WESTERN GRAY WHALE (*Eschrichtius robustus*) MOTHER AND CALF ECOLOGY OFF SAKHALIN ISLAND

A Thesis

by

OLGA ALEKSANDROVNA SYCHENKO

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2011

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Chair of Committee, Bernd Würsig
Committee Members, Randall Davis
Wyndylyn von Zharen
Head of Department, Thomas E. Lacher, Jr.

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ABSTRACT

Western Gray Whale (*Eschrichtius robustus*) Mother and Calf Ecology
Off Sakhalin Island. (May 2011)

Olga Aleksandrovna Sychenko, B.S., Far East National University

Chair of Advisory Committee: Dr. Bernd Würsig

The western population of gray whales (*Eschrichtius robustus*) is endangered with approximately 130 individuals remaining. Many individuals return annually to the same feeding sites off northeastern Sakhalin Island, indicating a site-specific dependence to this geographic area. This apparently critically important habitat is especially vital for nursing females and their calves, as female energetic requirements are increased during lactation, and calves need to be ready to separate and begin to feed on their own. This study focuses on movements, respirations and behavioral patterns of mother/calf pairs on their feeding ground, with data collected during summer-autumn of 2002-2009. Shore-based observations included three methods: theodolite tracking, focal-animal behavior sampling, and photo-identification. Whales were categorized as three groups of individuals: mother/calf pairs, weaned calves, and other individuals. Analyses were performed to assess differences between groups of individuals, and in relation to their behavior. The null hypothesis of the study was that there were no differences in movement/respiration/behavioral patterns and habitat use between different groups of individuals. Results did not support this hypothesis. Significant differences in movements and respirations were found for certain groups of individuals. These differences also varied in relation to the whales' behavioral activity (feeding, feeding/traveling, and traveling). The shore-based photography was used to obtain additional information on individuals (especially mother/calf pairs) and their sightings, as well as to evaluate the success of this approach. A total of 144 individuals, including 10 females (sighted with calves) and 31 calves were identified during 2004-2009. The shore-based photo-identification approach was successful, and due to being a non-invasive technique, is recommended as a supplemental approach to vessel-based photo-ID efforts.

Reproductive success and survival of western gray whales are concern especially due to the presence of industrial activity in the area, as well as recently increased mortalities of female gray whales off Japan. Therefore, the results of this study indicate the importance of considering differences in needs and habitat utilization of different groups of individuals for basic science information as well as for management purposes of protection of western gray whales.

ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

The gray whale (*Eschrichtius robustus* Lilljeborg, 1861) occurs in the northern hemisphere of the Pacific Ocean. In Russian waters, two populations of this species are found in the seas of the Far East: the western North Pacific (or Korean-Okhotsk) population and the eastern North Pacific (or California-Chukchi) population (Rice and Wolman 1971, Rice 1998). A recent study has found these two stocks to be genetically isolated (LeDuc *et al.* 2002). After intensive commercial whaling both populations were reduced to extremely low levels and only the eastern stock has recovered, with a population estimate of about 18,000 individuals (Buckland and Breiwick 2002, Rugh *et al.* 2005).

The western population, however, is considered one of the world's most endangered and least-known baleen whale populations (Clapham and Baker 2002, Weller *et al*. 2002). This population has been listed by the World Conservation Union (IUCN) as Critically Endangered, and in Category I of the Red Book of Russia (USFWS 1997, Hilton-Taylor 2000, Red Book of the Russian Federation 2000, Weller and Brownell 2000, Jones and Swartz 2002, Cooke *et al.* 2008). The current population assessment estimates 131 non-calf individuals (90% confidence interval 120-140), with annual survival rate of 0.69 and 0.985 for calves and non-calves, respectively. Out of 131 individuals, only 33 (CI 29-38) reproductive females are known to exist (Cooke

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This thesis follows the style of Marine Mammal Science.

2010). There is a sex-biased ratio of 58.5% males and 41.5% females, with 66.1% males and 33.9% females among calves (Weller *et al.* 2009a).

Western gray whales spend summer-autumn in the shallow waters of the Okhotsk Sea, primarily along the shelf off northeastern Sakhalin Island. In this region, the majority of the population is seen nearby Piltun Lagoon (Blokhin *et al*. 1985; Blokhin 1996; Weller *et al.* 2002; Gailey *et. al* 2008, 2009; Yakovlev *et al.* 2010a). Although the breeding grounds of western gray whales remain unknown, some evidence suggests that they may migrate south to the coastal waters of the South China Sea (Jones and Swartz 2002, 2009; Weller *et al.* 2008).

The near-shore affinity of gray whales makes them particularly vulnerable to environmental fluctuations and anthropogenic activities. For the past decade, industrial development in the coastal waters of northeastern Sakhalin, namely oil/gas development and exploration (including seismic activity, offshore platform installation, pipeline construction, dredging, vessel traffic) became a cause of concern, especially since the oil and gas fields overlap with primary western gray whale feeding grounds (Blokhin and Burdin 2001, Gailey *et. al* 2008). Most of the known individuals of this population return annually to the same shallow water feeding sites off northeastern Sakhalin, indicating a site-specific dependence to this geographic area (Weller *et al*. 2007, Yakovlev *et al*. 2010a). The strong fidelity to this area is likely due to the rich amount of prey availability found in this region (Fadeev 2002, 2003, 2007, 2010). This apparently critically important habitat is especially vital for pregnant and nursing females, as their energetic requirements are increased during pregnancy and lactation (Costa and

Williams 1999) and for calves due to their learning process before they are weaned. For the past five years, an apparent increase in gray whale mortality near Japan has been documented. Five females (including mother/cal pair) were incidentally caught or found entangled in fishing gear in waters off Japan during their migrations, resulting in their deaths (Cook *et al.* 2008, Weller *et al.* 2008).

Since their re-discovery in 1980s (Brownell Jr. and Chun 1977, Blokhin *et al.* 1985, Berzin and Blokhin 1986), scientific interest in western gray whales has increased, which has led to the development of a collaborative Russian-American long-term research program. However, many fundamental aspects of the life history of western gray whales remain unknown. Although our knowledge of this population has increased substantially during the past decade, there is an obvious need for further study. This is especially so, as the continued survival of this small population is uncertain (Brownell and Weller 2002, Bradford *et al.* 2008).

RATIONALE AND OBJECTIVES

Since there is no information on life history of females and calves of the western population on the feeding grounds, our observations can be considered as one of the first steps in their study. The study described here focuses on movement, breathing activity and behavior patterns of mother/calf pairs and weaned calves off the northeastern Sakhalin Island. It is a part of long-term behavioral monitoring of western gray whales that has been conducted by Russian-American researchers since 1997. It contributes to the current assessment of population ecology and status, to help structure mitigation and management strategies for the protection of this critically endangered population. The overall null hypothesis of the study is that there are no differences in movement/respiration/behavioral patterns and habitat use between different groups of individuals (mother/calf pairs, calves, and other individuals).

The specific objectives of the study are to:

1) describe the distribution (based on distance from shore estimates) of mother/calf pairs and weaned calves along the coast, and compare this to the distribution of non-mother/calf individuals;

2) evaluate spatial and temporal movement patterns of mother/calf pairs and weaned calves, and compare them to those of other individuals;

3) evaluate respiration patterns of mother/calf pairs, and weaned calves, and compare them to those of other individuals;

4) evaluate movement and respiration patterns of mother/calf pairs, calves, and other individuals in relation to different behavioral states;

5) apply shore-based photography data for additional individual and sighting information, and evaluate this technique as an alternative/complementary approach to vessel-based photo-identification.

CHAPTER II

MOVEMENT AND RESPIRATION PATTERNS OF WESTERN GRAY WHALES MOTHER/CALF PAIRS

The present study is based on non-invasive shore-based observations (Würsig *et al.* 1991). This is especially important in studying endangered species/populations and animals that inhabit areas that are under ecological and/or anthropogenic pressures. Because many studies on marine mammals are conducted on vessels at sea, in direct proximity to the animals, these studies may have potential impact itself by changing the behavior of observed animals. Therefore, shore-based observations are powerful in studies of the biology and behavior of near-shore cetaceans. Three shore-based methodologies were used in this study: 1) theodolite tracking to monitor temporal and spatial movements of whales, 2) focal-animal observations to monitor surface-dive breathing activity, and 3) photo-identification work for recognizability information.

Theodolite tracking as first developed by Roger Payne for southern right whales (*Eubalaena australis*) and first described in the literature for tracking dusky dolphins (*Lagenorhynchus obscurus*) and common bottlenose dolphins (*Tursiops truncatus*) (Würsig and Würsig 1979, 1980), has since been used by many researchers for studying a variety of species of marine mammals, including gray whales (for example, Malme *et al.* 1986; Heckel *et al.* 2001; Gailey *et al.* 2007b, 2009). The patterns in which whales come to the surface, respire, and dive are useful in characterizing different behaviors and potential changes in behavior (Dorsey *et al.* 1989). Changes in behavior of an animal can be a result of anthropogenic and/or natural factors. The focal-animal observations method can be applied to describe respiration patterns and other surface-visible behaviors of whales. Like theodolite tracking, this approach has been used in different studies of cetaceans as well: gray whales (Guerrero 1989, Würsig *et al.* 2000, Gailey *et al.* 2009), bowhead whales (Würsig *et al.* 1984, Carroll *et al.* 1987, Richardson *et al.* 1990), fin whales (Díaz López *et al.* 2000), minke whales (Stern 1992). The purposes of these different studies are to obtain information on potential impacts of anthropogenic activities in the animals' habitat, such as vessel traffic, oil/gas development and exploration, ecotourism; assess temporal and geographic habitat utilization, natural variations in behavior and distribution, as well as in relation to environmental and demographic factors. Chapter II is focused on evaluating the movement and respiration patterns of different groups of western gray whale individuals (mother/calf pairs, separated calves and other individuals in the population), as well as describing their behavior and distribution.

METHODS

Study Area

The study area is located off Lagoon Piltun on the northeastern coast of Sakhalin Island (Fig. 1, Fig. 2). The lagoon is approximately 90 km long and 15 km across at its widest point. The lagoon may be of biological influence to the surrounding waters. The coastal waters of the Sea of Okhotsk are mostly sand substrate with a gradually sloping continental shelf, with depth usually less than 20 m within 5 km from shore (Weller *et al*. 2000, Fadeev 2002). In 2002 and 2003, observations were conducted at four shore-based vantage points that were approximately 10 km apart, and provided a geographic coverage along 32 km of the coast. The location of each station was selected based on its height above sea level. Effort was conducted by one team of observers at one station per day. In 2004, two additional stations (to the south and north of the previous study area) were added to extend the geographic range, which provided spatial coverage of 66 km of the whales' nearshore feeding grounds (Table 1). Effort was extended by conducting observations by two research teams at two adjacent stations on each working day. Such approach allowed completing observations at all six stations in three days of proper weather conditions for collecting data. The additional team also provided increased sample sizes, which were critical to have sufficient data to examine patterns and potential anthropogenic influences. Effort at each station was conducted systematically from south to north: starting at the two most southern stations (South and 1st), proceeding at the middle ones (2nd and Station 07) on the second day, and moving to the most northern stations (Odoptu and North) on the third day. Research was conducted during summer and autumn of 2002-2009.

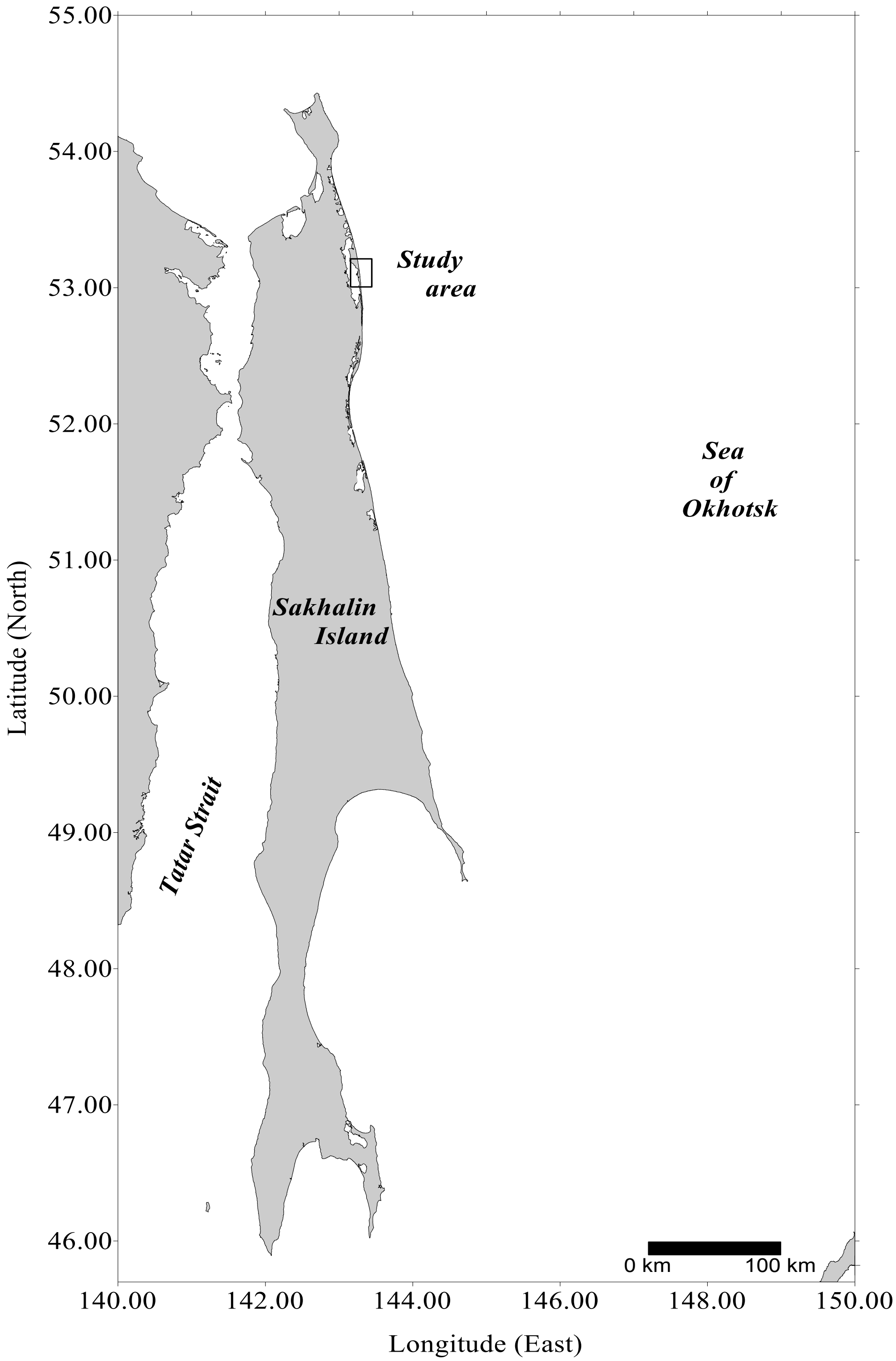

Figure 1. Study area in the northeastern portion of Sakhalin Island, Russia.

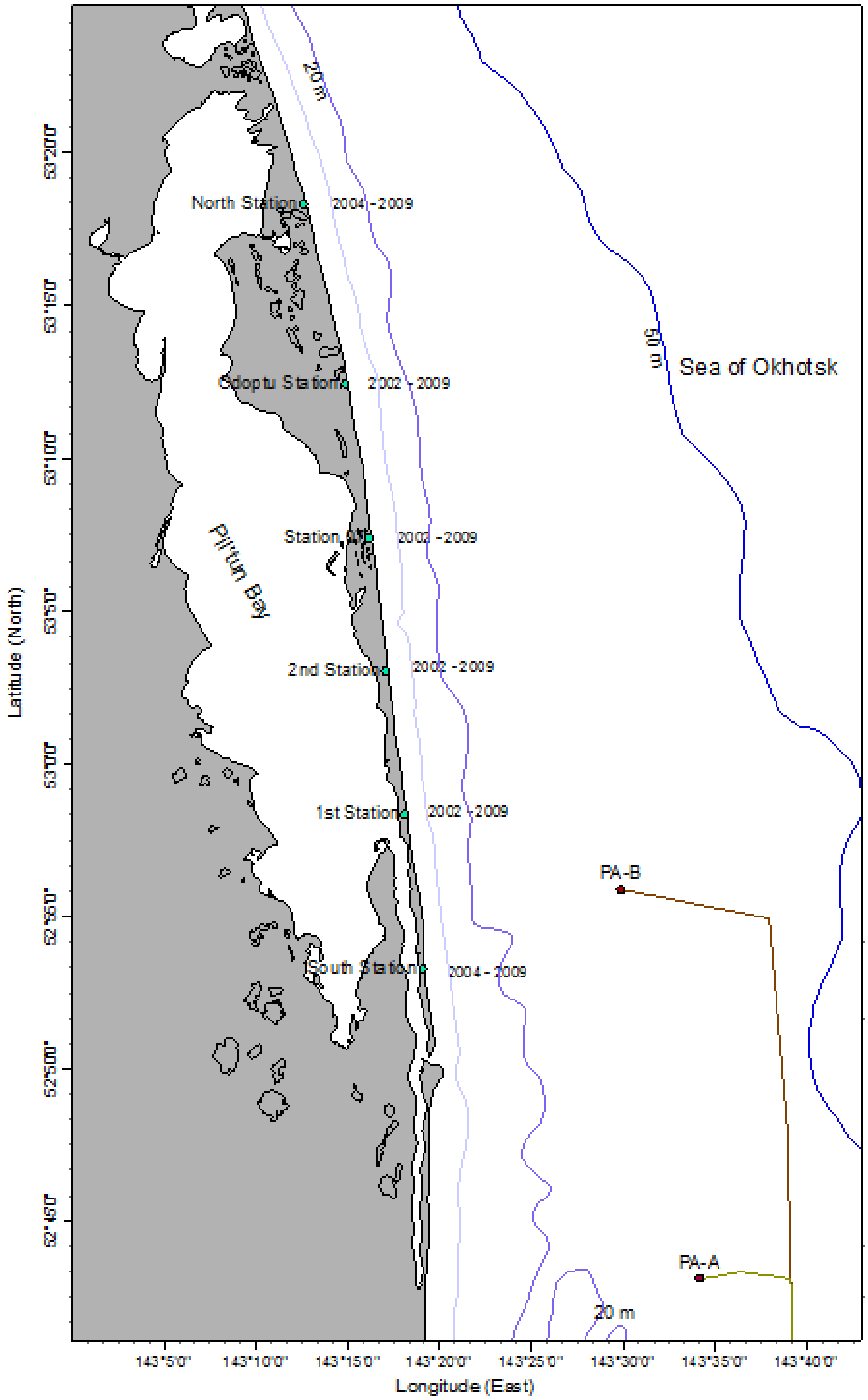

Figure 2. Geographic positions of six shore-based stations on the northeastern coast of Sakhalin Island (2002-2009). PA-A and PA-B are offshore oil platforms.

Table 1. Geographic positions and station heights (above the sea level) of six shore-based stations used for behavioral observations during 2002-2009.

Station	Latitude(North)	Longitude (East)	Station Height (m)
North Station	53° 18' 22.9"	143° 12' 35.3"	19.30
Odoptu Station	53° 12' 33.0"	143° 14' 51.4"	17.91
Station 07	53° 07' 30.0"	143° 16' 12.3"	8.81
2^{nd} Station	53° 03' 09.1"	143° 17' 04.5"	9.44
1^{st} Station	52° 58' 27.5"	143° 18' 06.6"	8.61
South Station	52° 53' 23.7"	143° 19' 05.5"	5.99

Environmental Conditions

Observations depended on environmental conditions. Visibility, sea state, swell height (m), and glare were recorded several times each field day. Visibility was determined on a scale of 1 to 5, with 1 indicating excellent (clearly defined horizon line with no obstruction) and 5 – no visibility (no visible horizon due to fog/rain, with visibility less than half the distance to the horizon and the observation point). To determine sea state, the Beaufort sea state scale was used, where 0 represents a flat sea, and 5 is a presence of moderate waves of some length, many whitecaps and small amount of spray. Theodolite and focal behavior observations were normally conducted in conditions with visibility 1-4 and sea state 0-4. Visibility 5 and sea state 5 were not acceptable for data collection. Sun glare could terminate observations for a period of time. For example, if the observed whale moved in to glare, theodolite tracking and focal follows were discontinued until the researchers could see the whale again. Other weather parameters, such as wind speed (km/h), wind direction, atmospheric temperature (°C), and barometric pressure (mB) were automatically recorded every 10 minutes at each station using hand-held weather devices, model Kestrel 4500.

Theodolite Tracking

A theodolite is a surveyor's instrument to collect information on movement patterns, spatial distribution and behavior of animals (Gailey and Ortega-Ortiz 2002). For marine mammals, this methodological technique was first introduced by Roger Payne in 1972 (Würsig *et al*. 1991). A theodolite measures horizontal angles from some arbitrarily selected reference point, and vertical angles relative to a gravity referenced level vector. The horizontal and vertical information can be converted into a geographic position (latitude and longitude), and can provide information about distance between the animal and observation site. Successive positions and times can be compared to calculate travel speeds and orientations of whales, alone or in relation to activity in the water, such as vessel movement (Würsig *et al*. 1991, Gailey and Ortega-Ortiz 2002). Lietz/Sokkisha Model DT5 and DT5A theodolites (with 30-power monocular magnification and 5-sec precision) were used in this study (Fig. 3).

Figure 3. Lietz/Sokkisha Model DT5A and DT5 theodolites were used to monitor the movement patterns of gray whales.

Theodolite tracking was conducted on a single or individually distinguishable whale in a group. On occasion, whales were tracked at distances further than 5 km from the observation site, but due to the relatively low station heights, any locations of whales beyond 4-5 km distance from the station (Würsig *et al*. 1991) were not included in analyses. Therefore, durations of tracks were limited by environmental conditions and the critical distance (4-5 km). Each geographic position recorded represents a "fix" of the whale or group of whales upon each surfacing, usually a whale respiration event. A series of fixes collected over time on single individuals or groups of individuals represents a trackline.

For each trackline, calculated leg speed (km/h), acceleration (km/h^2), reorientation rate (degrees/minute), linearity index, mean vector length, and ranging index (m/min) were analyzed. Acceleration evaluates changes of speeds to determine if an animal is generally increasing or decreasing speeds within a trackline. Reorientation rates represent a magnitude of bearing changes along a trackline. This rate was calculated as the summation of absolute values of all bearing changes along a trackline divided by the entire duration of the trackline in minutes (Smultea and Würsig 1995). Linearity index represents a deviation from a straight line, and is calculated by dividing the net geographic distance between the first and last fix of a trackline by the cumulative distances along the track. It ranges from 0 to 1, where 0 is a non-directional movement and 1 is a straight-line movement. Another directionality index, mean vector length (Cain 1989), was added as a movement variable due to its dependence on angular change within a trackline as opposed to distance values used in the linearity index. A ranging index was included to measure the minimal diagonal area of the whale's track by incorporating its course and track duration (Jahoda *et al.* 2003). In addition, the distance from shore to the observed animal was analyzed to see how individuals from different group categories utilize the area, and if this varies in relation to behavioral state.

