A Catch History of Blue Marlin *Makaira nigricans* in Hawaiian Waters: 1948-2011[1]

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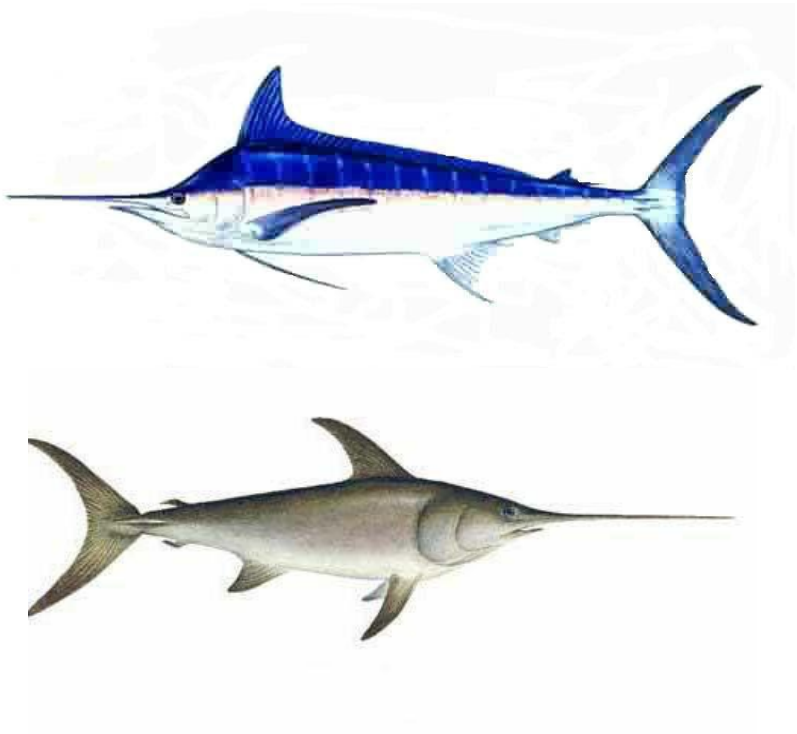

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Abstract

This working paper (ISC/13/BILLWG-1/14) presents a catch history for blue marlin *Makaira nigricans* in Hawaiian waters from 1948 through 2011 as input to the stock assessment to be conducted under the auspices of the ISC BILLWG. The data from 1948–1994, obtained primarily from Hawaii Division of Aquatic Resources records, are the nominal values presented to the ISC BILLWG in 2012. A more detailed, corrected catch history for the Hawaii-based pelagic longline fleet from 1995–2011 was prepared by using fishery observer data, commercial fishing logbooks, and sales records from public fish auctions. This work was necessary because species misidentifications of istiophorid billfishes are a longstanding problem in this fishery. Logbook data from unobserved fishing trips were corrected by applying the coefficients from a zero-inflated negative binomial model to the corresponding explanatory variables in the logbook reports to predict catches, which were then used as a comparison standard for the logbooks. The corrected catch estimates ranged from 2675 to 8296 fish per year, equivalent to 199.1 to 500.57 metric tons. The logbook corrections produced estimates that averaged 27.3% less per year than the official NMFS statistics. The catch in 1997 exceeded those from all other years by more than 170 metric tons. Estimated catches averaged 250.9 metric tons per year in 1998−2011. An appendix provides detailed methods for the catch data correction procedures.

Introduction

This working paper (WP: ISC/13/BILLWG-1/14) presents a long-term (1948–2011) catch history for blue marlin *Makaira nigricans* in Hawaiian waters. The ISC Billfish Working Group (BILLWG) recently completed a stock assessment for striped marlin *Kajikia audax* (Lee et al. 2012). Blue marlin is the next species scheduled for assessment by the BILLWG; this WP presents catch estimates to serve as input to it.

