Relationships between fleet-specific spawning potential ratios and measures of catch and effort for Japanese longline fleets targeting North Pacific Albacore Tuna

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ABSTRACT

In 2024, the Western and Central Pacific Fisheries Commission's Northern Committee (WCPFC NC) requested that the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) analyze the relationships between fleet-specific spawning potential ratios (SPRs), and effort for the portions of the Japanese longline (JPLL) fishery that targeted North Pacific Albacore Tuna (NPALB). In response to this request, this study: 1) identified the areas and quarters in which the JPLL fishery likely targeted NPALB; 2) calculated the fleet-specific SPRs for the NPALB targeting portions of the JPLL fishery; and 3) related the fleet-specific SPRs with the catch and effort for these portions of the JPLL fishery. The JPLL fishery operating in Areas 1 and 3 during Quarters 1 and 2 (i.e., F01_Q1 and F03_Q2) were likely to be targeting NPALB because these fleets had consistently high ratios of NPALB to total catch, consistently high NPALB CPUEs, relatively high NPALB catch, and relatively high fishing effort. Similarly, the JPLL fishery operating in Area 2 during Quarters 1 and 4 (i.e., F11_Q1 and F14_Q4) were likely to be targeting NPALB because these fleets had consistently high ratios of NPALB to total catch, and consistently high NPALB CPUEs. The fishing intensity in terms of SPR ($F_{\%SPR}$) were calculated for these two groups of fleets (i.e., JPLL_A13_Q12: F01_Q1 combined with F03_Q2; and JPLL_A2_Q14: F11_Q1 combined with F14_Q4), and found to be highly negatively correlated with the effort metrics (number of days, vessels and hooks), albeit with more variability than for catch. This suggests that these two NPALB-targeting JPLL fleets may be able to be managed using effort or catch controls. The increased variability in the relationships between effort and SPRs, relative to catch, should be taken into account. In addition, it should also be noted that the relationships between effort and SPR are slightly weaker for the JPLL_A2_Q14 fleet, which operates south of 30°N. It is recommended that the WG consider the information from this paper to develop advice on how fishing intensity should be interpreted into actual management under this harvest strategy, and to respond to the WCPFC NC request.

INTRODUCTION

In 2024, the Albacore Working Group (ALBWG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) responded to the requests from the Western and Central Pacific Fisheries Commission's Northern Committee (WCPFC NC) and the Inter-American Tropical Tuna Commission (IATTC), and provided advice on how to interpret fishing intensity in terms of SPR into management measures (ALBWG 2024). This advice was based on an analysis of the relationships between fleet-specific spawning potential ratios (SPRs) and measures of catch and effort for North Pacific Albacore Tuna (NPALB) (Teo et al. 2024). Teo et al. (2024) limited the analysis of SPR and effort to the Eastern Pacific Ocean (EPO) surface (EPOSF) fleet (i.e., the Canada and US troll and pole-and-line fleets) and the Japanese pole-and-line (JPPL) fleet because the NPALB management strategy evaluation (MSE) only focused on these two fleets when evaluating effort controls (ALBWG 2021). However, the WCPFC NC requested that the ISC analyze the relationships of SPR and effort for the portions of the Japanese longline (JPLL) fishery that targeted NPALB (WCPFC 2024). This targeting of NPALB by the JPLL fishery was expected to depend on area and season.

The main aim of this study was to estimate the relationships between fleet-specific spawning potential ratios and measures of catch and effort for the portions of the JPLL fishery that targeted NPALB. To accomplish this aim, this study: 1) identified the areas and seasons in which the JPLL fishery likely targeted NPALB, based on catch and effort metrics; 2) calculated the fleet-specific SPRs for the portions of the JPLL fishery that likely targeted NPALB; and 3) correlated and performed regressions of the fleet-specific SPRs with the catch and effort metrics for these parts of the JPLL fishery. The second and third steps will largely follow the methods described in Teo et al. (2024).

METHODS

Fleet structure

The 2023 assessment was not spatially explicit but instead used a fleets-as-areas approach (Hurtado-Ferro et al. 2014). Cluster analyses of the fishing operations and size composition data of the JPLL and US longline (USLL) fisheries in the north Pacific showed that there were five areas (Fig. 1) with relatively consistent size distributions of NPALB (ALBWG 2016; Ochi et al. 2016; Teo 2016). These five areas combined with other differences, like quarter and catch units, formed the basis of definitions of the 20 JPLL fleets in the 2023 assessment (Table 1).

The initial JPLL fleet structure for this study was based on the 2023 assessment (Table 1), albeit with some important differences. Some fleets in the 2023 assessment were set up as separate fleets even though they were in the same area and quarter, because their catch units were different (e.g., F01_Q1). However, these differences were not important for this study and were instead combined. In addition, the F19 and F20 fleets in the 2023 assessment included data from all four quarters but this study separated the F19 and F20 fleets into separate quarterly fleets. This resulted in a total of

16 area- and quarter-specific initial fleets for this study (Table 1).

The catch and effort statistics from these 16 initial JPLL fleets were used to identify the areas and quarters in which NPALB were likely targeted. The fleets for these NPALB-targeting areas and quarters were then combined into NPALB-targeting fleets from the same area for subsequent analyses (i.e., calculation of SPRs and correlations with catch and effort). The other areas and quarters (i.e., non NPALB-targeting) were combined into a single non NPALB-targeting fleet.

