Japanese length frequency data of Western Central North Pacific Striped Marlin (*Kajikia audax*). [1]

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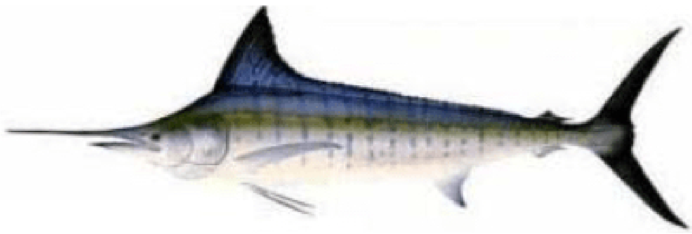

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Abstract

This paper compiled length frequency data obtained by Japanese longline and driftnet fishery for the WCNPO striped marlin stock assessment. Although ISC billfish working group used Japanese longline size data in the past stock assessment, Japanese size data sets were confirmed low area coverage and the possibility of bias from training vessel data. Thus, this paper focused on logbook data. In the longline fishery, striped marlin is a bycatch species, and one individual catch weight has been recorded in the logbook. This data converted to body length and estimated the effective sample size. The estimated size data complement the lack of the area that has not been sampled, and the several biases were also improved. Estimated data made the longline length frequency data set for SS3, and that fleet definition follows the analysis result of finite mixture model (flexmix). For the driftnet length frequency data, Japanese size data set was used and aggregated by year and quarter. To considering data pattern, the Japanese driftnet fishery is reasonable to define the fishery in two periods (first and fourth quarter, and second and third quarter).

Introduction

The ISC billfish working group (BILLWG) conducted an update stock assessment of WCNPO striped marlin update using Stock Synthesis 3 (SS3) (ISC 2015). However, the results of this updated assessment changed significantly from the previous assessment. The BILLWG pointed out that the fishery selectivity changed significantly due to the data update. The selectivity parameters estimates by size (fish length or weight) statistics. Therefore, the fish size data is a piece of essential information which significantly influences the result of the stock assessment. However, Japanese size statistics has various problems. For example, most Japanese longline size statistics is low resolution and low area coverage (Figure.1, Figure.2 E). Before the 1990s, since almost data had been from training vessels, there is also concern about the data bias by the training vessel (Figure.1, Figure. 2 F). The Japanese size statistics improved in 1999, but before that, it can not calculate the effective sample size because old statistics did not log operation number. Although late Japanese statistics are accurate, most sampling is sampling at Kesennuma Port (Figure.2 D). Thus, sampling biasing by the Kesennuma port is a concern.

On the other hand, the Japanese logbook data also has information of the striped marlin catch size. Striped marlin is a bycatch species for the Japanese longline fishery. As a result, most of the catch per operation is zero, followed by the catch of one fish (Figure.3). Such a one individual catch weight is alternative size information. The rate of one individual fish data is always stable after 1975 (Figure.3). Besides, we can expect broader time-spatial coverage than size statistics and logbook data can calculate effective sample size. However, there is also a problem with the use of logbook data. First of all, it is unknown whether coverage is broad or not. It is also vital whether equally appears one fish caught by time-spatially. Furthermore, conversion to the eye-fork length is necessary to use SS3 because logbook data records semi-dress weight.

Here, this paper estimated the eye-fork length frequency data from the logbook data and examined the validity of the estimated value. At the same time, the effective sample size was also calculated. The length frequency data of driftnet was aggregated and confirmed the Japanese size statistics. Finally, I created the dataset for SS3 and considered the reasonable fleet definition of SS3.

Material and methods

Longline length frequency data

The size statistics and logbook data includes size information of striped marlin caught by Japanese longline fishery. The size statistics are available from 1975, but the sampling method has changed dramatically in 1999 (Figure.2). Until 1998, length and weight data had classified separately. After 1999 data is the length and weight data by individual fish measurement. Later statistics includes Trip ID. Thus, the effective sample size can calculate in combination with logbook data. However, the number of available data will decrease. Early statistics measured body weight mainly, and that area resolution was low (Figure.2 D). Throughout the entire period, data have measured by port sampling and onboard (training vessel or observer), but the measurement source changed on time (Figure.2 C D). As described, Japanese size statistics includes several biases.

The logbook data describes trip ID, detailed data per operation (e.g., date, area position, number of fish catches and catch amount). The point to note is that logbook records the information of the one striped marlin catch. This paper uses this information to estimate the length frequency of Japanese longline fishery. There are two time series for Japanese longline logbook data (1975-1993 and 1994-2017). Early period data also have catch records of the set by set, but some logs include estimated weight data. Thus, later period logbook data was used for this study. In the early period, size statistics measured semi-dress weight of striped marlin. I also estimate eye-fork length using size statistics.

Estimate catch length

The semi-dress weight need to convert to eye-fork length. The length and semi-dress weight relationship equation used for the conversion formula and size statistics after 1999 was used for the parameter estimation. The length and semi-dress weight relationship equation is as follows:

$$W = 2.6104 \times 10^{-6} L^{3.2427} \exp(\epsilon), \epsilon \sim N(0, 0.1296), \quad (1)$$

where W is a semi-dress weight, L is an eye-fork length. The data and equation show goodness fit (Figure. 4). The estimated eye-fork length was randomly generated using conversion formula and logbook data. Finally, the estimated data were aggregated for each fleet defined by flexmix analysis (Table.1).

Data validation

Data validation was carried out in the following steps.

1. I compared the size statistics after 1999 with the logbook weight data to confirm the accuracy of the logbook. Comparison area is the main sampling area of size statistics ($25° - 35°$N, $120° - 150°$E).

2. In order to check whether there is a spatial bias in the one fish catch data, the mean weight of all catches and the mean weight which totaled one fish catch data were compared in the season-spatial.

3. Finally, estimated eye-fork length and observed data from the size statistics were compiled for each definition of the fleet and compared. The period of compared is from 1999 to 2017.

Effective sample size

The methodology of the effective sample has followed the methodology of Pennington(Pennington, Burmeister, and Hjellvik 2002). Firstly, it needs to estimate the mean fish length ($\hat{R}$) and its variance ($var(\hat{R})$) based on the clusters of fish caught at n trips.

$$\hat{R} = \frac{\sum_{i=1}^{n} M_i \hat{\mu}_i}{\sum_{n}^{i=1} M_i}, \tag{2}$$

where M_i is the number of striped marlins caught at trip i and $\hat{\mu_i}$ is an estimate of the mean length of fish of trip i. and that variance is

$$\begin{aligned} var(\hat{R}) &= \sum_{i=1}^{n} \frac{(M_i/\bar{M})^2(\hat{\mu}_i - \hat{R})}{n(n-1)}, \\ \bar{M} &= \sum_{i=1}^{n} \frac{M_i}{n}. \end{aligned} \tag{3}$$

Secondly, variance ($\hat{\sigma}_x^2$) of the population length distribution needs to estimate. It assumes that the number of m_i fish are randomly selected at each trip as:

$$\hat{\sigma}_x^2 = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m_i} (M_i/m_i)(x_{i,j} - \hat{R})^2}{M - 1} \tag{4}$$

where M is the total number of fish caught by season for each fleet definition, and $x_{i,j}$ is the length of the j^{th} fish of the trip i. Finally, the effective sample size that related to design effect is defined by

$$\begin{aligned} diff &= \frac{var(\hat{R})}{\hat{\sigma}_x^2/m}, \\ \frac{\hat{\sigma}_x^2}{\hat{m}_{eff}} &= var(\hat{R}). \end{aligned} \tag{5}$$

Thus effective sample size (m_{eff}) can be estimated by number of samples (m) and design effect ($diff$)

$$m_{eff} = m/diff. \tag{6}$$

The effective sample size of each fleet for the SS3 was estimated for by year and quarter (Table. 1).

Driftnet length frequency data

There are logbook data of Japanese driftnet fishery (1977-1993). However, this dataset records only catch number. The available size statistics have been recorded since 2005, but the number of samples is very small, and year and area coverage is low. Therefore, this study checked the size statistics of the driftnet fishery by quarter and examined whether it is necessary to define the seasonal fleet as well as the longline.

