Striped Marlin (*Kajikia audax*) length data available from 1995-2017 in the Hawaii-based longline fishery

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Abstract

Striped marlin (*Kajikia audax*) size frequency data are summarized for the Hawaii-based longline fishery from the Pacific Islands Regional Observer Program (PIROP) data set. Details on the spatial and temporal changes in mean lengths are presented, as well as a frequency table of the number of striped marlin measured per 5-cm length bin by year in 1995-2017. Results show relatively consistent annual mean lengths for striped marlin. The deep-set sector tends to catch the smallest age 0 and 1 individuals, although both deep-set and shallow-set sectors primarily catch fish smaller than the length at 50% maturity (177cm). Fish caught north of the Hawaiian Islands and in quarters two and three tend to be the largest and fish caught to the south and west of the Hawaiian Islands and in quarters one and four tend to be the smallest.

Introduction

Striped marlin (*Kajikia audax*) are a highly migratory billfish species that are caught primarily as non-target species in the North Pacific Ocean. The western and central North Pacific stock was last assessed in 2015 by the International Scientific Committee for Tuna and Tuna-like species in the North Pacific Ocean (ISC). This assessment was an age-structured assessment in Stock Synthesis and found that the stock was likely overfished ($F > F_{MSY}$) and that overfishing was occurring ($SSB < SSB_{MSY}$). The ISC has agreed to do a benchmark assessment of this stock bounded by the boundaries of the Western and Central Pacific Fisheries Commission (150°W) in 2019. This working paper describes the available length frequency data from the Hawaii-based longline fishery observer database for striped marlin caught west of 150°W for potential inclusion into this assessment. Striped marlin are caught as non-target species both the shallow-set and deep-set sectors. The deep-set sector tends to catch the majority of the striped marlin, although overall catch-per-unit effort is small. Descriptions of the data available and patterns of the data temporally and spatially are provided.

Methods

The Pacific Islands Fishery Observer Program (PIROP) provides detailed set-by-set data on the Hawaii-based longline fishery including the eye-fork length of fish caught in cm and a variety of operational variables, among them: location as latitude and longitude, vessel ID, hooks per float, and total number of hooks set, among others. Data are collected following the procedures outline in the PIROP observer manual (Pacific Islands Regional Office, 2017). Data were extracted from the PIROP database on 30 August 2018.

Striped marlin are caught as non-target species in both the deep-set tuna-targeting and shallow-set swordfish-targeting sectors of the Hawaii-based longline fleet. Observers were first placed onboard longline vessels in 1994. Observer coverage varied significantly prior to 2000, with observer coverage between 3.3 and 10.4% each year for the entire fishery (NMFS, 2017). Due to interactions with protected species the shallow-set sector was closed from 2001 to2004 and when it was reopened, 100% observer coverage occurred on shallow-set trips and ~20% observer coverage occurred on deep-set trips (Gilman *et al*., 2007). The deep-set trips are typically further south than the shallow-set trips, which are concentrated around the sub-tropical frontal zone (STFZ) where large swordfish are caught (Bigelow *et al.,* 1999). For this paper, deep-sets are

defined as sets with greater than 10 hooks per float prior to 2004 and greater than 14 hooks per float after 2004. This has been shown to better identify the recorded targeted fish by fishers than using greater than 14 hooks per float for all years (Sculley, 2019).

Prior to 2006 observers measured every fish caught. Since 2006, observers measured every third fish caught, regardless of species. Data west of 150°W were included in this analysis to correspond with the boundary of the Western and Central Pacific Fisheries Commission, which was the WG agreed-upon boundary for the 2019 assessment. In total, 37,354 striped marlin were measured.

Weights (W) of striped marlin were calculated by converting the eye-fork length in cm (L) to weight in kg using the weight-length relationship from Sun *et al.* (2011) which was used in the 2015 stock assessment:

$$W = 4.68 * 10^{-6} * L^{3.16}$$

This is a different weight-length relationship than the one estimated by Uchiyama and Kazama (2003) for Hawaiian-caught striped marlin ($W=7.65*10^{-6} * L^{3.24}$, Figure 1). Spatial plots are in 5x5 degree squares where cells with fewer than three vessels measuring striped marlin are excluded for confidentiality. Figures were made in R (version 3.4.0, R Core Team, 2017).

Results and Discussion

The mean eye-fork length of striped marlin caught in the Hawaii-based longline fishery was 134 cm. The size of striped marlin caught each year varied slightly between 130 and 140 cm EFL for most of the years in the time series, except for 2010, which had a mean EFL of 154 cm and 2011, which had a mean EFL of 125 cm (Figure 2). There are two modes in the length data, at 105cm and 140cm and most of the data are below the length at 50% maturity (177cm, Figure 3). This suggests that the Hawaii-based longline fleet catch primarily juvenile striped marlin. These two modes appear primarily in quarters one and four. Quarters two and three have a single mode around 160 cm and 135 cm, respectively (Figure 4).

This bimodal structure in the length data is similar to the one observed in the swordfish data from the Hawaii-based longline fishery and suggests an influx of one year old individuals to the population (Sculley *et al.,* 2018). Looking at the frequency of lengths by month, this peak first appears in September with fish <100 cm appearing in the fishery (Figure 5). These small fish become a larger component of the catch through March, when the peak merges with the second mode around 150 cm EFL. This suggests that recruitment to the fishery may begin in September and continue through the winter. Broken down by set type, the deep-set sector of the Hawaii-based longline fishery are catching the majority of these small fish (Figure 6). The shallow-set sector catches slightly larger (though still mostly immature, mean EFL = 149 cm) individuals than the deep-set sector (mean EFL = 132 cm), which exhibits the bimodal pattern described above.

