Morphological differences in the white patch on the flipper between J and O stocks of the North Pacific common minke whale

GEN NAKAMURA[1*], ICHIRO KADOWAKI[1], SHOUKA NAGATSUKA[1], RYOTARO HAYASHI[1], NAOHISA KANDA[3], MUTSUO GOTO[2], LUIS A. PASTENE[2] AND HIDEHIRO KATO[1]

[1] Laboratory of Cetacean Biology, Tokyo University of Marine Science and Technology, 4-5-7 Konan, Minato-ku, Tokyo 108-8477, Japan
[2] Institute of Cetacean Research, Toyomi Promotion Building 5F, 4-5 Toyomi-cho, Chuo-ku, Tokyo 104-0055, Japan
[3] Japan NUS Co. Ltd., Nishi-Shinjuku Kimuraya Building 5F, 7-5-25 Nishi-Shinjuku, Shinjuku-Ku, Tokyo 160-0023, Japan

ABSTRACT

Past studies have indicated that there are two different stocks (J and O stocks) in the North Pacific common minke whale *Balaenoptera acutorostrata* population. These two stocks differ from each other in certain characteristics, such as body size, conception dates, and *mt*DNA haplotypes. However, till date, few studies have investigated differences in the external body appearance between the two stocks. Therefore, in the present study, we focused on the unique white patch on the flipper of this whale species to elucidate inter-stock differences. We used animals collected from JARPNII research during 2012 and 2013; stock information was determined by microsatellite analysis (n = 220). We focused on the morphological differences in the size and pattern of the white patch on the flipper of each whale. The length of the white patch along the anterior (ventral) margin of the flipper tends to be proportionally larger in O stocks. The pattern of the boundary area of the white patch named as the "Grayish Accessary Layer (GAL)" was remarkably different between stocks. Within animals with "no GAL" type, 94% were J stock. Conversely, of animals with GAL expanding over the half the flipper width, 96% were O stock. We concluded from our study that there were clear morphological differences in the flipper color pattern between J and O stocks.

INTRODUCTION

The common minke whale *Balaenoptera acutorostrata* has been regarded as an important resource worldwide. However, commercial whaling has been under a moratorium since 1988. The International Whaling Commission (IWC) recommends stock-based as well as species-based management (Government of Japan, 1994). Attempts to clarify the stock structure of the North Pacific minke whale population began in the 1950s. In the 1980s, it was suggested that there are two minke whale stocks in seas around Japan (Ohsumi, 1983) comprising J stocks, which are mainly distributed from the Sea of Japan to the East China Sea, and O stocks, which are distributed from the Okhotsk Sea to the western North Pacific. The two whale stocks share the same feeding ground and they are mixed in the Okhotsk and Japanese coasts (Ohsumi, 1977; Hatanaka and Miyashita, 1997).

When preparing plans for the implementation of the Revised Management Procedure, the issue of stock structure was considered as one of the most important issue in the IWC. From 1994, the Japanese Whaling Research Programs under Special Permit in the Western North Pacific (JARPN) were conducted by the Government of Japan from 1994 to 1999. The main objective of that research was to clarify the stock structure of common minke whales in the western North Pacific. After 2000, additional research (JARPNII) has been conducted by the Government (Government of Japan, 1994; 2000).

Various aspects of the stock structure of the North Pacific minke whale population have been studied in-depth, including work on genetics (Wada, 1991; Kanda *et al*., 2009; Goto *et al*., 2009), conception

dates (Kato, 1992), and cookie cutter shark-induced scar marks (Bando *et al*., 2010). Morphological studies comparing body length; body proportions; and color patterns of the baleen plates, flippers, and tail flukes have also been conducted (Ohsumi, 1983; Kato, 1992; Hakamada and Bando, 2009; Kanda *et al*., 2010).

