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Decreased feeding ability of a minke whale (*Balaenoptera acutorostrata*) with entanglement-like injuries

BRIAN W. KOT
Department of Ecology and Evolutionary Biology,
University of California,
621 Charles E. Young Drive South,
Los Angeles, California 90095, U.S.A.
and
Mingan Island Cetacean Study, Inc.,
285 rue Green,
St. Lambert, Quebec J43 1PT, Canada
E-mail: bkot@ucla.edu

CHRISTIAN RAMP
Marine Zoologie,
Universität Bremen,
Postfach 330 440, 28334 Bremen, Germany
and
Mingan Island Cetacean Study, Inc.,
285 rue Green,
St. Lambert, Quebec J43 1PT, Canada

RICHARD SEARS
Mingan Island Cetacean Study, Inc.,
285 rue Green,
St. Lambert, Quebec J43 1PT, Canada

The effects of nonlethal injuries on the lives of whales are poorly understood. Such effects receive less attention than issues of entanglement frequency and acute mortality. Although fishing gear entanglements are thought to be the largest current threat to whales (Perrin *et al*. 1994) evidence is limited involving any significant effects that may persist beyond the entanglement period.

Here we detail an unusual encounter with a lunge-feeding minke whale (*Balaenoptera acutorostrata*) with fresh entanglement-like injuries to its head and ventral pouch. Although we cannot be certain of the exact cause of these injuries the laceration strongly resembled a rope injury; it was linear with clean edges and had a width typical of most fishing gear ropes in our study area. We also discuss results from a short-term comparative study that tested whether the whale fed differently than five uninjured minke whales feeding in the same area. This information: (1) quantifies how much a rope-like injury can restrict the expansion of a minke's ventral pouch while feeding, (2) provides the first minke whale lunge-feeding velocities from a photogrammetric method using digital video, and (3) describes a new lunge-feeding aerial maneuver for minke whales that is possibly associated with the injury.

Figure 1. Photograph of an injured minke whale (*Balaenoptera acutorostrata*) with a single, linear laceration running circumferentially around the head and ventral pouch. Closed arrow indicates the position of the injury and the open arrow indicates the direction of the lunge. Photo credit: Brian W. Kot/MICS.

On 25 July 2007, we encountered an injured minke whale at 1409 (EDT) repeatedly surface-feeding on capelin (*Mallotus villosus*). It was first observed offshore from Longue-Pointe-de-Mingan, Quebec, in the Gulf of St. Lawrence (Canada) near 50°14′N, 64°09′W. The length was estimated at 7–8 m, which is within the known size range of adult minke whales (Carwardine 1995). We observed the whale, photographed it, and captured digital video footage of its surface-feeding behavior for over 2 h from aboard a 4.8-m rigid-hull inflatable boat. A single, linear laceration ran circumferentially around the ventral pouch near the throat region and continued up both sides of the head near each eye (Fig. 1). It was most visible when the whale lunged above the surface. The laceration penetrated the skin into the blubber and wrapped almost entirely around the head. More extensive open wounds were evident in the ventral and ventrolateral portion of the laceration where it appeared deepest in the pouch wall. These wounds included localized areas where five to six adjacent pleats of the pouch were torn and red muscle tissue was exposed (see Fig. 1–3). No evidence of infection was apparent (Rowntree 1996, Osmond and Kaufman 1998, Knowlton and Kraus 2001).

We filmed as much surface-feeding activity as possible using a SONY HDR-HC3 digital video camera. We then selected feeding sequences that allowed us to analyze two-dimensional kinematics of lunge feeding (Kot 2005). Video clips were transferred *via* a StarTech FireWire card to a laptop computer and individual still frames were extracted from the 4–10-s duration video clips using Adobe Premiere Pro software. Sequences of frames were converted into bitmap images and ImageJ freeware (http://rsb.info.nih.gov/ij) was used to analyze feeding motion. Digital landmarks

