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A comparison of gear configuration and capture by hook, depth, and habitat for Japanese training vessel and Hawaii-based tuna longline fisheries

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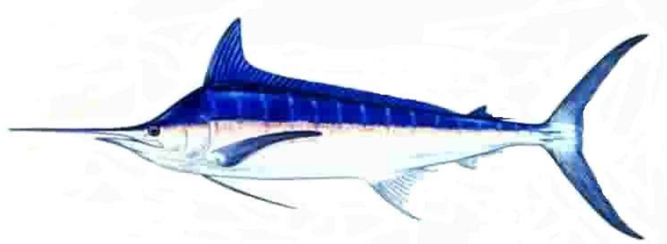

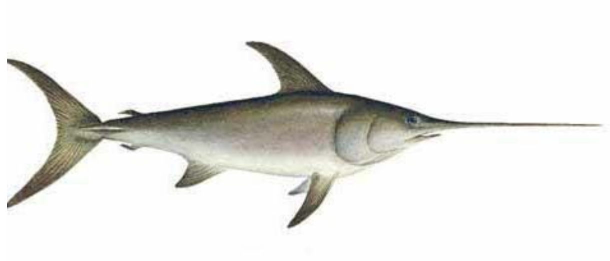

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Title: A comparison of gear configuration and capture by hook, depth and habitat for Japanese training vessel and Hawaii-based tuna longline fisheries.

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Abstract

Gear configuration was compared between the two largest at-sea monitored longline fisheries in the tropical and sub-tropical Pacific Ocean: Japanese training vessel and Hawaii-based tuna longline fisheries. Configuration differed markedly between fisheries in attributes such as hooks deployed between floats, floatline and branchline lengths, distance between hooks and catenary angle (sag ratio). Monitoring with time-depth recorders (TDRs) provided longline depth estimates and capture by hook, depth and habitat. There was good coherence among fisheries in vertical distribution profiles of nominal catch rate (CPUE) by depth; however absolute CPUE values differed. Catch rate profiles were categorized in relation to depth as: 1) increasing, decreasing and no apparent relationship. Bigeye and albacore tuna exhibited an increasing CPUE with depth and decreasing ambient temperature. All three istiophorid billfishes (striped marlin, blue marlin, and shortbill spearfish) and skipjack tuna had decreasing CPUE with depth. The blue shark profile indicated no apparent trend in CPUE with depth for a northern area (north of 20ºN) of the training vessel fishery and Hawaii-based fishery and a decline in CPUE at depths greater than 200 m for a southern area (south of 20ºS). There was no apparent depth or habitat trend in CPUE for yellowfin; however, results may be biased due to capture on longline deployment or retrieval. This study provided nominal CPUE with regard to depth and habitat and additional modeling could be conducted to incorporate covariates (e.g. time, space, bait type and oceanography) to explain catch by hook, depth and habitat.

Introduction

Catchability in pelagic longline fisheries has historically changed due to altering gear configuration and materials to target different species. Quantifying changes in catchability is important within stock assessments as effort time-series are greater than 50 years for the Japanese longline fishery in the Pacific Ocean. A critical aspect in understanding catchability is the depth and habitat that a longline exploits. The vertical distribution of a longline coupled with the overlap in species vulnerability determines catch rates in the context of depth-at-capture and habitat-at-capture for target, incidental and bycatch or non-marketable species.

Longline gear depth in the Pacific Ocean has been inferred through catenary geometry (e.g. Suzuki et al., 1977; Hanamoto, 1987; Gong et al., 1989; Grundinin, 1989; Ward et al., 1996; Saito 1992, Nakano et al., 1997) and observed with depth or temperature-depth recorders (Saito, 1973; Hanamoto, 1974; Nishi, 1990; Boggs, 1992; Mizuno et al. 1996, 1998, 1999, Okazaki et al. 1997; Bach et al., 2003; Bigelow et al. 2006).

Longline monitoring provides observed depth estimates and depth and habitat-at-capture that are more accurate than predictions based on catenary methods because environmental factors may shallow the longline thereby confounding catenary estimates and biasing depth and habitat-at-capture estimates. The amount of shallowing can depend on the prevailing oceanographic conditions and the material composition of the mainline. Shoaling estimates have been smaller for tarred krylon mainline (~10%, Saito, 1973; Hanamoto, 1974; Nishi, 1990, I assume the Nishi study was based on tarred gear??), and greater for monofilament gear (30−50%, Boggs, 1992; Bigelow et al. 2006) with one longline set exhibiting extreme shoaling (~70%, Mizuno et al. 1999). The aforementioned longline monitoring studies occurred with experimental research gear with the exception of one study (Bigelow et al. 2006) that obtained actual fishing depths for a commercial fishery.

The Japanese training vessel and Hawaii-based longline fisheries represent the two largest at-sea monitored fisheries in the tropical and sub-tropical Pacific Ocean. Research on gear configuration and estimating capture by hook, depth and habitat has broad implications for:

1) efficient species targeting,
2) reducing the catch of non-marketable species,
3) improved understanding of the gear component in various CPUE standardization models (e.g. GLM and statHBS) and
4) comparing regional similarities and differences in the vertical distribution of CPUE among longline fleets.

Specific objectives of this study include:

1) quantify and compare gear configuration used in the Japanese training vessel and Hawaii-based tuna longline fisheries,
2) monitor these fisheries with time-depth-recorders to estimate longline gear depth and habitat exploited and,
3) estimate capture by hook, depth and habitat for eight pelagic species as enumerated by training vessel personnel and observers in the Hawaii-based tuna fishery.

Methods

Gear configuration and depth were monitored on longline sets in the central North Pacific for Japanese training vessels from 2000 to 2006 and the Hawaii-based fishery from 1996 to 1999 (Table 1). Temperature-depth recorders (TDRs) were analyzed for 599 longline sets in the Hawaii-based tuna and swordfish fisheries (Bigelow et al. 2006). This study considered a subset of observed tuna longline sets (n=207) in the Hawaii-based fishery for a spatial area from 14º to 27ºN which corresponds to the subtropics. Areas to the south of 14ºN (north equatorial current and countercurrent) and north of 27ºN (subtropical frontal zone) were not considered because species may have different depth and habitat-at-capture relationships due to differing oceanography (Bigelow and Maunder 2007). There were 18,594 tuna longline sets observed for hook-at-capture from 1994 to 2006.

The Japanese training vessel fleet had a larger spatial distribution (0−45ºN, 140ºE−140ºW) than the Hawaii-based fishery (Figure 1). Within this broad area, effort largely occurred to the north and south of the Hawaii EEZ. The analysis considered two areas spatially stratified at 20ºN which roughly bisected the Hawaiian archipelago. There were a total of 4,154 sets observed for hook-at-capture, 3,556 sets that estimated depth from catenary geometry and 598 sets monitored depth with TDRs (Table 1). Estimated catenary depth was calculated as a sag ratio by the vessel operator as the ratio of the speed of the line thrower to vessel speed. Two TDRs were deployed on each longline set. One TDR was placed on the shallowest hook and a second TDR was placed at the middle hook position where the gear should be at the deepest depth.

The analysis considered eight species: yellowfin (YFT), skipjack (SKJ), bigeye (BET) and albacore (ALB) tuna, striped (MLS) and blue marlin (BUM), shortbill spearfish (SPF) and blue shark (BSK).

The rationale for choosing these eight species included:

1) numerically common and commercially valuable catch,
2) hook-at-capture was recorded for these species since 1994 in the Hawaii-based fishery, but was only recorded for other common species (e.g. mahimahi, lancetfish) since 2002.
3) represents species with different habitat-at-capture profiles and are used in contemporary habitat and CPUE modeling (statHBS, ISC/08/BILLWG−1/04).

