Preliminary report on homology of cross-section position in fin spine of striped marlin (Kajikia audax) for age estimation

Ayumu Furuyama[1], Miyuki Kanaiwa[1], Hirotaka Ijima[2], Akira Kurashima[2], Minoru Kanaiwa[1]

[1] Faculty of Bioresources, Mie University, Mie, Japan

[2] National Research Institute of Far Seas Fisheries, Fishery Research Agency, Shimizu, Shizuoka, Japan

Email: furuyama@bio.mie-u.ac.jp

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Abstract

One of the important age phenotypes of striped marlin is the fin spine. In this study, multiple sections of dorsal fin spines from a single spine were prepared and age estimation results were compared in order to test whether spines that had been cut off at the base during sampling could still be used for age estimation. The estimated ages of the 1/2 sections were compared with those of the 2/2 and 3/2 sections, and no significant differences were found between the sections, suggesting that even if a section cannot be made at 1/2 joint width due to cutting at the base of the spine, it can be used for age assessment if a section can be made at 2/2 or 3/2.

Introduction

The fin spine is used for age estimation of striped marlin *Kajikia audax* (Kopf et al. 2011, Shimose and Yokawa 2019), blue marlin *Makaira mazara* (Shimose et al. 2015), and swordfish *Xiphias gladius* (DeMartini et al. 2007, Sun et al. 2002. The dissecting position of the cross-section for the age estimation is generally determined based on 1/4 or 1/2 of the maximum condyle width (CW: DeMartini et al. 2007, Kopf et al. 2011, Shimose and Yokawa 2019, Shimose et al. 2015, Sun et al. 2002). The spine samples of marlins are collected by research vessels, commercial fishing, and more. In sampling by fisherman, the fin spines are sometimes cut off at the base. It is difficult to determine the dissecting position in such a case because of no condyle. Therefore the missing condyle of the spine is one of the limiting factors in sample size. In this study, we confirmed the homology of the annulus between 1/2CW section and other sections for age estimation of fin spines without condyle.

Materials and methods

The samples are 24 striped marlins caught by research vessels or commercial fishing in the sea around Japan during May 2020–June 2021 (Table 1). The striped marlins were measured Eye fork to length (EFL) and determined sex based on gonads. Dorsal fins were collected and preserved at –30°C. The EFL range of samples was 119.6–192.8 cm. The sexes of the samples were five males, 17 females, and 2 sex unknown individuals.

The primary method of age estimation was based on Shimose and Yokawa (2019). The dorsal fin spines were boiled, and soft tissues were removed in the laboratory. The longest and straightest spines were used for age estimation. The cross-sections were made at positions of

1/2CW, 2/2CW, and 3/2CW from the condyle base (Fig. 1). The sections were dissected to a thickness of 0.5 mm with a low speed saw (ISOMET Low Speed Saw LS, BUEHLER). The sections were attached to glass slides using a thermoplastic resin (CRYSTALBOND 509-1, AREMCO). The dissected surface of the sections was polished with a polishing machine (BMUD 120-A2, MARUTO), polishing cloth (2TS4, MARUTO), and abrasive (Baikalox alumina powder 0.3CR, Bailowski). The sections were magnified 8x with a stereomicroscope (EZ4D, Leica) and photographed with imaging software LAS EZ ver. 3.4.0. The photos of the section were saved as a jpeg file of 2048×1536 pixels. The pixel size of spine diameter in the photo was measured with a GNU Image Manipulation Program (GIMP) ver. 2.10.22. The pixel size of spine diameter was converted to “mm” using 1500 pixels as 10 mm. The linear equations for the logarithm values of the spine diameter and EFL were calculated for each of the three sections. The calculated equations were converted to reflect the individual difference in the relationship between spine diameter and EFL. In particular, the slopes of equations were modified to the value that was calculated by dividing the difference between intercepts and logarithm values of EFL by the logarithm value of spine diameter.

