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Review and working plan of re-estimation for growth curve of swordfish and striped marlin in North-West Pacific Ocean

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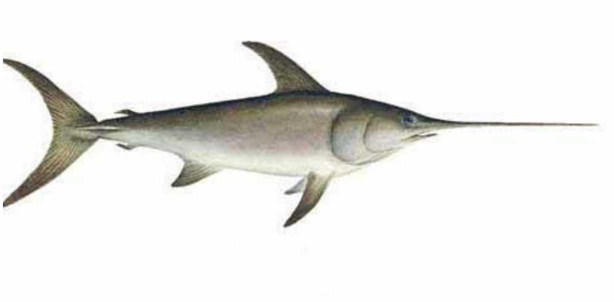

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## Abstract

We reviewed the estimated growth formulae for striped marlin and swordfish. The large differences among the estimated growth formulae in the eastern and western Pacific Ocean were observed. Therefore, we concluded it is necessary to investigate growth formulae in the operational area of Japanese vessels where located in the middle of both Pacific Ocean. We illustrated the framework of our working plan and reported the current progress of sampling.


## Introduction

The growth formula (i.e., changes in the size at each age) is one of the most important biological factors in the stock assessment. Since blue marlin, striped marlin, and swordfish are the species assessed by ISC Billfish WG, the growth formulae for these species are important. Blue marlin (*Makaira nigricans*) is believed to have similar growth characteristics throughout the entire North Pacific Ocean according to Shimose et al. (2015). Growth formulae of striped marlin (*Kajikia audax*) in the southwest Pacific Ocean have been estimated by Kopf et al. (2011). This study used otolith and dorsal fin spine in the southwest Pacific Ocean to estimate the formulae (Fig. 1a circle). In the northwest Pacific Ocean Sun et al. (2011) used dorsal fin spine to estimate growth formulae (Fig. 1a triangle). Comparing both studies, female striped marlin has a length difference of EFL (Eye Fork Length) of approximately 37.3cm at the 3-year-old. Male striped marlin has a length difference of EFL of approximately 32.1cm at the 3-year-old. Growth formulae of swordfish (*Xiphias gladius*) in the northeast Pacific Ocean have been estimated by DeMartini et al. (2007). This study used otolith and anal fin spine in the northeast Pacific Ocean to estimate the formulae (Fig. 1b circle). In the northwest Pacific Ocean Sun et al. (2011) used anal fin spine to estimate growth formulae (Fig. 1b triangle). Comparing both studies, a length difference of EFL of approximately 40.0cm at the 5-year-old for females and approximately 37.2cm at the 6-year-old for males are observed. These differences are caused by locality differences (Kopf et al. 2011 and DeMartini et al. 2007).

However, the growth formulae of striped marlin and swordfish nearby Japanese operational area have rarely been studied (Simose and Yokawa 2019). The purpose of the current study is to investigate the growth of striped marlin and swordfish in the Japanese coastal area. We will use otolith and anal fin spine to estimate age and growth formula. Considering data of gonad, we will clarify the characteristics of growth and maturity by age by sex.

**Materials and Methods**

We collected data from seven sources including commercial fisheries and sports fishing, between May and October in 2019. Samples of commercial fisheries were provided from Yaeyama port in Okinawa Prefecture (5/26-31, 10/23-25), and Shiogama fish market (9/2). Sample of sports fishing were provided from Nishiki port in Mie Prefecture (7/7, 7/28, 8/1, 8/9, 9/1, 9/11), The 41st Annual Japan International Billfish Tournament in (7/26-28), Toba Billfish Tournament International in Mie Prefecture (8/1-3), 13th Billfish Tournament in Ibaraki Prefecture (8/24-25), and 23rd Shiogama Billfish Tournament in Miyagi Prefecture (8/31-9/1). In total, 94 individuals including 42 individuals of blue marlin, 48 individuals of striped marlin, 3 individuals of swordfish, 1 individual of sailfish were collected. Additionally, in association with the National Research Institute of Far seas Fisheries, 1 individual of blue marlin, 1 individual of shortbill spearfish, 15 individuals of striped marlin, and 125 individuals of swordfish were collected from 1997 to 2019（Table 1）. Although we focused on striped marlin and swordfish, when we got other species we treated in the same way to improve sampling technique.