Focal-animal Observations

The patterns in which whales come to the surface, respire, and dive are useful in characterizing different behaviors and potential changes in behavior (Dorsey *et al*. 1989). Following the whale with the aid of a hand-held binocular (7x25), the behavioral observer stated each behavioral event (i.e. blow, fluke-out, head-out, dive, etc.) that was observed and immediately recorded (date, time, behavior, etc.) to the computer by a computer operator. The possibility to distinguish mothers and calves permitted conducting focal-animal observations while they were together. The duration of the focal session was limited by the critical distance (4-5 km) and environmental conditions. To describe surfacing-respiration-dive parameters, six variables were calculated:

1) surface time – duration of individuals remaining at or near the surface (minutes);
2) respiration interval – time between successive respirations per surfacing (minutes);
3) number of respirations per surfacing;
4) dive time – duration of individuals remaining submerged (minutes);
5) surface-respiration rate – mean number of exhalations per minute while the individual was at the surface (number of respirations/minute);

6) dive-surface respiration rate – number of exhalations per minute averaged over the duration of a surfacing-dive cycle (number of respirations/minute) (Gailey *et al*. 2007b).

To collect focal-animal data, eight main behavioral events were selected to be recorded in real-time for each individual observed (Gailey *et al*. 2007b) (Table 2). Any submergence of a whale lasting longer than 60 seconds was considered a dive.

Table 2. Behavioral events observed and recorded for each individual.

	Behavioral Events	Description
Respirations Events	Blow	rapid exhalation represented by the column of air at the sea surface; represents animal's breathing
	First Surface Blow	beginning of surface time, and end of dive time
	Missed Blow	breathing act occurred but was not recorded in real time
Diving Events	Peduncle Arch	portion of the body (back) observed before a whale's diving
	Fluke	raising of whale's fluke above the water before diving
	Missed Dive	missed diving behavioral events (whale remains submerged for > 60 seconds without any indication of diving)
Other Events	Head Out	raising of whale's head above the water (breathing act is assumed when head was observed above the water)
	Breach	vertical movement out of the water, at least third of the whale's body was observed (from other studies, breathing was assumed when breaching was observed)

Groups and Behavioral States

To analyze theodolite tracking and focal behavior data, all observed whales were separated into three groups:

1) mother/calf pairs – two individuals in close proximity to each other: current year's offspring (calf) smaller in size accompanied by an adult individual (mother), at times mother/calf pair may be observed in association with other calves of the same year but separated from their mothers at that moment;

2) calves – current year's calves that were observed with the mother earlier but had since separated, or defined as calves (small body size individuals, usually remaining close to the shore, and often may be observed in association with mother/calf pair or groups with other calves; also never being identified in previous years);

3) other individuals – any individual not included in first two groups. Individuals defined as yearlings of that year, and females sighted with calves (as mothers) that year but separated and observed without calves later in the season were excluded from "other individuals" group from present analyses.

Behavioral states were defined in the field and recorded for each individual/group of individuals observed at that time. Behavioral states were categorized into the following classifications:

1) feeding – non-directional movement with consistent periods of diving and surfacing and the animal remaining within the same area for an extended period of time;

2) traveling – directional movement through the area without consistent periods of diving and surfacing;

3) feeding/traveling – relatively slow directional movement with consistent periods of diving;

4) milling – non-directional movement within the area (including circling, playing in swells);

5) social – interactions between individuals, usually involves two or more whales displaying high level of surface activity (showing different parts of bodies above the water), sexual/courtship behavior, and chasing;

6) resting – individual remains motionless at the surface without periods of submerging;

7) nursing – interactions between an adult assumed as mother and calf (mother was observed rolling and calf diving under her), during which calf's feeding occurred;

8) unknown – undetermined behavior.

In this study, only three predominant behavioral states were used for analyses: feeding, feeding/traveling, and traveling. Other behavioral states were not included in the analyses due to few observations and therefore low sample size.

Data Management and Analyses

All movement and focal-animal data were collected in the field by three observers: theodolite operator, behavioral observer, and computer operator. All data were collected, recorded into a laptop computer, and stored in a Microsoft Access database with the assistance of the computer-based program "Pythagoras", which provides an efficient platform to simultaneously record theodolite tracking and focal-animal behavior data (Gailey and Ortega-Ortiz 2002). The database consisted of two components: 1) station settings – contained all information related to each observation station (such as location, height, reference azimuth, etc.). These parameters remained the same throughout a field season, but allowed for adding/correcting information if changes occurred, and 2) data file – database itself containing all data collected in the field, was created separately for each field season.

For both, theodolite tracking and focal follow sessions, additional information such as consecutive number of each group during the day, behavioral state, group size, environmental conditions, and comments were recorded (Gailey and Ortega-Ortiz 2002). Each geographic location of a whale being monitored was calculated in real-time and visually displayed in the Pythagoras tracking window, including distance from the observation site, speed and direction of animal movement for current theodolite record (“fix”), and duration of the track (Fig. 4). All surface-dive respiration events were also recorded and displayed in real-time in the focal follows window of Pythagoras, showing every event recorded, as well as calculated respiration interval and dive time for the current respiration cycle (Fig. 5). To make immediate records of observed event, each event was assigned to a particular key on the keyboard laptop, which was clicked by the computer operator once the behavior operator stated the event. In 2005, programmable keyboards (“X-Keys”) were incorporated to assist in recording focal-animal behavioral data. The device was connected to the laptop and interfaced with the Pythagoras software. Each key on the programmable keyboard was assigned to a behavioral event. This allowed using the laptop (if needed for adding/correcting) during the focal follow session. In addition, a voice recognition system was built into the Pythagoras system for data recording. The behavior operator wore headsets with a noise canceling microphone, and upon each observed event stated the name of the event into the microphone. The event was recorded immediately by voice recognition system and repeated back (via text-to-speech software) to the operator's headsets to confirm an accurate recording. However, the system was based on English language components and did not prove to be successful in recognizing variations in English speech due to foreign accents.

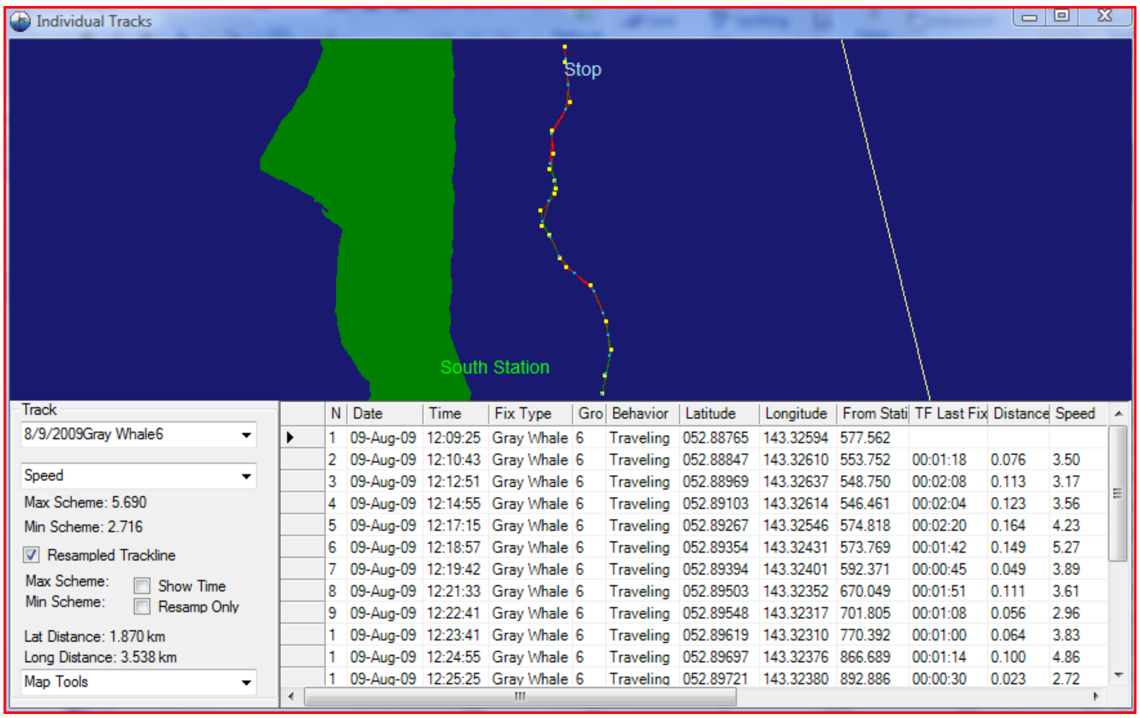

Figure 4. Example of the Pythagoras software visually displaying a trackline and spatial/temporal information associated with an individual's movement.

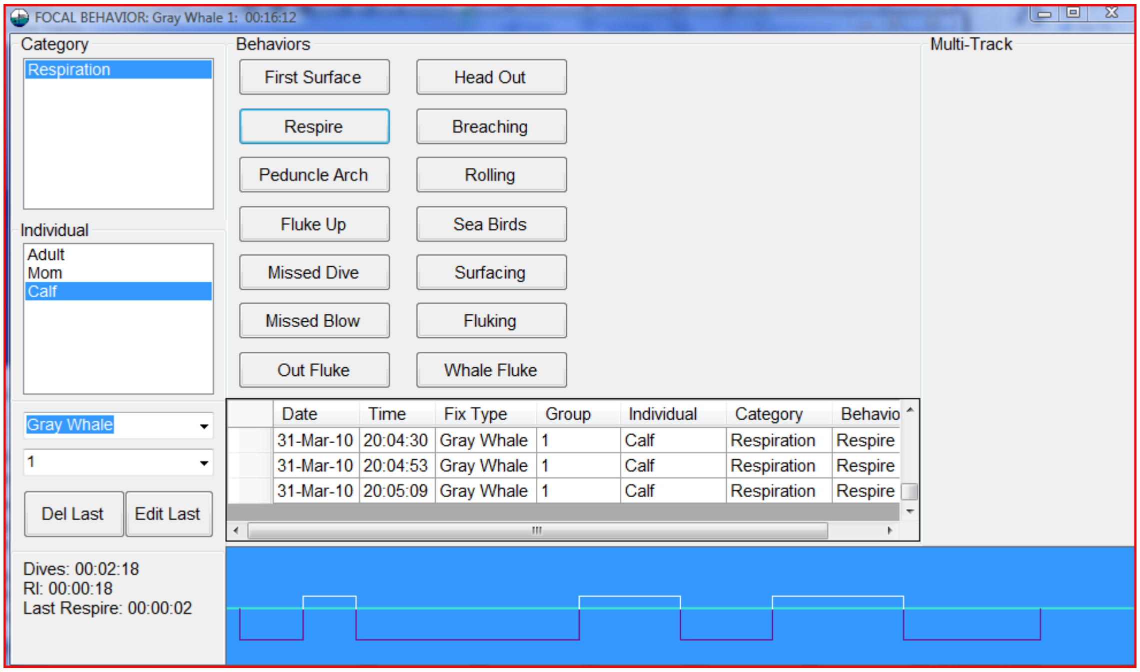

Figure 5. Example of the Pythagoras software visually displaying a respiration cycle and information associated with an individual's breathing/surfacing activity.

All movement and respiration variables (speed, acceleration, linearity, dive time, respiration interval, etc.) were calculated with the assistance of Pythagoras. Due to variations in the durations of each trackline, all tracklines and focal-animal sessions were binned into 10.5-minute intervals (bins). The duration of bins was consistent with previous studies conducted in the same area, and provided meaningful results (Gailey *et al.* 2007b, 2007c). For each 10.5-minute interval within each trackline and focal follow session, all movement and respiration variables were calculated. To avoid pseudoreplication, one bin with one mean value for each variable was randomly selected from a trackline and focal-animal follow session. For the analysis based on behavioral states of whales, one bin with one mean value for each variable was randomly selected for each behavioral state observed in a trackline/focal-animal session. Therefore, if an individual changed behavior within one observation, a few different bins were randomly selected for each behavioral state within a single trackline.

Both parametric and non-parametric distributions were present in a number of variables. Transformation procedures were employed, when appropriate, to convert non-parametric distributions to parametric ones for analytical purposes. Dependent on the variable and it's distribution, different transformations were performed. In both, general analyses and analyses in relation to behavioral states, the variables reorientation rate, ranging index, respiration interval, surface time, and dive time were log-transformed by the equation:

$$Y_i' = log_e(Y_i),$$

where Y_i is the original response, and Y_i' is the transformed response of observations *i*. The number of blows per surfacing was log-transformed by the similar equation with adding the constant 1 to avoid taking a logarithm of 1,

$$Y_i' = log_e(Y_i + 1).$$

The empirical logit transformation was applied to linearity index and mean vector length using the equation,

$$Y_i' = log_e\left[\frac{Y_i - 0.003}{1-(Y_i - 0.003)}\right],$$

where Y_i is the original response, and Y_i' is the transformed response of observations *i*. Due to the possibility of Y_i =1, the constant 0.003 was used to avoid division by 0

(Gailey *et al*. 2004). Square root transformations were applied to leg speed, distance to shore, and surface blow rate. Dive-surface blow rate was log-transformed for the general analysis, but had a normal distribution of data that considered behavioral states. The distribution of acceleration was normal in all data sets, therefore no transformations were applied.

RESULTS

Effort

A total of 246 (2928 hrs) days of effort were spent during the entire period of the study (Table 3). The number of working days varied each field season depending on the duration of the field season, and weather conditions. The longest field seasons were in 2006 and 2007; however, many unfavorable weather days in 2006 resulted in less effort in comparison to 2007. The latest onset of data collection occurred in 2002 (17 August) and 2008 (7 August). These field seasons did not provide information on whales in July and, therefore, some missed opportunities – especially in relation to mother-calf pairs – could have occurred more often in 2002 and 2008 than in other more complete seasons.

Table 3. Summary of effort conducted at six shore-based stations used for behavioral observations during 2002-2009.

Year	Days*	Hours**	First day of data collection	Last day of data collection
2002	26	192.26	17-Aug	28-Sep
2003	29	232.53	22-Jul	13-Sep
2004	24	348.19	31-Jul	21-Sep
2005	24	327.28	13-Jul	6-Sep
2006	32	413.83	26-Jun	26-Sep
2007	49	620.18	20-Jun	21-Sep
2008	30	384.9	7-Aug	30-Sep
2009	32	408.39	11-Jul	18-Sep
Total	246	2927.56	20-Jun	30-Sep

* Number of days represents actual (calendar) days.
** Number of hours represents total number of working hours spent at one station per day in 2002-2003 and two stations per day in 2004-2009.

Movement Patterns (Theodolite Tracking)

During the 2002-2009 field seasons, a total of 1290 theodolite tracking observations (consisted of 63,011 geographic positions) on gray whales were conducted: 124 – on mother/calf pairs, 70 – calves, and 1096 – other individuals (Table 4, Fig. 6). The duration of tracklines ranged up to 7 hours with a mean duration of 54 min./track.

Table 4. Summary of effort information on theodolite tracking conducted at six shore-based stations in 2002-2009.

Individuals	# Tracks	Mean duration (min)	Range (h)
Mom/Calf Pairs	124	60.00	0.02 - 5.52
Calves	70	48.52	0.01 - 3.85
Others	1096	54.02	0.01 - 7.22
Total	1290	54.00	0.01 - 7.22

(a)

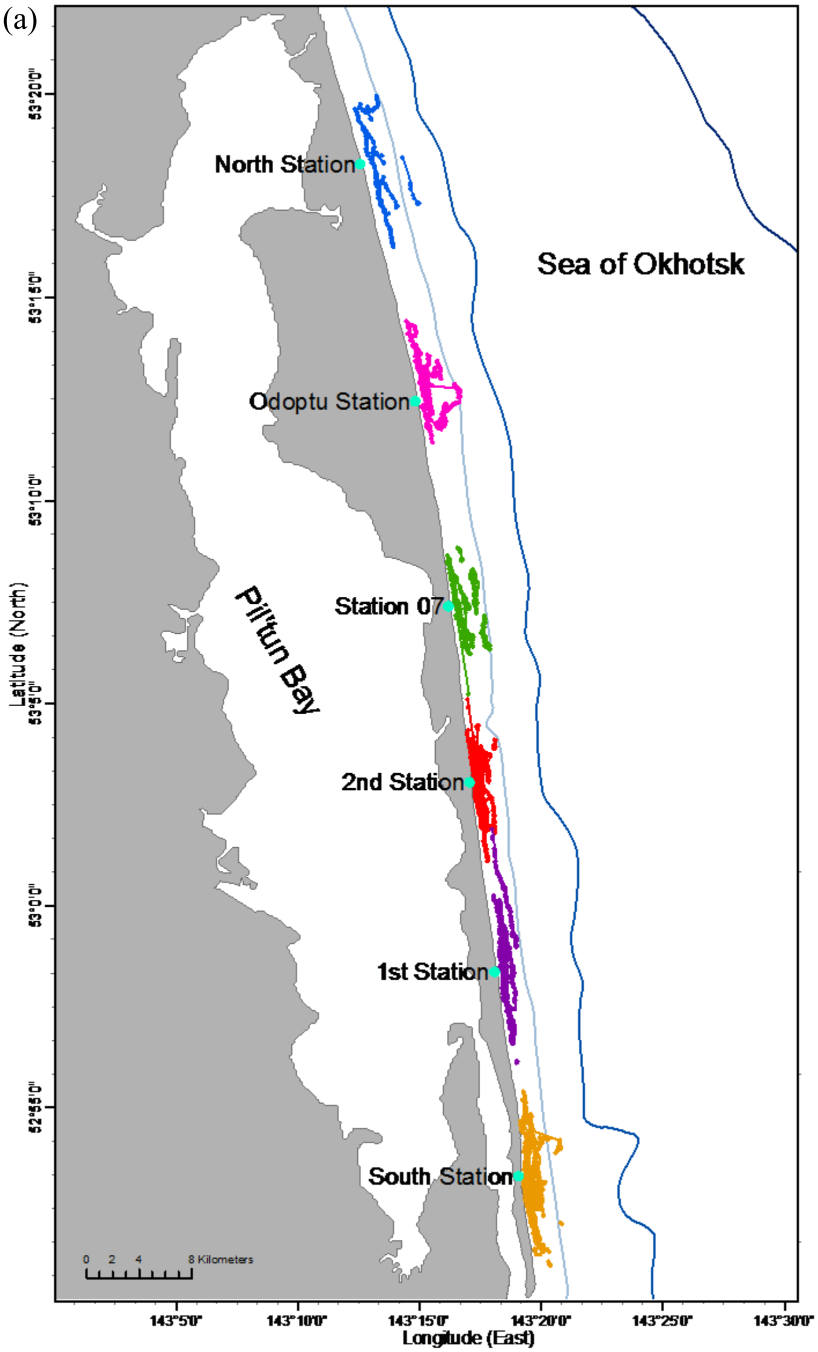

Figure 6. Tracklines of (a) mother/calf pairs (n = 124), (b) calves (n = 70), and (c) other individuals (n = 1096) along the coast of northeastern Sakhalin Island recorded during the summer-autumn months of 2002-2009. n – number of tracklines.

(b)

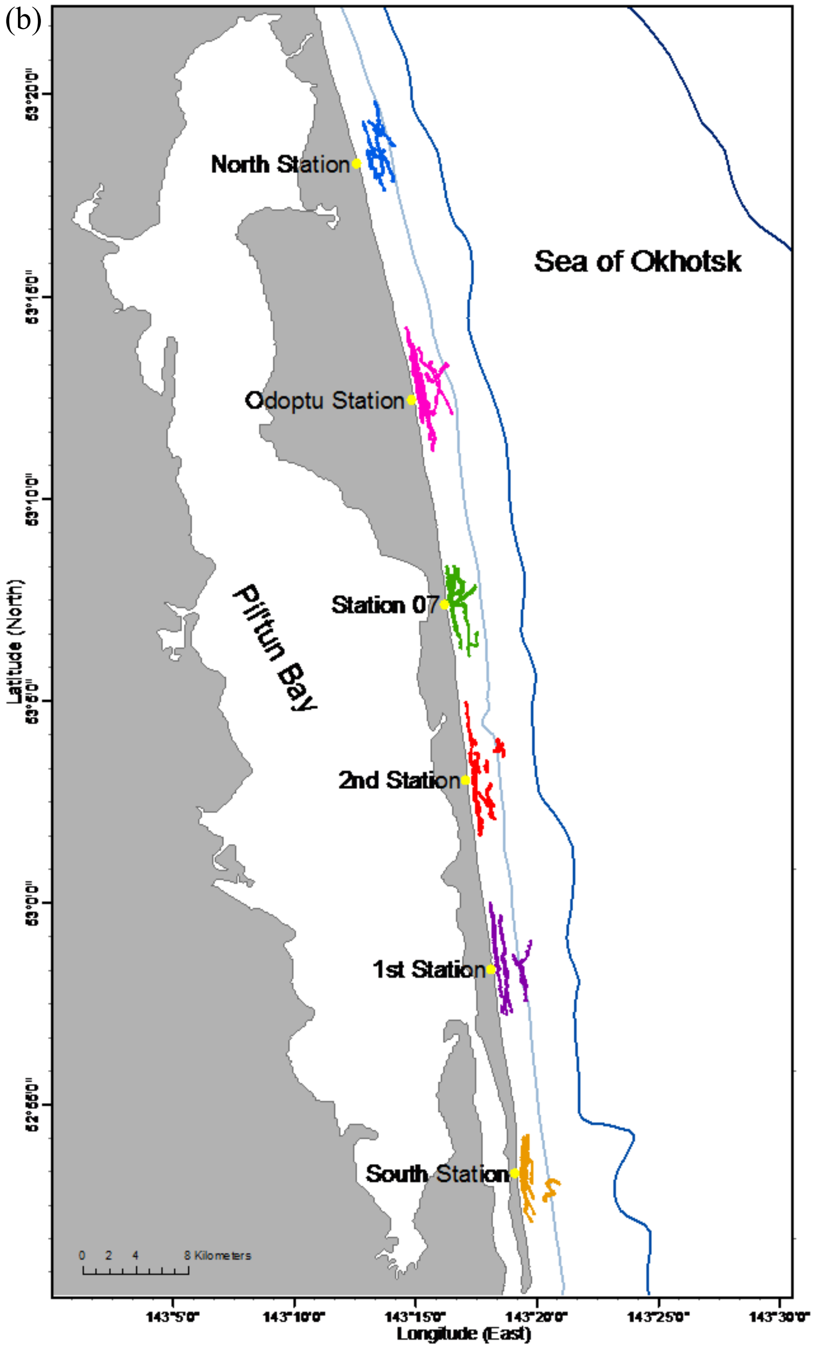

Figure 6. Continued.