Catch and effort

For each quarter during 1994 – 2021, which is the same period as the 2023 stock assessment, catch and effort metrics from the logbooks of 16 initial JPLL fleets (Table 1) were aggregated. These metrics include: 1) catch of NPALB in numbers of fish, 2) catch of NPALB in weight; 3) total catch (tunas, sharks, and billfish) in numbers of fish; 4) total catch (tunas, sharks, and billfish) in weight; 5) number of vessels; 6) number of hooks; and 7) number of vessel days. From these metrics, we calculated the: 1) quarterly ratio of NPALB to total catch in numbers of fish; 2) quarterly ratio of NPALB to total catch in weight; and 3) quarterly NPALB catch-per-unit-effort (CPUE) in number of fish per 1000 hooks. Most of the fleets included 28 quarters of data but the fleets in Area 5 often had less (Table 1).

NPALB targeting

The quarterly catch and effort metrics for each of the 16 initial JPLL fleets were examined to identify the fleets most likely to be targeting NPALB. The most important criteria for identifying NPALB-targeting were: 1) consistently high ratios (>0.66) of NPALB to total catch; and 2) consistently high NPALB CPUE (>15 fish / 1000 hooks). Note that these "high" levels are arbitrary and it is more important to consider the consistency of the catch and effort metrics with respect to other fleets. Secondarily, we also examined the amount of total fishing effort and NPALB catch of each fleet.

Spawning potential ratio

The NPALB targeting fleets operating in the same area were combined into a single fleet for simplicity, and the fishing intensities in terms of SPR ($F_{\%SPR}$) were calculated. The fishing intensities were calculated from the fleet-specific F-at-age and biological parameters of the base case model for the 2023 stock assessment, using the methods described in Lee & Taylor (2023). In short, the seasonal, fleet-specific F-at-age and biological parameters (e.g., M-at-age, weight-at-age, maturity-at-age) were used to simulate a fished population until a stable age distribution was approximated. The spawning stock biomass (SSB) per recruit of the fished population during the spawning season was then divided by the SSB per recruit of an unfished population with the same biological parameters to calculate the $F_{\%SPR}$ for the fleet.

Statistical analyses

Following Teo et al. (2024), the statistical analyses proceeded in two steps. First, a cross-correlation using Pearson's correlation coefficient was performed on the measures of catch, effort, and $F_{\%SPR}$ for the NPALB-targeting parts of the JPLL fishery. Then depending on the fleet and the results from the cross-correlation, one or more effort and/or catch variables were used as explanatory variables in a series of generalized linear models (GLMs) to explain the changes in SPR. The GLMs assumed that the intercept was at 0 (i.e., no intercept was estimated) because a catch or effort of 0 is expected to result in no change in SPR. Given the large number of correlations and GLMs performed, as well as the assumed lack of observation error, the statistical significance of the results should be interpreted with caution.

RESULTS AND DISCUSSION

NPALB targeting

The JPLL fishery in Areas 1 and 3 in Quarters 1 and 2 (i.e., F01_Q1 and F03_Q2) were likely to be targeting NPALB because these fleets had consistently high ratios of NPALB to total catch (Table 2 and Fig. 2), consistently high NPALB CPUEs (Table 2 and Fig. 3), relatively high NPALB catch (Table 2 and Fig. 4), and relatively high fishing effort (Table 2 and Fig. 5). The JPLL fishery in Areas 1 and 3 during Quarter 3 (i.e., F04_Q3) clearly did not target NPALB due to consistently low ratios of NPALB to total catch (Table 2 and Fig. 2), and consistently low NPALB CPUEs (Table 2 and Fig. 3). The F05_Q4 fleet was also considered to be non-NPALB-targeting but the evidence was less clear than for F04_Q3. The F05_Q4 fleet had moderate ratios of NPALB to total catch (Table 2 and Fig. 2) and moderate levels of NPALB CPUEs (Table 2 and Fig. 3). However, the NPALB catches were relatively high due to high levels of effort (Table 2). The F01_Q1 and F03_Q2 fleets were aggregated into a single NPALB-targeting fleet (JPLL_A13_Q12) for subsequent analyses, calculating $F_{\%SPR}$ and correlations with catch and effort.

The JPLL fishery in Area 2 in Quarters 1 and 4 (i.e., F11_Q1 and F14_Q4) were likely to be targeting NPALB because these fleets had consistently high ratios of

NPALB to total catch (Table 2 and Fig. 2), and consistently high NPALB CPUEs (Table 2 and Fig. 3). However, the NPALB catch was only at moderate levels (Table 2 and Fig. 4) due to moderate levels of fishing effort (Table 2 and Fig. 5). The JPLL fishery in Area 2 in Quarters 2 and 3 (i.e., F12_Q2 and F13_Q3) were likely to be non-NPALB-targeting because these fleets had moderate ratios of NPALB to total catch (Table 2 and Fig. 2), and moderate NPALB CPUEs (Table 2 and Fig. 3). The F11_Q1 and F14_Q4 fleets were aggregated into a single NPALB-targeting fleet (JPLL_A2_Q14) for subsequent analyses.

All the fleets in Areas 4 and 5 (i.e., F19_Q1, F19_Q2, F19_Q3, F19_Q4, F20_Q1, F20_Q2, F20_Q3, and F20_Q4) appeared likely to be non-NPALB-targeting. All these fleets exhibited relatively lower levels of NPALB to total catch ratios (Table 2 and Fig. 2), NPALB catch (Table 2 and Fig. 4), and effort (Table 2 and Fig. 5). All these fleets also had relatively lower CPUEs except for F20_Q1 and F20_Q4 (Table 2). However, the CPUEs for F20_Q1 and F20_Q4 were highly variable (Fig. 3), which indicated that if there was targeting of NPALB, it was likely inconsistent. These non NPALB targeting fleets, together with F04_Q3, F05_Q4, F12_Q2 and F13_Q3, were aggregated into a single fleet (JPLL_nonALBtgt) for subsequent analyses.

