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NOTE

Tagging young humpback whale calves: methodology and diving behavior

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ABSTRACT: Despite the importance of young animals to the proliferation of a species, logistic hurdles often prevent the study of individuals' behavior and habitat requirements. This is particularly an issue in the case of cetaceans, which spend a large proportion of their time at depth. We conducted a study to describe the dive behavior of young humpback whale *Megaptera novaeangliae* calves on their breeding grounds in Hawaii, USA. We first implemented and evaluated strategies for approaching whale groups and deploying suction-cup tags (DTAGs), resulting in 3 successful attachments of DTAGs in the winter of 2011. The approach technique that was most successful while minimizing reactions from the whale groups was a passive drift approach. Tagged calves exhibited consistent dives to shallow depths when their groups were stationary, and some deeper dives that approached the ocean bottom, up to 78 m in one case. Mean dive durations ranged from 2.2 to 3.5 min, with calves spending 40% of their time within 3 m of the surface. This is the first study to collect tag data from baleen whale calves less than 6 mo in age and provides habitat use data important for management of this endangered species.

KEY WORDS: Humpback whale · Calf · Tagging · Diving behavior · Hawaii

INTRODUCTION

Juvenile and calf survival is critical for the propagation of a species, especially for large, long-lived species that have few offspring, such as cetaceans. It is therefore important to understand the habitat use of very young animals in order to ensure their healthy development, particularly in the case of endangered species. The use of biologging tags is developing as a comprehensive way to study the underwater behavior of many marine mammals. In some species, such as pinnipeds, young animals can be instrumented and their behavior documented relatively easily (e.g. Raum-Suryan & Rehberg 2004, Pitcher et al. 2005, Rehberg & Burns 2008, Watanabe et al. 2009). Unfortunately, pelagic cetaceans are more difficult to access, and data are lacking on young calf behavior in many species. For humpback whales *Megaptera novaeangliae*, one of the best-studied baleen whales, little is known about the dive behavior of calves except what is seen during underwater observations and video by snorkelers and divers and what is inferred from patterns of surface behavior and respirations (Szabo & Duffus 2008, Zoidis et al. 2008, Cartwright & Sullivan 2009b, Felix & Botero-Acosta 2011).

Data from tags can give a continuous record of dive behavior and may have a smaller influence on animals than a focal follow vessel or a snorkeler. However, because of the close approach and high level of harassment thought to be involved in tag attachment, until suction-cup tags had been tested on adults and

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proven to be low-impact, scientists and managers refrained from deploying them on young calves. Tagging of adults with suction-cup tags has been reported to elicit mild and short-term reactions in most large species (Hooker et al. 2001, Johnson et al. 2009), although some smaller species have reacted more strongly and for a longer duration (Schneider et al. 1998). Biopsy sampling of large whales, which also involves close boat approaches, has also resulted in only mild behavioral reactions (Weinrich et al. 1992, Clapham & Mattila 1993, Brown et al. 1994). Given this precedent, we believed that, if conducted mindfully and conservatively, tagging of calves has the potential to yield valuable information on young animal behavior with minimal distress to the approached and tagged individuals.

Our goals with this manuscript are 2-fold. First we document our field procedures for tagging humpback whale calves on their breeding grounds, comparing 2 approach tactics and making recommendations on strategy for future experiments tagging young baleen whale calves. We then present a basic description of the diving behavior of the tagged animals, the first such description for this life stage of a baleen whale.

MATERIALS AND METHODS

Study location

This research was conducted between February 21 and March 4, 2011 in the leeward waters of Maui, Hawaii, USA. The research vessels included the RV 'Hihimanu' (hereafter 'big boat') and a 17 ft inflatable. The big boat was an 11 m safe boat style vessel with twin 250 hp Mercury 4-stroke outboard engines. The inflatable had a 25 hp Mercury 2-stroke outboard engine and could also be propelled by 2 people paddling with oars.

Tags

Humpback whale calves and their mothers were approached for tagging with suction-cup attached tags (DTAGs) that contained a hydrophone (description of acoustic data is beyond the scope of this paper) as well as a pressure sensor and 3-axis accelerometer and magnetometer, which were used in these analyses to produce depth and pitch according to the procedures in Johnson & Tyack (2003). Tags were deployed using a 7 m handheld carbon-fiber pole and stayed attached to the whale for a programmable duration (until dusk, in our case, due to logistic constraints).

