Abstract.–We report on 175 landings from 106 longline and 69 gillnet boats operating in the eastern North Atlantic Ocean and Mediterranean Sea, July 1991 to July 1992. Information on the catch and biology of five shark species (*Isurus oxyrinchus*, *Prionace glauca*, *Alopias superciliosus*, *Alopias vulpinus*, and *Sphyrna zygaena*) is analyzed and contrasted with swordfish (*Xiphias gladius*) landings. A total of 51,205 fish were sampled, of which 40,198 were sharks, 9,990 swordfish, and the rest other bony fish. Spatial, temporal, and gear analyses were performed to show the importance of shark bycatch in longline and gillnet fisheries operating from the south of Spain. We present information on population structures of the shark species, along with hypotheses about shortfin mako movements as suggested by landing data.

Manuscript accepted 18 February 1998.
Fish. Bull. 96:667–685 (1998).

Pelagic sharks associated with the swordfish, *Xiphias gladius*, fishery in the eastern North Atlantic Ocean and the Strait of Gibraltar

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The Spanish longline fleet operates in the eastern North Atlantic (FAO fishing area 27), north-central Atlantic (FAO 34), and the Mediterranean Sea (FAO 37). Sharks are the most important bycatch of swordfish (*Xiphias gladius* Linnaeus, 1758) fishing in all of these areas (Moreno and Morón, 1992b; Mejuto and Garcés[1]; Mejuto[2]). The fleets use surface longlines to catch swordfish and some sharks have become target species as well.

Three types of longliners operate along the south Spanish coast: "coastal longliners" that fish two to five days in the area of the Strait of Gibraltar and that in some cases use gill nets in spring and summer; "offshore longliners" that spend 15 to 25 days fishing as far south as Senegal; and "long distance freezer longliners" that operate mainly in the tropical Atlantic Ocean (Gulf of Guinea and off Brazil). Little is known about shark fishing off southern Spain (García, 1970; Bravo and Santaella, 1973; Amorín et al., 1979; Garcés and Rey, 1983; Moreno and Morón, 1992b); more is known about shark catches from the northern Spanish longline fleet (Mejuto and Garcés[1]; Mejuto[2]).

The biology of eastern Atlantic pelagic sharks has not been well investigated although detailed taxonomic studies (Moreno, 1982), morphology and growth studies (Blasco and Muñoz-Chápuli, 1981; Muñoz-Chápuli and Blasco, 1984; Moreno and Morón, 1992b), reproduction (Muñoz-Chápuli, 1984; Moreno et al., 1989; Moreno and Morón, 1992a), and faunistic studies (Belloc, 1934; Lozano Cabo, 1950; Bravo, 1974; Bravo[3]) are available.

The most common shark species taken by longliners are blue shark, *Prionace glauca* (Linnaeus, 1758) and shortfin mako shark, *Isurus oxyrinchus* Rafinesque, 1810, which represent 80% of the total shark bycatch (Garcés and Rey, 1983; Moreno and Morón, 1992b). Other sharks caught include the porbeagle, *Lamna nasus* (Bonnaterre, 1788), the hammerheads, *Sphyrna* spp., the bigeye thresher, *Alopias superciliosus* (Lowe, 1839), the common thresher, *Alopias vulpinus*

[1] Mejuto, J., and A. Garcés. 1984. Shortfin mako, *Isurus oxyrinchus*, and porbeagle, *Lamna nasus*, associated with longline swordfish fishery in NW and N Spain. ICES, Council Meeting 1984/G: 72.

[2] Mejuto, J. 1985 Associated catches of sharks, *Prionace glauca*, *Isurus oxyrinchus* and *Lamna nasus*, with NW and N Spanish swordfish fishery, in 1984. ICES, Council Meeting 1985/H: 42.

[3] Bravo, J. 1973. Elasmobranchii off Canary Islands. ICES, Council Meeting 1973/J: 17.

(Bonnaterre, 1788), and the requiem sharks, *Carcharhinus* spp. (Garcés and Rey, 1984). Bony fish are caught occasionally, including the northern bluefin tuna, *Thunnus thynnus* (Linnaeus, 1758), bigeye tuna, *Thunnus obesus* (Lowe, 1839), albacore tuna, *Thunnus alalunga* (Bonnaterre, 1788), oilfish, *Ruvettus pretiosus* Cocco, 1829, escolar, *Lepidocybium flavobrunneum* (Smith, 1849), and longbill spearfish, *Tetrapturus pfluegeri* Robins and de Sylva, 1963, (Mejuto and Garcés[1]; Mejuto[2]).

Materials and methods

Between July 1991 and July 1992, 106 longline and 69 gillnet landings (85.4% and 87.3% respectively of total longline and gillnet landings) were sampled at the Algeciras fish market (Cádiz, southern Spain), the largest market in southwestern Spain receiving 80% of the longline catch from this area (Anonymous, 1986). Data on the number of fish landed by species, days of each trip, active fishing days, number of sets and hooks for longliners, and net length and fishing time for gillnetters were collected during interviews with skippers.

The longline catch rate was calculated as hook rate (HR=number of fish/1,000 hooks), and gillnet catch rate was calculated as the average net length by trip multiplied by the number of sets. No total catch and effort data were available; catch rates are approximate indicators and do not reflect actual abundance. Fishing time was not included in effort calculations because it was constant for every boat and gear. The gears were set at dusk and retrieved before sunrise. Longlines ranged from 18 to 29 km in length and on average had 1500 hooks (range: 475 to 2500), set at a depth of 11 to 55 m. Gill nets were 2.5 km long, 14 m high, and had a mesh size of 40 cm.

All fish landed were identified to species level and counted. Most sharks were sexed and measured to the nearest centimeter for total length (TL) or fork length (FL), or both. Total length was measured from the rear tip of the upper caudal lobe to the snout tip, along the horizontal line of the body axis. Length data were grouped in 5-cm intervals of FL (shortfin mako and blue sharks) and TL (thresher and hammerhead sharks) for length-frequency analysis. Biometrical relationships between sexes were performed by simple linear regression analysis when the sample size was sufficiently large (shortfin mako, blue, and bigeye thresher sharks). Standard length (SL) has been used as the reference length for the relation with fork length (FL), total length (TL), and upper caudal lobe (UCL) (dorsal-caudal margin). The relation between FL and TL was also calculated. The area sampled (Fig. 1) was divided into 5° latitude sectors from 20°N to 40°N. Sectors 4 and 5 have the same latitude (35°N–40°N) but different longitudes, 3°W–8°W for sector 5, 8°W–13°W for sector 4. This division separates the gillnet fishing ground (sector 5) from the longline Atlantic area (sector 4).

A chi-square (χ^2) test was performed to test the fit of the sample to a normal distribution and to observe the variations in species by sector and month. Strong bias was expected because of the effect of discarded fish at sea. Single factor ANOVA was performed to compare the means of the samples by area.

Results

A total of 40,198 sharks and 11,007 bony fish were sampled from 175 landings from July 1991 to July 1992 (Table 1). The proportion of sharks landed was higher with longlines than with gill nets, but this might be related to the seasonal abundance of sharks and swordfish in the Strait of Gibraltar during the period when gill nets were used (Fig. 2).

The most common species landed by longlines in the areas studied were blue shark, shortfin mako shark, and swordfish (Table 2). Other chondrichthyans were less common, some rarely occurring in more than 10% of the landings.

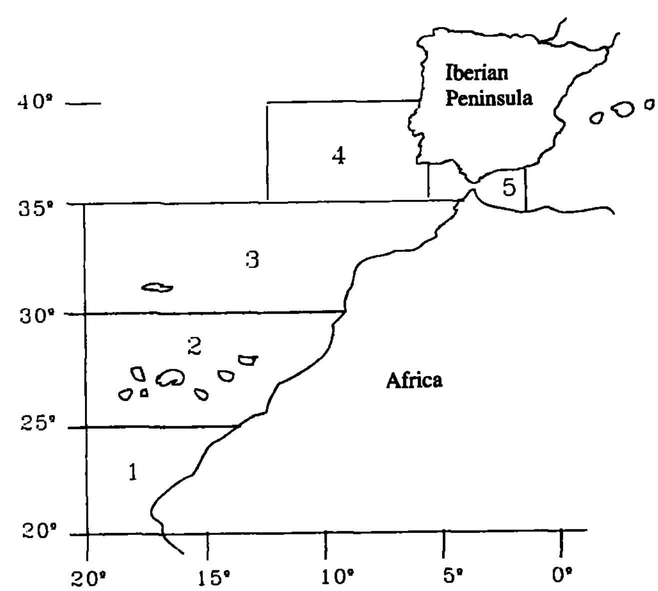

Figure 1
Map of the study area showing the five sectors into which the area was divided for the present paper.

Proportions of swordfish and the five most common shark species landed by longlines were significantly different (χ^2=5.41; df=20; P<0.001) in each sector (Table 3). The highest proportion of fish in all the sectors, except one (sector 1), was that of blue sharks, whereas the lowest proportion in all five sectors was that of the common thresher shark. Swordfish occurred with decreasing proportion from south to north in the Atlantic sectors, reaching a minimum in the Mediterranean sector. Shortfin mako sharks steadily decreased from sector 1 to sector 4. The proportion of sharks, overall, was greater than the proportion of swordfish in all sectors, and sharks were included in at least 80% of the landings in all sectors, where they were slightly greater in numbers than swordfish, except in sector 1.

Table 1

Total number of fish sampled from 175 landings at the Algeciras (Cádiz) fish market and percentage by species from July 1991 to July 1992.

Species	Number	Percentage
Isurus oxyrinchus	5947	11.6
Prionace glauca	32,661	63.7
Alopias vulpinus	52	0.1
Alopias superciliosus	557	1.1
Sphyrna zygaena	757	1.4
Other sharks	224	0.4
Total sharks	40,198	78.5
Xiphias gladius	9990	19.5
Other bony fish	1017	2.0
Total	51,205	100.0

The proportional distribution of fish from gillnet landings was significantly different from that of fish from longline landings in the same sector (χ^2=2.97; df=5; P<0.001) (Table 3). Gill nets were operated only in sector 5. Swordfish represented a much higher proportion in total gillnet landings than in longline landings; sharks represented only one third of total gillnet landings. The drop in the relative importance of sharks was due mainly to a much lower number of blue sharks in gillnet landings than in longline landings (8% compared with 82%). Bigeye thresher sharks slightly increased in landings (from 0.01% to 6%).