We measured LJFL (Low Jaw Fork Length), EFL, PFFL (Pectoral Fin Fork Length), and body weight of all individuals as situation permits. We recorded the condition of measurements such as round (the gut is removed), whole (the gut is not removed), and round-head-off (gut and head are removed). To estimate age, we collected otolith and fin spine. To investigate sex and maturity, we collected gonad. Regarding the treatment of the otolith, each otic capsule was encased in a 2.0ml microtube in child condition until age-counting. Then we extracted otolith from the otic capsule using a stereoscopic microscope (Nikon C-DSD115) and encased in 2.0ml micro tube filled with 75% ethanol. Sampled fin spines were stored in a child or frozen condition. Subsequently, we boiled the fin spines and removed flesh. The spines were dried and encased in plastic bags with zip fastener containing moisture-proof agent. The fin spines were sliced into a transverse thin-section of 0.3-0.5mm with a micro cutter (MC-201N). The sectioned samples were attached to a glass slide. Weights of each the right and left gonads were recorded, and subsequently 50g of sample was extracted from each of them. The sampled gonad was stored with 75% ethanol.

**Results and Discussions**

42 individuals of blue marlin were sampled and their EFL ranged from 160.7

to 273.0cm. 48 individuals of striped marlin were sampled and their EFL ranged from 150.9 to 169.8cm. 3 individuals of swordfish were sampled and their EFL ranged from 84.6 to 162.7cm. 1 individual of sailfish was sampled and the EFL was 185.7cm (Table 2). From some of these individuals, a sectioned sample of the otolith, fin spine, and gonad have already obtained (Table 3-5).

**Future work**

We will continue forming a thin-section of the remaining individuals. We will subsequently count the daily age ring of the otolith and annual age ring of the fin spine, measure the spine diameter and estimate sex and maturation using the gonads. As mentioned, the sectioning of spines has already been completed. Regarding otolith, we will slice the samples into the transverse section following Kopf et al. (2011) and Shimose and Yokawa (2019). We will then polish the transverse section with an abrasive machine (MT-110NT). We will take photos with a basic polarized-light microscope system (OLIMPUS ex41) and Camera (OLYMPUS E-600). Next, we will count the daily rings of each species. We will measure the fin spine diameter of each species, check the relationship between the number of the daily ring of the otolith and diameter of the spine, and count annual rings of the spine following Shimose and Yokawa (2019). We will fix the gonads with 75% ethyl alcohol or 4% PFA, embed it into paraffin, and stain with HE following Ashida et al. (2014) and Shimose et al. (2015). We will investigate the maturation of the gonad using an optical microscope.

From these data, we will estimate the growth formula especially for an early stage of striped marlin and swordfish caught around the Japanese fishing area.

## References


Ashida, H., N. Suzuki, T. Tanabe, N. Suzuki and Y. Aonuma (2014) Reproductive condition, batch fecundity, and spawning fraction of large Pacific bluefin tuna *Thunnus orientalis* landed at Ishigaki Island, Okinawa, Japan

DeMartini, E.E., J. H. Uchiyama, R. L Humphreys Jr., J. D. Sampaga, H. A. Williams (2007) Age and growth of swordfish (*Xiphias gladius*) caught by the Hawaii-based pelagic longline fishery

Kopf, R. K., P. S. Davie, D. Bromhead, and J. G. Pepperell (2011) Age and growth of striped marlin (*Kajikia audax*) in the Southwest Pacific Ocean

Shimose, T., M. Fujita, K. Yokawa, H. Saito and K. Tachihara (2015) Reproductive biology of blue marlin *Makaira nigricans* around Yonaguni Island, southwestern Japan

Shimose, T. and K. Yokawa (2019) Age estimation of striped marlin (*Kajikia audax*) in the eastern North Pacific using otolith microincrements and fin spine sections

Shimose, T., K. Yokawa and K. Tachihara (2019) Age determination and growth estimation from otolith micro-increments and fin spine sections of blue marlin (Makaira nigricans) in the western North Pacific