Gear configuration statistics were calculated for hooks between floats, floatline and branchline length and distance between hooks. TDR statistics for the Japanese training vessel fishery included the maximum TDR depth of the shallowest and deepest hook, while the Hawaii-based fishery included the average and maximum depth of the deepest hook. An observed catenary angle was calculated in R (version 2.2.0 for Linux) for each TDR monitored set based on hooks between floats, floatline and branchline length, distance between hooks and shallowest and deepest TDR depth (Japanese training vessel) or average and maximum TDR depth (Hawaii).

Results

Bigeye tuna and blue shark were the most common species caught in each fishery (Table 1). Skipjack ranked as the 3rd most common species caught in the Hawaii-based fishery, but was uncommon in the training vessel fishery probably due to hooks being deployed deeper in the water column. Albacore and yellowfin were intermediate in occurrence and blue marlin and spearfish typically ranked last. Striped marlin was more common in the northern area of the training vessel fishery than the southern area.

Comparison of gear configuration

Gear configuration between fisheries differed markedly in all attributes (Tables 2−3, Figures 2−3). Longline gear in the Japanese training vessel fishery deploys fewer hooks between floats, longer floatline and branchline lengths and a greater distance between hooks. Training vessels have a larger catenary angle (~67.9º) or smaller sag ratio (~0.664) compared to the Hawaii-based fishery (catenary angle=59.3º, sag ratio=0.767). Depth profiles based on mean gear attributes (Figure 4) indicate that longline gear in the Japanese training vessel fishery obtains deeper depths while deploying substantially less hooks between floats. Deeper depths are obtained from the larger catenary angle, greater distance between hooks and longer floatline and branchline lengths. Differences are also evident in profiles of total hooks when stratified by 40-m depth intervals (Figure 5). Training vessels deploy few hooks in the upper portion of the water column (0−80 m) due to long floatline and branchlines. In contrast, the Hawaii-based fishery deploys a substantial amount of hooks in the 40 to 80 m depth stratum. We illustrated CPUE results at 40 m depth intervals and profiles were similar when stratified at smaller intervals (e.g. 20 m).

Training vessels deploy an increasing number of hooks with depth with most hooks fishing at 240 to 280 m in both the northern and southern areas (Figure 5). The Hawaii-based fishery deploys a similar amount of effort from 40 to 240 m with a decline in effort at deeper depths. The Hawaii-based fishery typically deploys hooks from 8º to 26ºC with most hooks fishing at temperatures warmer than 18ºC. The study did not estimate the total hooks by temperature for training vessels, but we would expect that the fishery would exploit cooler waters given the deeper depth distribution and that longline effort was conducted in cooler waters to the north of the Hawaii archipelago.

CPUE with depth and habitat

There was good coherence among fisheries in vertical distribution profiles of nominal CPUE by depth; however nominal CPUE values differed (Figures 6−7). Catch rate comparisons between fisheries are only appropriate from 80 to 360 m where fishing effort overlaps. Within the training vessel fishery, CPUE profiles were similar between northern and southern areas, but nominal CPUE was higher for striped marlin and bigeye tuna in the northern area (Figure 6). The training vessel fishery in the southern area had higher depth specific CPUE than the Hawaii-based fishery for five species (MLS, BUM, SPF, YFT, BET), similar CPUE for albacore and blue shark and lower CPUE for skipjack. While the Hawaii-based fishery has lower nominal CPUE in most depth intervals, catch rates for blue and striped marlin are probably equivalent to the training vessel fishery when the shallow depth stratum (40−80 m) is included. It should be noted that there are apparent high CPUE values in the Hawaii-based fishery in depth strata 0−40 m, 400−440 m and 440−480 m for several species (Figure 7), but these are probably biased due to low fishing effort (Figure 5).

Catch rate (CPUE) profiles can be categorized after Nakano et al. (1997) in relation to depth as: 1) increasing, decreasing and no apparent relationship. Bigeye and albacore tuna exhibited an increasing CPUE with depth and decreasing ambient temperature. All three istiophorid billfishes (MLS, BUM, and SPF) and skipjack tuna had decreasing CPUE with depth. The blue shark profile indicated no apparent trend in CPUE with depth for the northern area of the training vessel fishery and Hawaii-based fishery and a decline in CPUE at depths greater than 200 m for the southern area. There was also no apparent depth or habitat trend in CPUE for yellowfin; however, results may be biased due to capture on longline deployment or retrieval (see Discussion).

Hook-at-capture

Hook-at-capture estimates were generated from all observed sets. Results are presented for the four and six most common hook between float configurations used in the training vessel and Hawaii-based fisheries, respectively (Figures 8−9). Hook-at-capture results are similar to the subset of TDR monitored sets depicting CPUE with depth. Bigeye and albacore tuna have the highest catches on the deepest hooks. The shallowest hooks adjacent to the longline floats have substantially higher billfish catch than any deeper hooks. Skipjack catch is highest on the 2nd or 3rd hooks closest to the float in each fishery. Blue shark and yellowfin catch is highest on intermediate hooks, though differences between adjacent hooks are not as large as in other species.

Discussion

A comparison of gear configuration and depth exploited indicates that longline catchability would not be similar between training vessel and Hawaii-based fisheries. The Hawaii-based tuna fishery deployed substantial effort at 40−80 m that does not occur in the training vessel fishery. Fishing at these shallow depths has implications for increased catches of incidental (e.g. billfishes, mahimahi) and bycatch species (e.g. skipjack, marine turtles).

The study produced nominal catch rates with regard to depth and habitat. The training vessel fishery in the southern area had higher depth specific CPUE from 80 to 360 m for five species, and it is unknown why the Hawaii-based fishery had lower catch rates in a similar spatial area. Modeling could be conducted in future studies that incorporates covariates to explain catch by hook, depth or habitat. Within longline fisheries, oceanography (e.g. ambient temperature, depth of thermocline, oxycline) has a greater influence on the vertical distribution in catch rates than depth per se (Bigelow and Maunder, 2007). Physiological preferences differ among species and the combination of oceanography and physiological ecology determines the vulnerability to longline gear. Covariates for modeling consideration could include time (quarter), space (longitude and latitude), bait type and oceanography.

Several studies have investigated depth and habitat relationships for pelagic species on experimental longline surveys in the Pacific Ocean. Boggs (1992) reviewed earlier work on swimming depths of target tunas and other incidental catches in tuna longline fisheries and presented results using TDRs and hook timers on experimental longline gear to estimate fish capture time and depth. Most of the striped marlin and spearfish were caught at depths of <120 m, whereas most bigeye tuna were caught at depths of >200 m. The study also deployed hook timers which confirmed whether a species was caught on a moving (sinking or rising) or settled hook. The percentage of fish caught on moving hooks differed by species: 12% bigeye, 12% yellowfin, 32% striped marlin, 21%

spearfish and 28% mahimahi. No hook timers were used in the training vessel or Hawaii-based longline fishery, thus depth and habitat-at-capture estimates may be biased due to capture on moving hooks. In particular, yellowfin tuna is known to inhabit the mixed layer and upper thermocline (Brill et al. 1999) and the moderate catch rates on deep hooks may relate to moving rather than settled hooks.

Nakano et al. (1997) developed depth-at-capture relationships based on catenary formula and compared the efficiency of shallow and deep longline gear. Species caught on the longline were classified into three groups: those having a decrease, an increase and no clear trend in catch rate with depth. Species caught more frequently at shallow depths included: skipjack tuna, striped marlin, blue marlin, black marlin, sailfish, shortbill spearfish, wahoo, mahimahi, snake mackerel and oceanic white tip shark. Albacore, bigeye tuna, opah, lancetfish, sickle pomfret and thresher sharks were mainly caught at deeper depths. Yellowfin tuna, swordfish, escolar, shortfin mako and blue shark showed no clear trends. Results on eight species in this study were classified the same as in Nakano et al. (1997).

The training vessel fishery probably cannot be used as a surrogate for depth and habitat exploited by the Japanese distant-water commercial fishery. While there is little published information on distant-water gear configuration, the current tuna fishery deploys more hooks between floats (~20−24), longer floatline and branchline lengths, shorter distance between hooks (~40 m) and a smaller catenary angle (larger sag ratio) than training vessels (K. Yokawa, pers. communication with fishing masters). Differences in gear configuration relate to fishing objectives: Training vessels prefer to fish over a large depth range in order to increase species diversity for training activities, while distant-water vessels attempt to target a 150 m layer in the water column from 150 to 300 m to effectively target bigeye tuna.

