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Long-term track movement of Antarctic minke whales revealed by satellite-monitored tag experiments conducted by the Institute of Cetacean Research

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ABSTRACT

This paper presents progress of the work on long-term track movement of Antarctic minke whales based on satellite tagging experiments conducted by the Institute of Cetacean Research. In particular, the experiments focused on investigating the migratory links between whales in the feeding and breeding areas. Five examples of northward tracks from Antarctic feeding areas in the Indo-Pacific sector of the Antarctic to lower latitudes areas are presented. The five tracks suggested some migration patterns in the Indian and Pacific Oceans. These results showed that tracking of Antarctic minke whales by satellite-monitored tags provides precise and direct evidence of migratory links. This work should be continued and the number of whales tagged should be increased. This information will greatly assist the interpretation of the stock structure hypothesis of Antarctic minke whales derived from genetic and sighting data analyses.

INTRODUCTION

Understanding the stock structure of whales is crucial for assessment and management purposes. The Antarctic minke whale *Balaenoptera bonaerensis* (hereafter AMW) is one of the most abundant species in the Southern Hemisphere, and its abundance exceeds 500,000 animals (IWC, 2012). As in the case of other rorqual whales, the AMW is assumed to migrate between winter tropical and sub-tropical breeding areas and summer Antarctic feeding areas (Kasamatsu *et al.*, 1995). However, evidences of direct links are scarce. Only three Discovery tag-marked AMWs were recovered at lower latitude areas, showing movements from feeding to breeding areas. An AMW marked at 35°W (east of Antarctic Peninsula) and two AMWs marked at 19°E were recaptured off Brazil at latitude 6°S–7°S in the Atlantic Ocean (Buckland and Duff, 1989). These were the only cases showing direct evidence of links between breeding and feeding grounds for this species.

The Institute of Cetacean Research (ICR) has conducted detailed research of the AMW and its ecosystem in the Indo-Pacific sector of the Antarctic in austral summer, through the former programs JARPA (Japanese Whale Research Program under Special Permit in the Antarctic), JARPAII (the second phase of JARPA) and the NEWREP-A (New Scientific Whale Research Program in the Antarctic Ocean). A summary of the biological and ecological research outputs from these programs is available in Murase *et al.* (2020). In the austral summer 2019/20 the ICR commenced a new non-lethal research program in the Indo-Pacific sector of the Antarctic called JASS-A (Japanese Abundance and Stock-structure Surveys in the Antarctic). The main objective of the JASS-A is the estimation of the abundance and abundance trends of the AMW and other large whale species. Research on the stock structure of large whales is the other main objective of the JASS-A, which is essential for appropriately interpreting the results of abundance estimates.

A review of the stock structure studies on the AMW in the Indo-Pacific sector was provided by Murase *et al.* (2020). The current stock structure hypothesis of the AMW in the Indo-Pacific sector of the Antarctic involves the occurrence of at least two stocks, the eastern Indian Ocean stock (I-stock) and the western South Pacific stock (P-stock) (IWC, 2008; Pastene and Goto, 2016; Kitakado *et al.*, 2014; Murase *et al.*, 2020). These stocks are presumed to be related to the breeding areas for this species suggested by Kasamatsu *et al.* (1995) based on sighting density indices. Figure 1 shows a schematic representation of the distribution of the I- and P-stocks in the Antarctic feeding grounds and the geographical locations of the low latitude breeding areas suggested by Kasamatsu *et al.* (1995).