The white patch on the flipper is a unique characteristic of the common minke whale. Moreover, the position, size, and shape of the white patch on the flipper are clearly different between the North Pacific, North Atlantic, and southern hemisphere populations. Therefore, the white patch on the flipper may serve as a useful distinguishing characteristic for taxonomy classification purposes (Nakamura *et al*., 2014). Among North Pacific common minke whales, it has been reported that the area ratio of the white patch on the flipper differs between J and O stocks (Kanda *et al.,* 2010). Kanda *et al*. (2010) suggested that the white patch length in proportion to the overall flipper length may differ; however, there was still no clear indicator to identify the two stocks. Therefore, we focused on the white patch of the flipper of the North Pacific minke whale in more detail. The aim of this study was to clarify the morphological differences between stocks so that a morphological index could be developed that will help to correctly identify whale stocks from their appearance.

MATERIALS AND METHODS

The samples were collected during offshore and coastal (Sanriku and Kushiro) research of the Japanese Whale Research Program under Special Permit in the Western North Pacific-Phase II (commonly known as JARPNII), during 2012 and 2013. The survey was conducted in accordance with the Article VIII of the International Convention for the Regulation of Whaling and in accordance with the Japanese law. The animals were identified and classified into either J or O stock using genetic analyses along with a combination of microsatellite and Bayesian clustering analyses following the methods of Pastene *et al*. (2016: SC/F16/JR38). We conducted research on 220 animals (138 males, body length: 3.82–8.16 m; 82 females, body length: 4.06–8.68 m), which were assigned into the appropriate stock based on their high membership probability (>90%).

In this inter-stock comparison study, we focused on the proportional size and boundary area pattern of the white patch on the flipper of each whale. We measured the following three flipper characteristics after the flipper was dissected from the whale's body: flipper length, distance from the tip of the flipper to the distal end of the white patch (Point A), and the tip to mesial end of the white patch (Point B) (Fig. 1). These points were measured to millimeter scale accuracy using measuring tape or a stainless steel caliper. The boundary area pattern of the white patch named as "Grayish Accessary Layer (GAL)" were classified into groups, based on the criteria described below (Fig. 2):

no GAL type: Animals with no grayish band near the boundary,
Type 1: With small GAL not fused to the other side,
Type 2: GAL is connected to the other side, and
Type 3: GAL expands over the half-line of the flipper width.

RESULTS

Proportional size of the white patch on the flipper

The proportional length of Point A (distance from the tip of the flipper to the distal end of the white patch) to the flipper length was 61.3±4.7% (n = 47) and 63.8±4.5% (n=168) for J and O stocks, respectively. Although the values overlapped, the distal end of the white patch tends to be relatively far from the tip of flipper in O stocks compared with that in J stock whales (Mann–Whitney U-test, $p < 0.01$) (Fig. 3 a).

The proportional length of Point B (distance from the tip of the flipper to the mesial end of white patch) to the flipper length was 29.7±4.5% (n = 49) and 30.3±4.7% (n = 169) for J and O stocks,

respectively. The values are quite similar between the two stocks, and therefore, no statistical differences were observed in this characteristic (Mann–Whitney *U*-test, $p > 0.05$) (Fig. 3 b).

Classification by GAL type

The relationship between the type of stock and pattern of the boundary in the white patch (GAL) of individual whales was studied. More than 80 % whales were categorized as Types 1 ($n = 32$) and 2 ($n = 143$) comprised both stocks. However, 94% of the "no GAL" type ($n = 16$) whales comprised J stock, and 96% of Type 3 ($n = 27$) whales comprised O stock (Fig. 4). The frequency of the J and O stocks were distinct among GAL types (Pearson's chi-square test, $p < 0.01$).

DISCUSSION

The present study reported the morphological differences in the white patch pattern on the flippers of individual whales with the aim of improving the identification of North Pacific common minke whales by stock. Previous studies mentioned the possibility that the pattern of the white patch on the flipper differs in these whales within as well as between particular oceans/seas, thus suggesting the possibility of inter-stock differences (Kato, 1992; Nagatsuka, 2010; Nakamura *et al*., 2014). As indicated by these studies, definite morphological differences in the white patch of the flipper were observed between stocks.