(c)

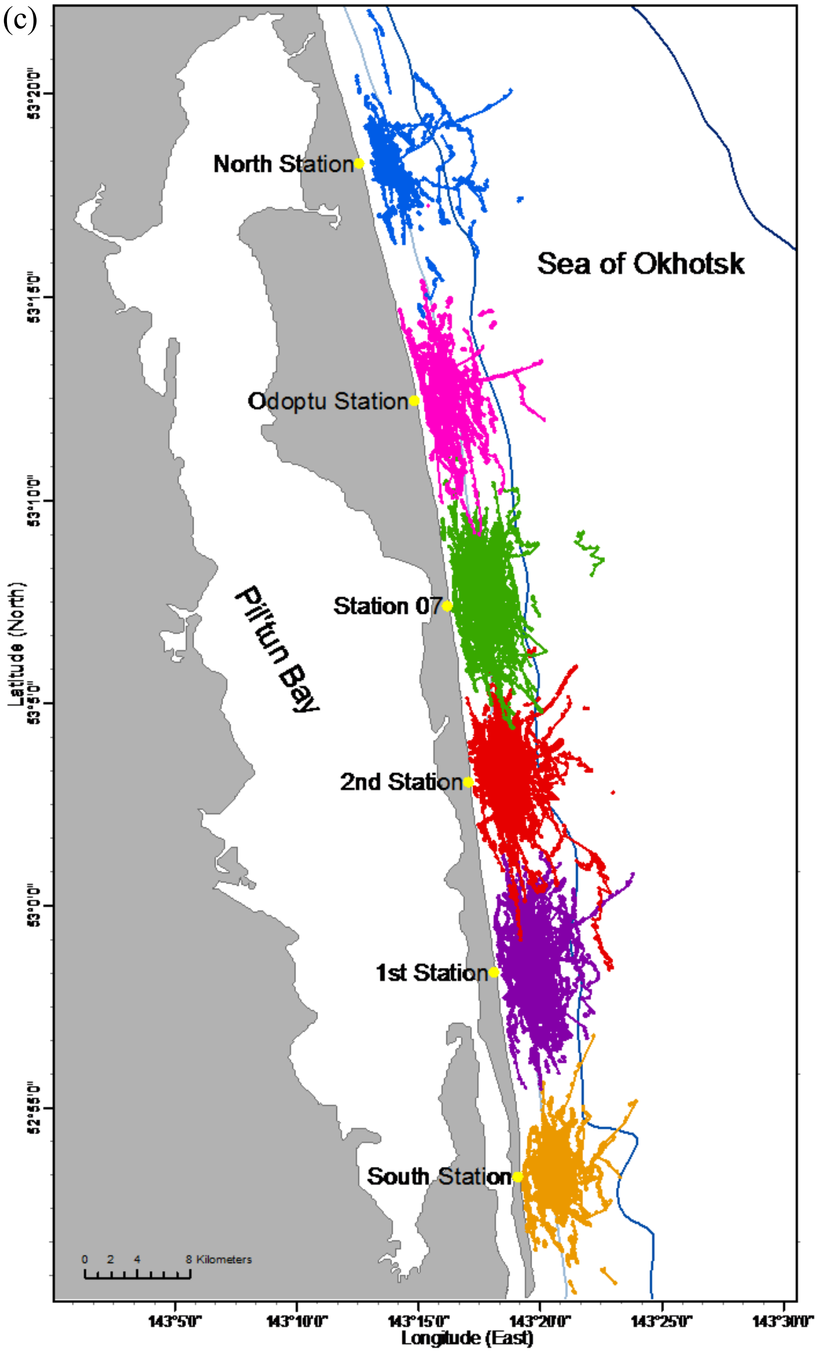

Figure 6. Continued.

The analytical data set yielded 719 tracklines (88 tracklines for mother/cal pairs, 54 – calves, and 577 – other individuals) that were suitable for movement analyses. The results for all movement parameters calculated for the three groups of individuals (mother/cal pairs, calves, and other individuals) are shown in Table 5.

The general movement analyses showed no significant differences in speed ($F = 0.83$, $df = 2$, $P = 0.43$), acceleration ($F = 1.48$, $df = 2$, $P = 0.23$), and ranging index ($F = 2.13$, $df = 2$, $P = 0.12$) between the three groups of individuals (Fig. 7, 8, 12). Reorientation rate ($F = 6.60$, $df = 2$, $P = 0.001$), linearity index ($F = 7.65$, $df = 2$, $P < 0.001$), and mean vector length ($F = 8.35$, $df = 2$, $P < 0.001$) were, however, significantly different between mother/calf pairs and calves, and between calves and other individuals, with calves having the lowest reorientation rate and highest linearity and mean vector length (Fig. 9, 10, 11). Distance to shore was also significantly different between all groups of individuals ($F = 68.16$, $df = 2$, $P < 0.001$), increasing from mother/calf pairs to calves, to other individuals (Fig. 13).

Table 5. Summary information of movement parameters of gray whales obtained from general analyses of theodolite tracking data (2002-2009).

Variable	Individuals	Mean	Median	Min	Max	SD	n
Speed (km/h)	Mom/Calf Pairs	2.33	2.02	0.31	9.22	1.593	88
	Calves	2.70	2.36	0.60	6.58	1.655	54
	Others	2.52	1.92	0.15	9.25	1.921	577
Acceleration (km/h²)	Mom/Calf Pairs	-0.03	-0.01	-0.86	0.35	0.208	88
	Calves	0.00	0.02	-0.51	0.42	0.172	54
	Others	0.01	0.01	-0.84	0.95	0.217	577
Reorientation Rate (°/min)	Mom/Calf Pairs	21.91	18.23	1.32	72.35	16.965	88
	Calves	12.75	8.18	1.53	46.78	10.897	53
	Others	19.66	14.58	1.08	87.21	15.813	577
Linearity Index	Mom/Calf Pairs	0.79	0.89	0.07	1.00	0.255	88
	Calves	0.92	0.97	0.14	1.00	0.148	54
	Others	0.82	0.92	0.06	1.00	0.214	573
Mean Vector Length	Mom/Calf Pairs	0.76	0.83	0.06	1.00	0.238	88
	Calves	0.89	0.96	0.22	1.00	0.162	54
	Others	0.78	0.89	0.08	1.00	0.239	576
Ranging Index (m/min)	Mom/Calf Pairs	35.36	30.52	3.76	152.86	27.106	87
	Calves	43.07	37.57	8.05	109.23	28.304	54
	Others	38.60	27.78	2.87	153.74	32.489	574
Distance from shore (km)	Mom/Calf Pairs	0.55	0.44	0.14	1.90	0.325	88
	Calves	0.81	0.68	0.23	2.32	0.477	54
	Others	1.30	1.31	0.03	4.34	0.679	577

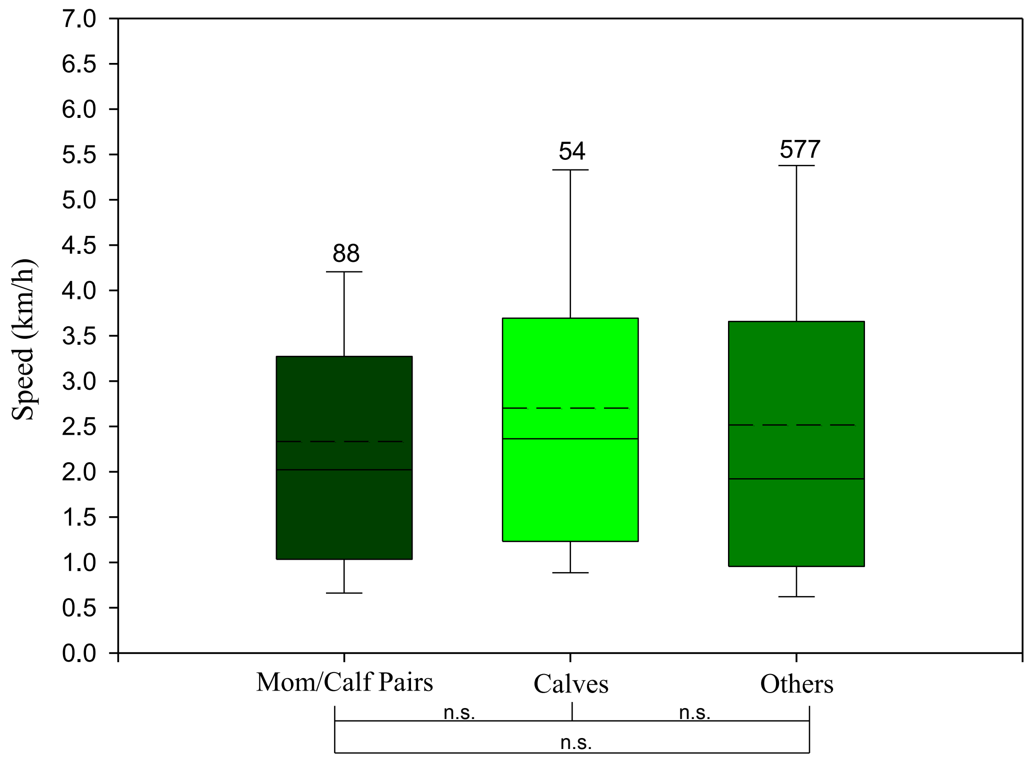

Figure 7. Leg speed of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. The dashed lines represent mean values, solid lines represent the 50th percentile, each box represents the 25th and 75th percentile, and whiskers represent the 10th and 90th percentile. Lines under the x axis illustrate significant differences among the different groups (P value if significant and n.s. if non-significant).

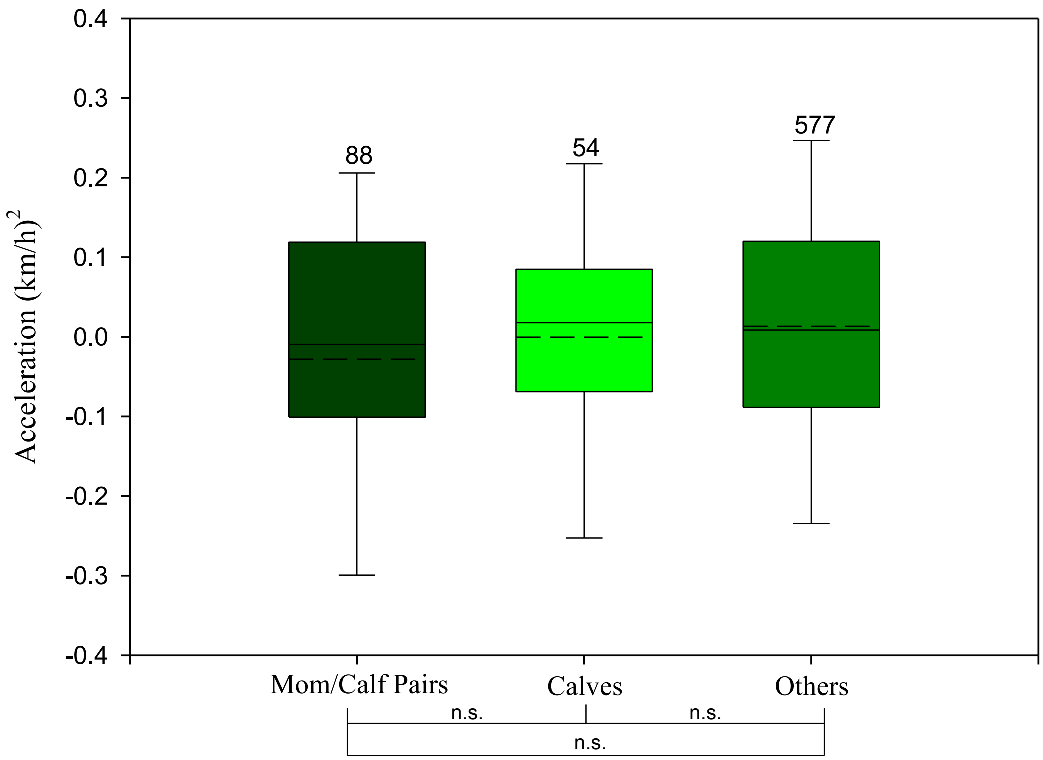

Figure 8. Acceleration of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. Displays as in Figure 7.

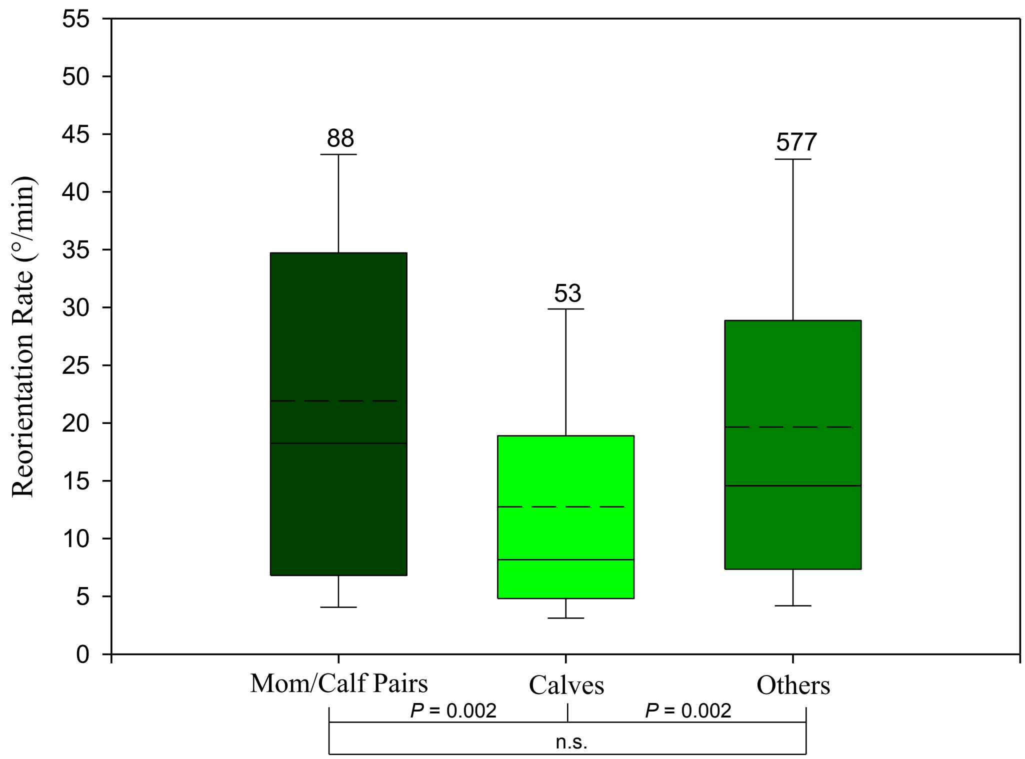

Figure 9. Reorientation rate of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. Displays as in Figure 7.

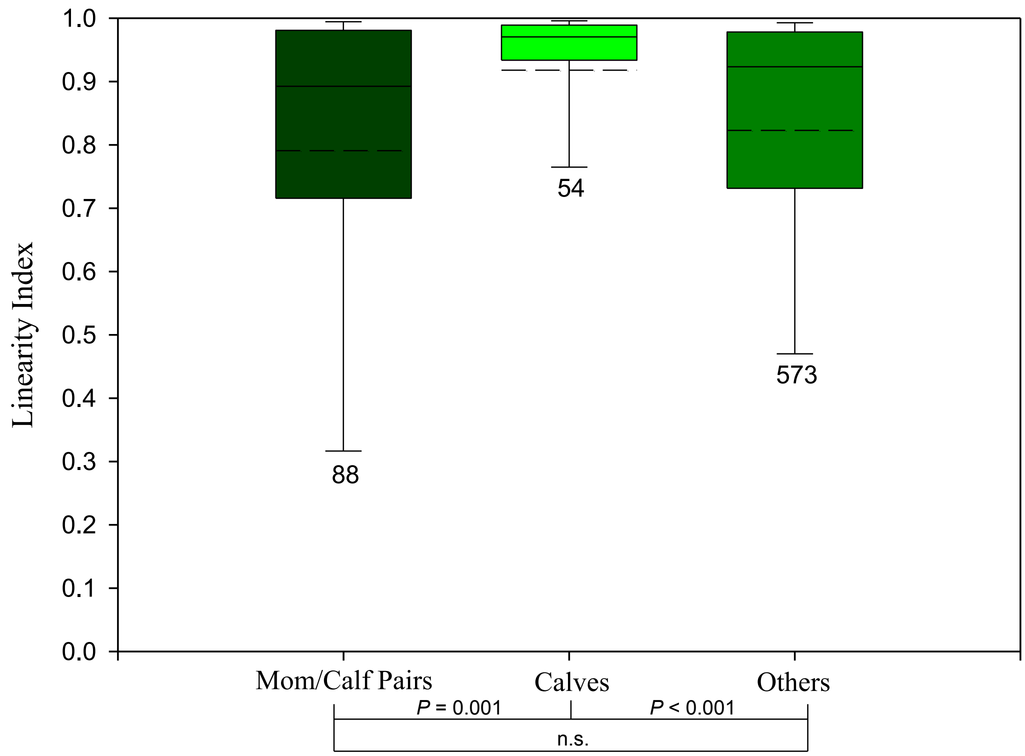

Figure 10. Linearity index of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. Displays as in Figure 7.

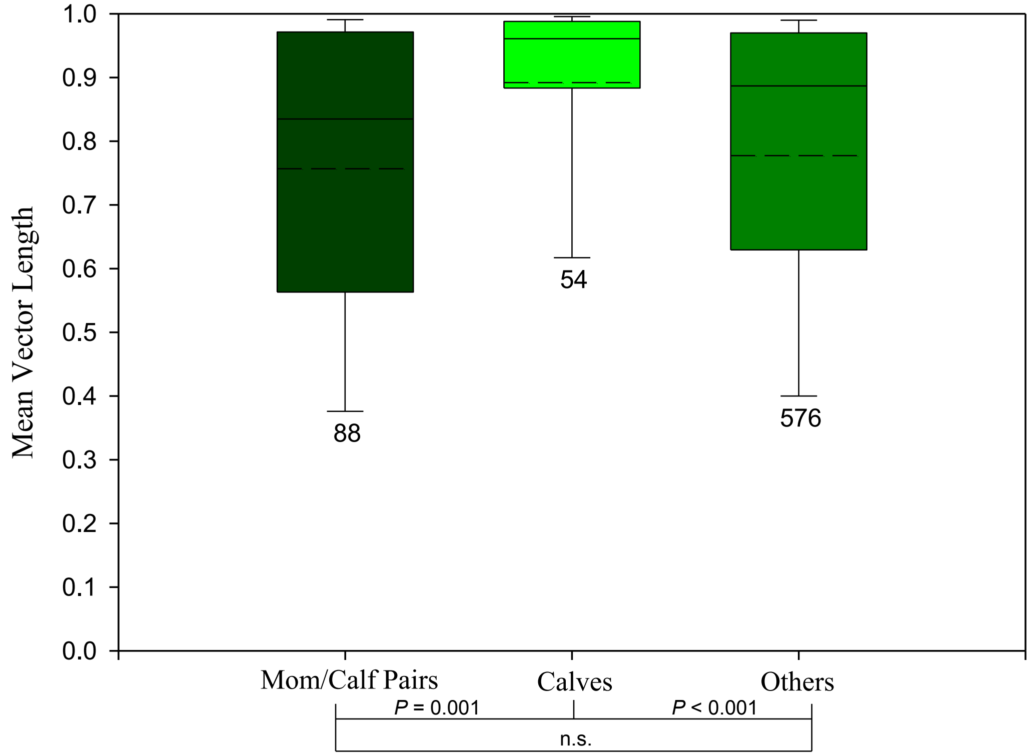

Figure 11. Mean vector length of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. Displays as in Figure 7.

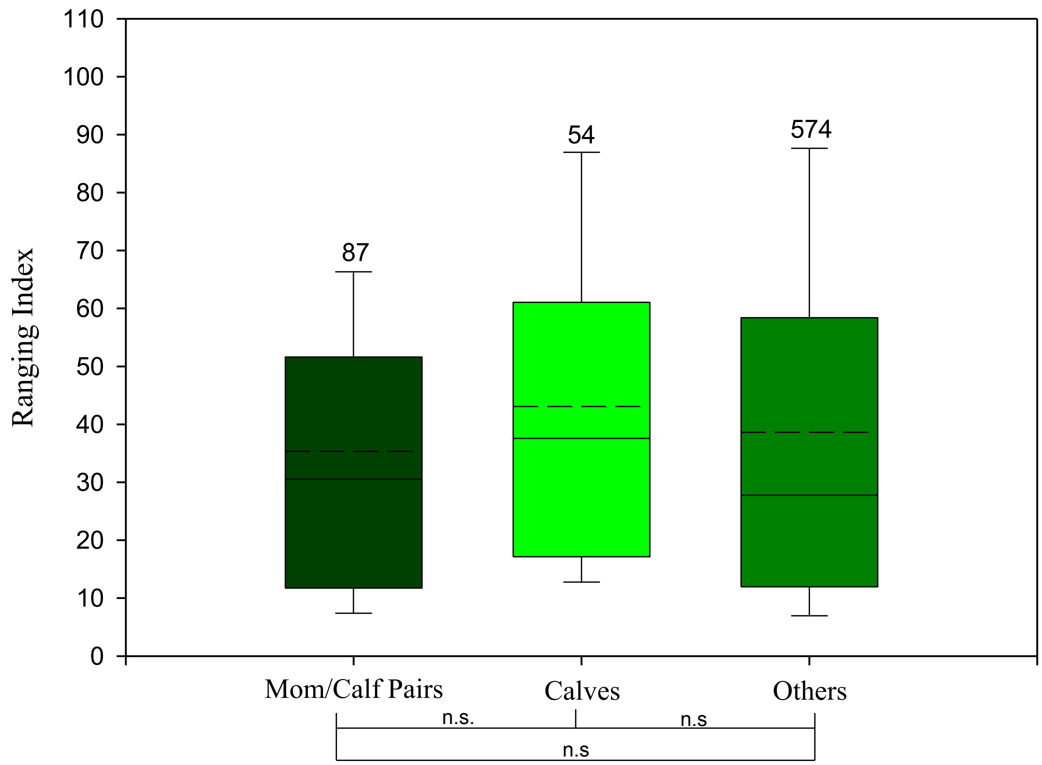

Figure 12. Ranging index of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. Displays as in Figure 7.

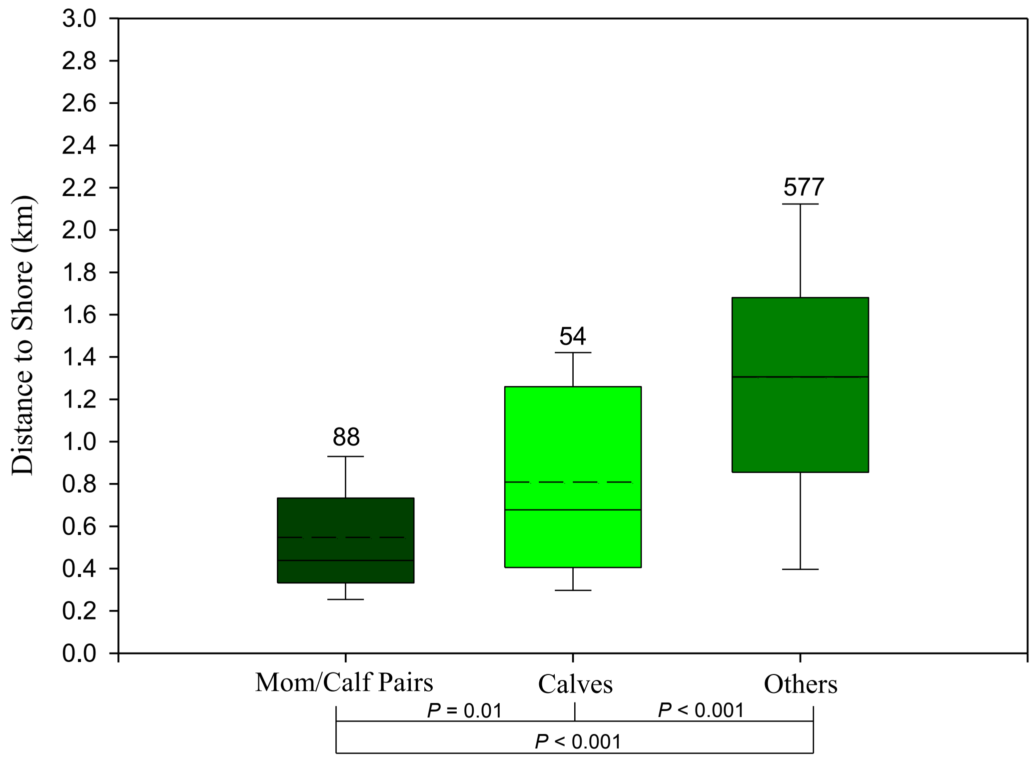

Figure 13. Distance from shore of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. Displays as in Figure 7.