Boggs (1992) proposed that eliminating shallow hooks could substantially reduce the catch of spearfish, striped marlin and other recreationally important billfish without reducing fishing efficiency for bigeye tuna. In this study we have developed metrics of hook-at-capture to preliminary illustrate the efficacy of such a hook removal. Additional modeling of CPUE by hook, depth and habitat could prove useful in statistically developing a reconfigured longline gear that reduces incidental and bycatch species while maintaining or increasing target (bigeye tuna) catches.

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Table 1. Number of longline sets and individuals caught by species by Japanese training vessels and the Hawaii-based tuna longline fisheries. A subset of longline sets were monitored with time-depth recorders (TDRs) and have known depth and environmental conditions.

Species	Japan - North		Japan - South		Hawaii	
	Observed	TDR monitored	Observed	TDR monitored	Observed	TDR monitored
Longline sets	1,825	310	2,329	268	18,594	207
Bigeye tuna	42,406	7,542	51,080	6,502	151,705	2,102
Blue shark	8,369	1,292	17,862	2,334	98,539	1,292
Skipjack	381	49	2,643	363	39,191	346
Albacore	3,199	38	11,445	1,190	36,714	853
Yellowfin	1,560	260	10,128	854	34,149	424
Striped marlin	3,978	887	4,366	519	25,399	373
Spearfish	827	139	3,177	439	19,544	227
Blue marlin	358	47	3,554	277	5,324	138

Table 2. Mean, standard deviation, median and range (in parentheses) of longline gear configuration for Japanese training vessels. See Figure 1 for northern and southern area designation.

Variable	Spatial area		
	All	North	South
Hooks between floats	12.8±1.3, 13 (2–18, n=10,201)	12.7±1.4, 13 (2–18, n=4,361)	12.9±1.1, 13 (8–18, n=5,840)
Floatline (m)	38.0±5.3, 39 (14–50, n=10,175)	38.0±5.8, 40 (14–50, n=4,353)	38.0±4.9, 39 (25–48, n=5,822)
Branchline (m)	29.4±5.3, 30 (10–56, n=10,191)	28.0±5.1, 30 (10–48, n=4,353)	30.4±5.2, 30 (20–56, n=5,838)
Distance between hooks (m)	48.1±3.8, 48 (25–69, n=10,131)	48.2±3.7, 48 (25–60, n=4,350)	48.0±3.8, 48 (25–69, n=5,781)
Maximum TDR depth of shallowest hook (m)	109.8±17.6, 110 (76–184, n=659)	110.7±15.7, 110 (90–184, n=312)	109.0±19.1, 108 (76–150, n=347)
Maximum TDR depth of deepest hook (m)	302.8±26.6, 300 (100–470, n=867)	306.6±30.8, 310 (100–470, n=415)	299.4±21.4, 300 (215–417, n=452)
Observed catenary angle (ϕ) from TDR monitoring	67.9°±6.5, 69.3, (41.7–85, n=659)	69.1°±6.0, 69.9°, (41.7°–85°, n=312)	66.9°±6.9°, 69.3, (43.8°–80.7°, n=347)
Minimum TDR Temperature (°C)			

Table 3. Mean, standard deviation, median and range (in parentheses) of longline gear configuration collected by observers in the Hawaii-based tuna fishery.

Variable	
Hooks between floats	27.2±2.9, 28 (15–38, n=18,594)
Floatline (m)	23.9±4.7, 23.4 (3–60, n=18,520)
Branchline (m)	12.3±2.3, 12.1 (3.5–24.7, n=10,660)
Distance between hooks (m)	31.1±8.8, 29 (12.8–79.5, n=17,470)
TDR depth of deepest hook (m)	245.3±74.9, 251.8 (61–504, n=207)
Maximum TDR depth of deepest hook (m)	303.9±82.4, 308.2 (69–614, n=207)
Observed catenary angle (ϕ) from TDR monitoring based on average TDR depth	50.4°±11.7, 48.9, (30.3–83.5, n=179)
Observed catenary angle (ϕ) from TDR monitoring based on maximum TDR depth	59.4°±12.2, 59.3, (34.0–85, n=193)
Minimum TDR Temperature (°C)	13.0±3.8, 12.1, (6.1–25.8, n=207)

Figure 1. Geographical areas of longline analyses for Japanese training vessels and observed Hawaii-based tuna fishery. Japanese data were analyzed as northern (north of 20ºN) and southern (south of 20ºN) areas.

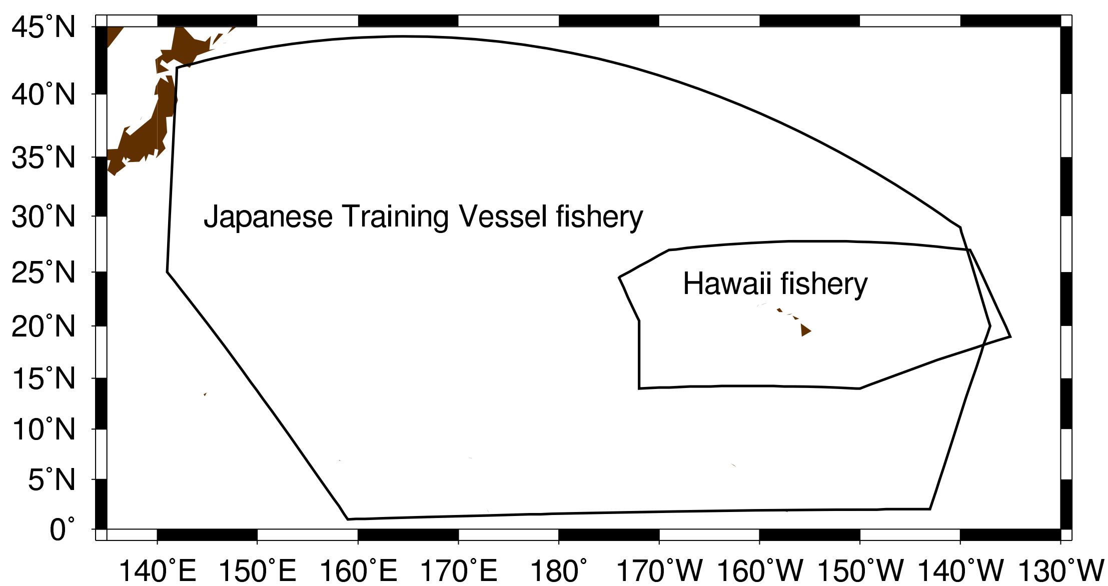


Figure 2. Observed catenary angle, shallowest hook depth and deepest maximum hook depth from time-depth recorder (TDR) measurements for Japanese training vessels.

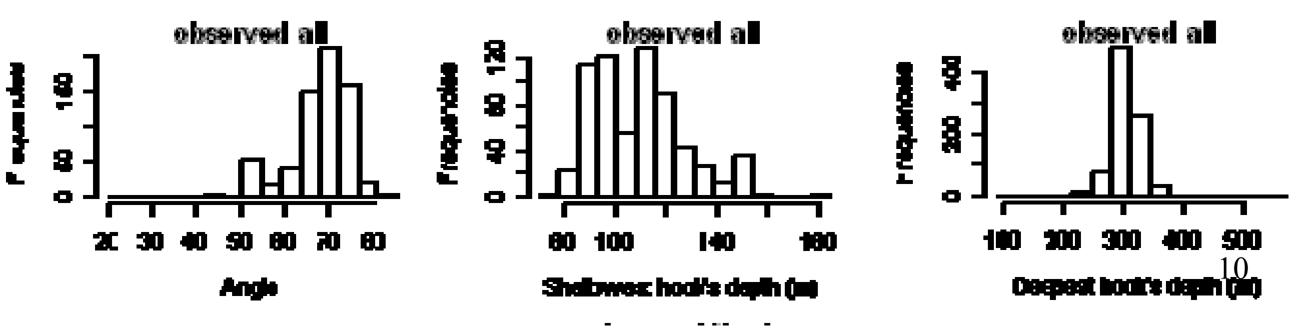


Figure 3. Observed catenary angle, mean and deepest maximum hook depth from time-depth recorder (TDR) measurements for observed Hawaii-based tuna fishery.