The proportions of fish landed by longline differed significantly by month (χ^2=3.55; df=48; P<0.001) (*A. vulpinus* not considered) (Table 4), although blue shark was always the most predominant. Swordfish and shortfin mako sharks had the next highest proportions, whereas the other species never reached more than 5% of monthly catches. Sharks always accounted for more than 50% of the monthly catch, and more than 80% in 10 out the 13 months sampled.

Proportions of fish in gillnet landings also differed significantly by month (χ^2=1.10; df=35; P<0.001) (March not considered) (Table 4). Swordfish had the highest proportion, except during the month of April. Blue sharks were taken in small proportions for most months (0–37%). The proportion of thresher sharks varied from month to month. Bigeye thresher sharks were taken at a maximum (10%) in August 1991 and July 1992; common thresher sharks also reached 10% in January 1992. The proportion of sharks exceeded

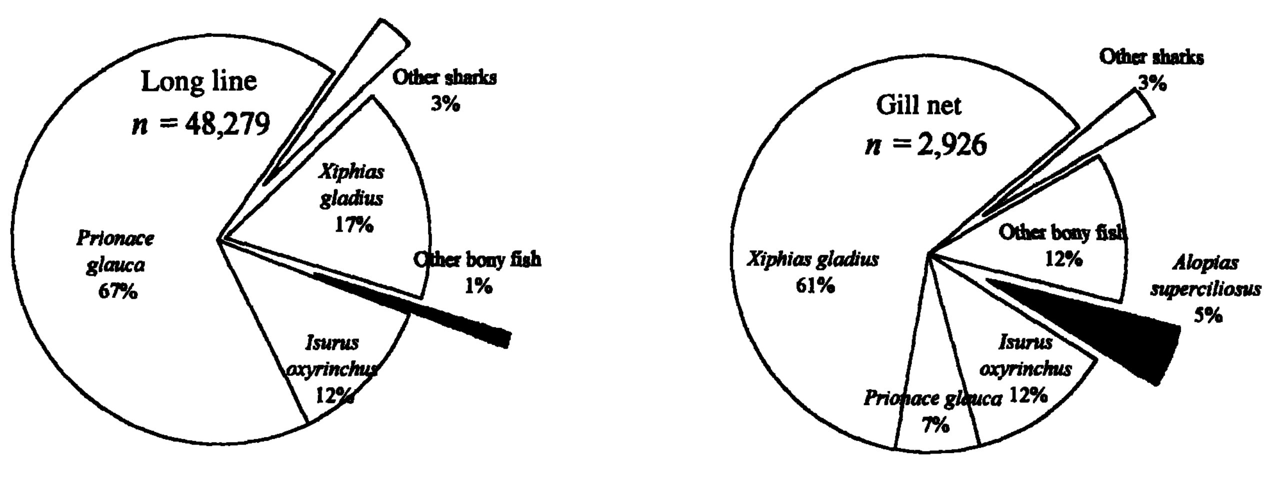

Figure 2

Species composition (% of fish) landed by the gillnet and longline fisheries operating in the eastern Atlantic Ocean and western Mediterranean Sea.

Table 2

Species occurrence by number of landings and proportion (%) by gear.

Species	Appearance (no. of landings)			Percentage		
	Longline	Gillnet	Total	Longline	Gillnet	Total
Isurus oxyrinchus Rafinesque, 1810	102	45	147	96.2	65.2	84.0
Isurus paucus Guitart Manday, 1966	11	1	12	10.4	1.4	6.8
Lamna nasus (Bonnaterre, 1788)	2	5	7	1.9	7.2	4.0
Alopias superciliosus (Lowe, 1839)	61	23	84	57.5	33.3	48.0
Alopias vulpinus (Bonnaterre, 1788)	11	11	22	10.4	15.9	12.6
Carcharhinus spp.	7	0	7	6.6	0	4.0
Carcharhinus falciformis (Bibron, 1841)	2	0	2	1.9	0	1.1
Galeocerdo cuvier (Péron and Lesueur, 1822)	1	0	1	0.9	0	0.6
Prionace glauca (Linnaeus, 1758)	102	19	121	96.2	27.5	69.1
Sphyrna zygaena (Linnaeus, 1758)	43	26	69	40.6	37.7	39.4
Mobula mobular (Bonnaterre, 1788)	2	0	2	1.9	0	1.1
Polyprion americanus (Schneider, 1801)	2	0	2	1.9	0	1.1
Coryphaena hippurus Linnaeus, 1758	3	7	10	2.8	10.1	5.7
Brama brama (Bonnaterre, 1788)	0	1	1	0	1.4	0.6
Sparus pagrus Linnaeus, 1758	1	0	1	0.9	0	0.6
Lepidocybium flavobrunneum (Smith, 1849)	37	1	38	34.9	1.4	21.7
Ruvettus pretiosus Cocco, 1829	5	0	5	4.7	0	2.8
Acanthocybium solandri (Cuvier, 1832)	1	1	2	0.9	1.4	1.1
Auxis spp.	0	4	4	0	5.8	2.3
Auxis rochei (Risso, 1810)	0	1	1	0	1.4	0.6
Katsuwonus pelamis (Linnaeus, 1758)	1	2	3	0.9	2.9	1.7
Thunnus alalunga (Bonnaterre, 1788)	6	3	9	5.7	4.3	5.1
Thunnus albacares (Bonnaterre, 1788)	4	0	4	3.8	0	2.3
Thunnus obesus (Lowe, 1839)	16	1	17	15.1	1.4	9.7
Thunnus thynnus (Linnaeus, 1758)	4	3	7	3.8	4.3	4.0
Makaira nigricans Lacépède, 1801	0	4	4	0	5.8	2.3
Tetrapturus spp.	14	21	35	13.2	30.4	20.0
Tetrapturus albidus Poey, 1860	1	2	3	0.9	2.9	1.7
Xiphias gladius Linnaeus, 1758	101	63	164	95.3	91.3	93.7
Total landings	106	69	175	60.6	39.4	100.0

Table 3

Total number of the five most important shark species and swordfish recorded in landings and percentage by species, gear, and sector. Sectors (1–5) are indicated under gear type.

	Number						Percentage					
	Longline					Gillnet	Longline					Gillnet
	1	2	3	4	5	5	1	2	3	4	5	5
I. oxyrinchus	915	1648	2211	578	241	354	17	14	12	7	10	14
P. glauca	1865	7757	14207	6538	2082	212	34	64	76	76	82	8
A. vulpinus	4	1	7	2	2	36	0	0	0	0	0	1
A. superciliosus	28	266	101	7	9	146	1	2	1	0	0	6
S. zygaena	188	39	392	82	2	54	3	0	2	1	0	2
Total sharks	3000	9711	16918	7207	2336	802	55	80	90	84	92	31
X. gladius	2410	2426	1822	1386	199	1747	45	20	10	16	8	69
Total	5410	12137	18740	8593	2535	2549	11	24	38	17	5	5

swordfish in only one of nine months sampled for gillnet landings.

Shortfin mako shark

Longline catch rates are shown in Table 5; Atlantic catch rates were always higher than those in the Mediterranean. Variation in the longline catch rate (Table 6) was at a minimum in December and May, peaking in April and September. In gillnet fishing (Table 7), shortfin mako shark catch rates were relatively lower than swordfish catch rates.

Table 8 gives biometrical information by sex, and longline and gillnet frequency distributions of different lengths by sex are presented in Figures 3 and 4. The distribution was not significantly different between sexes in longline (χ^2=54.4; df=39; P>0.05) and gillnet (χ^2=20.5; df=23; P>0.5) landings. The distribution by size of males varied significantly by sector (F=28.796; df=5, 1428; P<0.001). The distribution by size of females also varied significantly by sector (F=14.985; df=5, 1429; P<0.001).

The maximum size of females landed by longlines tended to increase from sector 1 to sector 3 (Fig. 5A). The maximum size of males tended to increase in Atlantic sectors from south to north (Fig. 5B). Smallest maximum sizes for both sexes occurred in the Mediterranean Sea, and in sector 1 for males. Gill nets catch bigger females and smaller males than do longlines in the same sector. The monthly variations

Table 4

Monthly longline and gillnet catch distribution for the five most important shark species and for swordfish by number of fish (n) and percentage (%). Species codes: IO = *Isurus oxyrinchus*; PG = *Prionace glauca*; AV = *Alopias vulpinus*; AS = *Alopias superciliosus*; SZ = *Sphyrna zygaena*; TOT-SHX = Total sharks; XG = *Xiphias gladius*;

Gear and month	IO		PG		AV		AS		SZ		TOT-SHX		XG		Total
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
Longline															
Jul 91	224	16.85	992	74.64	2	0.15	31	2.33	21	1.58	1270	95.56	59	4.44	1329
Aug 91	891	19.96	2865	64.19	1	0.02	3	0.07	147	3.29	3907	87.54	556	12.46	4463
Sep 91	422	15.93	2158	81.46	0	0	7	0.26	28	1.06	2615	98.72	34	1.28	2649
Oct 91	584	9.57	3338	54.68	0	0	32	0.52	131	2.15	4085	66.91	2020	33.09	6105
Nov 91	970	14.10	4333	62.99	4	0.06	25	0.36	252	3.66	5584	81.17	1295	18.83	6879
Dec 91	30	12.35	105	43.21	0	0	5	2.06	0	0	140	57.61	103	42.39	243
Jan 92	863	10.02	6117	71.03	4	0.05	110	1.28	30	0.35	7124	82.72	1488	17.28	8612
Feb 92	868	9.07	6988	73.03	2	0.02	135	1.41	79	0.83	8072	84.36	1497	15.64	9569
Mar 92	423	9.04	3208	68.53	1	0.02	54	1.15	1	0.02	3687	78.77	994	21.23	4681
Apr 92	109	10.64	913	89.16	0	0	1	0.10	0	0	1023	99.90	1	0.10	1024
May 92	25	8.01	283	90.71	1	0.32	0	0	0	0	309	99.04	3	0.96	312
Jun 92	114	10.45	783	71.77	1	0.09	8	0.73	2	0.18	908	83.23	183	16.77	1091
Jul 92	70	15.28	366	79.91	0	0	0	0	12	2.62	448	97.82	10	2.18	458
Total	5593	11.80	32449	68.44	16	0.03	411	0.87	703	1.48	39172	82.62	8243	17.38	47415

Gear and month	IO		PG		AV		AS		SZ		TOT-SHX		XG		Total
	n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
Gillnet															
Jul 91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aug 91	19	7.39	0	0	1	0.39	37	14.40	5	1.95	62	24.12	195	75.88	257
Sep 91	106	22.70	30	6.42	2	0.43	27	5.78	22	4.71	187	40.04	280	59.96	467
Oct 91	53	9.62	2	0.36	0	0	3	0.54	12	2.18	70	12.70	481	87.30	551
Nov 91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dec 91	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Jan 92	6	6.25	0	0	15	15.6	0	0	1	1.04	22	22.92	74	77.08	96
Feb 92	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mar 92	0	0	1	33.33	0	0	0	0	0	0	1	33.33	2	66.67	3
Apr 92	54	24.00	83	36.89	15	6.67	7	3.11	2	0.89	161	71.56	64	28.44	225
May 92	76	11.66	90	13.80	1	0.15	0	0	0	0	167	25.61	485	74.39	652
Jun 92	14	15.22	1	1.09	0	0	6	6.52	4	4.35	25	27.17	67	72.83	92
Jul 92	26	12.62	5	2.43	2	0.97	66	32.04	8	3.88	107	51.94	99	48.06	206
Total	354	13.89	212	8.32	36	1.41	146	5.73	54	2.12	802	31.46	1747	68.54	2549

Table 5

Longline effort (number of hooks × 1000) and catch rates (number of fish/1000 hooks) by species and sector.