The length of Point B was not significantly different between stocks, whereas the length of Point A was proportionally larger in O stocks than in J stocks. This meant that the length of white patch along the anterior (ventral) margin of the flipper tends to be proportionally larger in O stocks. Statistical analyses also support these results. However, the range of the proportion are overlapped between stocks, and therefore, it would be difficult to classify whales into either stock with 100% accuracy based only on this characteristic.

The GAL pattern was the clearest characteristic for stock identification. We were able to define separate stocks with high probability (>90%) when the target animal was "no GAL" type or "Type 3". On the other hand, more than 80% of observed animals were classified into Type 1 (15%, $n = 32$) or 2 (66%, $n = 143$), and these were from both J and O stocks.

We conclude that distinct morphological differences in the flipper's white patch pattern were observed between J and O stocks whales, particularly in the GAL pattern (Fig. 5). These findings may help in the future development of a useful index to identify different North Pacific common minke whale stocks. Combined with the observations of other external characteristics, such as cookie cutter shark-induced scar marks and unsolved indicators that include body color pattern, the accuracy of whale stock identification in the ocean will be greatly improved.

ACKNOWLEDGMENTS

We thank the former leaders of the JARPNII Survey; Genta Yasunaga and Takeharu Bando of the Institute of Cetacean Research; Former Chief of the JARPNII Survey; Shigeo Tabata; Takahiro Hara of the National Research Institute of Far Seas Fisheries; the staff of Kyodo Senpaku Co., which is the main proponent of offshore surveys; and Representative Director Yoshiichi Shimomichi and the staff of the Association for Community-Based Whaling. We also thank the members of the Laboratory of Cetacean Biology, Tokyo University of Marine Science and Technology. The authors would like to thank Enago (www.enago.jp) for the English language review.

REFERENCES

Bando, T., Kanda N., Pastene, L. A., Kishiro T., Yoshida H. and Hatanaka H. 2010. An analysis of cookie cutter shark-induced body scar marks of common minke whales sampled by JARPNII in the context of stock structure hypotheses. Paper SC/D10/NPM6 presented to the First Intersessional Workshop of western North Pacific minke whale Implementation, December 2010 (unpublished). 5pp.

Goto, M., Kanda N. and Pastene L. A. 2009. Stock structure scenario of common minke whales from the Japanese waters as revealed by genetic data. Paper SC/61/NPM9. Presented to the 61st IWC Scientific Committee Meeting. May 2009 (unpublished). 3pp.

Government of Japan. 1994. Research plan for clarification of minke whale stock structure in the northwestern part of the North Pacific. Paper SC/46/NP1 presented to the IWC Scientific Committee, May 1994 (unpublished). 13 pp.

Government of Japan. 2000. Research plan for cetacean studies in the western North Pacific under special permit (JARPN II) (Feasibility study plan for 2000 and 2001). Paper SC/52/O1 presented to the IWC Scientific Committee, June 2000 (unpublished). 68pp.

Hakamada, T. and Bando T. 2009. Morphometric analysis on stock structure in the western North Pacific common minke whales (*Balaenoptera acutorostrata*). Paper SC/J09/JR27. Presented to the JARPN II Review Workshop, Tokyo, January 2009 (unpublished). 13 pp.

Hatanaka, H. and Miyashita T. 1997. On the feeding migration of Okhotsk Sea. West Pacific stock of minke whales, estimates based on length composition data. *Rep. Int. Whal. Commn* 47: 557-564.

Kanda, N., Goto M., Kishiro T., Yoshida H., Kato H. and Pastene L. A. 2009. Individual identification and mixing of the J and O stocks around Japanese waters examined by microsatellite analysis. Paper SC/J09/JR26 presented to the JARPN II Review Workshop, Tokyo, January 2009 (unpublished). 9pp.

Kanda, N., Goto M., Nagatsuka S., Kato H., Pastene L. A. and Hatanaka H. 2010. Analysis of genetic and non-genetic data do not support the hypothesis of an intermediate stock in sub-area 7. SC/D10/NPM8 presented to the First Intersessional Workshop of western North Pacific minke whale Implementation, December 2010 (unpublished). 8pp.

Kato, H. 1992. Body length, reproduction and stock separation of minke whales off Northern Japan. *Rep. Int. Whal. Commn* 42: 443-453.

