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**An estimation of EFL and processed weight relationships and
length frequency distributions for the Striped marlin,
Tetrapturus audax, caught by the Japanese longliner¹**

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Introduction

Japanese longliners have been catching pacific striped marlin (*Tetrapturus audax*) mostly as bycatches. National Research Institute of Far Seas Fisheries (NRIFSF) is collecting biological information, such as body length, body weight and sex, which could be important indices for estimating the amount of the resource of fish. The size data of striped marlin are reported mostly by the Japanese training vessel (Saito 2004). In addition, processed weight (gilled and gutted weight) data was also collected by the Japanese commercial vessel since 1970.

It is known that striped marlin has no clear differences in the weight-length relationships by sex (Skillman and Yong 1974). However, relationships between length and weight would be different among areas and seasons, because some reports suggested that striped marlin show seasonal latitudinal migration patterns, whose spawning grounds are in the tropical warm waters (Anraku and Yabuta 1959; Shiohama 1969). Their size compositions of longline catches change by year, season, region and sex (Kume and Joseph 1969; Ueyanagi, S 1953).

This document estimates the relationships between length and weight of striped marlin caught by Japanese longliners in the north Pacific, to examine their qualitative and quantitative limitations for the input of CPUE standardization and/or the age structured stock assessment model such as MULTIFAN-CL (Fournier et al. 1998).

Materials and Methods

The processed weight data for this study were obtained from the Japanese longline fishery statistics for 1970-2003 compiled at NRIFSF. The relationships between eye fork length (EFL, cm) and of striped marlin estimated in this study are shown in the following functions:

$$EFL = \alpha W^\beta, \varepsilon \sim N(0, \sigma^2)$$

We examined the relationships between EFL and processed weight using size data

collected at the Kesen-numa port fish market of northeastern Japan (Figure 1) between 2000 and 2003, with catch information of latitude, longitude, year and month. Fish was caught by the Japanese longliners in the north Pacific where ranged from 10°N to 50°N latitude and from 137°E to 160°W longitude (Figure 1, Table 1).

We applied general linear model (GLM) between EFL and processed weight. The calculation was performed through GLM procedure of SAS (ver.9.02). If we aggregated the year effect in Table 1, there are several cells with no data, then we used the merged cell (where the data pulled) as Table 2. For instance, 'A' in Table 2 shows in the range of January-June and 10-30N. In order to check where or not the parameters of length-weight relationship (i.e. a and b in Table 3) among cells (i.e. A, B, C, D), we estimated the parameter values by using maximum likelihood method about all the combinations of components. We calculated the AIC values all the combinations of grouping based on the log-likelihood in Table 4, and compared the goodness of grouping statistically (i.e. We used the same length-weight relationship in 'A' & 'D' and 'B' & 'D', respectively.). In this case, AIC is 127169.1.

As a result of comparison using AIC, we recommend to use four groups (A, B, C and D, in Table 4). That is, it is reasonable to use the different length-weight relationship in each cell (A, B, C and D) and then parameter values (a, b) are described in Table 3. Calculated relationships between EFL and weight of striped marlin used in this study are shown as follows;

$$EFL = e^{4.0929131} * W^{0.2745845} \text{ (0-30N, Quarters 1 and 2)}$$

$$EFL = e^{4.1396197} * W^{0.2593556} \text{ (30-50N, Quarters 1 and 2)}$$

$$EFL = e^{4.0675523} * W^{0.2748771} \text{ (0-30N, Quarters 3 and 4)}$$

$$EFL = e^{4.0857342} * W^{0.2743088} \text{ (30-50N, Quarters 3 and 4)}$$

Results and discussion

Area stratification used in this study was decided by using previous result and size data distribution (Figure 2). Area was defined as Northwest (NW, north of 30°N and West of 180°), Southwest (SW, south of 30°N and West of 180°), Northeast (NE, north of 30°N and 125 °W-180°) and Southeast (SE, south of 30°N and 125 °W-180°). We did not include the

data obtained in the EPO, because there were a lot of losses (for quarters and years) of data. The number of size data of striped marlin that converted from processed weight to EFL was 550 thousands (Table 5). Table 6 shows length data of striped marlin that obtained by the Japanese distant and offshore longliners between 1975 and 2005. The outlines of characteristics of these data are reported by Saito (2004). As a result, length data of striped marlin available was 745 thousands (Table 7). In the north middle Pacific, size data was not always exist in the north of 30°N, even if we adopt rough area and time division.