Result and discussion

The semi-dress weights on size statistics compared with logbook data that recorded simultaneously and these different data sources showed similar trends (Figure.5). The measurement accuracy of size statistics is high because striped marlin has directly measured at the port or onboard. Thus, Japanese logbook weight data confirmed to have similar accuracy to size statistics. The seasonal spatial trend of the semi-dress weight of only one fish catch showed a tendency similar to mean weight calculated from the total catch (Figure.6, Figure.7). In other words, it was considered that catches of only one fish appear randomly. Following the fleet definition of the SS3, the estimated length frequency data compared with the size statistics (Figure.8, Figure.9). By using the logbook, new length frequency data could be obtained (Area 4 in the quarter, Area 2 and Area3 in quarter 4) (Figure.7). Besides, the number of samples of Area 2 in quarter 2 and Area 2 in quarter2 increased (Figure.7). There is a difference in the Area 1 in quarter 3, but when confirming the data in detail, there was a spatial bias in the size statistics (Figure.7). Specifically, the size statistics sampled at this period tended to be biased to the north side where much large fish appeared. In this way, we could improve coverage and bias by creating length frequency data from logbook weight data. However, as future work, statistical analysis is necessary for these comparisons.

The effective sample size was also estimated using logbook (Table.1). This estimation value is useful for the next stock assessment because the effective sample size is essential information for the SS3 setting. Age 0 fish appears in Area 3 in quarter 1, Area 2 in quarter 2 and Area 2 in quarter 4 (Figure.10). Attention needs when estimating the selectivity in the SS3 because the appearance of age 0 fish may change substantially depending on the year. For example, Area 2 in quarter 2, there are many age 0 fish data in 2010 (Figure.12).

Size statistics of driftnet showed seasonal fluctuation (Figure.11). For example, quarter 1 is similar to quarter 4 and quarter 2 is similar to quarter 3 (Figure.11). It is desirable not to the fleet by area-quarter, but to define the two seasonal fleet that is quarter 1 and 4 and quarter 2 and 3, because the size statistics of the driftnet is low in spatiotemporal coverage.

Estimated eye-fork length in early period is similar to later period (Figure.10, Figure.13) but the number of samples in some area is not enough.

Summary and suggestions

- It is better to use logbook data because the Japanese longline size statistics has a lot of bias and low coverage.
- Logbook data includes the semi-dress weight of only one fish catch, but weight data need to convert to the eye-fork length.
- Although there are two data periods for logbook data, estimates value might use for some of the catch weight in the early period. Therefore, the later period datasets (from 1994 to 2017) are available for the stock assessment.
- The estimated length frequency data improved the area coverage and the sampling bias. Simultaneously, the effective sample size also calculated.
- The driftnet size statistics is low in spatiotemporal coverage, and logbook data cannot be substituted. When summarized by quarter, the first quarter and the fourth quarter, the second quarter and the third quarter showed a similar trend. Thus, the proposal is to use two fleet definitions for SS3.

Acknowledgement

The idea of creating length frequency data from logbook data is from Dr. H. Okamoto and Mr. Kotaro Yokawa. I would like to take this opportunity to express my appreciation.

References

ISC (2015). Stock assessment update for striped marlin (kajika audax) in the western and central north pacific ocean through 2013.

Pennington, M., L.-M. Burmeister, and V. Hjellvik (2002). Assessing the precision of frequency distributions estimated from trawl-survey samples. *Fishery Bulletin 100*(1), 74–80.

Table 1: Summary of Japanese length frequency data for stock synthesis 3.

No	Fleet name	Data source	Time Period	Eff n	Mirror
1	JPNLL qt1 area1	Log book (1x1)	1994-2017	Yes	-
2	JPNLL qt1 area2	Log book (1x1)	1994-2017	Yes	-
3	JPNLL qt1 area3	Log book (1x1)	1994-2017	Yes	-
4	JPNLL qt1 area4	Log book (1x1)	1994-2017	Yes	-
5	JPNLL qt2 area1	Log book (1x1)	1994-2017	Yes	-
6	JPNLL qt2 area2	Log book (1x1)	1994-2017	Yes	-
7	JPNLL qt3 area1	Log book (1x1)	1994-2017	Yes	-
8	JPNLL qt3 area2	Log book (1x1)	1994-2017	Yes	-
9	JPNLL qt4 area1	Log book (1x1)	1994-2017	Yes	-
10	JPNLL qt4 area2	Log book (1x1)	1994-2017	Yes	-
11	JPNLL qt4 area3	Log book (1x1)	1994-2017	Yes	-
12	JPNLL other	-	-	-	JPNLL area1 (by each qtr)
13	JPNDF qt14	Length-weight	2005-2017	No	-
14	JPNDF qt23	Length-weight	2005-2017	No	-
15	JPN others(1)	-	-	-	JPNLL area1 (by each qtr)

Table 2: Estimated effective sample size (m_{eff}). n: Number of trip. M: Total STM catch number. m: number of samples. $var(\hat{R})$: Variance of population mean length. $\hat{\sigma}_x^2$: Variance of measured STM. $diff$: Design effect

Year	Quarter	Area	n	M	m	$var(\hat{R})$	$\hat{\sigma}_x^2$	$diff$	m_{eff}
1994	1	Area 1	452	1310	953	1.23	269.70	4.34	220
1995	1	Area 1	380	1901	879	1.73	265.32	5.73	154
1996	1	Area 1	436	1512	908	0.97	242.35	3.62	251
1997	1	Area 1	389	1998	828	0.63	162.98	3.19	260
1998	1	Area 1	396	1657	773	0.71	204.43	2.70	286
1999	1	Area 1	408	2350	1012	1.11	248.72	4.53	223
2000	1	Area 1	247	661	422	2.75	265.86	4.36	97
2001	1	Area 1	274	832	515	0.88	202.57	2.23	231
2002	1	Area 1	349	932	644	1.27	256.83	3.18	203
2003	1	Area 1	238	757	450	2.64	277.67	4.29	105
2004	1	Area 1	422	1697	872	1.27	209.56	5.27	166
2005	1	Area 1	330	1267	678	0.60	173.62	2.34	290
2006	1	Area 1	280	1017	592	1.94	327.21	3.51	169
2007	1	Area 1	410	1609	787	1.44	214.57	5.28	149
2008	1	Area 1	552	2192	1186	0.34	176.75	2.26	524
2009	1	Area 1	461	1738	983	2.23	268.35	8.16	120
2010	1	Area 1	516	2367	1133	0.47	192.23	2.78	408
2011	1	Area 1	450	1640	953	0.64	241.12	2.52	378
2012	1	Area 1	477	4192	1811	1.25	350.55	6.43	282
2013	1	Area 1	469	3090	1030	0.26	121.10	2.25	457
2014	1	Area 1	425	2015	919	0.35	158.18	2.02	454
2015	1	Area 1	354	1734	752	0.46	163.87	2.13	353
2016	1	Area 1	563	2901	1352	0.45	209.38	2.89	469
2017	1	Area 1	455	2385	1014	0.31	144.07	2.18	465
1994	1	Area 2	543	5220	1554	1.97	326.11	9.40	165
1995	1	Area 2	619	5256	1746	1.84	411.66	7.79	224
1996	1	Area 2	520	4902	1506	0.72	254.87	4.23	356
1997	1	Area 2	574	4569	1403	0.63	259.35	3.40	413
1998	1	Area 2	616	4647	1545	0.62	250.01	3.86	400
1999	1	Area 2	463	4306	1404	0.65	254.23	3.58	392
2000	1	Area 2	568	3698	1518	1.20	357.80	5.10	298
2001	1	Area 2	504	4280	1481	2.49	372.31	9.90	150
2002	1	Area 2	558	4631	1684	0.74	302.44	4.10	410
2003	1	Area 2	523	4256	1540	0.63	228.45	4.23	364
2004	1	Area 2	409	3301	1163	0.48	178.15	3.12	372
2005	1	Area 2	427	2080	1136	0.69	235.20	3.32	342
2006	1	Area 2	431	1982	1136	1.34	347.16	4.40	258
2007	1	Area 2	358	1658	804	1.27	321.51	3.18	253
2008	1	Area 2	299	1783	739	1.40	258.52	4.01	184
2009	1	Area 2	283	1220	697	3.36	403.47	5.80	120
2010	1	Area 2	454	2122	1067	0.67	255.20	2.79	382
2011	1	Area 2	451	6709	1123	11.36	937.44	13.61	82
2012	1	Area 2	498	8370	2448	1.25	294.03	10.44	235
2013	1	Area 2	435	3572	1156	4.78	491.65	11.24	103
2014	1	Area 2	439	2438	1093	8.44	649.00	14.22	77

