Patterns of Western Gray Whale Behavior, Movement, and Occurrence off Sakhalin Island, 2007

Photo taken from shore, O. Sychenko.

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INTRODUCTION

There are two extant populations of gray whales (*Eschrichtius robustus*): the eastern North Pacific and western North Pacific (or Korean-Okhotsk) gray whales (LeDuc *et al.* 2002, Weller *et al*. 2002b, Moore and Clarke 2002). Both populations were depleted by commercial whaling in the mid 20th century. Today, the eastern population of gray whales has recovered from commercial whaling and consists of an estimated 18,000 individuals (Buckland and Breiwick 2002, Rugh *et al.* 2005). The western stock, however, remains one of the most endangered baleen whale populations in the world. Recent population assessments estimate that 121 individuals remain in this remnant population (Cooke *et al.* 2007, Jones and Swartz 2002, Yakovlev and Tyurneva 2008). The small number of whales remaining in combination with the fact that only 25-35 reproductive females are known to exist served as the basis for The World Conservation Union (IUCN) to list the western gray whale population as Critically Endangered (Hilton-Taylor 2000, Red Book of Russian Federation 2000, Weller and Brownell 2000).

Western gray whales are known to feed primarily off the northeastern coast of Sakhalin Island during each summer and fall. Recent sightings have placed known western gray whales that have been seen in the Sakhalin feeding grounds off the eastern coast of Kamchatka (Yakovlev and Tyurneva 2007, 2008). However, the majority of the population (especially mothers with recent calves) feed in the nearshore (Piltun feeding area) and offshore (Offshore feeding area) coastal waters of northeastern Sakhalin. For the past decade, research effort has continued to understand and monitor this endangered population while they remain on the feeding grounds (June-October). There is little evidence of western gray whales' migration routes, and the location of their wintering-breeding grounds remains unknown. It has been suggested that mating, calving, and early calf rearing take place south of Sakhalin Island, in or near coastal waters of the South China Sea (Jones and Swartz 2002).

Throughout their potential range, western gray whales face several threats to their future survival. Recent human-related mortality south of the Okhotsk Sea poses one of the most serious of threats to this population. In the past three years, five female western gray whales were incidentally caught or found entangled in fishing gear near Japan resulting in their death. If such mortality continues, even at a level of one individual per year, population projections suggest a high probability of population extinction (Cooke *et al.* 2007). Other threats to population survival include ship strikes, pollution, habitat damage, oil spills, and disturbance/displacement from key habitats (Richardson *et al*. 1989, Brownell 1999). Displacement or abandonment of whales from critical feeding and migratory habitat is possible, and may be caused by disturbance from noise of seismic surveys, vessel activity, other industrial activities, and the cumulative impact of all anthropogenic activity being conducted in a region. Gray whales have a high affinity for coastal habitats, which, unfortunately, makes them particularly susceptible to environmental perturbations and anthropogenic activity.

The feeding grounds of western gray whales are in the vicinity of existing and planned oil and gas developments. The primary operators in this region are the Sakhalin-1[Exxon Neftegas Limited (ENL)] and Sakhalin II [Sakhalin Energy Investment Company (SEIC)] projects. Both Sakhalin-1 and Sakhalin II have continued to sponsor monitoring programs to understand the natural patterns and assess potential impacts their activities may have on western gray whale behavior, movements, abundance, distribution, benthic communities, population trends, and ambient and anthropogenic sounds generated from their activity (summaries in Blokhin *et al.* 2003 a, b, Fadeev 2002, 2003, 2004, 2005, 2006, 2007, 2008, Meier *et al.* 2007, Vladimirov *et al* 2005, 2006, 2007, 2008, Weller *et al.* 1999, 2002a, Würsig *et al.* 2002, 2003, Yakovlev and Tyurneva 2003, 2004, 2005, 2006, 2007, 2008, Yazvenko *et al.* 2007 a ,b, Gailey *et al.* 2004, 2005, 2006, 2007a,b,c, Borisov *et al.* 2002, 2003, 2004a,b, 2005a,b, 2007, Rutenko *et al.* 2006a,b,c). This conservation and management approach involves annual monitoring of western gray whales during their foraging season to obtain additional understanding about the population, monitor changes that may occur, and actively mitigate potential impacts from industrial operations as well as other human-related activity. This approach attempts to ensure that the western gray whale foraging period is not disrupted, and that they are able to continue to feed in preferable feeding areas to gain the energy requirements needed to sustain them during their north and south bound migration, as well as when they are on their breeding grounds.

One of the primary concerns, in both short- and long-term, is the amount and levels of sound produced in relation to oil and gas project development and operation (vessel traffic, drilling, dredging) while individuals are utilizing important feeding habitats. The effects of underwater noise on baleen whales have been documented for a number of species, such as bowhead whales (Ljungblad *et al.* 1988; Reeves *et al.* 1984; Richardson *et al.* 1986, 1999), humpback whales (McCauley *et al.* 1998, 2000), and gray whales (Malme and Miles 1985; Malme *et al.* 1986). For eastern gray whales, Malme *et al.* (1986) found that ~10% of the whales stopped feeding and temporarily moved away from seismic sounds when received sound levels near the whales exceeded 163 dB re 1µPa (rms). For more continuous sounds, Malme *et al.* (1986) observed 10-50% of feeding eastern gray whales avoiding an area exposed to industrial noise levels of 120 dB. Tyack and Clark (1998) found that migrating eastern gray whales avoided a low frequency acoustic sound source when it was located directly in their migratory path. However, when the same sound source was placed offshore, no apparent avoidance behavior was observed. Western gray whales have also been documented to respond to sounds produced during seismic surveys (Gailey *et al.* 2007b, Johnson *et al*. 2007, Weller *et al.* 2002a,b; Würsig *et al.* 1999; Yazvenko *et al.* 2007a,b). One study found that whales traveled faster, changed directions of movement less, moved further from shore, and stayed under water longer between respirations when exposed to higher received sound levels (Gailey *et al.* 2007b). Similarly, Würsig *et al.* (1999) found that whales traveled faster and more linearly with short respiration intervals during seismic operations that occurred near the western gray whale feeding grounds in 1997.

In the past three years, increased levels of anthropogenic activity have occurred in relation to the installation of a nearshore oil platform (Piltun Astokh-B (PA-B), ~13 km from shore in 30 m water depth) and pipeline construction. During the summer of 2005, initial construction of the PA-B platform commenced with the placement of a Concrete Gravity Based Structure, or CGBS. With the exception of 'distance from shore', there was no relationship between the sound level variables measured during the construction activity and the measured behavioral response variables of gray whales observed during the construction period. This result could potentially be related to the noise mitigation strategy employed to minimize sound exposure levels above 120 dB within the Piltun feeding area during industrial/construction operations, and actively monitoring sound levels in the field (SEIC 2005, Rutenko 2006a,b,c). Distance from shore, however, was significantly associated with sound level, with gray whales predicted to be slightly further from shore as sound level increased. Sound levels were confounded, however, by nearby research vessels and CGBS related activity and therefore we were unable to directly test the effects of one or the other sound source. Gray whales were observed to be sensitive to nearshore research vessels and their response to these activities could have potentially led to the offshore movement observed in relation to sound levels. Gailey *et al.* (2007c) argued that some of the highest sound exposure levels were those due to nearshore research vessels as opposed to the offshore construction activity. The movement and location of the sound source in reference to the whale is likely to be an important aspect to how western gray whales may respond. Sound that is placed directly in the path of the whale or generated by an approaching vessel may result in reactions as opposed to sound sources that are further offshore and not directly in the pathway of the animal.

In 2006, pipeline construction activity was initiated from PA-B and Molikpaq (PA-A) platforms to where they came ashore south of the previously known (Piltun Area) nearshore feeding habitat. In 2007, top-side installation and pipeline tie-in construction activity occurred at the PA-B platform location. Construction activities consisted of multiple phases. For each of these phases, predictive acoustic models were conducted prior to construction and used as a mitigation measure to minimize sound levels within the gray whales feeding habitat. Sound levels were subsequently monitored in the field in real-time to ensure that levels were below the predetermined criteria levels. Both acoustic and behavior monitoring programs were employed during the construction phases to monitor potential impacts on the whales.

Observations of behavioral responses provide valuable information about the potential disturbance of whales due to activities that occur near or within their feeding habitat. Such information is used to reduce potential biological effects from sounds generated from the construction activity by helping define appropriate mitigation measures taken to ensure that such activities do not lead to diminished feeding. Multivariate analyses are currently being conducted to examine gray whale response to sound levels and vessel activity that occurred in 2006 and 2007. The results of these analyses will be presented in separate reports. In this report, we provide initial results about whale distribution, abundance, movements, and behaviors relative to presumably undisturbed as well as potentially affected conditions.

The 2007 behavioral research program was a continuation of effort conducted in 2001-2006. The objective of this research is to provide long-term observations of habitat use, distribution, abundance, movements, and behavior of western gray whales that occur in their Piltun feeding habitat. During the past two field seasons, the duration of the study was extended to monitor the construction activity that was scheduled early in the field season when fewer whales were likely to be present. Behavioral research was conducted from onshore locations that were at varying distances from the whales. The use of onshore locations has the advantage of avoiding the possibility of disturbing the whales. Three primary observation methods were used: 1) scan sampling to obtain relative abundance estimates, distribution, and group-size information; 2) theodolite tracking of individuals or groups to describe spatial movements, orientations, speeds, and habitat use; and 3) focal follow observations to monitor surfacing-respiration-dive parameters and other surface-visible behaviors. In addition to its ecological value, such information may be useful in the management of offshore industrial activities to reduce potential negative impacts on western gray whales feeding off northeastern Sakhalin Island.

METHODS

Research methods and analyses used in 2007 were consistent with those used in 2001-2006. Therefore much of this section is similar to those presented in Würsig *et al.* (2002, 2003) and Gailey *et al.* (2004, 2005, 2006, 2007a).

Study Area

Shore-based observations were conducted along 66 km of coastal region in the northeastern portion of Sakhalin Island, Russia (Figure 1). The study area encompasses a part of the nearshore Piltun feeding area, which is one of two known feeding grounds off northeastern Sakhalin Island used by western gray whales. The nearshore feeding habitat is rich in benthic prey, primarily amphipods and isopods, at depths of 5 to 15 m (Fadeev 2004, 2005, 2006, 2007). The high abundance of prey availability in the region may partially be influenced by a local lagoon ecosystem, known as Piltun Bay. Other nutrient sources that may stimulate primary productivity in the region could occur from upwelling and outflow from the Amur River. Research efforts are being conducted to better understand the relative contribution of nutrients to benthos in the area. The nearshore waters of the Sea of Okhotsk are generally characterized by sand substrate with a gradually sloping continental shelf.

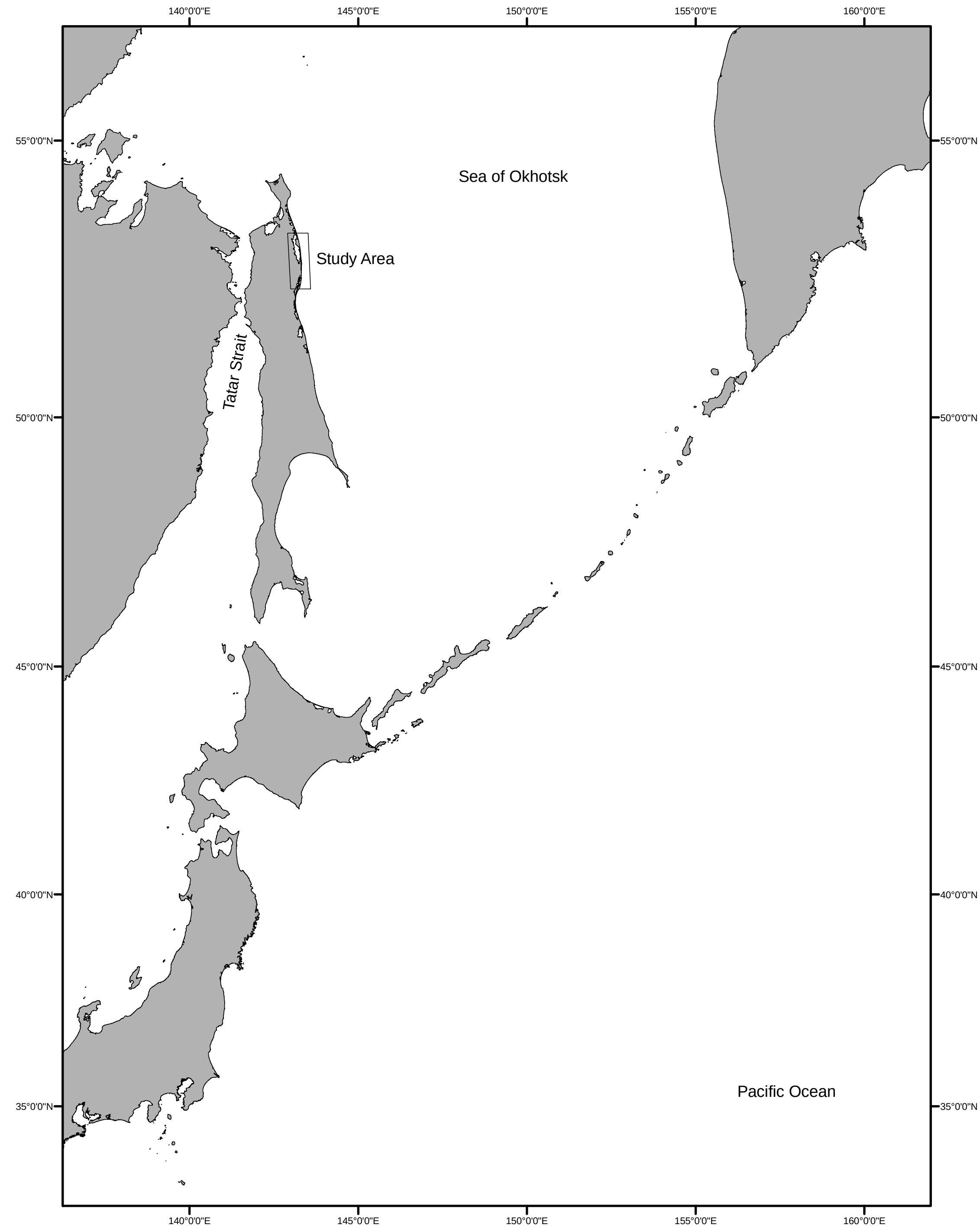

Figure 1. Study area in the northeastern portion of Sakhalin Island in Far East Russia. Figure 2 shows details of the study area.

Shore-Based Observations

Six locations were chosen to conduct behavioral observations on western gray whales during the summer of 2007 (Table 1). Each station was selected based on its height above sea level relative to the surrounding dunes to enable sufficient range for observations (Table 1). Two stations (2^{nd} Station and Station 07) had been used since 2001 (Gailey *et al.* 2007b); 1^{st} Station and Odoptu Station were incorporated in 2002, and North Station and South Station were added in 2004.

Two separate behavioral teams conducted research on every possible good weather day. From late June to mid-July, the potential disturbance of western gray whales by the PA-B top-sides installation was monitored from the two stations closest to the PA-B platform.

After primary construction of the top-sides was completed in mid-July, western gray whale behavioral monitoring was conducted by progressively moving from the southern-most station to the northern-most station. Once the northern-most station was reached (North Station & Odoptu Station), then the next day of effort continued at the southern-most stations (South Station & 1^{st} Station). This approach optimized research effort to collect data at each station after three favorable weather days.

Table 1. Six shore-based vantage points along the northeastern coast of Sakhalin Island, Russia.

Station Name	Latitude	Longitude	Height (m)	Station Distance from Shoreline (m)
North Station	53° 18' 22.9"	143° 12' 35.3"	18.05	66
Odoptu Station	53° 12' 33.0"	143° 14' 51.4"	17.25	79
Station 07	53° 07' 30.0"	143° 16' 12.3"	8.72	49
2nd Station	53° 03' 09.1"	143° 17' 04.5"	8.21	61
1st Station	52° 58' 27.5"	143° 18' 06.6"	8.66	62
South Station	52° 53' 23.9"	143° 19' 05.3"	4.27	55

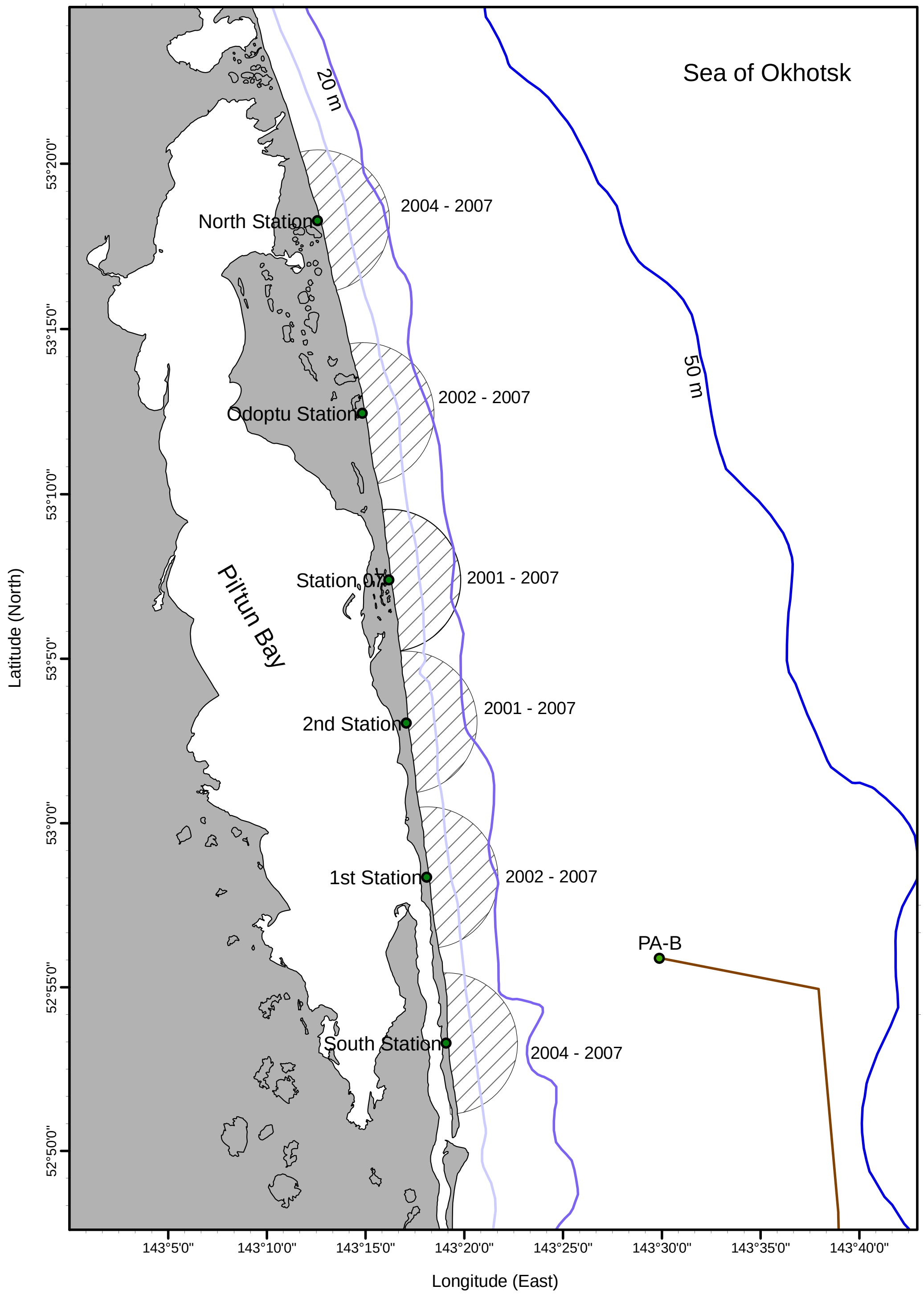

Figure 2. Locations of six shore-based behavioral stations on the northeast coast of Sakhalin Island, Russia. Semi-circular grids illustrate approximate viewable range (4 km) from each shore-based station. Dates indicate years when data were collected at each station.