Respiration Patterns (Focal-animal Observations)

During the 2002-2009 field seasons, a total of 444 focal behavioral observations on gray whales were conducted: 17 – mother/calf pairs, 35 – calves, and 392 – other individuals (Table 6). The duration of focal-animal sessions ranged from 9 minutes to 7 hours ($\overline{\chi}$ = 58.68 min./session) of one consistent observation.

Table 6. Effort information on focal behavioral observations conducted at six shore-based stations during 2002-2009.

Individuals	# Focals	Mean duration (min)	Range (h)
Mom/Calf Pairs	17	40.85	0.17 - 1.67
Calves	35	35.93	0.17 - 2.10
Others	392	61.22	0.17 - 7.03
Total	444	58.68	0.17 - 7.03

The results for all respiration parameters calculated for the three groups of individuals (mother/cal pairs, calves, and other individuals) are presented in Table 7. Respiration interval ($F = 14.17$, $df = 2$, $P < 0.001$) and dive time ($F = 11.84$, $df = 2$, $P < 0.001$) were significantly different between mother/calf pairs and other individuals, and between other individuals and calves, with other individuals having longer respiration interval and the shortest dive time (Fig. 14, 17). Surface blow rate ($F = 5.78$, $df = 2$, $P = 0.003$) was also significantly different between mother/calf pairs and other individuals, and had a marginal value $P = 0.052$ between calves and other individuals (Fig. 18). Number of blows per surfacing ($F = 0.50$, $df = 2$, $P = 0.60$), surface time ($F = 0.51$, $df = 2$, $P = 0.60$), and dive-surface blow rate ($F = 0.45$, $df = 2$, $P = 0.64$) were not found to be significantly different between different groups of individuals (Fig. 15, 16, 19).

Table 7. Summary information of respiration parameters of gray whales obtained from general analyses of focal-animal observations (2002-2009).

Variable	Individuals	Mean	Median	Min	Max	SD	n
Respiration Interval (min)	Mom/Calf Pairs	0.52	0.45	0.35	0.83	0.162	17
	Calves	0.48	0.48	0.20	0.77	0.156	34
	Others	0.37	0.32	0.15	0.88	0.165	389
Surface Time (min)	Mom/Calf Pairs	1.70	1.30	0.30	6.32	1.496	17
	Calves	1.96	1.17	0.20	11.40	2.261	31
	Others	1.63	0.98	0.05	15.82	2.020	389
Dive Time (min)	Mom/Calf Pairs	1.67	1.65	1.18	2.57	0.428	17
	Calves	1.81	1.72	1.02	3.27	0.581	31
	Others	2.42	2.23	1.02	5.92	0.965	383
Number Blows/Surfacing	Mom/Calf Pairs	4.33	3.67	1.38	9.50	2.346	17
	Calves	5.06	3.50	1.17	21.00	3.802	31
	Others	5.05	4.00	1.00	25.00	3.429	388
Surface Blow Rate (blows/min)	Mom/Calf Pairs	3.26	3.23	1.68	5.65	1.133	17
	Calves	3.69	2.86	1.65	8.88	1.811	31
	Others	4.44	4.51	1.39	10.00	1.799	390
Dive-Surface Blow Rate (blows/min)	Mom/Calf Pairs	1.10	1.07	0.81	1.38	0.169	16
	Calves	1.22	1.22	0.59	1.95	0.337	28
	Others	1.19	1.15	0.42	2.25	0.338	370

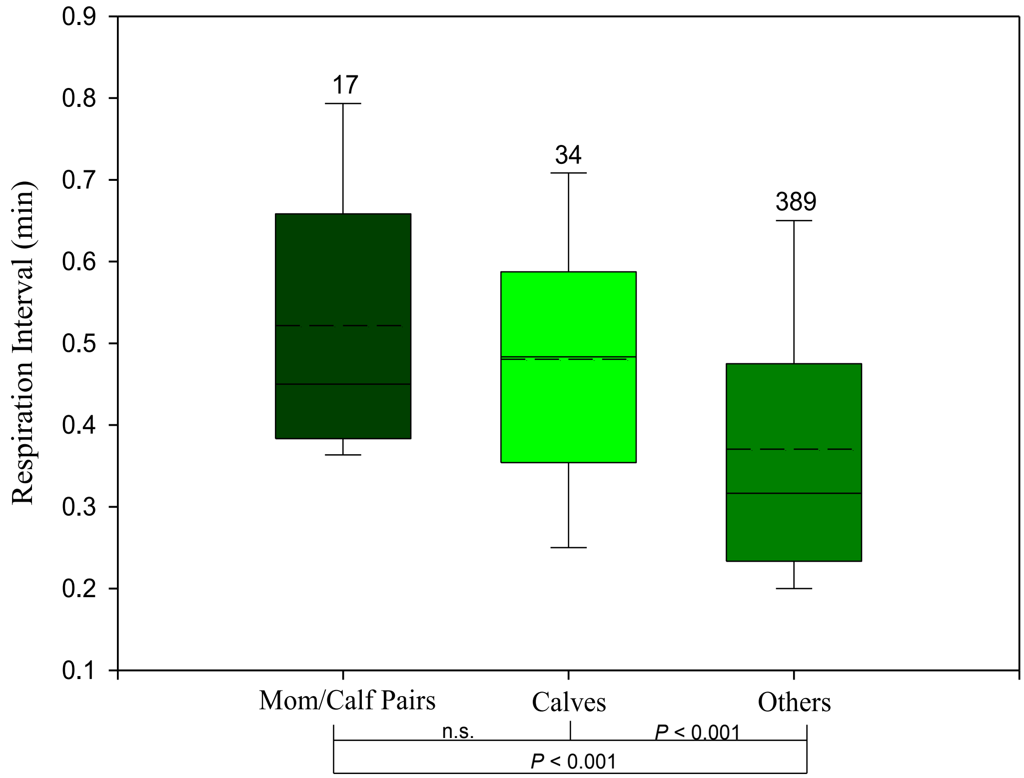

Figure 14. Respiration interval of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. Displays as in Fig. 7.

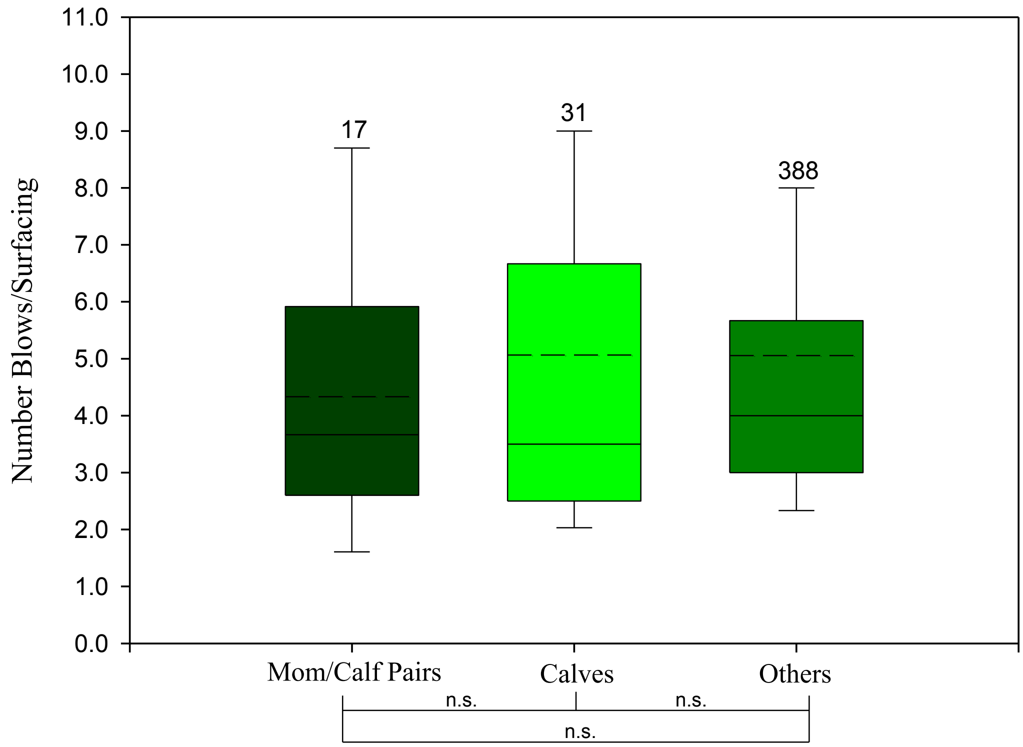

Figure 15. Number of respirations per surfacing of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. Displays as in Fig. 7.

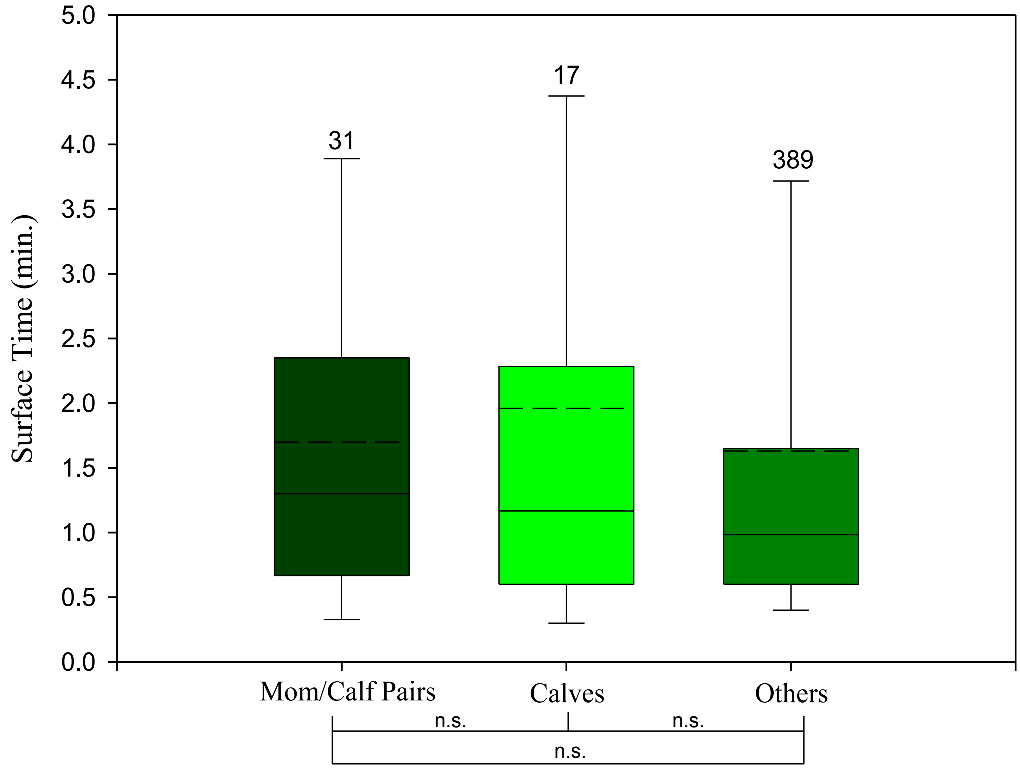

Figure 16. Surface time of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. Displays as in Fig. 7.

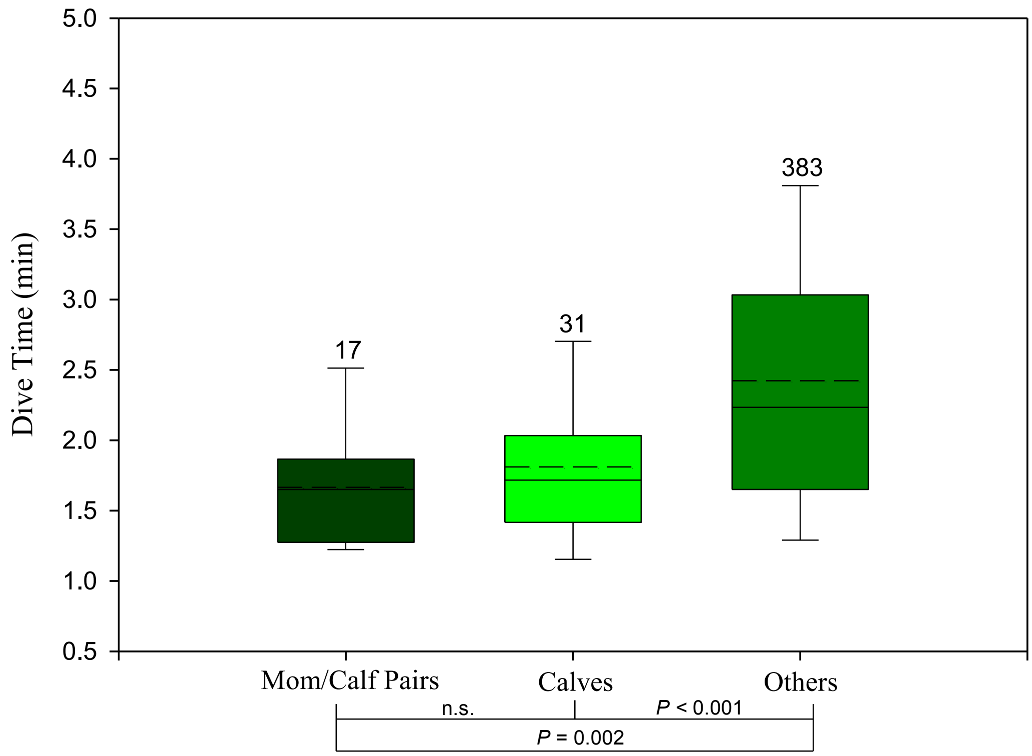

Figure 17. Dive time of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. Displays as in Fig. 7.

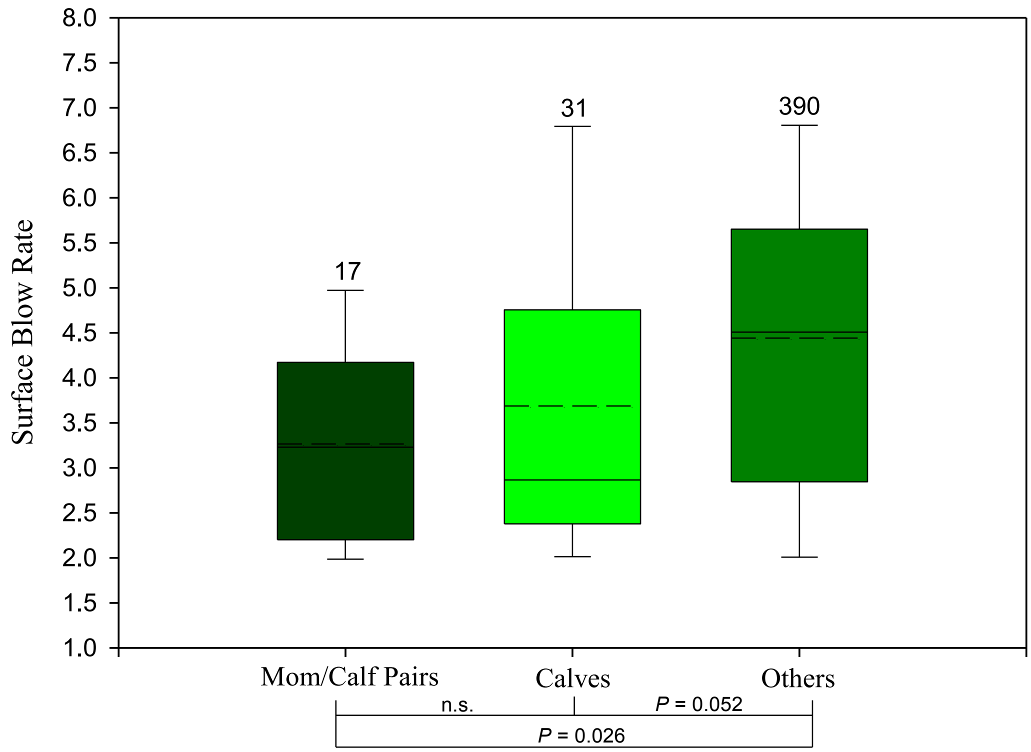

Figure 18. Surface blow rate of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. Displays as in Fig. 7.

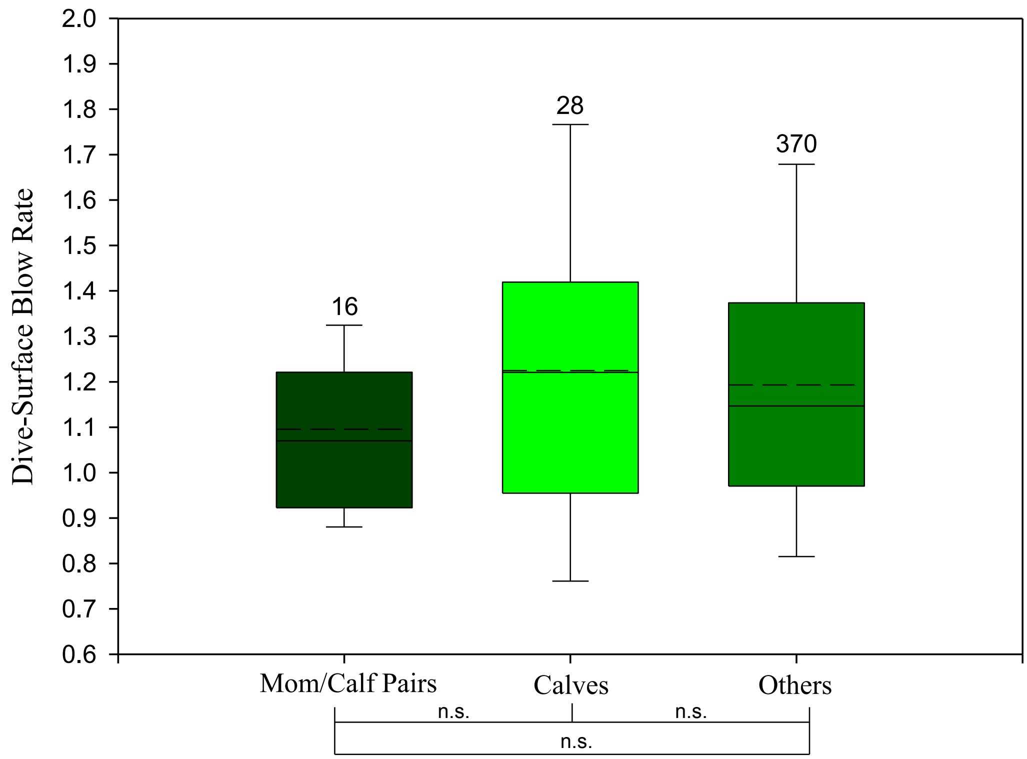

Figure 19. Dive-surface blow rate of mother/calf pairs, calves and other individuals observed at six shore-based stations in 2002-2009. Displays as in Fig. 7.

Behavior

Animal movement and respiration patterns can be affected by their current activity. To examine these differences among the different groups of individuals, analyses were conducted to consider behavioral states. During our study, gray whales were observed to be engaged in different behavioral activities: feeding, feeding/traveling, traveling, milling, socializing, nursing, and resting. However, the frequencies of different behavioral states observed in all individuals were not the same (Fig. 20). The majority of the whales were feeding, feeding/traveling, and traveling. Therefore, the analyses were based on these three primary behavioral states. Other behavioral states provided limited sample size for statistical analyses. The results of all movement parameters examined here for the three groups of individuals (mother/calf pairs, calves, and other individuals) relative to their behavioral activity are presented in Tables 8, 9, 10, and 11.

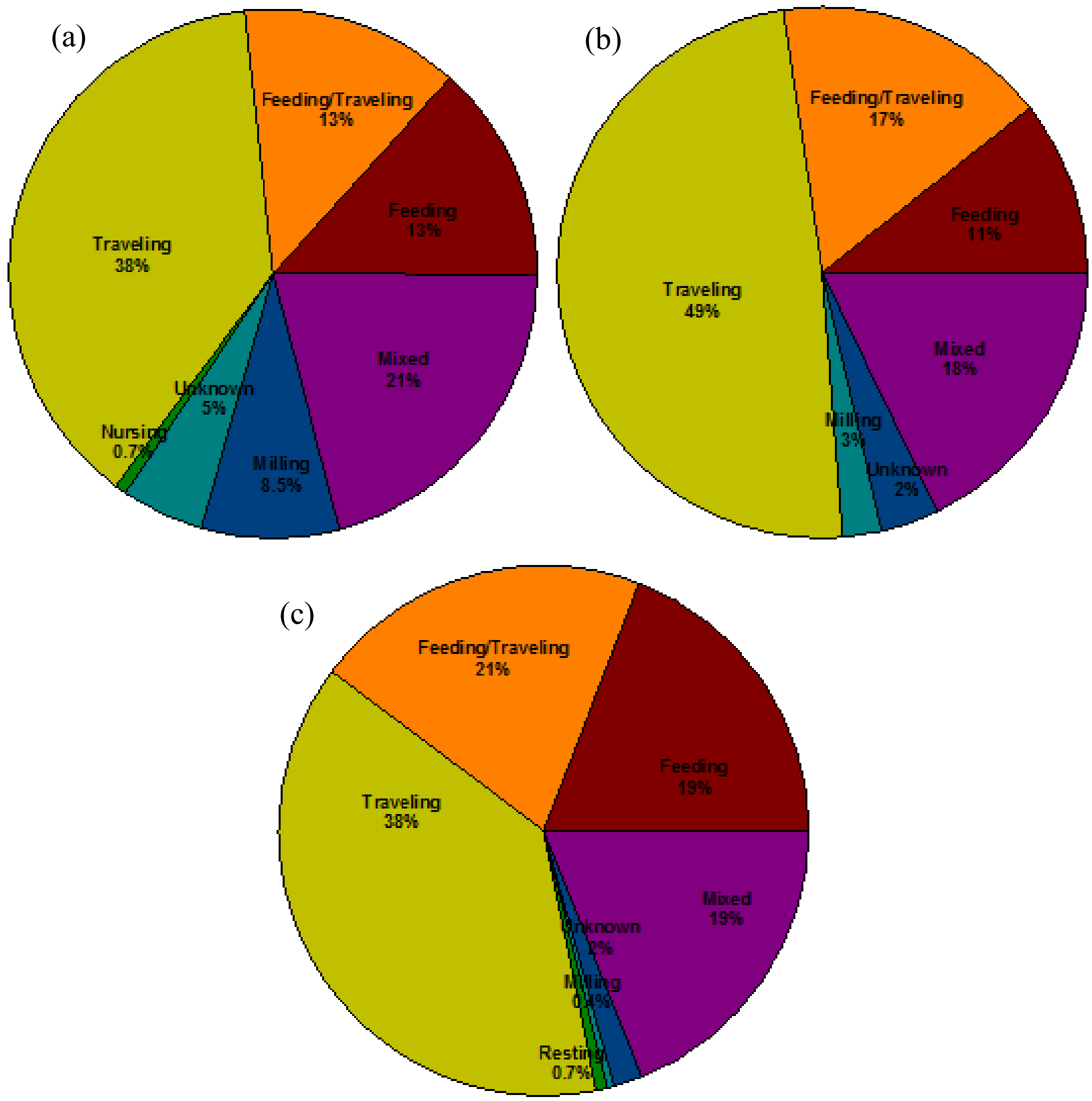

Figure 20. Behavioral states that were present in 10.5-minute bins of all tracklines of (a) mother/calf pairs, (b) calves, and (c) other individuals (2002-2009). “Mixed” represents category of combined behavioral states, when at least two of them were present within one bin.

Table 8. Summary information of movement variables of mother/calf pairs for different behavioral states (2002-2009).