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Year	Quarter	Area	n	M	m	$var(\hat{R})$	$\hat{\sigma}_x^2$	$diff$	m_{eff}
2015	1	Area 2	542	4740	1505	0.44	207.18	3.22	467
2016	1	Area 2	371	1452	860	1.22	296.75	3.54	243
2017	1	Area 2	278	1486	648	1.01	186.76	3.50	185
1994	1	Area 3	120	9726	615	3.00	360.73	5.11	120
1995	1	Area 3	101	6973	672	14.19	678.36	14.05	48
1996	1	Area 3	181	6855	742	0.96	260.11	2.75	270
1997	1	Area 3	161	5853	647	7.67	540.60	9.18	70
1998	1	Area 3	165	3642	587	0.65	163.48	2.33	251
1999	1	Area 3	143	5470	522	1.98	283.23	3.64	143
2000	1	Area 3	151	3892	470	2.03	300.57	3.18	148
2001	1	Area 3	160	4376	538	10.08	678.86	7.98	67
2002	1	Area 3	102	3011	279	3.17	227.87	3.88	72
2003	1	Area 3	102	5391	433	3.64	370.33	4.26	102
2004	1	Area 3	66	3302	357	6.55	564.82	4.14	86
2005	1	Area 3	71	2041	576	2.54	460.40	3.17	182
2006	1	Area 3	81	1794	497	3.52	483.68	3.62	137
2007	1	Area 3	100	1529	539	2.49	318.21	4.22	128
2008	1	Area 3	93	1321	532	3.19	431.13	3.94	135
2009	1	Area 3	107	1203	396	6.53	572.05	4.52	88
2010	1	Area 3	76	802	219	2.50	263.73	2.07	106
2011	1	Area 3	113	2371	397	18.90	839.15	8.94	44
2012	1	Area 3	97	3449	527	4.74	412.28	6.05	87
2013	1	Area 3	113	1762	477	7.35	664.54	5.28	90
2014	1	Area 3	83	2671	378	10.49	783.52	5.06	75
2015	1	Area 3	93	2488	349	1.38	207.65	2.32	150
2016	1	Area 3	65	783	277	8.04	471.46	4.72	59
2017	1	Area 3	94	1377	370	0.78	170.83	1.69	219
1994	1	Area 4	45	175	86	43.51	359.26	10.42	8
1995	1	Area 4	49	93	74	7.78	301.11	1.91	39
1996	1	Area 4	56	180	126	1.90	283.65	0.84	149
1997	1	Area 4	46	122	73	23.47	358.74	4.78	15
1998	1	Area 4	44	126	70	17.00	364.95	3.26	21
1999	1	Area 4	64	204	129	3.57	248.42	1.86	70
2000	1	Area 4	40	75	60	33.50	1000.97	2.01	30
2001	1	Area 4	32	88	59	16.41	424.78	2.28	26
2002	1	Area 4	33	50	48	9.29	323.98	1.38	35
2003	1	Area 4	30	89	46	4.78	268.24	0.82	56
2004	1	Area 4	42	130	81	16.26	469.15	2.81	29
2005	1	Area 4	23	47	32	93.77	581.47	5.16	6
2006	1	Area 4	20	29	29	15.40	376.78	1.19	24
2007	1	Area 4	10	11	11	97.31	855.79	1.25	9
2008	1	Area 4	10	14	14	63.10	449.84	1.96	7
2009	1	Area 4	7	8	8	47.04	365.74	1.03	8
2010	1	Area 4	12	15	15	17.54	200.42	1.31	11

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Year	Quarter	Area	n	M	m	$var(\hat{R})$	$\hat{\sigma}_x^2$	$diff$	m_{eff}
2011	1	Area 4	25	97	56	47.55	786.12	3.39	17
2012	1	Area 4	18	67	49	4.77	204.88	1.14	43
2013	1	Area 4	8	22	22	2.21	178.38	0.27	81
2014	1	Area 4	6	12	12	8.55	710.84	0.14	83
2015	1	Area 4	11	18	18	16.29	336.11	0.87	21
2016	1	Area 4	9	14	11	9.56	90.44	1.16	9
2017	1	Area 4	5	5	5	37.46	187.32	1.00	5
1994	2	Area 1	840	16896	2112	1.27	417.91	6.42	329
1995	2	Area 1	823	15369	2323	2.08	535.10	9.03	257
1996	2	Area 1	798	20917	2211	2.84	511.59	12.29	180
1997	2	Area 1	773	12865	2020	0.95	365.39	5.25	384
1998	2	Area 1	802	17999	1859	1.70	453.47	6.97	267
1999	2	Area 1	906	13676	2481	0.98	360.02	6.76	367
2000	2	Area 1	790	7007	2204	0.91	327.91	6.15	359
2001	2	Area 1	765	8318	2257	1.59	481.20	7.46	302
2002	2	Area 1	758	8745	2225	0.51	252.78	4.52	492
2003	2	Area 1	731	6627	1927	1.48	371.60	7.66	252
2004	2	Area 1	742	5951	2144	1.16	331.78	7.50	286
2005	2	Area 1	664	5676	1914	1.09	385.60	5.42	353
2006	2	Area 1	694	5381	1926	7.31	755.12	18.64	103
2007	2	Area 1	680	4539	1783	0.50	276.90	3.21	556
2008	2	Area 1	618	3464	1564	1.13	411.12	4.29	364
2009	2	Area 1	610	2810	1328	0.84	356.10	3.14	422
2010	2	Area 1	762	5712	1737	0.37	211.22	3.08	564
2011	2	Area 1	661	3387	1412	2.95	549.57	7.58	186
2012	2	Area 1	712	12209	3278	0.53	227.18	7.67	428
2013	2	Area 1	739	9247	1975	1.00	330.26	5.95	332
2014	2	Area 1	638	4512	1538	2.53	537.18	7.24	212
2015	2	Area 1	701	7225	1716	0.91	301.70	5.19	330
2016	2	Area 1	625	4314	1476	0.96	269.57	5.27	280
2017	2	Area 1	534	3241	1232	1.09	350.02	3.82	322
1994	2	Area 2	70	223	124	16.94	479.14	4.38	28
1995	2	Area 2	76	198	156	5.88	486.40	1.88	83
1996	2	Area 2	59	324	146	6.94	254.75	3.98	37
1997	2	Area 2	69	285	151	24.92	524.95	7.17	21
1998	2	Area 2	101	303	202	7.20	497.48	2.92	69
1999	2	Area 2	83	283	202	4.71	463.34	2.05	98
2000	2	Area 2	70	213	107	6.69	372.05	1.92	56
2001	2	Area 2	62	223	118	30.09	737.11	4.82	24
2002	2	Area 2	70	278	135	53.05	603.05	11.87	11
2003	2	Area 2	53	71	63	6.98	408.32	1.08	58
2004	2	Area 2	42	69	57	22.91	677.79	1.93	30
2005	2	Area 2	29	95	47	27.70	628.49	2.07	23
2006	2	Area 2	38	52	50	9.29	572.48	0.81	62

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Year	Quarter	Area	n	M	m	$var(\hat{R})$	$\hat{\sigma}_x^2$	$diff$	m_{eff}
2007	2	Area 2	35	54	48	45.31	1181.39	1.84	26
2008	2	Area 2	21	53	37	49.88	1129.64	1.63	23
2009	2	Area 2	17	24	24	71.10	989.36	1.72	14
2010	2	Area 2	24	270	50	55.10	459.01	6.00	8
2011	2	Area 2	28	284	71	21.25	639.62	2.36	30
2012	2	Area 2	25	65	47	16.55	431.94	1.80	26
2013	2	Area 2	21	195	38	41.37	774.97	2.03	19
2014	2	Area 2	34	70	45	137.42	1016.12	6.09	7
2015	2	Area 2	27	56	41	90.48	1062.46	3.49	12
2016	2	Area 2	19	39	24	18.62	302.92	1.48	16
2017	2	Area 2	10	15	11	188.15	1055.84	1.96	6
1994	3	Area 1	401	7939	1458	0.52	180.84	4.22	345
1995	3	Area 1	296	12671	804	0.97	217.98	3.56	226
1996	3	Area 1	364	6384	1233	0.86	230.99	4.58	269
1997	3	Area 1	354	5833	1083	0.56	204.19	2.97	365
1998	3	Area 1	434	14112	1257	2.88	374.10	9.67	130
1999	3	Area 1	427	6741	1306	0.64	198.39	4.18	312
2000	3	Area 1	386	6625	1204	0.59	141.54	4.99	241
2001	3	Area 1	341	10695	968	0.67	169.73	3.84	252
2002	3	Area 1	357	5852	1232	0.55	155.66	4.38	281
2003	3	Area 1	341	5126	1029	1.14	194.38	6.05	170
2004	3	Area 1	376	5592	1358	0.91	236.74	5.21	261
2005	3	Area 1	278	2918	852	1.76	291.98	5.14	166
2006	3	Area 1	322	3551	1093	0.97	206.66	5.11	214
2007	3	Area 1	375	3365	1182	0.68	214.95	3.73	317
2008	3	Area 1	316	2159	925	0.60	201.71	2.75	336
2009	3	Area 1	328	2632	933	0.56	190.34	2.75	340
2010	3	Area 1	297	1956	833	2.92	227.12	10.70	78
2011	3	Area 1	325	5299	979	0.48	154.43	3.04	322
2012	3	Area 1	323	3189	1447	0.65	180.91	5.20	278
2013	3	Area 1	251	1519	598	1.31	236.75	3.32	180
2014	3	Area 1	241	2843	835	0.65	164.63	3.31	252
2015	3	Area 1	225	1380	494	3.09	233.89	6.54	76
2016	3	Area 1	200	1868	432	2.16	177.99	5.24	82
2017	3	Area 1	198	980	490	1.13	187.74	2.96	166
1994	3	Area 2	57	334	105	12.18	529.93	2.41	44
1995	3	Area 2	30	147	69	46.20	630.74	5.05	14
1996	3	Area 2	112	659	254	17.99	471.96	9.68	26
1997	3	Area 2	38	214	124	16.43	421.69	4.83	26
1998	3	Area 2	51	322	135	10.84	506.44	2.89	47
1999	3	Area 2	70	219	128	28.67	693.66	5.29	24
2000	3	Area 2	35	102	58	6.72	223.55	1.74	33
2001	3	Area 2	64	140	105	9.55	442.70	2.27	46
2002	3	Area 2	28	107	73	5.00	333.79	1.09	67