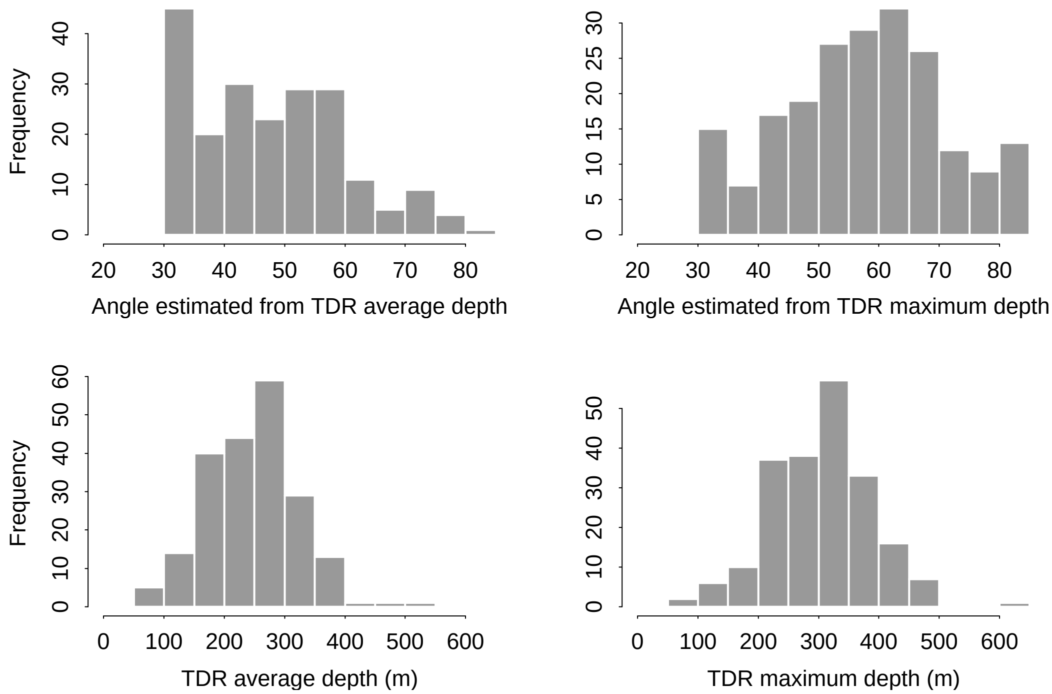


Figure 4. Comparison of typical gear configuration deployed in Japanese training vessel and Hawaii-based tuna fisheries.

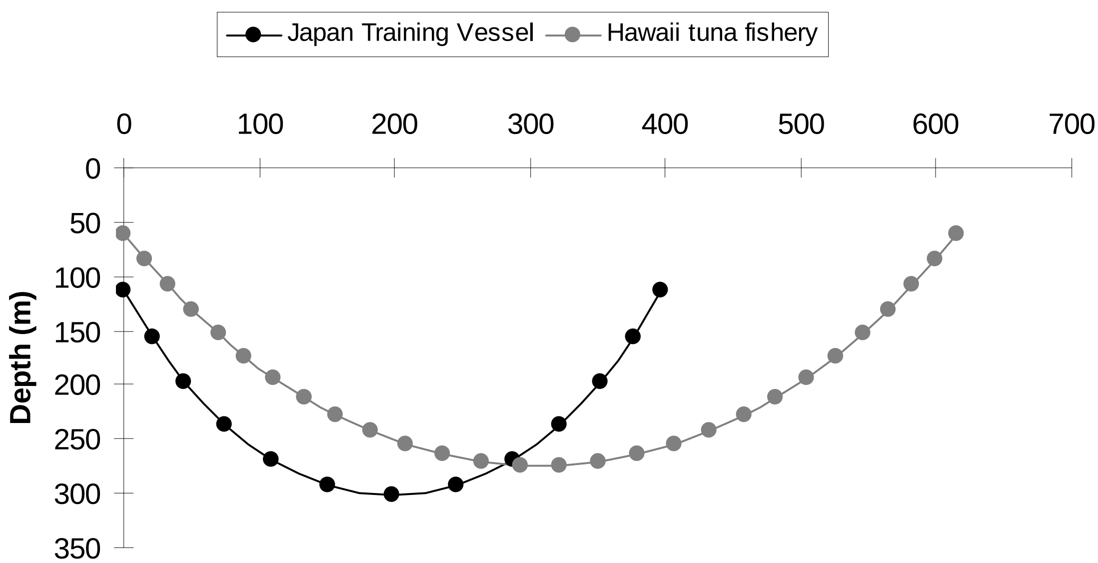


Figure 5. Total hooks deployed by depth and temperature from time-depth recorder (TDR) monitoring in Japanese training vessel and Hawaii-based tuna fisheries.

