A comparison of catches of swordfish, *Xiphias gladius,* and other pelagic species from Canadian longline gear configured with alternating monofilament and multifilament nylon gangions

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The Canadian large pelagic longline fishery extends from Georges Bank south of Nova Scotia to the Flemish Cap, east of Newfoundland, and operates from May through November, when swordfish (*Xiphias gladius*), the main species targeted, migrate into and adjacent to the Canadian EEZ. Fishing effort progresses from west to east and back again and from offshore to inshore along the edge of the continental shelf (Stone and Porter, 1999) following swordfish movements associated with seasonal warming trends of surface water temperature, and a northward movement of the edge of the Gulf Stream (Beckett, 1974). In winter, swordfish are confined to warmer waters associated with the Gulf Stream outside the Canadian EEZ and are not easily accessed by the Canadian fleet. In recent years, national swordfish quotas for the Canadian fishery (established by the International Commission for the Conservation of Atlantic Tunas) have been reached by early fall.

Pelagic longlining was first introduced as a method for fishing swordfish in Canadian Atlantic waters in 1962, having been stimulated by reports of incidental swordfish catches by foreign longliners targeting tuna or laminid sharks (Beckett[1]). Prior to 1962, harpooning was the principal method used to capture swordfish on the continental shelf, where large females (mean round weight ~120 kg) were targeted as they swam or "basked" in surface waters during the day. This fishery occurred primarily during July and August, and required calm, clear weather to visually detect individual fish (Beckett[1]). During the early to mid 1960s, the Canadian fleet rapidly converted to surface longline gear which proved to be far more efficient than harpooning. Not only were daily catches much higher, but vessels could operate during inclement weather (unsuitable for harpooning) and fish farther offshore as waters cooled over the continental shelf. As a result, the fishing season extended, the fishing area expanded, catch rates increased, and the average weight of fish declined because both male and female swordfish were captured (Caddy, 1976; Hurley and Iles, 1981; Beckett[1]).

Pelagic longline gear adopted for use by Canadian fishermen is similar to that used in the New England fishery (Berkeley et al., 1981) and consists of a continuous backline up to 64 km long, supported in the water column by styrofoam floats with up to 2000 baited hooks suspended on gangions spaced at regular intervals (Fig. 1). Although the general design of pelagic longline gear is relatively simple, operating characteristics (including area, month and time of set, surface temperature, fishing depth, number of hooks between floats, bait) can significantly affect the catch rates and species composition of the catches. With swordfish fishing, usually three to five hooks are attached between floats and lightsticks are attached intermittently to some of the gangions above the bait to attract swordfish or their potential prey species. The gear is set during the early evening, allowed to soak overnight for 6–12 hours and retrieved at daybreak. The length of the float lines determines the depth of the backline, and along with the length of the gangions, distance between buoys and speed at which the backline is set (i.e. the gear tends to sink more at slower setting speeds) determine the actual depth the baits will fish. In the Canadian swordfish fishery, baits are often fished at depths of 12 m or less in the upper water column to take advantage of the diurnal feeding migrations of swordfish and their movement into near surface waters at night (Carey and Robison, 1981).

In the early 1960s, the first floating longlines used modified halibut bottom longline gear buoyed by a variety of objects (Beckett[1]). Both the backline and gangions were made of tarred multifilament nylon and the gangions were spliced directly to the backline. Monofilament nylon was first used by Canadian fishermen in the late 1960s, when a short (~38 cm) mono leader was attached between the tarred multifilament nylon segment of the gangion and the hook. In the late 1970s (following an eight year closure of the Canadian fishery when it was illegal to land swordfish in Canadian ports owing to perceived high levels of mercury in swordfish meat), gangions consisted of an upper tarred multifilament section with a clip for attaching it to the

[1] Beckett, J. S. 1971. Canadian swordfish longline fishery. Int. Comm. Conserv. Atl. Tunas. SCRS Report 80/71/36, 14 p. International Commission for the Conservation of Atlantic Tunas, 8 Corazon de Maria, 28002 Madrid, Spain.