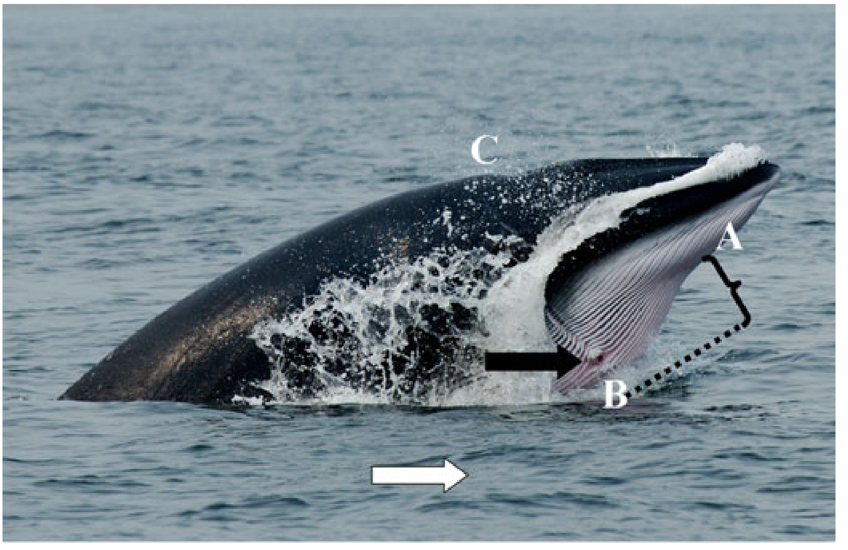

Figure 2. Photograph of the right side of the same injured minke whale. Closed arrow indicates the position of the laceration and an open wound with torn ventral pleats. Open arrow indicates the direction of the lunge. (A) and (B) represent the pouch distention distance. (C) indicates the blow holes (see text for a description of each symbol). Photo credit: Brian W. Kot/MICS.

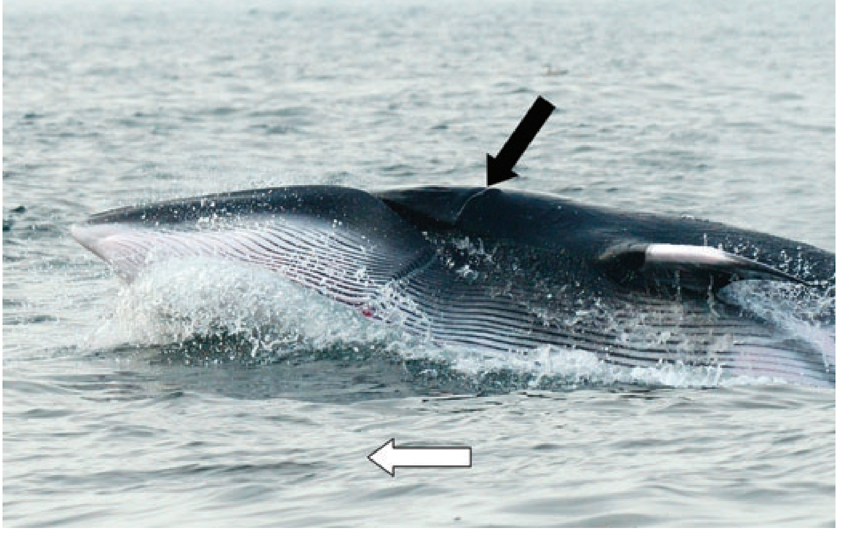

Figure 3. Photograph of the left side of the injured minke whale showing the rope-like laceration. Closed arrow indicates the dorsal-most position of the injury as it extends down the left side of the head and pouch. Open arrow indicates the direction of the lunge. Photo credit: Brian W. Kot/MICS.

were placed on the tip of each whale's rostrum then distances of the movement were measured across a known time period determined from the standard 0.033-s interval between digital video frames. A scale of reference was then applied to each video clip using a digital photograph system where pixels were used previously to measure objects of known size (see Jaquet 2006). This photogrammetric technique allowed us to measure dorsal fin height and then apply the known distance to video still images for calculations of lunge-feeding velocity and ventral pouch distention. Both values were determined for the injured whale and then compared to those from other uninjured minkes in the area ($n = 5$). Table 1 shows a complete list of each whale's lunging velocity, pouch distension percentage, dorsal fin height, and locality information. The measurements of each dorsal fin provided evidence that velocity calculations were not biased by individual size variation in each whale.

