Full paper

COMPARISON OF SHAPES OF THE WHITE FLIPPER PATCH BETWEEN TWO SUB-SPECIES OF COMMON MINKE WHALES (*BALAENOPTERA ACUTOROSTRATA*)

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Abstract

The North Atlantic and North Pacific minke whales are regarded as two different subspecies. In this study we aimed to clarify the morphological differences of the white patch on the flipper between these subspecies. Morphological measurements were taken from the left flipper of sexually mature animals, collected from the North Atlantic (N=15) and the North Pacific (N=16) oceans. The length between the tip of flipper to the distal border of the white patch relative to the total flipper length showed no statistical differences between the two subspecies. However, the length between the tip of flipper to the proximal border of white patch relative to the total flipper length was significantly larger in the North Atlantic (74.31%) as compared to the North Pacific (63.62%) minke whales. Also, the mean angle between the proximal boundary line of the white patch and the longitudinal axis of the flipper was significantly different between the North Atlantic (70.05 degrees) and the North Pacific (92.29 degrees) minke whales. These results show that there are clear morphological differences in the white patch of the flipper between the two minke whale subspecies.

Key words common minke whale, *Balaenoptera acutorostrata*, flipper, white patch morphology, subspecies, taxonomy.

Introduction

The common minke whale (*Balaenoptera acutorostrata*) is distributed worldwide and is regarded as an important marine resource, particularly in the North Atlantic and North Pacific. Taxonomically, common minke whales are classified into two subspecies: *B. a. acutorostrata* in the North Atlantic and *B. a. scammoni* in the North Pacific. Although a distinctive population exists in the Southern hemisphere, generally known as the "dwarf" minke whale (*B. a.* subsp.), the taxonomical status of this subspecies is still under discussion (Rice, 1998). Since external characteristics are important classification criteria for taxonomy, various studies have focused on the differences in these characteristics to distinguish minke whale populations within and between oceans (Omura and Sakiura, 1956; Christensen *et al.*, 1990; Kato *et al.*, 1992; Nakamura *et al.,* 2014). A unique characteristic of the common minke whale is the white patch on their flippers. Compared to the North Pacific minke whale, the dwarf minke

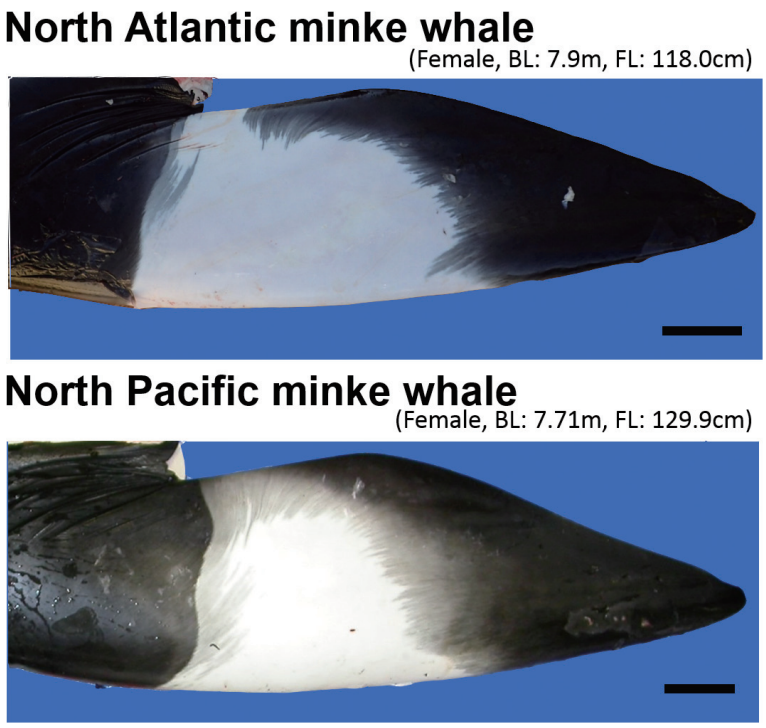

Fig. 1. Examples of typical appearances of minke whale flippers for the North Atlantic minke whale (top) and the North Pacific minke whale (bottom). See also photographs in Appendix 1. Scale bars indicate 10 cm.