SPR vs catch and effort

Similar to the general results of Teo et al. (2024) for all the longline fleets, the pairs plots of the aggregated NPALB targeting fleets (JPLL_A13_Q12 and JPLL_A2_Q14) and the non NPALB targeting fleet (JPLL_nonALBtgt) show that catch was very highly negatively correlated with fleet-specific SPR (Figs. 6 – 8). However, in contrast to the Teo et al. (2024) results, the effort metrics (number of days, vessels and hooks) for JPLL_A13_Q12 and JPLL_A2_Q14 also appeared to be highly negatively correlated with fleet-specific SPR (Figs. 6 & 7), albeit with more variability than for catch. In contrast, Teo et al. (2024) found only a relatively weak negative correlation between fleet-specific SPR and effort metrics for the JPLL fishery, and with high variability. Interestingly, the JPLL_nonALBtgt fleet also showed a negative correlation with fleet-specific SPR (Fig. 8), albeit with a weaker correlation than the two NPALB-targeting fleets. This suggests that separating the JPLL fishery into less aggregated fleets improved the relationships between catch and effort, and hence SPRs, which is not surprising. The GLM results show that to reduce fishing intensity in SPR by 0.01, reductions in effort of approximately 2.2 million and 2.0 million hooks in a single quarter for JPLL_A13_Q12 and JPLL_A2_Q14, respectively (Fig. 9) were required.

Overall

This study found that the JPLL fishery operating in Areas 1 and 3 in Quarters 1 and 2 (JPLL_A13_Q12) and in Areas 2 in Quarters 1 and 4 (JPLL_A2_Q14) could be considered to be targeting NPALB. The effort of these two NPALB-targeting fleets had highly negative correlations between SPR, and both catch and effort. This suggests that these two NPALB-targeting JPLL fleets may be able to be managed using effort or catch controls. The increased variability in the relationships between effort and SPRs, relative to catch, should be taken into account. In addition, it should also be noted that the relationships between effort and SPR is slightly weaker for the JPLL_A2_Q14 fleet, which operates south of 30°N (Fig. 1).

It is recommended that the WG consider the information from this paper to develop advice on how fishing intensity should be interpreted into actual management under this harvest strategy, and to respond to the WCPFC NC request.

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Table 1. Fleet structure of the Japan longline fishery in this study and the corresponding fleets in the 2023 stock assessment.

Fleet name (This study)	Fleet name (2023 assessment)	Area	Quarter
F01_Q1	F1_JPLL_A13_Q1_J_wt, F2_JPLL_A13_Q1_A_wt, F6_JPLL_A13_Q1_J_num, F7_JPLL_A13_Q1_A_num	1 and 3	1
F03_Q2	F3_JPLL_A13_Q2_wt, F8_JPLL_A13_Q2_num	1 and 3	2
F04_Q3	F4_JPLL_A13_Q3_wt, F9_JPLL_A13_Q3_num	1 and 3	3
F05_Q4	F5_JPLL_A13_Q4_wt, F10_JPLL_A13_Q4_num	1 and 3	4
F11_Q1	F11_JPLL_A2_Q1_wt, F15_JPLL_A2_Q1_num	2	1
F12_Q2	F12_JPLL_A2_Q2_wt, F16_JPLL_A2_Q2_num	2	2
F13_Q3	F13_JPLL_A2_Q3_wt, F17_JPLL_A2_Q3_num	2	3
F14_Q4	F14_JPLL_A2_Q4_wt, F18_JPLL_A2_Q4_num	2	4
F19_Q1	Quarter 1 of F19_JPLL_A4_num	4	1
F19_Q2	Quarter 2 of F19_JPLL_A4_num	4	2
F19_Q3	Quarter 3 of F19_JPLL_A4_num	4	3
F19_Q4	Quarter 4 of F19_JPLL_A4_num	4	4
F20_Q1	Quarter 1 of F20_JPLL_A5_num	5	1
F20_Q2	Quarter 2 of F20_JPLL_A5_num	5	2
F20_Q3	Quarter 3 of F20_JPLL_A5_num	5	3
F20_Q4	Quarter 4 of F20_JPLL_A5_num	5	4

Table 2. Mean catch and effort metrics of fleets. Each stratum consists of aggregated data for a single quarter and area. See Table 1 for details of fleet names. Color indicates relatively high (red) and low (green) values for each column.

Fleet name	Albacore to total catch ratio	Albacore CPUE (fish/1000 hooks)	Albacore catch (1000s fish)	Number of vessels	Number of hooks (millions)	Number of vessel days (1000)	N (quarters)
F01_Q1	0.696	27.69	360.14	44.1	13.066	6.562	28
F03_Q2	0.735	17.98	147.81	23.4	8.057	4.339	28
F04_Q3	0.229	3.02	13.13	40.0	3.659	1.756	28
F05_Q4	0.529	11.86	203.22	69.0	16.636	7.708	28
F11_Q1	0.726	20.52	162.35	56.1	7.824	4.040	28
F12_Q2	0.589	12.23	72.85	47.8	5.774	2.925	28
F13_Q3	0.607	10.73	42.06	35.3	3.906	2.055	28
F14_Q4	0.700	15.84	70.63	35.2	4.473	2.506	28
F19_Q1	0.350	8.85	44.24	98.5	4.329	1.596	28
F19_Q2	0.163	3.26	7.24	68.5	2.033	0.780	28
F19_Q3	0.383	7.86	7.24	43.9	0.987	0.395	28
F19_Q4	0.303	6.55	16.85	65.7	2.316	0.859	28
F20_Q1	0.439	14.76	18.42	12.6	0.821	0.245	23
F20_Q2	0.083	3.07	0.06	1.9	0.016	0.005	8
F20_Q3	0.076	1.35	0.35	9.9	0.164	0.060	26
F20_Q4	0.352	13.14	18.25	21.4	1.030	0.321	27

