SEXUAL DIMORPHISM IN THE DORSAL FIN OF PACIFIC WHITE-SIDED DOLPHINS (*LAGENORHYNCHUS OBLIQUIDENS*) FROM COASTAL WATERS OFF JAPAN

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Abstract

Records of external measurements of 35 male and 40 female Pacific white-sided dolphins collected from 1970 to 2020 were examined for the shape change of the dorsal fin and the difference between males and females. For mature individuals based on a body length of 200 cm, which is an approximate guideline for maturity, a significant difference was detected in the ratios of the front edge length and the tip height which were 3.8 on average with a maximum value of 5.6 in males, and 2.8 (average) and 3.1 (maximum value) in females, respectively. It was concluded that sexually mature males could be distinguished by measuring the shape of the dorsal fin.

Key words: allometry, dorsal fin, growth, morphology, Pacific white-sided dolphin.

The Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) is an endemic species of the North Pacific Ocean, and even a mature individual is relatively small, with a body length of 2.5 m or less. Length at birth is reported to be about 80–95 cm. The distribution area on the western side of the Pacific Ocean is along the Sea of Japan and the Pacific coast of Japan on the western Pacific Ocean (Leatherwood and Reeves, 1982, Brownell *et al.*, 1999). Hayano *et al.* (2004) identified a distribution gap around the longitude of 150°E or between Japanese coastal waters and the offshore western and central North Pacific, and concluded that samples from these two geographical areas came from different populations. The authors suggested that the low genetic difference could be due to the short time since reproductive isolation between the two geographical populations off Japan. The origin of the Japanese name "Kama-iruka" is that the dorsal fin resembles a "sickle" (Kasuya, 2017).

Regarding individual identification of dolphins and whales, the dorsal fin is one of the most obvious traits to consider whether in the wild or in captivity. The dorsal fin shape, size, color, scratches, and cuts are used to identify an individual. Killer whales (*Orcinus orca*) are known as an example where individual identification and identification by sex and maturity status is possible by observing the dorsal fin. The male dorsal fin (height to width ratio) could be readily distinguished from that of a female, and a height to width ratio of 1.4 or greater was indicative of a mature male (Olesiuk *et al.*, 1990, 2005).

In the case of the Pacific white-sided dolphin dorsal fin morphology, it has been found that sexually mature males have a pronouncedly curved and round dorsal fin (Walker *et al.*, 1986). Furthermore, Kasuya and Yoshida (1990) and Kasuya (2017) clarified that the tip of the dorsal fin hangs down in mature males from the point of measurement of the height of the tip of the dorsal fin and the overall height. Attempts have been made to identify sexually mature males from photographs of the dorsal fins of wild Pacific white-sided dolphin herds using this method (Morton, 2006). However, there are

no studies that have examined the body length and dorsal fin measurements of this species in comparison with the sex.

In this study, we investigated changes in dorsal fin shape and curvature using proportion measurements of Pacific white-sided dolphins collected in the waters of both the Pacific Ocean side and the Sea of Japan side of Honshu, Japan, over the past 50 years from 1970 to 2020. The purpose of this study was to clarify the difference in dorsal fin shape between males and females with changes in body length, and to contribute to the biological database of Pacific white-sided dolphins.

The measurements used in this study are shown in Fig. 1. The proportion measurement records of 35 males and 40 females were used. These measurement records include post-mortem measurements (bycatch or after death in captivity) and live individuals' latest measurements data at Kamogawa Sea World (KSW). It is a characteristic of Pacific white-sided dolphins distributed in the coastal waters of Japan that individual differences in body length are large in all age ranges. The range shared by sexually mature and immature individuals was 180–234 cm for males and 195–209 cm for females (Kasuya, 2017). From this, the guideline for sexually mature body length was roughly set to 200 cm in this paper.

