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Utility of data logging for the estimation of availability bias in sighting surveys

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ABSTRACT

This paper describes the progress of the work by the Institute of Cetacean Research on satellite-based data logging experiments conducted with the aim of obtaining diving and surfacing duration data of the Antarctic minke whale for estimating availability bias. The paper is organized to provide information on field equipment for tagging, the data obtained on Antarctic minke whale and results of preliminary estimation of availability bias. Tags were successfully attached to Antarctic minke whales, and some diving and surfacing duration data were obtained. Based on these data, estimates of availability bias are presented. However, such estimates should be considered as preliminary and further experiments to obtain additional behavioral data are recommended.

INTRODUCTION

Abundance estimates of whales based on sighting data and the distance sampling method are affected by a negative bias called 'availability bias' (McLaren, 1961; Marsh and Sinclair, 1989). To address this point, Laake *et al.* (1997), Okamura *et al.* (2012) and Borchers *et al.* (2013) presented analytical methods that used whale diving and surfacing duration data to correct for availability bias. These studies were based on diving and surfacing duration data from visual observations or from archival tags. However, visual observation is not ideal for obtaining data on diving and surfacing behavior particularly in elusive species such as the Antarctic minke whale. Also, retrieving archival tags over several days while conducting the sighting survey is not a practical approach.

Satellite tagging provides a new and useful alternative to in obtaining data on diving and surfacing behavior. Satellite tags were deployed on Antarctic minke whales during the 2021/22 and 2022/23 Japanese Antarctic Sighting and Stock structure Survey (JASS-A) surveys with a particular aim to obtain diving and surfacing duration data. Such data could be used to estimate availability bias following some of the methods indicated above.

This paper briefly reports the details of field equipment for tagging, the data obtained on the Antarctic minke whale and the results of preliminary estimation of availability bias.

FIELD EQUIPMENT FOR TAGGING EXPERIMENTS

The following equipment was used in the tagging experiment:

– Satellite tags (SPLASH10-f-333, Wildlife Computers, US) in the Low-Impact Minimally Percutaneous External electronics Tag (LIMPET) with two 6.8 cm darts and six petals;
– Aerial Rocket Transmitter System (LK-ARTS, Skutvik, Norway); and
– Deployment arrows (originally developed by Wildlife Computers and modified by the Institute of Cetacean Research [ICR]) (Figure 1).

The deployment arrows and tag were attached using adhesive (Aron Alpha Jelly, TOAGOSEI Co., LTD., Japan). The tags were shot from the bow deck (8 m above the sea) using an LK-ARTS, with air pressure set at 14 bar. The video of the experiment in the Antarctic Ocean can be seen at the following URL: https://www.youtube.com/watch?v=_wlSpleQEM8.

The SPLASH 10-f-333 can be configured to define specific ranges of diving and the types of data sought using the software Mk10 Host (Wildlife Computers, 2023). Data such as the maximum depth of each dive and the duration of diving and surfacing are received, rather than a full-resolution diving behavior.

In this study, the tags were configured to provide data for each diving and surfacing event as behavior message. A whale was considered diving when it penetrated deeper

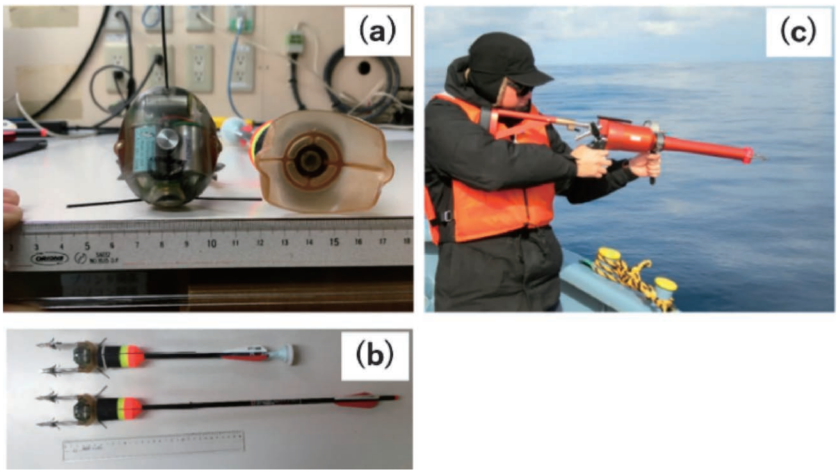

Figure 1. Equipment for satellite tagging: the satellite tags (SPLASH10-f-333) and the cup of the deployment arrow (a); original arrows developed by Wildlife Computers for a crossbow (b); and aerial rocket transmitter system (LK-ARTS) (c).