One of the important aspects to be investigated is the

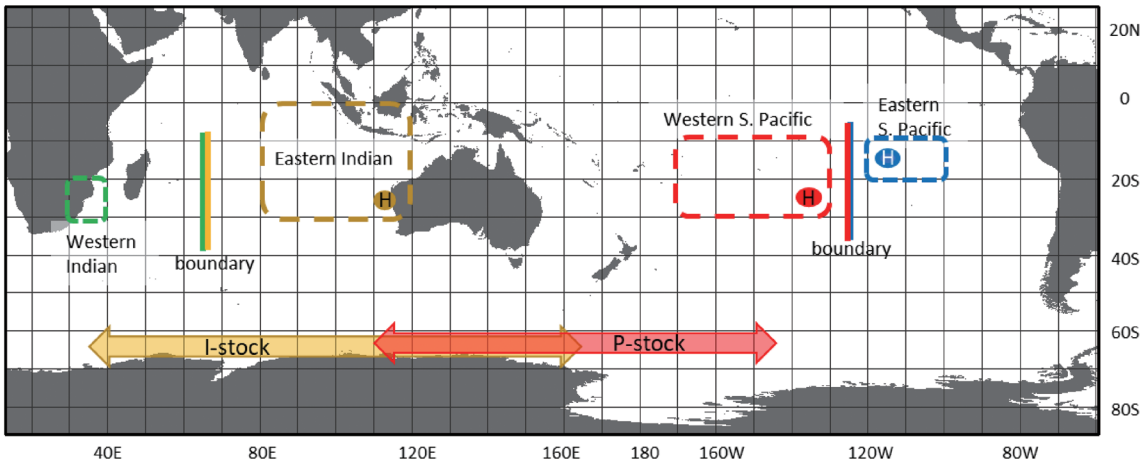

Figure 1. Hypothesis on stock structure of Antarctic minke whales in the feeding grounds of the Indo-Pacific sector of the Antarctic derived from genetic analyses (I- and P- stocks) (IWC, 2008; Pastene and Goto, 2016; Kitakado *et al.*, 2014) and location of breeding areas of this species suggested by the sighting records (Kasamatsu *et al.*, 1995). The figure shows the distribution of the eastern Indian Ocean stock (I-stock) and western South Pacific stock (P-stock) (Pastene and Goto, 2016), and an overlap sector (Kitakado *et al.*, 2014). The four breeding areas suggested by sighting density indices (Kasamatsu *et al.*, 1995) are also shown with dashes-line, and the highest density parts are marked with the letter "H". Vertical bars represent possible boundaries (Kasamatsu *et al.*, 1995).

links between the hypothesized stocks in the feeding areas and breeding areas. Satellite tracking of whales can be useful for this purpose. Long-term tracking of AMWs were previously reported (Lee *et al.*, 2017; Konishi *et al.*, 2020). However only a few tracks showed evidence of northward migration pattern from the Antarctic Peninsula (Lee *et al.*, 2017).

This paper presents the progress on the work of long-term track movement of AMWs based on satellite tagging experiments conducted by the ICR. Information on the link between whales in the feeding and breeding areas will greatly assist the interpretation of the stock structure hypothesis in the feeding ground based on genetic analyses.

TAGGING EXPERIMENTS ON ANTARCTIC MINKE WHALES BY THE ICR

In this report, tagging results using SPOT6-type tags, which are designed to investigate horizontal movement, are presented (Wildlife Computers Inc.; Figure 2). The tags were deployed using an air compressed launcher LK-ARTS (Figure 3), fired from the research vessel *Yushin-Maru* No.2 (Konishi *et al.*, 2020). Five tracking records with clear northward migration movements were selected for this paper.

Long-term track movement of AMWs

The five northward tracking movements of AMWs are shown in Figure 4 and the relevant data are presented

Figure 2. SPOT6-type tags (Wildlife Computers Inc.) connected to ICR's ISOD-type anchor and LK-Carrier.

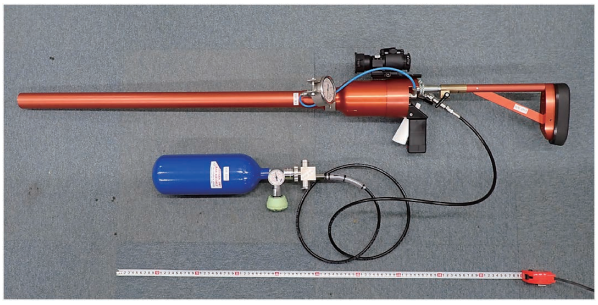

Figure 3. Whale tagger LK-ARTS used during the NEWREP-A and JASS-A tagging experiments.

in Table 1. The tag deployments were made in the sector 10°E–30°E (west of Indian Ocean Sector) and in the sector 170°W–140°W (Pacific Sector), south of 60°S. These records indicated that the western and eastern movements seem to be closely related to the direction of westward Antarctic Coastal Current and eastward Circumpolar Current, respectively (see Nicol *et al.*, 2000).

Two AMWs in the Indian Ocean Sector were tagged in

Figure 4. Five cases of northward tracking movement of Antarctic minke whales tagged during the NEWREP-A and JASS-A programs. All deployments were conducted during the austral summer on the feeding ground. Two former whaling locations in South Africa and Brazil are also shown.

Table 1
Relevant data of five satellite-tracked Antarctic minke whales in Figure 4 during the NEWREP-A and JASS-A programs.

