Aquatic Mammals 2019, *45*(1), 14-20, DOI 10.1578/AM.45.1.2019.14

Short Note

A Case of Natural Killer Whale (*Orcinus orca*) Entrapment in Northern Norway: From Assessment to Rescue

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Cetacean entrapments are usually caused and maintained by physical barriers such as fishing gear, marine debris, or seasonally forming ice (Reeves et al., 2013; Westdal et al., 2017). A less common type of entrapment can occur when cetaceans enter embayments, estuaries, or other semi-enclosed coastal features and are unwilling or unable to exit following the same (reverse) course. Regardless of their cause, entrapments can lead to mortality of portions or the entire group of animals and pose a conservation threat to small populations. Entrapment events have been documented for a wide range of cetacean species (Reeves et al., 2013) and, in some cases, interventions have been used to free the entrapped individuals (Bain, 1995; Moore et al., 2010; Groom & Coughran, 2012).

On 2 May 2017 (hereafter referred to as Day 1), a group of nine killer whales (*Orcinus orca*) entered an enclosed bay called Trælvikosen, off Brønnøysund on the coast of central Norway. Although killer whales are common in Norwegian coastal waters, this was the first sighting of this species reported in this bay. After several days of repeated sightings, concerns about the potential entrapment of the whales were raised. The very shallow narrow exit, combined with strong tidal currents and the presence of young calves in the group, may have deterred the whales from returning to open water. To identify potential signs of stress and to determine if intervention was necessary, the whales were monitored for behaviour combining land-based observations, aerial drone imagery, and underwater acoustic recordings. Based on this effort and because the confined bay was believed to have few if any prey for these whales known as fish-eaters, members of the local community and scientists carried out a successful operation to free the whales.

Herein, we describe the main behaviours observed throughout the 19 days of entrapment and outline those that were potentially indicators of stress. We further describe the rescue operation step by step. This constitutes the first account, of which we are aware, of natural killer whale entrapment in the scientific literature, providing baseline information for responding to similar cases in the future.

The entrapment occurred in Trælvikosen, a bay located off Brønnøysund on the central coast of Norway (65° 28' 37.28" N, 12° 14' 3.79" E; Figure 1a & b). The bay has a surface area of approximately 1.5 km^2 and is divided into two main pools connected by a 10-m deep channel. The depths in the pools range from 10 to 90 m. Pool 1 opens to the Norwegian Sea through two distinct channels that are 40 and 60 m long and 1 to 3 m deep at low tide. Both channels merge into a single one that leads to open water. The depths in Pool 1 rise rapidly from 35 to 5 m within 50 m of the mouth of the exit channel (Figure 1c). Spring tidal amplitude is 192 cm, and regular tidal amplitude falls to 127 cm. Opportunistic echosounder surveys failed to detect any schools of fish in either of the pools at the time of entrapment (E. Jourdain, unpub. data, May 2017).

Photographs, videos, and observations were opportunistically collected from shore by local residents from Day 1, by scientists from Day 10, and throughout the entrapment and the rescue operation using various digital cameras and lenses. Individual killer whales were identified using scarring and pigmentation patterns on the saddle patch and notches in the dorsal fin (Bigg, 1982). When a calf was seen on multiple days alongside the same adult-sized individual, the