The spatial patterns of fish size by length and weight are illustrated in Figure 7~~Figures 7~~Figure 10~~-10~~.The largest fish are caught north of the Hawaiian Islands, north of 30°N while those caught around the Hawaiian Islands and to the west are much smaller. The largest fish are also

caught in the north and the smallest in the south in quarter one. Overall, fish are the largest in quarter two and smallest in quarter four.

Overall, it appears that the Hawaii-based longline fishery catches primarily small, likely immature striped marlin as non-target species. Mean eye-fork length has been relatively consistent throughout the time series. Larger fish are typically caught to the north of Hawaii and smaller fish are typically caught to the south of Hawaii. An influx of age 0 and age 1 fish can be seen entering the deep-set sector in the fall, and cohorts can be observed growing through the year into the following spring. The small fish caught around Hawaii suggests that the area may be a nursery for juvenile fish.

Literature Cited

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Tables

Table 1. Number of striped marlin measured in the Hawaii-based longline fishery from 1995-2017 in 5 cm bins. Bin values indicate the maximum size of fish in the bin, inclusive.

Year	20	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150
1994	0	0	0	0	0	0	0	0	0	0	4	5	14	18	20	20	12	11	13	23	35	50
1995	0	0	0	0	0	0	0	0	0	4	3	12	41	43	56	35	44	75	91	87	71	56
1996	0	0	0	0	0	0	0	0	0	0	0	5	20	48	93	83	59	54	85	118	120	81
1997	0	0	0	0	0	0	0	0	0	0	2	10	21	33	31	14	17	15	26	23	24	43
1998	0	0	0	0	0	0	1	0	0	1	3	8	7	14	21	42	28	45	64	82	86	73
1999	0	0	0	0	0	0	0	0	0	0	6	4	21	33	31	37	25	26	30	25	33	27
2000	0	0	0	0	0	0	0	0	0	0	2	6	20	50	88	92	44	22	37	38	59	48
2001	0	0	0	0	0	0	0	1	0	13	28	112	297	455	398	346	283	350	454	442	362	293
2002	0	0	0	0	0	0	0	2	0	5	13	86	137	210	185	131	83	100	119	192	226	195
2003	1	0	0	0	1	0	1	0	6	28	87	327	654	851	596	348	289	370	508	619	549	446
2004	0	0	0	0	0	0	0	2	2	5	20	103	262	366	332	225	128	160	177	272	330	383
2005	0	0	0	0	3	3	3	5	14	64	121	208	186	190	247	249	187	194	246	292	380	558
2006	0	0	0	0	0	1	0	2	0	6	8	22	46	75	86	119	131	143	167	249	204	159
2007	0	0	0	1	0	0	0	1	0	6	5	13	16	21	29	14	10	15	24	28	42	46
2008	0	0	1	0	1	1	0	3	5	8	16	28	34	46	54	45	61	93	100	106	102	104
2009	0	0	1	0	0	0	0	0	0	2	2	8	13	15	25	16	11	24	46	49	43	41
2010	0	0	0	0	0	0	0	0	0	0	1	1	3	2	2	4	5	6	9	15	20	31
2011	0	0	0	1	0	0	0	1	6	14	32	52	113	189	192	136	87	87	55	81	60	50
2012	0	0	0	0	0	0	0	0	0	4	8	34	35	48	59	55	56	34	43	63	61	75
2013	0	0	0	1	0	0	0	2	1	5	7	29	60	50	40	31	29	34	56	65	95	110
2014	0	0	0	0	0	0	0	0	0	2	7	32	73	91	63	55	39	67	77	92	108	77
2015	0	1	0	0	0	0	0	0	1	0	7	5	21	25	27	23	15	37	36	45	86	122
2016	0	0	0	0	1	0	0	0	1	0	4	13	29	61	87	101	48	27	50	49	58	46
2017	0	0	0	0	0	0	0	0	1	1	3	7	32	67	91	78	43	49	73	76	73	70

Year	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	245	255
1994	39	38	37	28	15	6	10	3	2	0	0	0	0	0	0	0	0
1995	60	45	52	34	17	12	8	2	0	0	0	0	0	0	1	0	0
1996	52	32	23	18	15	5	3	0	0	0	0	0	0	0	0	0	0
1997	32	36	37	23	10	5	5	1	0	0	0	0	1	0	0	0	0
1998	55	20	12	7	4	6	2	2	0	0	0	0	0	0	1	0	0
1999	31	24	29	19	19	6	2	2	0	1	1	0	0	0	0	0	0
2000	53	36	23	13	6	5	0	3	2	0	0	1	0	0	0	0	0
2001	215	140	101	65	31	20	7	1	5	2	1	0	1	0	0	0	0
2002	149	117	90	64	33	15	9	3	0	0	0	0	1	0	0	0	1
2003	289	248	200	138	67	17	10	0	1	2	2	2	1	1	0	0	0
2004	310	192	103	69	45	25	10	2	0	2	0	1	0	0	0	0	0
2005	519	508	381	249	101	57	39	4	10	6	3	2	1	0	0	0	0
2006	128	101	99	60	43	17	14	0	2	1	2	2	0	0	0	0	0
2007	47	60	34	25	29	9	3	1	1	1	1	0	0	0	0	1	0
2008	103	105	120	86	49	25	12	9	7	2	0	1	0	2	0	0	0
2009	58	44	61	47	40	15	10	2	2	0	0	0	0	1	0	0	0
2010	30	32	35	31	19	12	10	1	0	0	0	0	0	0	0	0	0
2011	41	40	49	33	37	13	3	3	5	1	0	1	0	0	0	0	0
2012	50	51	42	28	11	9	6	3	1	1	0	1	0	1	0	0	0
2013	74	77	64	52	22	17	5	5	0	1	0	1	0	0	0	0	0
2014	53	45	50	28	18	16	6	2	1	0	0	1	0	0	0	0	0
2015	126	92	69	41	25	9	8	4	0	1	0	1	0	2	1	0	0
2016	54	69	71	46	36	17	13	2	3	0	1	0	0	0	0	0	0
2017	74	69	50	32	22	18	15	5	2	1	1	0	0	0	0	0	0