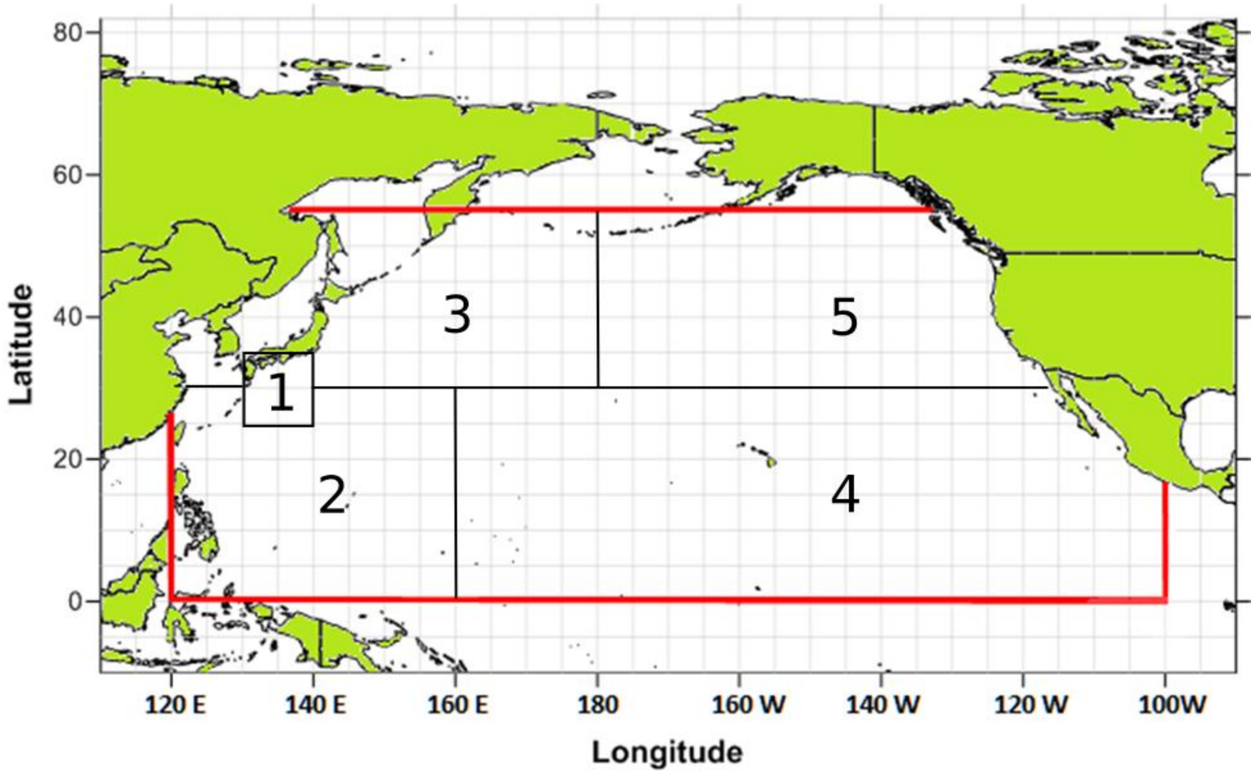

Figure 1. Spatial domain (red box) of the north Pacific albacore stock (*Thunnus alalunga*) in the 2023 stock assessment. Fishery definitions were based on five fishing areas (black boxes and numbers) defined from cluster analyses of size composition data.