Variable	Behavior	Mean	Median	Min	Max	SD	n
Speed (km/h)	Feeding	0.82	0.74	0.32	1.48	0.309	19
	Feed/Travel	1.30	1.21	0.31	2.22	0.541	19
	Traveling	3.28	3.19	1.01	9.22	1.410	54
Acceleration (km/h²)	Feeding	-0.05	-0.03	-0.37	0.12	0.125	19
	Feed/Travel	0.01	-0.03	-0.22	0.28	0.154	19
	Traveling	-0.01	-0.03	-0.39	0.47	0.186	53
Reorientation Rate (°/min)	Feeding	42.44	37.12	8.02	73.23	17.792	19
	Feed/Travel	30.93	29.20	7.41	70.09	16.965	19
	Traveling	10.83	8.06	1.32	34.76	8.633	54
Linearity Index	Feeding	0.49	0.42	0.09	0.98	0.285	19
	Feed/Travel	0.72	0.74	0.22	1.00	0.216	19
	Traveling	0.94	0.98	0.54	1.00	0.094	54
Mean Vector Length	Feeding	0.48	0.50	0.11	0.96	0.202	19
	Feed/Travel	0.60	0.65	0.17	0.98	0.260	19
	Traveling	0.90	0.97	0.42	1.00	0.146	54
Ranging Index (m/min)	Feeding	8.50	6.83	2.44	16.63	4.021	19
	Feed/Travel	17.02	15.94	3.76	36.44	9.643	19
	Traveling	49.74	49.38	15.18	95.17	19.162	53
Distance from shore (km)	Feeding	0.59	0.47	0.18	1.39	0.335	19
	Feed/Travel	0.73	0.71	0.18	1.98	0.431	19
	Traveling	0.46	0.40	0.13	1.00	0.211	54

Table 9. Summary information of movement variables of calves for different behavioral states (2002-2009).

Variable	Behavior	Mean	Median	Min	Max	SD	n
Speed (km/h)	Feeding	0.93	1.06	0.30	1.58	0.403	9
	Feed/Travel	1.20	1.08	0.38	3.09	0.752	14
	Traveling	3.45	3.20	0.96	6.58	1.573	41
Acceleration (km/h²)	Feeding	0.06	0.07	-0.15	0.24	0.137	9
	Feed/Travel	-0.13	-0.08	-0.58	0.08	0.198	14
	Traveling	0.05	0.05	-0.42	0.56	0.212	41
Reorientation Rate (°/min)	Feeding	38.80	44.44	5.09	56.52	18.327	9
	Feed/Travel	28.02	30.20	5.86	50.72	14.682	14
	Traveling	9.23	6.62	1.53	35.42	7.496	41
Linearity Index	Feeding	0.60	0.55	0.35	0.99	0.195	8
	Feed/Travel	0.81	0.81	0.52	0.98	0.143	14
	Traveling	0.95	0.98	0.72	1.00	0.074	41
Mean Vector Length	Feeding	0.50	0.39	0.18	0.98	0.325	9
	Feed/Travel	0.67	0.62	0.28	0.97	0.224	14
	Traveling	0.93	0.97	0.42	1.00	0.113	41
Ranging Index (m/min)	Feeding	10.77	10.94	2.69	17.65	5.647	9
	Feed/Travel	17.42	14.06	4.92	50.04	12.571	14
	Traveling	55.34	51.36	14.99	109.23	27.399	41
Distance from shore (km)	Feeding	0.77	0.53	0.25	1.35	0.464	9
	Feed/Travel	0.86	0.92	0.26	1.45	0.382	14
	Traveling	0.79	0.55	0.24	2.11	0.533	41

Table 10. Summary information of movement variables of other individuals for different behavioral states (2002-2009).

Variable	Behavior	Mean	Median	Min	Max	SD	n
Speed (km/h)	Feeding	0.89	0.76	0.15	4.10	0.518	174
	Feed/Travel	1.51	1.22	0.19	5.07	0.909	186
	Traveling	3.88	3.72	0.33	9.31	1.810	348
Acceleration (km/h²)	Feeding	-0.02	0.00	-0.81	0.73	0.166	174
	Feed/Travel	-0.01	0.00	-0.66	0.68	0.172	186
	Traveling	0.02	0.02	-0.94	0.78	0.269	345
Reorientation Rate (°/min)	Feeding	36.47	35.12	5.11	80.22	16.092	174
	Feed/Travel	21.37	19.08	1.42	70.70	12.256	186
	Traveling	10.17	8.04	1.15	44.17	7.405	348
Linearity Index	Feeding	0.55	0.55	0.06	0.98	0.245	174
	Feed/Travel	0.81	0.88	0.12	1.00	0.189	186
	Traveling	0.94	0.97	0.27	1.00	0.103	348
Mean Vector Length	Feeding	0.52	0.52	0.04	0.99	0.236	174
	Feed/Travel	0.75	0.79	0.17	1.00	0.206	186
	Traveling	0.92	0.96	0.34	1.00	0.117	348
Ranging Index (m/min)	Feeding	10.03	8.24	1.86	46.21	6.740	174
	Feed/Travel	21.99	17.12	1.89	82.70	14.877	186
	Traveling	61.29	58.58	4.58	153.14	30.415	348
Distance from shore (km)	Feeding	1.33	1.34	0.04	2.60	0.566	174
	Feed/Travel	1.31	1.32	0.04	4.29	0.599	186
	Traveling	1.27	1.29	0.03	4.11	0.699	348

Table 11. Summary of mean values of movement variables of mother/calf pairs, calves and other individuals for different behavioral states (2002-2009).

Variable	Behavior	Mother/Calf	Calves	Other
Speed (km/h)	Feeding	0.82	0.93	0.89
	Feed/Travel	1.30	1.20	1.51
	Traveling	3.28	3.45	3.88
Acceleration (km/h²)	Feeding	-0.05	0.06	-0.02
	Feed/Travel	0.01	-0.13	-0.01
	Traveling	-0.01	0.05	0.02
Reorientation Rate (°/min)	Feeding	42.44	38.80	36.47
	Feed/Travel	30.93	28.02	21.37
	Traveling	10.83	9.23	10.17
Linearity Index	Feeding	0.49	0.60	0.55
	Feed/Travel	0.72	0.81	0.81
	Traveling	0.94	0.95	0.94
Mean Vector Length	Feeding	0.48	0.50	0.52
	Feed/Travel	0.60	0.67	0.75
	Traveling	0.90	0.93	0.92
Ranging Index (m/min)	Feeding	8.50	10.77	10.03
	Feed/Travel	17.02	17.42	21.99
	Traveling	49.74	55.34	61.29
Distance from shore (km)	Feeding	0.59	0.77	1.33
	Feed/Travel	0.73	0.86	1.31
	Traveling	0.46	0.79	1.27

Movement analyses of all three groups of individuals (mother/calf pairs, calves and other individuals) found significant differences in speeds ($F = 539.23$, $df = 2$, $P < 0.001$) while individuals were engaged in different behavioral activity: increasing from feeding to feeding/traveling, to traveling (Fig. 21). Speed ($F = 3.82$, $df = 2$, $P = 0.02$) was also different for the different individuals after accounting for differences in behavioral states. Post-hoc comparisons had a marginal significance value of $P = 0.05$ between mother/calf pairs and other individuals, which could be related to sample size. The interaction terms between behavioral states and individual groups did not indicate to be an influential factor. Suggesting that the combination of the individual groups and the movement parameters did not influence the movement variable being analyzed, but rather it was one or the other factor that influenced the results. In fact, the interaction term was not found to be significantly different for any of the movement variables.

The maximum speed of 9.2 km/h was observed for mother/calf pair in association with another weaned calf on one single occasion. Three individuals were observed on 2 September 2009 at Station 07 traveling fast parallel to shore, and later at 2^{nd} Station, where they slowed down and milled for 3 hours (with the speed ranging from 0.4 to 2.3 km/h).

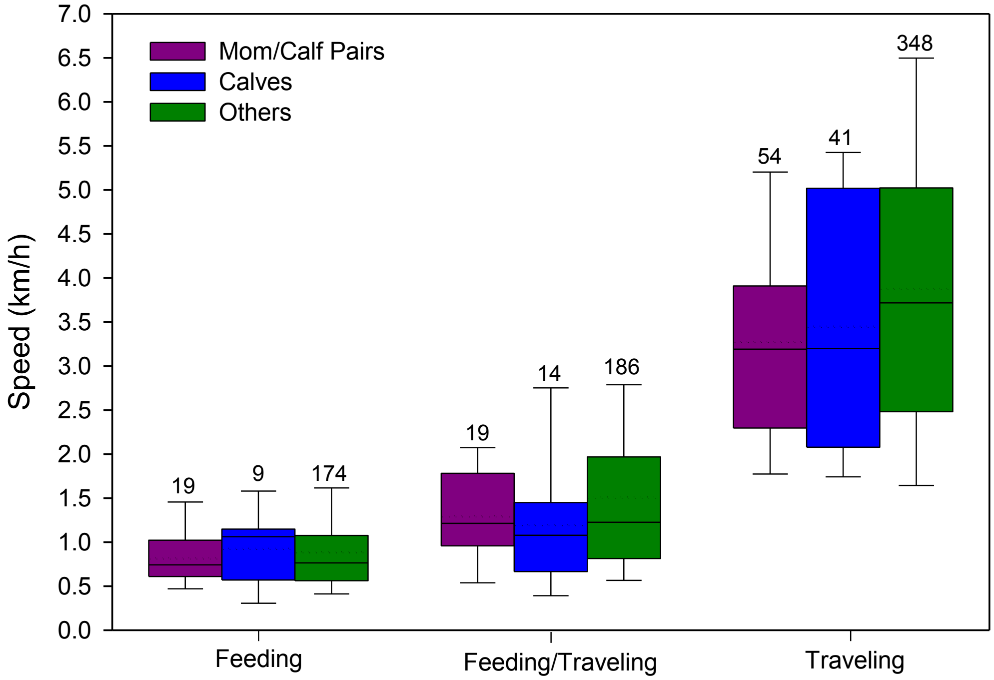

Figure 21. Speed of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. The dashed lines represent mean values, solid lines represent the 50th percentile, each box represents the 25th and 75th percentile, and whiskers represent the 10th and 90th percentile.

Significant differences occurred for acceleration during behavioral activities (F = 3.77, df = 2, P = 0.02); however, the post-hoc comparison did not indicate any significant differences while individuals were engaged in different behavioral activity. This may be due to small sample sizes for behavioral activities of calves and mother/calf pairs. No significant differences were found in acceleration in the different individuals (F = 0.32, df = 2, P = 0.72, Fig. 22).

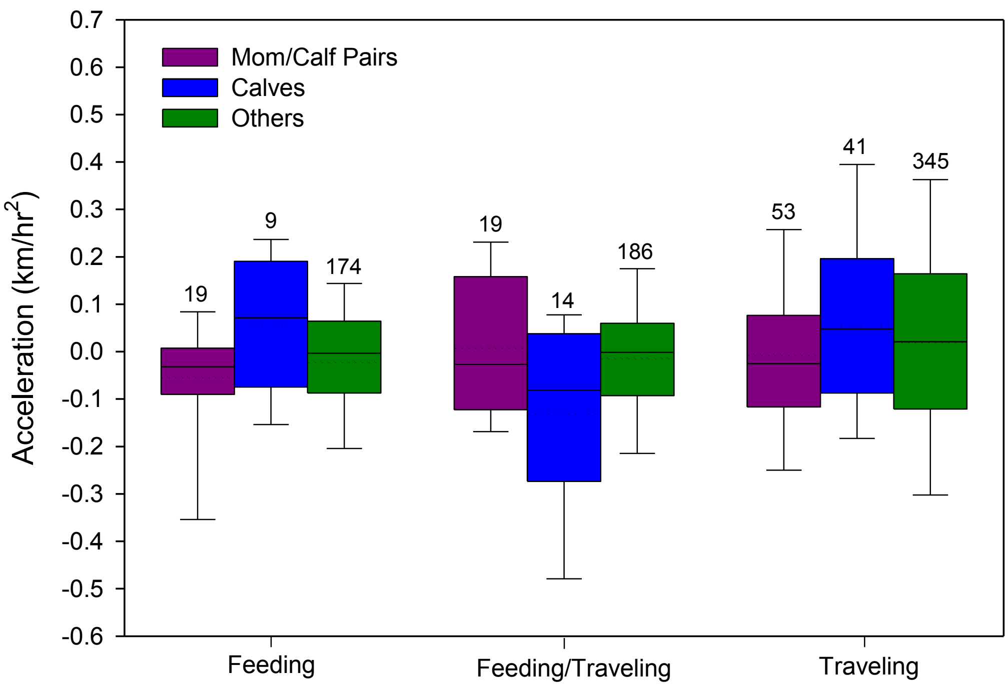

Figure 22. Acceleration of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. Displays as in Fig. 21.

Reorientation rates had significant differences (F = 357.24, df = 2, P < 0.001) while individuals were engaged in different behavioral activity: with the highest and lowest values for feeding and traveling, respectively. But there were no significant differences (F = 1.67, df = 2, P = 0.19) for the different individuals after accounting for differences in behavioral states (Fig. 23).

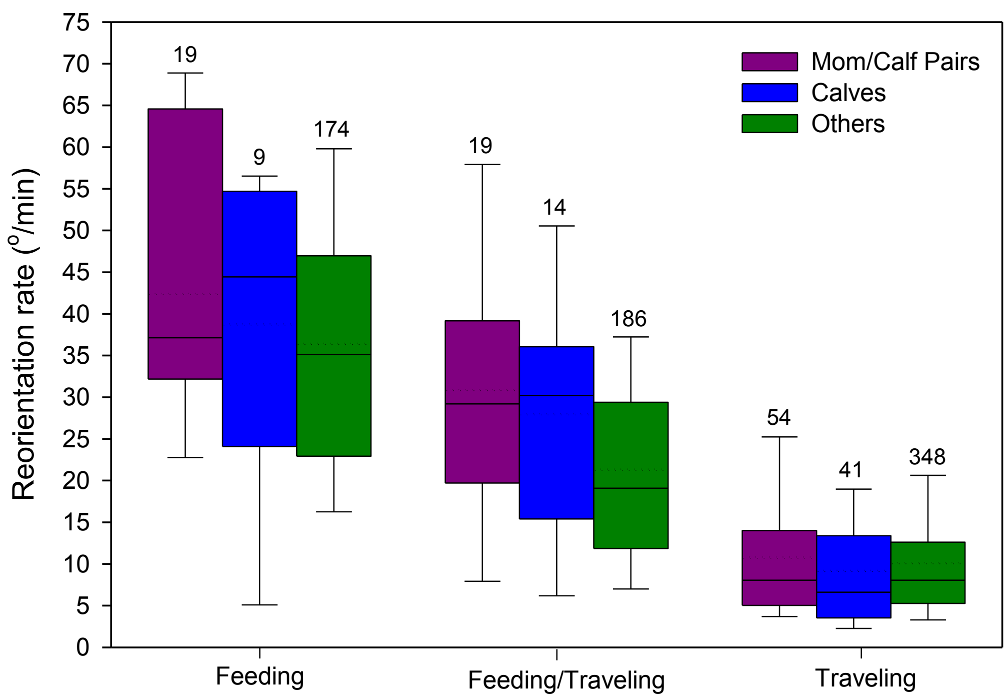

Figure 23. Reorientation rate of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. Displays as in Fig. 21.

Linearity index and mean vector length were significantly different (F = 261.18, df = 2, P < 0.001; F = 274.66, df = 2, P < 0.001, respectively) while individuals were engaged in different behavioral activities: increasing from feeding to feeding/traveling, to traveling. However, individual differences in the groups analyzed found no differences in linearity (F = 1.87, df = 2, P = 0.15, Fig. 24), and mean vector length (marginal value of P = 0.05, F = 2.92, df = 2). Post-hoc comparisons of mean vector length suggested that the marginal significance was between mother/calf pairs and other individuals, which could be related to limited sample size (Fig. 25).

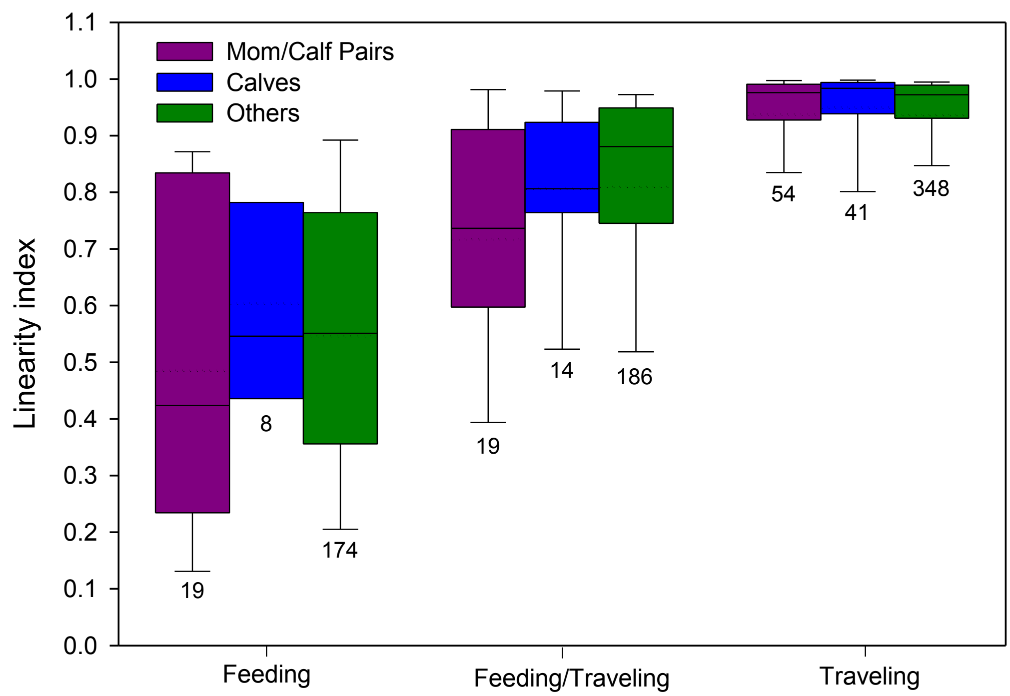

Figure 24. Linearity index of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. Displays as in Fig. 21.

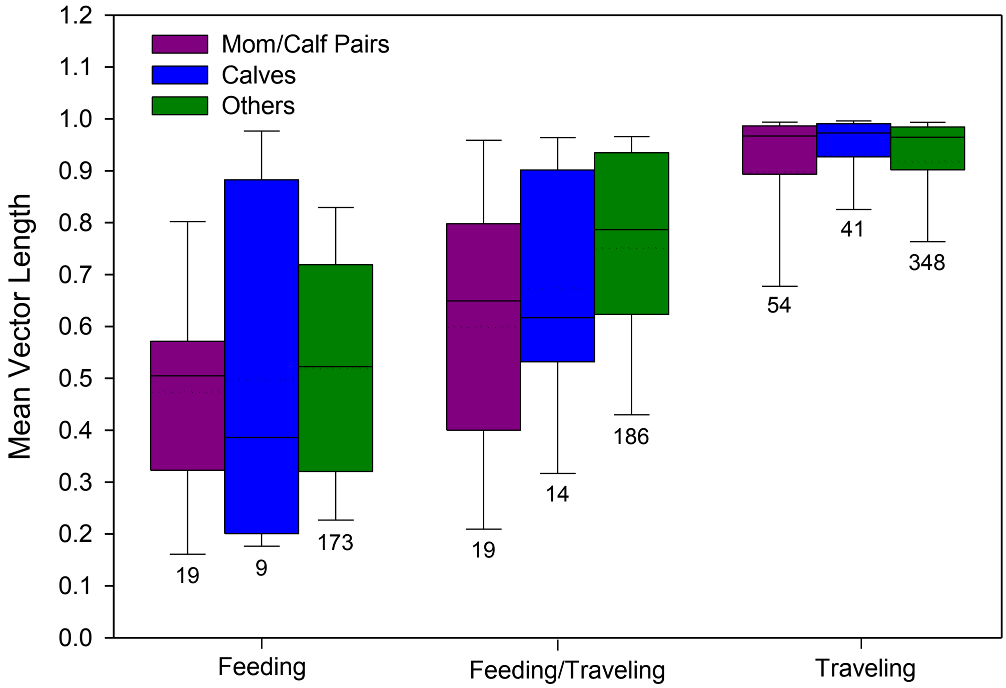

Figure 25. Mean vector length of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. Displays as in Fig. 21.

Significant differences (F = 717.51, df = 2, P < 0.001) were found in ranging index while individuals were engaged in different behavioral activity, with the lowest and highest values for feeding and traveling, respectively (Fig. 26). After accounting for the behavioral differences, the analysis showed a marginal significance value of P = 0.05 (F = 2.94, df = 2), which did not result in any significant differences in post-hoc comparison, and could be related to small sample size.

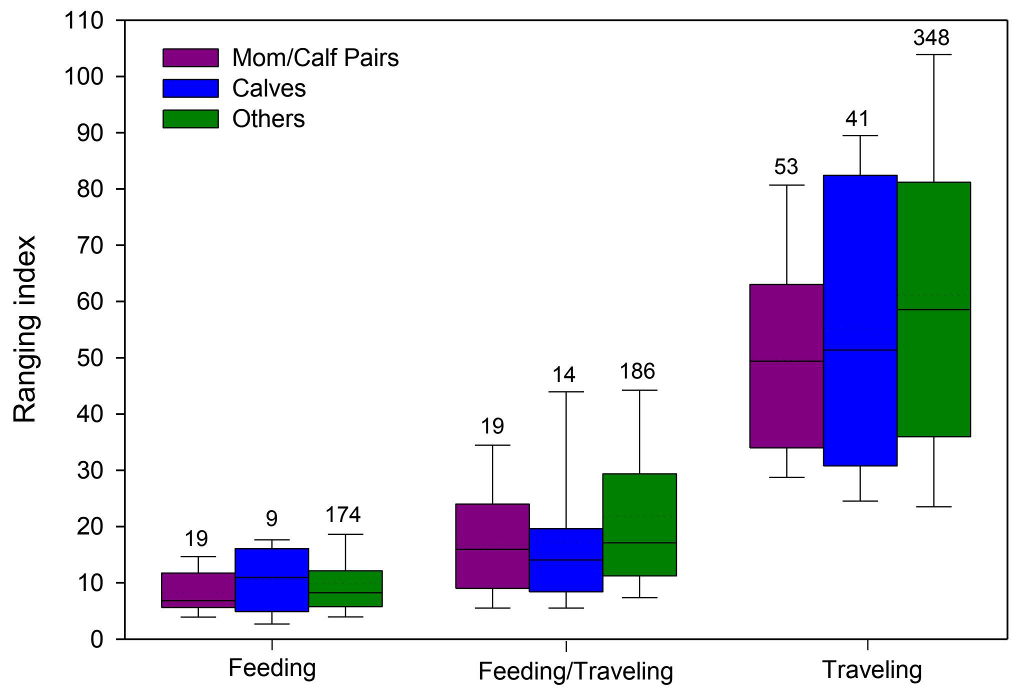

Figure 26. Ranging index of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. Displays as in Fig. 21.

Distance from shore was significantly different (F = 5.38, df = 2, P = 0.005) between individuals during feeding and traveling, and feeding/traveling and traveling (Fig. 27). It was, also found to be different (F = 78.67, df = 2, P < 0.001) for the different individuals after accounting for differences in behavioral states: between mother/calf pairs and other individuals (P < 0.001), other individuals and calves (P < 0.001), and mother/calf pairs and calves (P = 0.005), with the furthest distance from shore for other individuals.