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backline and a lower monofilament leader to which the hook was attached. The monofilament leader made up one half (~1.8 m) of the overall length of the gangion (~3.6 m) and was considered to yield better catch rates because it was assumed to be less visible to swordfish and other pelagic species. This innovation also effectively reduced shark damage to the gear because only the monofilament leader had to be replaced if it was bitten off. In the late 1980s, fishermen began to use monofilament nylon for both sections of the gangion and for the backline on the assumption that this would further improve catch rates by decreasing overall visibility of the gear.

Canadian pelagic longline fishermen have been using monofilament gangions for over a decade now and generally agree over its ability to outperform the older tarred multifilament nylon gangions in terms of swordfish catchability, although this theory has never been tested scientifically. In this note, the results of a collaborative science and industry study involving the Canadian Department of Fisheries and Oceans and the Nova Scotia Swordfishermen's Association are presented. Our study was designed to compare the catchability of swordfish and other pelagic species on commercial longline gear configured with alternate monofilament and tarred multifilament nylon gangions. It was based on the premise that some species can avoid capture on the tarred multifilament gangions which are thicker, darker, and possibly more "visible" than the monofilament nylon gangions.

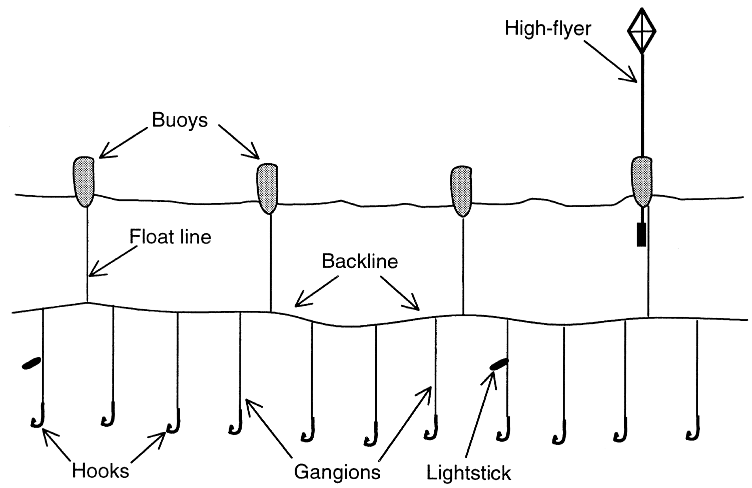

Figure 1

Schematic diagram illustrating typical Canadian pelagic longline gear configuration. (Note: this configuration differs slightly from the one used in our experiment.)

Materials and methods

The study was conducted aboard the 19-m fishing vessel *Nova Blue* from 22 July to 2 August 1999, along the edge of Georges Bank (depth to bottom: 360–1400 m) from Corsair Canyon to the Northeast Peak (Fig. 2). This area is closed annually to commercial longlining operations from 1 January to 1 August to reduce bycatches of bluefin tuna and small swordfish. Therefore, no other vessels were fishing in this closed area at the time this experiment was conducted. The gear was deployed each evening between 1800–2300 h in surface waters following the 20–22°C isotherm from south to north, allowed to soak overnight, and hauled back from north to south beginning at daybreak (~0600 h) the following morning. Haulback operations generally required 10 hours—occasionally exceeding 12 hours when the gear parted off or became entangled.

Ten surface longline sets were completed with standard commercial longline gear configured with alternately spaced monofilament and tarred multifilament nylon gangions. It was assumed that this approach would minimize the variability in catches between gangion types resulting from the different depth and temperature regimes over the length of the set (i.e. up to 64 km). Generally, 20 sections of gear were deployed for most sets (one section=72 hooks and 23 buoys), yielding a total of 1440 hooks per set (for sets 4–10), although there was some variation in hook number for the first three sets (set 1: 1008 hooks; sets 2–3: 1656 hooks). Although the 1:1 ratio of gangion types was not maintained in some gear sections owing to gear damage and subsequent replacement, the overall ratio for the entire set remained at 1:1.