Environmental Parameter Measurements

Environmental conditions were recorded several times per day to ensure consistent and reliable results for all three methodological techniques employed by the shore-based monitoring teams (see below). The relative visibility, glare concentration and horizontal angles, swell heights, cloud cover and sea state (Beaufort scale values 0-4 were recorded in this study, with 3 being small whitecaps and > 3 generally unacceptable for most analyses except for movement patterns and when whales were < 2 km from the observation point) were recorded. Hand-held weather stations (Kestrel 4000) were used at each station to automatically record temperature, barometric pressure, wind speed, wind direction, humidity, and several other environmental parameters at 10-min intervals throughout each day of effort at each observation station. After each field day, the environmental data were downloaded to a computer and stored for later use. If any of the above-mentioned environmental parameters hampered observations, then research effort was discontinued until conditions were acceptable. Temperature and barometric pressure information was used to estimate a refraction correction for calculations of distance approximation.

Scan Sampling

To monitor the relative number and distribution of gray whales in the study area, scan sampling methods were conducted hourly when focal behavior sessions were not being conducted. Two observers used hand-held binoculars (7x50 Fujinon FMTRC-SX with reticle and compass) to progressively scan a predetermined section of the study area ranging from 0° to 180° magnetic North (magnetic declination relative to true North = 11.81° West in summer of 2007). Each scan was initiated from the northern portion of the study area and proceeded to the southern portion, with a maximum of one scan per hour. The duration of each scan was determined based on the rate of scan (i.e. °/min) in 2001-2003 (20° to 160° = 140°/15 min = 9.33 °/min). Due to the increased coverage area in 2004 - 2007 and the need to be consistent with previous data, the duration was calculated to be 19.28 min. (180° / (9.33 °/min) = 19.28 min). Once an observer sighted a whale or whales, then the number of whales, angular distance between the whale and the horizon (based on binocular reticles), magnetic bearing, and estimated distance from the station were recorded. The *Pythagoras* software, developed by Gailey and Ortega-Ortiz (2002), was used to 1) inform the observers of the approximate region they should be scanning for every 10° magnetic North, 2) provide a data entry form to record sighting information, and 3) calculate geographic position and visually display sightings in real-time.

The observation range of this study does not encompass the entire Piltun feeding area. Therefore, the results presented here represent patterns and trends that were observed at the six observation regions, which is only a portion of the Piltun feeding area. See Vladimirov *et al.* (2008) for a broader scale overview of western gray whale distribution and abundance.

Theodolite Tracking

The spatial and temporal movement patterns of gray whales were monitored with Lietz/Sokkisha Model DT5 theodolites with 30-power monocular magnification and 5-sec precision. The theodolite tracking technique converts horizontal and vertical angles into geographic positions of latitude and longitude for each theodolite recording. The tracking of individuals over time provides information about the animals' relative speeds and orientations, alone or in relation to seismic or other human activity on the water (see Würsig *et al.* 1991, Gailey 2001, Gailey and Ortega-Ortiz 2002, and Gailey *et al.* 2004, for further description and mathematical calculations). A theodolite tracking session was initiated when a single or an individually recognizable gray whale in a group could be identified and the individual was sufficiently close to the station (4-5 km) to be tracked. Each individual was continually tracked until the animal was lost, moved beyond a 4-5 km distance from the station, or when environmental conditions hampered further tracking. Due to the relatively low elevations of each station, a maximum of 4 km distance from the station was the criterion to ensure reliable data for analysis of speeds, orientations, and displacement (see Table 1, for station elevations and Würsig *et al.* 1991 for height-related errors).

For each theodolite recording, subsequently referred to as a "fix", the date, time, and vertical and horizontal angles were stored in a Microsoft Access database with the relative distance, bearing referenced to true North, and geographic position calculated in real-time by the theodolite computer program *Pythagoras* (Gailey and Ortega-Ortiz 2002).

Focal Behavior Observations

Focal behavior sessions of behavior and respiration events (*sensu* Altmann 1974, Martin and Bateson 1993) were conducted on individual gray whales. A focal behavior session was initiated when all observers determined that a single whale could be monitored continuously and reliably enough so that respiration and critical behavioral events would not be missed. The reason for choosing a single or individually recognizable whale was that it was generally impossible to distinguish an individual within a group. A focal session would be terminated once the whale moved out of the 4-5 km range, or when the above conditions were not met. At least one behavioral observer would follow individuals with the aid of the hand-held binoculars (7x50 Fujinon). The behavioral observer verbally stated each behavioral event, and a computer operator recorded this into a laptop computer with *Pythagoras* (Gailey and Ortega-Ortiz, 2002). To minimize inter-observer variability, the behavioral observer's observations were periodically evaluated by other observers. In most focal follow sessions, behavior and respiration events were recorded simultaneous to spatial and temporal movements measured by theodolite tracking of the focal animal.

Data Analysis

Scan Data – For a broad overview of whale relative abundance, scan data of whales and pods were analyzed for the entire survey area. Whale distribution was analyzed using the fixed kernel method to graphically evaluate areas where animals were most frequently seen (Worton 1989). The number of whales or pods per station was evaluated at different time periods for each day of effort and for different seasons. For this study, season refers to the 'summer' periods when data were recorded during June – July, and 'autumn' periods when data were recorded during the months of August – September.

Due to non-normal distribution of scan data, both numbers of whales and pods were transformed (log (# whales or pods +1)) for analytical purposes. Based on the observer height above sea level, geographic bearing, and reticle readings of each sighting, the distance between the observer and the whale(s) was calculated (see Lerczak and Hobbs 1998 for distance equations). In addition, a refraction index was used to correct for potential errors in the line-of-sight estimation of distance (Leaper and Gordon 2001); the refraction index was calculated using temperature and pressure information that was recorded by a hand-held (Kestrel 4000) environmental device at each observation station. Due to differences in observation heights among the stations, a threshold of $\leq$ 6 km from the station, determined by evaluating the frequency distribution of sightings in relation to distance from station and the station's relative height, was used for some analyses (i.e. comparing relative abundance values between stations) to compare between different stations (Figure 3). For other analyses that were dependent on geographic location, such as distance from shore, a threshold of 10 km from the observation station was adopted. The rationale for the increased threshold for the distance from shore analysis was to increase the coverage area to incorporate sightings further from shore to be represented in the analysis. This ensures that if there are animals further from shore, such as those illustrated in Figure 6 **continued.** at Odoptu Station, then these offshore (> 6 km) sightings are included in distance from shore estimates.

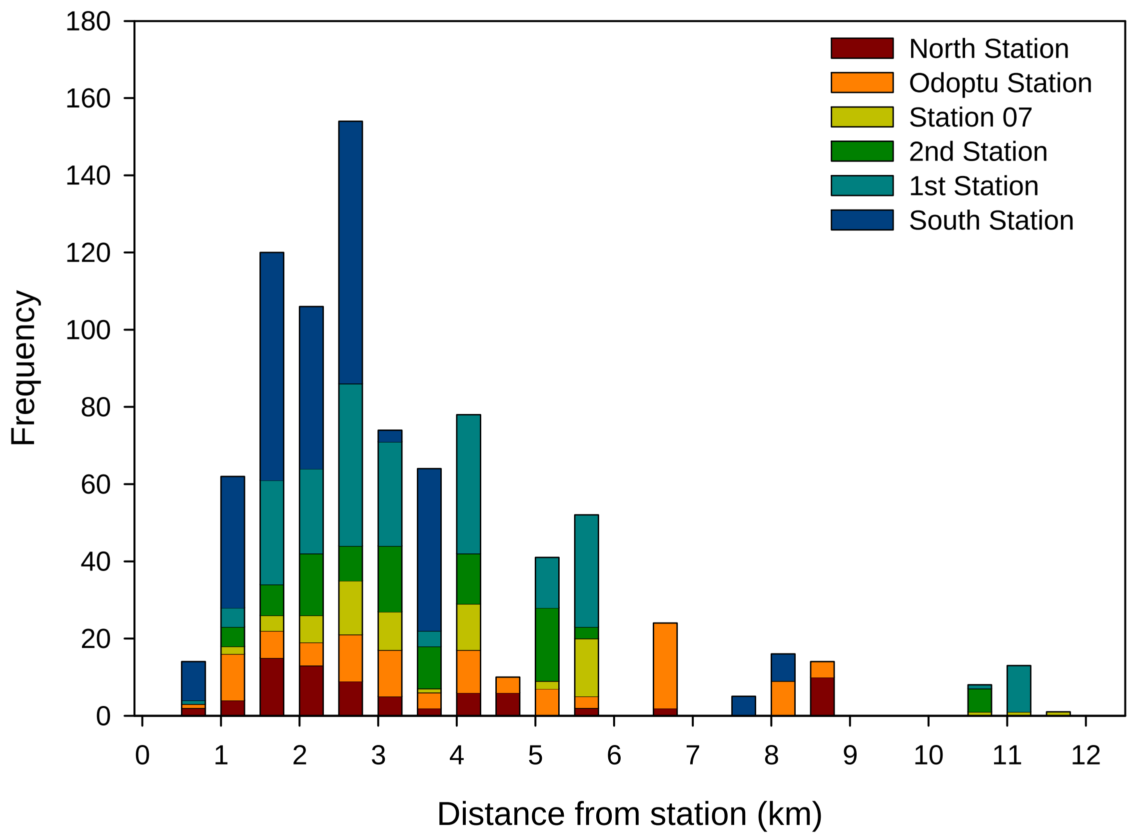

Figure 3. Frequency of sighting distances of western gray whales from six shore-based vantage points, northeast Sakhalin Island, Russia.

Theodolite Data – Theodolite tracking information was evaluated in terms of each animal's relative speeds, orientations, and displacement. Due to potential issues related to over- or under-sampling and to ensure that fixes within a single track were uncorrelated, each trackline was interpolated temporally, as suggested by Turchin (1998). The temporal component was based on evaluating the entire trackline dataset in terms of step lengths, turning angles, number of fixed data points, and fix rate. A 90-sec interpolation criterion was based on an autocorrelation analysis performed on western gray whale movement patterns (see Würsig *et al.* 2002). The iterative interpolation strategy started by focusing on the first whale position in a track, and then interpolating a geographic position, based on the actual fix data, 90-sec apart. The result of the interpolation procedure yielded tracklines with pairs of fix points (steps) separated by time intervals of approximately 90 seconds.

For each interpolated trackline, the calculated leg speed, acceleration, linearity, reorientation rate, ranging index, and mean vector length were analyzed (Table 2). Leg speed is estimated by calculating the distance traveled between two sequential fixed points within a trackline divided by the time interval between the two points. Acceleration evaluates changes within leg speed to determine if an animal is generally increasing or decreasing speeds within a trackline. Linearity is an index of deviation from a straight line, calculated by dividing the net geographic (straight-line) distance between the first and last fix of a trackline by the cumulative distances along the track. Linearity values range between 0 and 1, with 0 indicating no net movement and 1 indicating a straight line (Batschelet 1980). In addition to linearity, another directionality index r (mean vector length; Cain 1989) was incorporated as a measure of angular change within a trackline as opposed to distances. Mean vector length values range from 0 (great scatter) to 1 (all movements in the same direction) (Cain 1989). Reorientation rates represent the magnitude of bearing changes along a trackline. This rate is 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).

A ranging index was included to measure the minimal diagonal area of the whale's track incorporating its course and track duration (Jahoda *et al.* 2003). A "displacement" analysis was conducted to evaluate natural movement patterns of western gray whales among different behavioral states. Displacement is defined as a straight-line distance an animal moved spatially from the start of the track (i.e. step 0) to the n^{th} step. Confidence intervals for the displacement analysis were determined using bootstrap methods. The bootstrap was conducted by randomly selecting (with replacement) i_n paths (where i_n was defined as the number of paths with n moves), and calculating the mean squared displacement. After 1000 iterations of the bootstrap, the 95% confidence interval for each step was selected from the 26^{th} and 975^{th} values as the lower and upper limits, respectively. Due to the nature of this analysis, all paths were used for low n steps (i.e. step 0), but as n increases, the number of paths decrease. The consequence of this is wider error bars at higher n steps (Turchin 1998).

Behavioral/Respiration Data – To evaluate potential behavioral changes, focal behavioral data were quantified by six variables: 1) blow interval (times less than 60 s between subsequent exhalations per surfacing), 2) number of blows per surfacing, 3) surface time (duration the animal remains at or near the surface), 4) dive time (logged whenever a submerged whale did not blow for > 60 s), 5) surface blow rate (mean number of exhalations per minute during a surfacing), and 6) surface-dive blow rate (number of exhalations per minute averaged over the duration of a surfacing-dive cycle, using the dive previous to the surfacing) (Table 2). The determination of a 60 s dive criterion was based on evaluating the bi-modal frequency distribution and survivorship analysis of all subsequent blows (regardless of time between blows), where the 60 s threshold was between the two (blows and dives) different distributions. One approximately 10.5 min long bin was randomly selected per each behavioral observation session to address independence (a measure of autocorrelation), and one mean calculated per each of the six variables per ten minute bin (see next section).

Table 2. Description of the movement and respiration variables derived from track line and focal follow observations, Sakhalin Island, Russia.

	Variable	Definition
Movement Parameters	Leg Speed	Distance traveled between two sequential fixed points within a trackline divided by the time interval between the two points
	Acceleration	Changes within leg speed to determine if an animal is generally increasing or decreasing speeds within a trackline
	Linearity	An index of deviation from a straight line, calculated by dividing the net geographic distance between the first and last fix of a trackline by the cumulative distances along the track
	Mean Vector Length	A directionality index r (Cain 1989) dependent on angular changes - range from 0 (great scatter) to 1 (all movements in the same direction)
	Reorientation Rate	Magnitude of bearing changes, calculated by the summation of absolute values of all bearing changes along a trackline divided by the entire duration of the trackline in minutes
	Distance-from-Shore	Distance of animal from the closest perindicular distance from the nearby coastline
	Ranging Index	Measure of the minimal diagonal area of the whale's track incorporating its course and track duration (Jahoda *et al.* 2003)
Respiration Parameters	Respiration Interval	Duration less than 60 s between subsequent exhalations per surfacing
	Dive Time	Any interval where exhalation period is greater than 60 s
	Surface Time	Duration the animal remains at or near the surface
	Number Blows/Surfacing	Total number of exhalations per surfacing
	Surface Blow Rate	Mean number of exhalations per minute during a surfacing
	Dive-Surface Blow rate	Number of exhalations per minute averaged over the duration of a surfacing-dive cycle, using the dive previous to the surfacing

Theodolite and Focal Follow Data Bins – Due to variation in duration between tracklines and focal follows, all data were binned into 10.5-min intervals per tracking/focal follow session. "Binning" involved combining locations within intervals of time lasting approximately 10.5 min, and viewing the interval of time as the basic observation unit upon which responses and explanatory variables were measured. Each 10.5-minute interval of time was called a *bin*, and ended at an actual or interpolated geographic location. Due to non-constant track lengths, one or multiple bins were obtained for each track. For each bin, the above-mentioned tracking and behavioral values of interest were calculated. Due to variation in the number of bins per tracking session, and to avoid pseudoreplication in analyses, one bin was randomly selected from each trackline or focal behavior session. Therefore, the sampling unit used for analyses was one representative bin per trackline or focal follow session.

The behavioral state of gray whales was associated with each bin and classified as one of the following four levels: Feeding, Feeding/Traveling, Traveling, and Mixed. Classification of behavior into one of these four categories was based on field observations regarding a whale's predominant behavior at the time of each bin. Feeding behavior was characterized by non-directional movement where whale(s) generally remain in one localized area with consistent periods of diving. Traveling behavior was characterized as swimming in one general direction and often remaining at the surface without consistent dives. Feeding/Traveling behavior consisted of whale(s) swimming at relatively slow speeds with consistent periods of diving and having directional persistence in movement. Mixed behavior was any combination of transitional behaviors, other behaviors (such as socializing, resting, etc), or unrecognized/unknown behaviors comprising a substantial portion of the bin.

Transformations - Histograms were evaluated for each of the response (abundance, movement, and respiration) related variables. Transformations for each non-normal distribution were performed to approximate normal distributions for analytical purposes. The distributions of linearity and mean vector length were highly skewed, non-normal in shape, and contained values that ranged from 0 to 1. The empirical logit transformation was applied to linearity and mean vector length. A small constant of 0.003 was subtracted from each observation to avoid division by zero when the original response was 1.0. The distributions of leg speed, reorientation rate, range, respiration interval, dive time, blows per surfacing, dive-surface blow rate, and surface time were non-normal. Each of these variables was log transformed.

RESULTS

Effort

The 2007 field season commenced on 20 June and ended on 25 September 2007. A total of 52 days (626 hrs) of effort was spent at the six shore-based observation stations (Table 3, Appendix 1). The initial focus of observations was to monitor whales near the PA-B planned construction activity. Consequently, research effort from June to mid-July was restricted to the observation stations closest to the construction site (1st and South stations). Weather conditions during the 2007 field season were relatively good compared to previous years. Due to weather conditions in 2004-2006, approximately 33-43% of the potential days of research effort were spent collecting data. In 2007, 54% of the available effort days had sufficient weather conditions to conduct observations. In particular, the months of August and September had relatively high number of days of good weather for this region.

Table 3. Field season effort at six shore-based stations during 20 June to 25 September 2007, Sakhalin Island, Russia.

Month	Days	Actual days	Effort (hrs)
June	15	8	97.23
July	18	10	95.25
August	37	19	266.84
September	33	15	166.2
Total	103	52	625.52

Scan Data

General – During a total of 334 scans, 1183 whale counts were recorded from 860 sightings (Table 4). An average of 3.7 scans was conducted per day of effort at each station. Distribution of gray whale sightings from the six stations is shown in Figure 4-6; although whales could be sighted up to about 10 km from the station with the highest elevation (North Station, 18.1 m), they were generally < 5 km from shore (Figure 8; Table 5). Relatively few gray whales were observed early in the season (June-July) compared to later in the season (August – September). Fewer whales were recorded in northern regions (North and Odoptu stations) in 2007 compared to previous years (Table 15). More whales were recorded in increasing numbers throughout the field season in southern regions (1^{st} and South stations) of the study area.

The average gray whale relative abundance for the entire study area was 3.2 ± 3.63 SD (Median = 2, Range: 0-20, N = 334) whales and 2.3 ± 2.66 (2, 0-16, 334) pods per scan. The mean pod size detected was 1.4 ± 0.66 (1, 1-4, 775) whales per pod (Figure 7).

Table 4. Summary of scans during 2007 at six shore-based stations, Sakhalin Island, Russia.