Figures

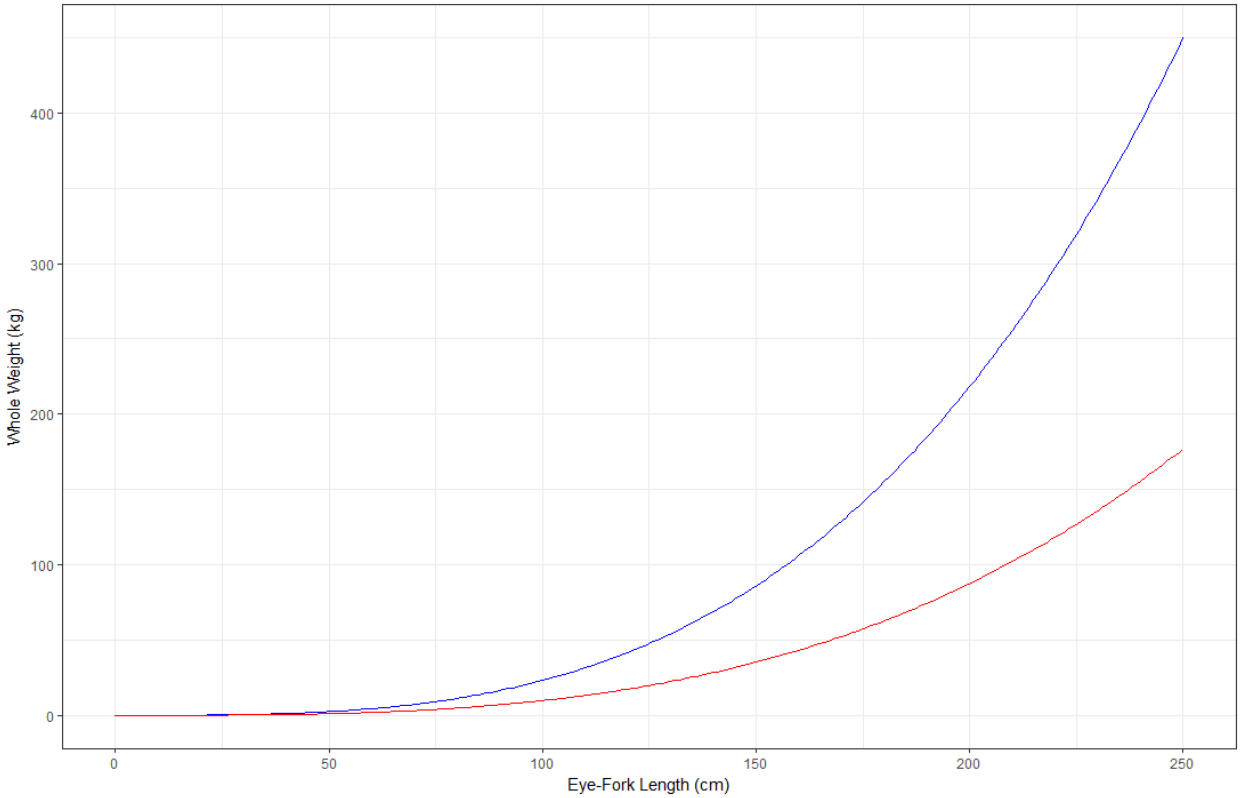

Figure 1. Weight-length relationship for striped marlin by Sun *et al.*, 2011 (red) used for this paper and Uchiyama and Kazama 2003 (blue).

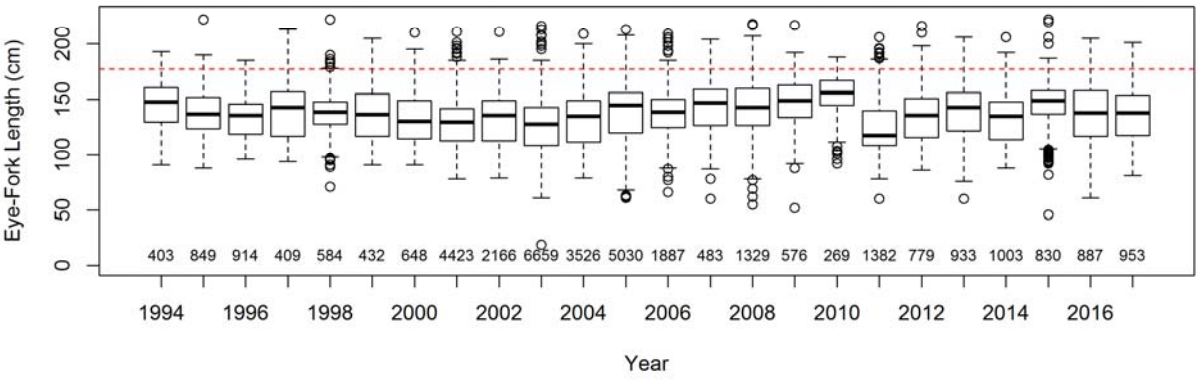

Figure 2. Boxplot of striped marlin lengths by year from the Hawaii-based longline observer dataset. Red dashed line indicates the length at 50% maturity (177cm). The number of fish measured in each year are listed below the boxplot for the year.