Table 2: Estimated effective sample size (m_{eff}). n: Number of trip. M: Total STM catch number. m: number of samples. $var(\hat{R})$: Variance of population mean length. $\hat{\sigma}_x^2$: Variance of measured STM. $diff$: Design effect

Year	Quarter	Area	n	M	m	$var(\hat{R})$	$\hat{\sigma}_x^2$	$diff$	m_{eff}
2003	3	Area 2	42	301	106	8.86	446.52	2.10	50
2004	3	Area 2	49	204	81	182.64	969.33	15.26	5
2005	3	Area 2	31	69	53	19.63	694.02	1.50	35
2006	3	Area 2	25	50	36	35.22	564.94	2.24	16
2007	3	Area 2	26	69	52	28.56	497.25	2.99	17
2008	3	Area 2	16	23	23	44.06	521.54	1.94	12
2009	3	Area 2	29	45	35	26.67	574.57	1.62	22
2010	3	Area 2	36	256	70	59.86	733.12	5.72	12
2011	3	Area 2	29	44	38	56.46	946.81	2.27	17
2012	3	Area 2	29	92	65	27.71	386.59	4.66	14
2013	3	Area 2	22	41	30	26.75	415.51	1.93	16
2014	3	Area 2	34	62	60	12.95	591.76	1.31	46
2015	3	Area 2	26	101	45	6.40	393.61	0.73	62
2016	3	Area 2	30	99	44	2.91	272.22	0.47	93
2017	3	Area 2	28	63	41	20.84	476.06	1.79	23
1994	4	Area 1	854	17288	2959	0.27	197.17	4.00	740
1995	4	Area 1	880	24941	2702	0.40	202.19	5.30	509
1996	4	Area 1	878	13859	2740	0.17	159.81	2.96	927
1997	4	Area 1	811	12299	2293	0.32	219.40	3.39	676
1998	4	Area 1	910	15311	2717	0.20	169.24	3.29	826
1999	4	Area 1	867	11731	2673	0.44	220.65	5.34	501
2000	4	Area 1	786	9600	2642	0.40	173.05	6.04	437
2001	4	Area 1	765	10333	2554	0.70	254.21	7.04	363
2002	4	Area 1	609	5834	1689	0.25	156.01	2.66	634
2003	4	Area 1	531	5161	1588	0.39	182.84	3.40	467
2004	4	Area 1	581	6558	1822	0.66	230.58	5.22	349
2005	4	Area 1	539	4150	1771	1.07	352.26	5.37	330
2006	4	Area 1	554	4395	1681	0.53	229.63	3.89	432
2007	4	Area 1	827	8004	2412	0.26	177.42	3.53	683
2008	4	Area 1	620	3255	1653	0.42	248.82	2.78	595
2009	4	Area 1	619	2919	1475	0.42	240.33	2.60	567
2010	4	Area 1	577	2848	1441	0.64	233.08	3.95	365
2011	4	Area 1	687	8004	2068	0.36	180.16	4.12	502
2012	4	Area 1	555	8952	2941	0.46	179.48	7.57	388
2013	4	Area 1	617	4112	1773	0.39	207.01	3.30	537
2014	4	Area 1	552	4413	1458	0.65	176.27	5.39	271
2015	4	Area 1	545	2159	1135	0.97	278.57	3.96	287
2016	4	Area 1	546	2723	1305	0.29	186.87	2.04	639
2017	4	Area 1	349	1351	719	0.93	233.85	2.87	251
1994	4	Area 2	19	792	40	57.87	844.17	2.74	15
1995	4	Area 2	11	1070	12	12.82	136.33	1.13	11
1996	4	Area 2	13	162	23	60.04	308.23	4.48	5
1997	4	Area 2	11	112	28	11.61	131.45	2.47	11
1998	4	Area 2	15	308	39	6.36	267.97	0.93	42

Table 2: Estimated effective sample size (m_{eff}). n: Number of trip. M: Total STM catch number. m: number of samples. $var(\hat{R})$: Variance of population mean length. $\hat{\sigma}_x^2$: Variance of measured STM. $diff$: Design effect

Year	Quarter	Area	n	M	m	$var(\hat{R})$	$\hat{\sigma}_x^2$	$diff$	m_{eff}
1999	4	Area 2	12	173	26	82.56	617.56	3.48	7
2000	4	Area 2	22	498	79	3.06	236.56	1.02	77
2001	4	Area 2	4	99	4	9.13	34.90	1.05	4
2002	4	Area 2	11	100	23	50.29	568.94	2.03	11
2003	4	Area 2	14	441	33	19.11	274.69	2.30	14
2004	4	Area 2	10	176	23	28.55	407.93	1.61	14
2005	4	Area 2	19	334	55	37.24	613.81	3.34	16
2006	4	Area 2	9	166	17	97.37	343.25	4.82	4
2007	4	Area 2	18	232	81	32.08	540.42	4.81	17
2008	4	Area 2	19	398	64	5.01	338.47	0.95	68
2009	4	Area 2	12	69	24	33.03	314.97	2.52	10
2010	4	Area 2	7	20	15	110.61	518.86	3.20	5
2011	4	Area 2	4	30	5	448.73	1102.25	2.04	2
2012	4	Area 2	5	21	10	134.41	468.90	2.87	3
2013	4	Area 2	7	80	15	260.64	1159.15	3.37	4
2014	4	Area 2	6	33	15	25.95	247.19	1.57	10
2015	4	Area 2	4	60	13	176.25	841.30	2.72	5
2016	4	Area 2	4	27	12	37.29	565.16	0.79	15
2017	4	Area 2	7	28	18	16.79	446.04	0.68	27
1994	4	Area 3	63	152	120	6.41	412.07	1.87	64
1995	4	Area 3	35	80	61	13.10	404.96	1.97	31
1996	4	Area 3	77	190	150	2.80	313.58	1.34	112
1997	4	Area 3	30	61	41	20.11	328.28	2.51	16
1998	4	Area 3	64	241	146	4.21	294.29	2.09	70
1999	4	Area 3	54	136	117	7.81	332.41	2.75	43
2000	4	Area 3	46	96	81	6.34	275.15	1.87	43
2001	4	Area 3	37	120	93	6.12	255.43	2.23	42
2002	4	Area 3	34	93	73	6.53	271.29	1.76	42
2003	4	Area 3	40	93	64	8.56	503.19	1.09	59
2004	4	Area 3	34	70	62	32.03	539.96	3.68	17
2005	4	Area 3	16	37	29	28.48	435.58	1.90	15
2006	4	Area 3	21	29	29	13.36	295.55	1.31	22
2007	4	Area 3	9	9	9	7.39	66.48	1.00	9
2008	4	Area 3	7	18	10	142.00	1138.34	1.25	8
2009	4	Area 3	16	27	25	14.60	334.95	1.09	23
2010	4	Area 3	18	163	49	21.76	789.05	1.35	36
2011	4	Area 3	26	217	107	2.58	193.75	1.42	75
2012	4	Area 3	9	25	17	33.13	396.97	1.42	12
2013	4	Area 3	11	20	18	18.74	213.93	1.58	11
2014	4	Area 3	14	50	41	16.78	435.21	1.58	26
2015	4	Area 3	11	26	24	8.24	283.22	0.70	34
2016	4	Area 3	6	28	26	0.33	193.52	0.04	595
2017	4	Area 3	8	28	26	3.24	170.67	0.49	53