Station	Days	# Scans	# Sightings	# Individuals
North Station	11	38	77	114
Odoptu Station	12	46	117	164
Station 07	14	50	70	92
2nd Station	14	48	107	155
1st Station	22	86	219	296
South Station	18	66	270	362
All Stations	91	334	860	1183

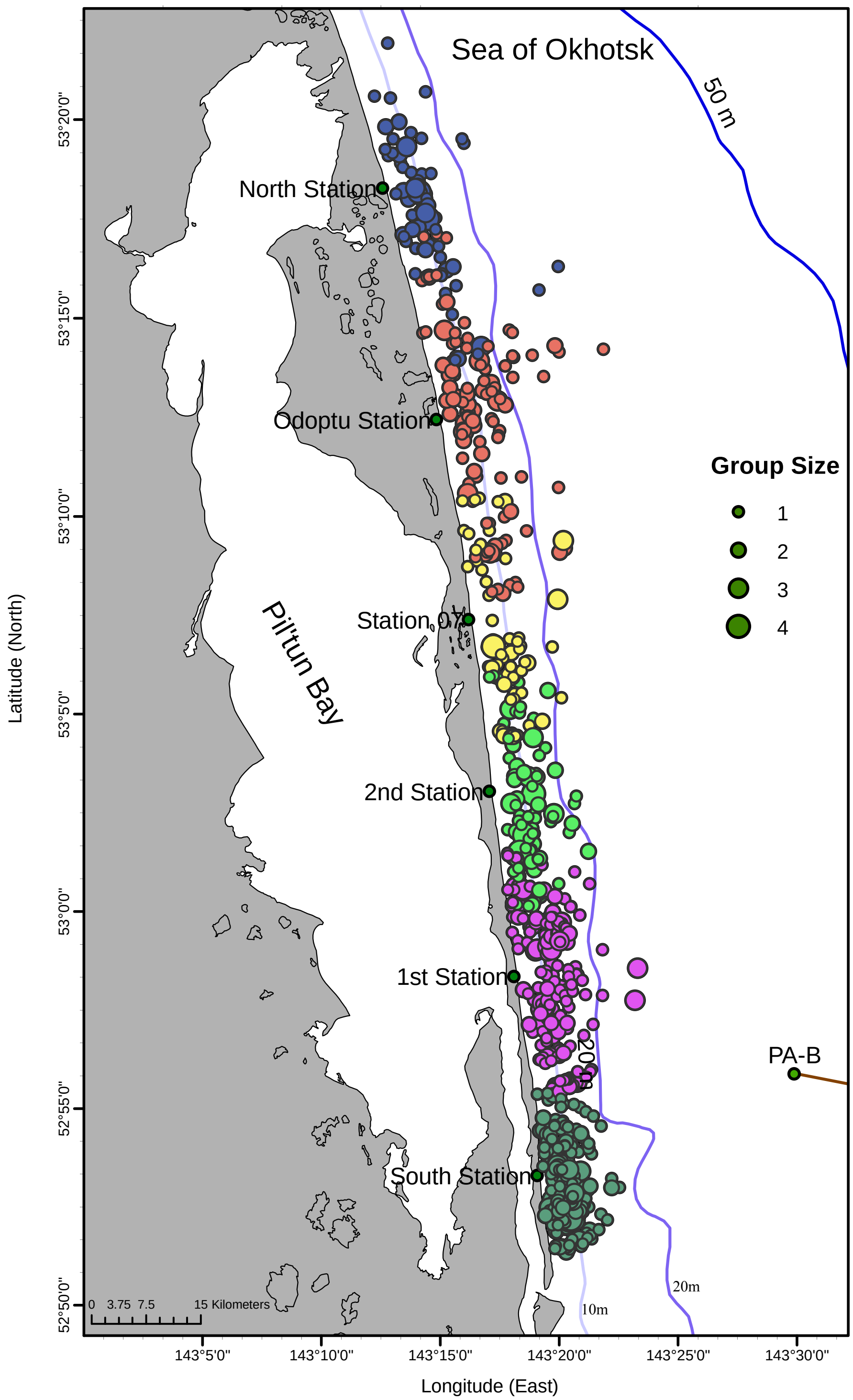

Figure 4. Geographic positions of sightings of western gray whales at six shore-based stations on Sakhalin Island, summer 2007, Sakhalin Island, Russia.

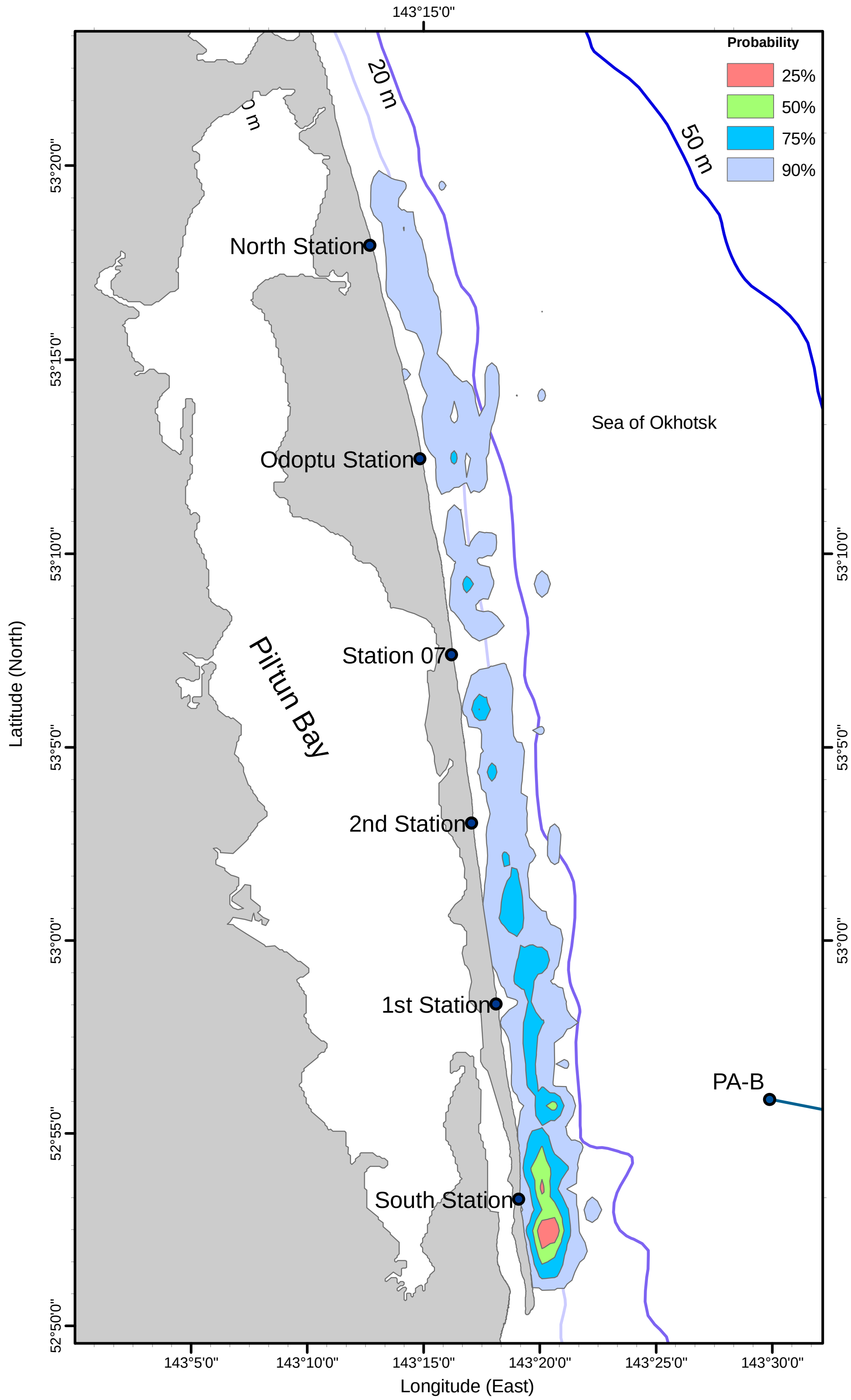

Figure 5. Distribution of western gray whales from six shore-based positions during the June-September of 2007, Sakhalin Island, Russia. Blue – red represents the kernel density probability contours.

A.

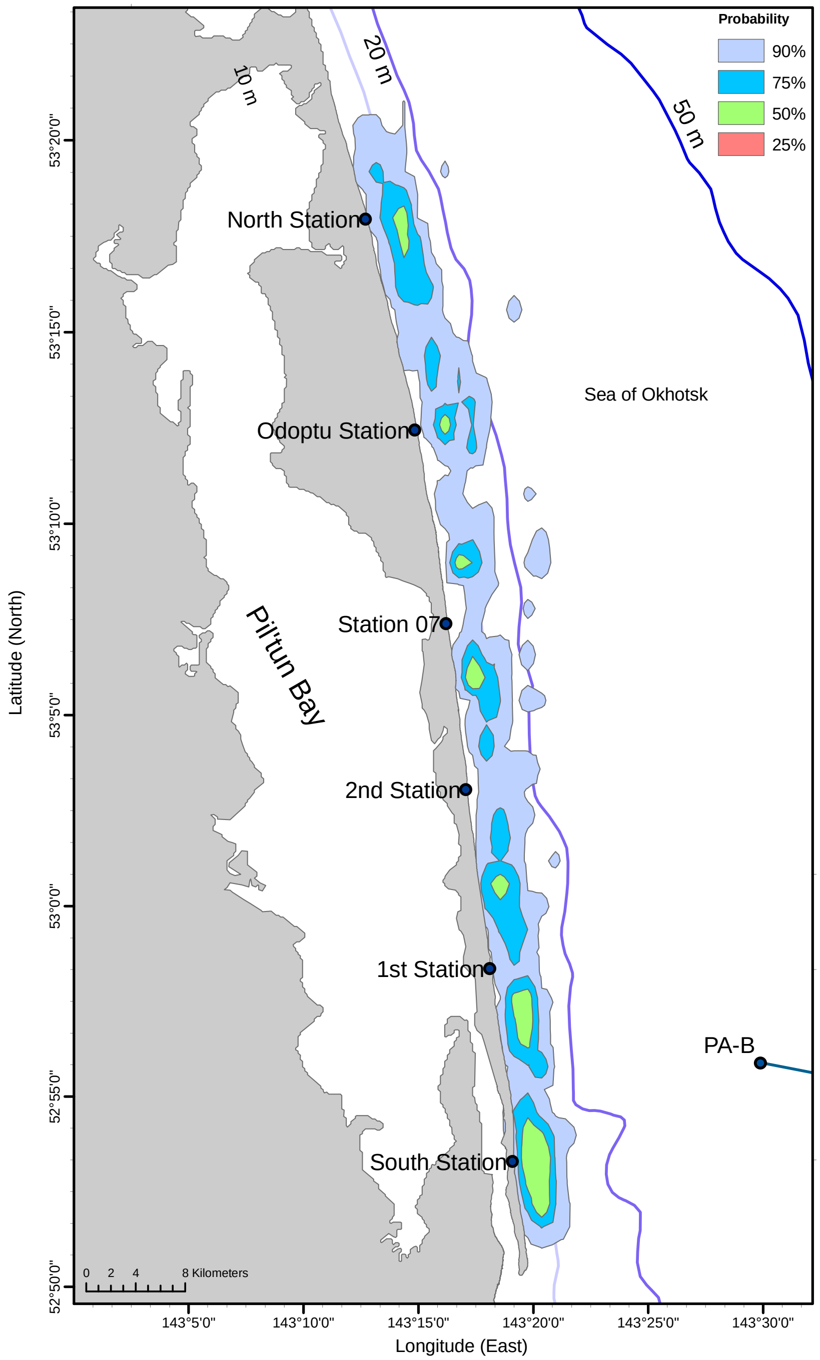

Figure 6. Distribution of western gray whales from six shore-based positions from (A) August, and (B) September of 2007, Sakhalin Island, Russia. Blue – red represents the kernel density probability contours. June-July sightings were excluded due to unequal sampling in the northern region during this period.

B.

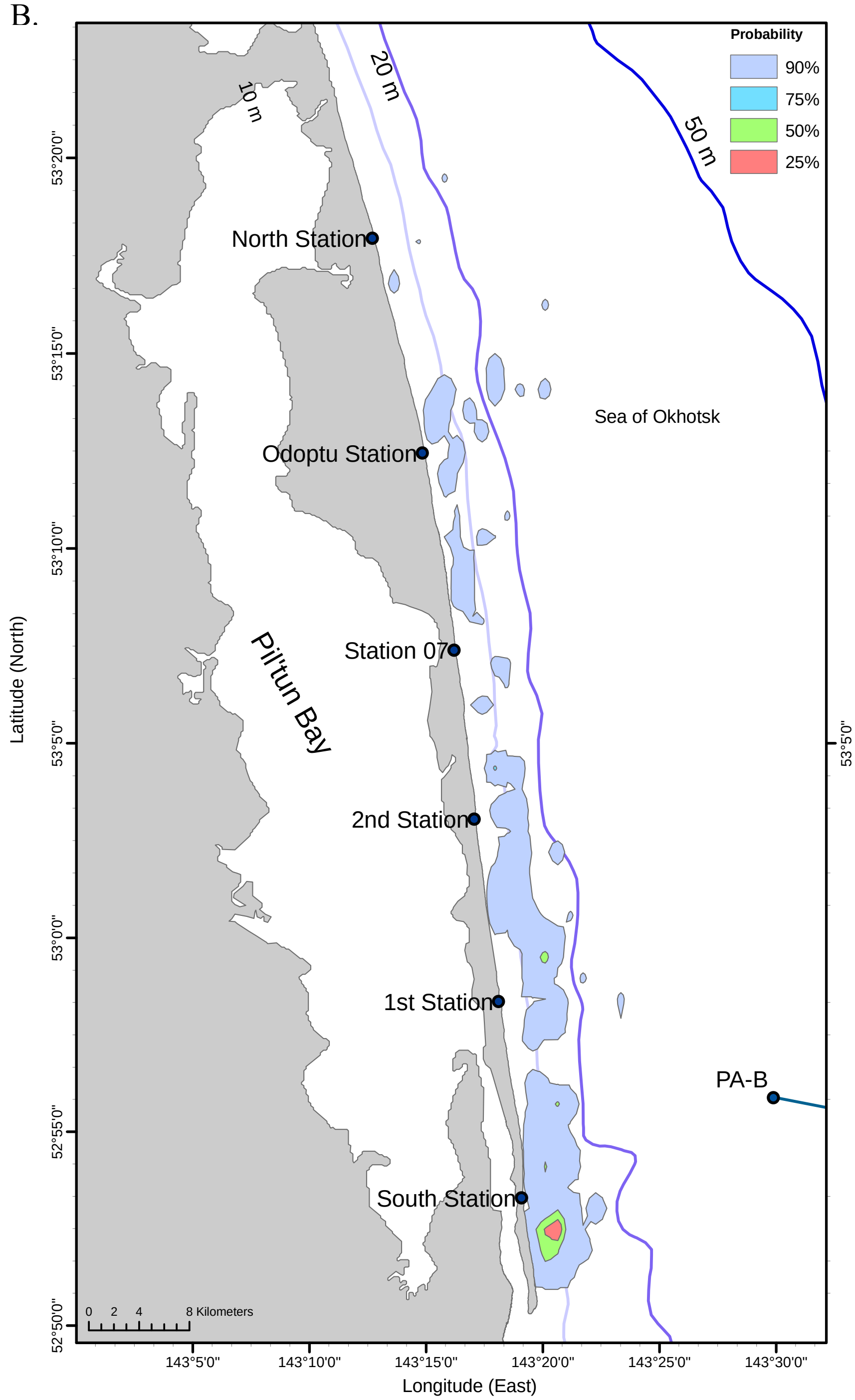

Figure 6 continued.

A.

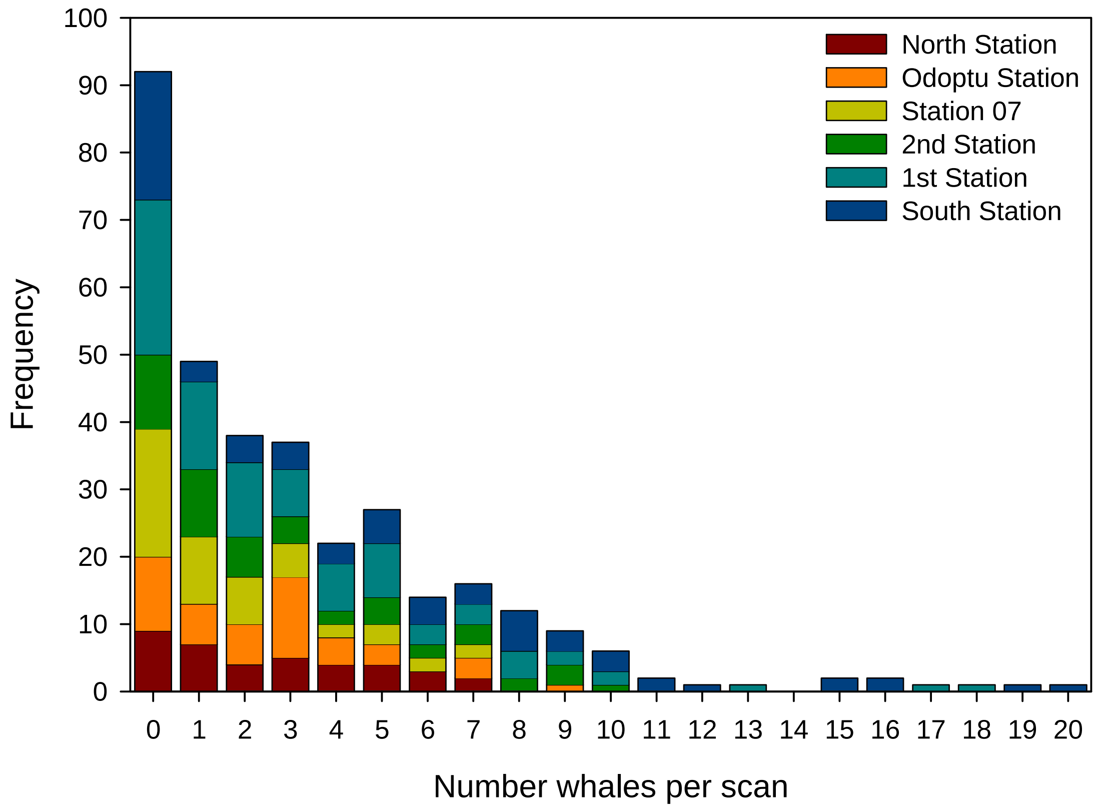

Figure 7. Frequency histograms of numbers of whales (A) and pods (B) detected per scan throughout the study period, and pod size (C), Sakhalin Island, Russia.

B.