whale has much larger white patches which extend to their shoulders. This feature has been used to distinguish these two subspecies (Arnold *et al.*, 1987; Kato and Fujise, 2000; Arnold *et al*., 2005). Nakamura *et al.,* (2015) reported that the shape of the white patch would be a powerful taxonomical character to morphologically distinguish the stocks in the North Pacific. Horwood (1989) reviewed and described the differences in the shape of the white flipper patch between the North Atlantic and North Pacific common minke whales. Notably, the latter has a small central projection of the white area into the black area of the flipper, whereas in the former, the white area is more angled with no such projection.

Fig. 1 shows the color patterns of flippers from North Atlantic and North Pacific common minke whales. These different characteristics of the white patches have not yet been thoroughly described and compared. Using a photogrammetric method, Nakamura *et al.* (2014) showed that the white patch is significantly larger in the North Atlantic common minke whale as compared to the North Pacific one. However, to clarify the morphological differences of flipper between the two common minke whale subspecies, a more detailed analysis based on unified methodologies and controlled conditions is needed. The aim of this study was to specify the relative size and differences of the white flipper patch between the North Atlantic and North Pacific common minke whales, now based on measurements made directly on flippers obtained from animals taken in commercial (North Atlantic) and research (North Pacific) catches.

Materials and Methods

The data from North Atlantic common minke whales were collected during Norwegian commercial whaling operations conducted south of the Svalbard islands during the summer season in 2016 (Fig. 2). The North Pacific common minke whale data were collected from the survey of the second phase of the Japanese Whale Research Program under Special Permit in the Western North Pacific (commonly known as JARPN II), conducted in the coastal and offshore waters of Japan in 2012 and 2013

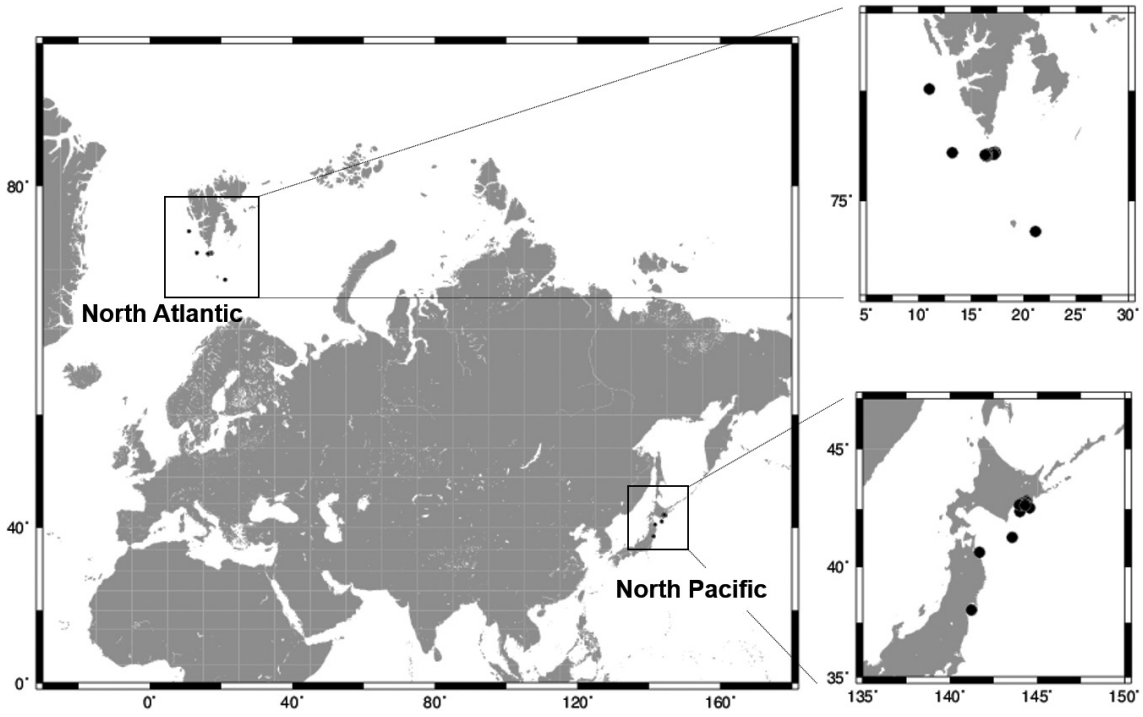

Fig. 2. Location where materials of the North Atlantic and North Pacific minke whales were collected.