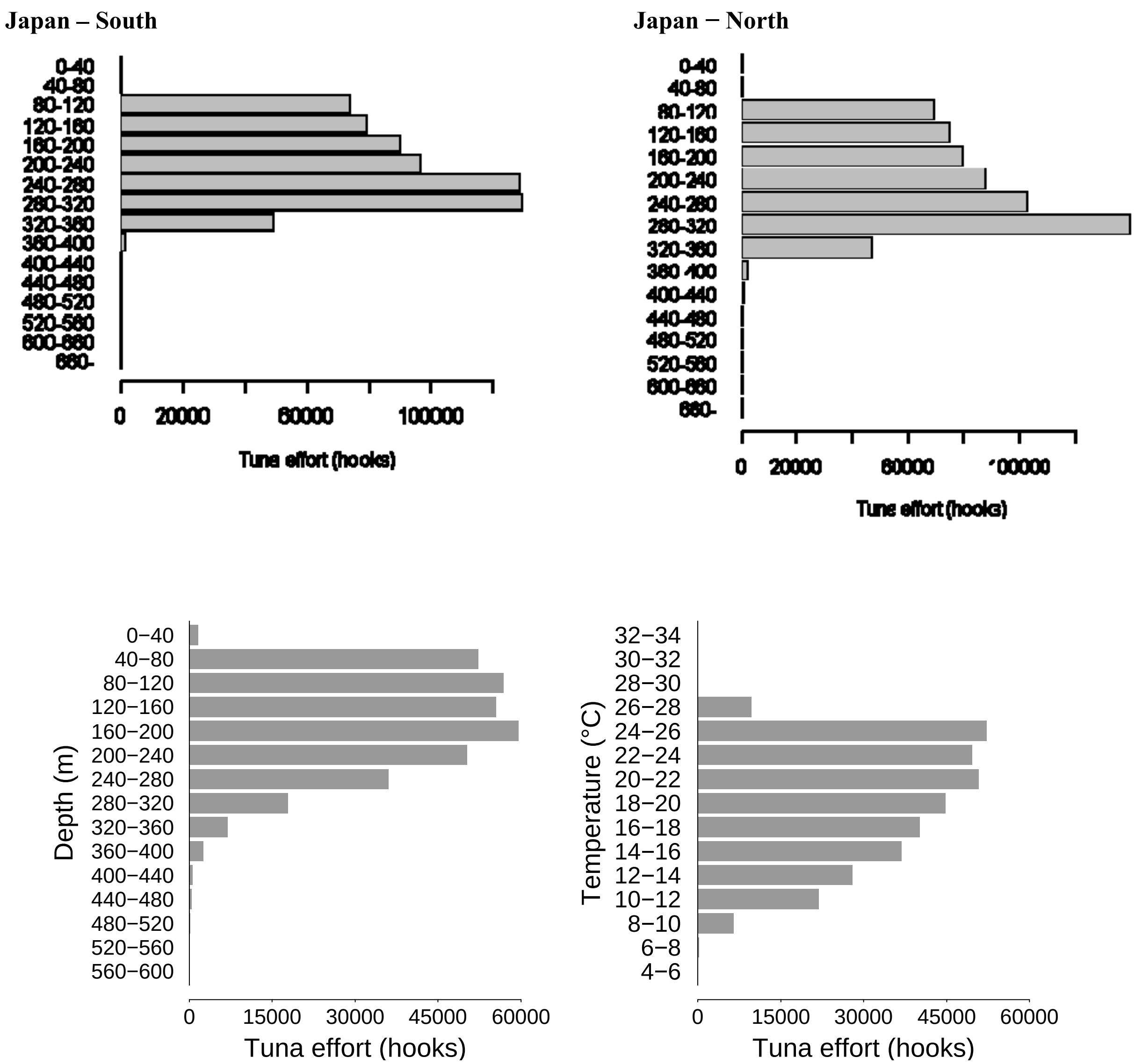
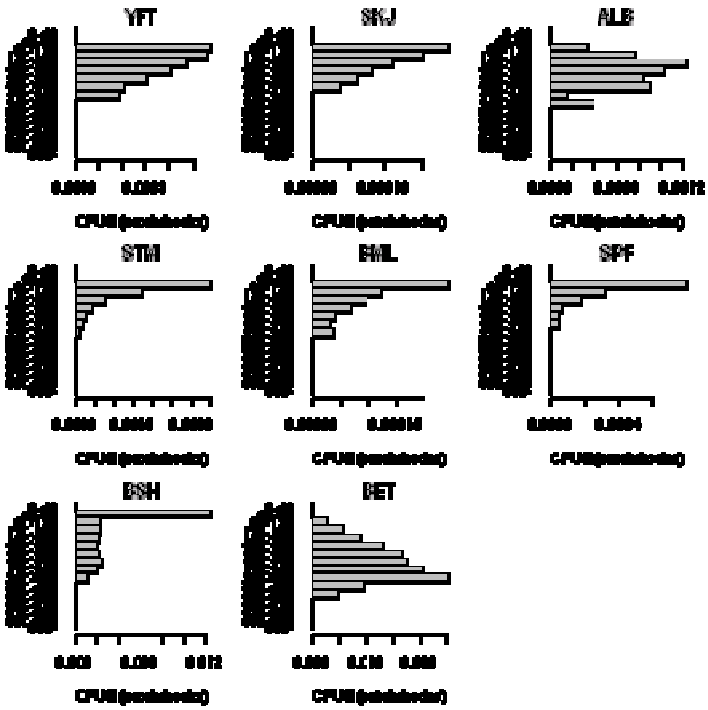


Figure 6. Comparison of vertical distribution in catch rates by depth for eight species caught by Japanese training vessels in the northern and southern areas based on estimated depth and time-depth recorders (TDRs).

North



South

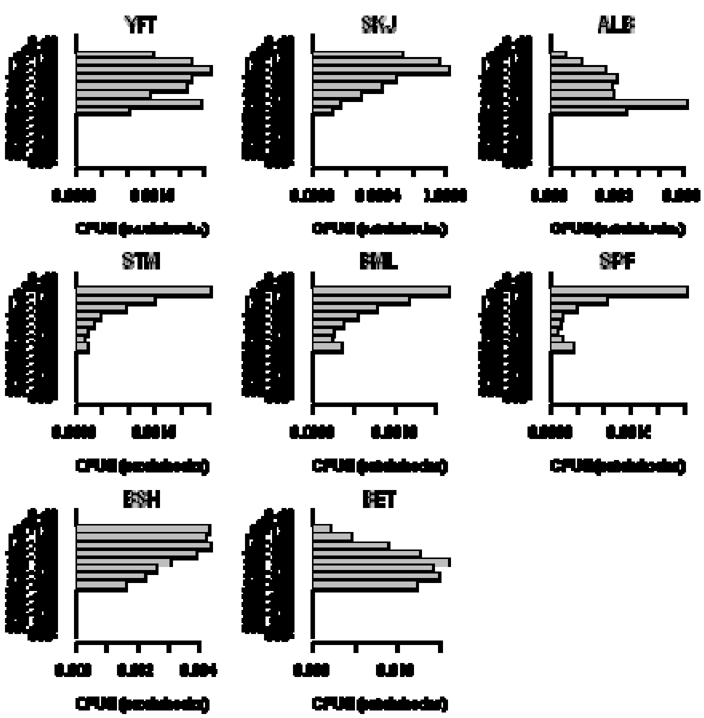


Figure 7. Comparison of vertical distribution in catch rates by depth and temperature for eight species caught by the Hawaii-based tuna fishery (n=207 sets) based on time-depth recorders (TDRs).

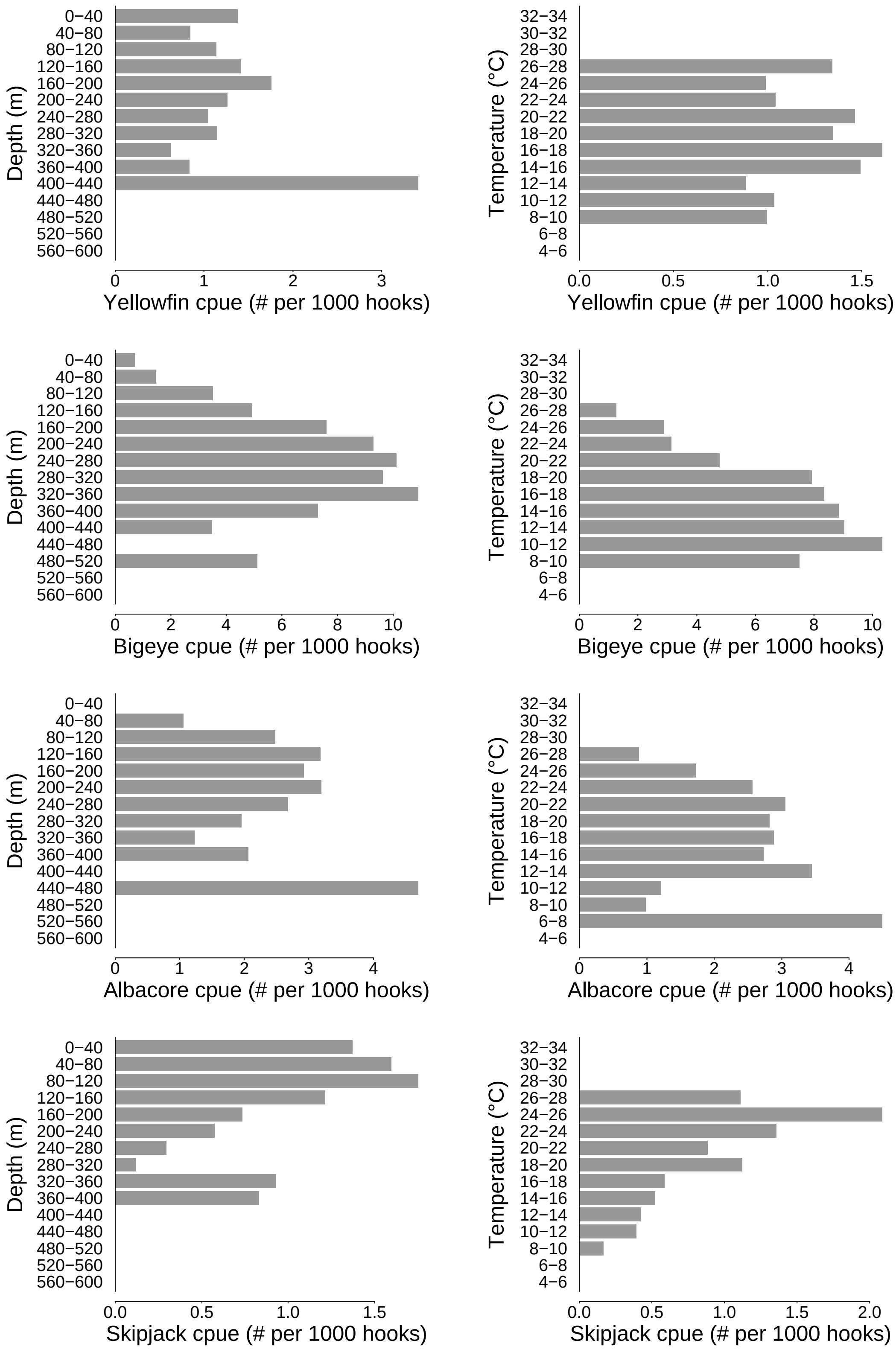


Figure 7 Continued.