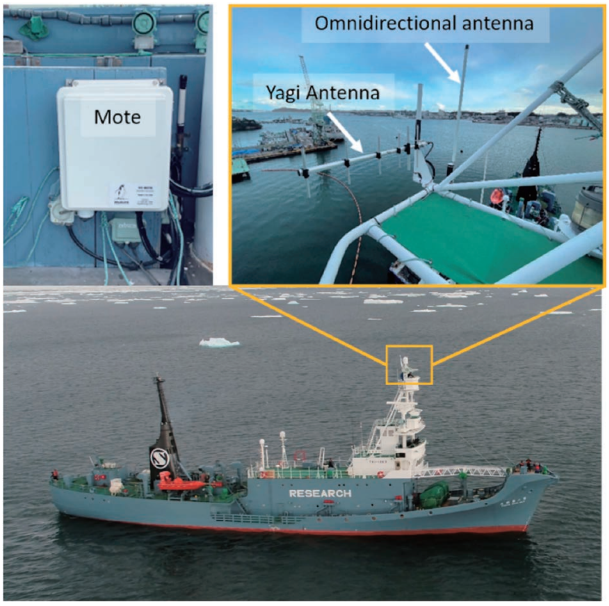

Figure 2. Mote Enclosure mounted on the upper bridge (upper left), and Yagi and omnidirectional antenna mounted on the top barrel of the research vessel (upper right). By connecting an USB memory stick to the Mote Enclosure, the data received by the antenna can be retrieved (the retrieved data must be decoded by Wildlife Computers portal).

than 4 m. The start and end of the recording were based on a depth of 1 m, and the sampling interval was one second. The percentages of time spent in arbitrary depth bins (0; 1; 3; 5; 10; 30; 50; 100; 150; 200; 250; 300; 400; >400 m) were obtained, and the diving duration bins (10; 20; 30; 40; 50 sec; 1; 2; 3; 4; 5; 10; 15; 20; >20 min) were recorded 12 times a day at two-hour intervals starting at 00:00 UTC. Tags were programmed to transmit 24 hours a day and were limited to 3,000 transmissions per day.

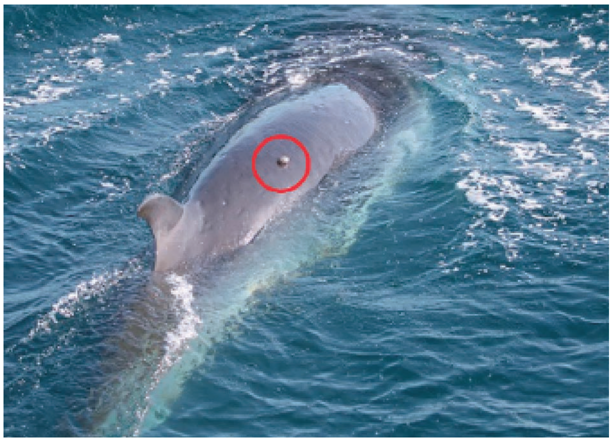

Figure 3. Antarctic minke whale with a SPLASH10-f-333 tag attached on 2 February 2022, at 71°16′S, 132°10′W. The red circle indicates the attached position of the tag.

Mote (Wildlife Computers, US) is a stationary listening station and can continuously log telemetry data from satellite tags on animals within the reception range (Jeanniard-du-Dot *et al.*, 2017). Mote was installed on the research vessel (*Yushin-Maru* No. 2, *YS2*), and Yagi and omnidirectional antenna were equipped on the top barrel (approximately 20 m above the sea level) (Figure 2). The Yagi antenna has directivity and about a 60° beamwidth within which distant signals (about 8.5 nautical miles when placed at 20 meters) were received. The omnidirectional antenna can receive signals from all directions, but the distance will be shorter.