Sun, C., W. Hsu, N. Su, S, Yeh, Y. Chang, Wei-Chuan Chiang (2011) Age and growth of striped marlin (*Kajikia audax*) in waters off Taiwan: A revision

Sun, C., S. Wang and S. Yeh (2002) Age and growth of the swordfish (*Xiphias gladius* L.) in the waters around Taiwan determined from anal-fin rays

Tables and Figures

Table 1 Number of sampling individuals of each location and each species

| | Mie University | | | | | | NRIFSF | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ibaraki Prefecture | Mie Prefecture | Miyagi Prefecture | Okinawa Prefecture | Shizuoka Prefecture | total | E.Pacific | N.W.Pacific | no data | total | total |
| blue marlin | 10 | 7 | 2 | 6 | 17 | 42 | | 1 | | 1 | 43 |
| F | 5 | 4 | 2 | 1 | 16 | 28 | | | | | 28 |
| M | 3 | 1 | | 1 | | 5 | | | | | 5 |
| U | 2 | 2 | | 4 | 1 | 9 | | 1 | | 1 | 10 |
| sailfish | | 1 | | | | 1 | | | | | 1 |
| U | | 1 | | | | 1 | | | | | 1 |
| shortbill spearfish | | | | | | | | 1 | | 1 | 1 |
| U | | | | | | | | 1 | | 1 | 1 |
| striped marlin | 4 | 1 | 39 | 5 | | 49 | | 13 | 2 | 15 | 64 |
| F | 2 | | 14 | | | 16 | | 6 | 1 | 7 | 23 |
| M | 2 | | 8 | | | 10 | | 5 | 1 | 6 | 16 |
| U | | 1 | 17 | 5 | | 23 | | 2 | | 2 | 25 |
| swordfish | | | | 2 | | 2 | 55 | 67 | 3 | 125 | 127 |
| F | | | | | | | 19 | 21 | 2 | 42 | 42 |
| M | | | | | | | 17 | 43 | | 60 | 60 |
| U | | | | 2 | | 2 | 19 | 3 | 1 | 23 | 25 |
| total | 14 | 9 | 41 | 13 | 17 | 94 | 55 | 82 | 5 | 142 | 236 |

Table 2 The size (EFL)-frequency distribution by 10cm intervals of female and male billfish collected from Japan longline fishery area.

| | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 | 210 | 220 | 240 | 250 | no data | 270 | 230 | total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mie University | | | 1 | | | | 6 | 8 | 3 | 1 | 9 | 12 | 15 | 7 | 5 | 9 | 4 | 1 | 1 | 10 | 1 | 1 | 94 |
| blue marlin | | | | | | | | | | | 2 | 2 | 5 | 5 | 5 | 9 | 4 | 1 | 1 | 6 | 1 | 1 | 42 |
| F | | | | | | | | | | | | 1 | 3 | 4 | 4 | 8 | 4 | 1 | 1 | | 1 | 1 | 28 |
| M | | | | | | | | | | | 2 | 1 | 1 | | | 1 | | | | | | | 5 |
| U | | | | | | | | | | | | | 1 | 1 | 1 | | | | | 6 | | | 9 |
| sailfish | | | | | | | | | | | | | | 1 | | | | | | | | | 1 |
| U | | | | | | | | | | | | | | 1 | | | | | | | | | 1 |
| striped marlin | | | | | | | 6 | 8 | 3 | 1 | 7 | 10 | 10 | 1 | | | | | | 3 | | | 49 |
| F | | | | | | | | | | | 3 | 6 | 6 | 1 | | | | | | | | | 16 |
| M | | | | | | | | | 2 | | 2 | 3 | 3 | | | | | | | | | | 10 |
| U | | | | | | | 6 | 8 | 1 | 1 | 2 | 1 | 1 | | | | | | | 3 | | | 23 |
| sword fish | | | 1 | | | | | | | | | | | | | | | | | 1 | | | 2 |
| U | | | 1 | | | | | | | | | | | | | | | | | 1 | | | 2 |
| NRIFSF | 4 | 23 | 21 | 15 | 7 | 8 | 8 | 10 | 6 | 6 | 10 | 11 | | 1 | 2 | 1 | | 1 | | 8 | | | 142 |
| blue marlin | | | | | | | | | | | | | | | | | | 1 | | | | | 1 |
| U | | | | | | | | | | | | | | | | | | 1 | | | | | 1 |
| Shortbill spearfish | | | | | | | | | | | | | | | | | | | | 1 | | | 1 |
| U | | | | | | | | | | | | | | | | | | | | 1 | | | 1 |
| striped marlin | | | 1 | | | | 3 | 1 | | 2 | 4 | 2 | | | | | | | | 2 | | | 15 |
| F | | | | | | | 1 | 1 | | 1 | 2 | 1 | | | | | | | | 1 | | | 7 |
| M | | | 1 | | | | 1 | | | 1 | 2 | 1 | | | | | | | | | | | 6 |
| U | | | | | | | 1 | | | | | | | | | | | | | 1 | | | 2 |
| sword fish | 4 | 23 | 20 | 15 | 7 | 8 | 5 | 9 | 6 | 4 | 6 | 9 | | 1 | 2 | 1 | | | | 5 | | | 125 |
| F | | 7 | 6 | 9 | 1 | 5 | 2 | 1 | 2 | 2 | 2 | 2 | | 1 | 1 | | | | | 1 | | | 42 |
| M | 1 | 8 | 11 | 5 | 6 | 3 | 2 | 8 | 3 | 1 | 4 | 6 | | | 1 | 1 | | | | | | | 60 |
| U | 3 | 8 | 3 | 1 | | | 1 | | 1 | 1 | | 1 | | | | | | | | 4 | | | 23 |
| total | 4 | 23 | 22 | 15 | 7 | 8 | 14 | 18 | 9 | 7 | 19 | 23 | 15 | 8 | 7 | 10 | 4 | 2 | 1 | 18 | 1 | 1 | 236 |

Table 3 Progress of processed otolith samples

| | blue marlin | sailfish | Shortbill spearfish | striped marlin | sword fish | total |
|---|---|---|---|---|---|---|
| **Mie University** | 42 | 1 | | 49 | 2 | 94 |
| Sectioned otolith | 7 | | | | | 7 |
| Un-sectioned otolith | 35 | 1 | | 49 | 2 | 86 |
| **NRIFSF** | 1 | | 1 | 15 | 125 | 142 |
| Sectioned otolith | | | | | 2 | 2 |
| Un-sectioned otolith | 1 | | 1 | 15 | 123 | 140 |
| total | 43 | 1 | 1 | 64 | 127 | 236 |

Table 4 Progress of processed fin spine sample

| | blue marlin | sailfish | Shortbill spearfish | striped marlin | sword fish | total |
|---|---|---|---|---|---|---|
| **Mie University** | 42 | 1 | | 49 | 2 | 94 |
| Sectioned spine | 38 | 1 | | 49 | 2 | 90 |
| Un-ectioned spine | 4 | | | | | 4 |
| **NRIFSF** | 1 | | 1 | 15 | 125 | 142 |
| Un-ectioned spine | 1 | | 1 | 15 | 125 | 142 |
| total | 43 | 1 | 1 | 64 | 127 | 236 |

Table 5 Progress of processed fin spine sample

| | blue marlin | sailfish | Shortbill spearfish | striped marlin | sword fish | total |
|---|---|---|---|---|---|---|
| Mie University | 42 | 1 | | 49 | 2 | 94 |
| Stained gonad | 31 | | | 27 | | 58 |
| Un-stained gonad | 11 | 1 | | 22 | 2 | 36 |
| NRIFSF | 1 | | 1 | 15 | 125 | 142 |
| Stained gonad | | | | | 1 | 1 |
| Un-stained gonad | 1 | | 1 | 15 | 124 | 141 |
| total | 43 | 1 | 1 | 64 | 127 | 236 |