This blue marlin catch history consists of a 46-year nominal catch time series (1948–1994) previously reported by Walsh et al. (2012), followed by a 17-year corrected catch series (1995–2011). Catch history correction for the latter period was feasible because a mandatory commercial logbook program was initiated for this fishery in 1990, the Pacific Island Regional Observer Program (PIROP) was founded in 1994, and commercial sales data were available from public fish auction sales records. The availability of these three data sources permitted development and use of statistical methodology specifically intended for evaluation of billfish logbook data accuracy (Walsh et al. 2005; 2007).

The principal finding of previous studies was that corrected blue marlin catch estimates were considerably lower and more accurate than National Marine Fisheries Service (NMFS) statistics (Walsh et al. 2005; 2007). This WP lengthens the time series of corrected data for blue marlin in this pelagic longline fishery, where it is an economically valuable incidentally caught species.

This WP is written with the intention of providing fully comprehensible input to the stock assessment. Thus, an appendix provides details of the methods and calculations used to estimate blue marlin catch data from Hawaiian waters.

Methods

Description of the fishery

The companion WP (Walsh et al. 2013: ISC/13/BILLWG-1/13) presents a description of the Hawaii-based pelagic longline fishery. An additional overview of this longline fishery and others taking billfishes in Hawaiian waters is provided in Ito (2013: ISC/13/BILLWG-1/04).

Data sources

A 46-year nominal catch history for blue marlin in Hawaiian waters (1948−1994), derived primarily from Hawaii Division of Aquatic Resources (HDAR) records was presented to the BILLWG as Table 1 in Walsh et al. (2012). Additional details regarding acquisition and archival of marlins catch data in 1948−1994, including a critique of accuracy are in Walsh and Ito (2011).

Catch data from 1995−2011 were extracted from the electronic data archive at the NOAA Fisheries Pacific Islands Fisheries Science Center (PIFSC). The fishery observer data were

collected by the PIROP. Auction data were collected PIFSC personnel twice weekly through 1999. Complete auction sales records have been provided electronically by the HDAR since January 2000. Logbooks were collected by PIFSC personnel, followed by keypunching and archival on-site in an ORACLE data base.

Catch and tonnage estimates

Numerical catch estimates were obtained by adding the catches reported by PIROP observers, the totals from uncorrected logbooks (i.e., those accepted as accurate), and predicted values replacing data deemed questionable. Tonnage estimates (metric tons: MT) were obtained by multiplying the corrected quarterly catch estimates by quarterly mean weights obtained from fish auction records.

Supplementary information

Table A1 presents a comparison of observer data, logbooks on observed trips, and logbooks on unobserved trips to elucidate the bias in the self-reported logbook data. Table A2 provides summary statistics for the operational parameters used in the catch history correction for 1995−2011.

Results

Catch history

The annual estimates of blue marlin catches from 1948–1994 (Table 1) are taken from Walsh et al. (2012, ISC/12/BILLWG-1, WP 3, Table 1, pp. 11–15). There was no attempt to correct these estimates because fishery observer reports and sales records were not available.

The HDAR time series appeared to consist of several intervals. The average annual landings in 1948−1957 were 89.87 MT (74.28−123.42 MT). This decreased to an annual average of 46.36 MT for 1958−1969 (31.44−60.92 metric tons). Reported landings from 1971−1975 (1.37−34.86 MT) were very low. Higher landings (124.03 MT) were reported in 1977, followed by a gradual increase to 264.07 MT in 1988. The reported landings for 1989−1994 were much higher (367.54−534.79 MT).

The corrected annual catch totals from 1995−2011 in logbooks (Table 2) ranged from a maximum of 8296 in 1997 to a minimum of 2675 in 2007. The 1997 catch exceeded those in all other years by more than 75%. The second and third quarter catches in 1997 were greater than those in all other years. The highest catch in later years was taken in 2006 (4333 blue marlin), followed immediately by the minimum.