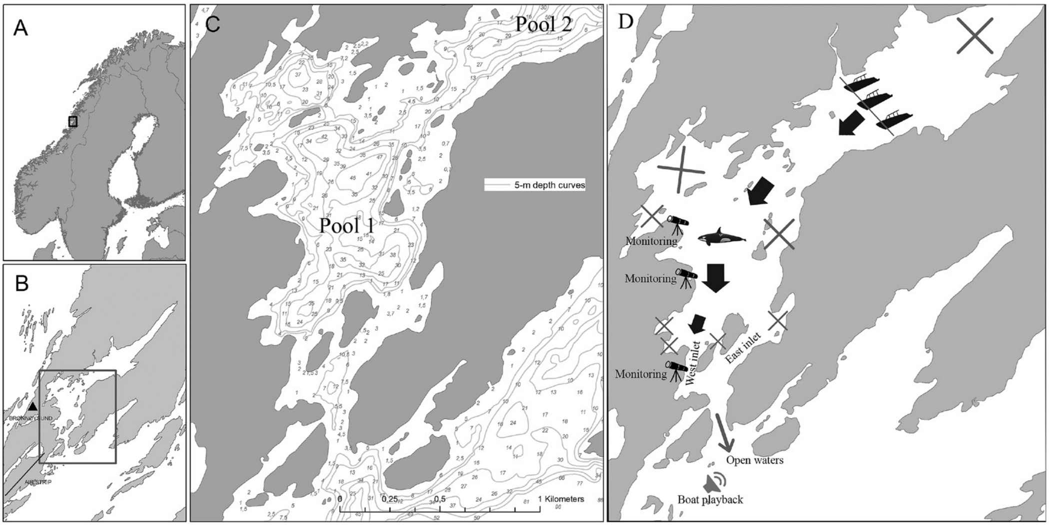

Figure 1. Maps showing (A), (B), and (C) location, topography, and configuration of Trælvikosen bay (Norway) and (D) visuals of the strategy used for the rescue operation

two animals were presumed to be a mother–calf pair. An unmanned aircraft DJI Phantom IV, with a DJI 1/2.3" CMOS camera, was used for aerial photography and filming. Behavior was recorded *ad libitum* from Day 10 during discrete observation periods (Mann, 1999). Killer whale vocalizations were monitored using an H2a hydrophone (Aquarian Audio & Scientific, Anacortes, WA, USA; frequency response: 20 to 100,000 Hz; sensitivity: -180 dB re 1V/µPa) connected to a Zoom H1 recorder (Zoom Corp, Tokyo, Japan; 24-bits resolution at a sampling frequency of 48 kHz), deployed to 8 m deep, approximately 400 to 800 m from the whales, from a moored aluminium boat. Resulting spectrograms were visually inspected using *Adobe Audition*, Version 8.1.0. Each recording was inspected to assess any presence of repeated call sequences. Repeated call sequences were defined as the production of the same call type (i.e., showing similar frequency contour and overall acoustic characteristics; e.g., Zwamborn & Whitehead, 2017) three or more times at roughly regularly spaced intervals (range: 1 to 5 s between consecutive calls).

Based on methods used in similar entrapment cases that occurred in 1994 in Barnes Lake, Alaska (Bain, 1995), and in 2014 at Aristazabel Island, British Columbia, Canada (L. Barrett-Lennard, unpub. data, 2014), two approaches were proposed to direct the killer whales towards the exit from the bay. The first was to use a line of boats moving slowly from the head of the bay to drive the whales towards the exit channels. Twenty-five motor boats, no more than 20 m apart, were used to create a physical and acoustic barrier. To dissuade the whales from escaping between or below the boats, vessels were equipped with a pair of 2-m-long weighted ropes that added an underwater dimension to the boat barrier. Each boat was also equipped with hollow pipes that could be struck in the water to create an acoustic deterrent if the whales threatened to pass under the boats (as used in Barnes Lake; Bain, 1995). Use of the pipes was recommended only if clearly necessary.

The second approach was to play calls of Norwegian killer whales actively feeding on herring (see Curé et al., 2012) outside the bay to attract the whales to open water (Figure 1d). Previous studies conducted on various free-ranging cetacean species have shown that playbacks of conspecific or heterospecific sounds can induce approach or avoidance responses (Filatova et al., 2011; Curé et al., 2012, 2015). We prepared three versions of killer whale acoustic recordings that lasted 15 min and were transmitted at an average source pressure level of 150 dBrms re 1 µPa corresponding to the source level of killer whale vocalisations observed in natural conditions (Curé et al., 2012). Sounds were played using a micro track TASCAM DR-40 recorder and amplified by a SONY XM-N502 amplifier connected to a Lubell LL9162T loudspeaker (frequency range: 0.2 to 20 kHz) deployed under water from a boat to approximately 8 m depth. To assess how the playback might affect the whales' behaviour and, in particular, to ensure that it did not cause an aversive response, we conducted a trial on the morning of the rescue day at about 500 m from the whales. The whales immediately changed their horizontal course towards the sound source and switched from slow travel to active porpoising towards the source. During the rescue operation, the playback boat was positioned outside the bay, about 200 m from the exit (Figure 1d). Playbacks were to be started upon entrance of the whales into the channel to better guide them through the sinuous inlet.