Monofilament gangions consisted of two 3.6-m sections of 400-lb test, 2-mm diameter monofilament nylon attached together with stainless steel crimps, with the lower section or leader attached to a no. 9 Mustad J-hook (Fig. 3). Multifilament gangions had a 3.6-m upper section of tarred braided nylon (400 lb test, 5-mm diameter), and a lower 3.6-m monofilament leader (400-lb test, 2-mm diameter) to which a no. 9 Mustad J-hook was attached. Therefore, the lower section (leader) of both gangion types was monofilament nylon and the upper section varied between multifilament and monofilament nylon material. With this configuration, only the leader section had to be replaced if damaged by sharks. Each leader also had three luminous green beads and one in 20 had a green lightstick attached 1 m above the hook (Fig. 3). When the gear were set, gangions were clipped onto a monofilament backline (730 lb test) at intervals of 36 m after baiting the hooks with whole Atlantic mackerel (*Scomber scombrus*). Styrofoam buoys with 2–4 m droplines were clipped to the backline after every third hook, and a highflyer attached to the backline at the end of each section. Fishing depth during each set was estimated to vary between 9 and 11 m from the surface.

The catch (in numbers) of all pelagic species was recorded by gangion type for each section of gear within a set. The curved lower jaw fork length (LJFL, cm) was obtained for all commercial-size swordfish (i.e. ≥119 cm LJFL) by using a metal tape measure. No measurements were obtained for live or dead under-size swordfish (i.e. <119 cm LJFL based on visual estimation); however, their catch was recorded. Under-size swordfish were not brought aboard the vessel but were released in the water by cutting the gangion as close to the hook as possible. Other species were not measured because most of these were also released alive after capture.

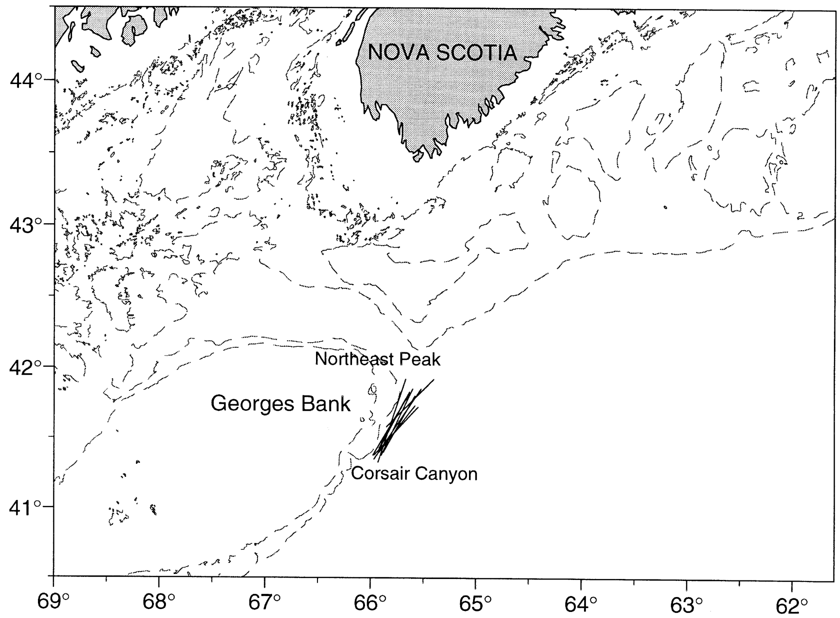

Figure 2

Geographic location of ten pelagic longline sets conducted off Georges Bank between 22 July and 2 August 1999, to examine the catches of pelagic species on monofilament and tarred multifilament nylon gangions.

Chi-square (χ^2) was used to determine if the observed frequency of catches by gangion type for each species differed significantly (α<0.05) from an expected 1:1 ratio for individual and combined sets. Catches of commercial-size and under-size swordfish were combined for this analysis because the method for size determination of under-size fish was considered too subjective for a separate analysis by size category. Only cases where 10 or more observations were available for each species were used for within-set comparisons. Because very few captures of any species occurred on gangions with lightsticks attached, the influence of lightsticks on catch rates in this experiment were assumed to be negligible, even though they are often used by fishermen (at much higher deployment rates) to improve catches of swordfish. A two-way ANOVA was used to examine differences in the mean lengths (LJFL) of commercial-size swordfish ≥119 cm LJFL) by set and gangion type after testing for homogeneity of variances.