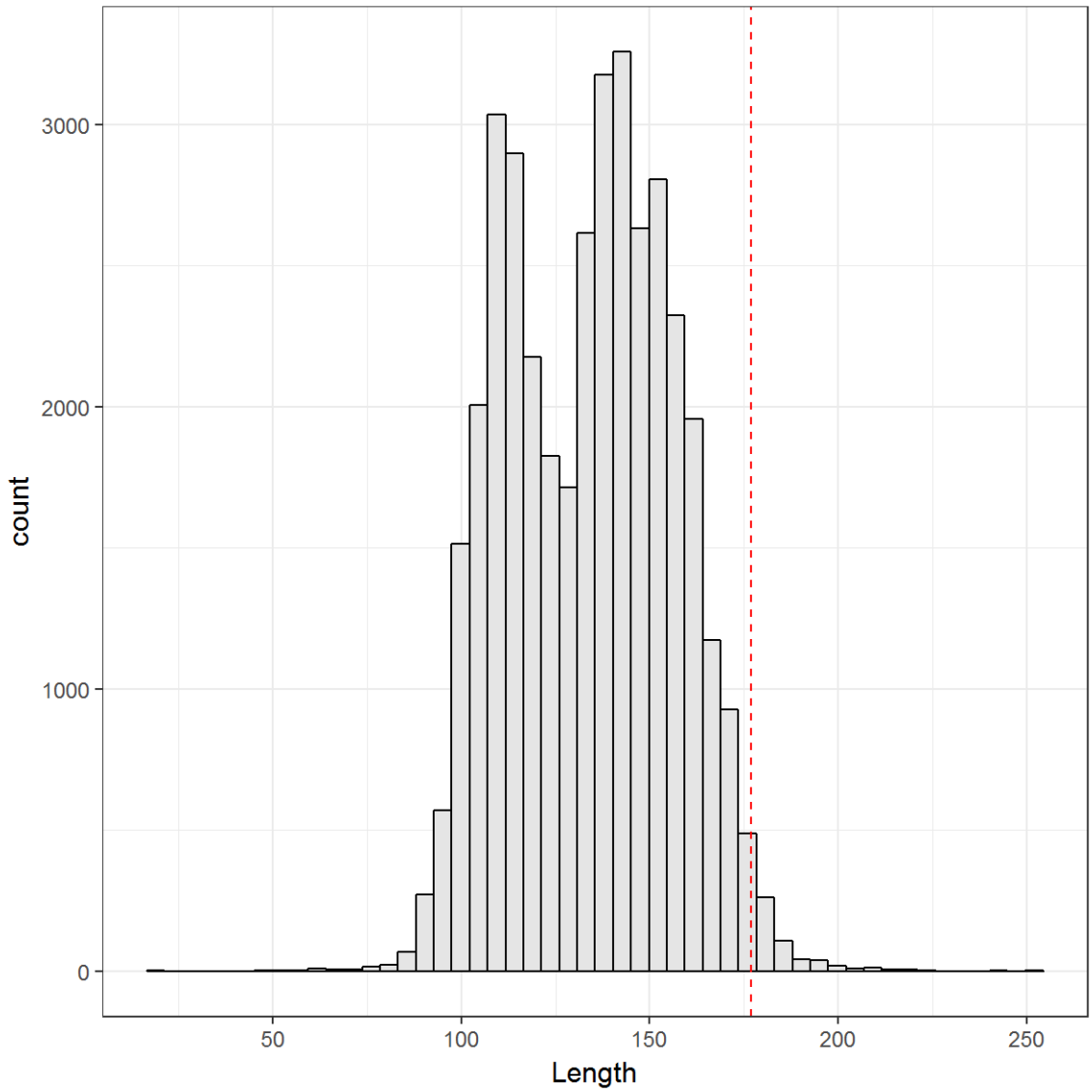

Figure 3. Histogram of all striped marlin lengths available in the Hawaii-based longline observer dataset. Red dashed line indicates length at 50% maturity (177cm).