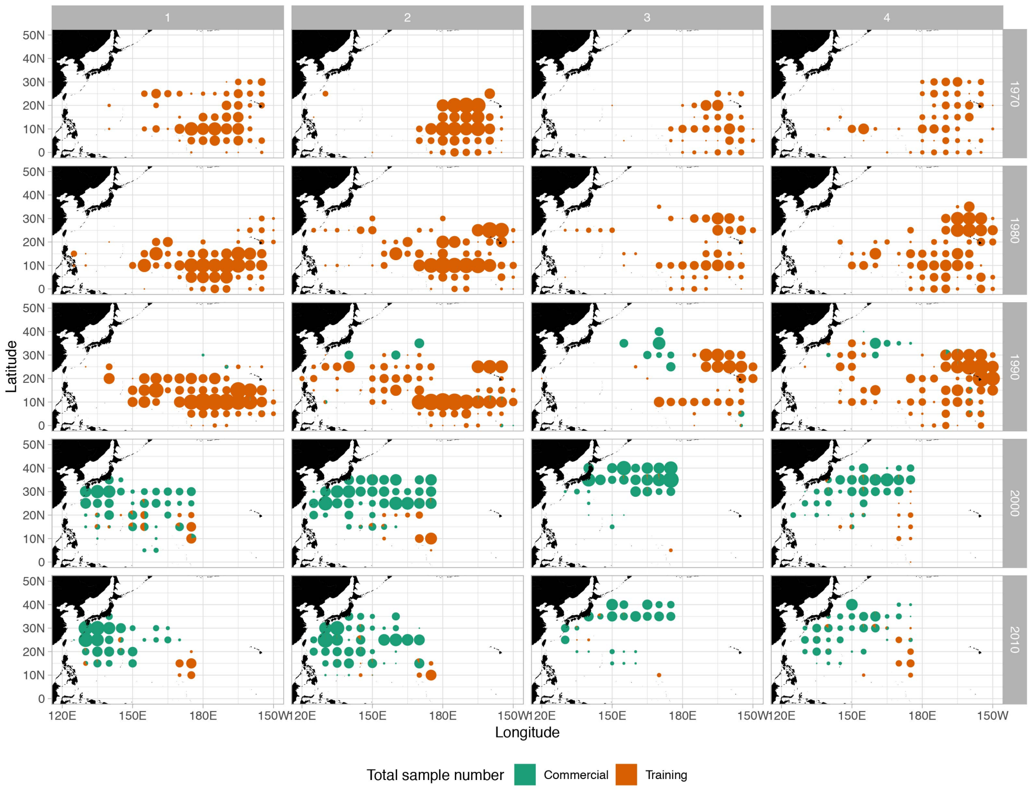

Figure 1: The number of samples of size statistics of striped marlin. In this figure, Japanese longline data set with the resolution of 5 ° × 5 ° or more were used.

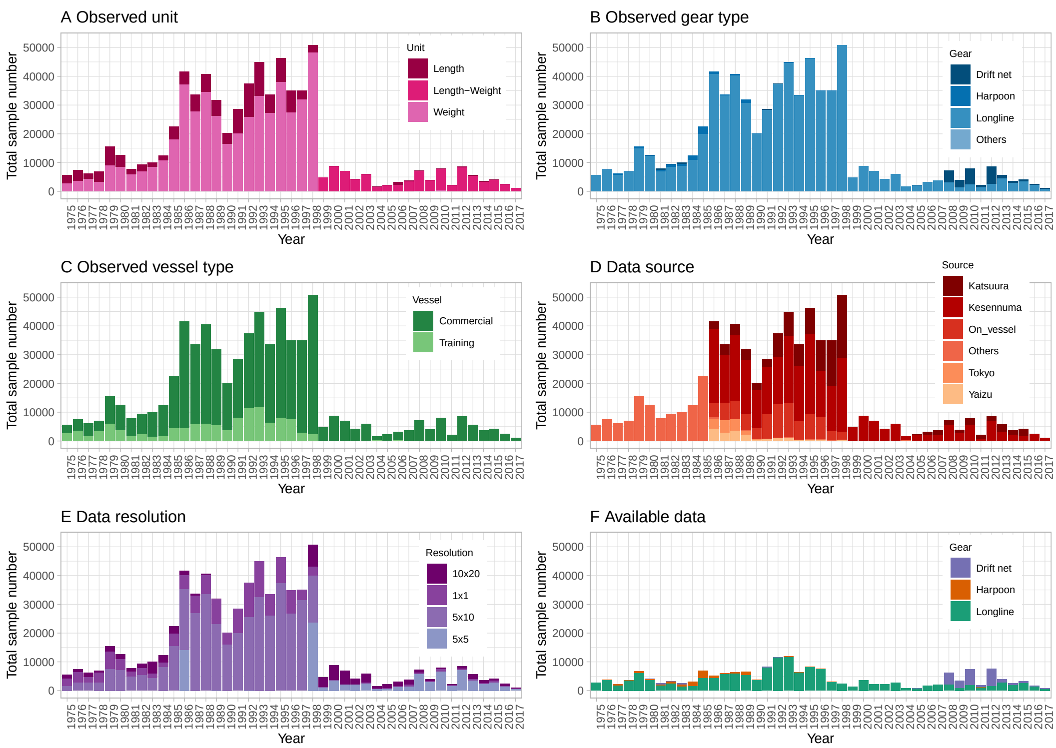

Figure 2: The number of WCNPO striped marlin samples on Japanese length-weight data. Available dataset (panel F) is chosen by length data with high-resolution (5 ° × 5 ° more).

Figure 3: Catch numbers ratio of Japanese longline fishery. Catch numbers are summarized by set by set using Japanese logbook data.

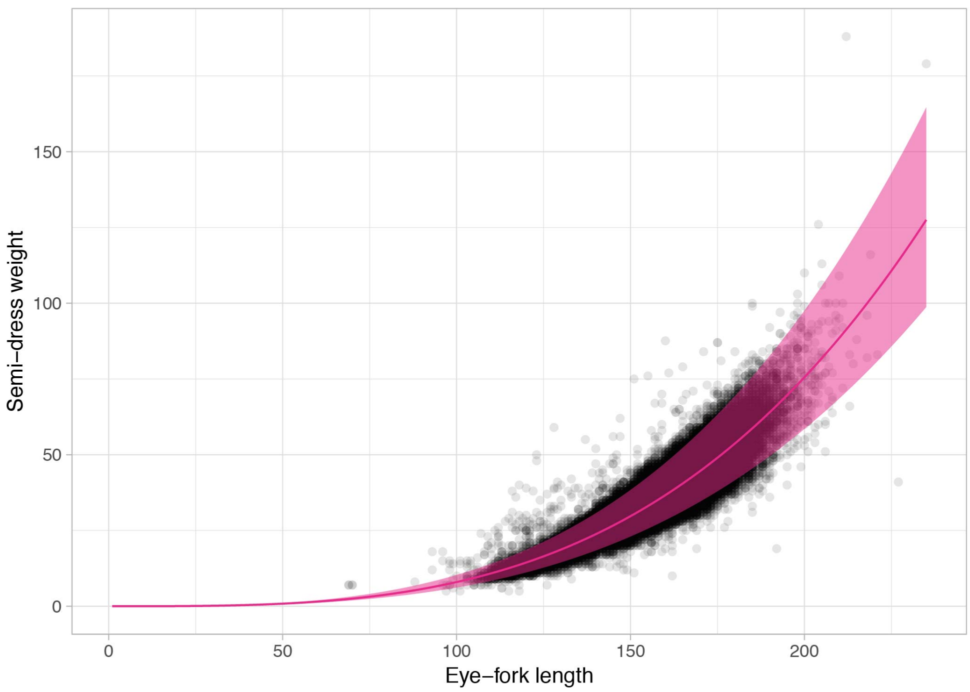

Figure 4: The length-weight (semi dress weight) relationship for WCNPO striped marlin. The solid red line is predicted line, black dots denote raw data, and the shaded ribbon is 95% prediction interval. All parameters were estimated by maximum likelihood estimation using Japanese length-weight data which period is between 1999 and 2017.