Results

The primary species captured included swordfish *(Xiphias gladius*), blue shark (*Prionace glauca*), shortfin mako shark (*Isurus oxyrinchus*), pelagic stingray (*Dasyatis violacea*), loggerhead turtle (*Caretta caretta*), white marlin (*Tetrapturus albidus*), common dolphinfish (*Coryphaena hippurus*) and yellowfin tuna (*Thunnus albacares*). A total of 1093 captures (all eight species combined) occurred from 10 pelagic longline sets, with 66.7% of captures occurring on monofilament and 33.3% on multifilament gangions. Catches of swordfish averaged 38.8 fish per set (based on 334 kept plus 54 released as under-size), followed by blue shark (34.1/set), shortfin mako shark (9.7/set), pelagic stingray (9.4/set), loggerhead turtle (6.6/set), white marlin (6.0/set), common dolphinfish (3.7/set), and yellowfin tuna (1.0/set).

Commercial-size swordfish ranged from 120 to 242 cm LJFL (mean=154.4 ±21.14, n=334). Swordfish captured on monofilament nylon and multifilament nylon gangions were very similar in mean length (154.7 ±21.66 and 153.8 ±20.18 cm LJFL, respectively) and overall size composition (Fig. 4). There was no significant difference between mean lengths of commercial-size swordfish by set or gangion type, nor was there evidence of an interaction between these factors (F=0.736, P=0.690, df=333, 19), indicating that there were no size-related preferences for one gangion type over the other for swordfish ≥119 cm LJFL.

Observed swordfish captures by gangion type differed significantly from an expected 1:1 ratio in all but two of the 10 sets, with higher catches on monofilament gangions compared with the multifilament (Table 1). Similarly, observed captures of blue sharks differed significantly from expected in 3 of 10 sets, with higher catches on the monofilament gangions. For all other species, fewer than 10 sets were available for χ^2 comparisons because less than 10 individuals were captured for some sets. In the case of mako shark, only 5 of 10 sets had sample sizes ≥10, but no significant difference occurred between the observed and expected catch frequency by gangion type, although more captures occurred on monofilament gangions for most sets. For white marlin and loggerhead turtle, only 2 of 10 sets had sample sizes ≥10 and showed no significant differences in catch by gangion type, although most occurred on monofilament. However, for pelagic stingrays, 3 out of 4 sets available for comparison showed significant differences between observed and expected catches by gangion type, with higher catches on the monofilament gangions. The catch per set of yellowfin tuna and common dolphinfish was too low for statistical comparisons. Captures of all species combined were significantly higher on monofilament gangions for 9 out of 10 sets (Table 1).

For all species, 60% or more of catches from combined sets occurred on monofilament gangions (Table 2). When the catches by species for all 10 sets were pooled, the