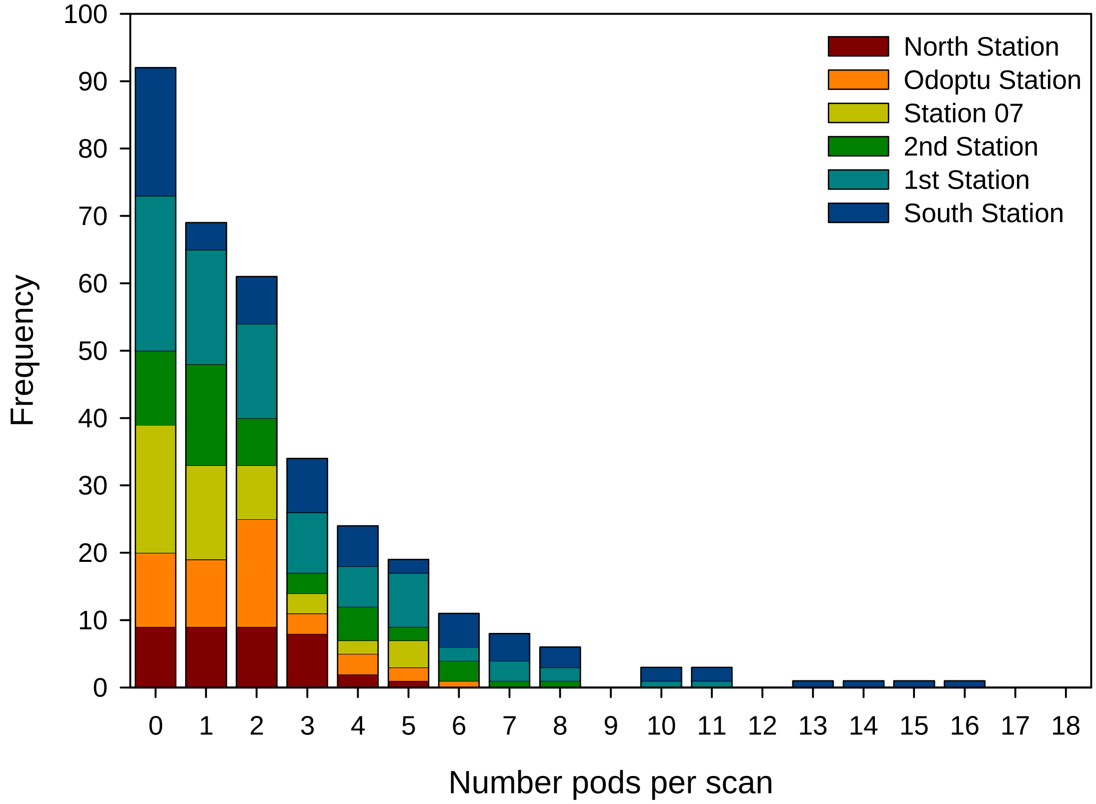

Figure 7 continued.

C.

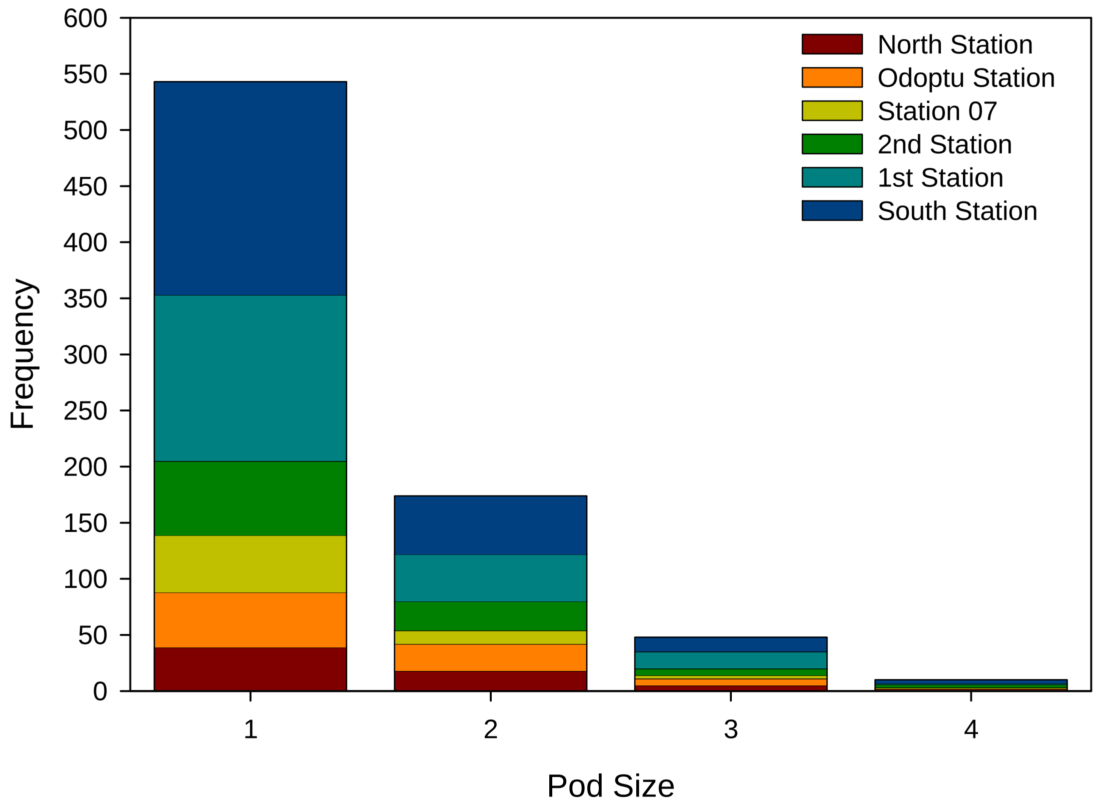

Figure 7 continued.

<u>Distance from shore</u> – Western gray whales were observed on average 1.6 ± 1.06 km from shore among the different stations (Figure 8 and Table 5). Whales at one of the most northern locations (Odoptu Station) tended to be slightly further from shore (2.1 km); however, when compared to sightings from the other stations, this difference was not statistically significant. The distance from shore at South Station was significantly (F = 13.42, df = 5, $P < 0.0001$) closer to shore compared to other stations except Station 07. There were no differences in the distances of whales from shore among the different months (June, July, August, and September) of observation (F = 12.29, df = 3, P = 0.09).

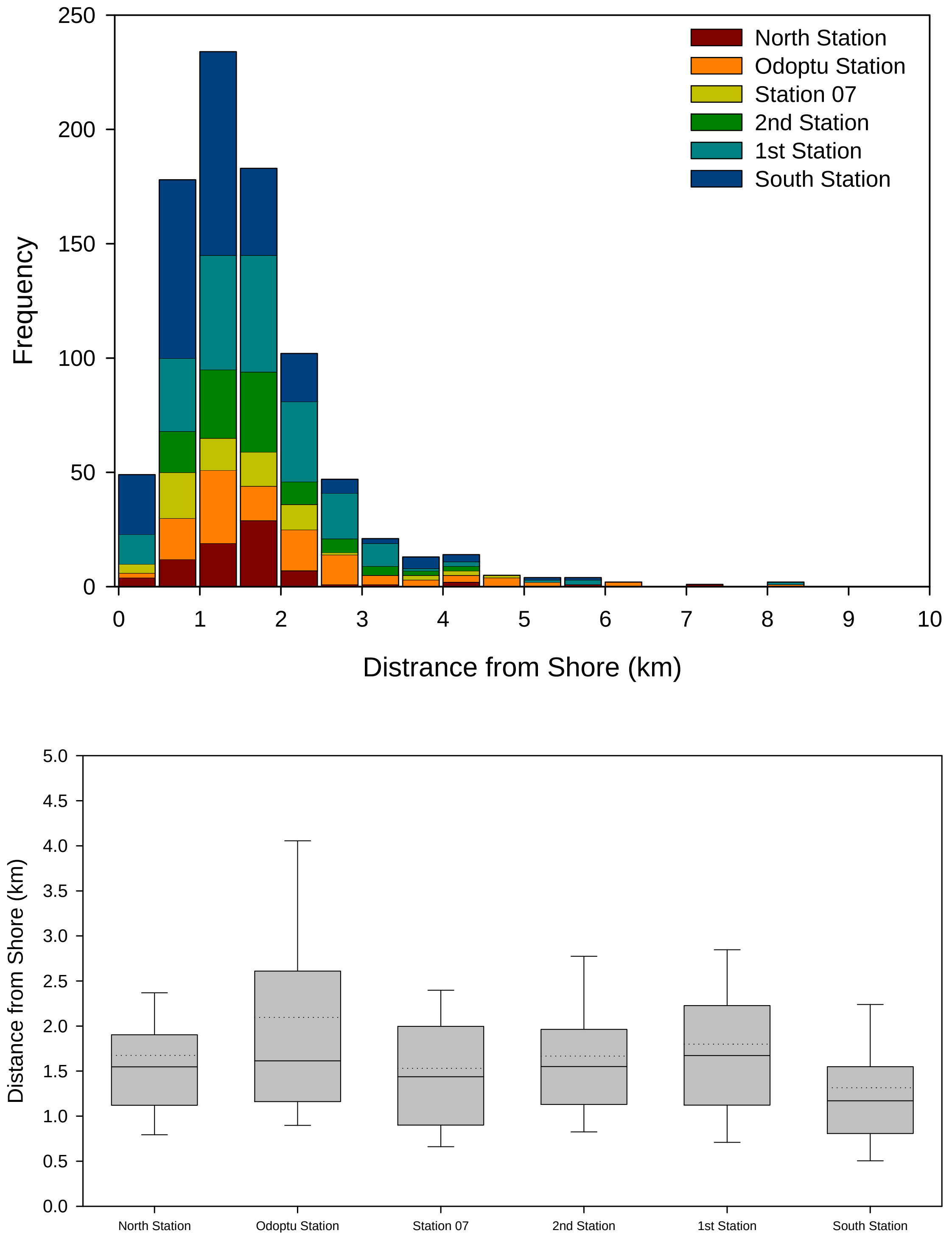

Figure 8. Frequency distribution (A) and box plot (B) of distance of western gray whale sightings from shore off Sakhalin Island, Russia, during June-September of 2007.

Table 5. Distance of western gray whales from shore at six shore-based stations, Sakhalin Island, Russia. Sample size represents number of sightings of gray whales.

Stations	Mean(km)	Median (km)	SD (km)	N	Min (km)	Max (km)
North Station	1.7	1.5	1.05	77	0.40	7.08
Odoptu Station	2.1	1.6	1.35	117	0.20	8.21
Station 07	1.5	1.4	0.93	70	0.22	4.81
2nd Station	1.7	1.6	0.77	107	0.52	4.24
1st Station	1.8	1.7	1.18	219	0.12	10.78
South Station	1.3	1.2	0.84	270	0.09	5.91
Total	1.6	1.4	1.06	860	0.09	10.78

Morning vs. Afternoon – We found no significant difference in the number of whales (χ^2 = 0.004, df = 1, P = 0.99) or pods (χ^2 = 0.15, 1, 0.70) detected in the morning vs. in the afternoon (Figure 9). In the morning, the mean number of whales was 3.3 ± 3.81 SD (Median = 2, Range: 0-20, N = 164); in the afternoon, the mean number of whales was 3.2 ± 3.45 (2, 0-19, 170). In the morning, the mean number of pods was 2.4 ± 2.87 (2, 0-16, 164); in the afternoon, the mean number of pods was 2.2 ± 2.45 (2, 0-14, 170).

A.

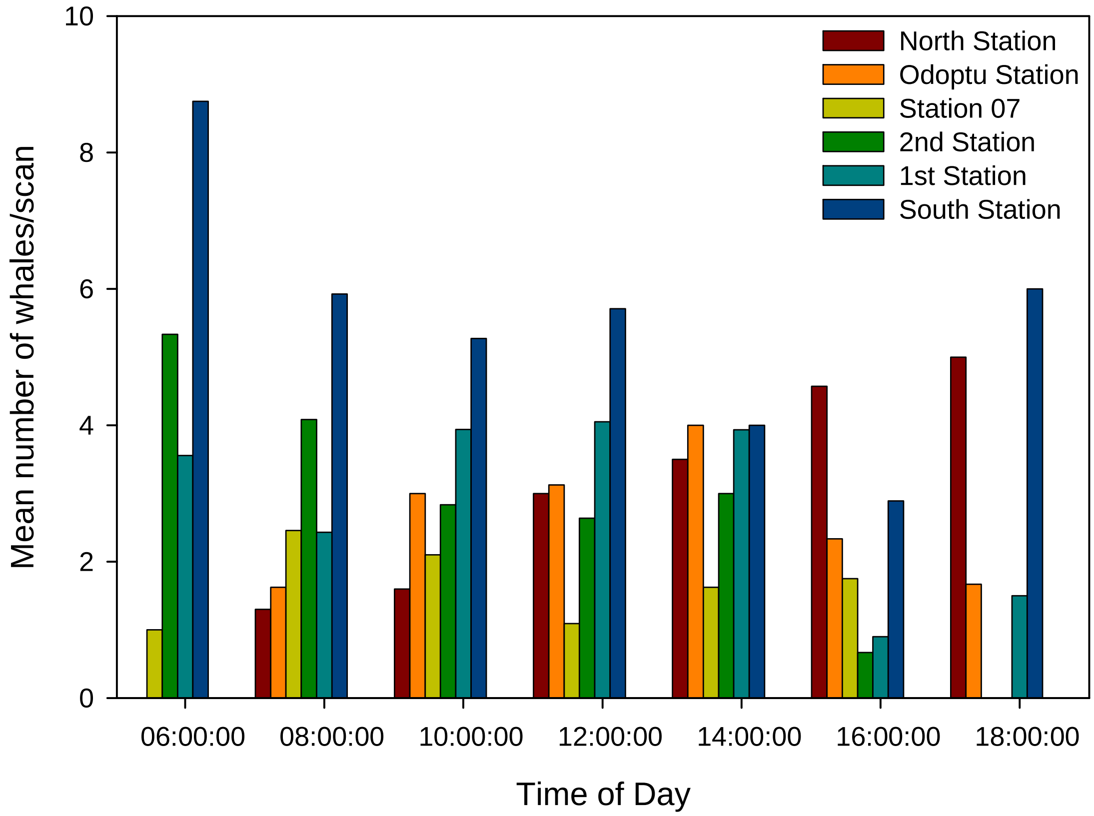

Figure 9. Mean number of whales (A) and pods (B) per time of day at six shore-based stations, Sakhalin Island, Russia.

B.

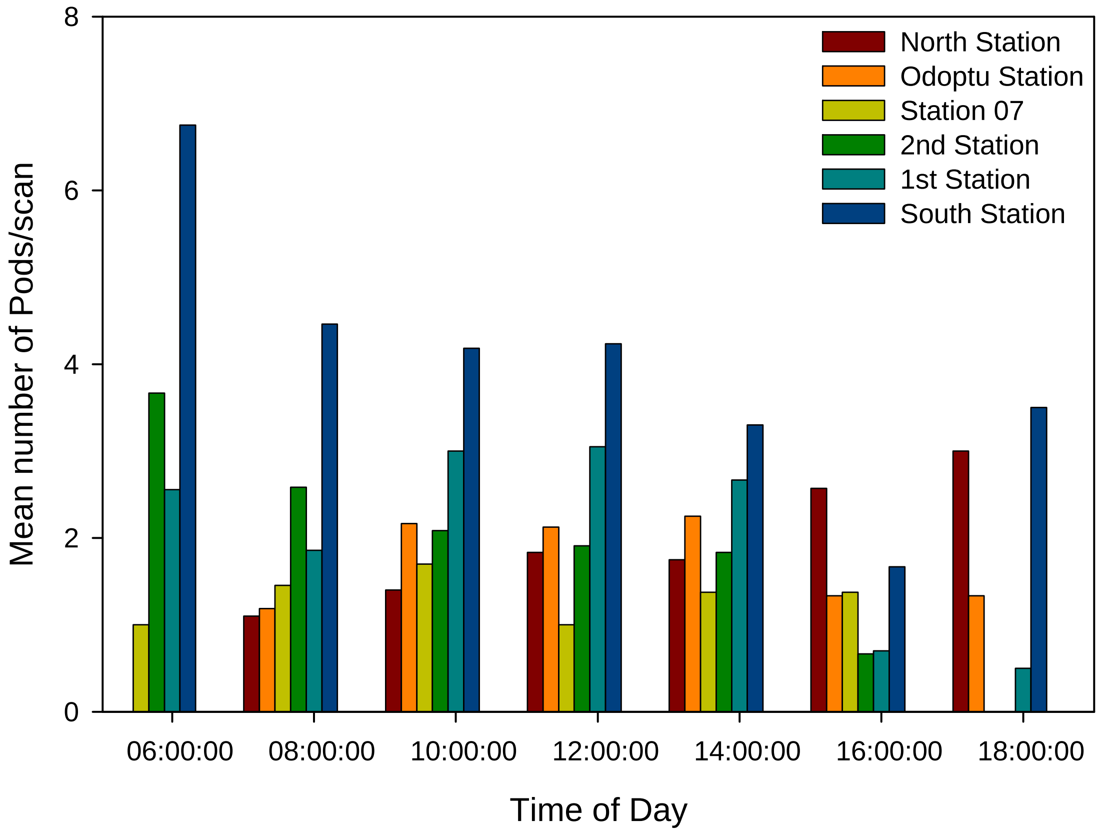

Figure 9 continued.

Stations – The mean numbers of whales and pods observed over the duration of the study were significantly different among stations (whales $F = 11.58$, $df = 5$, $P < 0.005$; pods 5.32, 5, <0.001), with more whales and pods recorded at the southernmost shore station on average for the entire season (Table 6). Season was included as a covariate to explain variation for different temporal periods (see below). Post-hoc comparisons indicated that all stations had similar numbers of whales/pods throughout the season with the exception of the two southern stations (1st and South stations). These regions typically had the highest number of whales.

Table 6. Number of whales (A) and pods (B) detected at six shore-based stations, Sakhalin Island, Russia. Sample size is the number of scans per station.

A.

Station	Mean	Median	SD	Range	N
North Station	2.6	2	2.24	0-7	38
Odoptu Station	2.5	3	2.20	0-9	46
Station 07	1.8	1	2.05	0-7	50
2nd Station	3.1	2	3.04	0-10	48
1st Station	3.3	2	3.71	0-18	86
South Station	5.2	5	5.19	0-20	66
Total	3.2	2.0	3.6	0-20	334

B.

Station	Mean	Median	SD	Range	N
North Station	1.7	2	1.34	0-5	38
Odoptu Station	1.7	2	1.49	0-6	46
Station 07	1.3	1	1.53	0-5	50
2nd Station	2.1	1	2.11	0-8	48
1st Station	2.4	2	2.48	0-11	86
South Station	3.9	3	4.11	0-16	66
Total	2.3	2	2.66	0-16	334

Although there tended to be more whales in the southern regions, there was also a great degree of temporal variability (daily and seasonal). In late June through July, few whales were observed in the region; however, later in the feeding season (August through September) there were more whales observed. There was significant ($F = 105.37$, $df = 1$, $P < 0.0001$) seasonal variation, with more whales observed at almost all stations later in the feeding season (August – September) than during the early part of the feeding season (June-July). However, the most northern locations (North and Odoptu) had non-significant changes in abundance for the entire season. This may be due to a low sample size (N=2) early in the season because of the focus during that period on PA-B construction in the southern region (Table 7). In August-September, there was significantly greater number of whales in the southern part of the study area compared to the northern region (Figure 10).

Table 7. Relative abundance of western gray whales from June-July and August-September, 2007.