DATA OBTAINED

In the 2021/22 JASS-A survey, two Antarctic minke whales were tagged. Figure 3 shows the tag attached to the whale′s body (PTT 207827). The vessel tracked this

Table 1
Details of diving and surfacing duration data of an Antarctic minke whale tagged in the 2021/22 JASS-A survey. Data obtained from 6 February 00:01:00 (UTC) to 17 February 13:33:24 (UTC) 2022.

PTT ID	Number of days with data obtained	Type	*n*	duration mean (sec)	SD	Duration min (sec)	Duration max (sec)	Duration range (sec)
207827	11.6	Dive	50	196.52	145.91	6	680	674
		Surfacing	50	39.12	65.55	2	348	346

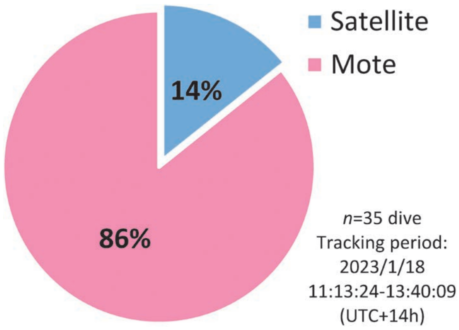

Figure 4. Percentage of behavioral data recorded by satellite and Mote from an Antarctic minke whale tagged in the 2022/23 JASS-A survey.

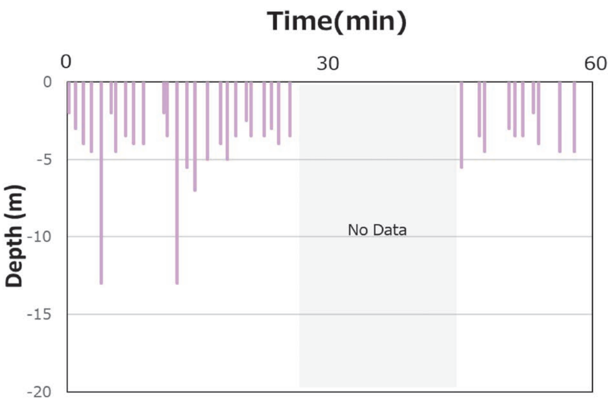

Figure 5. The diving behavior of an Antarctic minke whale (PTT 224705) tagged during the 2022/23, and recorded for 60 min after tag attachment. This whale repeatedly dived at depths shallower than 15 m. There were periods when data was not received even while the Mote was tracking the individual.

individual and stayed more than 0.5 n.miles away from the whale during the tracking. During the tracking diving and surfacing duration data were received via Mote consecutively for 26 min, but no data were received via satellite. The diving and surfacing duration of this whale are summarized in Table 1. Although the tag was attached to the whale for more than 10 days, only 50 dives were recorded in total. This is possibly because the tag was not sufficiently out of the water and the signal was weak.

In the 2022/23 survey, two Antarctic minke whales were successfully tagged. Antarctic minke whale (PTT 224705) was tracked on 18 January 2023, from 11:13 to 13:40 (UTC+14 hours) and data were received via Mote. There were 35 dives recorded during the tracking. Of these, 30 dives were recorded by the Mote, indicating its usefulness (Figure 4). The time duration of the attached tag on the water surface may be too short to transmit behavior messages to a satellite.

The Mote is suited for acquiring a large amount of data and can obtain each diving and surfacing duration of a whale, which is challenging to collect by satellite alone.

Figure 5 shows the diving behavior of the same whale recorded for 60 minutes after the tag was attached. The time period during which data could not be received, even when the Mote was running, suggests that it is particularly difficult to receive data from this species.