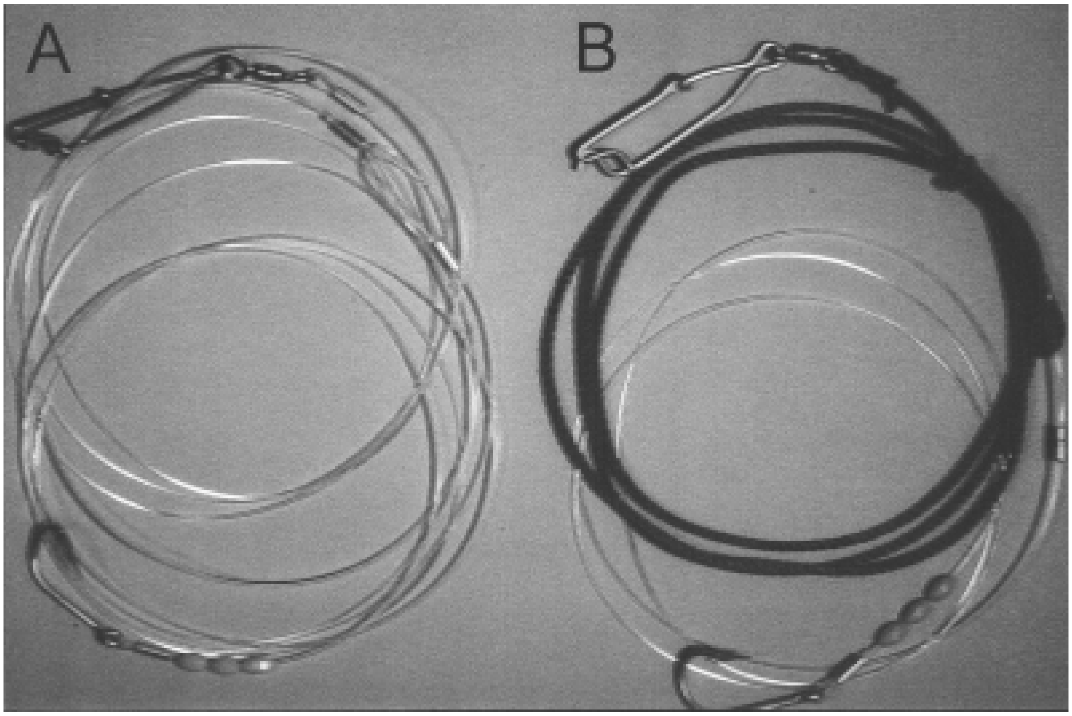

Figure 3

Monofilament nylon (**A**) and tarred multifilament nylon (**B**) gangions used for ten pelagic longline sets conducted off Georges Bank from 22 July to 2 August 1999.

observed captures by gangion type differed significantly from an expected 1:1, with the monofilament nylon outperforming the tarred multifilament nylon gangions for 6 of 8 species (Table 2). The catch ratio by gangion type (i.e. monofilament versus multifilament) for all species combined was 2:1 and was highest for yellowfin tuna (9:1) and lowest for mako shark (1.5:1).

Discussion

The purpose of our analysis was to examine differences in pelagic longline catch by species for two different types of gangion and was based on the premise that monofilament nylon gangions currently used by Canadian pelagic longline fishermen yield higher catches than the tarred multifilament nylon gangions used in the past. Although only a small data set from a limited geographic area was available for this analysis, it was apparent in the case of swordfish and blue shark that catches were significantly higher on monofilament gangions, which yielded double the catch of the multifilament gangions for

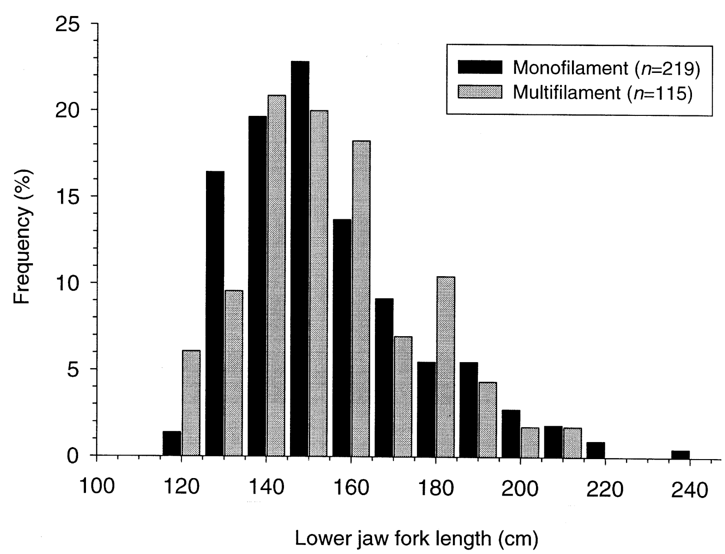

Figure 4

Size distributions of commercial-size swordfish ≥119 cm LJFL) captured on monofilament and tarred multifilament nylon gangions during a pelagic longline study conducted off Georges Bank from 22 July to 2 August 1999.