Station	June-July	August-September
North Station	1.0 ± 0.00 (2)	2.7 ± 2.27 (36)
Odoptu Station	1.0 ± 1.41 (2)	2.6 ± 2.21 (44)
Station 07	0.4 ± 0.70 (17)	2.5 ± 2.14 (33)
2nd Station	1.2 ± 1.53 (14)	3.9 ± 3.19 (34)
1st Station	1.1 ± 1.34 (44)	5.5 ± 4.03 (42)
South Station	1.4 ± 2.85 (30)	8.4 ± 4.55 (36)
Total	1.1 ± 1.84 (109)	4.3 ± 3.82 (225)

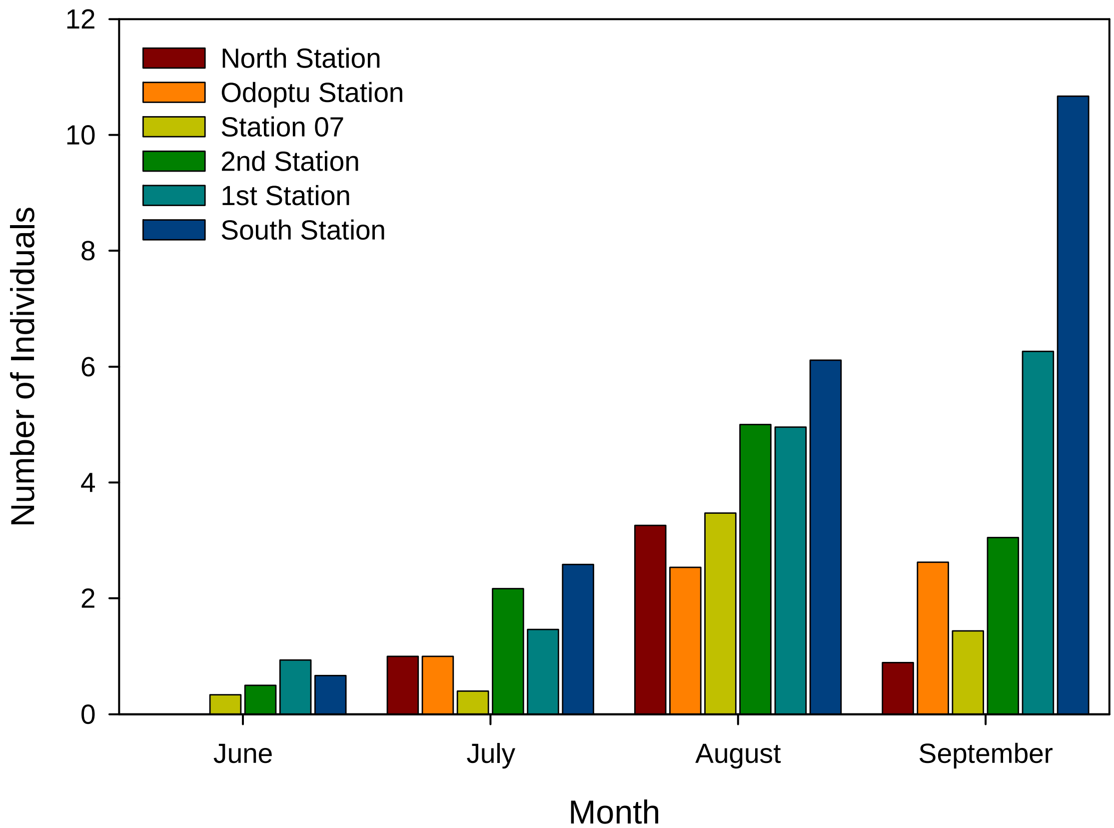

Figure 10. Mean number of western gray whales observed for four months of observations at six shore-based locations, Sakhalin Island, Russia.

Theodolite Tracklines

Gray whales were tracked for a total of 298 hours ($\overline{\chi}$ = 1.2 hrs/track), with individual tracks ranging from 5 min to 7 hrs of continuous monitoring of movement patterns

(Table 8). A total of 249 different tracklines with 14,712 geographic positions were recorded (Figure 11). The majority (77%) of the tracklines were recorded during the months of August and September (Table 9). This result is mainly due to the fewer numbers of whales observed in the study area during June and July compared to August and September when the weather was better and more effort was expended. Figure 12 illustrates areas of observed feeding and feeding/traveling activity. In general, gray whales were observed to be primarily feeding in the northern (Odoptu and North stations) and southern portions (1st and South stations) of the study area, and traversing across the central region. However, the majority of the feeding activity (80%) in the northern region occurred from mid-July through August. Little concentrated feeding activity was observed at one of the intermediate stations (Station 07). Whales in this region were typically observed to be feeding/traveling or simply traveling (Figure 13).

Table 8. Summary of trackline data gathered at six shore-based stations, Sakhalin Island, Russia.

Station	Tracks	Mean Duration (hr)	Range (hr)
North Station	23	2.04	0.2 - 7.0
Odoptu Station	30	1.79	0.1 - 6.6
Station 07	35	1.10	0.1 - 2.9
2nd Station	36	1.14	0.1 - 4.3
1st Station	60	1.06	0.1 - 6.2
South Station	65	0.84	0.1 - 5.0
Total	249	1.20	0.1 - 7.0

Table 9. Summary of trackline data gathered during June – September, 2007, Sakhalin Island, Russia.

Month	Tracks	Mean Duration (hr)	Range (hr)
June	25	0.87	0.1 - 2.2
July	32	0.86	0.1 - 2.7
August	116	1.30	0.1 - 7.0
September	76	1.29	0.1 - 6.2
Total	249	1.20	0.1 - 7.0

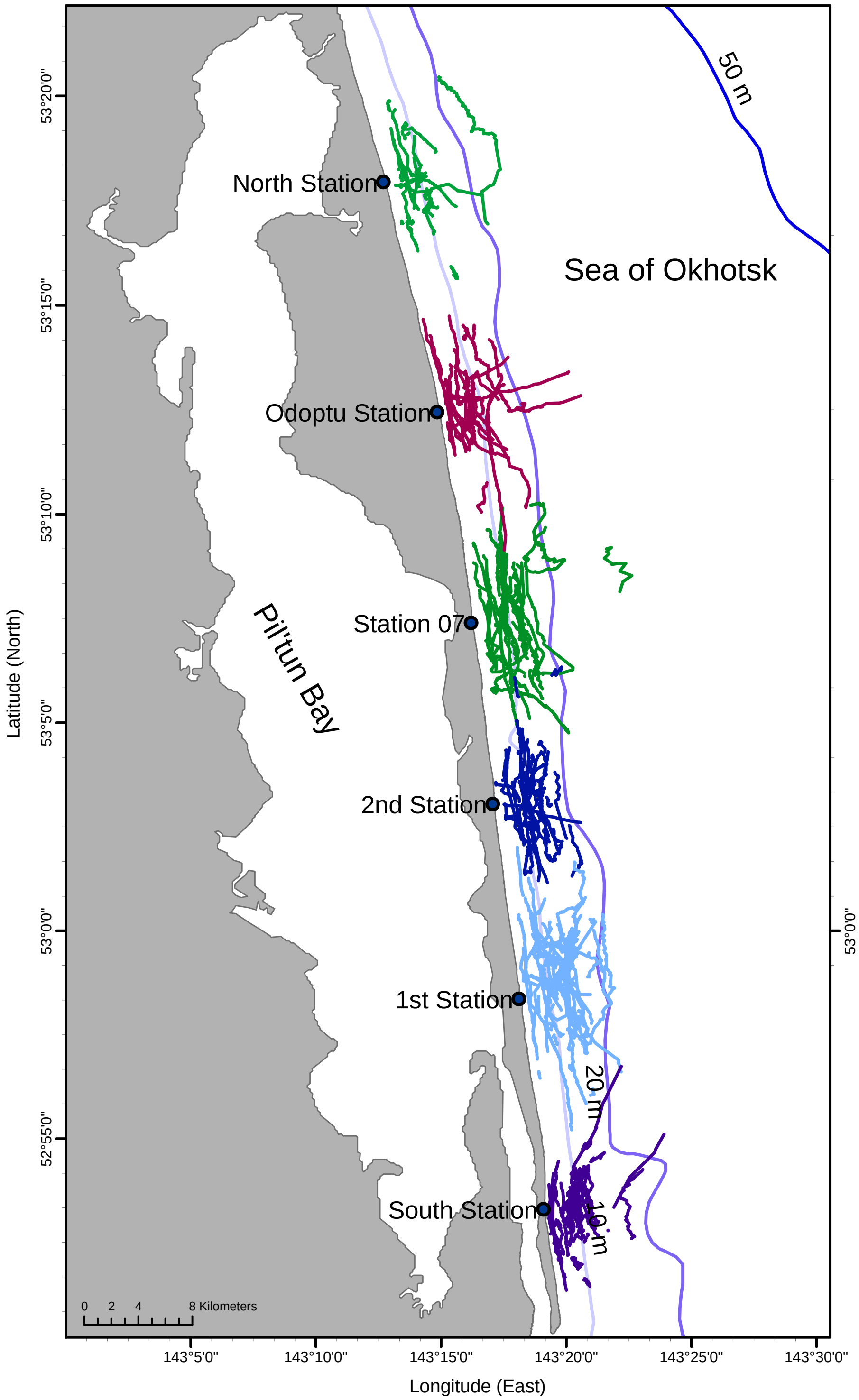

Figure 11. Tracklines of western gray whales measured from six shore-based stations during summer 2007, Sakhalin Island, Russia (N = 249).

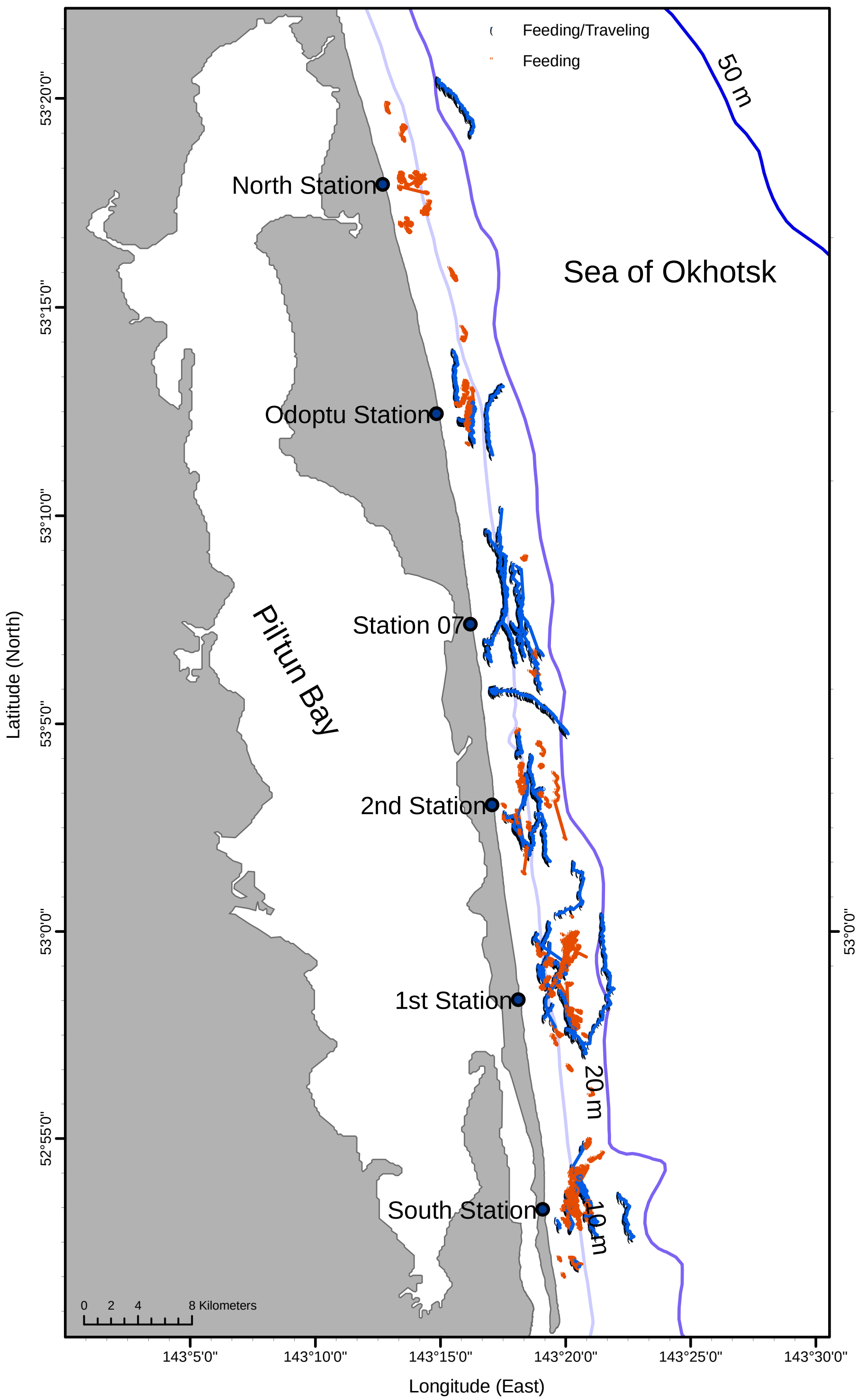

Figure 12. Feeding and Feeding/Traveling tracklines of western gray whales in the Piltun feeding area, Sakhalin Island, Russia.

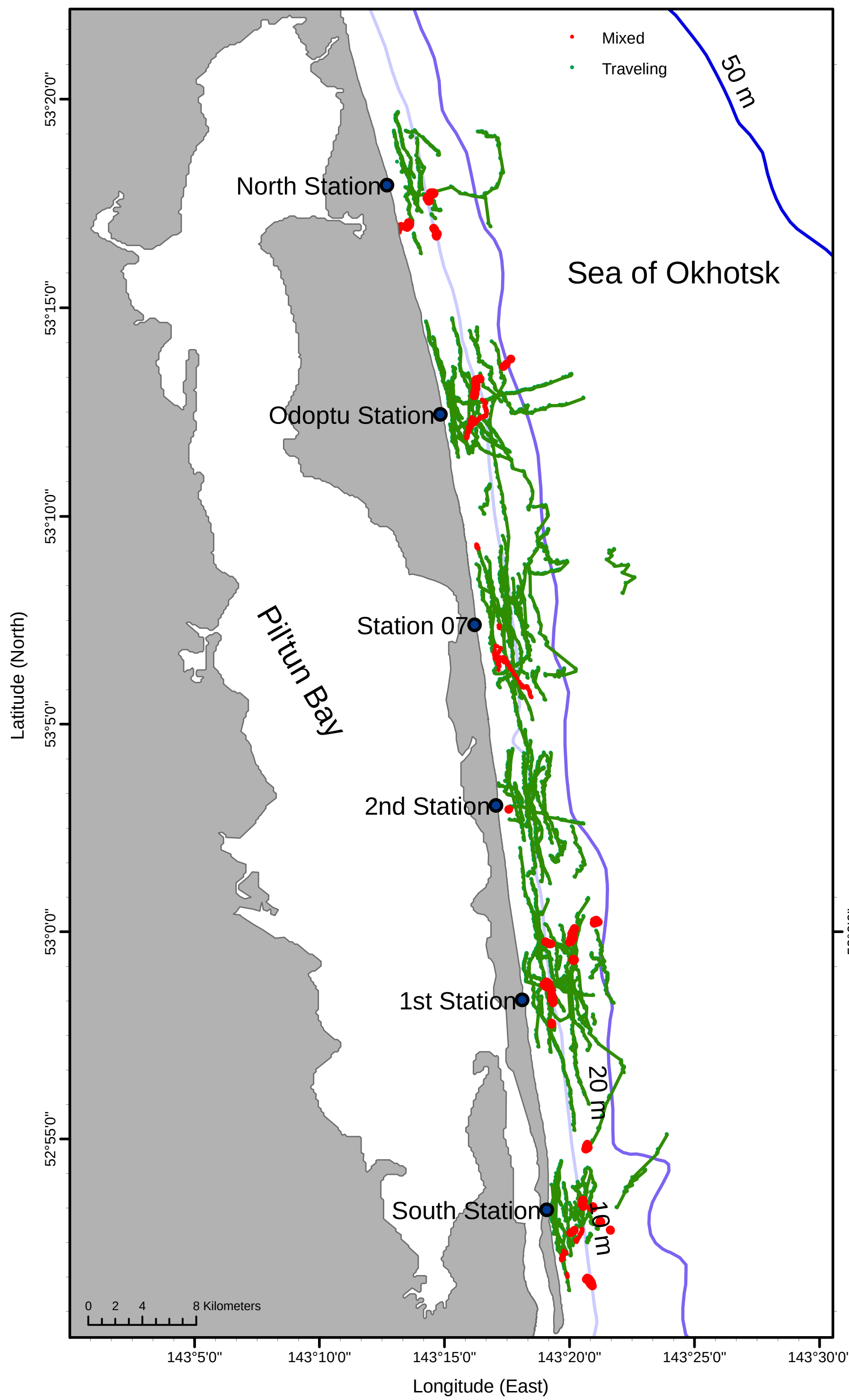

Figure 13. Traveling and mixed behavior tracklines of western gray whales in the Piltun feeding area, Sakhalin Island, Russia.

The analytical data set, consisting of only recognizable or single individuals, yielded 176 tracklines that were suitable for analysis (Table 10). On average, gray whales were observed moving 2.4 ± 1.76 SD km/h (Median = 1.9, Range = 0.2 - 7.3; Figure 14), accelerating 0.01 ± 0.229 km/h^2 (0.02,-0.82 – 1.08; Figure 15), reorienting 17.3 ± 14.52 °/min (11.8, 0.7 – 64.3; Figure 16), and ranging 36.2 ± 29.87 m/min (26.2, 1.2 – 121.4; Figure 19). The mean vector length and linearity index were 0.79 ± 0.236 (0.92, 0.06 – 1.00; Figure 17) and 0.81 ± 0.234 (0.94, 0.11 – 1.00; Figure 18), respectively. These directional indices indicate a more straight-line path movement as opposed to a non-directional feeding type behavior. This result is likely caused by having more traveling type tracklines in the dataset (see Behavior section below).

Table 10. Summary data for movement parameters of western gray whales during June-September 2007, Sakhalin Island, Russia.