Meetings with the local community were used to recruit vessel owners, assign tasks, and acquire needed equipment. There were at least two volunteers on each vessel, and a rescue boat stood by to assist in the event of an accident. To prevent the killer whales from stranding, people in kayaks were positioned in shallow areas with instructions to splash the water if the whales approached, assuming it would act as a deterrent. A closed social media group was created to facilitate information exchange and discussion among community members and the local rescue team while keeping the event quiet and localized. During the operation, the whales were constantly monitored for their positions and behavioural states by a land-based observer standing on a cliff for a better overview of both the boats and whales. Assisted by the drone operator, the observer also benefited from an aerial perspective, using the flight monitor to verify a calm and grouped state of the whales at all times. The observer was in constant contact with the boat coordinator using Citizens Band radios. The boat coordinator, in turn, directly guided the other 24 boats using a VHF radio from the monitoring boat, which was located in the central position in the line. The monitoring boat was also in charge of focal-following the whales from a minimum 300 m distance upon release for behavioural observations. In the event the whales dispersed or showed signs of panic, the operation was to be aborted and postponed.

For the success of the operation, it was crucial to get the killer whales to the mouth of the exit channel at 2026 h, the approximate time of predicted high tide. It was assumed that the highest water level and lowering tidal current in the channel would promote the whales' willingness to exit the bay. Not knowing how the whales would react to the herding process nor how long it would take, the operation was cautiously initiated 3 h prior to high tide.

Between Day 1 and Day 10, 1,420 photographs and 34 min of video data were opportunistically collected by local residents. From Day 10 to Day 19, 1,459 photographs, 191 min of aerial footage, and 194 min of acoustic recordings (Figure 2) were collected by scientists.

The nine killer whales entered the bay on 2 May 2017 (Day 1) through the eastern inlet during spring high tide. The whales were identified from previous sightings and a resulting identification catalogue (Jourdain & Karoliussen, 2018) as one adult male (NKW-880), an adult female (NKW-366) accompanied by a calf estimated at under 2 y (NKW-366a), an adult female (NKW-704) accompanied by a neonate calf (NKW-704a), an adult female (NKW-877) accompanied by a subadult individual (NKW-877a), and two adult female-sized individuals (NKW-879 and NKW-878; gender undetermined). While four of the whales (NKW-877, 877a, 879, and 880) had left the bay on their own by Day 16, the rescue operation aimed at guiding the five remaining individuals out of the bay. Main behavioural observations and logistical events are summarized in Table 1.

The rescue operation took place on 20 May (Day 19) under clear skies and 6 m/s of north wind. All boats and kayaks gathered outside of the bay at 1700 h before travelling around the outer edges of the bay (farthest from the killer whales) to their assigned positions. Despite the sudden increase in boat traffic, the five whales continued slow travelling in Pool 2. At 1733 h, all volunteers were in place and the operation commenced. At 1737 h, as the whales travelled from Pool 2 to Pool 1, the boat drivers formed a line across Pool 2 and started travelling at 2 to 4 kts, approximately 600 m behind the whales. The whales maintained a course ahead of the boats towards the mouth of the eastern channel at 1744 h and patrolled for 1 min before moving on to the mouth of the western channel where they remained until the boats arrived at 1757 h. The barrier of boats stopped about 200 m away from the western mouth, 100 m from the whales. The boats were only adjusting their positions to prevent any gap in the line but otherwise remained motionless with running engines, leaving the whales with space and time to make their own decision to leave the bay. Despite a water level barely 40 cm lower than that predicted at high tide, the group of whales turned around at the same location at each pass by the inlet mouth.