Field procedure

Because it is generally accepted that mother–calf pairs show increased sensitivity to boat approach, we documented our approach techniques, varying approach platform and speed to identify the most appropriate method for tagging. We broke our efforts down into 3 stages. A whale group was initially observed from a position outside 100 yd (ca. 91 m) for at least 3 dive cycles to assess its behavior and to determine whether it was an appropriate group for tagging (Stage 1). We targeted groups that were not traveling quickly or erratically and groups in which the mother–calf relationship indicated some level of calf independence. Indications of this included lone calf surfacings, longer breath-holding capabilities by the calf, greater distances between the mother and calf during surface intervals, and less general synchrony between the 2 whales. The calves we approached also had a low degree of furl in their dorsal fin, and we believe these calves to be of the older age class, 'age class 2' as determined by Cartwright & Sullivan (2009b). Ages of calves approached were estimated to range between 1 and 3 mo.

Once determined to be acceptable for tagging, groups were approached inside 100 yd (91 m) (Stage 2). The entire encounter or sequence of maneuvers while within 100 yd (91 m) was considered an 'approach,' under guidelines from the National Marine Fisheries Permit (no. 14682) under the Marine Mammal Protection Act. Within this approach, we defined a third stage, or 'attempt' (Stage 3). This encompassed a tagging event, a swing of the tagging pole, or a close and assertive boat approach with the intent to tag. No more than 3 approaches or 3 attempts per individual were performed.

Attempts varied according to some combination of the 2 research platforms ('big boat' and 'inflatable') and motoring ('active') or drifting/paddling ('passive'). Reactions to tagging attempts were determined in accordance with previous research (Weinrich et al. 1992, Hooker et al. 2001; and see Fig. 1). Choice of approach method depended on whale behavior. The passive approaches required a group that was stationary. For these, the estimated location of the whale group under water was determined based on the location of the terminal dive by the mother before a period of calf milling. It is a common resting behavior on the

Hawaiian breeding grounds for the calf to surface alone, swim in a circle, and dive back down to the mother's stationary location at depth ('circling intervals' in Cartwright & Sullivan 2009b). This is due to the calf's need to breathe more frequently than the mother. We tried to position the boat near the calf's predicted surfacing position, minimizing underwater noise by using either a slow idle engine speed combined with a drift, or when in the inflatable, paddling with the engine off. If the calf surfaced close enough to our location, a tag was attached.

Active approaches involved following the whales under power while they were moving at the surface. All active approaches were done at slow speeds (1 to 2 knots), and approaches were terminated if the whales showed evasive swimming patterns or signs of disturbance such as tail swishes or 'tonal' or 'trumpeting' blows. A tag was deployed if the boat was able to come alongside the whales in close enough proximity for attachment.

Once DTAGs had been attached, the research vessel retreated to a following distance of 100 yd (91 m) or more and commenced a behavioral focal follow (Altmann 1974) of the tagged animal until tag detachment. Regardless of whether a tag was successfully attached, we continued to track groups for a minimum of 3 calf dive cycles to verify that the group returned to its pre-approach behavioral state.

Data analysis

Pressure and accelerometer data were calibrated and processed using custom tools in Matlab 2007b. A dive was defined as any excursion below 10 m, which is approximately 2 calf body lengths. Calves regularly exceeded the 1 body length limit while exhibiting surface active behaviors, so 10 m was chosen to target actual dives and eliminate incidental body movements. Dive metrics were chosen according to guidelines established for describing cetacean dive behavior (Hooker & Baird 2001). Bottom depths in areas of calf diving were estimated using ArcGIS and Shoals light detection and ranging (LIDAR) data collected by the US Army Corps of Engineers.

RESULTS

Tagging

A total of 27 whale groups were approached for tagging during the 2 wk field season, and tags were successfully deployed on 3 occasions (whales were named 'c055,' 'c059,' and 'c060' based on the day of the year on which they were tagged; Fig. 1). One moderate reaction occurred during a passive big boat approach, during which a small piece of PVC tagging equipment broke off and fell in the water in the line of sight of the calf. One strong reaction occurred during a passive inflatable approach, when the male escort in the group breached after a tagging attempt on the calf. The behavior of the mother–calf pair did not change as observed from the surface, but we conservatively scored the reaction as 'strong.' All other reactions were classified as either 'mild' or 'none' except for 1 moderate reaction to an active big boat attempt. All 3 successful attachments were com-