N = 176	Mean	Median	Min	Max	SD
Leg Speed (km/h)	2.4	1.9	0.2	7.3	1.76
Reorientation Rate (°/min.)	17.3	11.8	0.7	64.3	14.52
Acceleration (km/h^2)	0.01	0.02	-0.82	1.08	0.229
Mean Vector Length	0.79	0.92	0.06	1.00	0.236
Linearity Index	0.81	0.94	0.11	1.00	0.234
Ranging Index (m/min.)	36.2	26.2	1.2	121.4	29.87
Distance from shore (km)	1.4	1.4	0.1	4.4	0.72

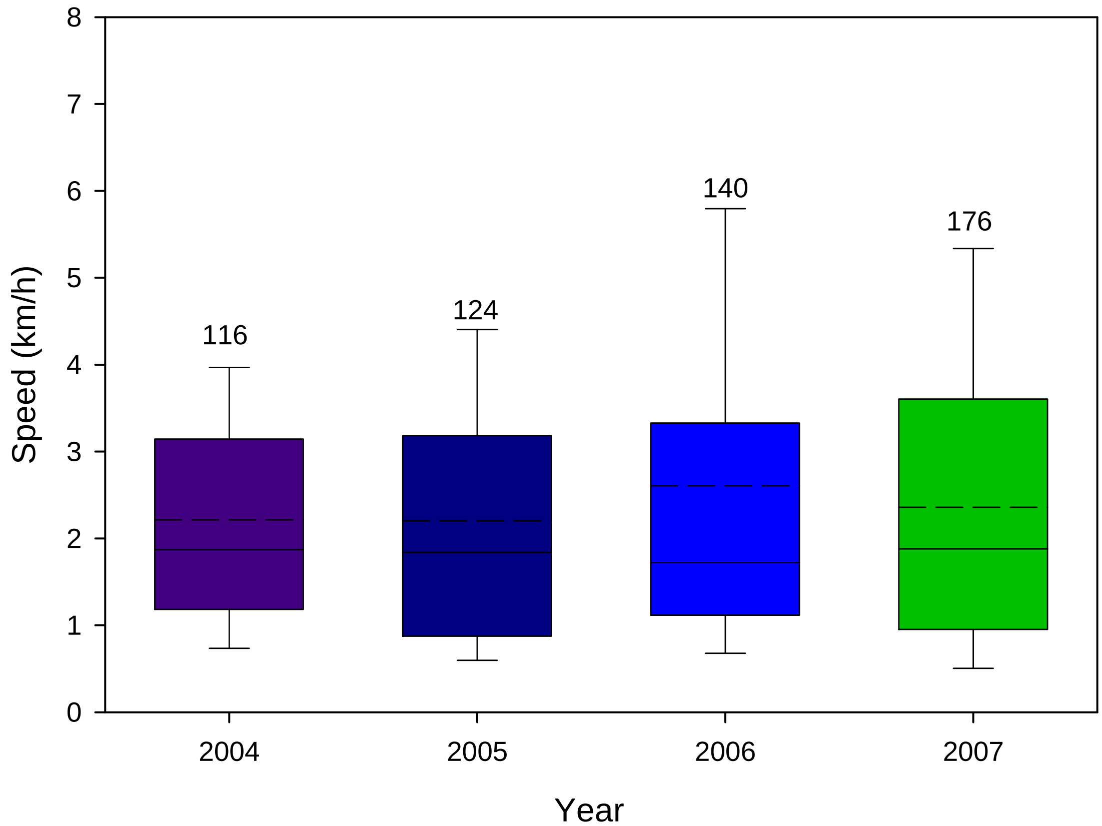

Figure 14. Leg Speed for all single or recognizable individual gray whales observed at six (2004-2005 and 2007) to nine (2006) shore-based stations, Sakhalin Island, Russia. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

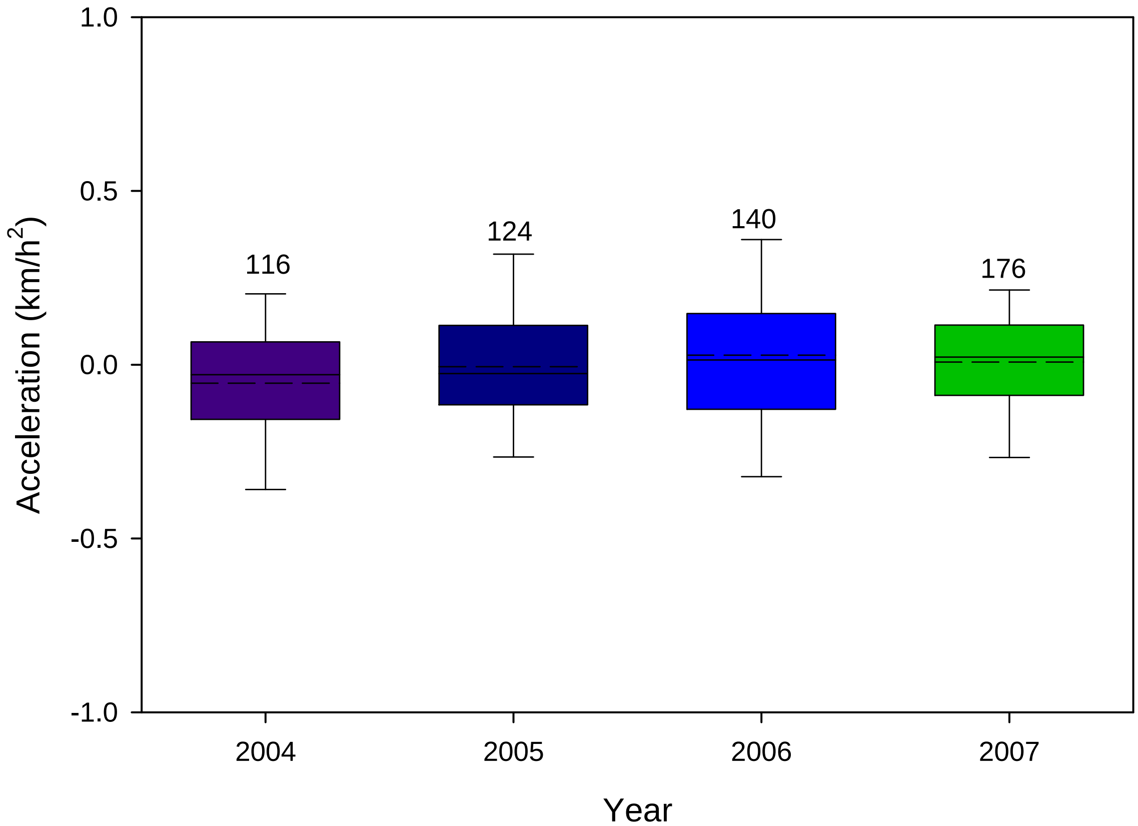

Figure 15. Acceleration for all single or recognizable individual gray whales observed at six (2004-2005 and 2007) to nine (2006) shore-based stations, Sakhalin Island, Russia. The negative values of acceleration represent deceleration. Display as in Figure 14.

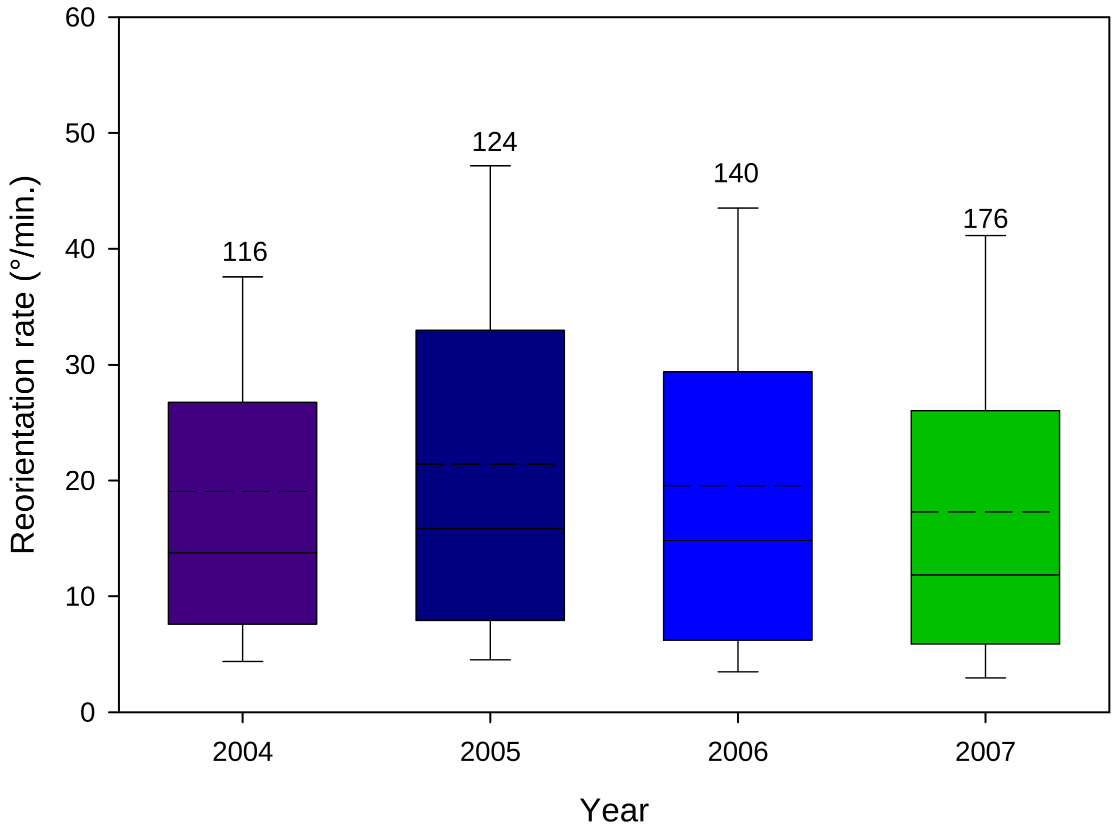

Figure 16. Reorientation rate for all single or recognizable individual gray whales observed at six (2004-2005 and 2007) to nine (2006) shore-based stations, Sakhalin Island, Russia. Display as in Figure 14.

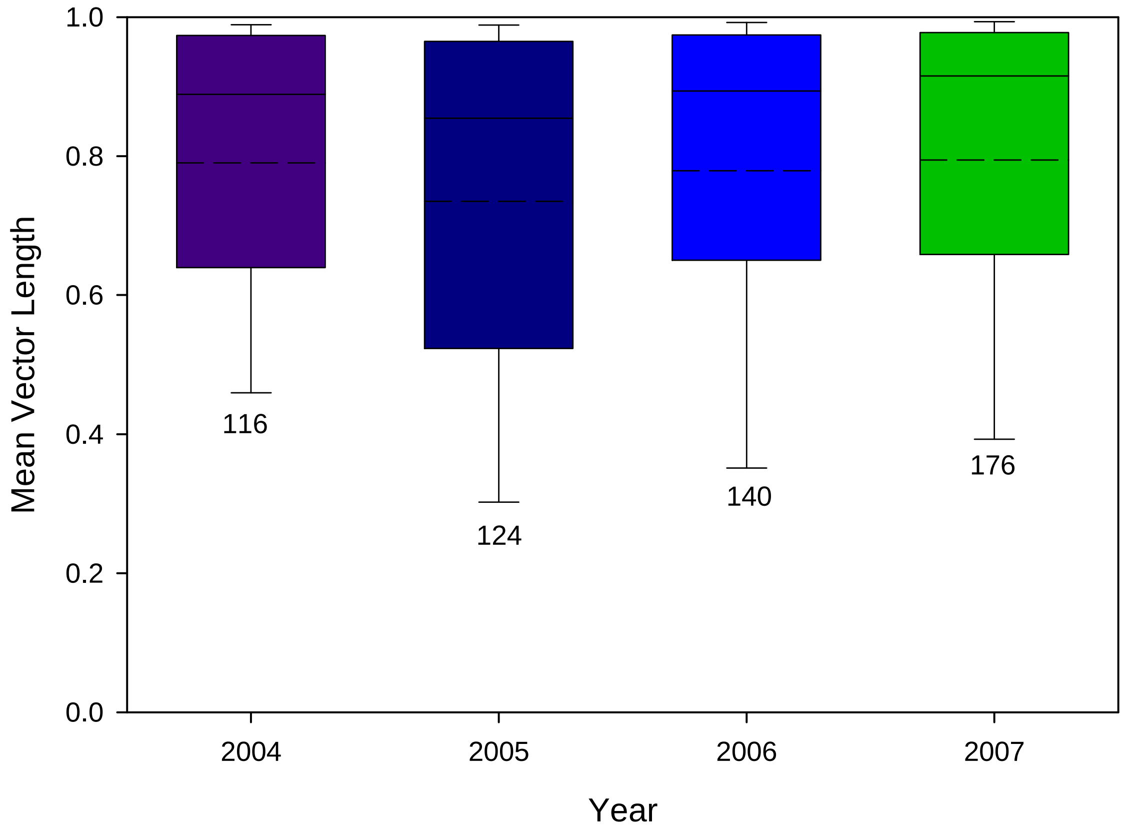

Figure 17. Mean vector length for all single or recognizable individual gray whales observed at six (2004-2005 and 2007) to nine (2006) shore-based stations, Sakhalin Island, Russia. Display as in Figure 14.

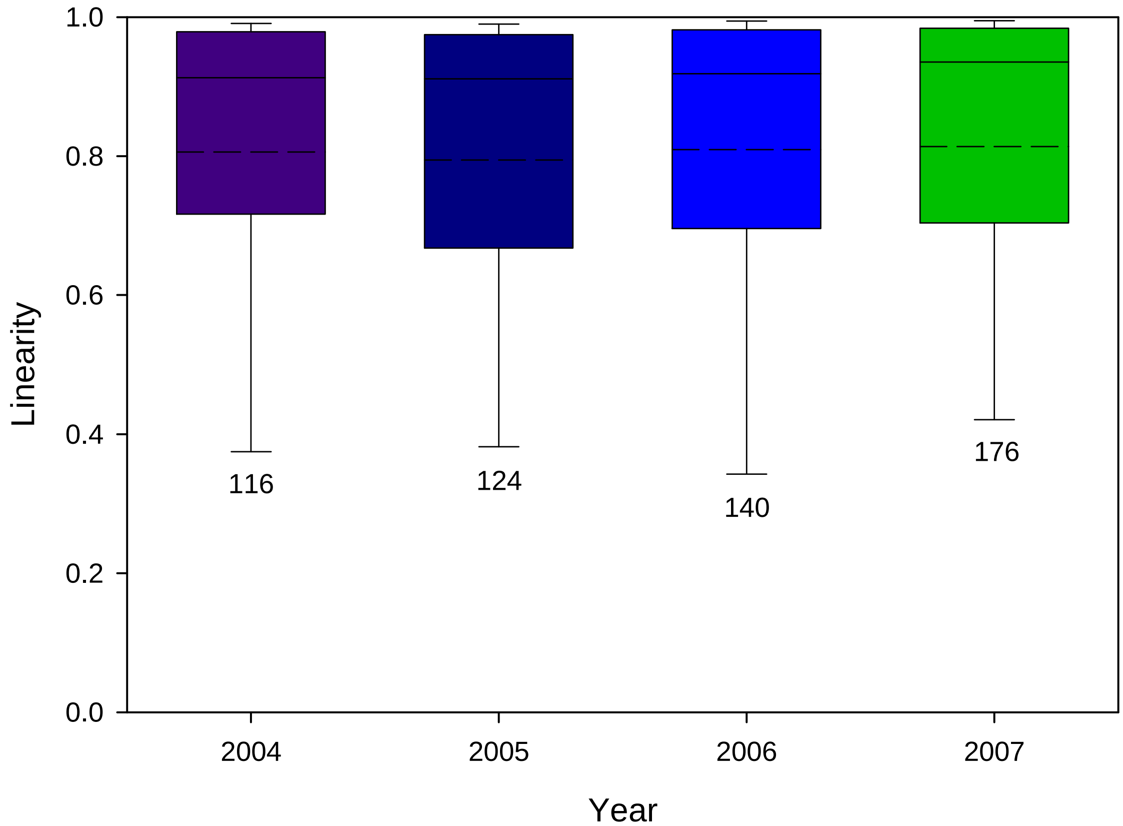

Figure 18. Linearity index for all single or recognizable individual gray whales observed at six (2004-2005 and 2007) to nine (2006) shore-based stations, Sakhalin Island, Russia. Display as in Figure 14.

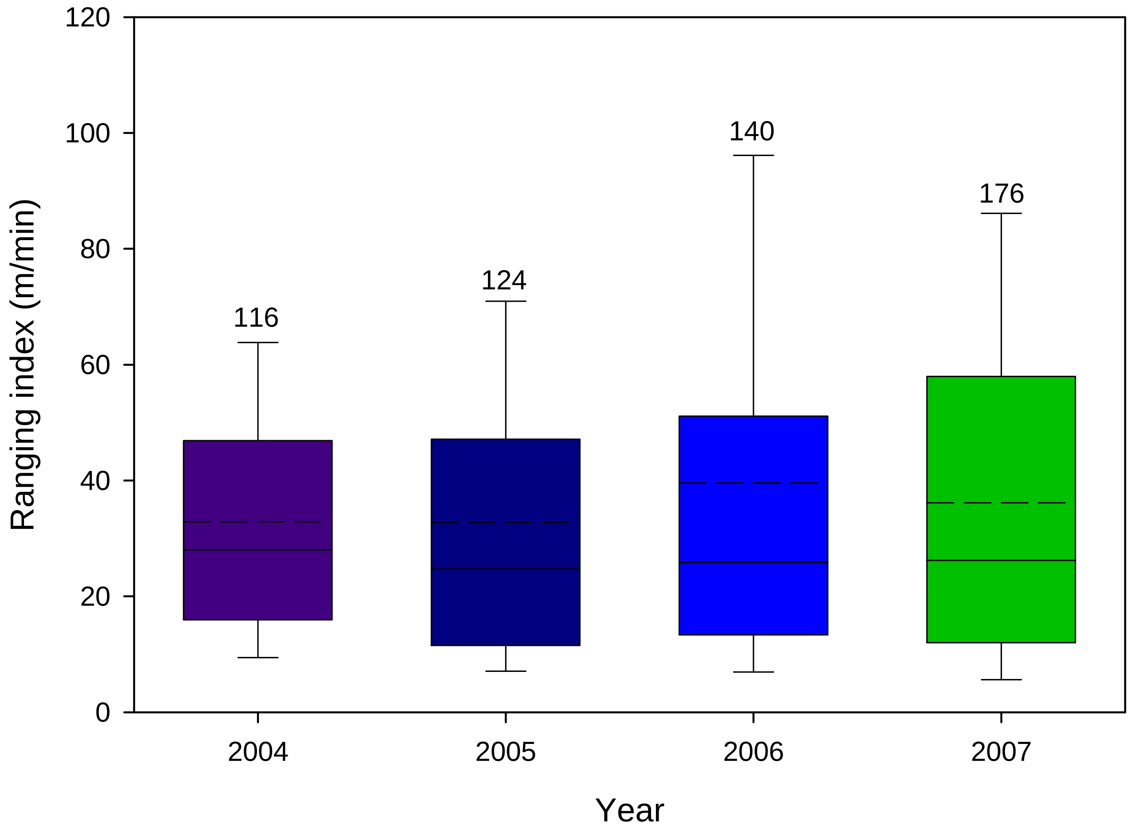

Figure 19. Ranging index for all single or recognizable individual gray whales observed at six (2004-2005 and 2007) to nine (2006) shore-based stations, Sakhalin Island, Russia. Display as in Figure 14.

Focal Follow Observations

Focal follow observations were conducted for a total of 139 hrs, on 105 individual gray whales from 21 June to 21 September 2007 (Table 11). The mean duration of a focal session lasted approximately 1.3 hours (range 0.18 – 7.03 hrs), and a total of 12,593 behavior events were recorded. Due to the seasonal increase in the number of whales and good weather later in the season, approximately 80 percent of the focal data were collected during the months of August and September (Table 12).

Table 11. Summary of focal behavior data gathered at six shore-based stations, Sakhalin Island, Russia.

Station	Focals	Mean Duration (hr)	Range (hr)
North Station	13	1.77	0.7 - 3.4
Odoptu Station	13	1.58	0.3 - 5.1
Station 07	18	1.11	0.2 - 2.4
2nd Station	21	1.22	0.2 - 2.2
1st Station	25	1.25	0.3 - 7.0
South Station	15	1.23	0.2 - 3.6
Total	105	1.32	0.2 - 7.0

Table 12. Summary of focal behavior data gathered during the months of June-September, 2007, Sakhalin Island, Russia.

Month	Focals	Mean Duration (hr)	Range (hr)
June	7	1.04	0.2 - 1.8
July	14	0.99	0.4 - 2.0
August	52	1.30	0.2 - 5.1
September	32	1.56	0.2 - 7.0
Total	105	1.32	0.2 - 7.0

The average duration between subsequent respirations/blows while individual gray whales were observed at the surface was 0.37 ± 0.177 SD minutes (Figure 20), with 4.93 ± 3.224 (Figure 21) blows per surfacing. The time that individuals were observed at the surface was 1.58 ± 1.970 (Figure 20) minutes, while individuals dove for 2.53 ± 0.940 (Figure 20) minutes. The dive-surface blow rate and the surface blow rate were 1.14 ± 0.331 (Figure 21) and 4.79 ± 1.955 (Figure 21) blows per minute, respectively (Table 13). The general respiration patterns were within the natural range of variability observed during 2004 - 2006.