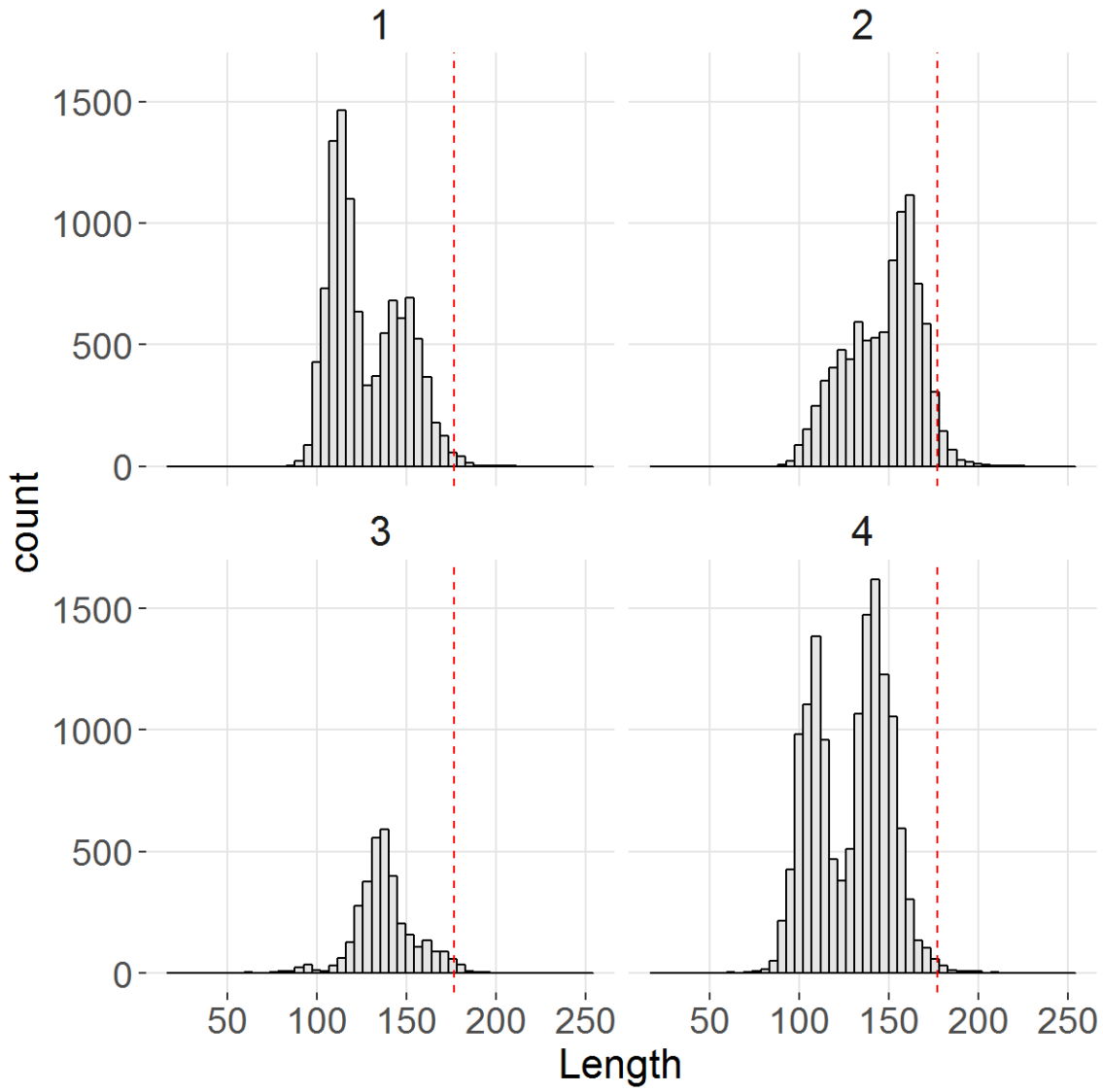

Figure 4. Histograms of lengths of striped marlin available in the Hawaii-based longline observer dataset by quarter (Quarter 1 top left, quarter 2 top right, quarter 3 bottom left, quarter 4 bottom right). Red dashed line indicates length at 50% maturity (177cm).

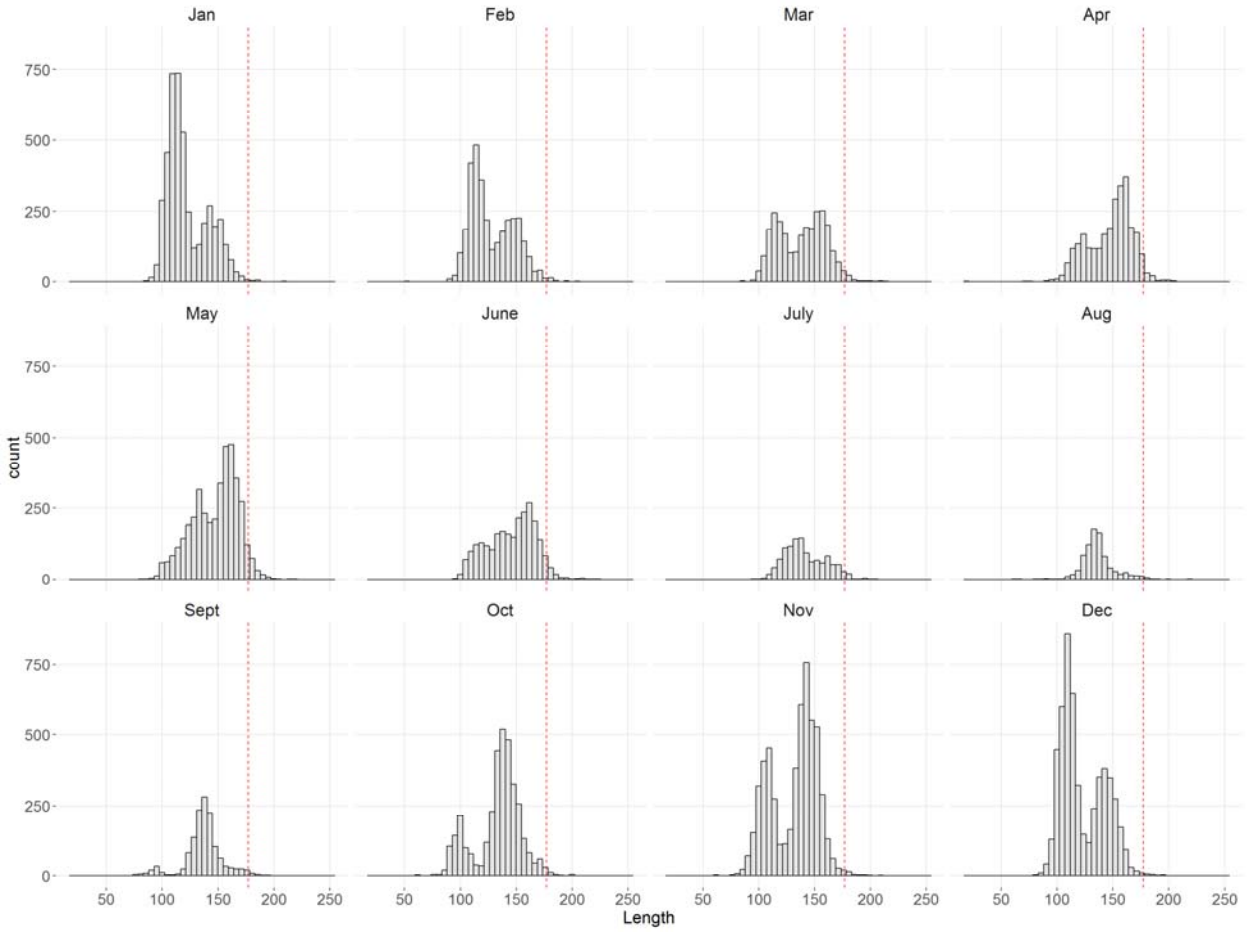

Figure 5. Histogram of striped marlin lengths (in cm) by month available from the Hawaii-based longline observer dataset. Red dashed line indicates length at 50% maturity (177cm).