An annulus was defined as a translucent zone that continues unbroken from the top to the bottom of the section. The pixel size of the diameter of annulus was measured and converted to “mm” using the same methods of spine diameter. The EFL at each age was back-calculated by the modified equations for the spine diameter and EFL. The annulus of one year old was assumed that formed at EFL of 137.3 cm or more. The annulus with back-calculated EFL of less than 137.3 cm was excluded from the annulus count as the false annulus. The formation period of the translucent zone was assumed July, which is the recruitment month in the stock assessment (International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific 2019). The outermost annulus in the section of the merlin at April-June was excluded from the annulus count. The annulus was counted independently by two readers. When the estimated age was different between the two readers, the age was determined by the discussion of the readers. The individual was excluded from the analysis if the readers could not get the consensus.

R ver. 4.0.4 was used for statistical analysis. The differences of estimated age between the readers or the positions of cross-section were confirmed by McNemar, Evans & Hoenig, and Bowker test using “ageBias” function in FSA package (Ogle 2015). The differences of back-calculated EFL between the positions of cross-section were confirmed by paired t-test.

Results

The spine diameter and EFL at each position of the cross-section are shown in Fig. 2. The equations in Fig. 2 were modified to the following equations based on the spine diameter and EFL.

1/2CW section : ln(Back-calculated EFL) = (ln(EFL)-3.7003)/ln(SD)×ln(AD)＋3.7003

2/2CW section : ln(Back-calculated EFL) = (ln(EFL)-3.8543)/ln(SD)×ln(AD)＋3.8543

3/2CW section : ln(Back-calculated EFL) = (ln(EFL)-3.7449)/ln(SD)×ln(AD)＋3.7449

SD and *AD* are Spine diameter and annulus diameter, respectively. The EFL at annulus was back-calculated by those modified equations.

Because the 3/2CW sections of three individuals were broken in dissecting, those sections could not be used for age estimation (BF4557, BF4563, BF4729). The results of age estimation for each reader are shown in Table 2. There are significant differences in estimated ages between the two readers in the 1/2CW and 2/2CW sections, but not in the 3/2CW sections (Table 3, the significance level is 5%). For all but one of the individuals, reasonable age was determined through the discussion of two readers. The age of the 1/2CW section of BF4729 could not get consensus in the discussion. Thus, the following results are for 23 individuals, excluding BF4729. The age of 1/2CW sections and EFL were shown in Fig. 3. In this study, only 0–3 ages were observed.

The 19 individuals in the 2/2CW section and the 16 individuals in the 3/2CW section showed the same age as in the 1/2CW section. There were three individuals in 2/2 sections and two in 3/2 sections that age decreased by one year compared with that in 1/2 sections. On the other hand, one individual in the 2/2 section and three individuals in the 3/2 section showed that age increased by one year older than that in 1/2 sections (Table 4). There was no significant difference in age between the 1/2CW section and 2/2CW or 3/2CW section (Table 5, the significance level is 5%).

The differences of back-calculated EFL between 1/2 section and 2/2CW or 3/2CW sections were 0.85±5.24 cm for 2/2CW and 0.07±10.98 cm for 3/2CW (mean±SD: Fig. 4). The back-calculated EFL were not significant different between 1/2 section and 2/2CW or 3/2CW sections (2/2CW: t = -0.64, df = 19, p = 0.53; 3/2CW: t=-0.12, df = 17, p = 0.91). The difference of back-calculated EFL in 1/2CW section between two readers was 3.56±5.99 cm.

Discussion

In this study, differences of estimated age between the 1/2CW section and 2/2CW or 3/2CW sections were observed in some individuals, but estimated ages were not significantly different between the 1/2CW section and the other two sections. Thus, it is considered that changes in the position of the cross-section have little effect on the age estimation.