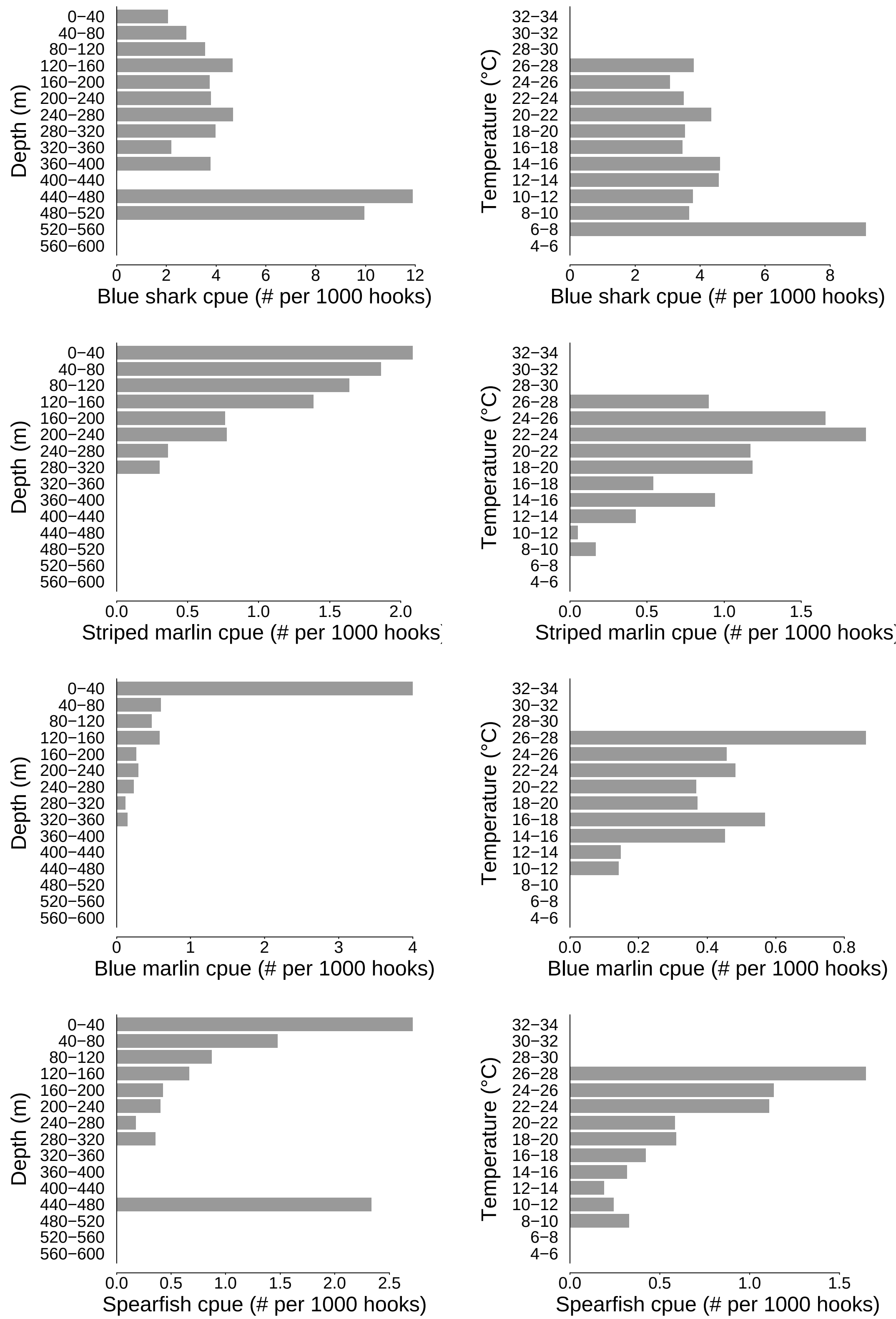


Figure 8. Comparison of hook-at-capture for eight species by four frequently used longline gear configurations. (12−15 hooks between floats) in the Japanese training vessel fishery.

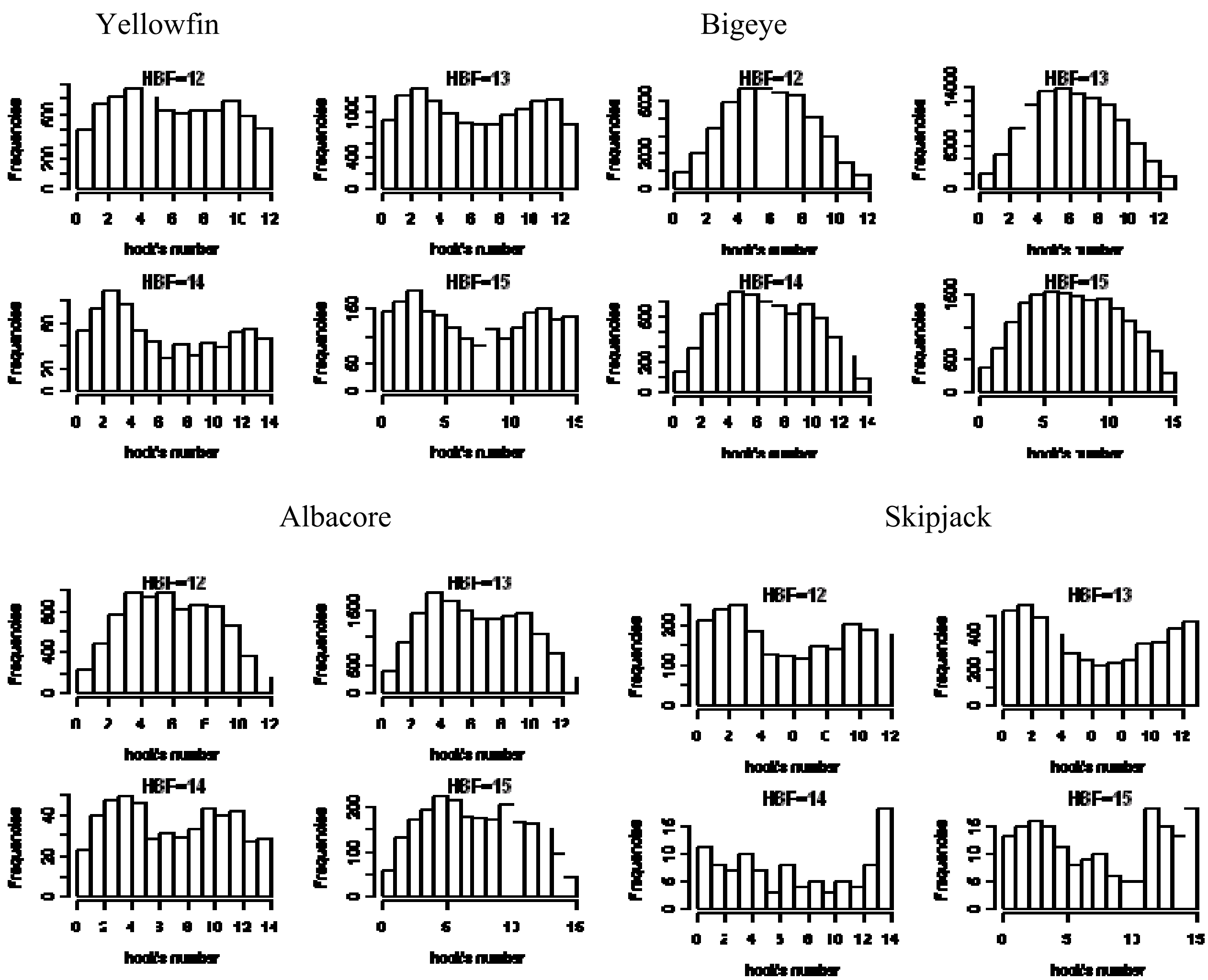
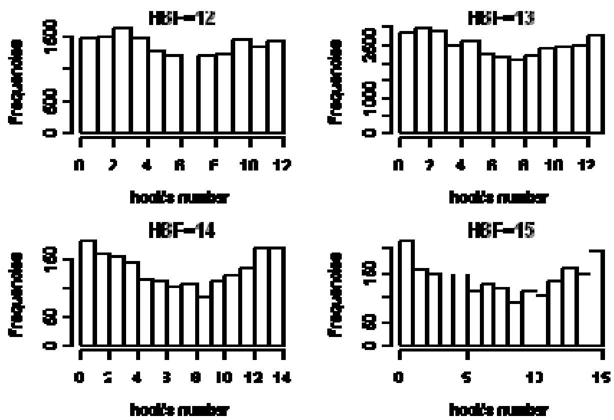
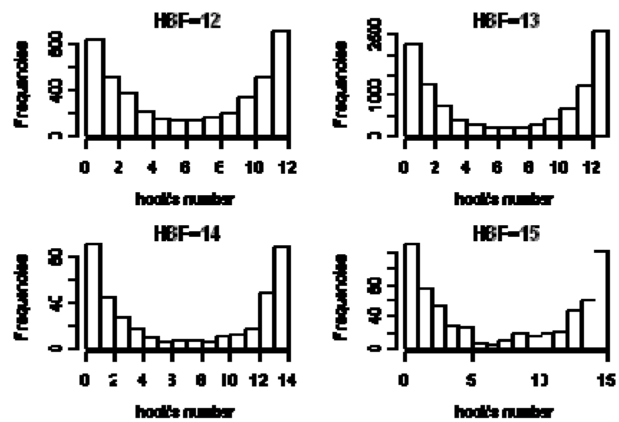