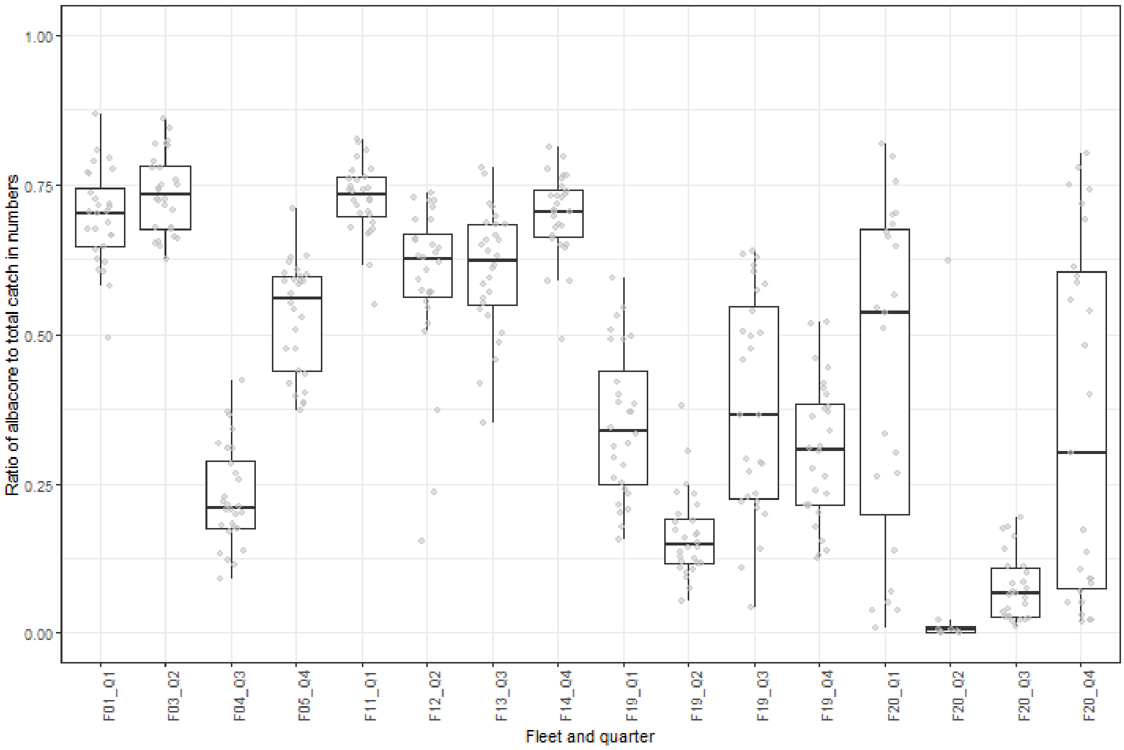

Figure 2. Box plots of the ratios of albacore to total catch in numbers for each fleet and quarter combination. See Table 1 for details of each fleet. Upper and lower bounds of boxes indicate the 75 and 25% quartiles. Horizontal dark line within boxes indicate the median of the distribution. Whiskers indicate the maximum and minimum extents of the data within 150% of the inter-quartile range. Gray circles indicate jittered data of the distribution.

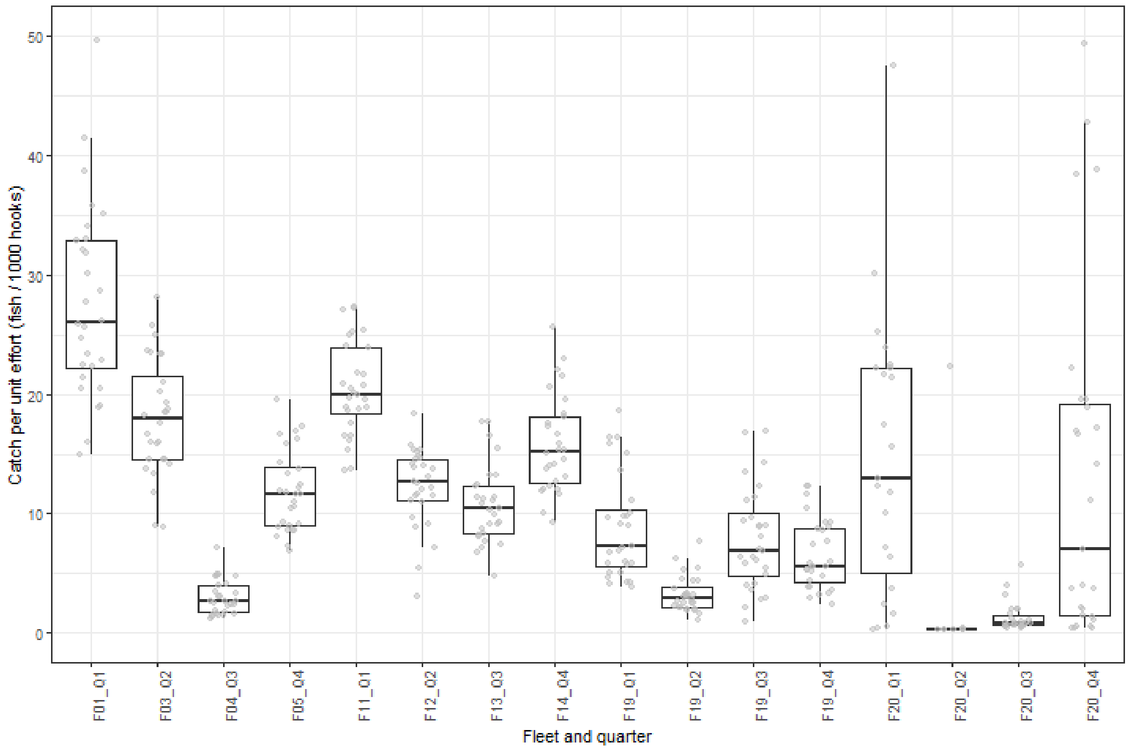

Figure 3. Box plots of the albacore catch per unit effort (CPUE; fish per 1000 hooks) for each fleet and quarter combination. See Table 1 for details of each fleet. Upper and lower bounds of boxes indicate the 75 and 25% quartiles. Horizontal dark line within boxes indicate the median of the distribution. Whiskers indicate the maximum and minimum extents of the data within 150% of the inter-quartile range. Gray circles indicate jittered data of the distribution.