Length frequency distribution for striped marlin in each area and quarter during 1970-2003 is shown in Figure 3. Observed characteristics are as follows;

1. In some areas (NW and SE), length frequency distribution pattern showed a bimodal distribution.
2. Length frequency distribution pattern was different between east and west, especially in the 1st and 2nd quarter, though the quarter and latitude of area were same.
3. The difference of length frequency distribution pattern among area seemed to reflect the difference of growth and the amount of recruitment among years and areas.
4. If the area had bimodal distribution pattern, the shape of length frequency distribution changed to the monomodal distribution in 3rd and 4th quarter. This is because the small and the large individuals might be mixed in 3rd and 4th quarter.

It is necessary to use size data which include information of every year and quarter, to estimate catch composition more accurately. However, the size data obtained by the Japanese distant and offshore longliner can be limited. It is effective to collect further biological information especially in the north middle Pacific and EPO, for the robust CPUE standardization.

Literature cited

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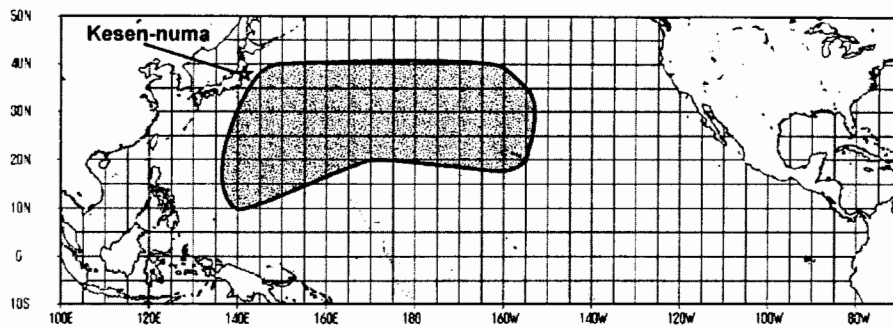


Figure 1. Fishing area of striped marlin for length-weight data that collected in Kesen-numa port fish market between 2000 and 2003 (dotted area). Specimens examined in Kesen-numa fish market (star).

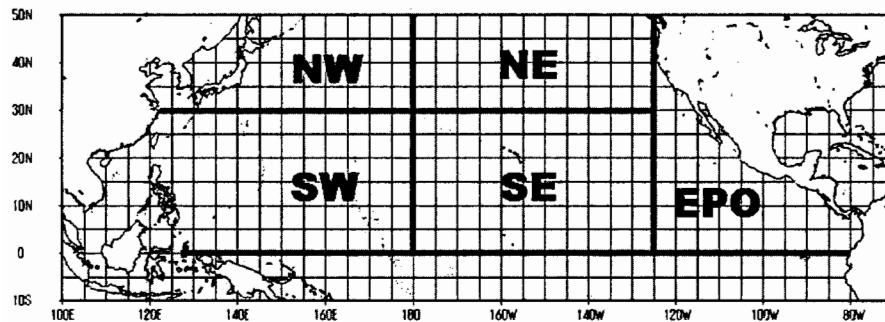


Figure 2. Area stratification used in this study. Only the weight data collected in EPO was not used in this study, because there are several years and seasons with no size data.