For the next 2 h, the killer whales stayed in a tight group, swam continuously between the mouth of the inlet and the deepest part of the pool section, performed short dives, and spy-hopped on a few occasions. At 2000 h, with the high tide imminent and therefore at the best water depth possible in the exit channels, it was decided to reduce the area available to the whales. The boats slowly converged towards the five whales, promoting their next trip to the inlet mouth. Although the whales attempted the same sharp turn away from the inlet, the boats closed in, and three of the whales entered the channel at 2016 h. Aerial footage showed that NKW-366 and her calf appeared reluctant to follow their counterparts, abruptly stopping at the shallowest and narrowest point of the inlet mouth. While the other three whales

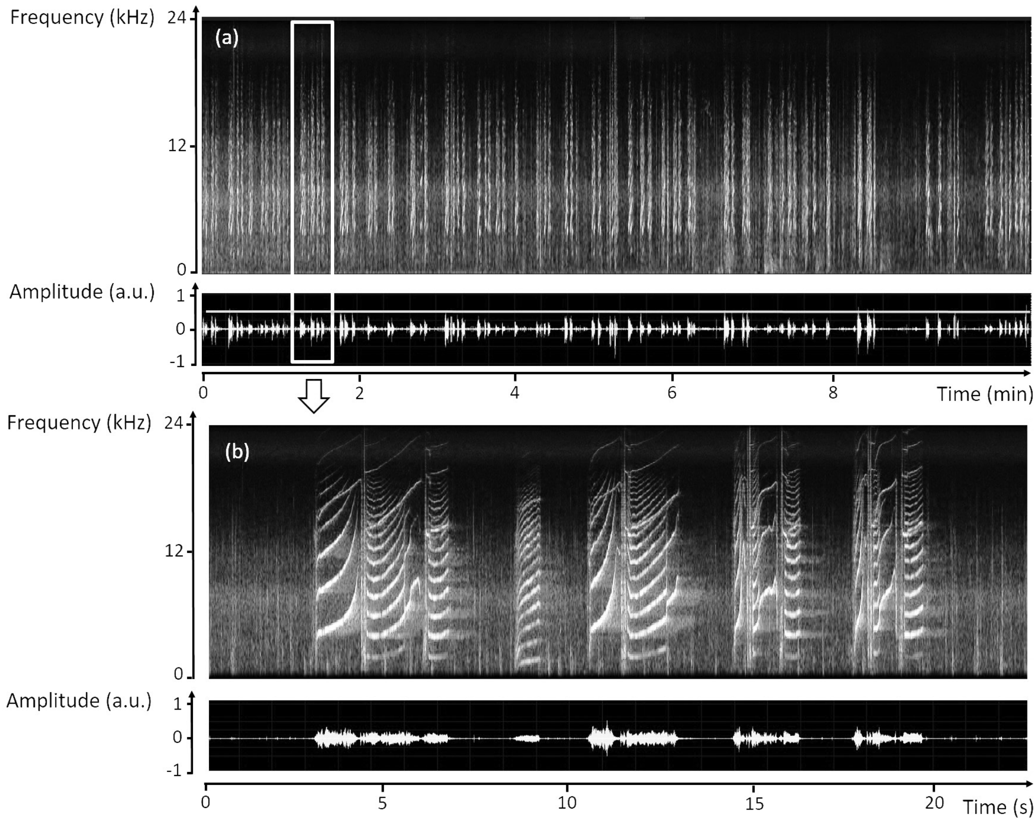

Figure 2. Spectrograms and oscillograms of (a) a sample of a typical long sequence of killer whale repeated calls produced on Day 17 after two group members went missing, and (b) an enlargement of a few repeated calls (Blackman-Harris window; FFT window size: 4,096 points; overlap: 75%; spectral resolution: 25 Hz)

waited 50 m ahead in the channel, NKW-366 and her calf hesitated for over 1 min; NKW-366 sharp turned twice and rolled three times. It was only once the boats positioned themselves 30 m away from the mother–calf pair that these two whales finally entered the channel and took the lead of the group. As the playback started at 2018 h, the five whales further progressed through the inlet, moving at variable speeds (Figure 3). The playback stopped at 2032 h, and the whales continued fast swimming and porpoising into open waters until 2107 h when the monitoring boat left them.