The injured minke performed nearly continuous bouts of surface-feeding lunges over 81 min. It lunged 50 times (0.6 per minute) into schools of capelin, which were seen leaping out of the water just prior to the whale's appearance. The whale lunged forward above the surface using either of two feeding techniques: breaching the water while axially rotated 90° onto its right side so the ventral pouch faced our boat (Fig. 1), or breaching the water upright with the rostrum forming about a 45° angle with the surface (Fig. 2). The minke fed within 20–40 m of water depth, similar to that reported by Naud *et al*. (2003). Lunging velocities ranged from 2.1 to 4.0 m/s (mean ± SE = 3.1 m/s ± 0.5), which were within range of those from the five uninjured minkes recorded in the area (1.9–4.7 m/s; mean ± SE = 3.1 m/s ± 0.5). To control for different velocities evident during different lunge-feeding techniques we only analyzed video clips of a similar technique used by all the minkes in this study. Unpaired *t*-test results showed that different velocities were not statistically significant ($P > 0.05$) across injured and uninjured individual whales. This indicates that the injured whale could accelerate normally into prey aggregations.

We defined ventral pouch distention as the maximum observed distance a whale's pouch would extend during feeding. Placement of digital landmarks on video still images allowed us to consistently measure pouch distention that was normal to the longitudinal body axis. The first landmark was placed on the pouch under the mandibles (A in Fig. 2) and the second was placed on the most ventral point of the distended pouch (B in Fig. 2). To ensure consistent placement of landmark B on the curvilinear surface of the pouch we used a reliable anatomical reference landmark, the posterior-most point on the blow holes (C in Fig. 2). The actual position of the relaxed pouch was not possible to measure because our observations only took place when the pouch was fully distended. Therefore, we estimated this position by placing a consistent landmark on an area of the pouch under the mandibles that was not distended (A in Fig. 2). The results for the injured whale showed a mean distention measurement of 208% ± 19 SE from the relaxed position. The results from the uninjured whales showed a mean distention measurement of 265% ± 11 SE from the relaxed position. Table 1 shows the relationship between these measurements and indicates that the difference in distention between the injured and uninjured minkes is statistically significant using an unpaired *t*-test. This means that the injured whale distended its pouch 22% less than the uninjured ones. This may have been due to a

Table 1. Lunge-feeding velocities (LFV), ventral pouch distention measurements (PD) and dorsal fin height (D) from measurements of the injured minke whale and five uninjured minke whales in the Mingan Islands study area (Quebec, Canada) during July 2007. Kinematics of lunge-feeding (m/s) was calculated using photogrammetric techniques similar to Kot (2005). Pouch distension measurements were taken using video still frames imported into ImageJ freeware (http://rsb.info.nih.gov/ij). Individual and mean values (± SE) are presented according to location (latitude and longitude), time and date. Difference in mean PD values between the injured whale and the uninjured ones is statistically significant ($P < 0.05$).

Specimen	LFV (m/s)	PD (%)	D (cm)	Latitude	Longitude	Time (EDT)	Date
Injured minke whale	4.0	170	21	50°14′42″	64°10′18″	14:48:50	07.25.07
	3.4	233	21	50°14′45″	64°10′15″	14:54:22	07.25.07
	2.1	221	21	50°14′20″	64°10′15″	15:27:40	07.25.07
Mean ± SE	3.16 ± 0.5	208 ± 19					
Uninjured minke whales	4.3	264	23	50°15′54″	64°08′16″	08:34:54	07.04.07
	4.7	224	21	50°14′31″	64°08′27″	13:07:19	07.23.07
	2.1	277	24	50°15′47″	64°08′10″	14:24:11	07.24.07
	2.7	273	17	50°15′39″	64°09′01″	07:12:01	07.24.07
	1.9	287	21	50°17′10″	64°01′43″	12:31:55	07.22.07
Mean ± SE	3.17 ± 0.5	265 ± 10	21 ± 1				

restriction in the elastic properties of the ventral pouch caused by the laceration and associated open wounds.