Sector	Effort	*I. oxyrinchus*	*P. glauca*	*A. vulpinus*	*A. superciliosus*	*S. zygaena*	Total sharks	*X. gladius*
1	302.4	3.03	6.17	0.013	0.09	0.62	9.92	7.97
2	534.0	3.09	14.53	0.002	0.50	0.07	18.19	4.54
3	462.9	4.78	30.69	0.015	0.22	0.85	36.55	3.94
4	61.8	3.90	33.69	0.032	0.15	0.03	37.80	3.22
5	297.5	1.94	21.98	0.007	0.02	0.28	24.23	4.66
Total	1658.6	3.37	19.56	0.010	0.25	0.42	23.62	4.97

Table 6

Longline effort (number of hooks × 1000) and catch rates (number of fish/1000 hooks) by species and month.

Month	Effort	*I. oxyrinchus*	*P. glauca*	*A. vulpinus*	*A. superciliosus*	*S. zygaena*	Total sharks	*X. gladius*
Jul 91	67.40	3.32	14.72	0.03	0.46	0.31	18.84	0.88
Aug 91	180.40	4.94	15.88	0.01	0.02	0.81	21.66	3.08
Sep 91	41.30	10.22	52.25	0.00	0.17	0.68	63.32	0.82
Oct 91	195.00	2.99	17.12	0.00	0.16	0.67	20.95	10.36
Nov 91	185.20	5.24	23.40	0.02	0.13	1.36	30.15	6.99
Dec 91	16.80	1.79	6.25	0.00	0.30	0.00	8.33	6.13
Jan 92	296.60	2.91	20.62	0.01	0.37	0.10	24.02	5.02
Feb 92	393.20	2.21	17.77	0.01	0.34	0.20	20.53	3.81
Mar 92	206.90	2.04	15.51	0.00	0.26	0.00	17.82	4.80
Apr 92	5.00	21.80	182.60	0.00	0.20	0.00	204.60	0.20
May 92	12.80	1.95	22.11	0.08	0.00	0.00	24.14	0.23
Jun 92	47.00	2.43	16.66	0.02	0.17	0.04	19.32	3.89
Jul 92	11.00	6.36	33.27	0.00	0.00	1.09	40.73	0.91
Total	1,658.60	3.37	19.56	0.01	0.25	0.42	23.62	4.97

Table 7

Gillnet effort (average net length (number of sets) and catch rates (number of fish/unit of effort) by species and month.

Sector	Effort	*I. oxyrinchus*	*P. glauca*	*A. vulpinus*	*A. superciliosus*	*S. zygaena*	Total sharks	*X. gladius*
Jul 91	—	—	—	—	—	—	—	—
Aug 91	118.50	0.16	0.00	0.01	0.31	0.04	0.52	1.65
Sep 91	152.90	0.69	0.20	0.01	0.18	0.14	1.22	1.83
Oct 91	90.90	0.58	0.02	0.00	0.03	0.13	0.77	5.29
Nov 91	—	—	—	—	—	—	—	—
Dec 91	—	—	—	—	—	—	—	—
Jan 92	36.50	0.16	0.00	0.41	0.00	0.03	0.60	2.03
Feb 92	—	—	—	—	—	—	—	—
Mar 92	2.00	0.00	0.50	0.00	0.00	0.00	0.50	1.00
Apr 92	48.00	1.13	1.73	0.31	0.15	0.04	3.35	1.33
May 92	122.50	0.62	0.73	0.01	0.00	0.00	1.36	3.96
Jun 92	30.00	0.47	0.03	0.00	0.20	0.13	0.83	2.23
Jul 92	56.00	0.46	0.09	0.04	1.18	0.14	1.91	1.77
Total	657.30	0.54	0.32	0.05	0.22	0.08	1.22	2.66

of maximum, median, and minimum sizes are presented in Figure 6, A and B.

Blue shark

Blue sharks are often discarded at sea because they are not commercially valuable in the Spanish market; real catch rates are biased by this factor, especially in the more distant sectors where the tendency is to try to improve long trips with more valuable species, i.e. with swordfish and shortfin mako shark. Therefore, sectors 1 and 2 had lower catch rates, based on landings, than sectors 3, 4, and 5 (Table 5). Longline catch rates by month (Table 6) ranged from 6 to 52 fish/1000 hooks, except for an extremely high rate in April (182 fish/1000 hooks). Gillnet catch rates for this species were very low in relation to other species, in some months almost negligible (Table 7).

In the longline fishery, sex ratio by sector was close to 1 male:0.25 females, except in sector 3 where it was almost equal (1 male:0.92 females); gillnet sex ratio (1 male:2.45 females) was inverse to that observed for longlines in the same sector. Monthly data were not sufficient to be analyzed and therefore were grouped by quarter, i.e. July–September 1991, October–December 1991, January–March 1992, and April–June 1992. Because of the effect of discarded fish at sea and inappropriate sex sampling, we were unable to make significant assertions about sex ratio variability.

The distribution of overall length frequency is presented in Figure 7A. In longline landings, modal

Table 8

Biometric relations of standard length (*SL*) with fork length (*FL*), total length (*TL*), and upper caudal lobe length (UCL); and of fork length with total length by sex for *Isurus oxyrinchus*, *Prionace glauca*, and *Alopias superciliosus*, and both sexes combined for *Alopias vulpinus* and *Sphyrna zygaena*.

Females	Males	Total
Isurus oxyrinchus		
FL = 1.086 SL + 1.630	*FL* = 1.086 SL + 1.409	*FL* = 1.086 SL + 1.515
r^2 = 0.993 *n* = 852	r^2 = 0.993 *n* = 911	r^2 = 0.993 *n* = 1,763
TL = 0.817 SL + 0.400	*TL* = 1.209 SL + 0.435	*TL* = 1.207 SL + 0.971
r^2 = 0.986 *n* = 852	r^2 = 0.983 *n* = 681	r^2 = 0.985 *n* = 1,533
UCL = 3.693 SL + 13.094	*UCL* = 3.795 SL + 10.452	*UCL* = 3.758 SL + 11.640
r^2 = 0.874 *n* = 507	r^3 = 0.898 *n* = 477	r^2 = 0.903 *n* = 1,054
TL = 1.106 *FL* + 0.052	*TL* = 1.111 *FL* - 0.870	*TL* = 1.108 *FL*-0.480
r^2 = 0.985 *n* = 853	r^2 = 0.984 *n* = 911	r^2 = 0.984 *n* = 1,746
Prionace glauca		
FL = 1.076 SL + 1.862	*FL* = 1.080 SL + 1.552	*FL* = 1.079 SL + 1.668
r^2 = 0.993 *n* = 1,043	r^2 = 0.997 *n* = 1,276	r^2 = 0.996 *n* = 2,319
TL = 1.249 SL + 7.476	*TL* = 1.272 SL + 4.466	*TL* = 1.262 SL + 5.746
r^2 = 0.986 *n* = 1,043	r^2 = 0.993 *n* = 1,272	r^2 = 0.990 *n* = 2,315
UCL = 0.219 SL + 4.861	*UCL* = 0.316 SL + 2.191	*UCL* = 0.306 SL + 3.288
r^2 = 0.903 *n* = 1,038	r^2 = 0.948 *n* = 1,264	r^2 = 0.929 *n* = 2,302
TL = 1.158 *FL* + 5.678	*TL* = 1.117 *FL* + 2.958	*TL* = 1.167 *FL*+ 4.133
r^2 = 0.988 *n* = 1,043	r^2 = 0.992 *n* = 1,272	r^2 = 0.990 *n* = 2,315
Alopias superciliosus		
FL = 1.075 SL + 3.346	*FL* = 1.081 SL + 3.324	*FL* = 1.073 SL + 4.150
r^2 = 0.987 *n* = 90	r^2 = 0.980 *n* = 76	r^2 = 0.986 *n* = 166
TL = 1.939 SL - 11.990	*TL* = 1.897 SL - 7.359	*TL* = 1.937 SL -12.630
r^2 = 0.976 *n* = 77	r^2 = 0.946 *n* = 70	r^2 = 0.970 *n* = 147
UCL = 0.967 SL -9.588	*UCL* = 0.922 SL -5.353	*UCL* = 0.966 SL - 10.908
r^2 = 0.952 *n* = 75	r^2 = 0.869 *n* = 71	r^2 = 0.932 *n* = 146
TL = 1.775 *FL* - 13.007	*TL* = 1.722 *FL* - 7.295	*TL* = 1.773 *FL*- 14.456
r^2 = 0.956 *n* = 77	r^2 = 0.923 *n* = 70	r^2 = 0.949 *n* = 147

Alopias vulpinus			*Sphyrna zygaena*		
Relation	r^2	*n*	Relation	r^2	*n*
FL = 1.118 SL - 2.29	0.989	22	*FL* = 0.845 SL + 1.077	0.998	56
TL = 1.930 SL + 9.331	0.956	22	*TL* = 1.322 SL + 8.397	0.994	56
UCL = 0.926 SL + 25.670	0.949	22	*UCL* = 0.329 SL + 8.799	0.975	55
TL = 1.687 *FL* + 20.483	0.932	22	*TL* = 1.225 *FL* + 7.528	0.994	56

length for males (95 cm FL) was slightly greater than for females (80 cm FL), whereas in gillnet landings it was equivalent (100 cm FL). Mean lengths in the longline landings, including nonsexed specimens, ranged from 85 cm FL in sector 5 to 205 cm FL in sector 1. The mean length for gill nets was the same for