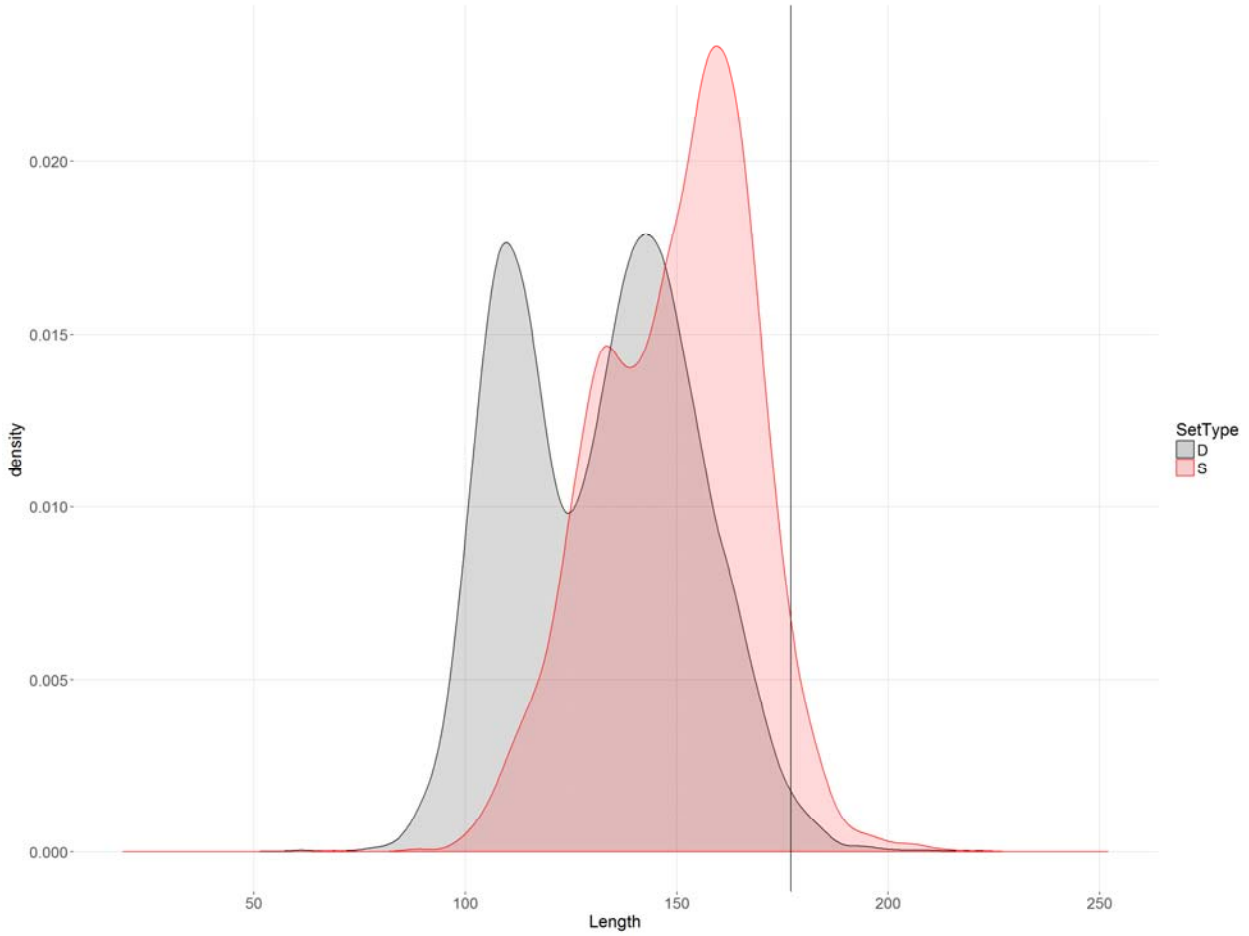

Figure 6. Density plot of striped marlin lengths (in cm) available in the Hawaii-based longline observer dataset. Gray vertical line indicates length at 50% maturity. Grey shading indicates fish caught in the deep-set sector, red shading indicates fish caught in the shallow-set sector.