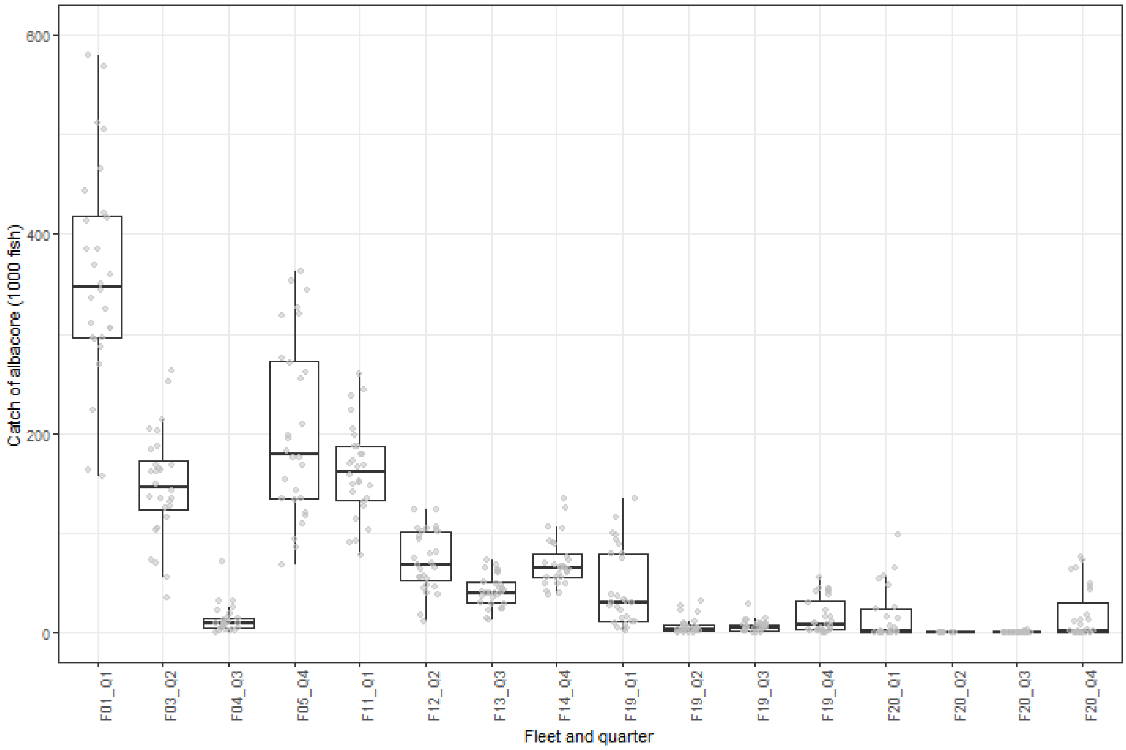

Figure 4. Box plots of the albacore catch (1000 fish) for each fleet and quarter combination. See Table 1 for details of each fleet. Upper and lower bounds of boxes indicate the 75 and 25% quartiles. Horizontal dark line within boxes indicate the median of the distribution. Whiskers indicate the maximum and minimum extents of the data within 150% of the inter-quartile range. Gray circles indicate jittered data of the distribution.

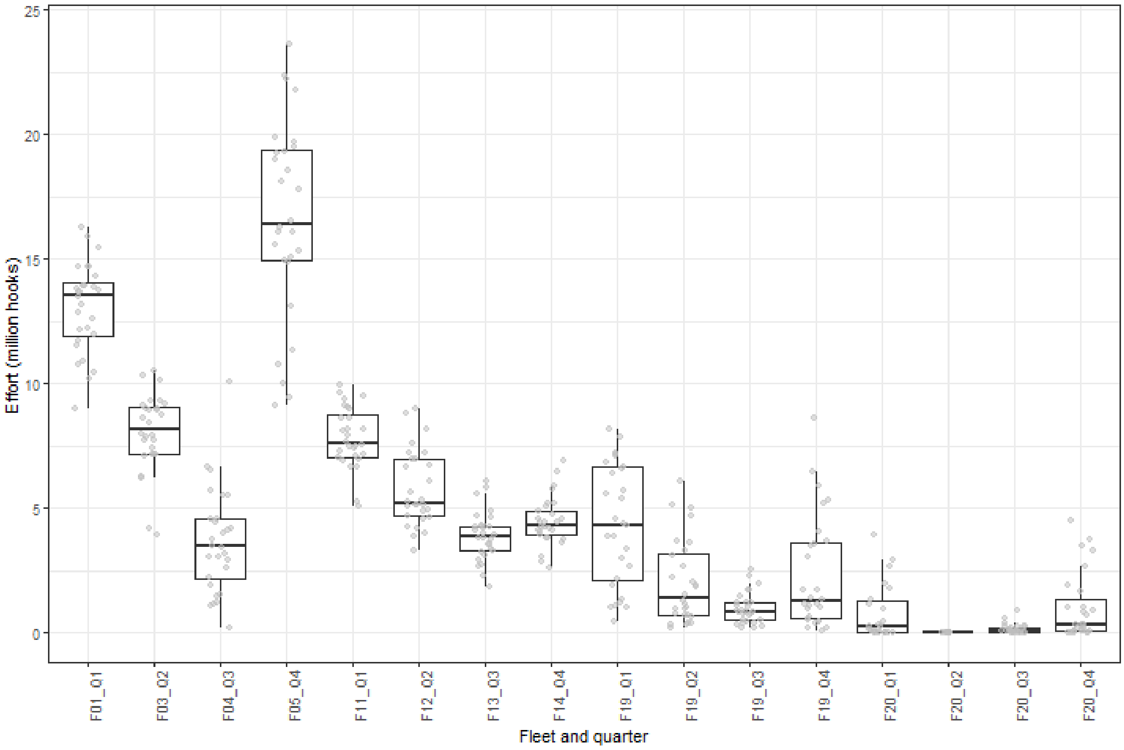

Figure 5. Box plots of the effort (millions of hooks) for each fleet and quarter combination. See Table 1 for details of each fleet. Upper and lower bounds of boxes indicate the 75 and 25% quartiles. Horizontal dark line within boxes indicate the median of the distribution. Whiskers indicate the maximum and minimum extents of the data within 150% of the inter-quartile range. Gray circles indicate jittered data of the distribution.