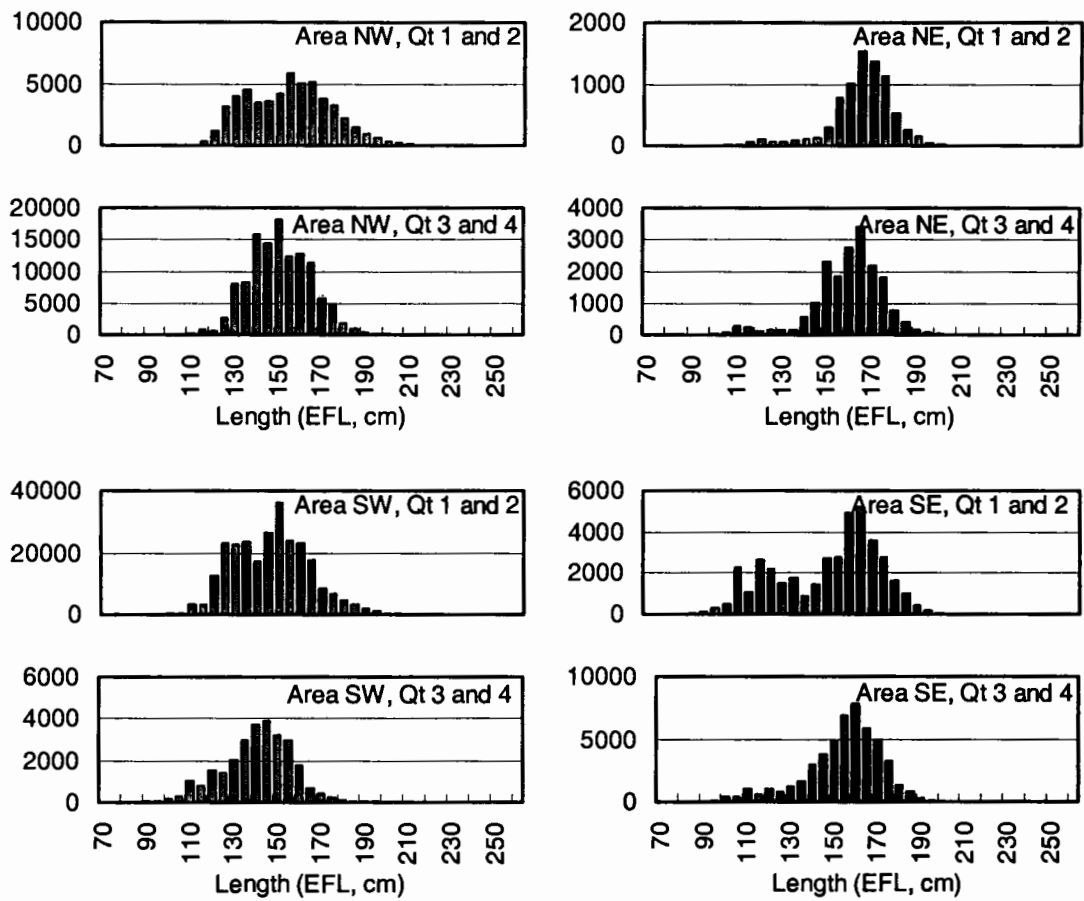


Figure 3. Length frequency distribution of Striped marlin in each area and quarter during 1970-2003 period.

Table 1. The amount of size data of striped marlin recorded at the Kesen-numa port fish market between 2000 and 2003.

Year	Quarter	10-20N	20-30N	30-40N	40-50N
2000	1	1	74	279	0
	2	0	1875	570	0
	3	0	0	2511	1742
	4	0	3	1137	80
2001	1	5	32	223	0
	2	0	873	827	0
	3	0	0	4462	789
	4	0	0	797	44
2002	1	0	0	73	0
	2	0	0	0	0
	3	0	0	0	0
	4	0	0	4	0
2003	1	89	393	279	0
	2	0	1003	816	0
	3	0	0	3792	473
	4	0	0	397	42
Total		95	4253	16167	3170

Table 2. Settings of marged cells.

Quarter / Latitude	10-30N	30-50N
1,2 (Jan.-Jun.)	A	B
3,4 (Jul.-Dec.)	C	D

Table 3. Results of calculation of length-weight relationships.