The differences of back-calculated EFL between 1/2CW section and 2/2CW or 3/2CW sections were smaller than that between two readers. Further, the significant differences of EFL between positions of cross-sections were not observed. Therefore, even if the positions of cross-section change, growth curves can be estimated using the back-calculated EFL. Those results suggested that the spines with lost condyle can be used for age and growth estimation if cross-section can be made at 2/2CW or 3/2CW position.

However, the estimated age in the 1/2CW section was significantly different between the two readers. This difference may be due to the lower skills of readers in age estimation because, after discussion, most samples could get consensus. Thus, the results in this study were preliminary. It is necessary to estimate the age again. In addition, only 0–3 ages were observed in this study. In the Southwest Pacific Ocean, the striped marlines had been observed up to 8 years old (Kopf et al. 2011). Because the samples in this study were biased to younger marlins, it is unknown that the results in this study can be adapted for older marlins over 4 years old. But we expect that the same results will be obtained even in older individuals because fin spines of older individuals are thicker and more legible than those of younger individuals.

In the future study, we will confirm the homology of annulus between 1/2CW and 1/4CW sections, and those in the older individuals. Furthermore, it is necessary to develop a method to determine the position of 2/2CW and 2/3CW based on the diameter and thickness of the spine with lost condyle.

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Table 1 The samples of striped marlins.

ID	Catch Date	EFL (cm)	Sex	Fishery type
BF4552	14 May 2020	164.6	M	Research vessel
BF4554	17 May 2020	192.8	F	Research vessel
BF4555	20 May 2020	170.2	F	Research vessel
BF4557	20 May 2020	154.0	F	Research vessel
BF4558	21 May 2020	155.0	F	Research vessel
BF4563	21 May 2020	154.0	M	Research vessel
BF4564	26 May 2020	147.0	F	Research vessel
BF4578	24 May 2020	144.0	U	Research vessel
BF4700	8 Feb. 2021	179.5	U	Commercial Fishing
BF4702	8 Feb. 2021	190.5	M	Commercial Fishing
BF4705	8 Feb. 2021	179.5	F	Commercial Fishing
BF4729	22 Apr. 2021	149.0	F	Research vessel
BF4731	22 Apr. 2021	150.0	F	Research vessel
BF4749	22 Apr. 2021	119.6	F	Research vessel
BF4752	26 Apr. 2021	147.0	M	Research vessel
BF4753	26 Apr. 2021	161.0	F	Research vessel
BF4773	28 Apr. 2021	124.8	F	Research vessel
BF4778	28 Apr. 2021	125.0	F	Research vessel
BF4779	28 Apr. 2021	127.4	F	Research vessel
BF4786	1 May 2021	151.0	M	Research vessel
BF4794	2 May 2021	155.0	F	Research vessel
BF4813	8 Jun. 2021	175.6	F	Research vessel
BF4815	9 Jun. 2021	167.0	F	Research vessel
BF4816	9 Jun. 2021	130.8	F	Research vessel

Table 2 The result of age estimation by two readers.

Estimated age by reader 1	Estimated age by reader 2											
	1/2CW				2/2CW				3/2CW			
	0	1	2	3	0	1	2	3	0	1	2	3
0	9	0	0	0	7	0	0	0	6	3	0	0
1	4	7	0	0	7	5	1	0	2	4	1	0
2	0	0	3	0	0	1	3	0	0	0	5	0
3	0	0	1	0	0	0	0	0	0	0	0	0

Table 3 The results of McNemar, Evans & Hoenig and Bowker test about the differences of estimated age between two readers.

Tests of symmetry	1/2CW			2/2CW			3/2CW		
	df	χ^2	*p*-value	*df*	χ^2	*p*-value	*df*	χ^2	*p*-value
McNemar	1	5.00	0.03	1	5.44	0.02	1	0.67	0.41
Evans-Hoening	1	5.00	0.03	1	5.44	0.02	1	0.67	0.41
Bowker	2	5.00	0.08	2	7	0.03	2	1.20	0.55

Table 4 The differences of estimated age between 1/2CW section and 2/2CW or 3/2CW sections.