The corrections (Table 3) resulted in downward adjustments every year except 1997. The reason that 1997 differed was that 36% of the large negative SR were associated with sets in 1997, and replacing these negative outliers with predicted values increased the corrected catch estimate.

The tonnage estimates (Table 4) in 1995−1999 varied 2.5-fold (199.1−500.57 MT). Estimates averaged 250.9 metric tons per year in 1998−2011. It was noteworthy that the HDAR estimates from 1990, 1991, and 1994 (Table 1) were greater than those from all later years, reflecting the effects of catch correction, although the catches in 1997 and 1995 to a lesser extent approached the earlier levels.

Discussion

This work lengthens the corrected catch history for blue marlin in this longline fishery. Published studies have documented overreporting of blue marlin caused primarily by misidentifications of striped marlin (Walsh et al. 2005; 2007). The crux of the issue is the upward bias in logbook reporting for blue marlin, which is apparent even on observed trips. It can be inferred that these corrected catch estimates are more accurate than the NMFS official catch statistics.

Acknowledgments

Brent Miyamoto and Christopher Tokita helped with acquisition of longline catch data. Diosdado Gonzales and Russell Ito helped with acquisition of fish auction data.

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Table 1. Summary of blue marlin *Makaira nigricans* landings from Hawaiian waters at quarterly intervals in 1948–1994. Data are presented in two columns per page. Annual totals are in boldface type. This table is taken from Table 1 in Walsh et al. (2012).

Year	Quarter	Landings (MT)	Year	Quarter	Landings (MT)
1948	1	13.93	**1949**	1	13.12
	2	28.33		2	34.31
	3	16.52		3	16.57
	4	20.73		4	17.39
	Annual	**79.51**		**Annual**	**81.39**
1950	1	20.91	**1951**	1	11.26
	2	38.03		2	31.74
	3	30.10		3	21.01
	4	34.38		4	21.69
	Annual	**123.42**		**Annual**	**85.70**
1952	1	11.89	**1953**	1	13.29
	2	39.32		2	24.16
	3	18.45		3	18.99
	4	12.99		4	17.84
	Annual	**82.65**		**Annual**	**74.28**
1954	1	17.30	**1955**	1	14.18
	2	42.36		2	62.33
	3	27.33		3	23.07
	4	15.26		4	22.75
	Annual	**102.25**		**Annual**	**122.33**
1956	1	13.42	**1957**	1	9.07
	2	33.67		2	51.44
	3	19.09		3	13.21
	4	17.76		4	20.48
	Annual	**83.94**		**Annual**	**94.20**

Table 1, continued.

Year	Quarter	Landings (MT)	Year	Quarter	Landings (MT)
1958	1	11.43	**1959**	1	8.36
	2	34.57		2	17.22
	3	8.82		3	13.82
	4	12.34		4	13.55
	Annual	**67.16**		**Annual**	**52.95**
1960	1	3.79	**1961**	1	7.95
	2	14.45		2	18.10
	3	10.12		3	13.89
	4	12.06		4	12.70
	Annual	**40.42**		**Annual**	**52.64**
1962	1	6.35	**1963**	1	7.14
	2	16.07		2	23.03
	3	11.18		3	13.07
	4	14.55		4	12.57
	Annual	**48.15**		**Annual**	**55.81**
1964	1	7.13	**1965**	1	3.88
	2	14.41		2	10.79
	3	8.28		3	13.24
	4	8.07		4	12.01
	Annual	**37.89**		**Annual**	**39.92**

Table 1, continued.