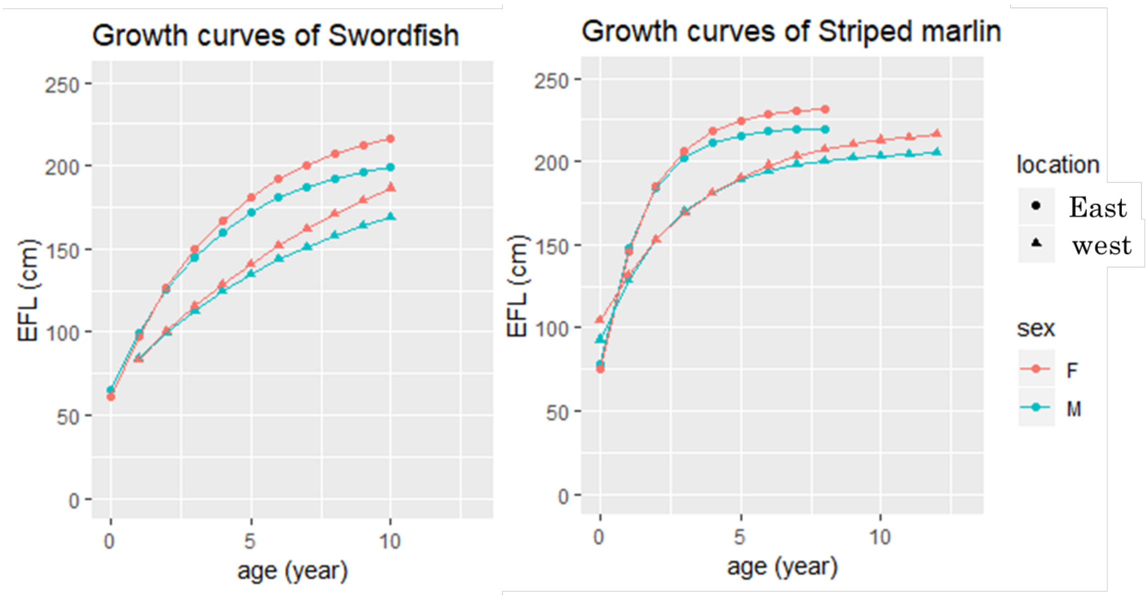


Figure 1

(A) Growth curve of Swordfish per location per sex (East vs West)

(B) Growth curve of Striped marlin per location per sex (East vs West)

Appendix

Table A.1 The summary of the previous studies

| species | author | survey area | measured part | sample size | | | | otolith | fin spine | growth formula |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | F | M | U | total | | | |
| swordfish | DeMartini et al. (2007) | around Hawaii | EFL | 715 | 582 | | 1297 | ○ | ○ | $L_t=L_\infty(1-e^{-k(t-t_0)})$ |
| | | | | | | | | | | $L_t=L_\infty(1-e^{-K(1-m)(t-t_0)})^{1/1-m}$ |
| | Sun et al. (2002) | around Taiwan | LJFL | 327 | 329 | 61 | 717 | × | ○ | $L_t=L_\infty(1-e^{-k(t-t_0)})$ |
| | | | | | | | | | | $L_t=L_\infty(1-e^{-K(1-m)(t-t_0)})^{1/1-m}$ |
| striped marlin | Kopf et al. (2011) | around Australia | EFL | 206 | 211 | | 417 | ○ | ○ | $L_t=L_\infty(1-e^{-k(t-t_0)})$ |
| | Sun et al. (2011) | around Taiwan | LJFL | 207 | 267 | | 474 | × | ○ | $L_t=L_\infty(1-e^{-k(t-t_0)})$ |
| | | | | | | | | | | $L_t=L_\infty(1-e^{-K(1-m)(t-t_0)})^{1/1-m}$ |

Table A. 2 The summary of growth parameter estimated by DeMartini,et al. (2007). Estimates (±standard error, SE) for the standard von Bertalanffy and the generalized von Bertalanffy growth formu-las (VBGFs) fitting mean back-calculated eye-to-fork length (EFL)-at-age against age for male and female swordfish (*Xiphias gladius*) ≥60 cm EFL caught in the region of the Hawaii-based longline fishery during 1993–97. $L_\infty$ = asymptotic length; k and K = growth coefficients; $t_0$ = hypothetical age at length zero; m = fitted fourth parameter.