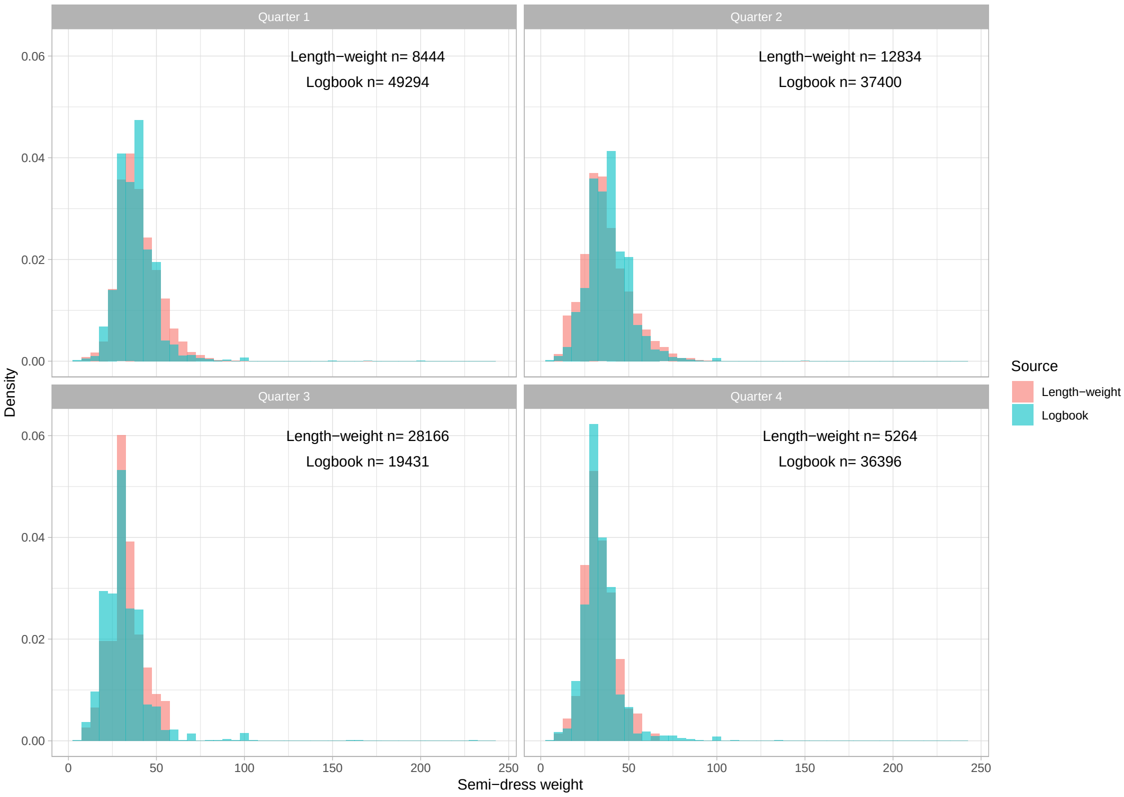

Figure 5: Data validation between logbook and length-weight data. Japanese logbook and length-weight data observe semi-dress weight of individual striped marlin at the same time. Datasets of the large catch number and large sample size area ($25\ ^\circ - 35\ ^\circ$N, $120\ ^\circ - 150\ ^\circ$E) are used to avoid sampling bias by area in this comparison.

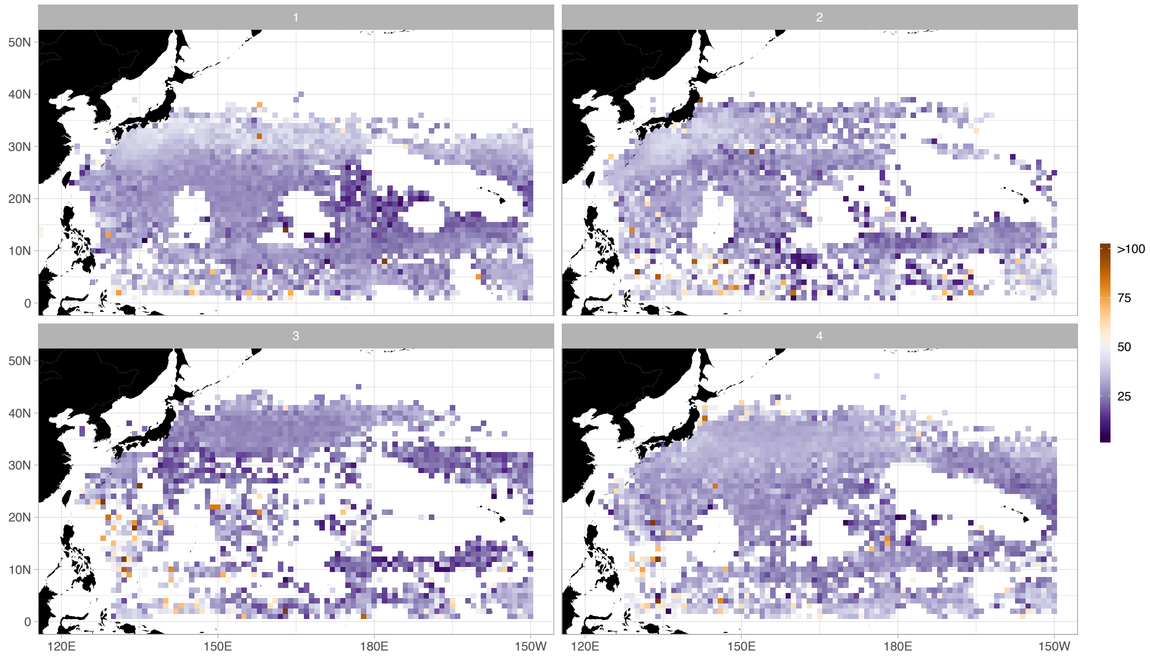

Figure 6: The spatial trend of the mean semi-dress weight of striped marlin calculated by one individual catch data.

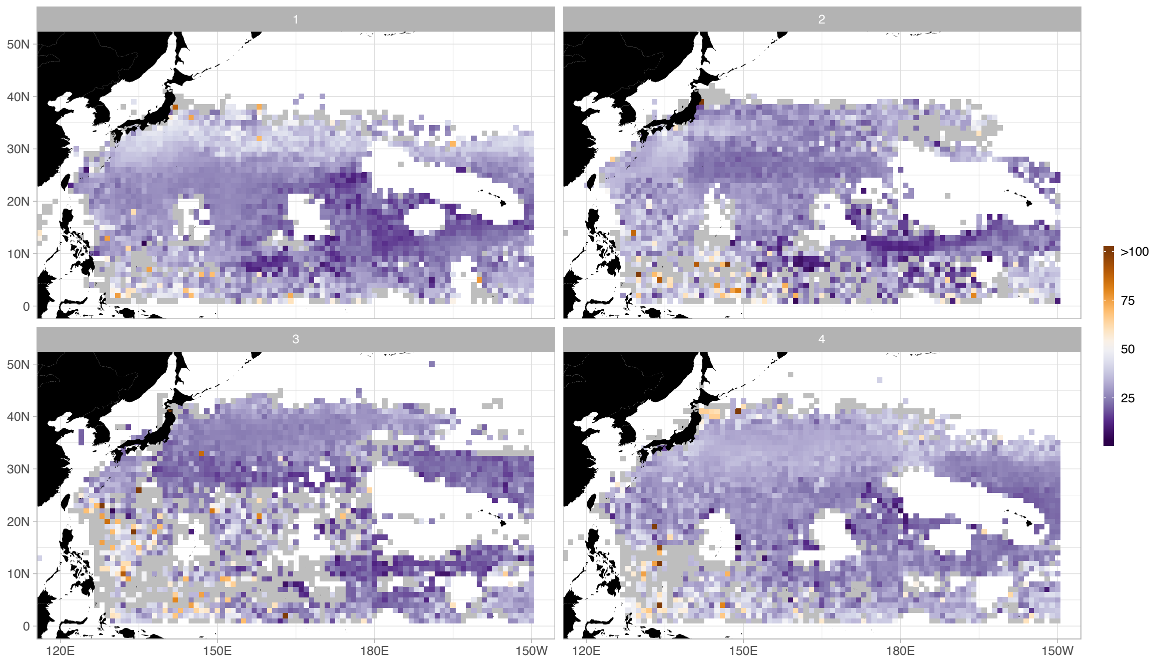

Figure 7: The spatio-seasonal variation of the mean semi-dress weight of striped marlin calculated by all catch data. The grid filled by gray denotes there is no catch for striped marlin throughout the time (1994-2017).