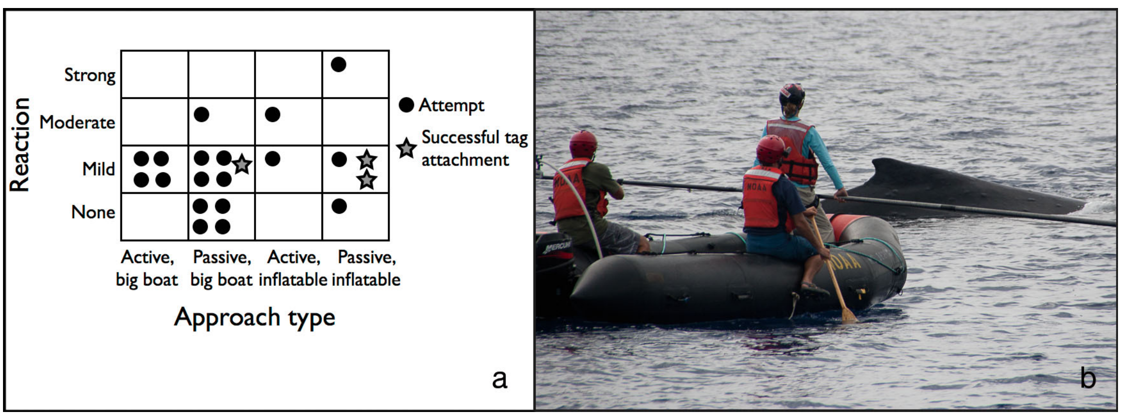

Fig. 1. *Megaptera novaeangliae.* (a) Whale reactions to tagging attempts by approach type. The matrix includes attempts on both mother and calf. 'None' indicates no change in behavior; 'mild' reactions included delayed surfacing, fast dive, small tail flick, or slow evasive swimming; 'moderate' reactions included fast evasive swimming, tonal blows, or large tail flicks; and 'strong' reactions included surface activity or aggressive displays toward the boat. (b) A passive, paddle-up approach in the inflatable vessel

pleted using the passive drift method, and 2 of those 3 involved paddling to the calf's milling location using the inflatable vessel. We saw no evidence of a prolonged effect of the tagging activities; groups that were stationary generally returned to stationary resting behavior within 1 to 2 dive cycles. All 3 tags remained attached for the programmed deployment.

Calf dive behavior

General behavior of the calves (from visual surface observations) included rest/milling, slow travel, and surface active travel, which included surface active behaviors such as breaches, peduncle throws, and tail slaps. One such rest/milling period can be seen during the first half of the dive record of c059, and a surface active period can be seen during the second half of the dive record of c055 (Fig. 2).

The maximum dive depth amongst the 3 calves was 78 m (whale c060), but all 3 calves dove to depths that were close to the estimated sea floor depth on several occasions. Bottom excursion dives can be seen in Fig. 2, based on the estimated bottom depth plotted beneath the dive profile. Both c055 and c060 moved into deeper water during the second half of the deployment and did not continue diving to the bottom.

Dive durations ranged from <1 min to a maximum of 5 min, and there was no strong relationship between dive duration and post-dive surface interval (c055: $r^2 = 0.003$, $F = 0.79$, $p = 0.79$, $n = 25$; c059: $r^2 = 0.005$, $F = 0.16$, $p = 0.69$, $n = 35$; c060: $r^2 = 0.07$, $F = 5.4$, $p = 0.02$, $n = 69$). Mean and modal maximum dive depths were similar, between 14 and 25 m, respectively, although tagged calves overall spent 40% of their time between 0 and 3 m. Descent pitch magnitude was significantly steeper than ascent pitch magnitude (paired *t*-test using means for each individual: $t = -9.4$; $p = 0.01$). Overall dive statistics are summarized in Table 1.