The following allometric equation was used to extract growth patterns at each point:

$$y = \beta x^{\alpha}$$

where x defines the body length; y, the length (cm) of the measurement points; α , the allometric coefficient; and β is a constant. The *t*-test was conducted using allometric coefficients to reveal growth patterns at each measurement point, and the data were grouped into three different growth patterns: positive allometry (hyperallometry) when the allometric coefficient was significantly greater than 1, isometric allometry and negative allometry (hypoallometry) when the allometric coefficient was less than 1. These statistical analyses were conducted by using the packaged tools in the statistical software R (R Core Team, 2021). Fig. 2 shows the obtained body length plotted against each measurement point of dorsal fins for males and females. The body length (measurement point No. 1, Fig. 1) ranged from 71 cm (fetus) to 231 cm for males and 70.5 cm (fetus) to 225 cm for females. As the body length increased, each measured value also increased, and the slope of the graph increased. For differences between males and females in each graph, the length of dorsal fin base (measurement point No. 2, Fig. 1) differed between males and females. The maximum value was 49.0 cm for males and 41.0 cm for females. However, the height of the dorsal fin tip (measurement No. 3) was conspicuously narrower in individuals of body length 200 cm or more for both males and females (Fig. 2). In other words, the tip of the dorsal fin tended to hang down as individuals sexually matured in both males and



Fig. 1. External measurement points of Pacific white-sided dolphin used in the present study: No. 1, from the tip of the upper jaw to notch in the tail fluke (body length); No. 2, length of dorsal fin base; No. 3, height of dorsal fin tip; No. 4, length from the front edge to fin tip and No. 5, length from fin tip to trailing edge.



Fig. 2. Relative growth of measured points in dorsal fin and body length of the Pacific white-sided dolphin. Closed circles (left) represent males and open circles (right) represent females, respectively. The dotted line indicates the approximate body length of a sexually mature (200 cm) individual.

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females. The front edge length (measurement point No. 4, Fig. 1) was also different between males and females. For individuals with a body length over 200 cm, dorsal fins grew longer in males than in females. The maximum value was 59.4 cm for males and 47.5 cm for females. The dorsal fin trailing edge length (measurement point No. 5) values varied widely for both males and females. This may be due to the variety of trailing edge shapes. The maximum value was 39.0 cm for males and 29.6 cm for females.

 Table 1. Allometry of the length of dorsal fin measurement points and body length of Pacific white-sided dolphin males and females.

Male	Measurement points	α	β	R^2	Growth pattern	P-value
No. 2	Length of dorsal fin base	1.06	0.14	0.96	isometric allometry	0.135
No. 3	Tip height	0.63	0.56	0.50	negative allometry	0.003**
No. 4	Front edge length	1.09	0.15	0.93	isometric allometry	0.097
No. 5	Trailing edge length	0.87	0.25	0.72	isometric allometry	0.204
Female	Maggungen ont a ginta		0	2	O 1 1	D 1
remate	Measurement points	α	β	R^2	Growth pattern	P-value
No. 2	Length of dorsal fin base	1.01	<i>β</i> 0.16	<i>R</i> ² 0.93	isometric allometry	0.782
No. 2 No. 3	Length of dorsal fin base Tip height	α 1.01 0.45	β 0.16 1.55		isometric allometry negative allometry	0.782 0.000**
No. 2 No. 3 No. 4	Length of dorsal fin base Tip height Front edge length	α 1.01 0.45 0.92	β 0.16 1.55 0.32	<i>R</i> ² 0.93 0.32 0.91	isometric allometry negative allometry isometric allometry	P-value 0.782 0.000** 0.137

** indicates a statistically significant difference (p < 0.01) between sexes in the length of dorsal fin measurement points and body length (see also Fig. 2).



Fig. 3. Pacific white-sided dolphin dorsal fin growth-related ratio change No. 4/No. 3 shows front edge length to tip height ratio and No. 5/No. 3 shows trailing edge length to tip height ratio. Closed circles (left) represent males and open circles (right) represent females, respectively. The dotted line indicates the approximate body length of a sexually mature (200 cm) individual.