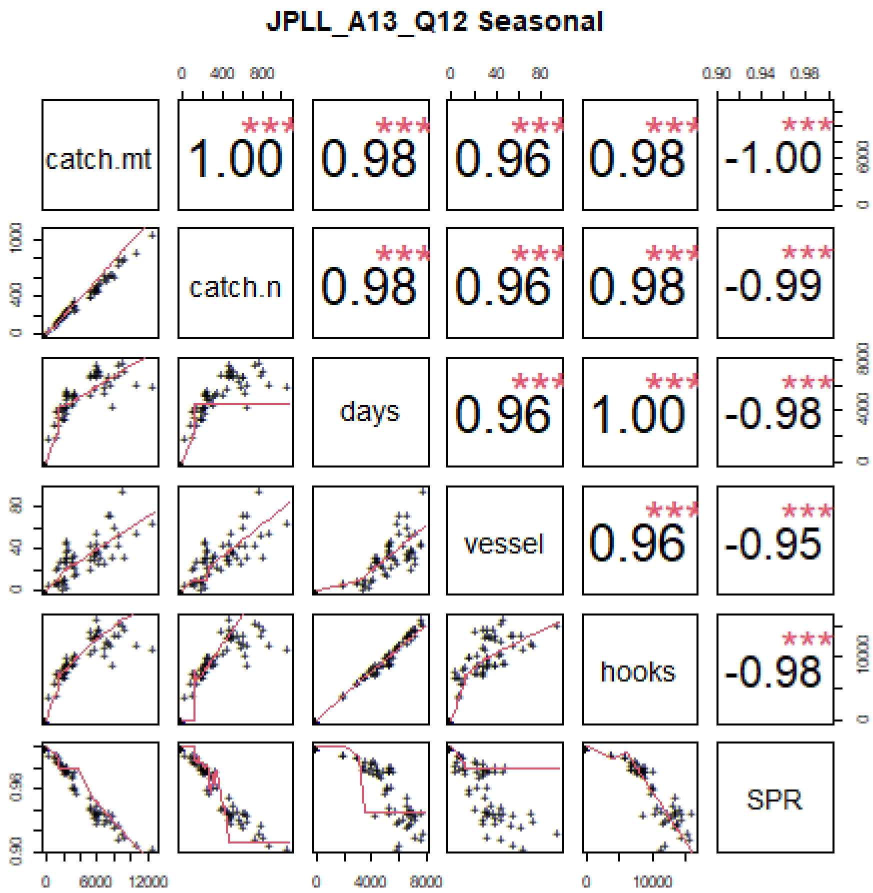

Figure 6. Pairs plot and correlations of quarterly catch (metric tons and 1000s of fish), and effort (number of days, number of vessels, and 1000s of hooks) versus estimated quarterly spawning potential ratios for Japan longline in Areas 1 and 3 during Quarters 1 and 2, which were found to be targeting North Pacific Albacore (JPLL_A13_Q12). Lower triangle shows plots of variable. Upper triangle shows Pearson correlation coefficients, with asterisks indicating statistical significance (* p<0.05; ** p<0.01; *** p<0.001).

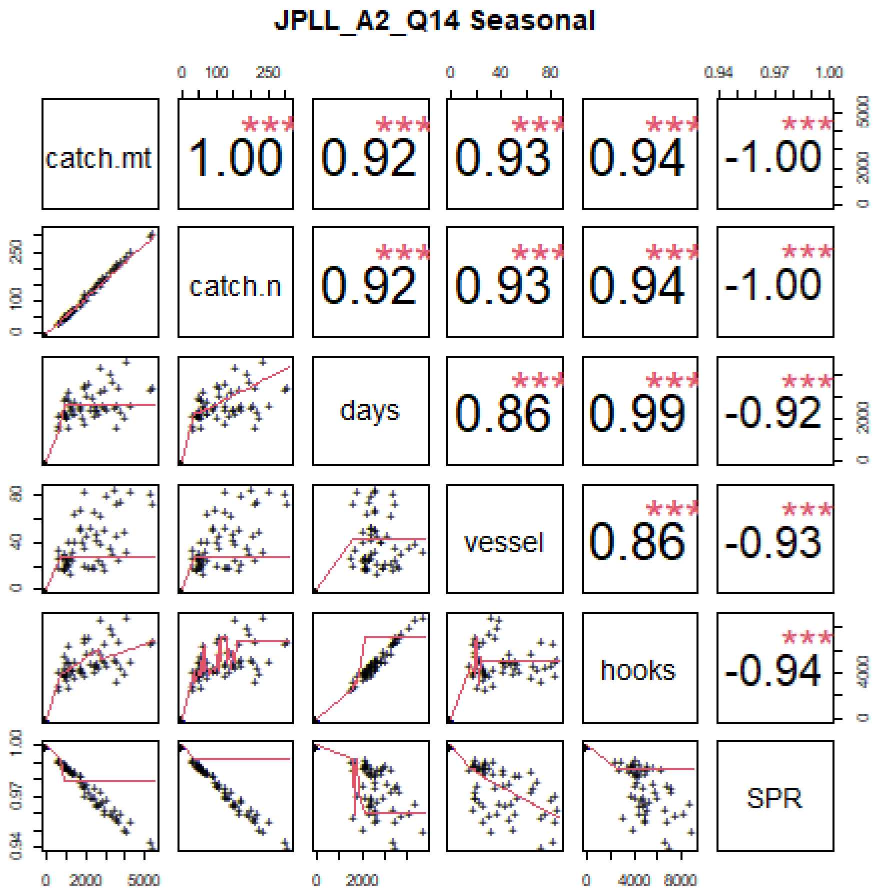

Figure 7. Pairs plot and correlations of quarterly catch (metric tons and 1000s of fish), and effort (number of days, number of vessels, and 1000s of hooks) versus estimated quarterly spawning potential ratios for Japan longline in Area 2 during Quarters 1 and 4, which were found to be targeting North Pacific Albacore (JPLL_A2_Q14). Lower triangle shows plots of variable. Upper triangle shows Pearson correlation coefficients, with asterisks indicating statistical significance (* p<0.05; ** p<0.01; *** p<0.001).