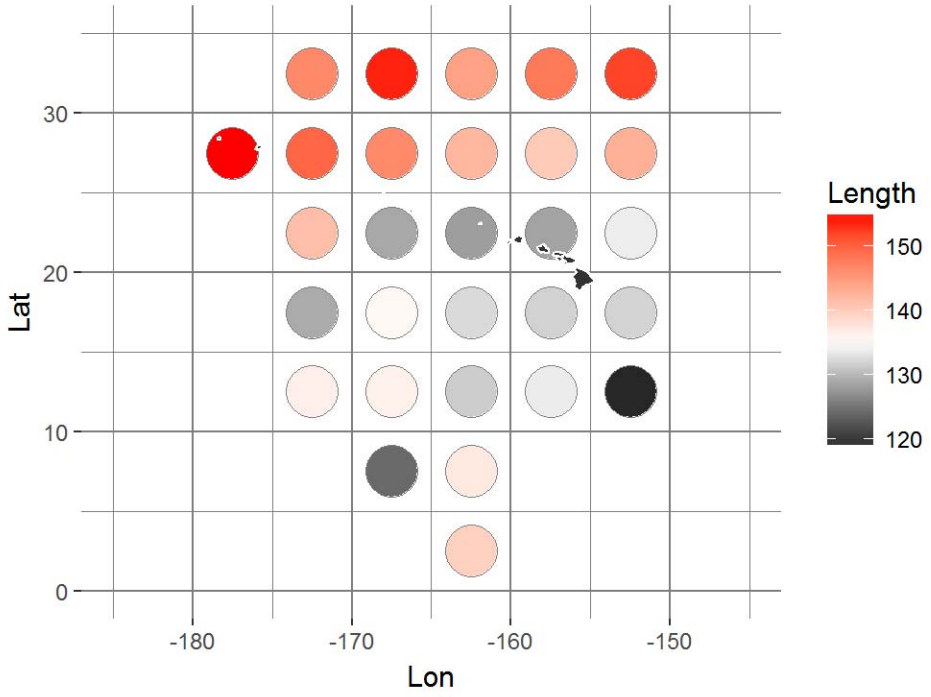

Figure 7. Mean length (in cm) by 5x5° squares of striped marlin caught in the Hawaii-based longline fishery. Squares with fewer than 3 vessels with measured fish were removed for confidentiality.

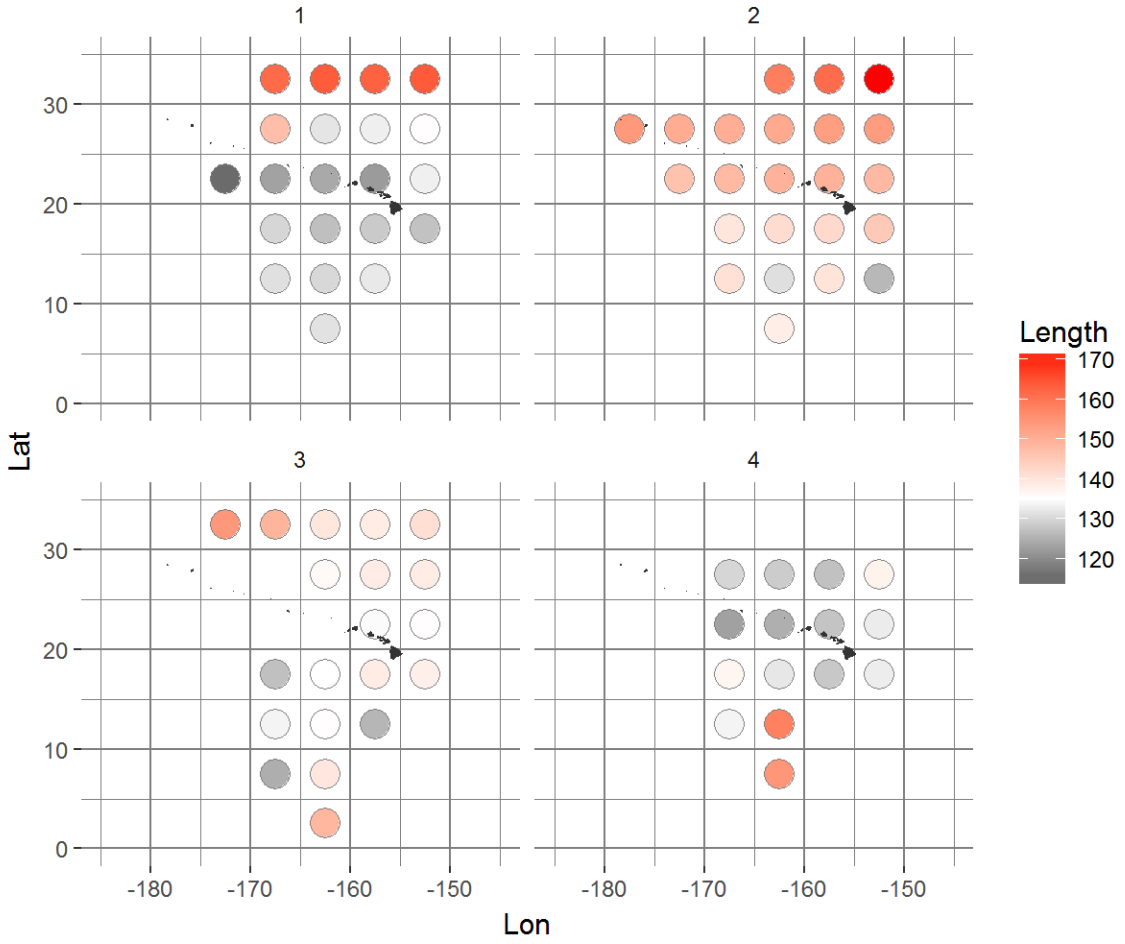

Figure 8. Mean lengths (in cm) by quarter of striped marlin caught in the Hawaii-based longline fishery (quarter 1 top left, quarter 2 top right, quarter 3 bottom left, quarter 4 bottom right). Squares with fewer than 3 vessels with measured fish were removed for confidentiality.