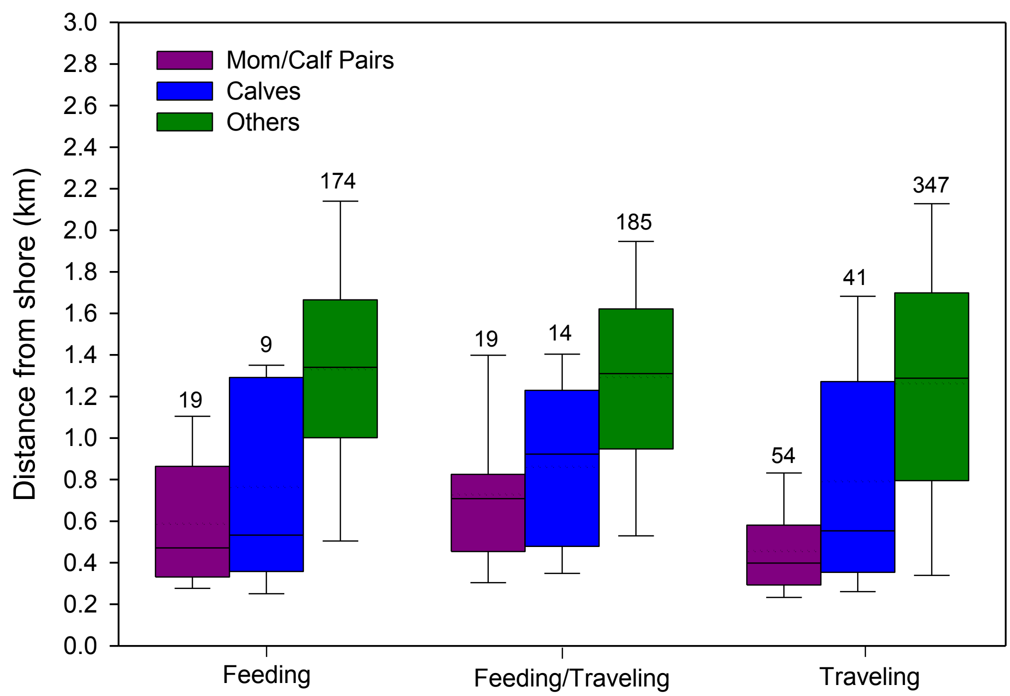

Figure 27. Distance from shore of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. Displays as in Fig. 21.

The results for all respiration parameters calculated for the three groups of individuals (mother/calf pairs, calves, and other individuals) relative to their behavior are presented in Tables 12, 13, 14, and 15.

Table 12. Summary information of respiration variables of mother/calf pairs for different behavioral states (2002-2009).

Variable	Behavior	Mean	Median	Min	Max	SD	N
Respiration Interval (min)	Feeding	0.32	0.27	0.27	0.42	0.087	3
	Feed/Travel	0.41	0.38	0.32	0.60	0.110	5
	Traveling	0.58	0.57	0.37	0.95	0.185	10
Surface Time (min)	Feeding	0.71	0.50	0.30	1.33	0.548	3
	Feed/Travel	1.45	1.27	0.48	3.05	1.002	5
	Traveling	1.45	1.18	0.50	3.28	0.884	10
Dive Time (min)	Feeding	1.80	1.67	1.55	2.18	0.337	3
	Feed/Travel	2.21	2.23	1.58	3.37	0.729	5
	Traveling	1.60	1.40	1.18	2.50	0.451	10
Number Blows/Surfacing	Feeding	3.14	2.75	1.67	5.00	1.700	3
	Feed/Travel	3.82	3.33	2.50	6.00	1.377	5
	Traveling	3.90	3.45	1.50	9.50	2.228	10
Surface Blow Rate (blows/min)	Feeding	5.47	5.65	4.76	6.00	0.640	3
	Feed/Travel	3.53	3.65	1.82	4.36	1.012	5
	Traveling	2.73	2.27	1.83	4.59	0.969	10
Dive-Surface Blow Rate (blows/min)	Feeding	1.20	0.95	0.83	1.83	0.545	3
	Feed/Travel	1.01	1.17	0.53	1.26	0.297	5
	Traveling	1.14	1.14	0.87	1.43	0.192	10

Table 13. Summary information of respiration variables of calves for different behavioral states (2002-2009).

Variable	Behavior	Mean	Median	Min	Max	SD	N
Respiration Interval (min)	Feeding	0.42	0.45	0.27	0.55	0.144	3
	Feed/Travel	0.30	0.28	0.20	0.45	0.084	9
	Traveling	0.53	0.54	0.20	0.78	0.160	20
Surface Time (min)	Feeding	1.21	1.21	0.50	1.92	1.002	2
	Feed/Travel	0.83	0.78	0.30	1.35	0.416	9
	Traveling	1.55	1.38	0.23	4.57	1.133	18
Dive Time (min)	Feeding	1.48	1.50	1.30	1.63	0.168	3
	Feed/Travel	2.40	1.95	1.23	4.35	1.040	9
	Traveling	1.85	1.70	1.12	3.17	0.580	18
Number Blows/Surfacing	Feeding	4.15	4.15	2.80	5.50	1.909	2
	Feed/Travel	3.95	3.33	2.00	6.25	1.681	9
	Traveling	4.14	3.67	1.60	8.00	1.979	18
Surface Blow Rate (blows/min)	Feeding	4.53	4.53	3.24	5.82	1.824	2
	Feed/Travel	5.40	5.09	4.28	7.46	1.107	9
	Traveling	3.30	2.74	1.90	7.52	1.651	18
Dive-Surface Blow Rate (blows/min)	Feeding	1.60	1.60	1.36	1.84	0.343	2
	Feed/Travel	1.31	1.16	0.76	1.90	0.373	9
	Traveling	1.14	1.24	0.53	1.66	0.296	17

Table 14. Summary information of respiration variables of other individuals for different behavioral states (2002-2009).

Variable	Behavior	Mean	Median	Min	Max	SD	N
Respiration Interval (min)	Feeding	0.26	0.23	0.15	0.73	0.103	132
	Feed/Travel	0.32	0.27	0.17	0.82	0.141	130
	Traveling	0.46	0.45	0.17	1.00	0.169	205
Surface Time (min)	Feeding	0.83	0.75	0.10	2.80	0.447	132
	Feed/Travel	1.37	0.78	0.05	14.50	1.968	129
	Traveling	2.25	1.24	0.17	18.07	2.827	204
Dive Time (min)	Feeding	2.82	2.71	1.10	5.43	0.953	130
	Feed/Travel	2.62	2.46	1.03	5.50	0.836	124
	Traveling	2.09	1.88	1.03	5.15	0.852	198
Number Blows/Surfacing	Feeding	4.23	4.00	1.33	12.00	1.468	132
	Feed/Travel	4.76	4.00	1.00	25.00	3.172	128
	Traveling	5.54	4.00	1.13	32.00	4.349	202
Surface Blow Rate (blows/min)	Feeding	5.81	5.83	1.67	10.89	1.595	132
	Feed/Travel	5.04	5.11	1.39	10.91	1.758	128
	Traveling	3.54	3.24	1.48	8.09	1.451	205
Dive-Surface Blow Rate (blows/min)	Feeding	1.16	1.12	0.43	2.25	0.300	132
	Feed/Travel	1.16	1.13	0.47	2.23	0.327	123
	Traveling	1.23	1.16	0.37	2.47	0.382	193

Table 15. Summary of mean values of respiration variables of mother/calf pairs, calves and other individuals for different behavioral states (2002-2009).

Variable	Behavior	Mother/Calf	Calves	Other
Respiration Interval (min)	Feeding	0.32	0.42	0.26
	Feed/Travel	0.41	0.30	0.32
	Traveling	0.58	0.53	0.46
Surface Time (min)	Feeding	0.71	1.21	0.83
	Feed/Travel	1.45	0.83	1.37
	Traveling	1.45	1.55	2.25
Dive Time (min)	Feeding	1.80	1.48	2.82
	Feed/Travel	2.21	2.40	2.62
	Traveling	1.60	1.85	2.09
Number Blows/Surfacing	Feeding	3.14	4.15	4.23
	Feed/Travel	3.82	3.95	4.76
	Traveling	3.90	4.14	5.54
Surface Blow Rate (blows/min)	Feeding	5.47	4.53	5.81
	Feed/Travel	3.53	5.40	5.04
	Traveling	2.73	3.30	3.54
Dive-Surface Blow Rate (blows/min)	Feeding	1.20	1.60	1.16
	Feed/Travel	1.01	1.31	1.16
	Traveling	1.14	1.14	1.23

Focal-animal analyses of respiration variables of all three groups of individuals showed that respiration interval (Fig. 28) had significant differences ($F = 129.53$, $df = 2$, $P < 0.001$) while individuals were engaged in different behavioral activities, with the lowest and highest values for feeding and traveling, respectively. Respiration interval was also different ($F = 7.25$, $df = 2$, $P < 0.001$) in the different individuals: between mother/calf pairs and other individuals ($P = 0.005$), with mother/calf pairs having longer respiration intervals. The interaction term was not found to be significantly different for any of the respiration variables.

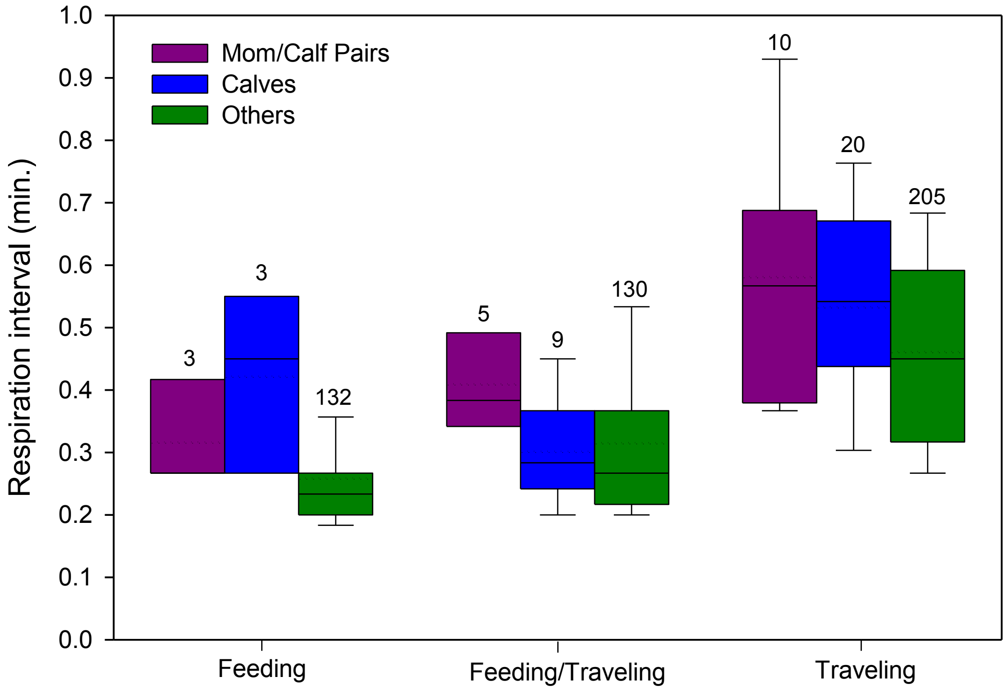

Figure 28. Respiration interval of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. Displays as in Fig. 21.

No significant differences (F = 2.47, df = 2, P = 0.08) were found in number of blows per surfacing between mother/calf pairs, calves and other individuals observed with different behaviors (Fig. 29). After accounting for the behavioral differences, the analyses suggested a marginal value of P = 0.05 (F = 3.11, df = 2), which did not result in any significant differences in post-hoc comparison, which could be related to the sample size.

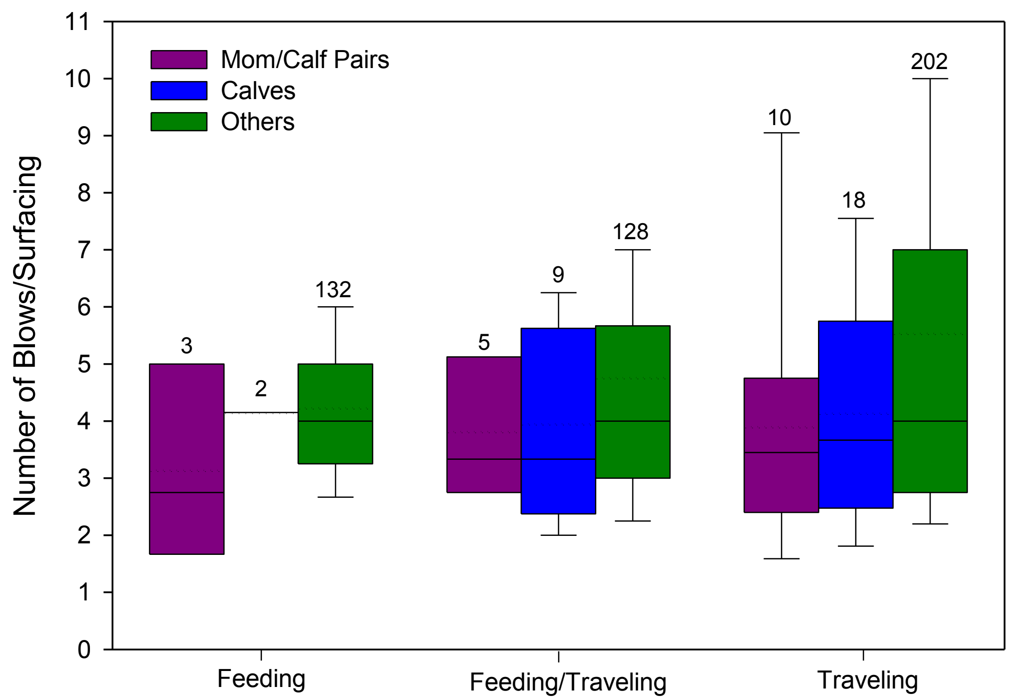

Figure 29. Number of respirations per surfacing of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. Displays as in Fig. 21.

Surface time and dive time were significantly different (F = 32.16, df = 2, P < 0.001; F = 39.78, df = 2, P < 0.001, respectively) while individuals were feeding and traveling (P < 0.001), and feeding/traveling and traveling (P < 0.001). Whales remained at the surface longer during traveling, and dove for a longer periods during feeding/traveling. However, when accounting for individual differences in the behavior, surface time was not different (F = 0.52, df = 2, P = 0.59, Fig. 30), while dive time was significantly different (F = 6.30, df = 2, P = 0.002, Fig. 31) between mother/calf pairs and other individuals (P = 0.01), with mother/calf pairs having shorter dives.

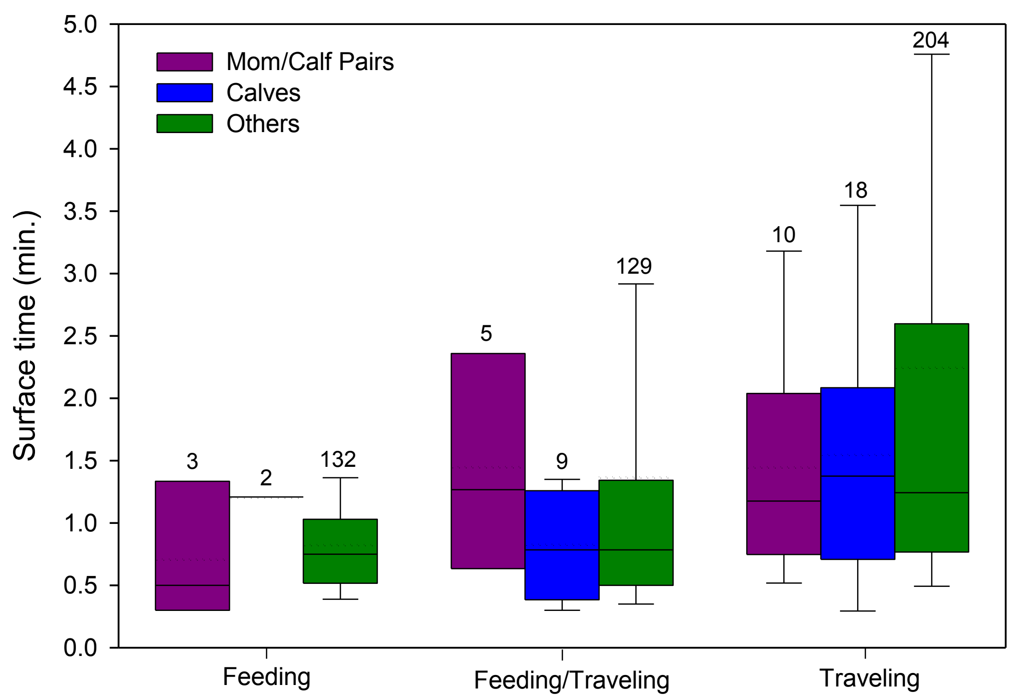

Figure 30. Surface time of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. Displays as in Fig. 21.

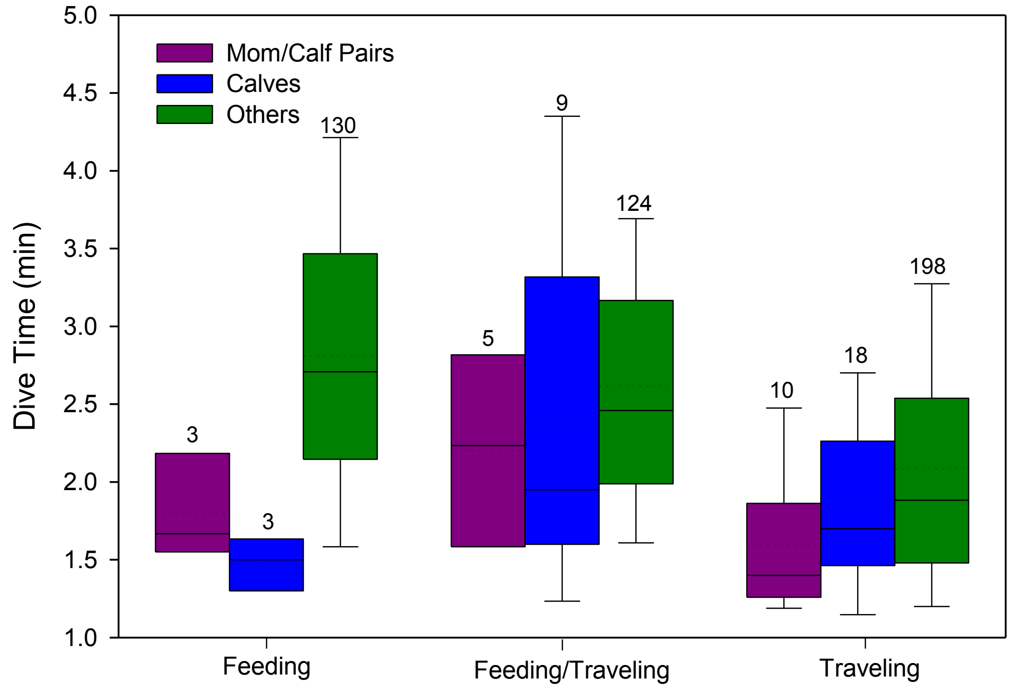

Figure 31. Dive time of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. Displays as in Fig. 21.

Surface blow rate was significantly different (F = 103.58, df = 2, P < 0.001) between all groups of individuals in relation to different behavioral states: decreasing from feeding to feeding/traveling, to traveling (Fig. 32). After accounting for the behavioral differences, the analyses indicated a marginal significance of P = 0.05 (F = 3.01, df = 2), which resulted in difference between mother/calf pairs and other individuals (P = 0.04) in post-hoc comparison, with other individuals having higher surface blow rate. There were no significant differences in dive-surface blow rate, for behavioral activities (F = 1.43, df = 2, P = 0.24), and individual differences (F = 0.63, df = 2, P = 0.53, Fig. 33).

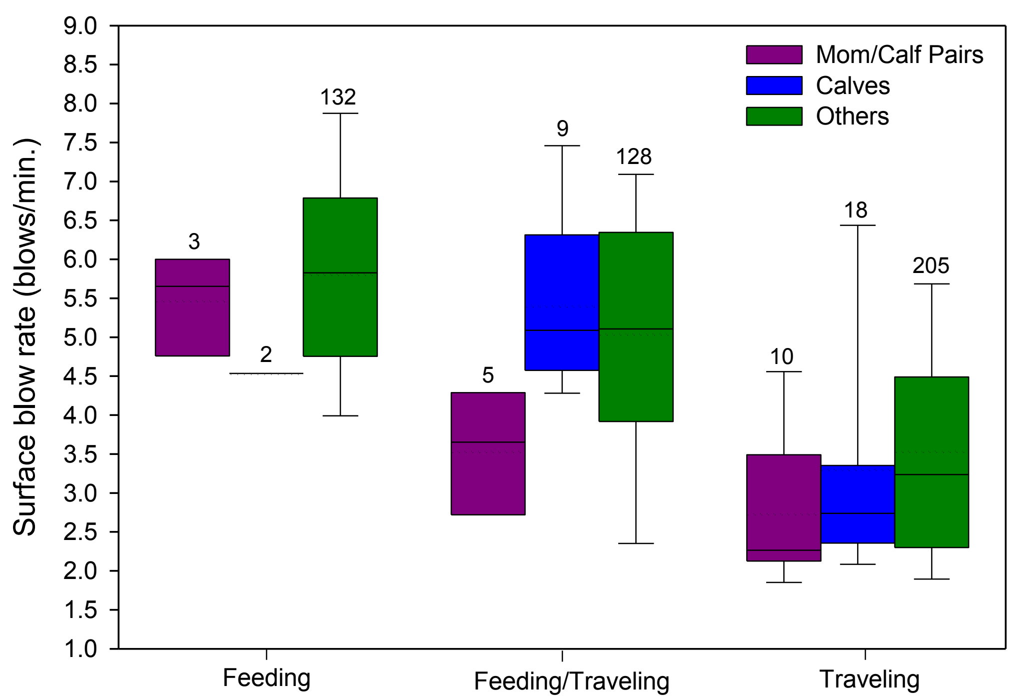

Figure 32. Surface blow rate of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. Displays as in Fig. 21.

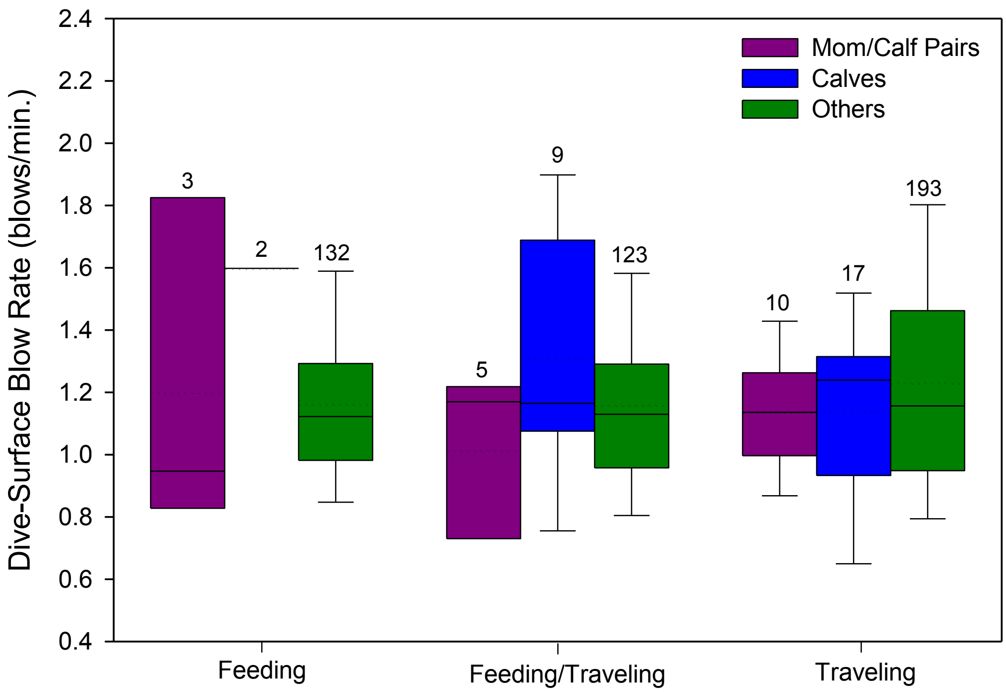

Figure 33. Dive-surface blow rate of mother/calf pairs, calves and other individuals in relation to different behavioral states observed at six shore-based stations in 2002-2009. Displays as in Fig. 21.