(Fig. 2). This research was conducted in accordance with Article VIII of the International Convention for the Regulation of Whaling, and Japanese law.

To minimize the effects of sex-specific and growth-dependent differences on the white patch, we analyzed sexually mature female whales only. A total of 15 animals, mean body length 8.07 m (range: 7.2–8.7 m) from the North Atlantic population, and 16 animals, mean body length 7.96 m (range: 7.10–8.68 m) from the North Pacific population were used in this study. Body length was measured from the tip of the snout to the notch of flukes, rounded to the nearest 10 cm for the North Atlantic minke whales and the nearest 1 cm for the North Pacific minke whales. Sexual status was determined by examining ovaries; whales possessing ≥1 corpus albicans or corpus luteum were regarded as sexually mature. The left flipper was removed and photographed. For each photograph, we carefully ensured that the camera was placed in the upper direction confronting the flipper. Then, the following lengths were measured in a straight line using a measuring tape to the nearest 0.5 cm: *Total flipper length*: The tip of flipper (a) to the end of the articular process of the humerus (c); *Measurement point A*: The tip of flipper (a) to the distal border of white patch (A); and *Measurement point B*: The tip of flipper (a) to the proximal border of white patch (B). *Measurement point C* (*Angle θ*) is the angle between the proximal boundary line of white patch and the longitudinal axis of the flipper. The proximal boundary line of white patch was defined as the line passing from the ventral (B) to dorsal (b) sides of the proximal border of white patch, whereas the longitudinal axis of the flipper is the straight line from the tip of flipper to the end of the articular process of the humerus. This angle was calculated by a photogrammetric method using the graphic software Canvas X (Fig. 3). T -testing was applied to test the differences between the two subspecies. It was considered that t was significant at $P < 0.05$. Standard deviation (S.D.) was adapted to measure the dispersion of the data. All statistical analyses were carried out using packaged tools in the statistics software R (R Development Core Team 2015).

Results and Discussion

To clarify inter-subspecies differences in the relative size of the white patch, the proportion of *Measurement points A* and *B* relative to the *Total flipper length* in percent, and *Measurement point C* in

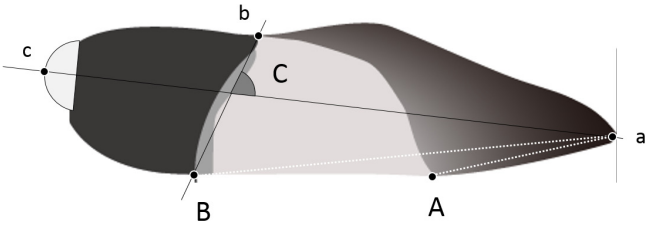

Fig. 3. Measurement points of the white patch of the left flipper from the common minke whale. *Total flipper length*: The tip of flipper (a) to the end of the articular process of the humerus (c), *Measurement point A*: The tip of flipper to the distal border of white patch (A), *Measurement point B*: The tip of flipper to the proximal border of white patch (B) and *Measurement point C* (Angle *θ*): The angle between the proximal boundary line of white patch (B-b) and the longitudinal axis of the flipper (a-c) were measured.