ESTIMATION OF AVAILABILITY BIAS

Table 2 summarizes the Antarctic minke whale's diving and surfacing duration data (PTT 224705) obtained during the 2022/23 JASS-A survey. Using the values of surfacing duration of 4.54 s and diving duration of 60.03 s, a preliminary estimation of availability bias was conducted based on the relatively simple method of Laake *et al.* (1997) under the following two survey cases: the first case is the ICR's vessel-based visual survey (see Isoda *et al.*, 2020), and the second is the ICR's planned UAV-based aerial survey (see Matsuoka and Yoshida, 2021; Katsumata and Yoshida, 2023).

Laake *et al.* (1997)'s formula to estimate availability bias is:

$$a = \frac{E(s)}{E(s)+E(d)} + \frac{E(d)\left[1-\exp\left\{-\frac{t(y_{max})}{E(d)}\right\}\right]}{E(s)+E(d)}$$

where a is the probability of a single whale being available on the transect line, $E(s)$ is the mean duration of surfacing, $E(d)$ is the mean duration of diving, and $t(y_{max})$ is the amount of time the ocean is in the observer's view on the transect line.

Table 2

Details of diving and surfacing duration from behavior messages on an Antarctic minke whale in the 2022/23 JASS-A cruise. Data were obtained from January 18, 2023, 11:13:24 (UTC+14h) to 13:40:09 (UTC+14h).

PTT ID	Type	*n*	Duration mean (sec)	SD	Duration min (sec)	Duration max (sec)	Duration range (sec)
224705	Dive	35	60.03	37.54	1	162	161
	Surfacing	35	4.54	1.79	2	12	10

Case 1: Vessel-based visual survey

Here it is assumed that the survey speed is 11.5 knots (approx. 21 km/h) and that an Antarctic minke whale can be sighted up to 2 n.miles ahead. Under these assumptions, the value of $t\ (y_{max})$ is 626.1 seconds; that of a is 1.00. This suggests that there are no missing Antarctic minke whale in the vessel-based survey due to diving.

Case2: UAV-based aerial survey

Here it is assumed that the survey speed is 43 knots (approx. 80 km/h), and that the UAV flies at an altitude at 100 m above the sea and that the camera captures a range 0.1 n.miles directly below the aircraft. Under these assumptions the value of $t(y_{max})$ is 8.4 seconds; that of a is 0.19. This suggests that more than 80% of Antarctic minke whales are not sighted due to diving.

DISCUSSION

This study presented the results of the first tagging experiment using SPLASH10-f-333 on Antarctic minke whales during Japanese whale surveys in the Antarctic. Tags were attached and data were obtained. Thus, this first attempt can be considered successful. This approach proved to be useful to obtain diving and surfacing duration data from an elusive species as is the case with the Antarctic minke whale. However, a data gap was observed in the behavior message even while Mote was active (Figure 5). In the case of animals that repeatedly make short diving, it is possible that too many behavior messages were created and transmitted. Since SPLASH10-f-333 can set the diving definition and types of data produced in a flexible way, it is important to set it to a configuration that maximizes the data collection relevant to the estimation of availability bias.

Laake's method has been applied to vessel-based visual surveys previously (e.g. Weir *et al.*, 2021). However, this method assumes that whales above the sea surface will always be sighted regardless of forward distance. However, the Antarctic minke whale has small blows and sometimes only the body is visible. Therefore, the assumption that these whales are always sighted up to 2 n.miles ahead is unlikely to be met. As a consequence, availability bias could be overestimated with this method, leading to an underestimation of abundance estimation. As for the vessel-based visual survey, the detection probability should be considered for the forward distance, as was described in Borchers *et al.* (2013).

For the aerial survey, the value a 0.19 is considered reasonable, because it is similar to Hansen *et al.* (2018), which estimates availability bias on aerial surveys using Laake's method for common minke whales in the North Atlantic Ocean. However, in the case of the aerial survey, the availability bias changes depending on the depth to which whales can be detected. The data in this study assumed that it can be detected when shallower than one meter, but this assumption also needs to be examined in the future. In both cases, the sample size of the diving and surfacing duration is still small, so it is necessary to accumulate more data to accurately correct the availability bias of abundance estimates using the distance sampling method.

In the 2022/23 JASS-A surveys, one fin whale and two humpback whales were successfully tagged and data on diving and surfacing duration were obtained. These data will be used to estimate the availability bias for these species in the near future.

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