Table 1 shows the values applied to the relative growth curve (relationship between the length of dorsal fin measurement points and body length) for males and females. Tip height in males, and tip height and front edge length in females showed negative allometry.

Fig. 3 shows front edge length to tip height (No. 4/No. 3) and trailing edge length to tip height (No. 5/No. 3) ratios by body length for males and females. The ratio rises sharply after a body length of 200 cm in males, while on the other hand such a change is not observed in females.

Fig. 4 shows the front edge length to tip height (No. 4/No. 3) and the trailing edge length to tip height (No. 5/No. 3) ratios of individuals over 200 cm in body length. The ratios of front edge length to tip height were significantly higher in males $(3.8\pm0.2, \text{mean}\pm\text{SE}, n=12)$ than in females $(2.8\pm0.1, n=10)$ (*t*-test, p<0.01). No significant difference was found in the trailing edge length to tip height ratios.

This study found that the dorsal fins of Pacific white-sided dolphins inhabiting the coastal waters of Japan differ in shape and size between males and females. Especially in length of dorsal fin base (measurement point No. 2) and front edge length (measurement point No. 4), males clearly grew more than females. When the ratio of dorsal fin was examined using these measurements (Fig. 1), a significant difference was found in the front edge length to tip height ratio (No. 4/No. 3). This difference in the shape of the dorsal fins of males and females was effective for individual identification of wild Pacific white-sided dolphins and identification of sexually mature males. Suzuki *et al.* (2020) suggested that there are at least two forms on the coastal waters of Japan, and from the result of genetic structural analysis of 64 Pacific white-sided dolphins kept at aquariums in Japan, they concluded that in the Japanese coastal waters, genetic exchange between populations with different genetic backgrounds seems



Fig. 4. Comparison of the dorsal fin ratios between mature males and females. No. 4/No. 3 shows front edge length to tip height and No. 5/No. 3 shows trailing edge length to tip height. The vertical black bars indicate the average error and * indicates a statistically significant difference (p<0.01) between sexes.

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to occur in the wild. In the future, it is hoped that differences in body length and external morphology between individuals of the forms identified by genetic structural analysis will be investigated.

As a conclusion, we compared the measured values of the dorsal fin for the Pacific white-sided dolphin using records from the coastal waters of Japan. It was shown that the ratio of the dorsal fin can be used to identify sexually mature males. Their dorsal fin (front edge length to tip height ratio) could be readily distinguished from that of females, and a ratio of 3.8 or greater was indicative of a sexually mature male.

Acknowledgements

We would like to express our deep gratitude to all the staff who have been involved in the continuous care of dolphins, and the measurement of proportions and the storage of records for over 50 years at Kamogawa Sea World. We would like to thank Masayuki Muramatsu and Naoko Suhara for their cooperation in preparing the figures and the significance test. Finally, we deeply appreciate the anonymous reviewers for their helpful suggestions.

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Received: January 21, 2021 Accepted: August 19, 2021 Published online: December 2, 2021

Appendix

Dorsal fin shape photos; ID, sex, sexual status, body length.

The photos are shown based on body length left to right, from top to bottom by male (this page) and female (next page). The individuals in the photos have been kept at KSW and confirmed to be mature and immature by reproductive history, sex hormones, and semen collection in the case of males.



ID 055: male, mature, 231 cm



ID 054: male, mature, 214 cm



ID 032: male, mature, 213 cm



ID 062: male, mature, 205 cm



ID BL1: male, mature, 200 cm



ID 065: male, immature, 158 cm



ID 063: male, immature, 183 cm

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Appendix (Continued.)



ID 056: female, mature, 225 cm



ID 061: female, mature, 207 cm



ID 052: female, mature, 194 cm



ID 046: female, mature, 195 cm



ID 060: female, immature, 205 cm