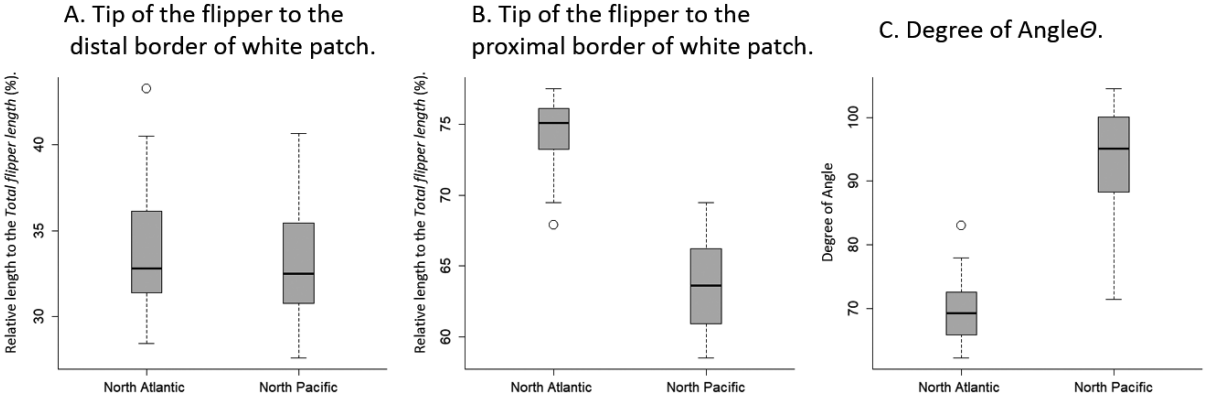

Fig. 4. Comparison of the mean values of three measurement points of the white patch on the flipper from the North Atlantic and North Pacific minke whales. A and B show relative size of the *Measurement point A* and *B* (see Fig. 3) to the *Total flipper length*.

Table 1. Mean values of each measurement points of white patch on the flipper of the North Atlantic and North Pacific minke whales.

Subspecies	Number of samples	A. Relative length between the tip of flipper to the distal border of white patch to the total flipper length (%)	B. Relative length between the tip of flipper to the proximal border of white patch to the total flipper length (%)	C. Angle*Θ*(°)
North Atlantic	15	33.97 ± 3.96	74.31 ± 2.58	70.05 ± 5.74
North Pacific	16	33.08 ± 3.64	63.62 ± 2.91	92.29 ± 10.15

degrees were compared between the two subspecies.

The mean proportion of *Measurement point A* relative to *Total flipper length* was 33.97% (S.D. = 3.96) and 33.08% (S.D. = 3.64) in the North Atlantic and North Pacific common minke whales, respectively. No significant differences were detected (Fig 4-A, Table 1). The mean proportion of *Measurement point B* relative to the *Total flipper length* was significantly larger in the North Atlantic (74.31%, S.D. = 2.58) as compared to the North Pacific (63.62%, S.D. = 2.91) common minke whales ($P < 0.01$; Fig 4-B, Table 1). The mean of *Measurement point C* was significantly distinct between the North Atlantic (70.05 degrees, S.D. = 5.74) and the North Pacific (92.29 degrees, S.D. = 10.15) common minke whales ($P < 0.01$; Fig 4-C, Table 1).

The results of our analysis indicate that clear morphological differences exist in the relative size of the white flipper patch between the two subspecies. Although the mean relative length of *Measurement point A* showed almost the same values between the two subspecies, the relative length of *Measurement point B* was significantly greater in the North Atlantic common minke whales than in the North Pacific ones. This indicates that overall, the North Atlantic common minke whales have a relatively larger white patch area than the North Pacific common minke whales. As mentioned above, the white patch of the dwarf minke whales covers its shoulder region and is much larger than that of North Pacific and North Atlantic common minke whales (Best, 1985; Kato and Fujise, 2000; Arnold *et al*., 2005). Pastene *et al*. (2007) reported that dwarf minke whales are genetically closer to the North Atlantic common minke whales than to the North Pacific ones. Therefore, the shape of the white patch may well serve as a suitable taxonomic feature to distinguish between subspecies of the common minke whale.