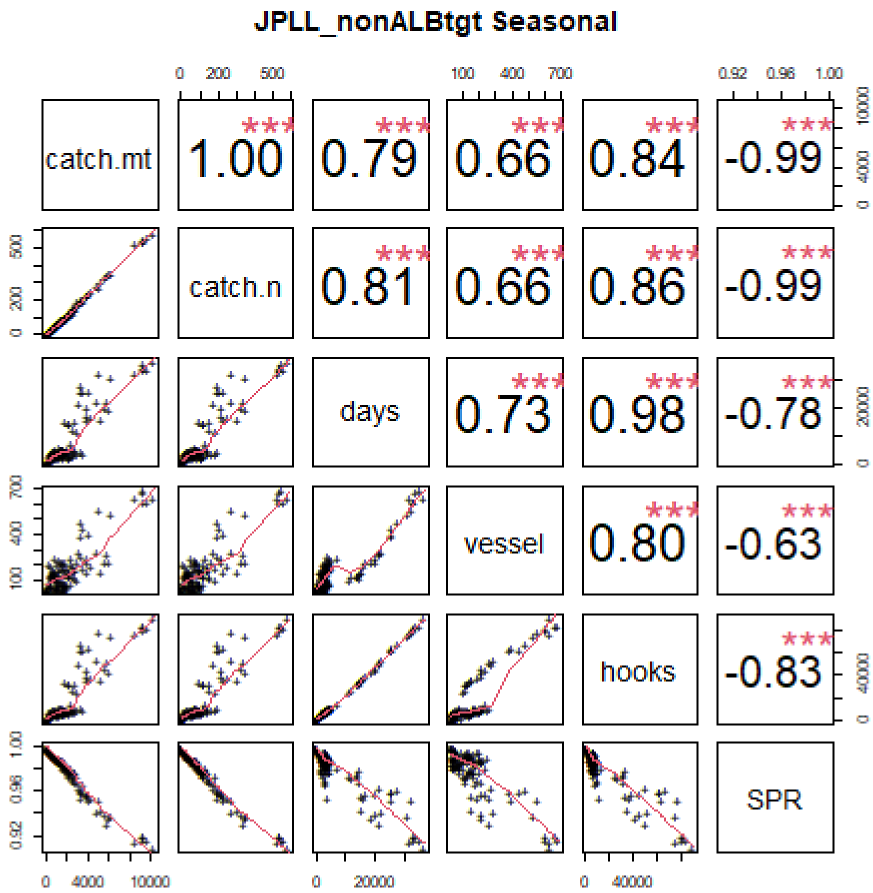

Figure 8. Pairs plot and correlations of quarterly catch (metric tons and 1000s of fish), and effort (number of days, number of vessels, and 1000s of hooks) versus estimated quarterly spawning potential ratios for all Japan longline found not to be targeting North Pacific Albacore (JPLL_nonALBtgt. Lower triangle shows plots of variable. Upper triangle shows Pearson correlation coefficients, with asterisks indicating statistical significance (* p<0.05; ** p<0.01; *** p<0.001).

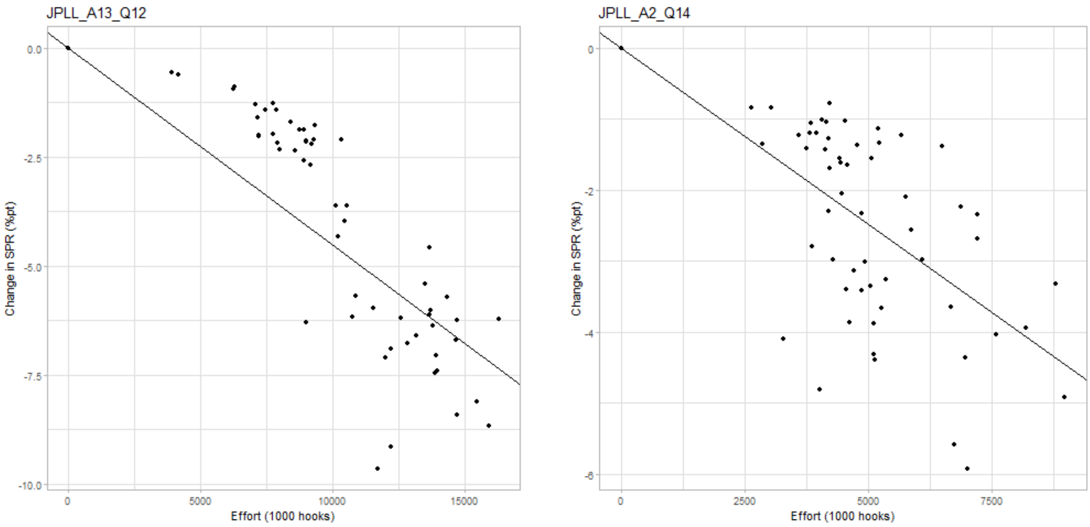

Figure 9. Estimated relationships between seasonal fishing effort (1000s of hooks) and expected change in spawning potential ratio (SPR; %pts) for the two aggregated Japan longline fleets targeting NPALB (JPLL_A13_Q12 and JPLL_A2_Q14) fleets using single variable GLMs with a fixed intercept at 0. Note that scales of the x- and y-axes are variable.