Number of cells	Marged cells n	SS	logL*(-2)	sum(logW)	sum(logL)	R^2	log(a)	b	a	
1	A	4345	7.113121	23203.52	13740.39	21545.21	0.884444	4.092913	0.274584	59.91417
1	B	3067	6.167014	17256.85	10162.49	15331.91	0.863574	4.13962	0.259356	62.77895
1	C	3	0.000337	7.783148	9.3553061	14.77422	0.995548	4.067552	0.274877	58.41381
1	D	16270	24.72997	86609.25	53469.4	81142.02	0.818328	4.085734	0.274309	59.4856
2	A, B	7412	13.35477	40540.31	23902.88	36877.13	0.87825	4.111776	0.267777	61.05504
2	A, C	4348	7.114886	23217.42	13749.75	21559.99	0.884564	4.090262	0.274589	59.75557
2	A, D	20615	31.94223	109886.5	67209.79	102687.2	0.840674	4.089929	0.273373	59.73564
2	B, C	3070	6.169269	17271.42	10171.85	15346.69	0.863802	4.139429	0.259406	62.767
2	B, D	19337	31.04131	104063.8	63631.89	96473.94	0.829149	4.099783	0.270249	60.32717
2	C, D	16273	24.73111	86622.61	53478.76	81156.8	0.818436	4.085712	0.274315	59.48425
3	A, B, C	7415	13.35662	40554.44	23912.24	36891.9	0.878325	4.111733	0.267788	61.05242
3	A, B, D	23682	38.23066	127315.3	77372.29	118019.2	0.844927	4.099167	0.270674	60.29004
3	A, C, D	20618	31.94351	109899.9	67219.15	102702	0.840736	4.089913	0.273377	59.7347
3	B, C, D	19340	31.04262	104077.4	63641.25	96488.71	0.829224	4.099758	0.270255	60.32567
4	A, B, C, D	23685	38.23204	127328.9	77381.64	118033.9	0.844976	4.09915	0.270679	60.28904

Table 4. Calculated values of AIC.

number of group	combination p*		logL*(-2) AIC	
1	A-B-C-D	3	127329	127335
2	A-B, C-D	6	127163	127175
2	A-C, B-D	6	127281	127293
2	A-D, B-C	6	127158	127170
2	A, B-C-D	6	127281	127293
2	B, A-C-D	6	127157	127169
2	C, A-B-D	6	127323	127335
2	D, A-B-C	6	127164	127176
3	A-B, C, D	9	127157	127175
3	A-C, B, D	9	127084	127102
3	A-D, B, C	9	127151	127169
3	B-C, A, D	9	127084	127102
3	B-D, A, C	9	127275	127293
3	C-D, A, B	9	127083	127101
4	A, B, C, D	12	127077	127101

*number of unknown parameters (i.e. degree of freedom)

Table 5. The amount of size data (processed weight and EFL) that obtained by the Japanese distant and offshore longliner between 1970 and 2003 (in this study).