Table 13. Summary statistics for surface-respiration-dive parameters of individual western gray whales, Sakhalin Island, Russia.

N = 105	Mean	Median	Min	Max	SD
Blow Interval (min.)	0.37	0.30	0.13	0.83	0.177
Blows/Surfacing	4.93	3.88	1.67	21.00	3.224
Surface Time (min.)	1.58	0.87	0.23	12.30	1.970
Dive Time (min.)	2.53	2.48	1.02	4.72	0.940
Surface Blow Rate	4.79	4.85	1.40	9.12	1.955
Dive-Surface Blow Rate	1.14	1.10	0.52	2.31	0.331

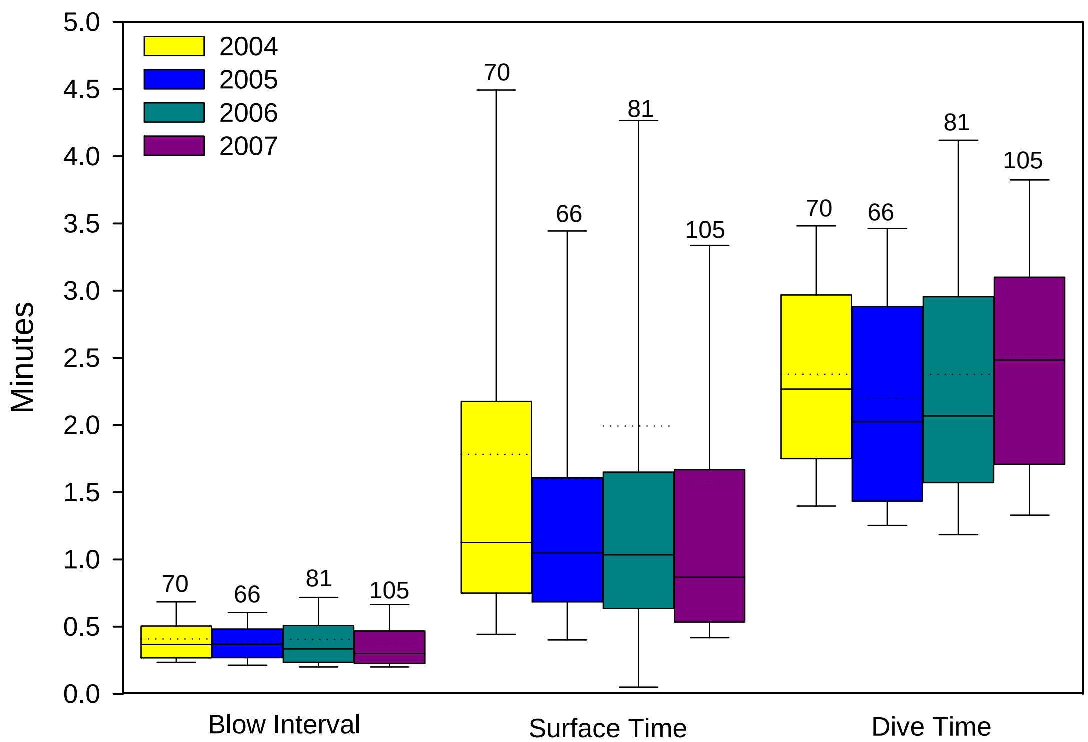

Figure 20. Blow interval, surface time, and dive time parameters of western gray whales, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

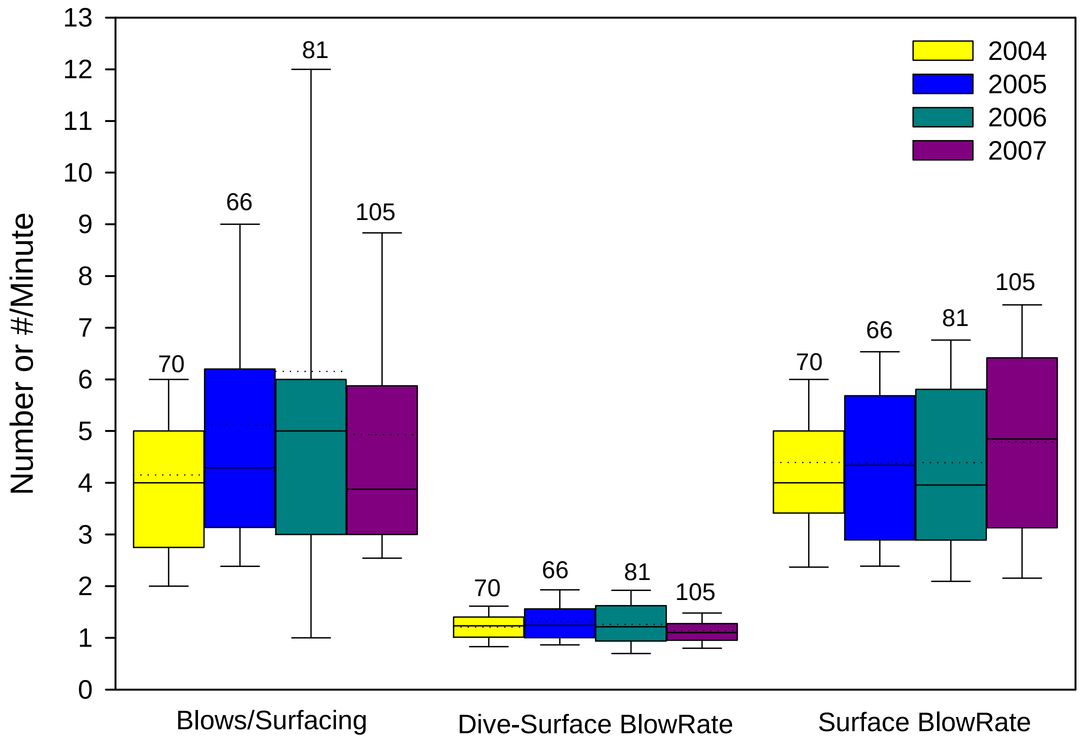

Figure 21. Number of blows per surfacing, dive-surface blow rate, and surface blow rate of western gray whales, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

Behavior

Three main western gray whale behavioral states were observed during the 2007 field season: 1) Feeding – whale(s) generally remain in one localized area with non-directional movement and consistent periods of diving; 2) Feeding/Traveling – whale(s) swim in one general direction at relatively slow speeds with consistent periods of diving; and 3) Traveling – whale(s) swim in one general direction and often remain at the surface without consistent dives. Other behavioral states were observed in 2007 such as milling, socializing, and resting, however, there were too few occurrences of these other behaviors to provide detailed analyses.

The gray whales' speeds ($F = 96.52$, $df = 2$, $P = <0.001$), reorientation rates (74.72, 2, <0.001), ranging indices (117.16, 2, <0.001), linearity (101.96, 2, <0.001) and mean vector length (89.60, 2, <0.001) were significantly different among the three primarily observed behavioral states. Respiration interval (22.97, 2, <0.001) was significantly lower during feeding than during traveling, and between feeding/traveling and traveling; but not between feeding/traveling and feeding. Gray whales spent significantly less time at the surface (10.33, 2, <0.01) with associated longer dive durations while feeding or feeding/traveling compared to traveling behavior. The surface-blow rate was also significantly different (21.58, 2, <0.01) between feeding and traveling whales. Acceleration, distance from shore, dive-surface blow rate, and number of blows per surfacing were all non-significantly different among the three behavioral states (Table 14, Figure 22 - Figure 34). The "displacement" of whales among the three behavioral states revealed significant differences with individuals displacing 0.06 km^2 (95% confidence interval: 0.04 – 0.10 km^2), 0.58 km^2 (0.29 - 0.79 km^2), and 3.04 km^2 (2.22 – 3.82 km^2) during feeding, feeding/traveling, and traveling behavioral states, respectively, after 20 steps (i.e., 30 minutes) (Figure 35). In comparison to previous years, feeding and feeding/traveling "displacement" behavior were within the same confidence intervals observed in 2002-2006. However, the displacement of whales traveling in 2006 and 2007 was significantly higher than confidence intervals of those observed in 2002-2005 (Figure 36).

Table 14. Movement and respiration variables of western gray whales during feeding, feeding/traveling, and traveling behavioral states Sakhalin Island, 2007. Post-hoc significance is denoted by F (Feeding), FT (Feeding/Traveling), and T (Traveling).

Variable	Feeding	Feeding/Traveling	Traveling	F (df = 2)	P	Post-hoc Significance
Speed (km/h)	0.9 ± 0.57 (56)	1.5 ± 0.92 (35)	3.4 ± 1.73 (115)	95.52	< 0.001	F-T, FT-T, FT-F
Reorientation rate (°/min)	29.6 ± 14.98 (56)	20.8 ± 12.18 (35)	8.9 ± 6.85 (115)	74.72	< 0.001	F-T, FT-T, FT-F
Linearity Index	0.6 ± 0.24 (56)	0.8 ± 0.17 (35)	0.9 ± 0.09 (115)	101.96	< 0.001	F-T, FT-T, FT-F
Mean vector length	0.6 ± 0.24 (56)	0.8 ± 0.20 (35)	0.9 ± 0.09 (115)	89.60	< 0.001	F-T, FT-T, FT-F
Ranging index (m/min)	11.6 ± 8.56 (56)	20.9 ± 14.77 (35)	54.2 ± 28.60 (115)	117.16	< 0.001	F-T, FT-T, FT-F
Distance to shore (km)	1.6 ± 0.55 (56)	1.6 ± 0.61 (35)	1.4 ± 0.70 (115)	3.61	0.029	
Acceleration (km/h^2)	0.0 ± 0.18 (56)	0.0 ± 0.17 (35)	0.0 ± 0.26 (115)	0.55	0.576	
Respiration Interval (min)	0.25 ± 0.091 (34)	0.32 ± 0.133 (28)	0.45 ± 0.162 (59)	22.97	< 0.001	F-T, FT-T
Surface Time (min)	0.73 ± 0.348 (34)	1.07 ± 0.764 (28)	1.86 ± 2.062 (59)	10.33	< 0.001	F-T, FT-T
Dive Time (min)	2.86 ± 0.816 (34)	2.87 ± 0.852 (28)	2.12 ± 0.823 (59)	14.21	< 0.001	F-T, FT-T
Dive-surface blow rate	1.09 ± 0.300 (34)	1.07 ± 0.241 (28)	1.14 ± 0.313 (59)	0.29	0.750	
Surface blow rate	6.12 ± 1.515 (34)	5.19 ± 1.644 (28)	3.91 ± 1.620 (59)	21.58	< 0.001	F-T, FT-T
Number Blows/Surface	3.94 ± 1.241 (34)	4.25 ± 1.617 (28)	4.97 ± 3.232 (59)	1.08	0.344	

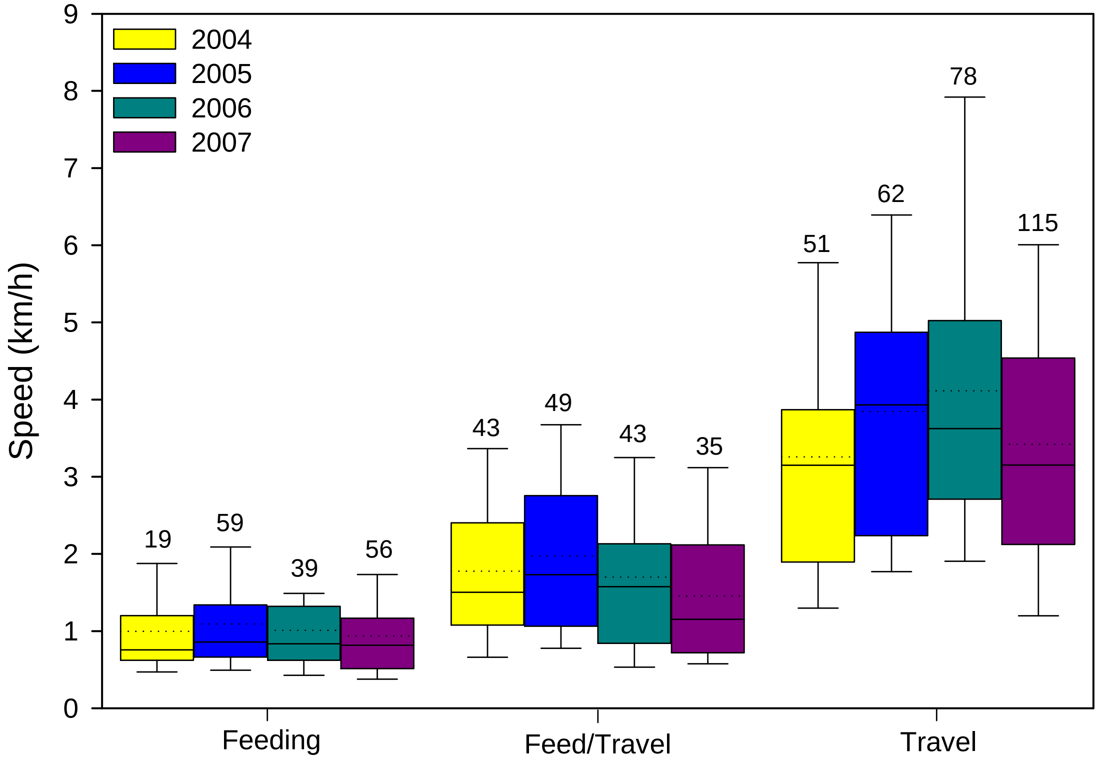

Figure 22. Speed of western gray whales during three behavioral states, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

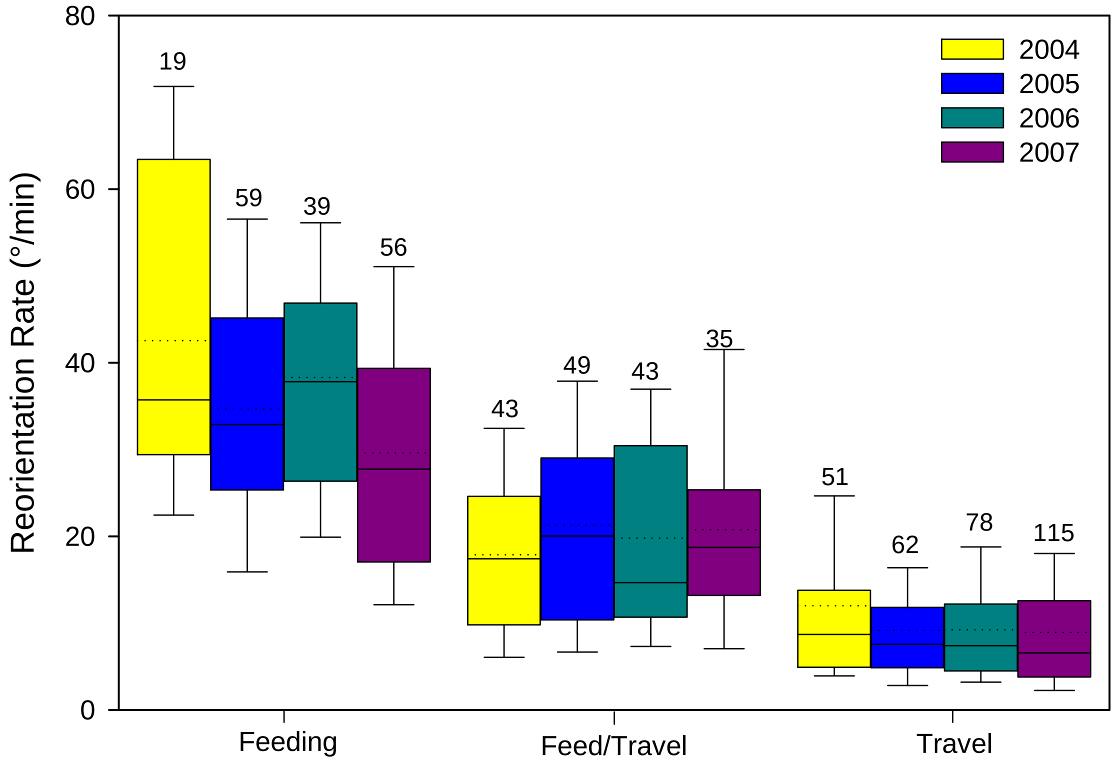

Figure 23. Reorientation rate of western gray whales during three behavioral states, Sakhalin Island, 2004-2007. Display as in Figure 14.

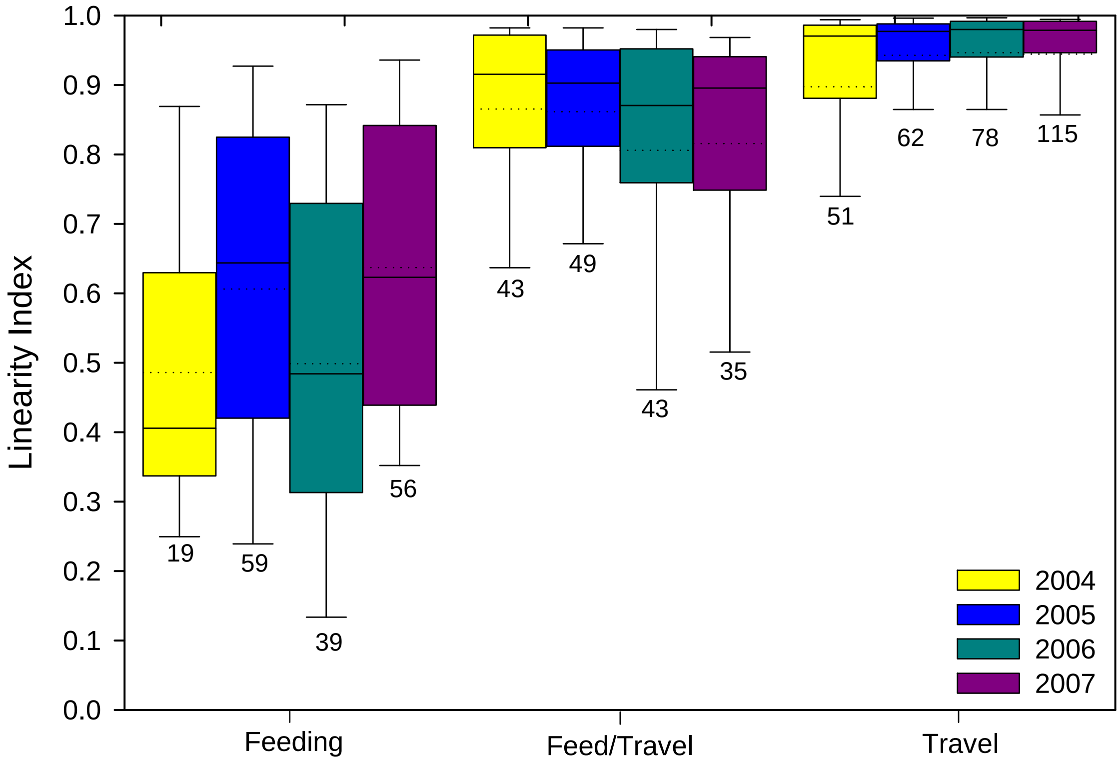

Figure 24. Linearity index of western gray whales during three behavioral states, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