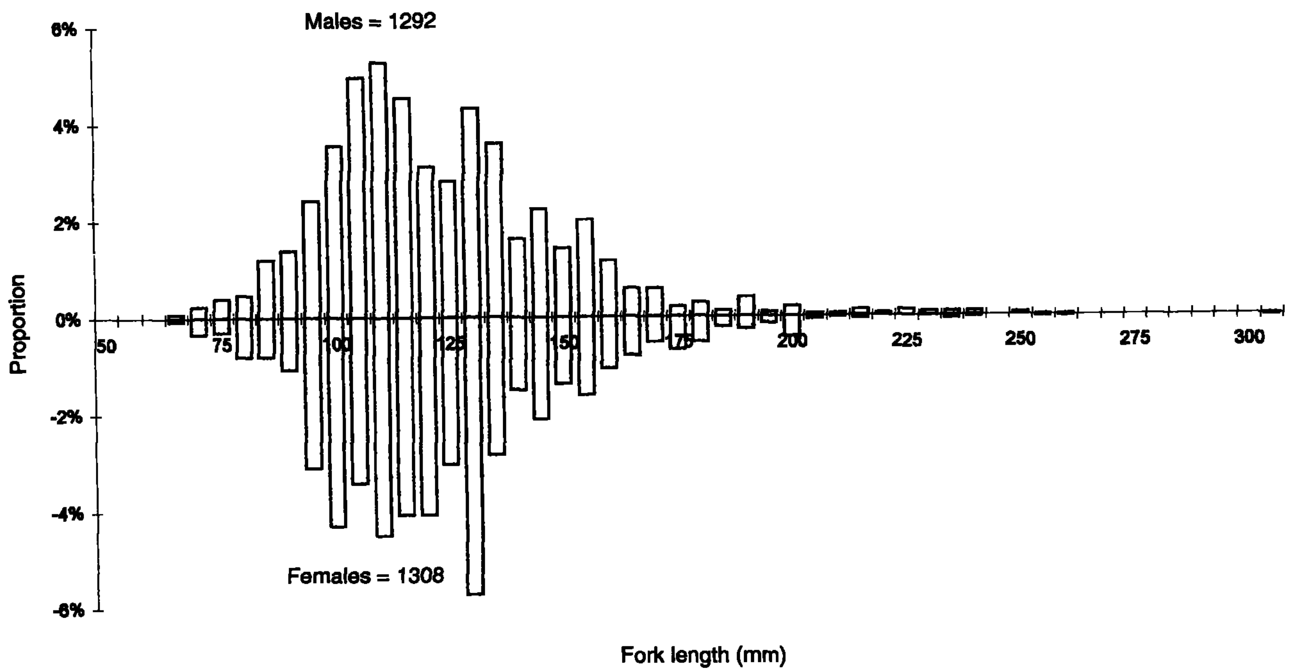

Figure 3

Total length-frequency distribution by sex of the shortfin mako shark longline landings from all sectors from July 1991 to July 1992.

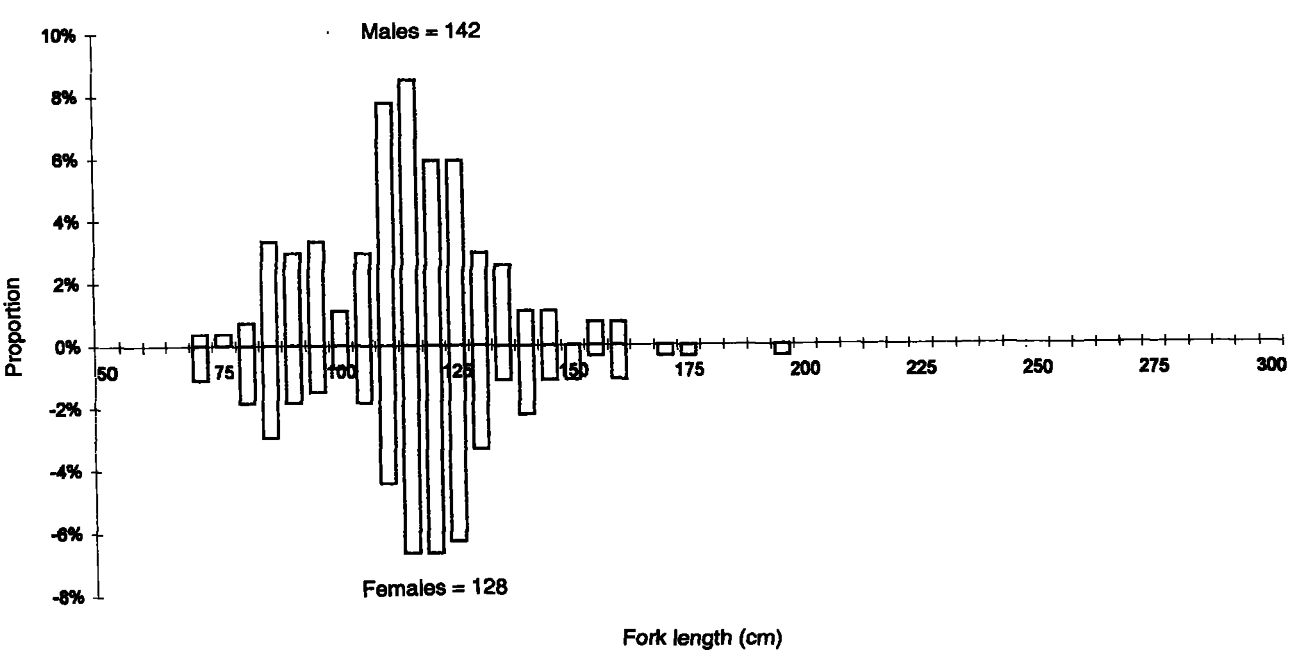

Figure 4

Total length-frequency distribution by sex of the shortfin mako shark gillnet landings from sector 5 from July 1991 to July 1992.

males and females (100 cm FL). The incompleteness of these data did not allow any temporal analyses.

Size distribution by sector varied significantly (F=387.130; df=5, 8214; P<0.001). Total mean size was greatest in sector 1, lowest in sector 5. Sector 3 had minimum-size females and males. The largest size females were found in sector 1; the largest males, in sector 4 (Fig. 7, B and C).

Table 8 shows biometrical comparisons by sex.

Bigeye thresher shark

Longline catch rates for bigeye thresher sharks were very low. However, this species was caught in all sectors, sector 2 having the highest rate (Table 5). There was a slight increase in the longline catch rate, from

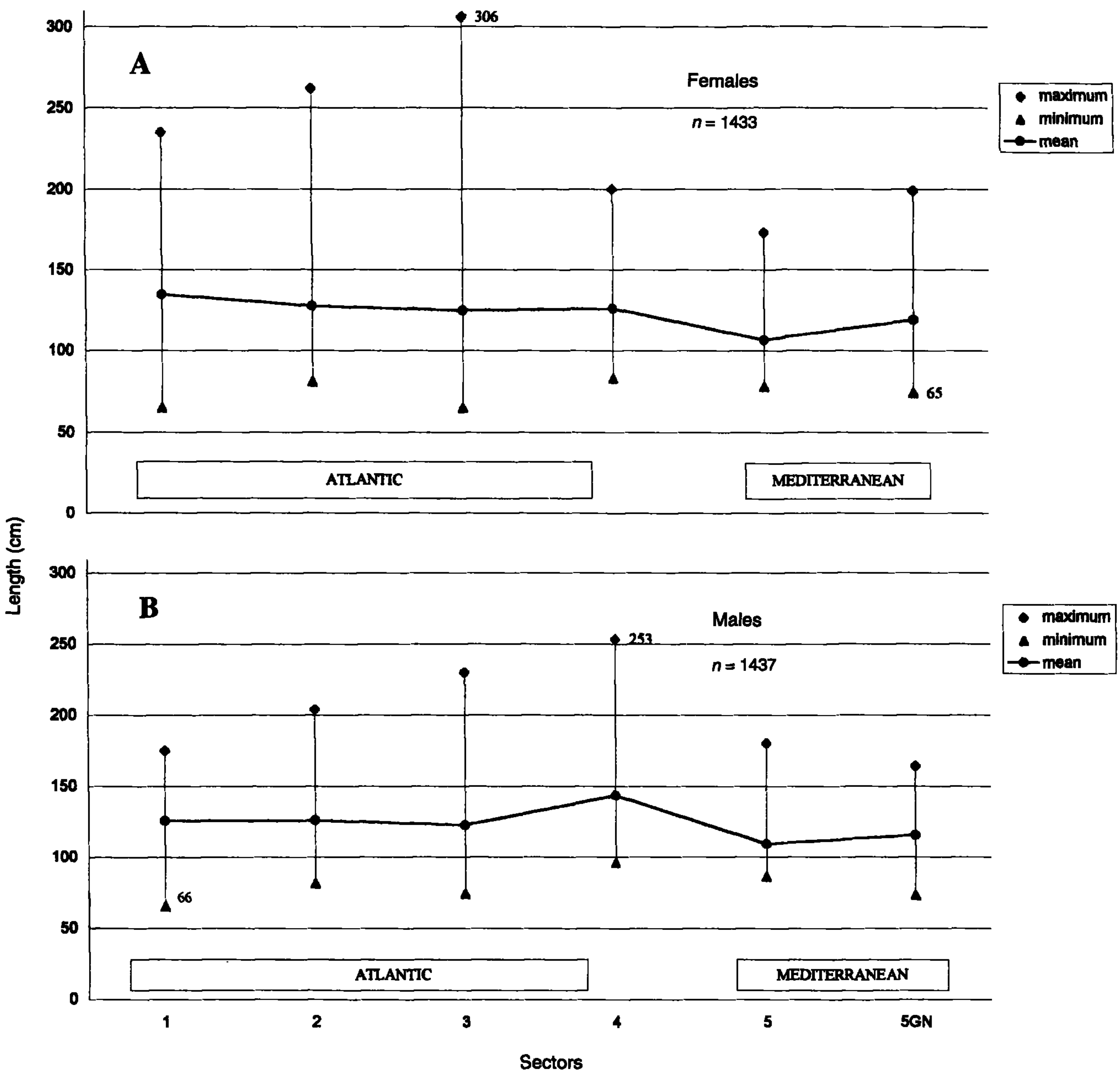

Figure 5

(A) Size range variation of shortfin mako shark females landed by longlines and gill nets (5GN) by sector from July 1991 to July 1992; **(B)** size range variation of the shortfin mako shark males landed by longlines and gill nets (5GN) by sector from July 1991 to July 1992.