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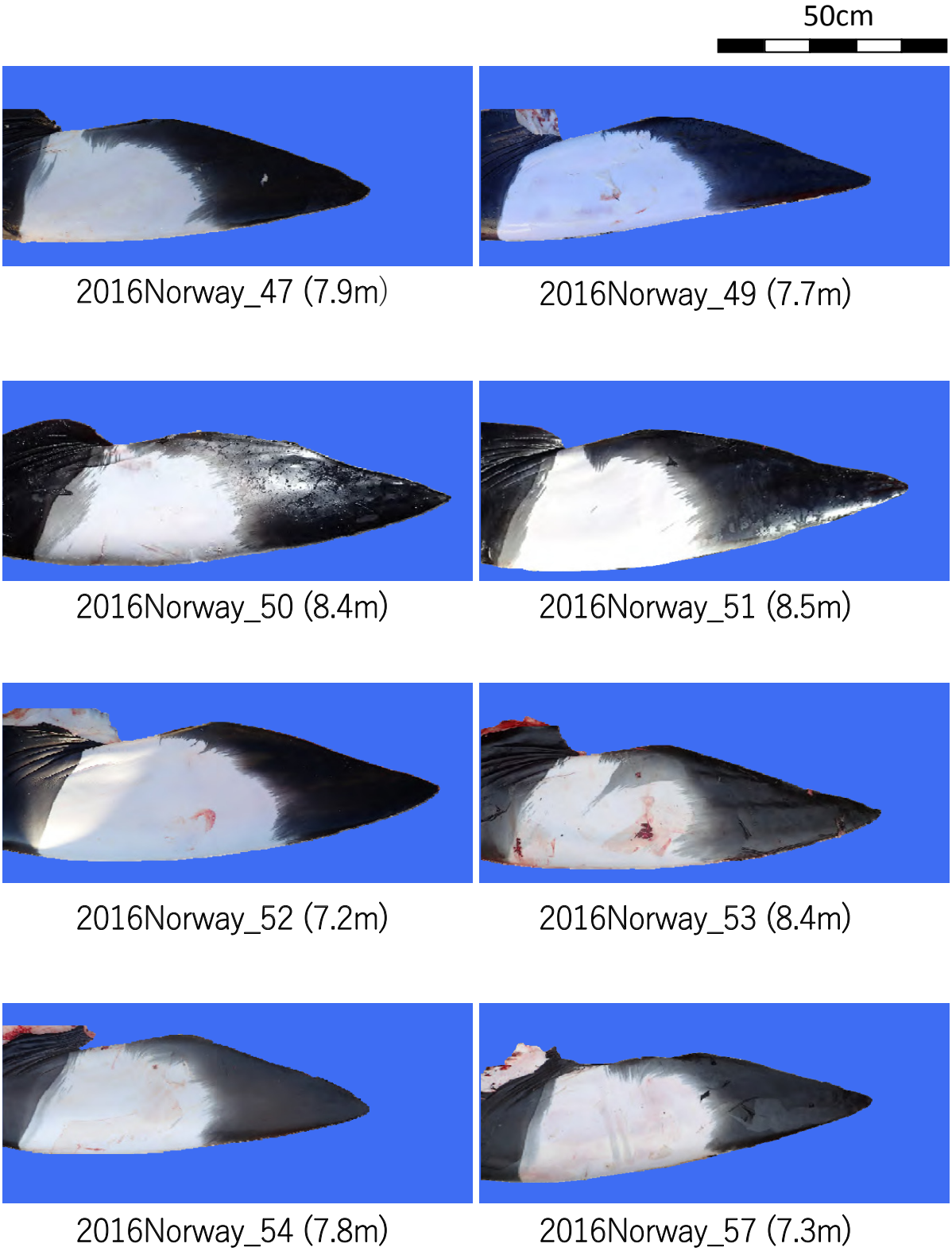
Appendices: Appendix 1-1. Pictures of the left flipper of the North Atlantic minke whale.



Appendix 1-2, (continued).

