the fishery, that monitoring of catch and effort data is maintained.

Acknowledgments

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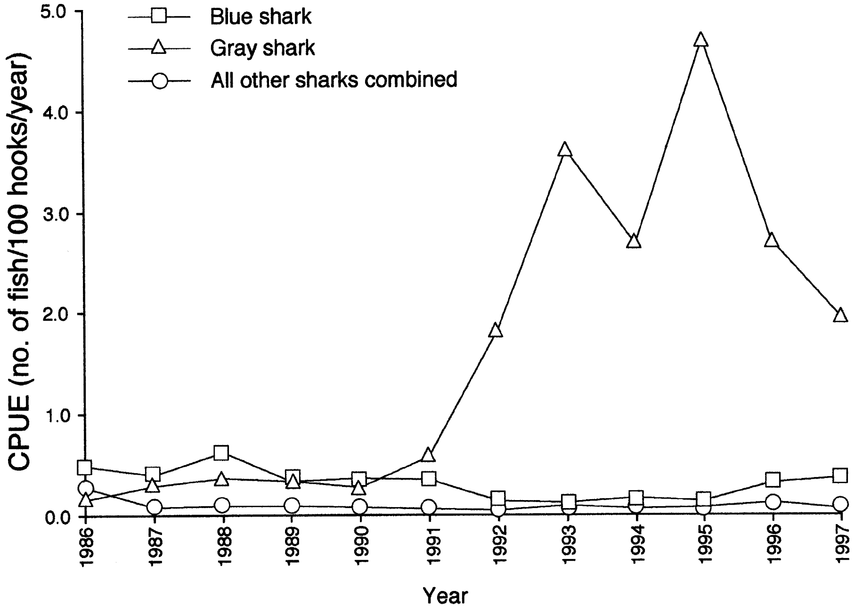

Figure 7.—Yearly CPUE estimates of gray shark, blue shark, and other sharks combined throughout the period examined.

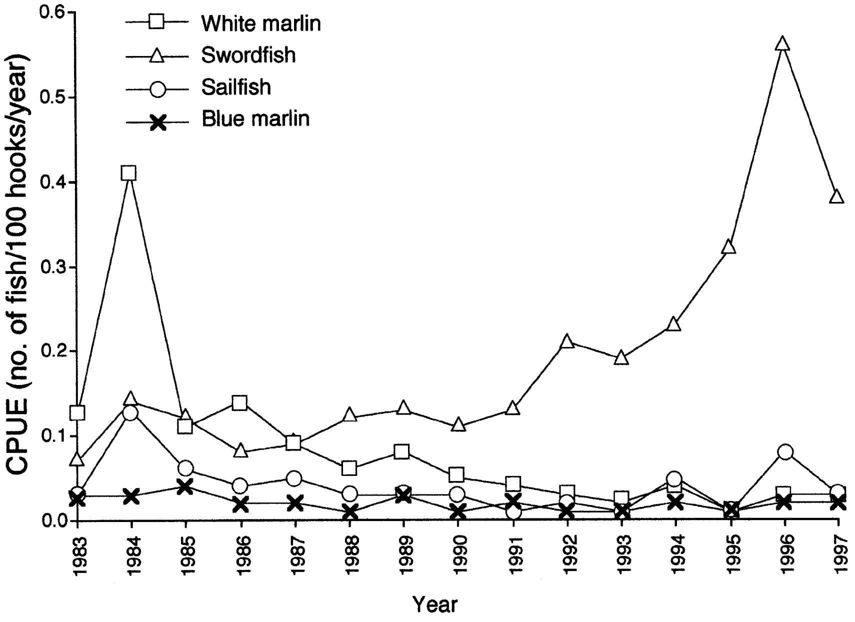

Figure 8.—Yearly CPUE estimates of white marlin, swordfish, sailfish, and blue marlin throughout the period examined.

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