Area	SW		NW		SE		NE		EPO		Total
	0-30N	0-30N	30-50N	30-50N	0-30N	0-30N	30-50N	30-50N	0-30N	0-30N	
Latitude	100E-180	100E-180	100E-180	100E-180	125W-180	125W-180	125W-180	125W-180	80-125W	80-125W	
Longitude	100E-180	100E-180	100E-180	100E-180	125W-180	125W-180	125W-180	125W-180	80-125W	80-125W	
Quarter	1, 2	3, 4	1, 2	3, 4	1, 2	3, 4	1, 2	3, 4	1, 2	3, 4	
1970	928	14	20	517	734	4925	0	1150	912	1676	10876
1971	903	101	197	183	2715	3697	565	1065	1319	5930	16675
1972	140	76	88	174	2365	1682	421	924	977	1696	8543
1973	1039	515	50	170	1560	4011	109	462	204	2373	10493
1974	1158	115	63	387	1435	1383	160	443	0	533	5677
1975	589	67	31	315	1637	767	0	719	0	755	4880
1976	389	119	117	21	1634	449	749	1042	0	0	4520
1977	700	196	160	75	954	1744	261	698	0	0	4788
1978	539	344	61	293	1635	348	54	277	0	0	3551
1979	2806	1303	789	853	2049	881	93	127	129	79	9109
1980	4485	346	641	1125	1772	138	124	428	60	0	9119
1981	2600	615	42	866	179	15	0	1309	0	271	5897
1982	2565	533	80	536	1889	288	1306	862	100	1259	9418
1983	2040	703	593	920	1965	59	420	1781	522	157	9160
1984	846	867	1704	2820	1053	131	1261	2340	15	138	11175
1985	6726	616	848	3939	2731	229	838	656	75	236	16894
1986	20171	3301	2176	6263	3192	663	102	1595	129	708	38300
1987	4196	214	460	194	270	0	98	158	148	9948	15686
1988	16333	1003	2499	8810	3159	565	150	1739	57	0	34315
1989	14516	811	1498	7175	977	296	327	75	311	635	26621
1990	8350	460	1654	5777	212	140	111	24	33	86	16847
1991	12346	350	1607	5798	141	11	61	20	19	29	20382
1992	14143	731	3361	7452	135	5	121	54	132	121	26255
1993	17423	1196	4066	9985	200	234	36	162	21	2	33325
1994	13535	990	3077	9355	63	50	34	207	9	37	27357
1995	16023	2071	3453	15880	49	442	175	262	3	10	38368
1996	14503	2026	4026	6480	212	450	114	46	0	0	27857
1997	18937	1174	5049	6667	100	41	47	50	2	0	32067
1998	27157	1860	8161	11015	88	188	0	31	8	0	48508
1999	17362	995	2655	1864	20	50	25	0	29	0	23000
2000	5975	1031	726	1625	17	9	0	0	0	0	9383
2001	6484	1906	1867	2074	30	17	0	0	0	0	12378
2002	6823	1108	1786	411	7	3	0	0	0	0	10138
2003	78	0	47	0	0	0	0	0	0	0	125
Total	262808	27757	53652	120019	35179	23911	7762	18706	5214	26679	549794

Table 6. The amount of size data that obtained by the Japanese distant and offshore longliner between 1975 and 2005. The data recorded in 2005 is still preliminary.

Area	SW		NW		SE		NE		EPO		Total
Latitude	0-30N	0-30N	30-50N	30-50N	0-30N	0-30N	30-50N	30-50N	0-30N	0-30N	
Longitude	100E-180	100E-180	100E-180	100E-180	125W-180	125W-180	125W-180	125W-180	80-125W	80-125W	
Quarter	1, 2	3, 4	1, 2	3, 4	1, 2	3, 4	1, 2	3, 4	1, 2	3, 4	
1975	241	21	0	0	1669	679	0	79	57	0	2746
1976	219	19	0	0	2769	315	76	132	133	75	3738
1977	63	10	0	0	1306	281	9	88	11	17	1785
1978	77	16	0	0	2977	233	3	0	41	0	3347
1979	677	234	0	0	4160	384	0	0	19	0	5474
1980	498	23	0	0	2788	281	0	0	54	0	3644
1981	56	18	0	0	1405	171	0	0	44	0	1694
1982	377	5	0	0	1853	127	0	0	0	0	2362
1983	118	36	0	0	872	394	0	0	0	0	1420
1984	340	149	0	14	479	455	15	365	0	0	1817
1985	1338	285	14	2	1365	630	0	863	23	0	4520
1986	1241	48	0	0	2816	165	0	182	0	0	4452
1987	691	12	0	0	3477	1378	11	249	0	0	5818
1988	420	130	3	0	3795	1202	2	766	0	0	6318
1989	442	16	0	0	4256	1340	0	6	4	0	6064
1990	738	130	0	0	1907	936	0	4	0	0	3715
1991	1323	163	0	0	4787	3503	0	589	17		10382
1992	3175	74	8	44	5776	5202	0	38	32	3	14352
1993	1461	41	2	48	6934	4047	5	82	48	10	12678
1994	1899	132	0	16	2666	2522	0	10	554	1	7800
1995	958	35	0	43	3915	3836	0	801	285	7	9880
1996	949	22	0	30	5302	2718	0	505	889	0	10415
1997	240	3	0	0	2114	676	0	311	357	285	3986
1998	220	63	10	5	816	1612	0	676	409	0	3811
1999	189	21	3	2	3114	1885	0	1032	157	5	6408
2000	194	0	0	0	1377	26	0	0	78	34	1709
2001	0	0	0	0	7	15	0	0	264	63	349
2002	2417	28	384	2013	1703	618	1	93	477	28	7762
2003	1645	18	939	4355	2513	1464	144	396	35	0	11509
2004	217	0	20	21	1453	936	0	105	0	0	2752
2005	59	0	0	0	506	0	0	0	0	0	565
Total	22482	1752	1383	6593	80877	38031	266	7372	3988	528	163272