One feeding technique used by the injured minke involved an aerial maneuver that has not been previously described. During this behavior, the whale would breach at a 30°–45° angle with the surface while feeding on its right side. It would rotate axially in mid-air to the left so that it landed upright on its chin. It performed this technique for 18 of the 50 (36%) observed lunges. Throughout the observation period we never saw the whale breach the surface from its left side, or spin in mid-air and land on its left side. This maneuver was used intermittently and always within one to four nonrotational feeding maneuvers. The most consecutive rotational maneuvers were five although 13 of the 18 (72%) occurred as single or doubly consecutive events. Some balaenopterids have been shown to favor their right sides while feeding (Tershy and Wiley 1992, Clapham *et al.* 1995), but this aerial rotation maneuver was not observed in any of the other feeding minkes. Perhaps the discomfort associated with injuries to the left side of the head and ventral pouch caused the whale to avoid landing on its left side during lunges (see Fig. 3).

Assessing the health effects of this injury involves understanding how the whale's feeding abilities were compromised and what long-term repercussions may have resulted. The animal was not emaciated nor did it appear to be in any immediate risk of death. Even though pouch distention was somewhat limited the whale still remained able to overtake and capture prey. If the deepest wounds that penetrated into the muscle were regularly reopened by pouch movements during feeding then some areas of the injury may have taken longer to heal than others. The healing process of similarly lacerated muscles typically forms connective scar tissue that is inelastic (Järvinen *et al.* 2005). Therefore, if scar tissue were to cause discrete areas of restriction (*e.g.*, between individual pleats) along the laceration then collectively they may have formed a shallow circumferential stricture around the pouch, explaining the 22% decrease in distention.

How this injury may have ultimately affected the minke's fitness is difficult to determine without follow-up observations. The high feeding frequency that we observed could be attributed to compensatory feeding behavior used to overcome limited use of the pouch but it would also increase energetic costs that could impact reproductive success. We do not know how long the injury persisted, but the whale's overall healthy appearance suggests that the injury event may have taken place well before our observations. Therefore, despite the effects of the injury and its resulting scars the whale may have learned to live with it. Perhaps the unusual aerial rotation maneuver, posed as a response to some level of discomfort, was an indicator of this behavioral adaptation.

Our photogrammetric technique using video still frames is a noninvasive field method that allowed us to generate some of the first lunge-feeding velocities ever recorded in minke whales. Previous tests on other balaenopterid species have shown us levels of accuracy that are within range of locomotion measurements taken by other researchers using more invasive techniques (Goldbogen *et al.* 2006). However, due to the difficulties of capturing stable video footage that is required for accurate measurements of whale locomotion we recommend using experienced videographers.

We also recommend calibrating the camcorder with moving objects of known velocity (*e.g.*, boat with a speedometer) to determine levels of error in measurements, especially on critical images that are slightly out of focus.

These methods can be applied toward quantifying various aspects of behavior, morphology, and locomotion in whales or any swimming animal at the sea surface. The most useful video footage comes from behaviors that partially or fully expose anatomy above the surface (*e.g.*, surface-feeding or breaching). However, some animals including whales spend very little time at the surface, which limits opportunities for observers to notice injuries. This may contribute to underestimates of entanglement effects in whales with injuries in physical locations that impair detection.

In summary, this investigation provides some of the first knowledge about possible effects of rope-like injuries on the feeding abilities of balaenopterid whales. It also shows how some whales may behaviorally adapt to negative effects from certain injuries. From a management perspective, it suggests that future research involving whale entanglements must include studies of injured animals while they are alive. This field element can be difficult to pursue but its resulting information, combined with more accessible knowledge about entanglement frequencies and acute mortality, is valuable and may provide more complete understanding about nonlethal effects of injuries to whales.

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