Year	Quarter	Landings (MT)	Year	Quarter	Landings (MT)
1966	1	2.89	**1967**	1	3.87
	2	10.59		2	7.97
	3	14.32		3	13.41
	4	9.37		4	6.19
	Annual	**37.17**		**Annual**	**31.44**
1968	1	3.94	**1969**	1	4.11
	2	12.98		2	11.31
	3	8.77		3	34.13
	4	6.10		4	11.37
	Annual	**31.79**		**Annual**	**60.92**
1970	1	2.22	**1971**	1	9.81
	2	9.22		2	8.18
	3	43.80		3	2.86
	4	23.55		4	0.46
	Annual	**78.79**		**Annual**	**21.31**
1972	1	0.47	**1973**	1	0.31
	2	0.66		2	0.74
	3	0.08		3	8.23
	4	0.16		4	5.86
	Annual	**1.37**		**Annual**	**15.14**
1974	1	3.10	**1975**	1	9.11
	2	5.15		2	8.55
	3	17.29		3	9.11
	4	9.32		4	6.23
	Annual	**34.86**		**Annual**	**33.00**

Table 1, continued.

Year	Quarter	Landings (MT)	Year	Quarter	Landings (MT)
1976	1	3.59	**1977**	1	23.76
	2	5.17		2	23.20
	3	23.42		3	54.38
	4	27.43		4	22.69
	Annual	**59.61**		**Annual**	**124.03**
1978	1	19.44	**1979**	1	21.42
	2	70.00		2	55.24
	3	81.79		3	62.34
	4	23.23		4	20.24
	Annual	**194.46**		**Annual**	**159.24**
1980	1	19.73	**1981**	1	32.45
	2	48.22		2	48.67
	3	68.57		3	76.08
	4	37.52		4	32.93
	Annual	**174.04**		**Annual**	**190.13**
1982	1	28.52	**1983**	1	15.05
	2	52.39		2	35.78
	3	64.32		3	56.57
	4	34.69		4	35.14
	Annual	**179.92**		**Annual**	**142.54**
1984	1	18.85	**1985**	1	29.78
	2	22.18		2	38.67
	3	67.29		3	45.37
	4	28.67		4	22.54
	Annual	**136.99**		**Annual**	**136.36**

Table 1, continued.

Year	Quarter	Landings (MT)	Year	Quarter	Landings (MT)
1986	1	34.54	**1987**	1	34.90
	2	53.35		2	60.15
	3	74.93		3	85.84
	4	46.20		4	58.66
	Annual	**209.02**		**Annual**	**239.55**
1988	1	36.22	**1989**	1	70.88
	2	34.62		2	115.05
	3	102.12		3	145.96
	4	91.11		4	145.11
	Annual	**264.07**		**Annual**	**477.00**
1990	1	73.61	**1991**	1	50.71
	2	130.38		2	153.37
	3	215.52		3	187.83
	4	97.16		4	142.88
	Annual	**516.67**		**Annual**	**534.79**
1992	1	80.25	**1993**	1	27.76
	2	95.71		2	79.31
	3	131.88		3	214.35
	4	59.70		4	145.26
	Annual	**367.54**		**Annual**	**466.68**
1994	1	91.38			
	2	115.78			
	3	247.77			
	4	69.56			
	Annual	**524.49**			

Table 2. Corrected quarterly and annual blue marlin *Makaira nigricans* catch totals in the Hawaii-based pelagic longline fishery in 1995−2011, including PIROP and logbook data.

Year	Quarter	Catch (number caught)	Year	Quarter	Catch (number caught)
1995	1	377	**1996**	1	974
	2	1435		2	1157
	3	1352		3	852
	4	1522		4	797
	Annual total	**4686**		**Annual**	**3780**
1997	1	456	**1998**	1	416
	2	2975		2	780
	3	3538		3	1096
	4	1327		4	841
	Annual	**8296**		**Annual**	**3133**
1999	1	393	**2000**	1	202
	2	916		2	622
	3	967		3	1784
	4	461		4	983
	Annual	**2737**		**Annual**	**3591**
2001	1	277	**2002**	1	533
	2	954		2	1110
	3	1600		3	859
	4	880		4	326
	Annual	**3711**		**Annual**	**2828**
2003	1	510	**2004**	1	846
	2	1702		2	1232
	3	487		3	916
	4	972		4	694
	Annual	**3671**		**Annual**	**3688**

Table 2, continued.