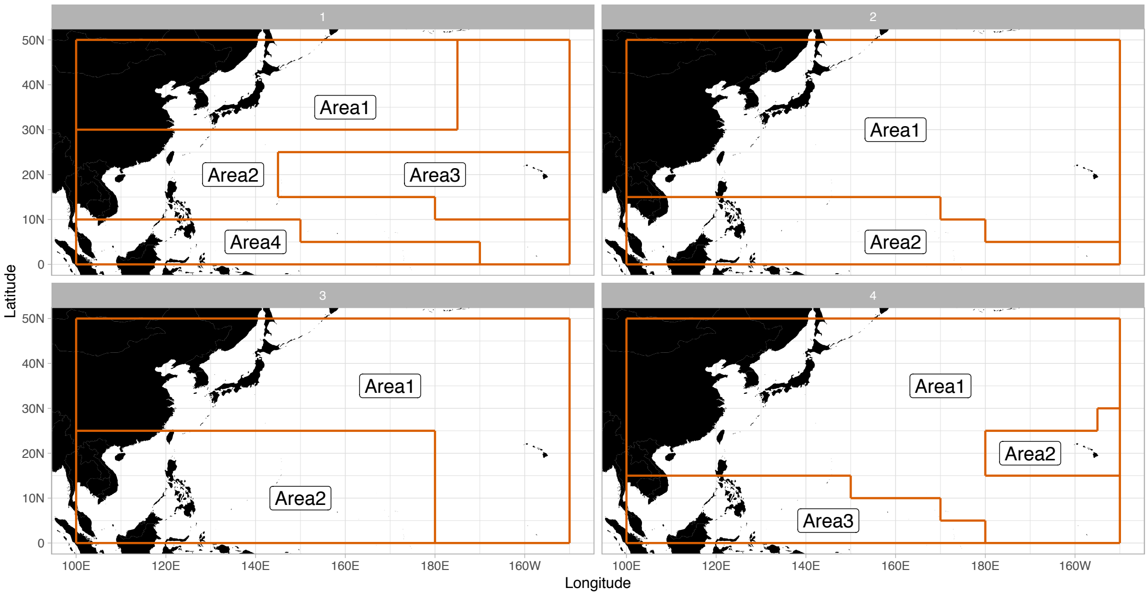

Figure 8: Japanese longline fleet definition for stock synthesis 3.

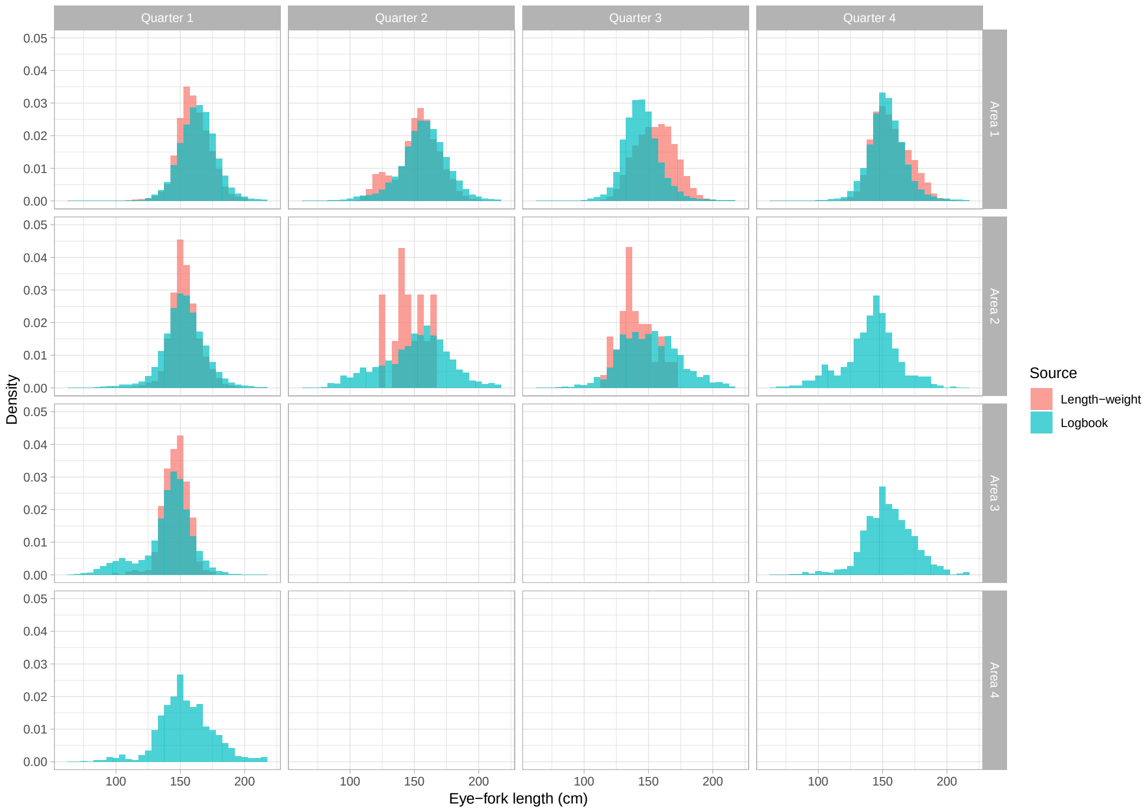

Figure 9: Comparison between the estimated eye-fork length (using logbook data) and sampling data (length-weight data) (1999-2017). All data sets were aggregated by fleet definition of Japanese longline fishery defined by the finite mixture model analysis.

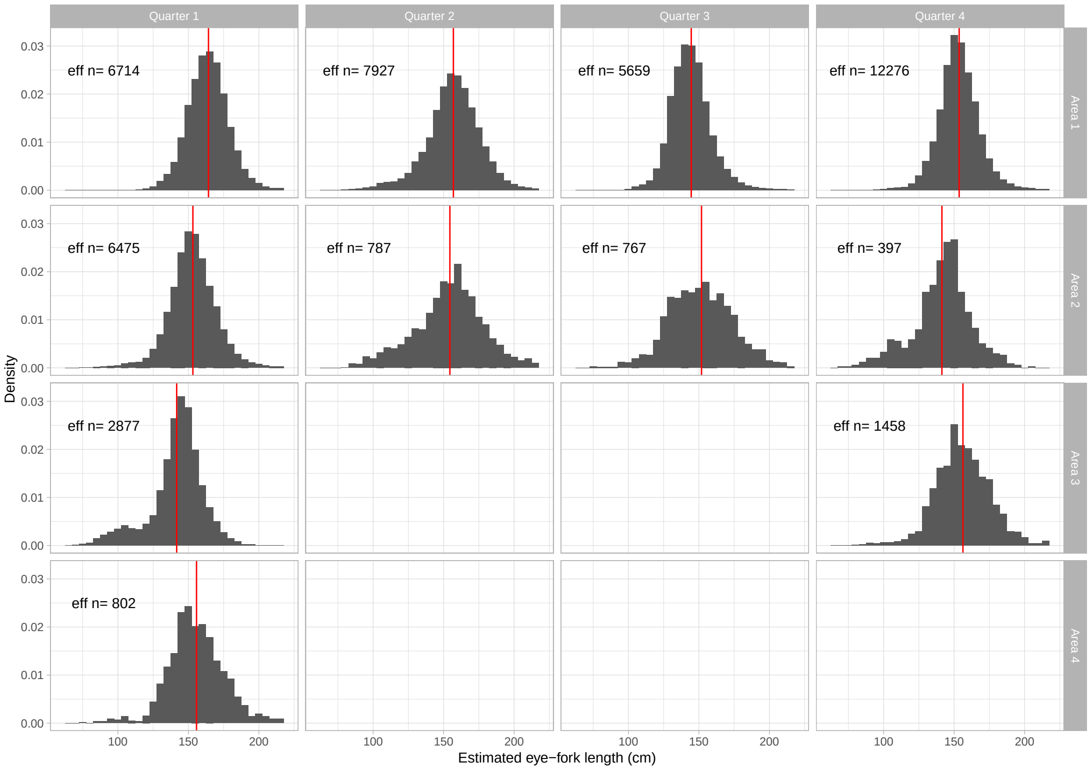

Figure 10: The Japanese longline length frequency data for stock synthesis 3 (1994-2017). All data sets was estimated by logbook data.