Table 7. The amount of totaled size data (EFL) that obtained by the Japanese distant and offshore longliner between 1970 and 2005. The data recorded in 2005 is still prerinimally.

Area	SW		NW		SE		NE		EPO		Total
Latitude	0-30N	0-30N	30-50N	30-50N	0-30N	0-30N	30-50N	30-50N	0-30N	0-30N	
Longitude	100E-180	100E-180	100E-180	100E-180	125W-180	125W-180	125W-180	125W-180	80-125W	80-125W	
Quarter	1, 2	3, 4	1, 2	3, 4	1, 2	3, 4	1, 2	3, 4	1, 2	3, 4	
1970	928	14	20	517	734	4925	0	1150	912	1676	10876
1971	903	101	197	183	2715	3697	565	1065	1319	5930	16675
1972	140	76	88	174	2365	1682	421	924	977	1696	8543
1973	1039	515	50	170	1560	4011	109	462	204	2373	10493
1974	1158	115	63	387	1435	1383	160	443	0	533	5677
1975	830	88	31	315	3306	1446	0	798	57	755	7626
1976	608	138	117	21	4403	764	825	1174	133	75	8258
1977	763	206	160	75	2260	2025	270	786	11	17	6573
1978	616	360	61	293	4612	581	57	277	41	0	6898
1979	3483	1537	789	853	6209	1265	93	127	148	79	14583
1980	4983	369	641	1125	4560	419	124	428	114	0	12763
1981	2656	633	42	866	1584	186	0	1309	44	271	7591
1982	2942	538	80	536	3742	415	1306	862	100	1259	11780
1983	2158	739	593	920	2837	453	420	1781	522	157	10580
1984	1186	1016	1704	2834	1532	586	1276	2705	15	138	12992
1985	8064	901	862	3941	4096	859	838	1519	98	236	21414
1986	21412	3349	2176	6263	6008	828	102	1777	129	708	42752
1987	4887	226	460	194	3747	1378	109	407	148	9948	21504
1988	16753	1133	2502	8810	6954	1767	152	2505	57	0	40633
1989	14958	827	1498	7175	5233	1636	327	81	315	635	32685
1990	9088	590	1654	5777	2119	1076	111	28	33	86	20562
1991	13669	513	1607	5798	4928	3514	61	609	36	29	30764
1992	17318	805	3369	7496	5911	5207	121	92	164	124	40607
1993	18884	1237	4068	10033	7134	4281	41	244	69	12	46003
1994	15434	1122	3077	9371	2729	2572	34	217	563	38	35157
1995	16981	2106	3453	15923	3964	4278	175	1063	288	17	48248
1996	15452	2048	4026	6510	5514	3168	114	551	889	0	38272
1997	19177	1177	5049	6667	2214	717	47	361	359	285	36053
1998	27377	1923	8171	11020	904	1800	0	707	417	0	52319
1999	17551	1016	2658	1866	3134	1935	25	1032	186	5	29408
2000	6169	1031	726	1625	1394	35	0	0	78	34	11092
2001	6484	1906	1867	2074	37	32	0	0	264	63	12727
2002	9240	1136	2170	2424	1710	621	1	93	477	28	17900
2003	1723	18	986	4355	2513	1464	144	396	35	0	11634
2004	217	0	20	21	1453	936	0	105	0	0	2752
2005	59	0	0	0	506	0	0	0	0	0	565
Total	285290	29509	55035	126612	116056	61942	8028	26078	9202	27207	744959