DISCUSSION

Approach techniques and animal reactions

We successfully attached 3 tags to humpback whale calves on the breeding grounds of Maui, Hawaii. This is a low success rate, as 27 whale groups were approached, and multiple approach sequences and/or attempts were performed on each of these

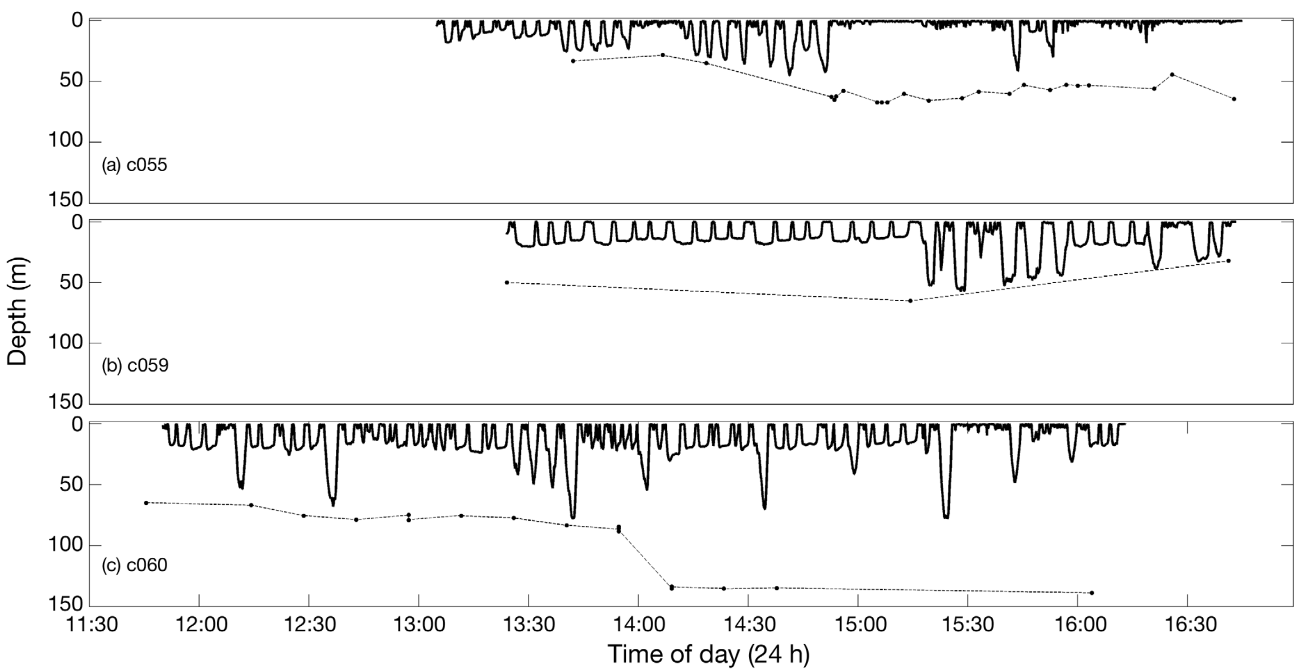

Fig. 2. *Megaptera novaeangliae.* Dive profiles for each of the 3 calves tagged, (a) c055, (b) c059, and (c) c060, aligned by time of day. Estimates of sea floor bottom profile are included as dotted lines, with depth estimates from light detection and ranging (LIDAR) at each data point that was a known geographic location of the tagged calf. Fine-scale bathymetry was not available for c059; therefore, the dotted line for c059 is based only on depth estimates at the tag-on and tag-off locations and on 1 intermediate point, given that the group was stationary for the first half of the tag record

Table 1. *Megaptera novaeangliae.* Summary statistics describing dives from 3 tagged calves. Mean and modal dive depths are the mean and mode of the maximum dive depths for each animal. Maximum depths were rounded to the nearest 1 m before calculation of the modal dive depth. Bottom time is time spent at >85% of the maximum dive depth for each dive. Mean (SD) parameters are listed. Values are reported across all dives >10 m performed by each whale

Whale	No. of dives >5 m	Mean dive duration (min)	Post-dive surface interval (min)	Max. dive duration (min)	Max. dive depth (m)	Mean dive depth (m)	Modal dive depth (m)	Mean bottom time (min)	Dive frequency (no. of dives h^{-1})	Ascent rate ($m\ s^{-1}$)	Descent rate ($m\ s^{-1}$)	Ascent pitch (°)	Descent pitch (°)
c055	26	2.2 (0.7)	4.1 (8.8)	3.3	45.1	24.1 (10.5)	15	0.9 (0.5)	8	0.9 (0.8)	0.6 (0.2)	23.0 (15.4)	–45.1 (15.7)
c059	36	3.5 (1.0)	1.1 (1.2)	5.0	57.3	23.6 (13.2)	14	2.4 (1.0)	13	0.7 (0.3)	0.6 (0.2)	40.8 (20.8)	–56.2 (16.9)
c060	70	2.6 (1.1)	1.2 (2.1)	4.7	78.1	25.2 (15.5)	21	1.3 (0.9)	16	0.6 (0.3)	0.7 (0.2)	37.0 (19.3)	–55.0 (16.1)