Kato, H., Kishiro T., Fujise Y. and Wada S. 1992. Morphology of minke whales in Okhotsk Sea, Sea of Japan and off the East Coast of Japan, with respect to stock identification. *Rep. Int. Whal. Commn* 42: 437-442.

Nagatsuka, S. 2010. Master's thesis. Tokyo University of Marine Science and Technology, Tokyo.

Nakamura, G., Kadowaki I., Nagatsuka S., Fujise Y., Kishiro T. and Kato H. 2014. Variation in a color pattern of white patch on the flippers of North Pacific common minke whales: Potential application for their interoceanic difference. *La mer* 52: 31-47.

Ohsumi, S. 1977. Minke whales in the coastal waters of Japan. *Rep. int. Whal. Commn* 27:164-166.

Ohsumi, S. 1983. Minke whales in the coastal waters of Japan in 1981, with special reference to their stock boundary. *Rep. int. Whal. Commn* 33:365-71.

Pastene, L.A., Goto, M., Taguchi, M. and Kitakado, T. Temporal and spatial distribution of the 'J' and 'O' stocks of common minke whale in waters around Japan based on microsatellite DNA. Paper SC/F16/JR38 presented to the JARPNII special permit expert panel review workshop, Tokyo, February 2016 (unpublished). 14pp.

Wada, S. 1991. Genetic structure of Okhotsk Sea –West Pacific stock of minke whales. Paper SC/43/Mi32 presented to the IWC Scientific committee, May 1991 (unpublished). 17 pp.

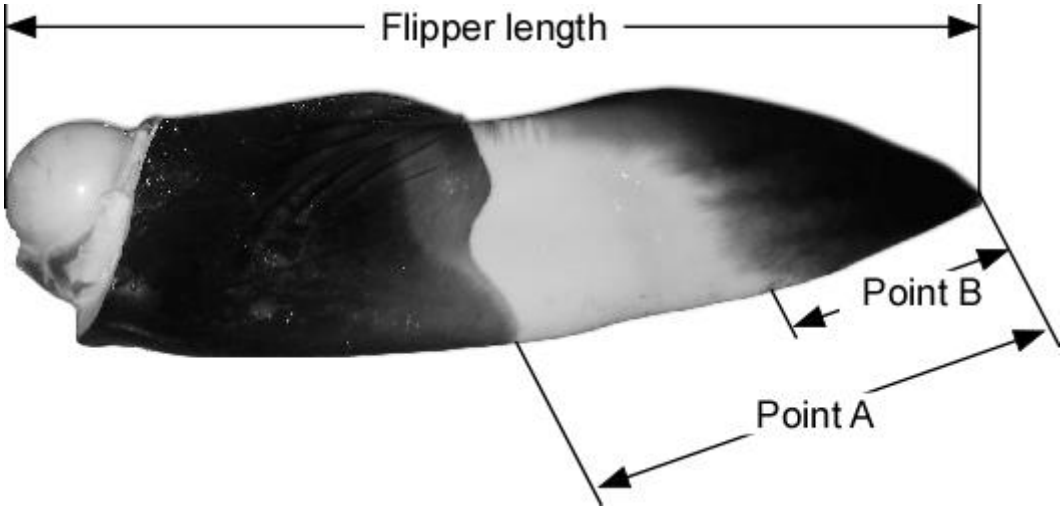

Fig. 1 Measurement points on the flipper.