Figure 8 Continued.

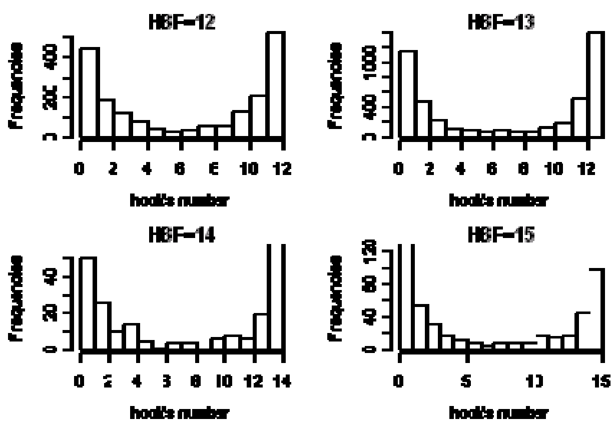
Blue Shark



Striped marlin



Spearfish



Blue marlin

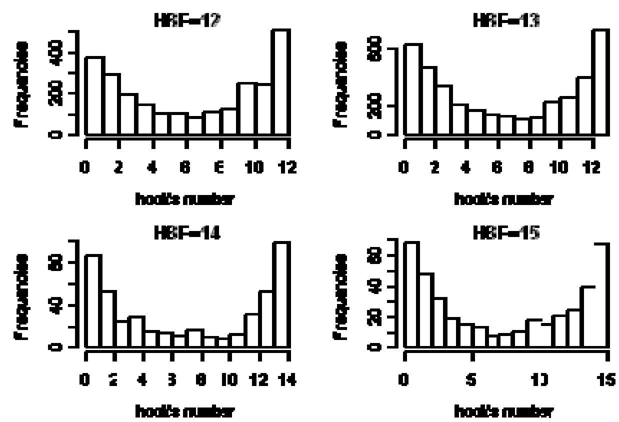


Figure 9. Comparison of hook-at-capture for eight species by six frequently used longline gear configurations in the Hawaii-based tuna fishery.

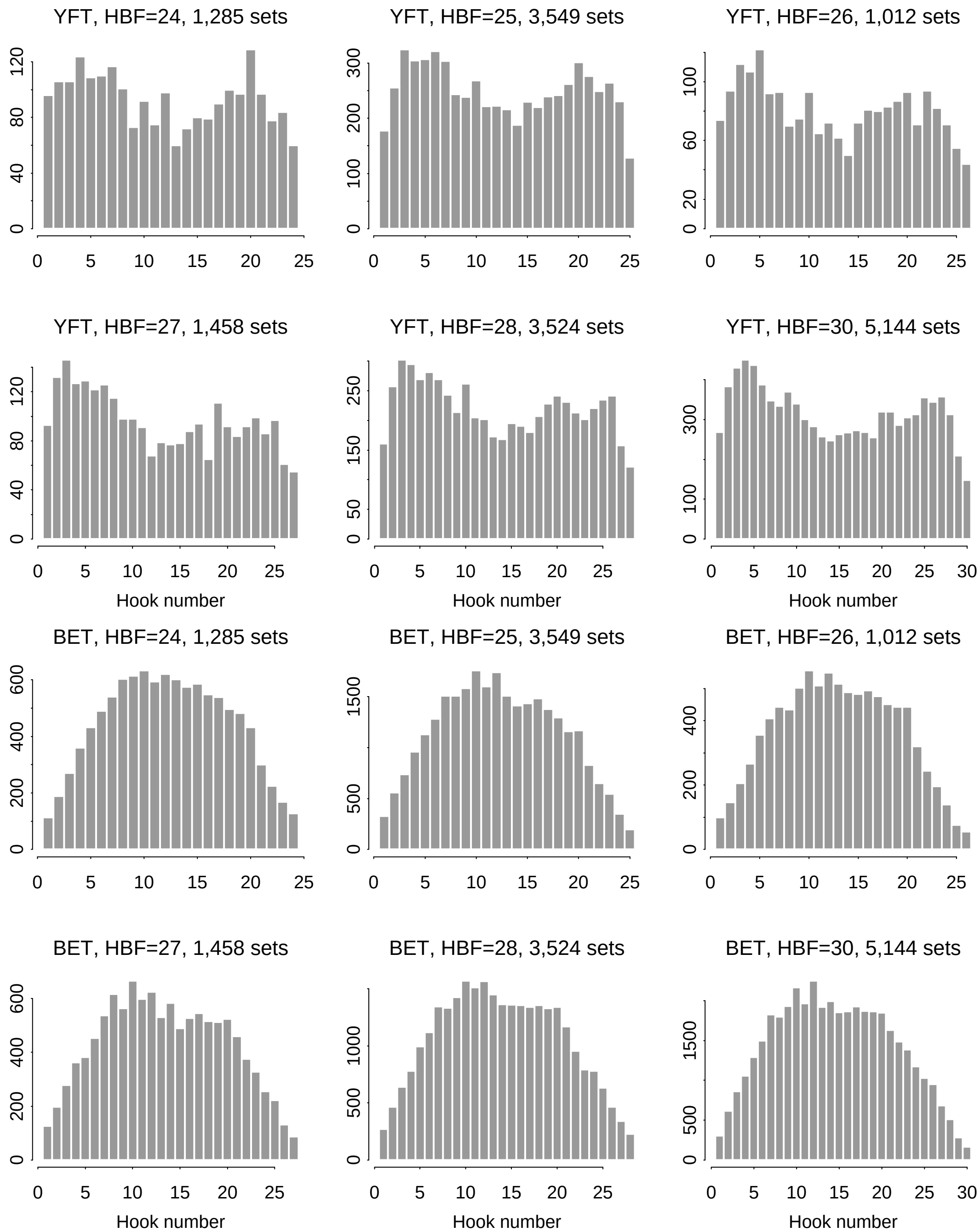


Figure 9 Continued.