This is the first known example of a natural killer whale entrapment for which material was collected from Day 1 and throughout the entrapment period, adding to our understanding of these rare and poorly documented events. Observations further enabled collection of a general description of their behaviour. It is also the first rescue operation for which continuous land-based and aerial monitoring was conducted, enabling assessment of the efficacy of the different steps used in the intervention, as well as the whales' responses to the rescue protocol.

Presumed signs of stress as observed throughout the 19 days of entrapment included continuous repeated swimming mainly across the deepest section of Pool 1; possible decreasing level of energy over time; apparent absence of feeding; and loud, repeated underwater calling. Routine-like swimming suggested some sort of stereotypy, a condition that could have arisen after the killer whales had explored their entire environment and started adopting unvarying behavior due to the lack of food or external stimuli. Stereotypic behaviours are common in captive animals and are recognized as indicators of poor animal welfare (Mason, 2006). Furthermore, as reported for Barnes Lake, the whales moved slowly and often quit raising the saddle patch above water when surfacing from Day 16. This could have been an attempt to conserve energy and could be indicative of a diminished physical condition (Bain, 1995).

Table 1. Chronology of effort, group composition, main behavioral observations, and logistical events that occurred throughout the 19 days of entrapment, beginning on 2 May 2017 (referred to as Day 1) until rescue. Missing days correspond to no effort and, thus, no observations collected.

		Material collected			Group size	Observed behavioural state(s)				
Day ~ Time	Period	Video	Photo	Sounds		Travel	Rest	Displays	Feeding	Description of activities and/or logistical events
1 ~ 1857 h	15 min	X			9	X				Whales enter the bay at high spring tide through the eastern channel.[1]
2 ~ Day time	2 h		X		9			X		Whales exhibited high-energy display behaviours, including repeated leaping.[2]
3 ~ 0817 h	15 min	X			9	X				The whales swim through the western channel at high tide but are observed going back to the bay.[1]
4 ~ 2159 h	15 min	X			9	X				Again, the whales swim through the western channel at high tide but are observed going back to the bay.[1]
5 ~ 1930 h	2 h	X	X		9	X				NKW-879 and NKW-880 are observed in pair, apart from the group, patrolling the western mouth at rising tide, fast swimming back and forth.[3,4]
5 ~ 2100 h	--	X	X		9	X				NKW-879 and NKW-880 are observed reunited with the rest of the group—all nine whales are fast swimming in a circle close to the western inlet mouth at high tide.[3,4]
8 ~ 2230 h	2 h		X		7	X	X	X		NKW-879 and NKW-880 are missing—the two whales had left the bay at an unknown time between Days 6 and 85. The remaining whales were observed slow travelling in a tight group, periodically logging and performing numerous spy-hops and tail-slaps.[5]
10 ~ 1000 h	12 h	X	X	X	7	X				Boat approach by scientists to collect close range photographs of the whales and make first sound recordings. The whales responded with strong avoidance, sharp turning away, and diving. Sound recordings revealed no audible sounds. During the entire day, the whales were seen continuously subsurface swimming across Pool 1.[1]
11 ~ 0830 h	4 h	X	X		7	X				The whales were seen continuously subsurface swimming across Pool 1 in a tight group formation.
16 ~ 2030 h	4 h	X	X	X	5	X	X			NKW-877 and NKW-877a are missing. The remaining whales are seen using Pool 2 for the first time, continuously swimming back and forth between the two pools. All three adult whales are producing loud calls and long trains of bubbles while travelling just below the surface. The tight group was split in pairs at times while maintaining synchronous heading and speed about 100 to 200 m apart. Calls were continuously heard over the entire recording period, from 2030 to 0130 h (Figure 2).
17 ~ 1013 h	4 h	X	X	X	5	X				The whales are travelling below the surface across Pool 1 and producing loud calls and long trains of bubbles during the 4 h recording (Figure 2).
17 ~ 2200 h	4 h		X	X						The whales are slow travelling across Pool 1 and are quiet.
18 ~ 1315 h	4 h		X	X	5	X				The whales are slow travelling across Pool 1 and are quiet.
19 ~ 1100 h	2 h	X			5	X				Playback trial—The whales immediately changed their horizontal course towards the sound source and switched from a slow travel to an active porpoising mode. As the playback was stopped after 1 min 45 s, the whales ceased their approach, dove, and moved away quickly.
19 ~ 1700 h	--	X	X		5	X				Rescue operation occurred.