DISCUSSION

Gray whales off northeastern Sakhalin Island were observed during each summer-autumn from 2002 to 2009. Mother/calf pairs and calves were present in the area throughout the entire period of the study. Although, most observations were conducted on non-mother/calf individuals (due to low number of reproductive females and calf production in the population), theodolite tracking and focal-animal observations were performed on all individuals, including mother/calf pairs and separated calves.

The results of this study indicate the differences in spatial distribution of mother/calf pairs, calves and all other individuals in the population along the coast of northeastern Sakhalin. Although, mother/calf pairs and separated calves were observed at distances up to 2 km from shore, the majority of them were sighted within 0.8 km, while the average distance utilized by other individuals was 1.3 km from shore. Other studies on eastern (Baldridge 1974, Leatherwood 1974, Rugh and Braham 1979) and western (Würsig *et al*. 2000) populations on the breeding grounds and during migration, and on the feeding grounds, respectively, suggest a tendency of female/calf groups to remain closer to shore than other individuals. Perryman *et al.* (2002) observed 87% of females with calves traveling within 0.4 km from shore during their northbound migration off California. Such near-shore affinity of mother/calf pairs could be related to avoidance of predators (i.e. killer whales), calm areas (better places for nursing), and/or more suitable conditions for calves during the learning process and while beginning to feed on solid food. Although, like mother/calf pairs, weaned calves were observed to stay within close proximity to the shore, on average they remained at further distances from shore (0.8 km) than mother/calf pairs (0.5 km), but closer than other individuals (1.3 km). This suggests that the distribution of weaned calves may be dependent on the same factors that influence mother/calf pairs' distribution, but becomes somewhat different and most likely carries transfer patterns from being dependent on mother to an independent behavior similar to adult whales.

Two types of analyses of movements and respirations were conducted: 1) general analyses – including all data regardless of behavioral state, and 2) analyses considering behavioral state – in relation to feeding, feeding/traveling and traveling. General analyses of movements showed that speed, acceleration, and ranging index were not significantly different between three groups of individuals. Mother/calf pairs moved at average speed of 2.3 km/h, with the maximum speed of 9.2 km/h on one single occasion. In 2010, Gailey *et al.* found that overall, gray whales off northeastern Sakhalin were moving on average 2.7 km/h (1.9 – 2.6 km/h in 2001-2008), while their behavioral analyses showed that average speed for traveling whales was 3.9 km/h. This indicates that the observed speed of 9.2 km/h for a mother/calf pair was unusually high even for traveling gray whales in the study area. The sighting of this group traveling with unusually high speed occurred in close proximity of industrial activity on shore (near Station 07), namely pile driving that was being conducted during the 2009 field season. However, preliminary analysis on gray whale behavior in relation to the pile driving activity did not show that the speed of whales observed in general near Station 07 varied from that of whales sighted from other stations (Gailey *et al.* 2010). Despite this, to make a solid conclusion on this particular case of unusually high speed for mother/calf pair would require additional detailed analyses on potential impacts of pile driving with the consideration of noise levels.

The overall average speed of mother/calf pairs was similar to the speed of weaned calves (2.7 km/h) and other individuals (2.5 km/h). Similar results were obtained in the study conducted on eastern gray whales on their breeding grounds and during migration, which did not indicate any differences in maximum speeds of mother/calf pairs and single adults (Harvey and Mate 1984, Mate and Harvey 1984). However, it is unlikely that the calf could sustain such speeds compared to an adult whale.

Reorientation rate, linearity index, and mean vector length were different between mother/calf pairs and calves, and between calves and other individuals; and were similar for mother/calf pairs and other individuals. Calves had a lower reorientation rate and higher linearity and mean vector length in comparison to those of mother/calf pairs and other individuals. This indicates that single calves or groups of weaned calves had more directional and straight movements than any other individuals. It may be related to more observations on traveling calves presented in the dataset, as it was found by Gailey *at el.* (2010) that traveling whales had lower reorientation rate and higher linearity index and mean vector length than feeding whales. In fact, in the general analysis of combining all data regardless of behavioral state, 61% of all calves' tracklines presented in the dataset were conducted on traveling calves, while only 47% of all mother/calf pairs' tracklines and 46% of all other individuals' tracklines were conducted on traveling whales. More directional and straight-line movements of weaned calves can also be related to the parallel traveling along the coast that is often observed in the study area. This may be due to remaining closer to shore, as the nearshore area can provide safer areas to avoid predators, especially once calves are no longer protected by their mothers.

Among the respiration variables, general analysis showed that only respiration interval, dive time, and surface blow rate were significantly different between the different groups of individuals. Mother/calf pairs and calves had similar respiration intervals between each other, but it was different to other individuals. The average respiration intervals between two subsequent blows of mother/calf pairs and weaned calves were 0.52 and 0.48 minutes, respectively, which were longer than respiration intervals of other individuals (0.37 min). Dive time was similar in mother/calf pairs and calves, but differed from other individuals. On average, mother/calf pairs and calves dove for 1.67 and 1.81 minutes, respectively, while other individuals had longer dives of 2.42 minutes. The respiration interval and dive time of mother/calf pairs and separated calves were similar to those of traveling whales (Gailey *et al.* 2010). A different study found that mean dive duration for mother/calf pairs observed on the winter grounds off Baja California was 1.54 minutes (Ludwig *et al.* 2001), which is similar to what has been observed during our study. Surface blow rate was significantly different between mother/calf pairs and other individuals, but similar to that of calves.

The number of blows per surfacing, surface time, and dive-surface blow rate were not different between different groups of individuals. Other individuals tended to remain on the surface longer and respire more than mother/calf pairs, but the differences were not found to be significant.

Because respiration and movement patterns depend on the whale's behavior, separated analyses of theodolite tracking and focal follows were conducted in relation to the behavioral states. The majority of the whales observed were feeding, feeding/traveling, and traveling. Other behavioral states occurred on occasion, but were not analyzed here. Overall, the dataset used for these analyses among all three groups of individuals, contained total of 51%, 25.5%, and 23.5% of traveling, feeding/traveling, and feeding behaviors, respectively. The high number of traveling whales on Piltun feeding ground may be related to their foraging strategy, such as feeding more on prey in the water column as opposed to benthic foraging (Gailey *et al.* 2010). Guerrero (1989) suggested that gray whales off Vancouver Island traveled more due to feeding on mysids in the water column. However, this most likely is not the case for traveling mother/calf pairs as they stay close to shore.

Although the general analyses of movement parameters suggest that all individuals were moving with the similar speeds, behavioral analyses indicated differences in this variable in relation to different behavioral states. Among all groups of individuals, speed varied significantly in feeding, feeding/traveling and traveling individuals, with the lower and higher speeds during feeding and traveling, respectively. However, after accounting for the behavior, speed differed only between mother/calf pairs and other individuals, with the first moving slower. Acceleration did not show differences between different groups of individuals in relation to their behavior. In fact, Gailey *et al.* (2004, 2005, 2006, 2009) never found this variable to depend on whale behavior, but found acceleration to be an important variable to monitor, especially in relation to close vessel approaches (Gailey *et al.* 2007a). Reorientation rate, linearity index, ranging index, and mean vector length were different in all groups of individuals, but those differences did not relate to the behavioral activities (with the exception of marginal values of differences in mean vector length between mother/calf pairs and other individuals). Distance from shore varied between feeding and traveling individuals, and was different between among all groups of individuals after accounting for differences in behavioral states. This suggests that for different individual groups, there were some preferable areas within certain distances from shore that were utilized by whales during particular behavioral activities.

Respiration interval varied between different groups of individuals engaged in feeding, feeding/traveling and traveling activities. It was also different between mother/calf pairs and other individuals after accounting for their behavior, with the mother/calf pairs having longer respiration interval. However, number of blows per surfacing was similar for all individuals and all behavioral states. Surface and dive durations were different between feeding and traveling, and feeding/traveling and traveling individuals. After accounting for the behavior, only dive time was different between mother/calf pairs and other individuals. Greater dive time for other individuals may be related to their feeding at greater depths then mother/calf pairs. Increasing of dive time for eastern gray whales at greater depths was documented by Würsig *et al.* (1986). Also, it was found that water depth was significantly associated with dive time of gray whales off Piltun (Gailey *et al.* 2007c).

Knowledge of the western population of gray whales has significantly increased for the last decade. Long-term monitoring of the population provided information on different aspects of gray whales life and habitat. However, since the western gray whales feed in an area with increasing anthropogenic activity, there is an obvious need for further study of this critically endangered population, including more sophisticated analyses of correlating data related to prey availability and gray whale presence, distribution, behavior, and movement. The lack of information on behavior and life history of gray whale females and calves is especially evident. For the present work, sample sizes of movement and respiration data were relatively small in relation to different behavioral activities of mother/calf pairs and weaned calves. Continued study would provide more data to compare the information on distribution, behavior and life aspects of females and calves on their feeding grounds from different years. Further combination of data on movements and respirations of whales with photo-ID information would provide for a better understanding of heterogeneity in whale behavior and distribution, as well as help to examine questions about seasonal group structure and interactions between different mother/calf pairs.

CHAPTER III

SHORE-BASED PHOTO-IDENTIFICATION

Photo-identification (photo-ID) methodology is widely used for studying different species of mammals, as an effective technique in providing information on different aspects of an animal's life, both population and individual levels. Depending on a species, different individuals in the population can be recognized by certain features on their bodies. Gray whales have distinctive body markings, such as natural coloration and pigmentation patterns, as well as scars, that are unique to an individual and can be used in individual recognition. It is therefore useful for obtaining information on population size, distribution, site fidelity, association patterns between individuals, behavior, social structure in the population, short-and long-term changes in the population, individual heterogeneity, and health conditions (Calambokidis *et al.* 2002, Bradford *et al.* 2008, Yakovlev *et al.* 2010a). Traditionally, photographs of whales are taken in the sea from small vessels (Weller *et al.* 2000, Yakovlev *et al.* 2010a). However, for some species that mainly utilize nearshore habitats, the shore-based approach can be applied (Würsig and Jefferson 1990, Payne 1995). Gray whales usually inhabit coastal areas and can be observed in close proximity to the shore. Being a totally non-invasive technique, shore-based photo-ID can be considered as an important alternative (opposite to vessel-based) or/and complementary approach in studies of endangered animals such as the western population of gray whales. Such approach, also, can be conducted on days when the weather is not acceptable for vessel-based photo-ID. However, it is limited needing very large photographic lens sizes, fog and heat haze, and distance in general.

Shore-based photography has been a part of the long-term monitoring program of endangered western gray whales on their feeding grounds off northeastern Sakhalin Island. It was initiated in 2004 to explore the technique of capturing individuals from the shore and provide additional information on sighted individuals, especially mother/calf pairs. For this study, photo-ID data were used as an additional confirmation tool in defining mother/calf pairs, as well as to obtain sighting information.

METHODS

In 2004, we used a Nikon D1x digital camera with a 100-400 mm Nikon lens and 2x tele-extender. The typical distance of successful captures ranged up to 1 km. Due to this initial success in 2004, a larger lens (Sigma 300-800 mm APO F5.6 EX DG, with a 2x tele-extender) was used in 2005. This allowed capturing individuals at greater distances of up to 2 km from the observation site. In 2006, additional sets of photographic equipment (a Nikon D2x and another 300-800 mm Sigma APO F5.6 EX DG lens, with 2x tele-extender) was provided to the second behavior research team, thus photo-ID effort was conducted at two stations per day. Photographs were taken opportunistically from stations where observations were conducted during that day, and between the stations along the coast on occasions when individuals were observed in close proximity to shore. This was often the case with mother/calf pairs and separated calves, as they tend to stay close to the shore. For each individual/group photographed, the date, time, group number, group size, behavior, corresponding number of track and focal behavior session, as well as card and frame numbers were recorded. While on the stations, photographs were usually taken simultaneously with the theodolite tracking and focal follows. When photo-ID was conducted at locations other than the observation stations, the geographic position of the photographer (using a GPS Garmin 76), and approximate distance to the whale were recorded to calculate geographic location of the animal photographed.

All photographs were downloaded from memory cards to the field computer after each working day into a folder with raw data sorted in the following manner: “Date” folder → “Card #” folder. Each “Card” folder contained all images of different individuals/groups photographed with the same card on the same day. All photo-ID data were processed using the computer-based “Photo ID” software (developed by Glenn Gailey, personal communication). Image processing consisted of the four main steps of renaming, filtering, matching within a group, and matching to the database:

1. All images were renamed in relation to each photo-ID session conducted in the field. Each “Date” folder now contained “Group #” folders, each of which included photographs taken on an individual or group of individuals during one photo-session. A specific name including date, group number, card number, and original frame number was giving to each photograph (for example, 0047_090823WGW0201_0018.TIF, where 0047 is unprocessed ID number, which is

changed to a final ID number after the individual is matched to the database; 02 is a group number; 01 – card number, and 0018 – frame number).

2. Once all data were sorted by day and groups within that day, each image was cropped and adjusted for easier visual access. Images of unacceptable quality or containing no information on individual whales were removed to separate "Extra" and "No info" folders, within the group folder (Fig. 34).

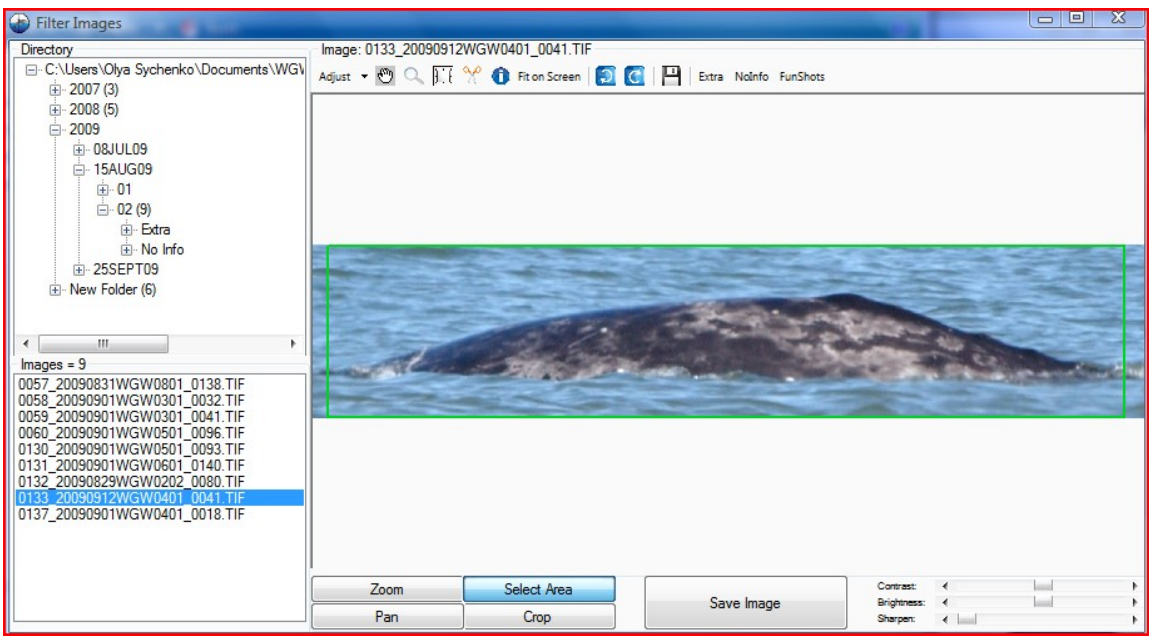

Figure 34. Example of "PhotoID" software to assist with cropping and adjusting the quality of digital images.

3. Matching within a group consisted of identifying all different individuals that were observed and photographed in this group, and finding the best quality image (of any aspect of the body) for each individual in this group (Fig. 35).

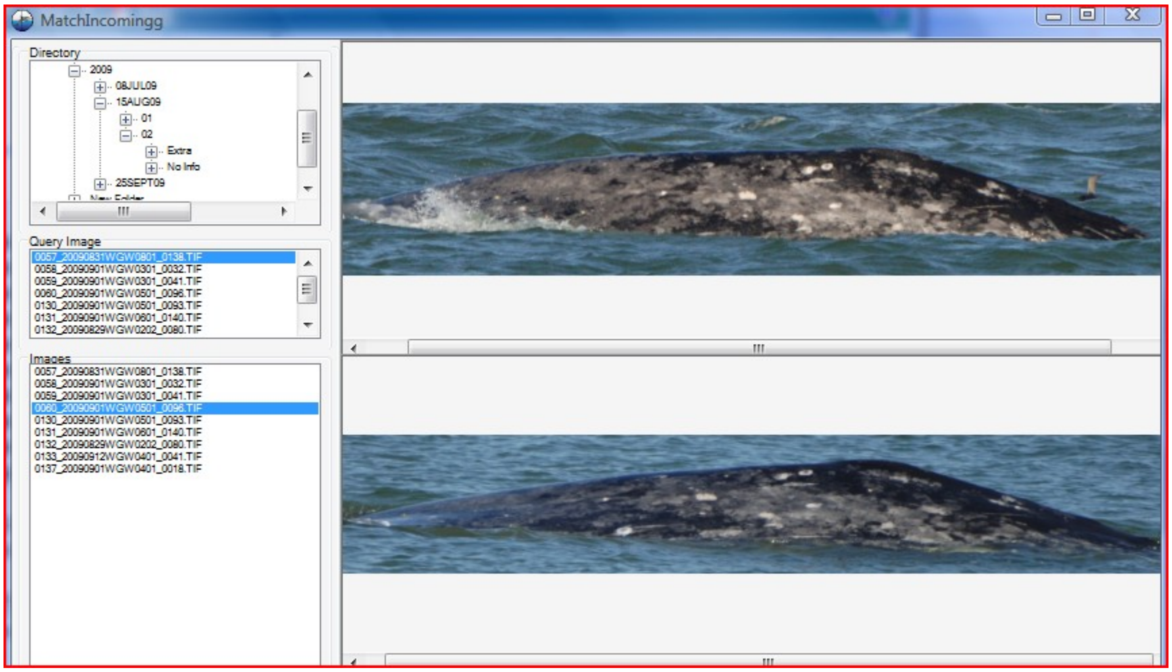

Figure 35. Example of “PhotoID” software during matching of individuals within the group and selecting the best quality image of each individual.

4. All representative images of individuals from each group were matched to the shore-based photo-ID database (Fig. 36). Traditionally, individuals in photo-ID catalogs include three body aspects of a whale: right and left sides, and ventral fluke (Weller *et al.* 2007). To be consistent with the data, collected by a separate team conducting photo-ID on WGW from a vessel (Yakovlev and Tyurneva 2004), the dorsal

fluke was also considered as a fourth aspect in our database. Normally, an individual can be classified and added to the catalog as a new individual based on the image of its right side. In shore-based photography, the success of capturing different aspects of a whale's body depends on the behavior of the animal and/or the direction of its movements during the photo-ID session. Therefore, at times there are limitations on obtaining information on all body aspects of an individual. However, due to the possibility of using the main western gray whale catalogs provided by other teams (Weller *et al.* 2009b, Tyurneva and Yakovlev 2009), on those occasions when aspects other than the right side are matched to the individuals identified in the main catalogs, an individual can be added to the shore-based database as a new sighting.

Each image added to the database was evaluated in terms of quality and individual distinctiveness. The quality of the photograph was valued on a scale from 1 (very low quality) to 5 (excellent). Individual distinctiveness was represented on a 1 (few markings/identifiable features, low distinctiveness) to 5 (highly distinctive with many identifiable features and markings) scale.

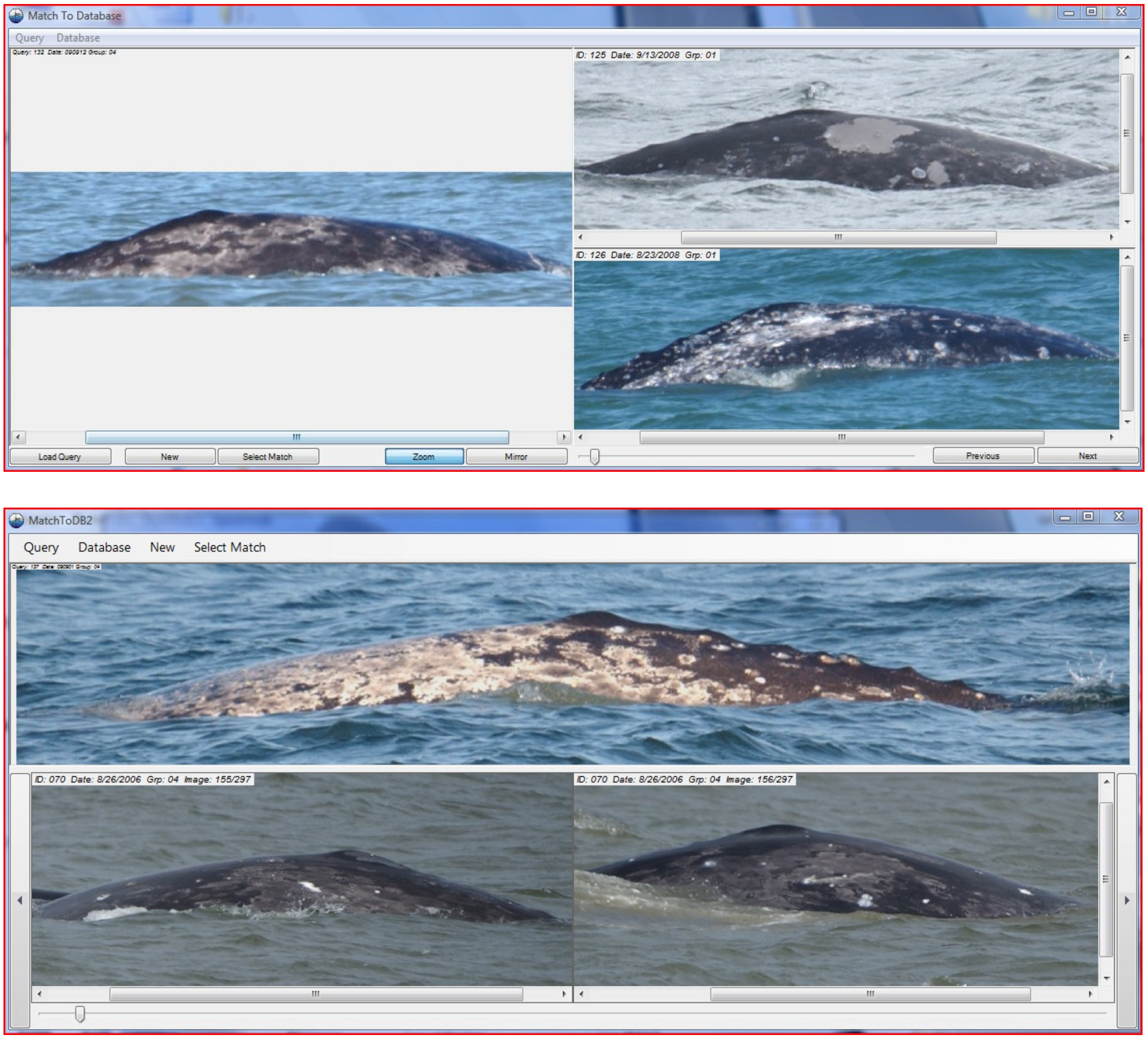

Figure 36. Example of "PhotoID" software assisting with the process of matching individuals to existing individuals in the database, using different (vertical and horizontal) views of compared images.