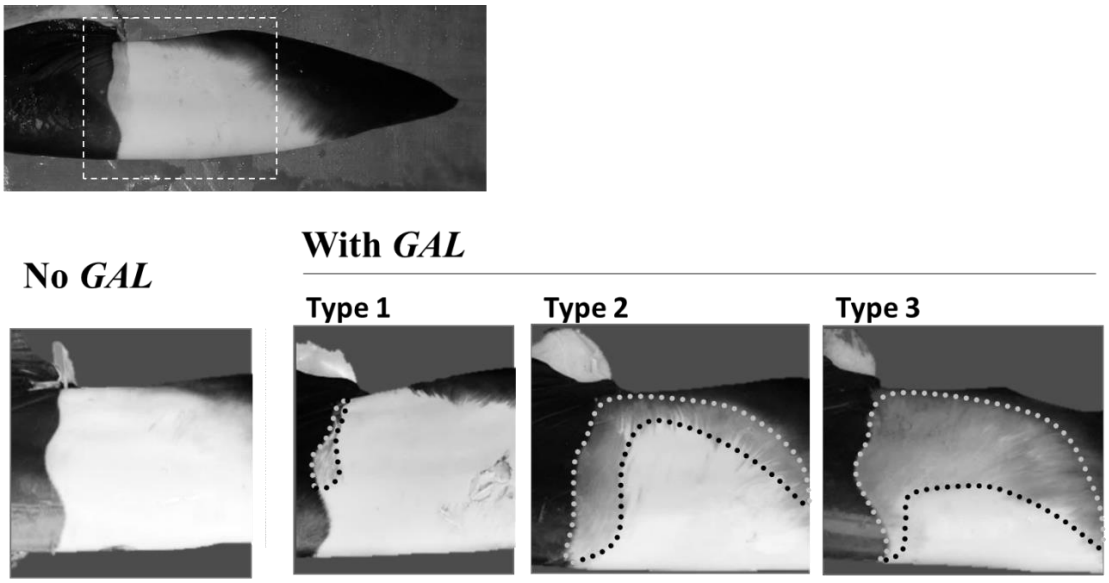

Fig. 2 Basis for the classification based on the GAL types (GAL: surrounded by dotted line).

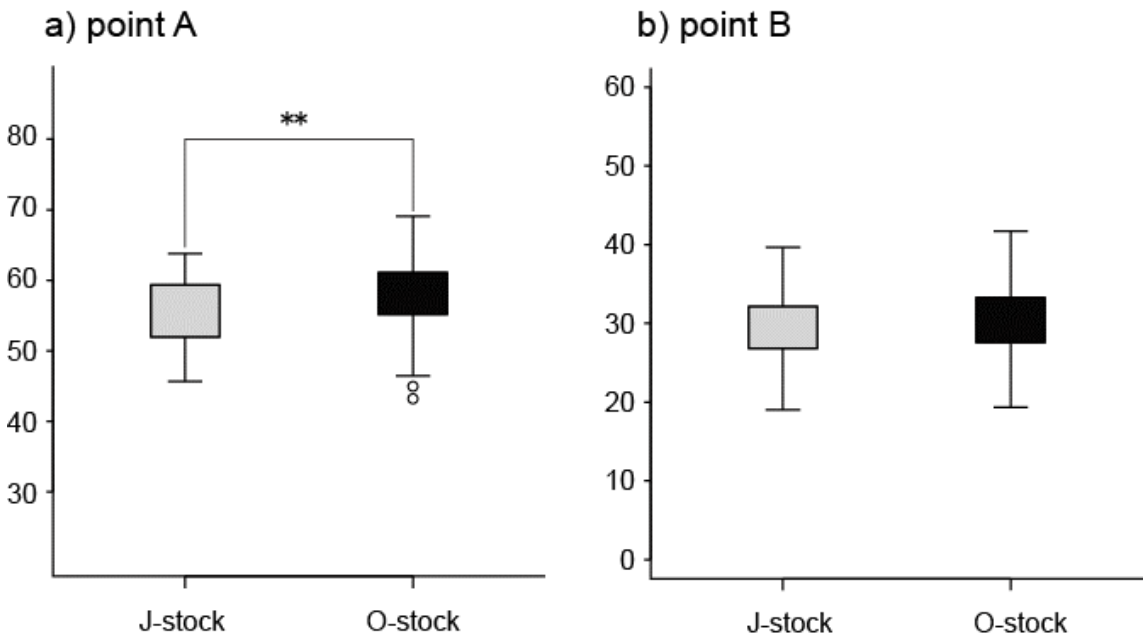

Fig. 3 Proportional size of white patch in the flipper. a) The proportional length of Point A (The distance from the tip of the flipper to the distal end of white patch) to the flipper length. b) The proportional length of Point B (The distance from the tip of the flipper to the mesial end of white patch) to the flipper length. In Point A, proportional length was larger wain O stocks compared to J stock whales (Mann–Whitney U-test, $p < 0.01$)