Table 1

Summary of pelagic longline catch by species and gangion type for sets 1 through 10. Chi-square statistics (χ^2) and corresponding P-values are presented for comparisons of catch by gangion type for species where total catch exceeded 10 individual per set. M = monofilament gangion; B = multifilament gangion.

	Set 1				Set 2				Set 3				Set 4				Set 5			
Species caught	M	B	χ^2	P	M	B	χ^2	P	M	B	χ^2	P	M	B	χ^2	P	M	B	χ^2	P
Swordfish	22	6	9.14	0.003	31	26	0.44	0.508	23	9	6.13	0.013	27	14	4.122	0.042	44	23	6.58	0.010
Yellowfin tuna	0	0	—	—	0	0	—	—	1	0	—	—	0	0	—	—	2	0	—	—
Mako shark	5	1	—	—	7	7	0.00	1.000	11	6	1.47	0.225	5	5	0.000	1.000	11	5	2.25	0.134
Blue shark	9	3	3.00	0.083	10	7	0.53	0.467	39	19	6.90	0.009	12	5	2.882	0.090	9	6	0.60	0.439
White marlin	4	1	—	—	8	1	—	—	4	0	—	—	7	3	1.600	0.206	5	2	—	—
Dolphinfish	2	0	—	—	4	3	—	—	2	0	—	—	6	1	—	—	1	2	—	—
Stingray	13	4	4.77	0.029	7	9	0.25	0.617	3	3	—	—	7	1	—	—	4	1	—	—
Loggerhead turtle	3	4	—	—	4	0	—	—	6	4	0.40	0.527	3	1	—	—	4	0	—	—
Total	58	19	39.00	0.000	71	53	18.00	0.106	89	41	48.00	0.000	68	30	38.0	0.000	80	39	41.00	0.000

	Set 6				Set 7				Set 8				Set 9				Set 10			
Species caught	M	B	χ^2	P	M	B	χ^2	P	M	B	χ^2	P	M	B	χ^2	P	M	B	χ^2	P
Swordfish	31	12	8.40	0.004	19	8	4.48	0.034	11	4	3.27	0.071	27	14	4.122	0.042	25	12	4.57	0.033
Yellowfin tuna	0	0	—	—	1	1	—	—	1	0	—	—	2	0	—	—	2	0	—	—
Mako shark	3	3	—	—	6	2	—	—	7	4	0.82	0.366	1	4	—	—	2	2	—	—
Blue shark	30	20	2.00	0.157	51	26	8.12	0.004	47	19	11.88	0.001	13	5	3.556	0.059	5	6	0.09	0.763
White marlin	1	1	—	—	5	0	—	—	1	0	—	—	7	3	1.600	0.206	5	2	—	—
Dolphinfish	2	1	—	—	2	0	—	—	0	0	—	—	3	2	—	—	5	1	—	—
Stingray	11	1	8.33	0.004	12	4	4.00	0.046	1	0	—	—	1	4	—	—	4	4	—	—
Loggerhead Turtle	4	4	—	—	5	2	—	—	2	2	—	—	5	6	0.091	0.763	4	3	—	—
Total	83	42	41.00	0.000	101	43	58.00	0.000	70	29	41.00	0.000	59	38	21.00	0.033	52	30	22.00	0.015

some sets. Although only the upper half of the multifilament gangion was made from braided nylon material (based on a configuration used by fishermen in the past), the differences in catches for these two species between this gangion and one constructed entirely of monofilament nylon were striking. A similar trend for the other pelagic species was not as evident on a set-by-set basis owing to lower catches; however, for combined sets, more captures occurred on the monofilament gear overall. Although these results clearly indicate differences in catches between gangion types, the influence of oceanographic conditions off Georges Bank, such as water temperature and thermocline depth, likely influence the availability and catchability of all species. Therefore, it is important to point out that results could differ among geographic areas with different oceanographic regimes.