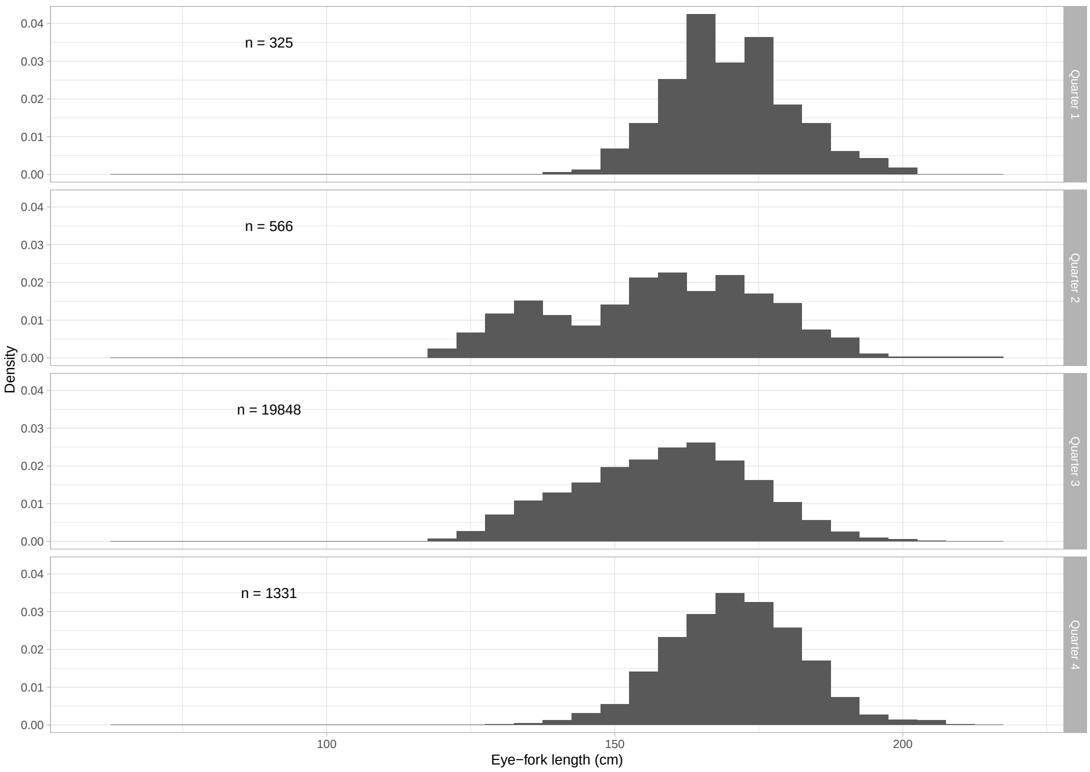

Figure 11: The Japanese coastal driftnet length frequency data for stock synthesis 3 (2005-2017).

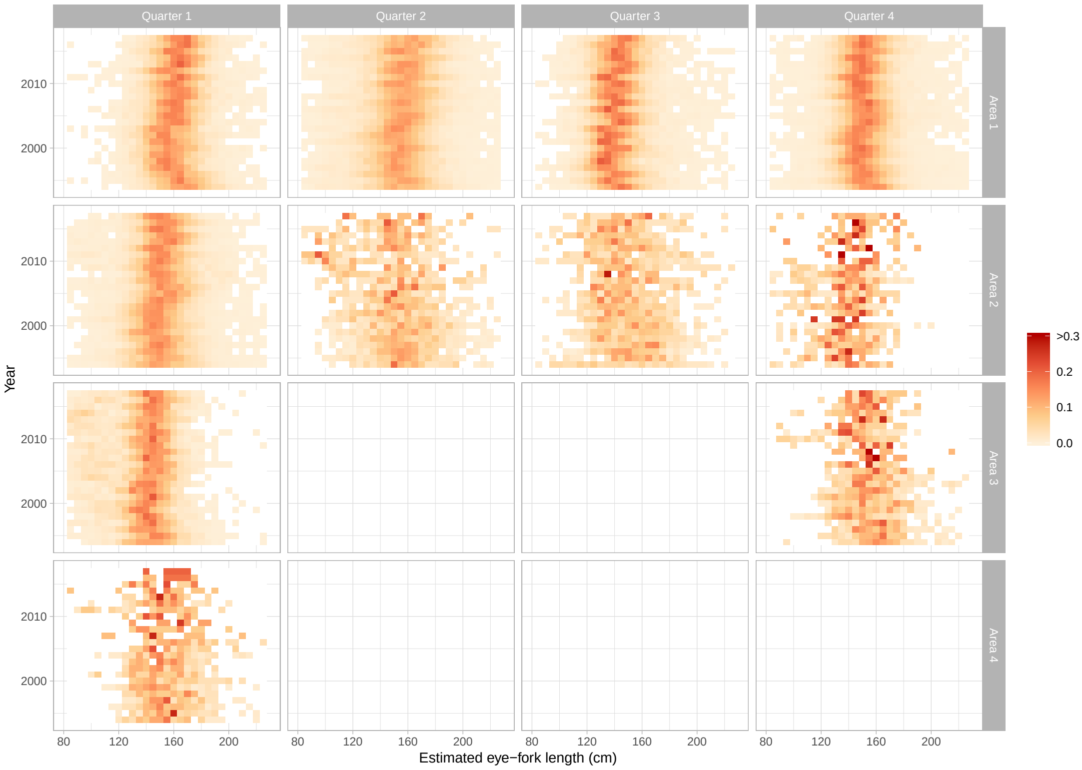

Figure 12: Time-spatial changes in Japanese longline length frequency data that was estimated by logbook data. The spatial definition follows the result of finite mixture model analysis.

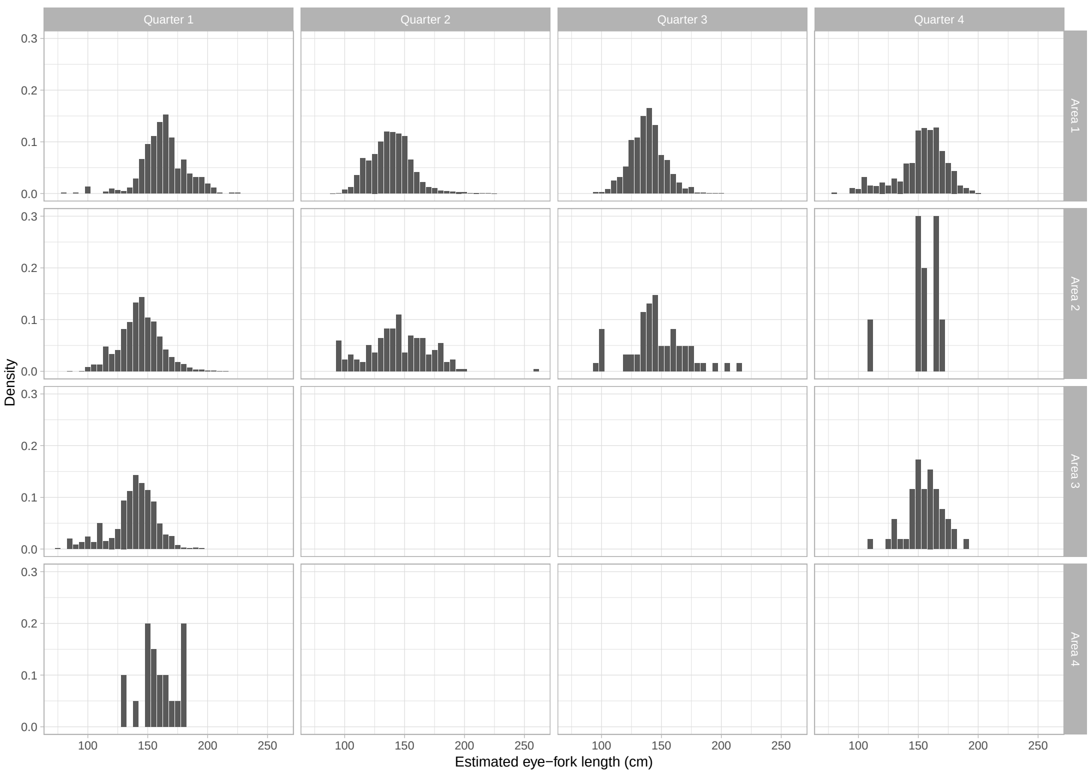

Figure 13: The Japanese longline length frequency data for stock synthesis 3 (1976-1993). All data sets was estimated by observed semi-dress weight data.