Estimated age at 1/2CW	Estimated age at 2/2CW				Estimated age at 3/2CW				
	0	1	2	3	0	1	2	3	Break
0	11	1	0	0	9	2	0	0	1
1	2	5	0	0	1	4	1	0	1
2	0	0	3	0	0	0	3	0	0
3	0	0	1	0	0	0	1	0	0

Table 5 The results of McNemar, Evans & Hoenig and Bowker test about the differences of estimated age between 1/2CW section and 2/2 or 3/2CW sections.

Tests of symmetry	2/2CW			3/2CW		
	df	χ^2	*p*-value	*df*	χ^2	*p*-value
McNemar	1	0.67	0.14	1	1.00	0.32
Evans-Hoening	1	0.67	0.14	1	1.00	0.32
Bowker	2	1.20	0.55	2	1.33	0.51

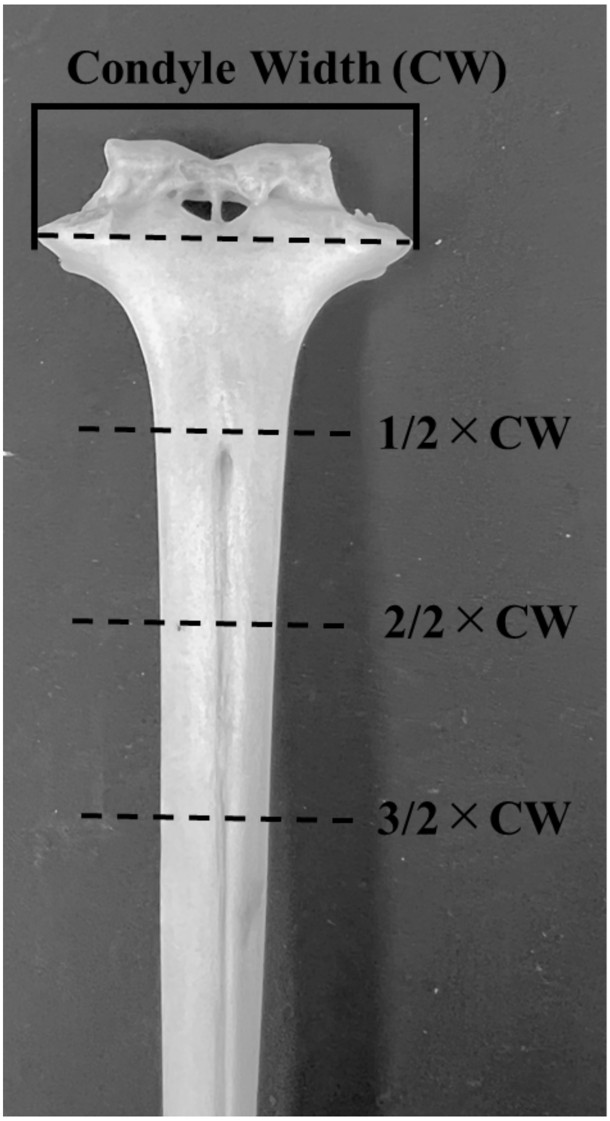

Figure 1 The positions of 1/2CW, 2/2CW and 3/2CW of the cross-section in the fin spine.