Reports of higher catches on monofilament gear have also been made for other species. Monofilament snoods (gangions) give higher catch rates for cod and haddock compared with multifilament snoods, and thinner snoods tend to give better catch rates than thicker ones (Bjordal and Lokkeborg, 1996). Under good light conditions, monofilament lines were observed to catch as much as three times more cod than multifilament lines (Bjordal and Lokkeborg, 1996). Over the past decade, Canadian bluefin tuna fishermen have gradually shifted to finer gauges of monofilament nylon line (i.e. from 400 lb to 120 lb test) for use on rod and reel gear because it is their perception that bluefin tuna have learned to recognize and avoid the heavier monofilament nylon line. The lower visibility of monofilament gangions used on longline gear is commonly used to explain why they give better catches than gangions made of multifilament nylon; however, the reason for the difference in catching power is unclear. Some pelagic fish species may be able to detect multifilament nylon gangions more readily because of their thicker diameter (5 mm versus 2 mm for monofilament) and darker color, and can make this distinction even during periods of darkness (i.e. when the pelagic longline gear is fishing). The higher visibility of multifilament lines may cause a restrained response towards attacking the baited hooks.

Whether multifilament nylon gangions are more easily detected by some species, likely depends on the role that vision plays as the dominant sensory mechanism. Some pelagic species have large eyes (i.e. yellowfin tuna, swordfish, white marlin, mako and blue shark) and are efficient visual predators even in dim light. Becuase visual acuity or resolution of detail improves with the size of the eye (Blaxter, 1980), some pelagic species may be better at detecting and avoiding the multifilament nylon gangions

Table 2

Summary of pelagic longline catches by species and gangion type for all sets combined. Chi-square statistics (χ^2) and corresponding *P*-values are presented for all species. M = monofilament gangion; B = multifilament gangion.

Species	Gangion	*n*	% by gangion type	Ratio (M:B)	χ^2	*P*	% of total catch
Swordfish	M	260	67.0	2.03:1.00	44.90	0.000	35.7
	B	128	33.0				35.2
Yellowfin tuna	M	9	90.0	9.00:1.00	6.40	0.011	1.2
	B	1	10.0				0.3
Mako shark	M	58	59.8	1.49:1.00	3.72	0.054	7.8
	B	39	40.2				10.7
Blue shark	M	225	66.0	1.94:1.00	34.84	0.000	30.9
	B	116	34.0				31.9
White marlin	M	47	78.3	3.62:1.00	19.27	0.000	6.5
	B	13	21.7				3.6
Dolphinfish	M	27	73.0	2.70:1.00	7.81	0.005	3.7
	B	10					2.8
Stingray	M	63	67.0	2.03:1.00	10.89	0.001	8.6
	B	31	33.0				8.5
Loggerhead turtle	M	40	60.6	1.54:1.00	2.97	0.085	5.5
	B	26	39.4				7.1
Total	M	729	66.7	2.00:1.00	123.00	0.000	100.0
	B	364	33.3				100.0

than others, as evidenced by the range of catch ratios between monofilament and multifilament gangions for the various species encountered during our study (Table 2).

Although no differences in the size of swordfish ≥119 cm LJFL occurred between gangion types, more swordfish were captured on monofilament gangions, along with other bycatch species. Although catches of all species were higher on the monofilament gear, the percentage of total catch represented by each species for each gear type was very similar (Table 2, last column). Therefore, by fishing an extra one or two sets with the multifilament gear, fishermen would get the same amount of catch as they would have if monofilament gear were used, but at greater cost because more sets and days at sea would be required to yield the same catch. Furthermore, the absence of any species-specific trends between gangion types indicates that the use of monofilament gangions does not reduce the bycatch of other pelagic species.

Catch-per-unit-of-effort (CPUE) indices based on commercial fishery statistics are often used in analytical models to investigate trends in resource abundance, particularly in the stock assessments for swordfish and bluefin tuna conducted by the International Commission for the Conservation of Atlantic Tunas. Catch rates are generally standardized for the effects of gear, area, month, and other factors by using general linear models (e.g. Hoey et al. 1997). The importance of gear changes and their effect on commercial catch rates is clearly evident in this study and underscores the need to detect and account for changes in gear technology in the development of any commercial catch rate series used in analytical stock assessments.

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