Year	Quarter	Catch (number caught)	Year	Quarter	Catch (number caught)
2005	1	772	**2006**	1	561
	2	1349		2	1391
	3	665		3	1136
	4	696		4	1245
	Annual	**3482**		**Annual**	**4333**
2007	1	489	**2008**	1	696
	2	854		2	1133
	3	580		3	686
	4	752		4	884
	Annual	**2675**		**Annual**	**3399**
2009	1	567	**2010**	1	381
	2	1503		2	1343
	3	1136		3	883
	4	400		4	415
	Annual	**3606**		**Annual**	**3022**
2011	1	764			
	2	1298			
	3	681			
	4	723			
	Annual	**3466**			

Table 3. Estimated annual catches of blue marlin *Makaira nigricans* in the Hawaii-based longline fishery in 1995–2011arranged according to the source reporting the catch. The nominal catch values are taken from the official NMFS statistics posted on the PIFSC website. Total corrected catch is the sum of fishery observer data and total corrected logbook catch.

Year	Fishery observer data	Logbooks (Accepted data)	Logbooks (Corrected data)	Total corrected logbook catch	**Total corrected catch**	Nominal catch	**Δ (Nominal – corrected)**
1995	344	3441	901	4342	**4686**	8721	**4035**
1996	357	3027	396	3243	**3780**	6555	**2775**
1997	250	7536	510	8046	**8296**	8224	**-72**
1998	274	2671	188	2859	**3133**	5315	**2182**
1999	100	2428	209	2637	**2737**	4833	**2196**
2000	677	2347	567	2914	**3591**	4577	**986**
2001	1049	2331	331	2662	**3711**	5983	**2272**
2002	819	1932	77	2009	**2828**	3830	**552**
2003	988	2461	222	2683	**3671**	5590	**1919**
2004	1074	2552	62	2614	**3688**	4768	**1080**
2005	1024	2380	78	2458	**3482**	4243	**761**
2006	1219	2982	132	3114	**4333**	5705	**1372**
2007	686	1953	36	1989	**2675**	3304	**629**
2008	1096	2268	35	2303	**3399**	4192	**793**
2009	1067	2415	124	2539	**3606**	4260	**654**
2010	765	2180	77	2257	**3022**	3511	**489**
2011	840	2577	49	2626	**3466**	4528	**1062**

Table 4. Estimated annual and quarterly catches (metric tons) of blue marlin *Makaira nigricans* in the Hawaii-based pelagic longline fishery in 1995−2011 obtained by multiplying the corrected catch in numbers by the quarterly mean weight per fish.

Year	Quarter	Metric tons	Year	Quarter	Metric tons
1995	1	16.83	1996	1	63.70
	2	102.95		2	87.82
	3	91.19		3	56.50
	4	117.48		4	45.80
	Annual total	**328.45**		**Annual**	**253.82**
1997	1	26.20	1998	1	30.09
	2	164.55		2	52.46
	3	215.39		3	84.36
	4	94.43		4	60.18
	Annual	**500.57**		**Annual**	**227.09**
1999	1	21.45	2000	1	15.95
	2	63.31		2	48.98
	3	74.31		3	133.42
	4	40.03		4	62.90
	Annual	**199.10**		**Annual**	**261.25**
2001	1	18.58	2002	1	34.28
	2	57.67		2	75.13
	3	103.23		3	56.73
	4	59.63		4	37.55
	Annual	**239.11**		**Annual**	**203.69**
2003	1	24.98	**2004**	1	48.94
	2	108.53		2	76.49
	3	39.62		3	42.98
	4	62.48		4	37.55
	Annual	**235.61**		**Annual**	**205.96**

Table 4, continued.