| DeMartini et al. (2007) | | | | |
|---|---|---|---|---|
| sex | $L_\infty$(EFL /cm) | k | $t_0$ | |
| F | 230.5 ± 3.94 | 0.246 ± 0.019 | -1.24 ± 0.167 | |
| M | 208.9 ± 5.60 | 0.271 ± 0.034 | -1.37 ± 0.259 | |
| | $L_\infty$ (EFL /cm) | K | $t_0$ | m |
| F | 227.2 ± 6.18 | 0.524 ± 0.871 | -2.41 ± 2.968 | 0.448 ± 0.771 |
| M | 221 ± 20.1 | 0.070 ± 0.080 | -0.15 ± 0.576 | -1.27 ± 1.122 |

Estimates of the growth curve of swordfish

Standard VBGF: $L_t = L_\infty\ (1 - e^{-k\,(t - t_0)})$

Generalized VBGF: $L_t = L_\infty\ (1 - e^{-K\,(1- m)(\,t - t_0)})^{(1/(1- m))}$

Table A.3 The summary of growth parameter estimated by Sun et al. (2002). Estimates for the standard von Bertalanffy and the generalized von Bertalanffy growth models for swordfish in the waters around Taiwan. Numbers in parentheses are standard errors.

| Sun et al. (2002) | | | | | |
|---|---|---|---|---|---|
| | sex | $L_\infty$(LJFL /cm) | k | $t_0$ | |
| method I | F | 281.809 | 0.101 | -3.204 | |
| | M | 224.170 | 0.14 | -3.089 | |
| method II | F | 267.441 | 0.13 | -2.302 | |
| | M | 207.520 | 0.198 | -1.955 | |
| | sex | $L_\infty$ (LJFL /cm) | K | $t_0$ | m |
| method I | F | 301.877 | 0.060 | -2.036 | -0.49 |
| | M | 231.772 | 0.660 | -1.556 | -0.625 |
| method II | F | 300.656 | 0.040 | -0.75 | -0.785 |
| | M | 213.052 | 0.086 | -0.626 | -0.768 |

Estimates of the growth curve of swordfish

Standard VBGF: $L_t = L_\infty \ (1 - e^{-k\,(t - t_0)})$

Generalized VBGF: $L_t = L_\infty \ (1 - e^{-K\,(1-m)(t-t_0)})^{(1/(1-m))}$

Table A. 4 The summary of growth parameter estimated by Kopf et al. (2011). Standard VBGCs and parameters estimated each sex of striped marlin in the southwest Pacific Ocean.

| Kopf et al. (2011) | | | | |
|---|---|---|---|---|
| | sex | $L_\infty$(LJFL /mm) | k | $t_0$ |
| observed | F | 2565 | 0.60 | -0.70 |
| | M | 2438 | 0.68 | -0.69 |
| back-calculation1 | F | 2628 | 0.46 | -0.71 |
| | M | 2615 | 0.44 | -0.81 |
| back-calculation2 | F | 2580 | 0.51 | -0.59 |
| | M | 2535 | 0.51 | -0.68 |
| back-calculation3 | F | 2605 | 0.48 | -0.92 |
| | M | 2543 | 0.49 | -1.00 |

Estimates of the growth curve of striped marlin

Standard VBGF: $L_t = L_\infty \ (1 - e^{-k\,(t - t_0)})$

Generalized VBGF: $L_t = L_\infty \ (1 - e^{-K\,(1- m)(\,t - t_0)})^{(1/(1- m))}$

Table A. 5 The summary of growth parameter estimated by Sun et al. (2011). The estimated values of growth parameters of Richards function for striped marlin in waters off Taiwan area.

| Sun et al. (2011) | | | |
|---|---|---|---|
| $L_\infty$ (LJFL /cm) | $t_0$ | K | m |
| 263.44 | -0.40 | 0.04 | -2.05 |

Estimates of the growth curve of Striped marlin

Standard VBGF: $L_t = L_\infty\ (1 - e^{-k\,(t - t_0)})$

Generalized VBGF: $L_t = L_\infty\ (1 - e^{-K\,(1-m)(t - t_0)})^{(1/(1-m))}$