groups. Overall, we found that our passive approach method (drifting with the current or paddling to maintain position, and tagging while the calf was alone at the surface) was most effective in minimizing the apparent impact on the group's behavior. Approaches were more difficult when the mother was also present at the surface. Because mothers' surfacing locations were more difficult to predict than those of the calf when groups were stationary, these attempts required a powered approach, which usually elicited evasive swimming from both animals.

Calf dive behavior

Calf mean dive durations averaged between 2 and 4 min, and calves spent the majority of their time near the surface. This was consistent with the 2.1 to 2.9 min mean dive times of age class 2 calves reported by Cartwright & Sullivan (2009a,b), which were measured from surface observations. Dive rates per hour for whales c059 and c060 were also consistent with the rate of 13 dives h^{-1} for age class 2 calves reported by Cartwright & Sullivan (2009a,b). Whale c055 had a lower number of dives h^{-1}, but its dataset included a long (>1 h) surface active period during which there were few dives below 10 m. Calf dive statistics contrasted with those available for adult humpbacks on the breeding grounds, which have shown dive durations up to 25.7 min (Baird et al. 2000) and maximum dive depths up to 240 m (Hamilton et al. 1997).

We found no strong relationship between dive time and post-dive surface interval in the tagged calves. This lack of relationship is similar to adult mysticetes, which are thought to forfeit diving capacity for engulfment and high-energy foraging lunge capacity (Schreer & Kovacs 1997, Goldbogen et al. 2012). However, these calves were not feeding on prey. Although the actual aerobic dive limit and metabolic rate have not been measured for humpback calves, it is likely that calves are diving short of their aerobic capacity and putting extra energy resources toward growth and development during this early life period.

Calves spent more of their time near the surface compared to tagged adult humpback whales: 54 versus 40% in the top 10 m of the water column, and 40 versus 15% in the top 0 to 3 m, calves (this study) versus adults (Baird et al. 2000), respectively. Rates of ascent and descent for adult humpbacks have been measured at 1.29 and 1.51 m s^{-1}, respectively (Baird et al. 2000), which is approximately double the rates exhibited by these tagged calves. The adults were larger, presumably stronger, and diving much deeper (regularly to depths below 100 m), but this difference may also be an indication of developing swimming ability in these young animals.

Periods of calf milling and surface activity were interspersed with deeper dives (up to 78 m) that on several occasions likely transited to the bottom. It would not be surprising if this bottom excursion behavior were routine. A humpback whale calf tagged on the feeding grounds in Antarctica (probably 5 to 8 mo older than the tagged animals in our study) executed many deep dives, including one to nearly 250 m (Tyson et al. 2012), and adult humpback whales have been found to dive to the bottom in the Hawaiian breeding grounds, even continuing competitive behavior at depth and near the bottom (Baird et al. 2000, Herman et al. 2007). In 2 of the 3 cases in our study, however, the groups moved into deeper water and the calves did not increase their dive depth beyond the maxima from earlier in the record.

We do not know how deep the adults in these groups were diving, but this may point towards a maximum depth capability of these younger animals.

SUMMARY AND CONCLUSIONS

Our results indicate that young humpback whale calves and their mothers may be sensitive enough to tagging procedures to merit specialized tactics. We recommend that future tagging studies with young animals be conservative with approach methods and minimize aggressive techniques until the reactions of both mother and calf to different aspects of researcher presence can be assessed. As always, the safety of the researchers should remain paramount. We cannot guarantee that the use of the methods reported here will eliminate the possibility of a strong reaction by any animal in the group that has the potential to inflict injury to scientific personnel or damage to the research vessel or equipment. These methods may also not be appropriate for all species, and particularly in some cases it is prudent to leave the engine running for safety reasons.

Also reported here are the first underwater dive records from tagged humpback whale calves on the breeding grounds. Calves exhibited shorter and shallower dives than previous reports of adults diving on the breeding grounds, suggesting developing diving capabilities, but were still able to transit to the bottom in some cases. These results create an important baseline for future studies of underwater behavior of young large whales. This will be important in assessing habitat requirements and management practices for nursery grounds of this endangered species.

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