Year	Quarter	Metric tons	Year	Quarter	Metric tons
2005	1	47.41	2006	1	37.78
	2	109.19		2	94.94
	3	66.81		3	88.58
	4	56.52		4	89.47
	Annual	**279.93**		**Annual**	**310.77**
2007	1	35.11	2008	1	42.69
	2	70.16		2	91.04
	3	57.00		3	65.31
	4	53.10		4	77.84
	Annual	**215.37**		**Annual**	**276.88**
2009	1	43.95	2010	1	28.91
	2	116.03		2	106.28
	3	96.16		3	80.36
	4	45.22		4	48.72
	Annual	**301.36**		**Annual**	**264.27**
2011	1	57.62			
	2	106.63			
	3	63.07			
	4	64.72			
	Annual	**292.04**			

APPENDIX

Catch History Correction: 1995−2011

This appendix presents detailed methodology and results regarding the catch history correction for 1995−2011. The contents are intended to elucidate the reporting bias requiring catch data correction (Table A1) and the methods used for correction (Table A2).

Methods

Evaluation of logbook data on observed trips

Table A1 presents descriptive catch statistics from observed and unobserved fishing trips. The observed trips were analyzed on an annual basis. The mean difference (i.e., observer-logbook) was calculated for each trip, and a paired *t*-test was computed for each year using the one-sided alternative that the mean difference was negative. Trip means were used to reduce the likelihood of spurious results caused by very large sample sizes as would have been the case with set-level data. Although these were repeated tests, $P<0.05$ was used as the significance criterion because this reporting bias has been thoroughly documented (Walsh et al. 2005; 2007).

Six of these annual differences (1996, 1997, 1999, 2001, 2002, 2005) were significant (all tests, $P < 0.05$). This indicated that upward bias in self-reported blue marlin catch data caused by species misidentifications sometimes occurred even in the presence of fishery observers.

Evaluation of logbook data on unobserved trips

The accuracy of catch data from unobserved fishing trips was assessed by comparing logbook data to estimates predicted by a zero-inflated negative binomial model, which was selected as the best-fitting CPUE standardization model for blue marlin (Walsh et al. 2013). This approach to data evaluation, in which a statistical model is used to predict catches as a comparison standard for catches reported in logbooks from unobserved fishing trips in this fishery, was developed by Walsh and Kleiber (2001) for blue sharks *Prionace glauca*. Istiophorid billfish catch histories were corrected in previous studies (Walsh et al. 2005; 2007) using methods similar to those employed for blue sharks, except that public fish auction sales records were available to verify (or not) the suspected misidentifications.

This work differed from the previous blue marlin studies (Walsh et al. 2005; 2007) in two main respects. The first is that a different type of statistical model was used for data evaluation. The second is that catch correction was conducted from a different perspective, reflecting different priorities. Previously, rigorous criteria (e.g., at least two sets that were apparent outliers on a trip) were established for correction of logbook values because the highest priority was avoidance of removing unusual but possibly correct data (Walsh et al. 2005; 2007). At present,

however, the priority was to remove as many inaccuracies as possible from the catch data. Therefore, sets with catches that appeared to be outliers were replaced with predicted catches unless previously verified (Walsh et al. 2005; 2007). Specifically, many longline trips in the latter half of 1997 had large catches of blue marlin verified by fish auction sales records; these catches consisted primarily of fish that were significantly smaller than those caught in the corresponding seasons of all other years in the study (Walsh et al. 2007).

In this study, catch and operational data from the PIROP were used to fit a zero-inflated negative binomial model according to procedures outlined in Zuur et al. (2009). Full details regarding the model fitting process are presented in Walsh et al. (2013).

Blue marlin catches on unobserved sets were predicted (Crawley 2009) by applying the model coefficients to the values of the same explanatory variables in the logbook reports. Table A2 presents summary statistics for the explanatory variables in both the model fitting (observer) and application (logbook) data sets.

Imputations were required for three of the explanatory variables in order to have complete cases necessary for the explanatory variables. The sea surface temperature (SST) was missing for 0.8% of the sets; these were replaced by within-trip mean values or the monthly mean for the fishery sector within the fishing region. Hooks per float were missing from 0.9% of the sets because this field was added to the logbook form in 1995. These values were estimated by regressing hooks per float on hook numbers when vessels with missing values did report hooks per float. Bait types were missing from 27.0% of the logbook reports. These were imputed according to vessel history.