Note: If not collected by authors, material courtesy of [1]Erik Gjemble, [2]Roger Holmstrand, [3]Olav Søla, [4]Raymond Hågen, and [5]Anne Kristin Nilsen.

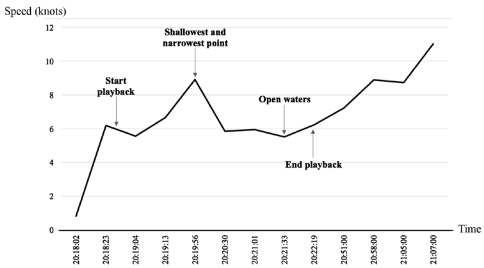

Figure 3. Horizontal average speed recorded for the rescued killer whales as they progressed throughout the shallow inlet and out in open waters, calculated as the ratio between the distance and time between two successive sightings of surfacing killer whales

Lastly, the killer whales produced loud and repeated calls in association with long bubble streams for several hours at a time when wandering over the entire bay on Days 16 and 17. Animals in a distressed state or separated from affiliate members can produce signature calls more intensely, more frequently, faster, and louder than normal (Kuczaj et al., 2015). As reported for bottlenose dolphins (Smolker et al., 1993), repeated sequences of such contact calls could have been an attempt to connect with NKW-877 and her offspring, missing from the same day. These observations paired with the presence of two nursing calves in the group and apparent absence of a food supply in the bay suggested that the whales' condition would likely deteriorate. This resulted in the decision to relocate the whales back to open waters.

The operation appeared to be an efficient and relatively unobtrusive method to direct the entrapped killer whales to open waters. Throughout the operation, all five remaining whales remained calm, tightly grouped, and stayed away from the shallow areas of the bay. Although the effectiveness of the coordinated line of boats was clearly pivotal to the rescue operation, the role of the playback remains less clear. Indeed, and in contrast with the response observed during the playback trial, the whales' speed and trajectory did not indicate any obvious response to the playback during the rescue effort. Possible explanations could be that the playback sound could not propagate faithfully (i.e., potentially not recognized as killer whale sounds by the whales) or did not transmit to the whales' position (i.e., not heard by the whales) given the physical constraints imposed by the complex topography of the sinuous shallow inlet, or that the whales habituated to the first sound exposure (i.e., playback trial; Deecke, 2006).

Because natural cetacean entrapments seldom happen and are rarely documented, they have been poorly understood, with no guidelines or protocols currently in existence for potential interventions. The entire group of rescued killer whales was resighted off Andenes the following September, about 700 km north from the entrapment location. In the present case, rescuing the entrapped whales not only promoted animal welfare but also prevented inherent social (human) controversy. Even though this short note remains largely descriptive and deficient in quantitative results, we suggest that it provides baseline information that could assist both decision making and response design in future entrapment cases.

Acknowledgments

We wish to thank all those who contributed to the rescue effort. Financial support was provided by Rune Sponberg, Malia Andenes, the Norwegian Orca Survey, and CEREMA (France). Anna Kilpi provided accommodations, and Per Kåre Hatten and Torghatten Camping & Strandrestaurant kindly provided accommodations and a five star dinner after the operation. Torhild Iren Øien lent a car to the team. Special thanks to Arild Magnus Jøssund, Arild Hanger, Olav T. Søla, Janicke Canutte Laumann, Kjersti Kolstad, Raymond Andre Hagen, and Solveig Lomsdal for playing key roles in planning the operation. We thank all the boat owners for providing boats and fuel, the volunteers who gave their time and energy, and the kayakers for their enthusiasm and dedication. Erik Gjemble, Roger Holmstrand, Olav Søla, Raymond Hågen, Ståle Bjørnvik, Anne Kristin Nilsen, and Arild Magnus Jøssund provided valuable photo and video material and information. Thanks to Ingrid Visser, Rob Lott, and Stephen Marsh for advice on final plan validation. Reviews and comments from two anonymous reviewers greatly improved this manuscript. We thank Dag Vongraven for mapping the site of entrapment.

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