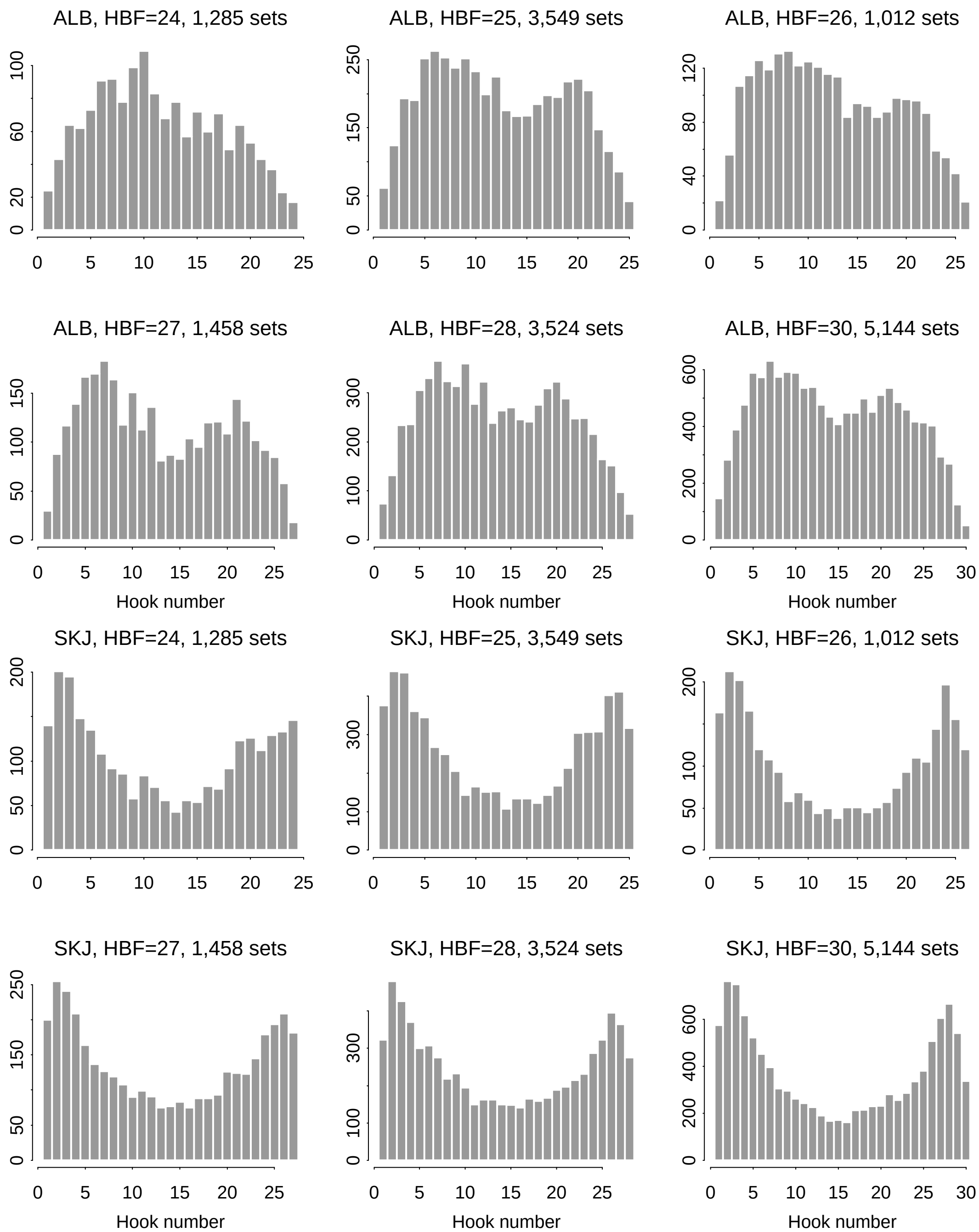


Figure 9 Continued.

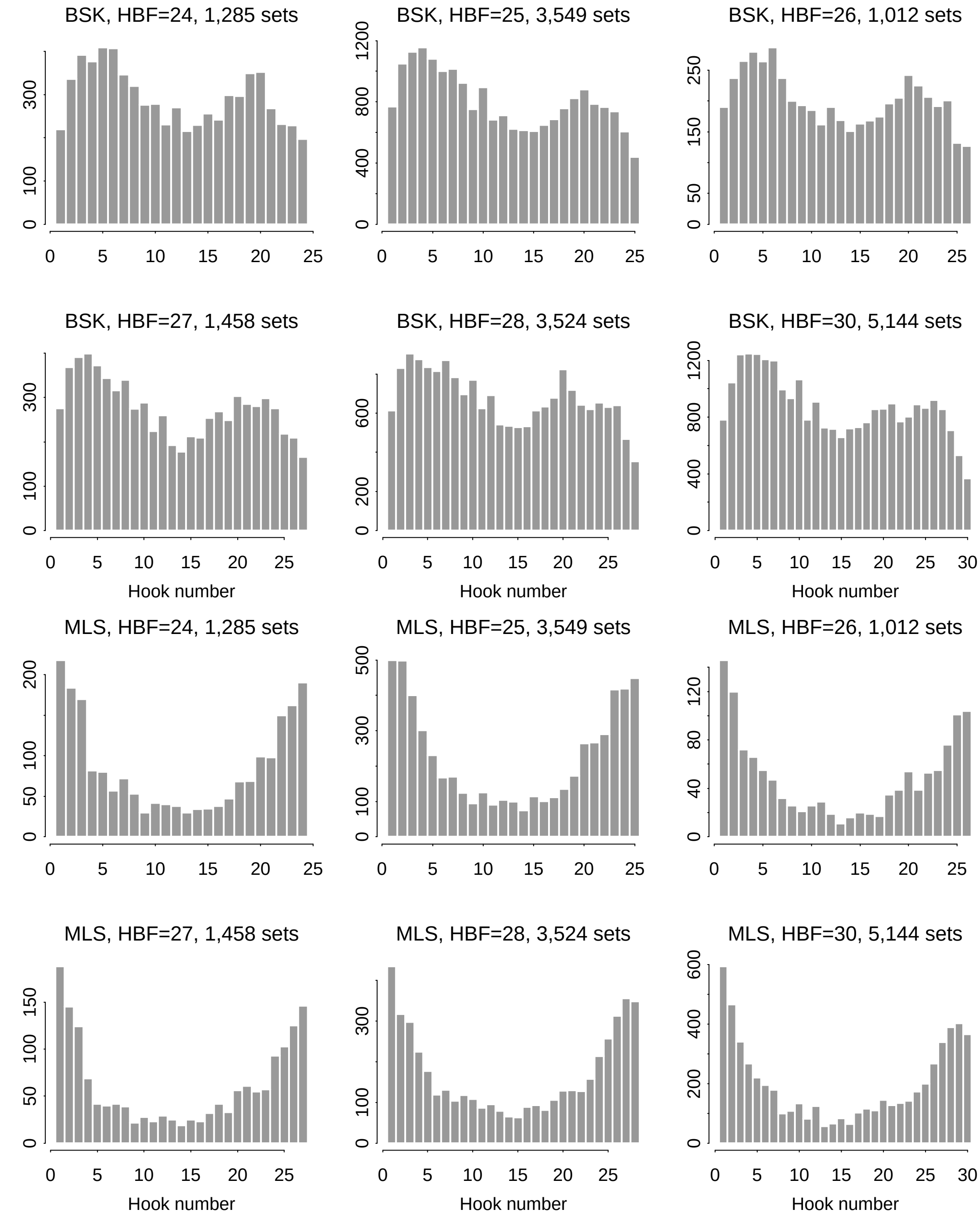


Figure 9 Continued.