Tracking colour	Tracking periods	Locations of deployments	Location of last transmission
Green	2 Feb. 2020–2 Sept. 2020	68.5°S; 14.6°E	30.5°S; 35.1°E
Blue	28 Jan. 2021–1 Jul. 2021	69.2°S; 19.4°E	40.2°S; 67.5°E
Red	27 Feb. 2018–3 Jun. 2018	76.7°S; 163.9°W	46.7°S; 140.7°W
Purple	6 Feb. 2022–6 Aug. 2022	71.5°S; 133.4°W	15.9°S; 109.2°W
Yellow	28 Jan. 2022–1 Jul. 2022	66.6°S; 129.8°W	59.9°S; 104.3°W

a similar longitudinal sector, however they showed different movement patterns. One animal moved eastward and started migrating to the north around 70°E (blue in Figure 4). The other animal showed a westward movement along the Antarctic coast, then changed its course to the east at 45°W in the offshore area, then started migrating in the northeast direction. This animal finally arrived at the area off the coast of Durban, South Africa, in September (green in Figure 4).

In the Pacific Sector, AMWs moved into the Ross Sea at first, then one whale started migrating to the east (yellow in Figure 4). Two others moved first to the east and then to the north (red and purple in Figure 4). The longest tracked animal showed northward migration and finally arrived at 16°S; 109°W in August.

In the previous study by Lee *et al.* (2017), two AMWs tagged in the west of the Antarctic Peninsula showed northward migration at different longitudinal bands in the Pacific Sector, while another one moved into the Atlantic Sector.

Interpretation of movements in the context of stock structure

The five cases of tracking AMWs presented in this paper demonstrated that their longitudinal range of movement at the feeding area are wider than previously reported (up to 80°). On the other hand, the migratory corridors to breeding areas involve a wide longitudinal range. In addition, AMWs appear to move in the northeast direction when they start the migration to the breeding areas. These latitudinal movement patterns will assist the interpretation of the stock structure hypothesis of this species in the Indo-Pacific sector of the Antarctic derived from genetic analyses.

As indicated earlier, the current hypothesis on stock structure by genetic evidence in the Indo-Pacific sector of the Antarctic feeding grounds involves at least two stocks, the I-stock and the P-stock (Pastene and Goto, 2016) (Figure 1). These authors suggested that the former could be related to the breeding area in the eastern Indian Ocean while the latter could be related to the breeding area in the western South Pacific suggested by sighting density indices examined by Kasamatsu *et al.* (1995). It is important to note that no genetic analysis has been conducted on whales in the hypothesized breeding areas at lower latitudes and that the genetic relationship among the proposed breeding areas remains unknown.

Indian Ocean sector

One of the whales tagged in the Indian Ocean Sector of the Antarctic reached the coast of Durban, in South Africa (Figure 4). This location corresponds to the western Indian

Ocean breeding area proposed by Kasamatsu *et al.* (1995) and Best (1982). This is a critical piece of evidence on movement from the tagging program conducted by the ICR. The migratory track of the second whale tagged in the Indian Ocean sector of the Antarctic is not complete therefore the migratory destination of this whale in the Indian Ocean is unknown. It should be noted that the two tracked AMWs were both at 0–10°E in the feeding ground.

Pacific sector

The migratory patterns of the three AMWs tagged in the Pacific sector of the Antarctic (Ross Sea) to lower latitudes were different from each other, however, they all moved in a northeast direction (Figure 4). The whale with the longest tracking record arrived at latitudes<20°S, in the eastern Pacific Ocean breeding area proposed by Kasamatsu *et al.* (1995). The final migratory destinations of the other two whales are unknown. However, the incomplete movement pattern, in particular that of the 'yellow' whale, suggests that it is unlikely that they reached the western South Pacific breeding area (Figures 1 and 4).

The three whales were tagged initially in the Antarctic in a sector corresponding to the P-stock (Figure 1). Assuming that whales in the proposed breeding areas of the western and eastern South Pacific Ocean are differentiated genetically, the tagging data are consistent with the notion that whales from genetically differentiated breeding stocks mix spatially in the feeding grounds, in this case in the Ross Sea. Mark-recovery tags in the past showed that AMWs marked in the Atlantic feeding ground at 35°W were recovered in the breeding area off Costinha, Brazil in the Atlantic Ocean (Buckland and Duff, 1989), suggesting that whales from a breeding ground (Brazil) could be distributed in a very distant feeding ground.

Future works

The number of tagged whales should be increased in the Indo-Pacific sector of the Antarctic. In particular, Antarctic minke whales in the core areas of distribution of the hypothesized I- and P- stocks should be targeted in the future. Technological improvement of the satellite tagging is also required in order to increase the duration of tracking whales.

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