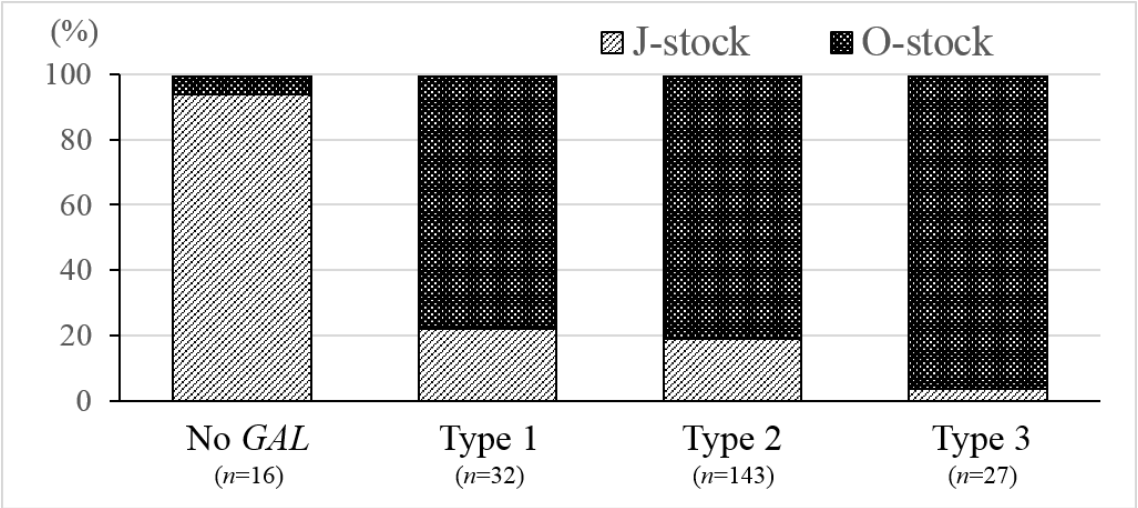

Fig. 3 The relationships between stock and the pattern of the boundary in white patch (GAL).

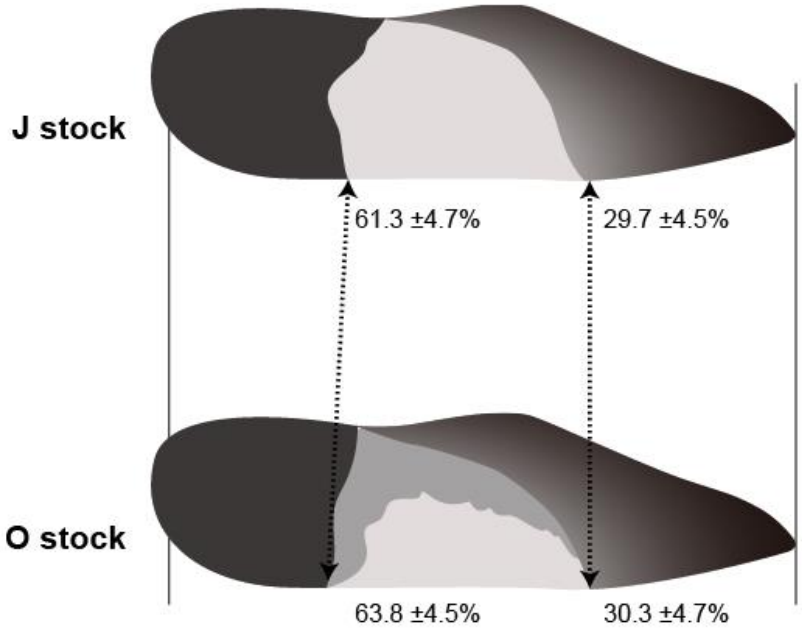

Fig. 4 Typical diagram of the white patch of the flipper in J and O stocks.