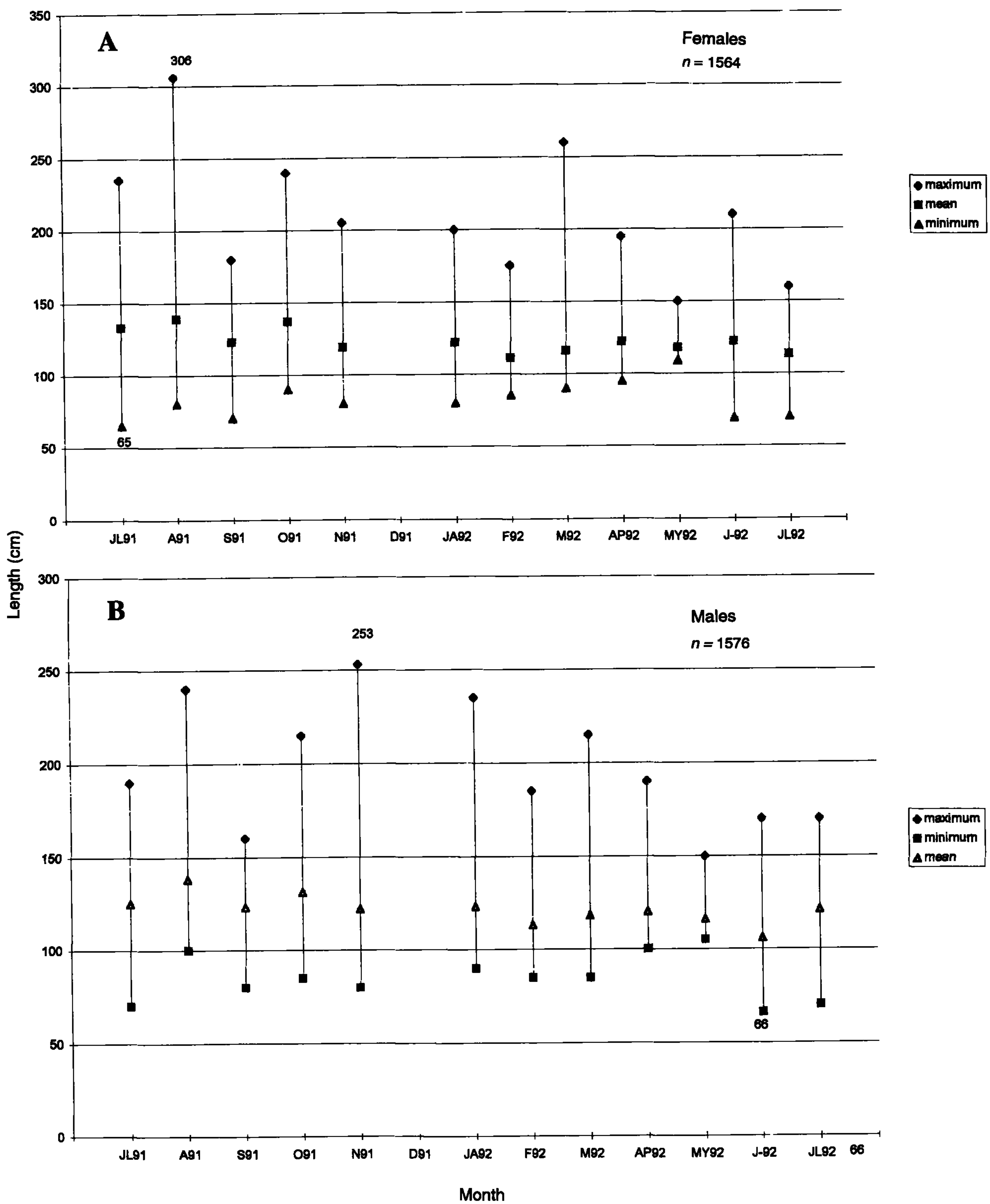

Figure 6

(**A**) Size range variation of the shortfin mako shark females landed by month (December 91 excluded); (**B**) size range variation of the shortfin mako shark males landed by month (December 91 excluded).

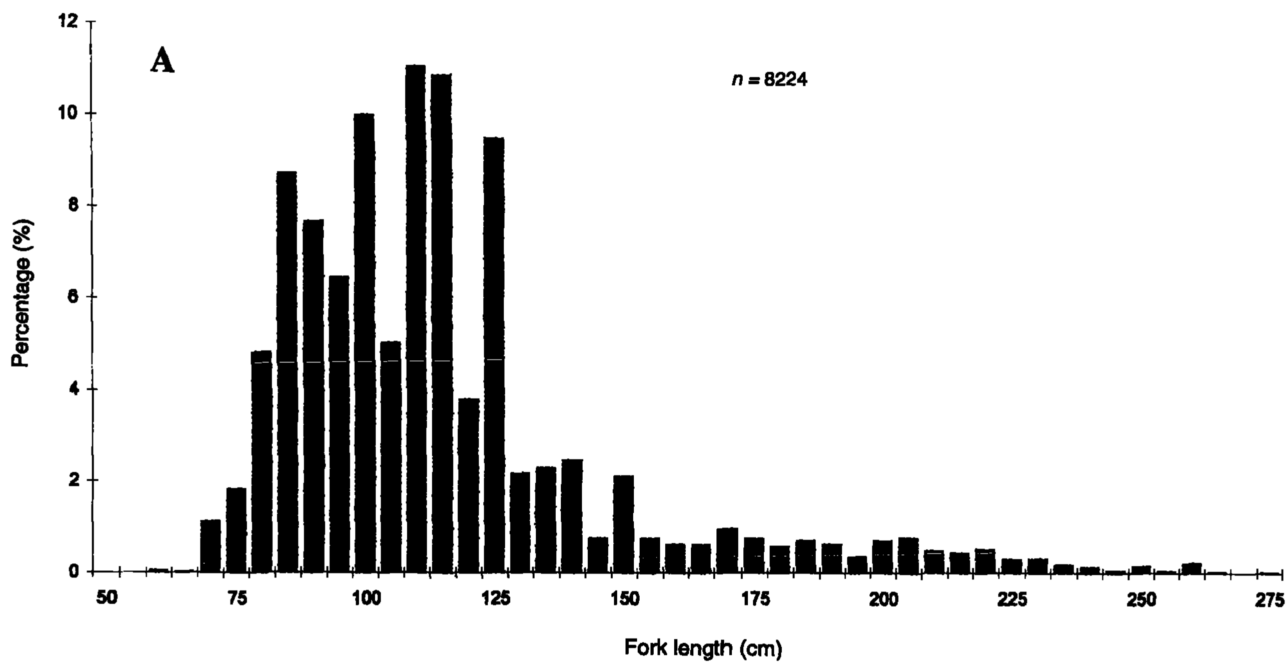

Figure 7

(**A**) Total length-frequency distribution of blue shark from longline and gillnet landings from all sectors from July 1991 to July 1992. (**B**) Size range variation of blue shark females landed by longlines and gill net (5GN) by sector from July 1991 to July 1992. (**C**) Size range variation of blue shark males landed by longlines and gill net (5GN) by sector from July 1991 to July 1992.

fall to winter, dropping during spring. A maximun catch rate was reached in July 1991 (Table 6). In gillnet fishing, catch rates were highest during summer months, with a maximum in July 1992 (Table 7).

The sex ratio found in longline fishing was fairly balanced, 1 male to 1.1 females in sector 2 to 1 to 0.93 females in sector 3. Females were more abundant than males in gillnet fishing (1 male:1.43 females). The distribution of sex ratio by sector was not significantly different (χ^2=9.14; df=5; P>0.1). The distribution of sex ratio varied significantly by month (χ^2=38.7; df=11; P<0.001). In longline fishing there were more males than females (1 male:0.66–0.69 females), except in February and March when the ratio was 1 male:1.45 females, and in September, when the proportion of females rose dramatically to 1 male:6.1 females. Gillnet fishing reflected a similar proportion during the same month (1 male:13.21 females).

The frequency distribution by size of fish from longline landings was quite similar for males and females (Fig. 8). Modal length for all sectors and months was near to 285 cm TL, the mean size approximately 280 cm TL. Minimum size was 180 cm TL for females, 195 cm TL for males. Maximum size was 40 cm greater for females (430 cm TL) than for males (390 cm TL).

The frequency distribution by size of fish from gillnet landings differed by sex (Fig. 9), with two modes for males (290 and 330 cm TL) and for females (395 and 410 cm TL).

The size range of fish by sector for longline landings was greater for females (183–432 cm TL) than for males (195–391 cm TL). Minimum sizes were found in sector 2 for both sexes, whereas the maximum for males was recorded in sector 3 and for females in sector 5. In gillnet landings, females ranged from 236 to 446 cm TL, with a mean size of 352 cm TL, 45 cm larger than the mean size of males (307 cm TL). As in longline landings, males had a smaller size range (246–373 cm TL). The length mode for females was 80 cm larger than for males (410 cm TL compared with 330 cm TL).

The size variation over time was not outstanding for males in either fishery, but there was a marked presence of large females during July–September in gillnet landings (288–446 cm TL) corroborated by longline landings in the same period (230–432 cm TL). The period of January to March was when the greatest number of fish were recorded (128) with the smallest size range (183–360 cm TL). Only one pregnant female (385 cm TL), with one pup, was recorded in gillnet landings in September 1991.