After predicting catches, the linear regression of the reported catches on the predictions was computed and the studentized residuals (SR) were extracted. "Large" SR were defined as $|\geq 2|$. These sets were often the suspected misidentifications.

The catches from sets with large SR except from 1997 were replaced with the model predictions rounded to the nearest integer. The large SR were then tabulated by vessels, and vessels with ≥ 100 were checked again using a one-sided alternative. Catches from sets with SR>1.7 were replaced with predicted values.

All computations were performed in R Version 2.14.1 for Windows or R Version 2.12.0 for Linux (R Development Core Team 2008). The zero-inflated negative binomial model was computed with the "pscl" library.

Table A1. Summary of nominal catch statistics for blue marlin *Makaira nigricans* in the Hawaii-based longline fishery in 1995–2011. Catches were reported by PIROP observers and in commercial logbooks. The entries for the mean catches per set and nominal CPUE are the mean±SD.

Data source	Sets	Total catch	Mean catch per set (±SD)	Mean nominal CPUE (±SD)	Retained	Released
PIROP Observers	51530	**12629**	0.25±0.71	0.144±0.496	95.2%	4.8%
Commercial logbooks (Observed)	51530	**13610**	0.26±0.84	0.160±0.601	97.0%	3.0%
Commercial logbooks (Unobserved)	208436	**75510**	0.36±1.08	0.258±1.056	98.0%	2.0%
PIROP Observers & Commercial logbooks	259966	**88139**	0.34±1.02	0.235±0.989	97.6%	2.4%

Table A2. Summary of the explanatory variables used in the catch history correction. Table entries are means, standard deviations, and ranges for continuous variables, and the percent use for baits. The total was 259,966 sets.

Data source	Sets	Fishery sector	Sea surface temperature (SST; °C)	Vessel length (ft)	Hooks	Hooks per float	Bait types
Fishery observers	51530	Shallow set 11632 sets	20.73±3.17°C 15.00−29.60°C	79.4±6.0 ft 56 – 98 ft	892.6±170.2 207 − 1448	4.5±0.8 2 − 14	Squid: 15.5% Mackerel:80.9% Other: 3.6%
		Deep set 39898 sets	25.30±1.77°C 14.87−30.45°C	70.5±10.4 40 – 100 ft	2106.0±402.8 202 − 4110	26.6±3.1 11 − 53	Sauries: 61.1% Mixed: 15.8% Sardines: 15.7% Other: 7.4%
Logbooks (Initial)	208436	Shallow set 28389 sets	21.54±3.29 8.70−28.65°C	74.8±8.9 ft 40 – 97 ft	809.1±163.5 19 − 2250	4.6±1.0 2 – 15	Squid: 70.5% Mackerel:25.6% Other: 3.9%
		Deep set 180128 sets	25.44±1.42°C 15.75−30.68°C	69.0±11.0 40 – 98 ft	2043.1±426.2 10 − 4775	27.3±3.4 5 − 88	Sauries: 44.3% Mackerel: 27.3% Mixed: 8.6% Sardines: 19.2% Other: 0.6%
Logbooks (Model application)	207780	Shallow set 28298 sets	22.02±3.26 15.00−28.65°C	74.8±8.9 40 – 97 ft	810.6±160.9 215 − 2250	4.6±1.0 2 – 15	Squid: 70.5% Mackerel:25.7% Other: 3.8%
		Deep set 179482 sets	25.43±1.41 15.75−30.00°C	69.0±11.0 40 – 98 ft	2044.5±423.2 203− 4775	27.3±3.4 5 − 88	Sauries: 46.2% Mackerel: 26.4% Mixed: 8.0% Sardines: 18.8% Other: 0.6%