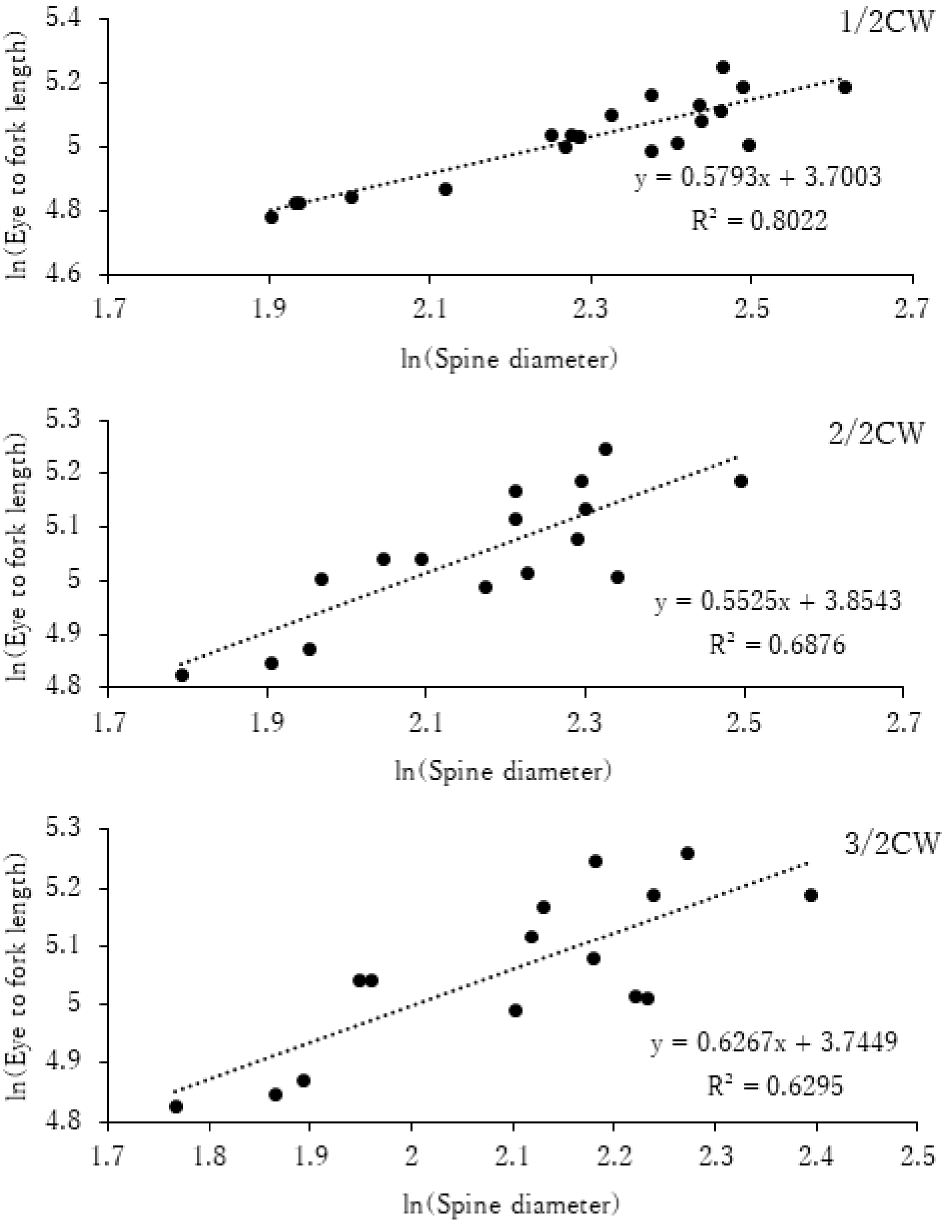

Figure 2 The relationship between spine diameter and EFL. The dotted lines are regression lines.