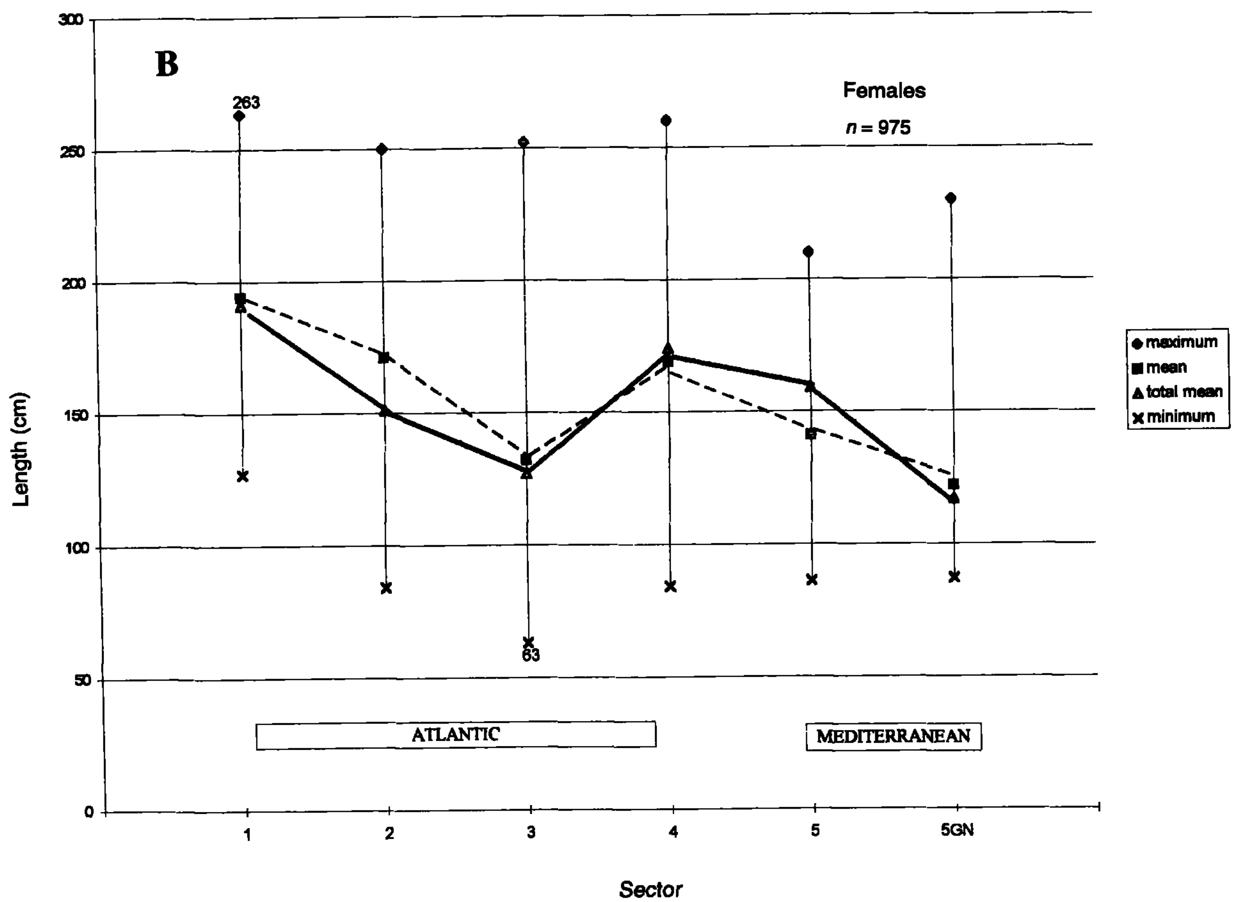

Figure 7 (continued)

Common thresher shark

Only 52 common thresher sharks were recorded during the sampling period; hence the catch rate never went beyond 0.1 fish/1000 hooks (Tables 5 and 6). The overall sex ratio was close to 1 male:2 females, with some differences between longline (1 male:2.16 females) and gillnet (1 male:1.75 females) landings.

The size range of fish was similar for longline and gillnet landings, as was the mean size for both sexes (325 cm TL for males, 350 cm TL for females). Maximum size was similar in longline (360 cm TL for males, 425 cm TL for females) and gillnet landings (355 cm TL for males, 435 cm TL for females). Minimum size was comparable for females in both fisheries (295 and 285 cm TL in longline and gillnet, respectively), but not for males; in longline landings, a 245-cm-TL male was recorded, whereas in gillnet landings the minimum-size male recorded was about the same size as the minimum-size female (280 cm TL). Although biometrical information on this species is found in Table 8, our small sample size did not permit analyses by sex. Only one pregnant female was recorded, measuring 385 cm TL; it was caught in sector 4 by longline in May and carried 4 embryos (3 males and 1 female), 75 to 80 cm FL.

Scalloped hammerhead shark

The catch rate for this species was low in all sectors and months, slightly greater for sectors 1 and 3 (0.6 and 0.8 fish/1000 hooks respectively), and never higher than 1 fish/1000 hooks (Tables 5–7). The highest overall catch rates by month in longline landings was in November 1991 and July 1992 (1.3 and 1.1 fish/1000 hooks). In gillnet landings the greatest catch rates were in September–October and June–July (0.1 fish/unit effort). Males were more abundant in the longline (1 male:0.61 females) than in the gillnet fishery, where females were dominant (1 male:1.37 females).

Females had a larger maximum size than males in both fisheries, 320 cm and 305 cm TL for females,

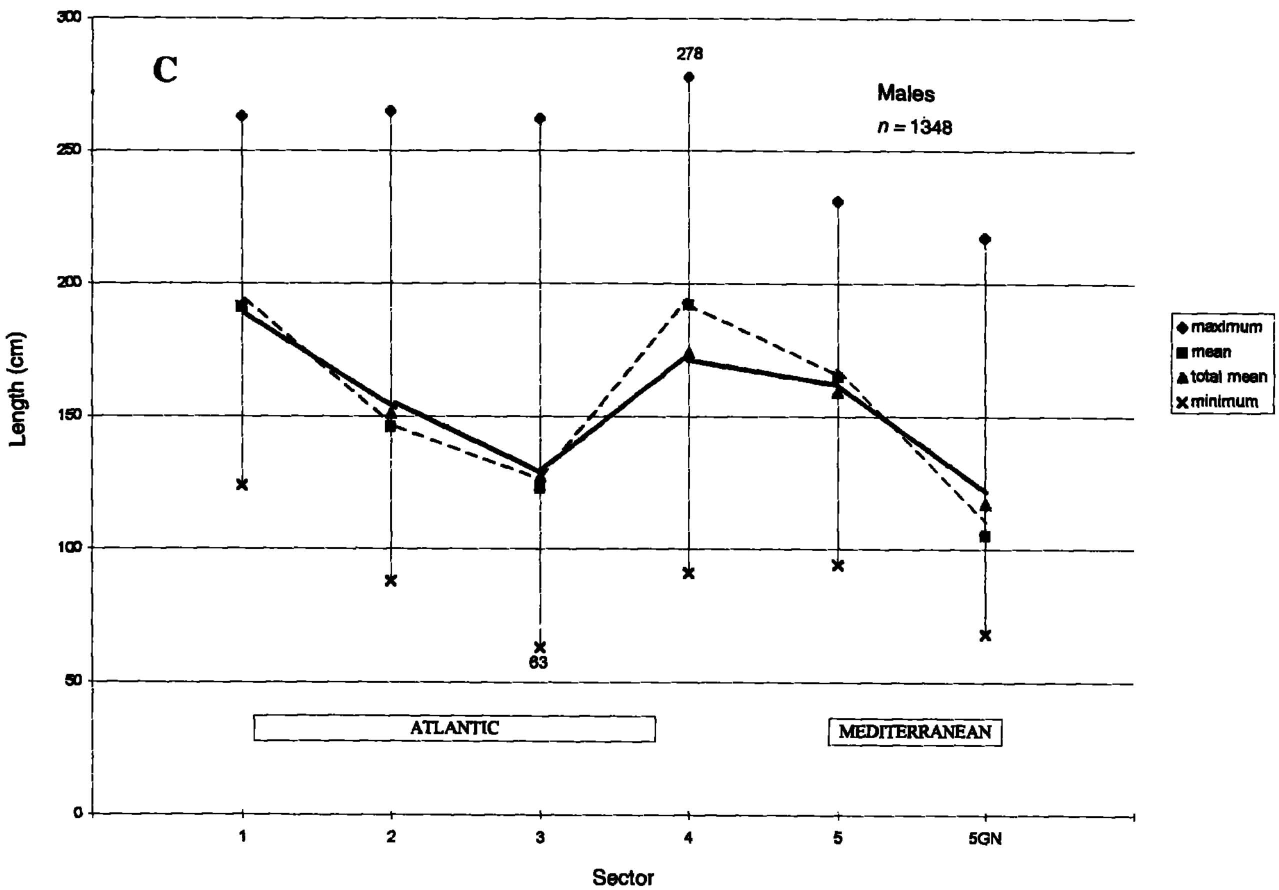

Figure 7 (continued)

280 and 275 cm TL for males, respectively, in longline and gillnet landings. Minimum size was greater in the gillnet fishery (185 cm TL for males, 165 cm TL for females) than in the longline fishery (105 cm TL for males, 115 cm TL for females). The mean size from longline landings was slightly greater for females (170 cm TL) than for males (150 cm TL). The mean size from the gillnet fishery was greater than from the longline fishery, with no difference between sexes (220 cm TL). Although biometrical information can be found in Table 8, the small sample size did not permit analyses by sex.

Discussion

The total proportion of sharks in relation to swordfish observed in the present study was similar to that found by Gouveia (1992) for an adjacent area, but the species composition was different (*P. glauca*, *I. oxyrinchus*, *Dasyatis violacea*, *Alopias* spp., *Mustelus mustelus*, *Sphyrna* spp., *T. obesus*, and *Alepisaurus ferox*). Sharks comprised a greater proportion of landings in the study area than in other Atlantic longline fishing grounds, i.e. off the Florida coast (Berkeley and Campos, 1988), the Caribbean coast (Tobias, 1991), and the northwestern coast of Cuba (Guitart, 1975). "Other bony fish" (the other category of fish) taken by longlines had a similar proportion to that found in data from other Mediterranean longline fisheries (Rey and Alot, 1984). The abundance of the most common shark species, blue and shortfin mako sharks, also agrees with results presented for the same area by Garcés and Rey (1984).