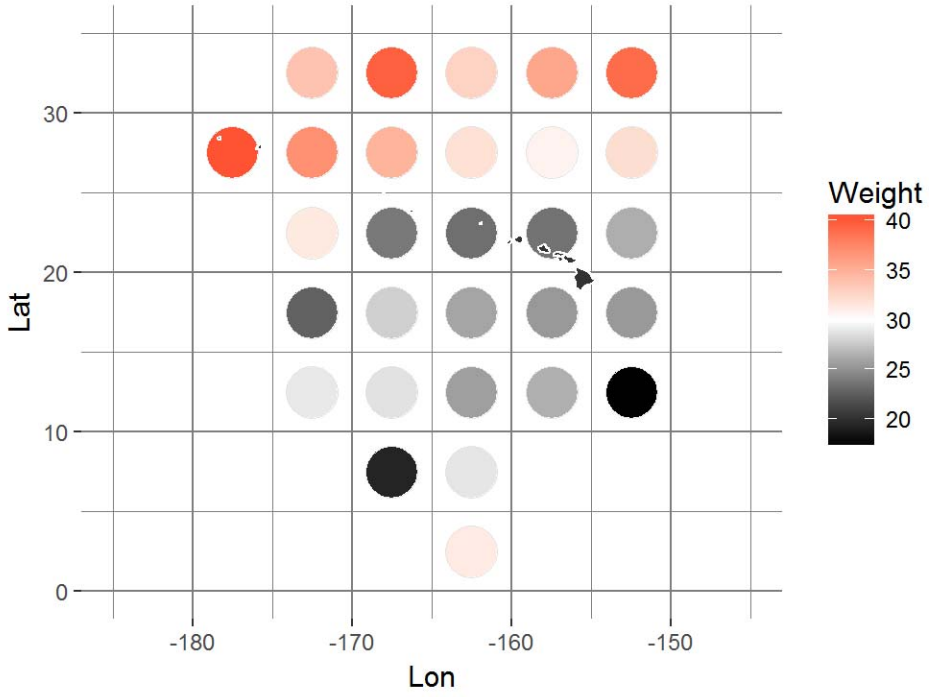

Figure 9. Mean weight (in kg) by 5x5° squares of striped marlin caught in the Hawaii-based longline fishery. Squares with fewer than 3 vessels with measured fish were removed for confidentiality.

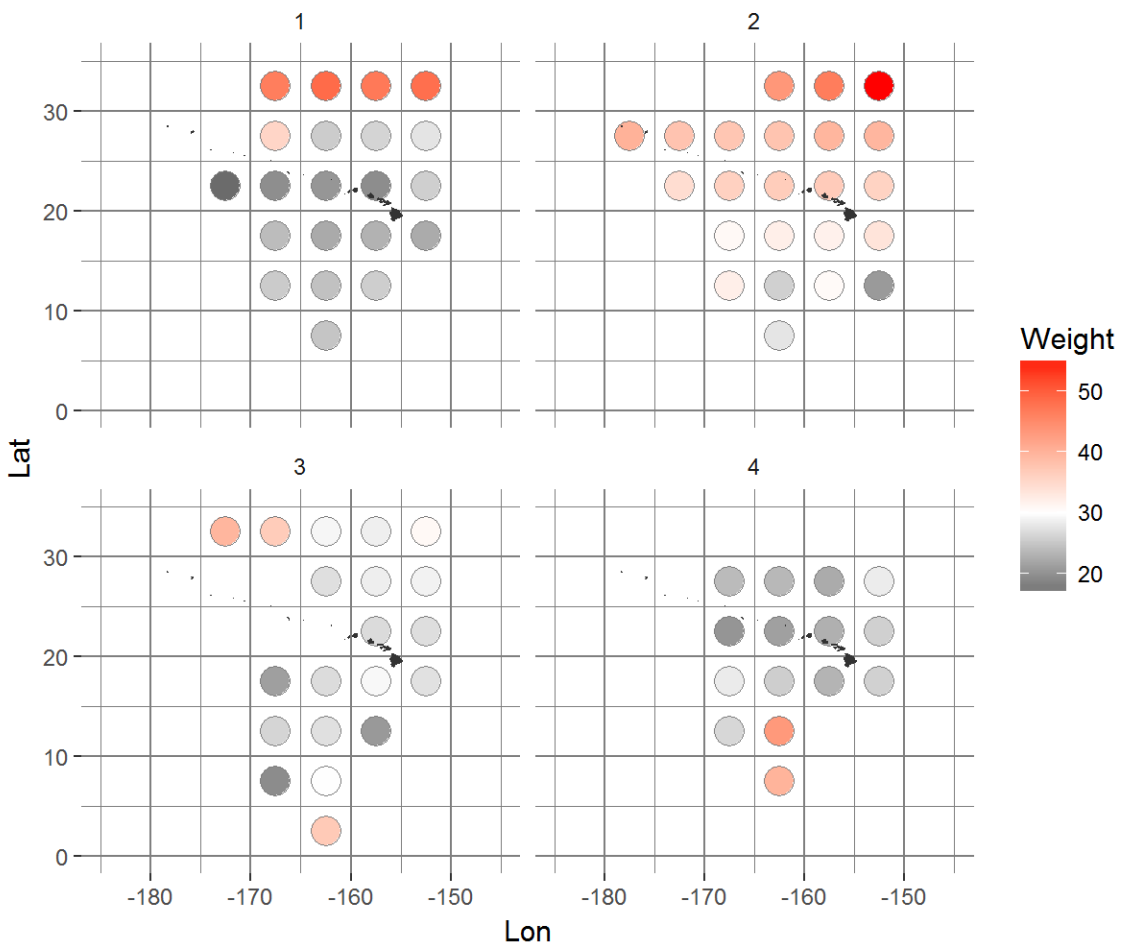

Figure 10. Mean weight (in kg) by quarter of striped marlin caught in the Hawaii-based longline fishery (quarter 1 top left, quarter 2 top right, quarter 3 bottom left, quarter 4 bottom right). Squares with fewer than 3 vessels with measured fish were removed for confidentiality.