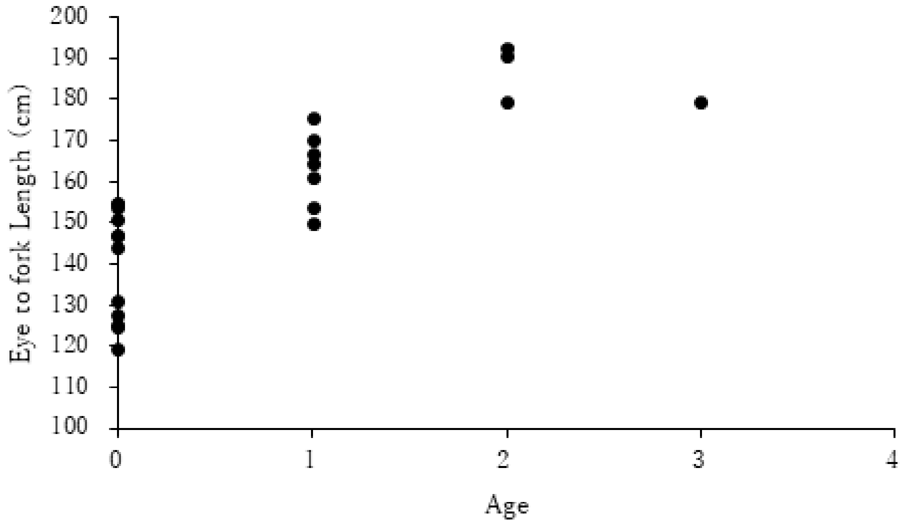

Figure 3 The relationship between age in the 1/2CW section and EFL.

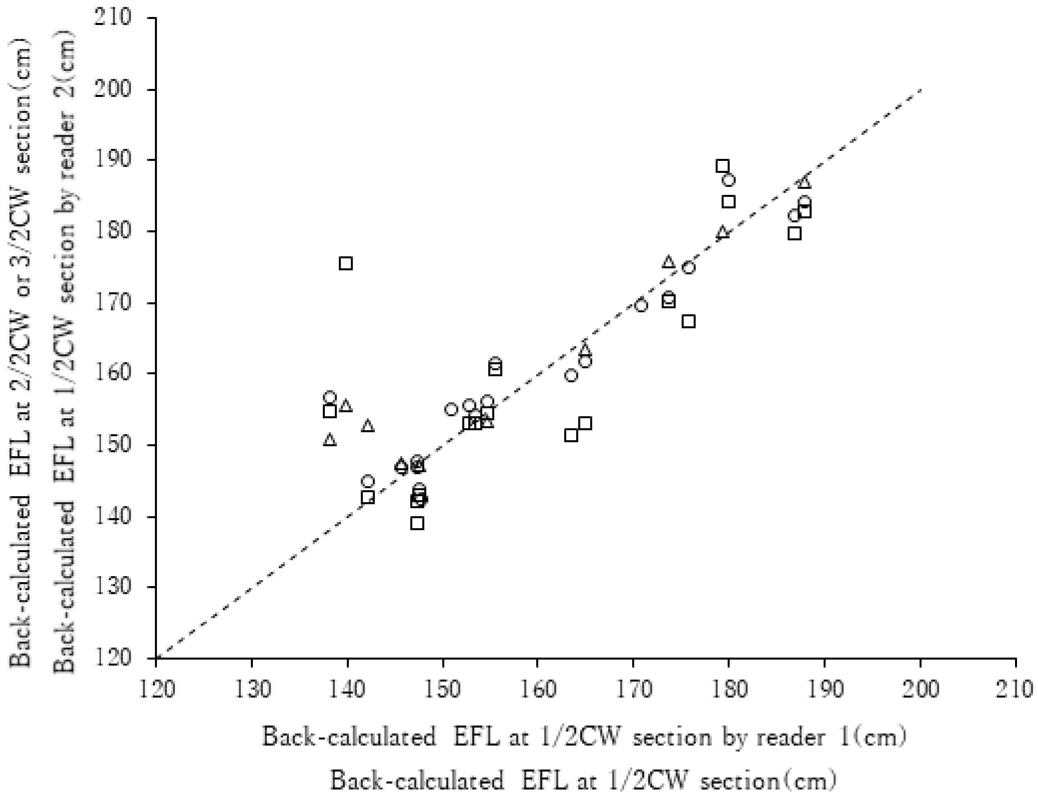

Figure 4 The relationships of back-calculated EFL between 1/2CW sections and other two sections, or two readers. The circles and squares show the EFL of the 2/2CW and 3/2CW sections, respectively, compared to the EFL of the 1/2CW section. The triangles show the EFL at 1/2 section by two readers.