Shortfin mako shark

This species was very common in the study area. This finding agrees with reports by Muñoz-Chápuli (1985), although catch rates obtained were slightly lower than estimates of Moreno and Morón (1992b) from the same area. Proportions of shortfin mako sharks,

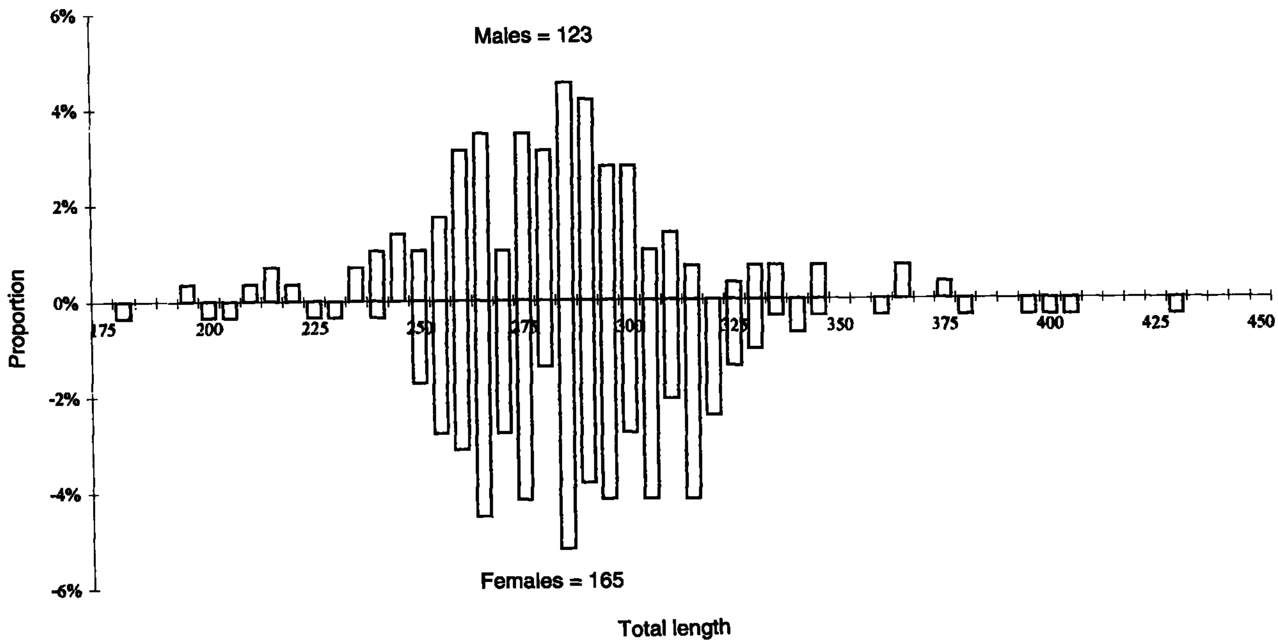

Figure 8

Total length-frequency distribution of the bigeye thresher shark by sex from longline landings from all sectors from July 1991 to July 1992.

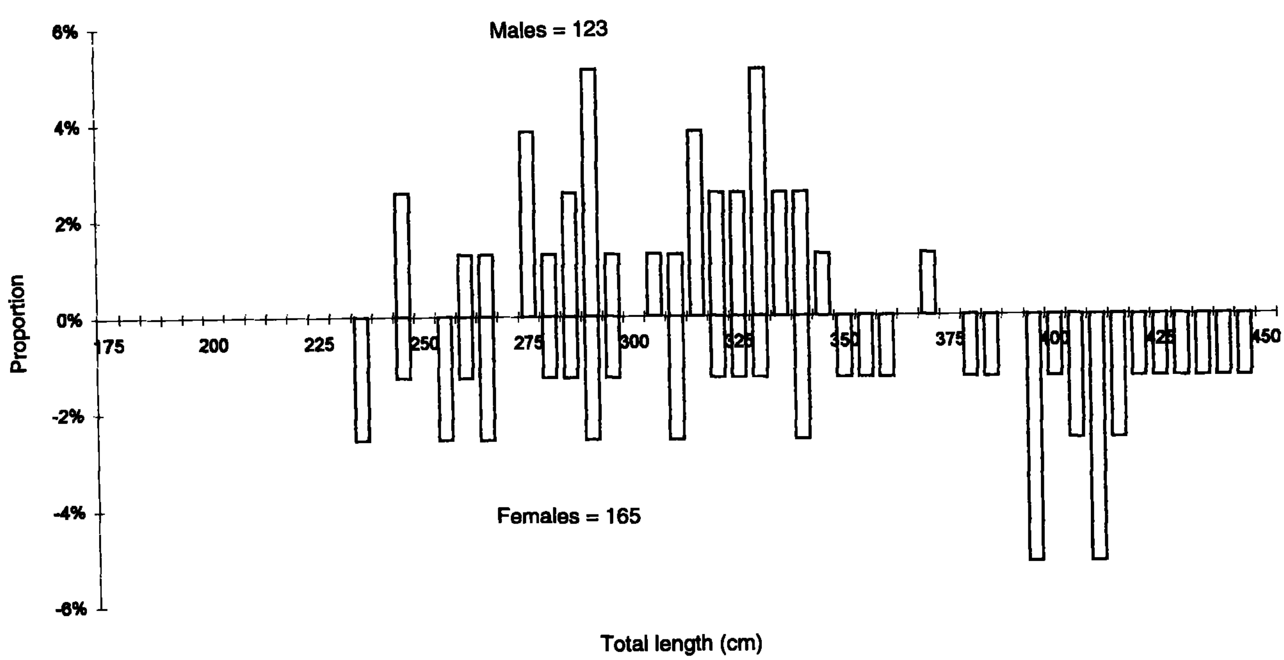

Figure 9

Total length frequency distribution of the bigeye thresher shark by sex from the gillnet landings from all the sectors from July 1991 to July 1992.

compared with swordfish, were similar to proportions calculated by Garcés and Rey (1983) for the northeastern Atlantic and Mediterranean Sea but were greater than the estimates of Rey and Alot (1984) for the western Mediterranean Sea and those of Mejuto[2] for the northeastern Atlantic just immediately north of the study area. Monthly variation in the longline catch rate in this study was different from that found off the northwestern Spanish coast by Mejuto and Garcés[1] and Mejuto[2], although it coincides with the increased trend observed during the last few months of the year. Monthly catch rate variation did not agree with results obtained on the other side of the Atlantic Ocean off the northwestern Cuban coast (Guitart, 1975). Shortfin mako shark and swordfish catch rates followed a similar decreasing trend from fall to March; in April the catch rate for shortfin mako sharks increased and that for swordfish dropped (Fig. 10), thus complementing each other.

Sex ratio (1 male:0.9 females) is different from that observed by Mejuto and Garcés[1] and Mejuto[2] in the northeastern Atlantic above 40°N, where males were more abundant (approx. 1 male:0.4 females). The increasing presence of males northwards (up to 1 male:0.6 females in sector 4) correlates with results observed by Mejuto and Garcés[1] and Mejuto[2] and may suggest sexual segregation to the north. For the same area of the present study, Muñoz-Chápuli (1984) observed a lower proportion of females (1 male:0.35 females) than we did, and although the sample size was small in that study (n=113), there was a similar trend in the increasing number of males northwards. The overall sex ratio observed in this study agrees with results presented by Moreno and Morón (1992b) from August 1983 to August 1985 for the same fleet operating in the same area. Mejuto[2] reported a trend of increase in percentage of males with increasing size (for size range 105–260 cm FL). This trend was not found in our study (Fig. 11).

The length-frequency distribution of the two fisheries was different from that found by Mejuto and Garcés[1] and Mejuto[2] for the area immediately north. It was also different from the one presented for the east coast of the United States (Pratt and Casey, 1983). In our study, modal values were always lower than those presented by the above-mentioned authors. Following the age structure proposed by Pratt and Casey (1983), we estimated that most of the fish in this study belonged to age class 1 and 2 for both sexes. The largest size of females corresponded to age class 5 (sector 3), and the largest size of males to

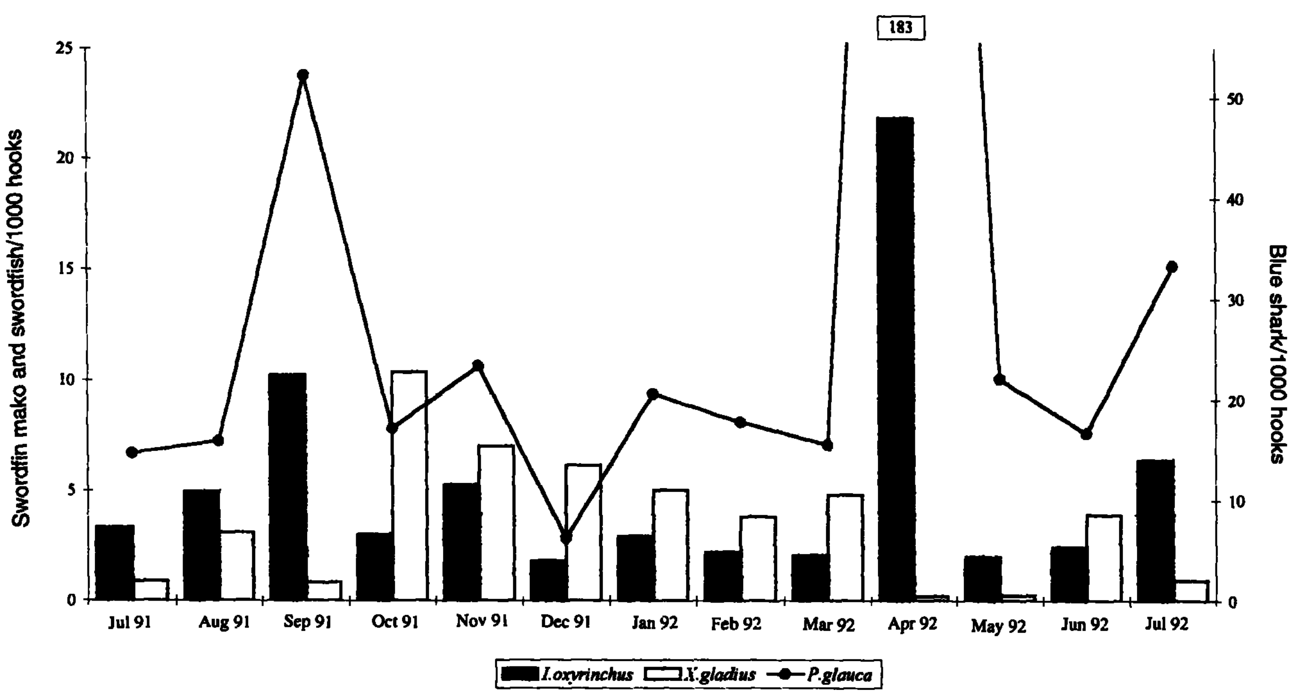

Figure 10

Comparison of longline catch rates (number of fish/1000 hooks) of the shortfin mako shark and swordfish (left "y" axis) and of the blue shark (right "y" axis) by month.

age class 4 (sector 4). The minimum size corresponded to age class 0 in all sectors.