RESULTS

Shore-based photo-identification efforts were conducted during summer-autumn of 2004-2009, and resulted in a total of 165 days of photographic records. A total of 16,050 digital photographs were processed prior to individual matching to the database (Table 16).

Table 16. Summary of shore-based photo-identification efforts conducted in 2004-2009.

Parameter	2004	2005	2006	2007	2008	2009	Total
# Days	16	17	28	47	24	33	165
# Photographs	900	1500	3200	5250	1500	3700	16050

The six years of shore-based photo-identification efforts yielded a total of 144 individuals (Fig. 37) with a mean of 5.6 numbers of resightings. Through all years, two individuals were sighted and photographically captured 21 times (Table 17). Out of these 144 individuals, 10 were females accompanied by a calf and 31 were calves of that year, either alone or accompanied by mothers (among those 10 females) (Table 18). The maximum number of resightings for calves, accompanied and unaccompanied by females, within one field season was nine (Fig. 38), recorded in 2009 for a calf never observed with another adult, that could have been its mother.

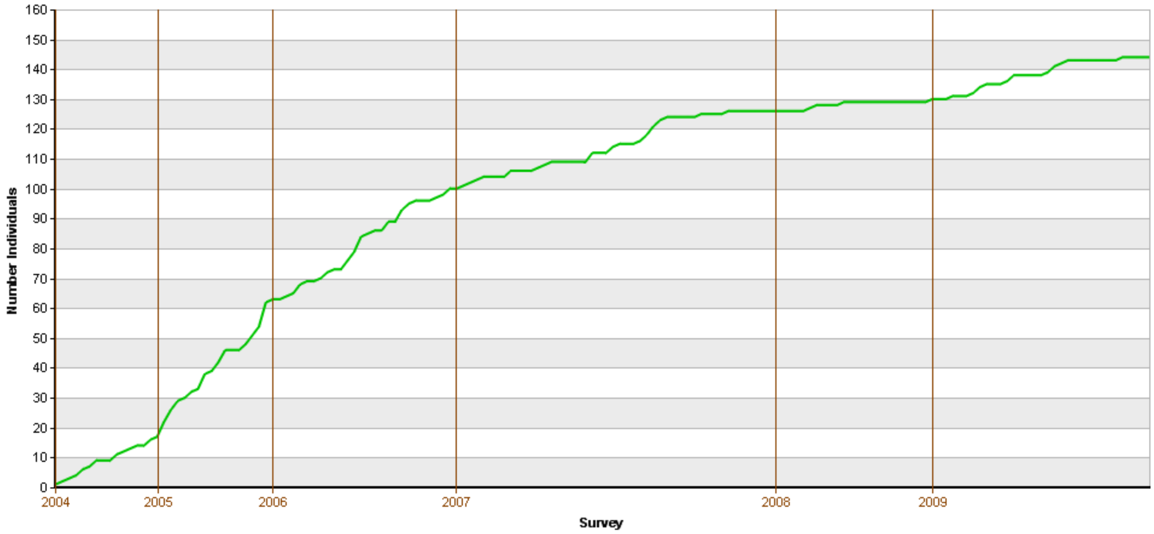

Figure 37. Discovery curve based on photo-ID data collected from shore during 2004-2009.

Table 17. Number of individuals photographed from shore and number of resightings recorded during 2004-2009.

Parameter	2004	2005	2006	2007	2008	2009	Total
# Individuals	16	52	66	83	31	67	144
# New Individuals	16	46	38	26	3	15	144
Mean # of Resightings	1.81	1.63	1.95	3.04	2.58	3.46	5.6
Max # of Resightings	7	5	5	9	6	9	21*
# Individuals with Max Resightings	2	1	3	1	1	2	2

* Number of resightings across all years.

Table 18. Summary of photo-ID data on mother/calf pairs and separated calves (observed alone) collected from shore during 2004-2009.

Parameter	2004	2005	2006	2007	2008	2009	Total
# Females	2	-	1	5	1	5	10*
# Calves	6	2	5	10	1	7	31
Max Resightings**	7	2	5	3	5	9	9
# Calves with Max Resightings	1	1	2	3	1	1	1
First M/C Sighting	31-Jul	-	16-Jul	5-Aug	7-Sep	25-Jul	16-Jul
Last M/C Sighting	17-Sep	-	26-Aug	10-Sep	25-Sep	19-Sep	25-Sep
First Single Calf Sighting	22-Aug	28-Jul	23-Aug	6-Aug	-	9-Aug	28-Jul

* Total number of individual females with calves (three females had more than one calf during six years).
** Number of resightings is counted for calves (some calves were observed with their mothers, other calves were only observed alone).

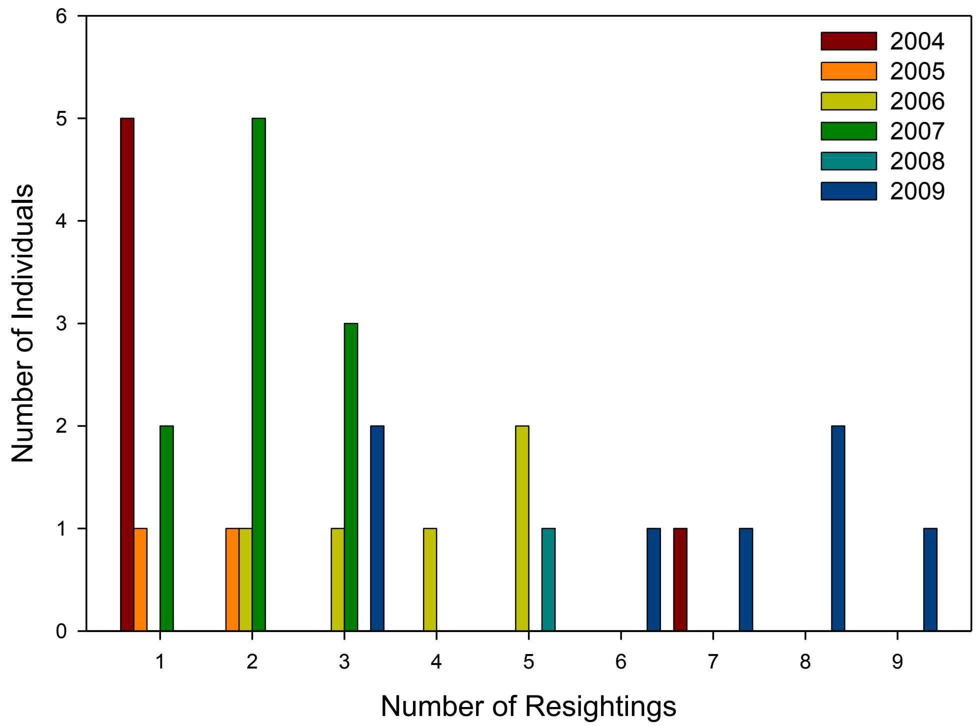

Figure 38. Number of resightings for all calves (accompanied by females only, accompanied by females and separated later, and calves never seen accompanied by females) photographed during 2004-2009.

Out of a total number of calves of 31 photographed during 2004-2009, 17 were never observed accompanied by mother, with the first unaccompanied calf photographically captured on 28 July in 2005. The earliest and the latest sightings of mother/calf pairs in the study area occurred on 16 July 2006 (South Station) and 25 September 2008 (Station 07), respectively. On the last occasion, mother and calf were observed together, but some temporal separation of calf was observed during this observation. The pair was observed for three hours feeding and feeding/traveling at 1.3-

1.5 km from shore. The calf separated from the female two times for 15-20 minutes moving away from her within 0.7 km to the south, but rejoined her back for the rest of the observation. On 7 September 2003 (Odoptu Station), another mother/calf pair was observed with some indicators of separation. After tracking the pair for about 30 minutes, the calf moved away from the female and was tracked alone for about 40 minutes feeding and traveling. When finishing tracking, the calf was 2 km away from the mother. However, we were not able to observe further to suggest if this was a permanent separation or temporal, and they might have rejoined later.

Among the 14 mother/calf pairs, eight approximate separation periods, between the last sighting of female and calf together and the first sighting when one of them were observed separately, were documented (Table 19). Six other mother/calf pairs remained together at the moment of their last observation.

Table 19. Approximate dates of mother/calf pair separations during 2004-2009.
(-) = neither calf nor female were observed separately from each other.

MC	Last time seen together	First time seen separately	Individual observed alone
1	17-Sep-04	22-Sep-04	Calf
2	26-Aug-06	31-Aug-06	Female
3	5-Aug-07	10-Sep-07	Calf
4	17-Aug-07	15-Sep-07	Female
5	21-Aug-07	1-Sep-07	Female
6	10-Sep-07	15-Sep-07	Female
7	9-Aug-09	26-Aug-09	Female
8	9-Aug-09	1-Sep-09	Calf
9	16-Aug-04	-	-
10	30-Aug-07	-	-
11	25-Sep-08	-	-
12	1-Sep-09	-	-
13	13-Sep-09	-	-
14	19-Sep-09	-	-

Weaned calves were often observed in groups of two and more calves together, as well as joining mother/calf pairs. Two or a few mother/calf pairs were also observed together on some occasions. Although gray whales are not highly social animals, such grouping between mother/calf pairs, as well as weaned calves may be an important aspect related to social learning.

In 2009, an individual known as a mother in previous years but had not been seen (by our team) with the calf in 2009, was observed in close interactions with other mother/calf pairs a few times during the field season. During the first sighting (31 August), the female was traveling with a mother/calf pair along the coast at approximately 0.2 km from shore. On 1 September, the same female was tracked alone and photographed from 1st Station. The individual was feeding and feeding/traveling for an hour at 1.5 km from the shore, then started traveling with increased speed to the south towards the shore, where she joined mother/calf pair (a different one than sighted on 31 August). All three individuals continued traveling south at 0.3 km from shore, and were later observed at South Station, feeding. After this, the female separated and fed alone for more than one hour, after which she continued traveling close to shore. After the female left, the remaining mother/calf pair continued feeding within the same area for about two hours. On 12 September, the same female was observed alone traveling along the coast at 0.3 km from shore. Later, this individual was confirmed as mother and photographed with the calf by vessel-based photo-ID team earlier in the season (Olga Tyurneva, personal communication). Such behavior of the female could have been related to her recent separation with the calf. On both occasions when the described female was sighted with mother/calf pairs, no signs of disturbances in the behavior of mother/calf pairs were observed during these interactions. Some alloparental behavior could take place during these interactions. Although, our low elevations of shore-based stations could possibly limit our abilities to recognize all activities under the water and determine nursing behavior (for example, the positioning of calf relative to the mother), some pectorals and flukes above the water were observed during the second occasion of such interactions.

Out of 24 calves sighted in 2004-2008, only 10 were resighted in following years (Table 20). None of the calves of 2007 and 2008 were observed in following years.

Table 20. Annual occurrences of calves through all years of shore-based photo-ID study. Seven individuals sighted as calves of 2009 are not included in the table. (C) = first year sighted as a calf. (+) = Years when calf was photographed, (-) = no sighting information obtained.

Calf	2004	2005	2006	2007	2008	2009
A	C	-	-	-	-	-
B	C	-	-	-	-	-
C	C	+	-	-	-	-
D	C	+	-	-	-	-
E	C	-	+	-	-	-
F	C	+	-	+	-	-
G		C	-	-	-	-
H		C	-	-	-	+
I			C	-	-	-
J			C	-	-	-
K			C	-	-	-
L			C	+	+	-
M			C	+	-	+
2007* - 10 calves						
2008* - 1 calf						

* Ten calves of 2007 and one calf of 2008 were never observed in following years.

Although we sighted 31 different calves during six years, only 14 mother/calf pairs (female and calf together) were photographically captured. Among all females observed with the calves, one female had calves in 2004, 2006, 2009, and two females were photographed with calves in two different years (both in 2007 and 2009). Also, eight females from different years that we did not observe with calves, were photographed alone later in the season, but have been confirmed as mothers those years by other teams that conduct photo-ID in the area from vessels (Weller *et al.* 2008, Yakovlev *et al.* 2010b) (Table 21). One of two individuals photographed 21 times in all years, was a female that has been observed every year: with calves in 2004, 2006, 2009, and alone in 2005, 2007, and 2008. In years without a calf, this female was sighted only once in the field season, while in years accompanied by a calf, this whale was one of the most often seen individuals.

Table 21. Annual occurrences of females through all years of shore-based photo-ID study. (M) = years when female was observed with a calf (as mother/calf pair), (+) = years when female was observed without a calf, (+m) = years when female was observed without a calf, but was confirmed as a mother by vessel-based photo-ID, (-) = no sighting information.

Female	2004	2005	2006	2007	2008	2009
A	M	+	M	+	+	M
B	-	+	+	M	-	M
C	-	-	-	M	-	M
D	-	+	+	-	-	M
E	-	-	-	M	+	-
F	-	-	-	+	-	M
G	-	-	+m	+	M	+
H	-	-	+	M	-	+
I	-	-	+	M	+	+
J	M	-	-	+	+m	-
K	+m	-	+	+	+	+m
L	-	-	+	+m	+	+m
M	-	-	+m	-	-	-
N	-	-	+m	+	-	+

DISCUSSION

A total of 144 individual gray whales were identified for the duration of the shore-based photo-ID study. The maximum number of new individuals added to the database in 2005 was related to the extended range of capturing individuals. The rate of discovering new individuals continued to be relatively high in 2006 and 2007. Although, only three new individuals were identified in 2008, this number increased in 2009. This was partially due to only one calf seen in 2008, and relatively high number of new calves observed in 2009. Also, an unusually low number of gray whales were observed in the nearshore Piltun area in 2008 (Gailey *et al.* 2009, Vladimirov 2009, Yakovlev *et al.* 2009), which resulted in the lowest number of photographed individuals in 2008 (not considering 2004, the first year of shore-based photo-ID).

Two vessel-based photo-ID studies, which is a part of the same western gray whale long-term monitoring program, were conducted in 1994-2009 and 2002-2009, respectively (Weller *et al.* 2009a, Yakovlev *et al.* 2010a). The shore-based photo-ID team has an access to the main catalogs provided by these teams. Based on information collected by Yakovlev *et al.* (2010b), seven years of their effort yielded a total of 177 identified gray whales. According to this number, the shore-based database contains approximately 80% of all identified gray whales presented in the main catalog of western gray whales off Sakhalin. In 2009, vessel-based photo-ID data (Yakovlev *et al.* 2010b) were compared to photo-ID data collected from shore: six individuals were photographed by the shore-based photo-ID team only. Four of these individuals were already observed in previous years and, thus, present in both the shore-based database and the main catalog. Two other whales were calves of 2009 and were added to the main catalog as new individuals. Also, one calf in 2004 was observed only during shore-based photo-ID efforts, and was added to the main catalog of western gray whales.

Overall, shore-based photo-ID resulted in a mean number of 5.6 resightings, with a maximum of 21 resightings for two individuals, one of which was a female observed with calves in different years. Although, the maximum mean number of resightings per season observed by the vessel-based photo-ID team was relatively high (5.3 resightings in 2009) compared to the shore-based photo-ID (3.6 resightings in 2009), the overall value across all years was higher in the shore-based photo-ID study (5.6 resightings) compared to 2.7 resightings obtained by the vessel-based team. Such a high number of individual resightings obtained during shore-based photo-ID is most likely related to the methodological differences between vessel-based and shore-based photo-ID. Vessel photo-ID covers more extensive geographic regions, but samples less intensively in a certain area. Also, because shore-based approach is less-dependent on the weather conditions, it allows conducting photo-ID on days when the vessel cannot conduct the surveys due to high sea state conditions, which provides more sighting information on individuals.

A total of 31 calves were identified during 2004-2009, however only ten different females were determined as mothers. This may be due to various reasons. Considering that only 33 (CI 29-38) reproductive females are currently known to exist in western population of gray whales (Cooke 2010), 10 females count for approximately 30% of all reproductive females. Also, mother/calf pairs are often observed to the south of our study area (Vladimirov *et al.* 2010), which most likely makes it impossible to photograph some of them before the separation between mother and calf occurs. At least 11 more females are present in the shore-based database that were confirmed as mothers

(Bradford *et al.* 2008), and were photographed from shore in different years, but never sighted with calves at the moment of observation. This results in total of 21 reproductive females included in the shore-based photo-ID database, which counts for approximately 64% of all reproductive females in the population.

The small number of calves observed in subsequent years may be partially related to them occurring off Kamchatka. Some of western gray whales have been observed in waters of south-eastern Kamchatka, including calves of different years sighted near Sakhalin that were observed off Kamchatka in subsequent years (Yakovlev *et al.* 2010b). The movements of western gray whales between Sakhalin and Kamchatka can be possibly a result of different factors, such as continual anthropogenic activity off northeastern Sakhalin (which can potentially cause whales to abandon the area and move to different habitat), using both areas off Sakhalin and Kamchatka as a historical habitat (Sleptsov 1955, Yablokov and Bogoslovskaya 1984), or changes in food abundance and availability (Fadeev (2009) found annual changes in food resources in waters off Sakhalin).

As was suggested by Weller *et al.* (2000), separation between mother and her calf occurs during July-September. Our study showed that out of 14 mother/calf pairs observed, eight separated in August-September. Another six remained together at the moment of their last sighting, four of which occurred in September, with the latest mother/calf pair sighting on 25 September 2008. Some temporal separations of calves from their mothers were observed during our study, which could be indications of soon permanent separation. Hamilton *et al.* (1995) reported temporal separations of right whale calves from their mothers occurring regularly throughout the day while females are feeding at depth. In southern right whales, the yearling calves were responsible for maintaining contact with the mothers, and females would move away during temporal separations (Taber and Thomas 1982). During our observations, on both occasions, calves moved away from their mothers.

Weaned calves were often observed in groups of two and more calves together, as well as joining mother/calf pairs. Two or a few mother/calf pairs were, also observed together on some occasions. Although gray whales are not highly social animals, such grouping between mother/calf pairs, as well as weaned calves may be an important aspect related to social learning.

Although shore-based photography is characterized by distance limitations, this can be minimized by using powerful photographic lenses to extend the range of capturing individuals. Shore-based photo-ID proved to be an effective approach in collecting photo-ID information from shore without disturbance to the whales. It increases sighting/resighting information on individuals, especially mother/calf pairs. It is less dependent on the weather conditions than vessel-based approach, allowing the collecting of data even during windy weather when small vessels cannot operate. Also, it can be conducted at low costs as compared to boat. Therefore, the shore-based photographic identification approach can be recommended to be a supplemental approach, with vessel-based photo-ID efforts, to provide valuable information in studies of this critically endangered population.

CHAPTER IV

CONCLUSIONS

This study examined movements, respirations and behavioral patterns of three groups of individuals: mother/calf pairs, separated calves, and other individuals on their feeding ground off northeastern Sakhalin Island. The results did not support the null hypothesis of the study and indicated differences in movement/respiration/behavioral patterns and habitat use between different types of individuals. Although, both general analyses and analyses in relation to behavioral states resulted in differences in movements, respirations and habitat use of mother/calf pairs, calves and other individuals, these results differed when accounting for the behavior, which indicated dependence of these parameters on behavioral activity of the whales. After accounting for the behavior, speed of mother/calf pairs was significantly lower of that of other individuals, but similar to the speed of weaned calves. Although reorientation rate, linearity index, ranging index, and mean vector length were different among all groups of individuals, those differences did not relate to the behavioral activities. Among the respiration variables, only two variables had significant differences between the different groups of individuals in relation to their behavior. Mother/calf pairs had longer respiration interval and shorter dive time compared to those of other individuals.

Three primary behavioral states were distinguished during this study: feeding, feeding/traveling, and traveling. Despite the study being conducted on gray whales on their feeding ground, the predominant behavior of all individuals was traveling. This may be related to food resources and thier distribution in case of adult whales, and particular patterns in whales' behavior and distribution in case of mother/calf pairs and calves.

There were differences in habitat use between different types of individuals, indicating that mother/calf pairs stay closer to shore in comparison to other individuals in the population. These results correspond to several studies conducted on gray whales of both populations (Baldridge 1974, Leatherwood 1974, Rugh and Braham 1979, Würsig *et al*. 2000, Perryman *et al.* 2002), and suggest that mother/calf pairs remain in close proximity to shore within their entire distribution range. Weaned calves preferred intermediate distances from shore – distances between close proximity of mother/calf pairs and greater distances of other individuals. This suggests that the period after a calf separated from its mothers plays an important role in calf development, and carries transfer patterns to an independent life. For mitigation and conservation purposes, it is necessary to consider the differences in habitat utilization of individuals of different ages and vulnerability to any potential anthropogenic disturbance not only of mother/calf pairs, but as well as weaned calves.

Social aspects of the behavior should be considered, including short-term and possibly long-term associations between different individuals, such as interactions between different mother/calf pairs, and interactions between weaned calves, as well as between weaned calves and yearlings. This study did not provide any information on behavioral ecology of yearlings, as it was not the objective. However, it is likely that juvenile stage plays the main role in preparing young whales to an adult life, as was stated by Sironi (2004) in his study of right whales, that young individuals "may establish social relationships and practice behavior that is relevant during adult life". Although, weaned calves have been observed interacting with mother/calf pairs, each other, and yearlings, as well as two mother/calf pairs associating with each other, we cannot fully explain the nature of such interactions, but social aspect is one of the main aspects to consider. Lack of information on behavior and habitat use of mother/calf pairs, weaned calves, and juveniles emphasizes the need of conducting detailed long-term studies on behavioral ecology of these groups of individuals.

Small sample size of movements and respirations data on mother/calf pairs and calves (especially in relation to the behavioral states) showed the difficulties of obtaining information even from several years of observations. This was primarily due to a low number of calf production in the population. Continued study is recommended to increase sample size and also, conduct inter-annual comparison due to presence/absence of industrial activities in different years, which could have had affected the current results.

Chapter III discussed the shore-based photo-ID method and examined success of this approach. The six years of shore-based photo-identification efforts yielded a total of 144 individuals (including 31 calves of different years and 10 females accompanying calves), which contained 80% of all individuals in the main western gray whale catalog obtained by traditional vessel-based approach. Also, shore-based photo-ID provided higher number of resightings across all years compared to that of vessel-based photo-ID. Our results from shore-based photo-ID provided highly valuable information for the main photo-ID study on western gray whales, especially on mother/calf pairs, which were included in the analyses of population assessments. The shore-based approach proved to be an effective in collecting photo-ID information without potential disturbance to the whales, and is recommended as an important supplemental approach in studies of coastal cetaceans, especially for endangered populations and species.

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VITA

Name: Olga Aleksandrovna Sychenko

Address: Texas A&M University at Galveston, Marine Mammal Research Program, 200 SeaWolf Parkway, OCSB Bldg. 3029, Galveston, TX 77553

Email Address: sychenko@mail.ru, filyacat@hotmail.com

Education: Diploma (B.S.). Ecology, Far East National University, Vladivostok, Russia, 2004
M.S. Wildlife and Fisheries Sciences, Texas A&M University, 2011