2016Norway_58 (7.7m)

2016Norway_59 (8.2m)

2016Norway_60 (8.7m)

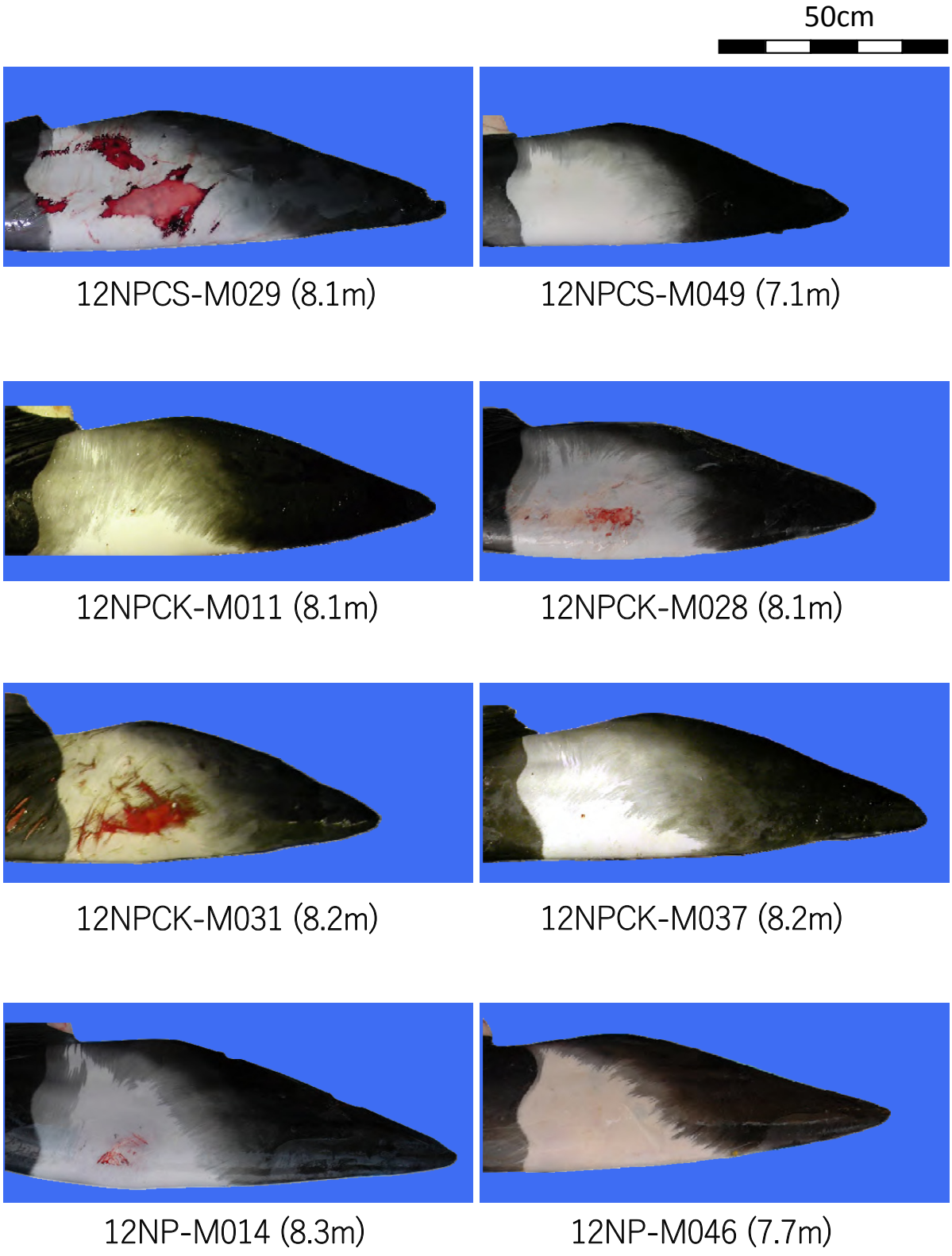
2016Norway_61 (8.0m)

2016Norway_62 (8.5m)

2016Norway_63 (8.5m)

2016Norway_65 (8.3m)

Appendix 1-3. Pictures of the left flipper of the North Pacific minke whale.



Appendix 1-4, (continued).