Maximum size decreased during March–May (see Fig. 6, A and B). In June and July there was a possible entry of newborn fish (65 cm) with the same birth size as that suggested by Compagno (1984). Mean size decreased during October–November. These changes in size distribution suggest a movement of the largest and mean-size shortfin mako sharks out of the study area. For an area just north of the one studied, Mejuto[2] showed a large increase in catch rate during the last quarter of the year, which could be attributed partially to entry of fish coming from our study area.

Blue shark

The abundance of this species in longline fishing has been mentioned by several authors (Bigelow and Schroeder, 1948; De Metrio et al., 1984; Muñoz-Chápuli, 1985; Stevens, 1990; Mejuto[2]). In the present study the proportion of blue sharks, compared with swordfish, was half that estimated by Garcés and Rey (1983) for an area that included our five sectors. However, it was greater than the proportion obtained by Rey and Alot (1984) in the western Mediterranean and very similar to that calculated by Mejuto[2] for the area just north of our study region. The number of fish landed increased northward and was greater than the number estimated by De Metrio et al. (1984) in the Mediterranean.

The temporal distribution of fish was also different for the Mediterranean (De Metrio et al., 1984) and for the northeastern Atlantic (Mejuto[2]). As in the case of shortfin mako sharks, the highest catch rates correlated with reductions in swordfish catch rates, i.e. April and September (Fig. 10).

The overall sex ratio (1 male:0.71 females) was inverse to that found by Rey and Alot (1984) in the Mediterranean. The latitudinal distribution of sexes was inverse to that estimated by Stevens (1990) off southwest Great Britain and Portugal and to that presented by Nakano et al. (1985) in a similar latitude in the central north Pacific.

Using Pratt (1979) and Cailliet et al's. (1983) age estimate, we found that frequency distribution of fish by size of landings in sector 1 showed that mature males were more abundant, whereas in the other sectors a greater proportion of immature fish were observed.

Bigeye thresher shark

The relatively frequent occurrence of this species noted by Muñoz-Chápuli (1985) contrasted with the low numbers observed in our study, with the low

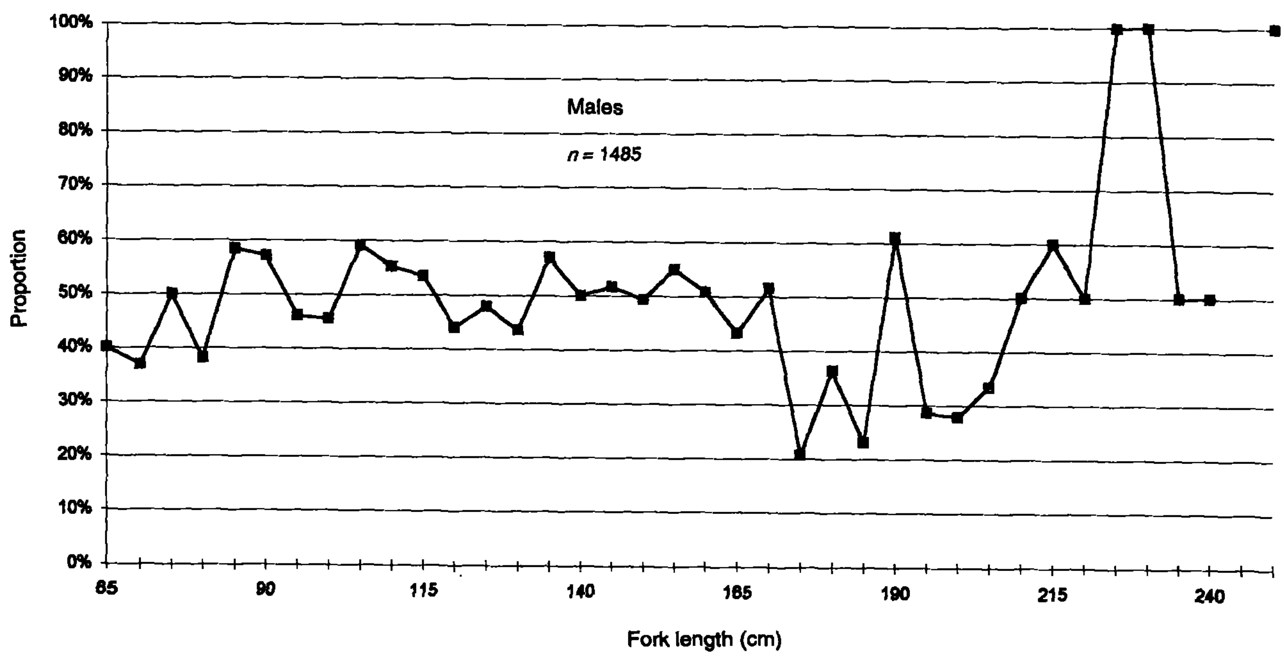

Figure 11
Proportion of male shortfin mako sharks in landings by size group (grouped by 5 cm FL).

numbers noted by Moreno and Morón (1992a) in the same area, and with the low numbers noted by Stillwell and Casey (1976) in the northwestern Atlantic. The sexual segregation hypothesized by Muñoz-Chápuli (1984) in this area, i.e. males distributed northward and females southward, was opposite that of our findings. Moreno and Morón (1992a) mentioned that most fish caught during the fall were pregnant females, whereas in this study mostly mature males from the longline fishery and mostly females from the gillnet fishery were recorded during the same period.

Most males in all sectors were adults (>276 cm TL, Moreno and Morón, 1992a). Most females would be have been considered mature in every sector according to Gubanov's (1979) first maturity size (>310 cm TL), but only in sector 5 according to Moreno and Morón's (1992a) criteria (340 cm TL). The largest fish was recorded in sector 5, a 432-cm-TL female, in September 1991, which, nevertheless, did not exceed the maximum for the species (460 cm TL, Nakamura, 1935).

Size distributions by month showed a greater proportion of immature males during the July–September period, whereas mature fish predominated the rest of the year. During January–June and October–December most females were around maturity size limit (300 cm TL, Gubanov, 1979).

Most births occur during fall and winter according to Moreno and Morón (1992a), and as these authors have suggested, sector 5 could be a breeding area. A pregnant female was recorded in September 1991, in sector 5, carrying only one pup. However, no newborn fish were recorded, according to birth sizes reported by Bigelow and Schroeder (1948), Bass et al. (1975), Gruber and Compagno (1981), and Moreno and Morón (1992a).

Common thresher shark

The scarcity of this species in the present study disagrees with observations of Muñoz-Chápuli (1985). The relative abundance of common thresher sharks found in sector 5 was similar to that presented by Moreno et al. (1989) for the same area. The maximum number during spring agreed with the number observed in California (Cailliet and Bedford, 1983) but did not coincide with the peak reported by Moreno et al. (1989) during fall in this area.

The sex ratio for this species in the area studied (1 male:2 females) differed greatly from estimates by Holts (1988) on the west coast of the United States (1 male:1 female). Moreno et al. (1989) noted the absence of males in May, which suggests sexual segregation during the reproduction period. A mature male was recorded in May at 330 cm TL, which represents the lower limit of maturity for males according to Cailliet et al. (1983).

Only one female was recorded below size of first maturity (260 cm TL, established by Gubanov, 1972; Cailliet and Bedford, 1983; Cailliet et al., 1983). Moreno et al. (1989) pointed out the probable existence of a breeding area close to the Strait of Gibraltar during spring time. The record of a 425-cm-TL pregnant female, with four full-term pups in May, supports this theory.

Scalloped hammerhead shark

According to sex and length data obtained from sectors 1, 3, and 5, the overall sex ratio (1 male:0.83 females) differed from the ratio observed by Muñoz-Chápuli (1984) in the same area (1 male:6 females).

If we follow Compagno's (1984) first maturity size criteria (256 cm TL for males, 304 cm TL for females), only 6% of males and 4% of females landed would be considered mature in our study area. Muñoz-Chápuli (1984) observed many pregnant females in the area throughout the year, but the lowest size recorded in our study (114 cm TL) was much greater than birth size (50–60 cm TL, Compagno, 1984). Moreover, the lack of mature females contradicts the assessment that the study area is a breeding area, as suggested by Muñoz-Chápuli (1985).

Conclusions

Sharks, because of their low reproduction rate and late sexual maturity, are extremely sensitive to fishing pressure (Holden, 1973, 1974, 1977). The vulnerability of shark populations as bycatch of some tuna and tunalike fishing is comparable to that of marine mammals (Burke and Francis, 1990). In recent years several cases of overexploitation in shark fisheries (Cailliet and Bedford, 1983; Holts, 1988; Vas, 1990; Hanan et al., 1993) and the effect of other fishing activities (recreational fisheries, the routine procedure of discarding sharks after removal of fins) on shark populations (Casey and Hoey, 1985; Stevens, 1992) has been described.

A lack of fishery statistics about sharks is commonplace all around the world. Du Buit (1989) commented on the complete absence of knowledge about most biological factors influencing shark populations off the coast of France and on the difficulty in sampling most of these migratory species.

Our study shows the importance of shark landings in the Atlantic swordfish longline fishery and points out the large number of immature fish involved.

Shortfin mako may be the shark species most affected by current fishing procedure despite the fact that the most common species caught is blue shark. As Casey and Kohler (1992) suggested with reference to the shortfin mako shark population in western north Atlantic, this species has a continuous distribution throughout the central and northeastern Atlantic Ocean, preferentially in the high production area of Saharian Bank (sector 3).

As it has been shown in this study, sharks greatly affect and are greatly affected by swordfish fishing. Therefore, the management of this fishing industry should be reoriented to multispecies models in which the effect of bycatch and the economic implications of bycatch should be included in the management models for a proper approach to the present situation in the industry.

Acknowledgments

We are indebted to Enrique Majuelos who has been indispensable in collecting data used in this paper and to Emilio García, Florencio González, Jesús Gutiérrez, and Pedro Güemes for collaboration in sampling. We would also like to thank Julio Alonso for his help in the statistical analyses. Finally, we want to acknowledge Manuel Alcántara for collaboration with the computer analyses and Jaime Mejuto and J. I. Castro for valuable review comments. Beverly Rising helped with manuscript translation. This work has been financed through project 2481 (1990) of the Universidad Complutense of Madrid.

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