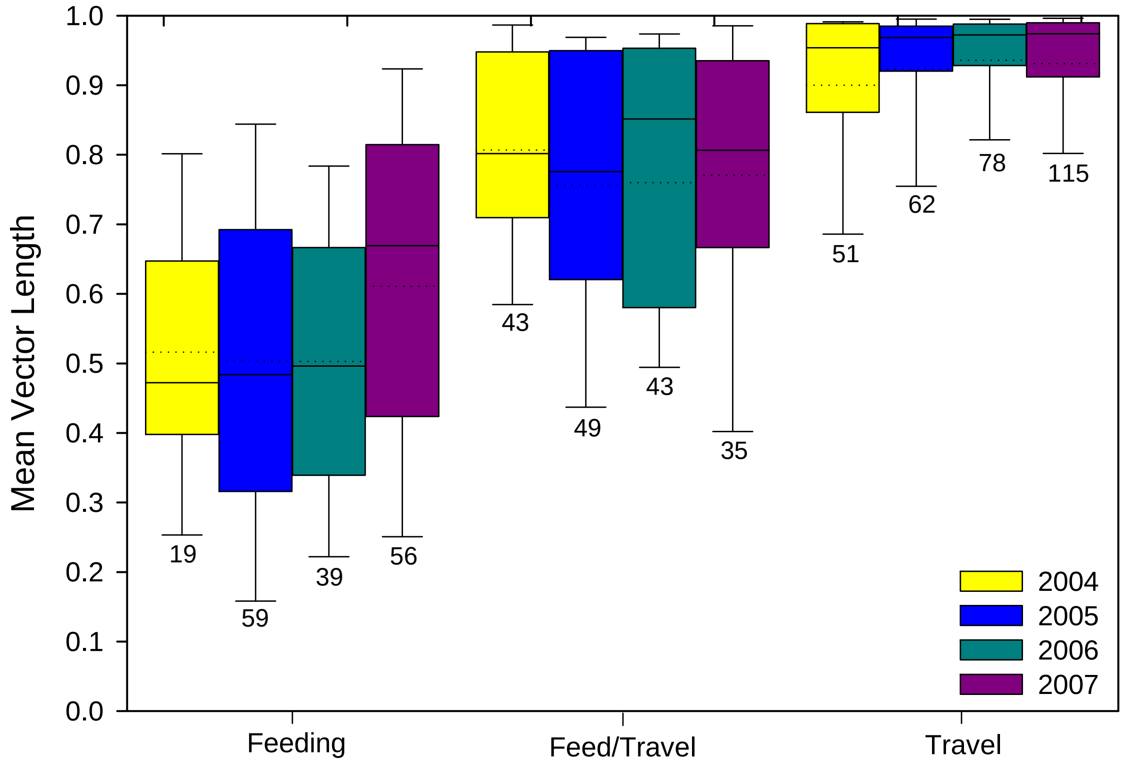

Figure 25. Mean vector length of western gray whales during three behavioral states, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

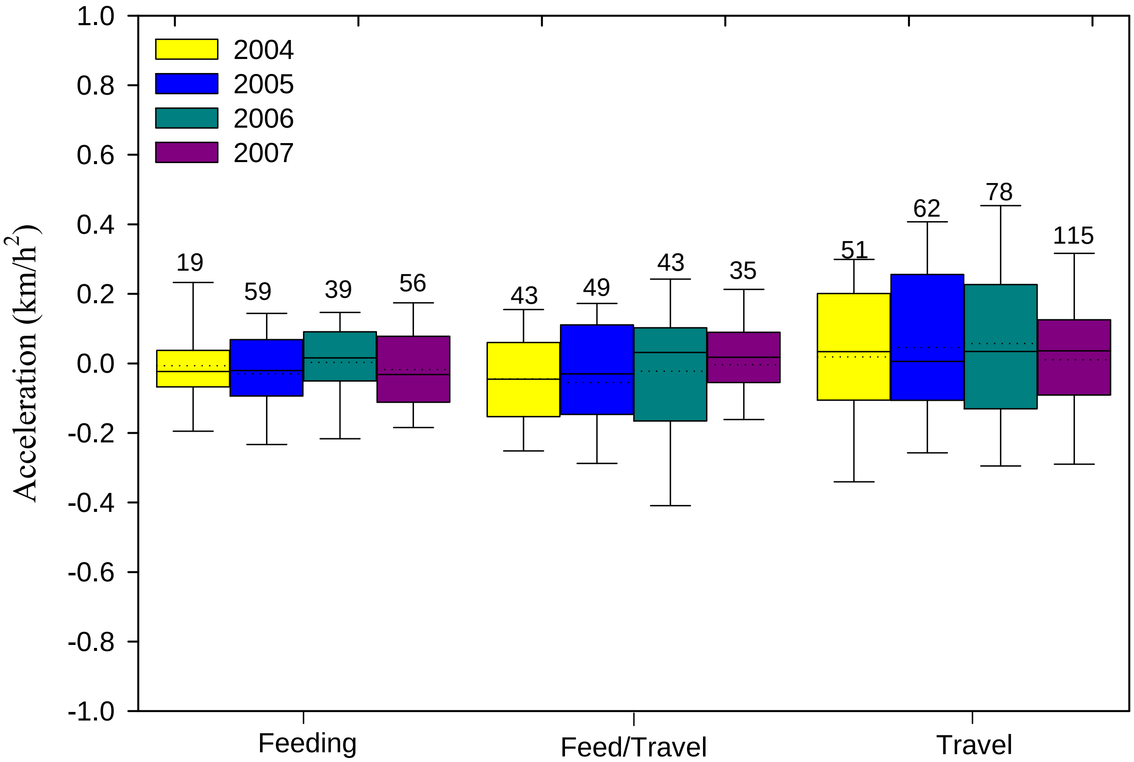

Figure 26. Acceleration of western gray whales during three behavioral states, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

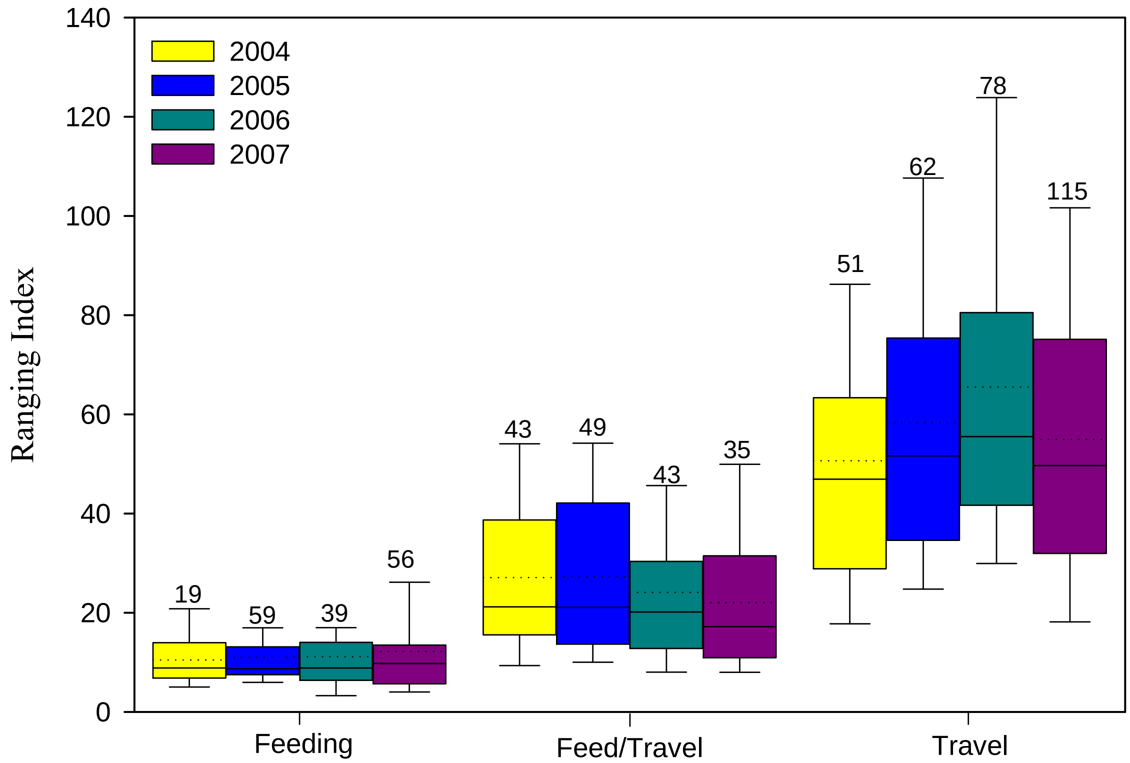

Figure 27. Ranging index of western gray whales during three behavioral states, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

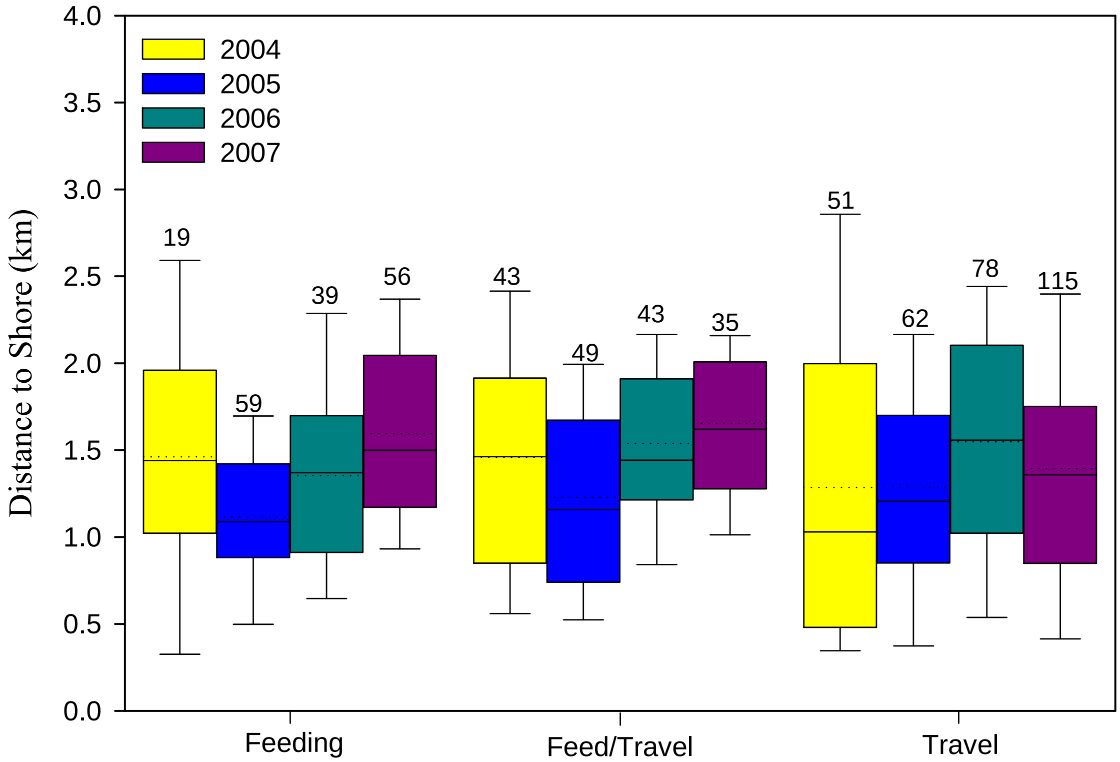

Figure 28. Distance to shore of western gray whales during three behavioral states, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

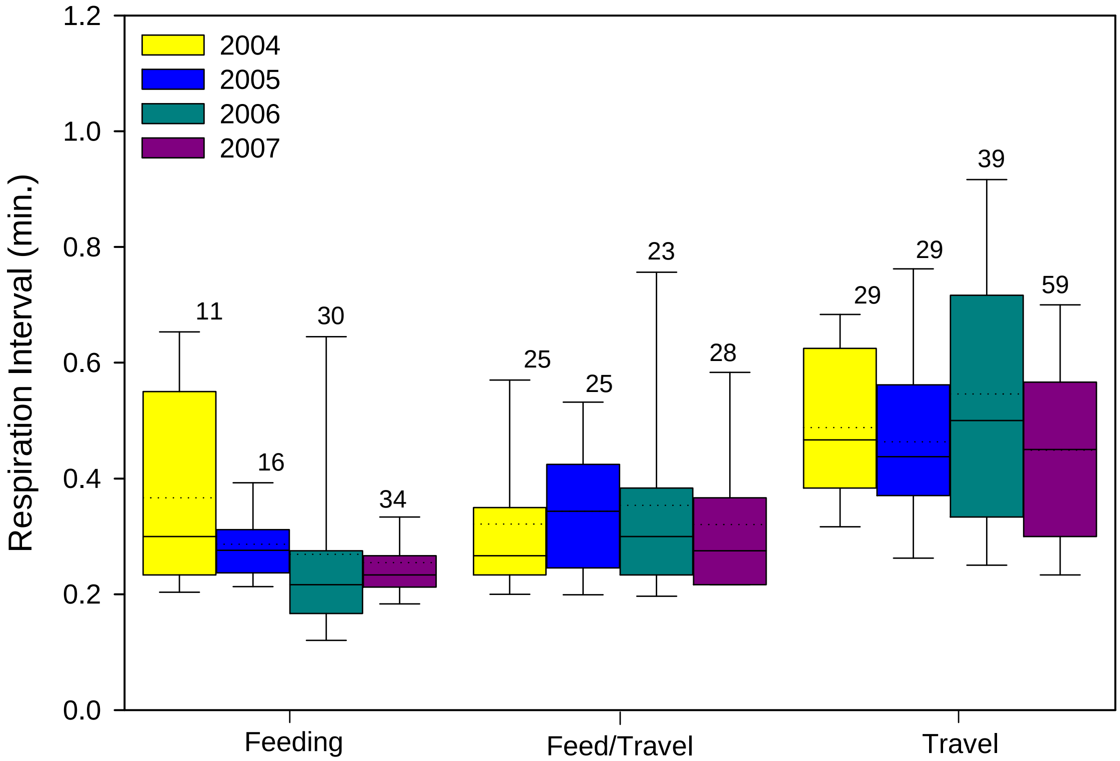

Figure 29. Respiration interval of western gray whales during three behavioral states, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

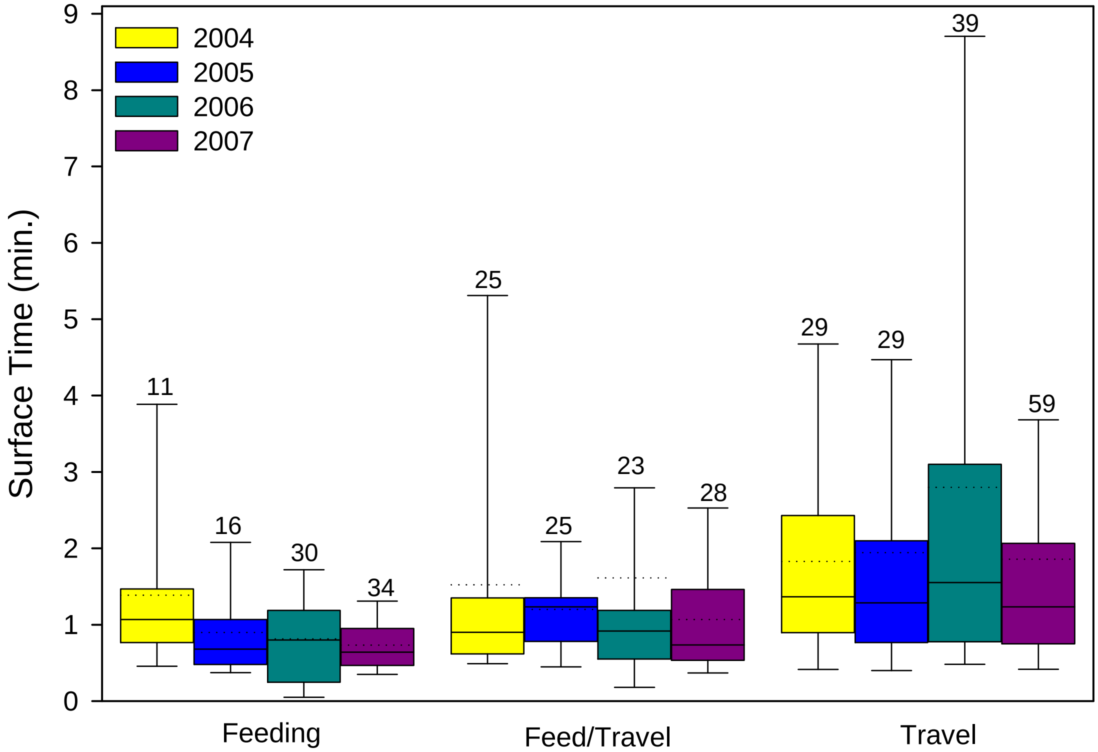

Figure 30. Surface time of western gray whales during three behavioral states, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

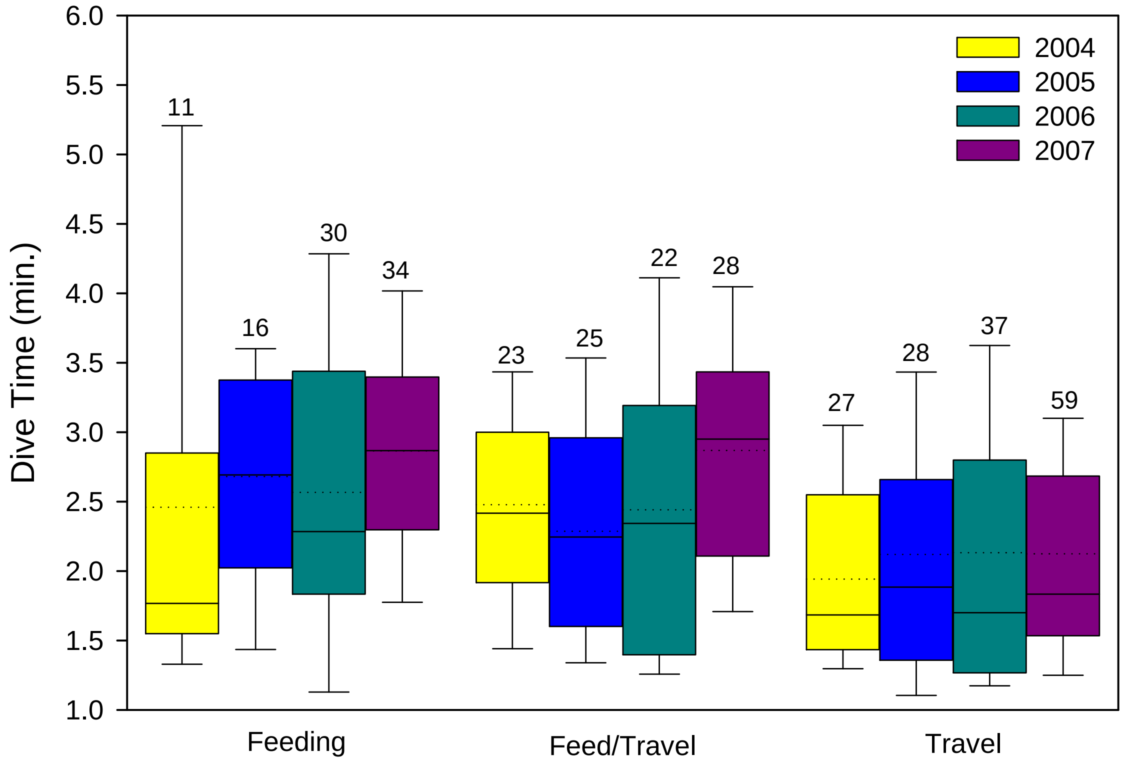

Figure 31. Dive time of western gray whales during three behavioral states, Sakhalin Island, Russia. Display as in Figure 14.

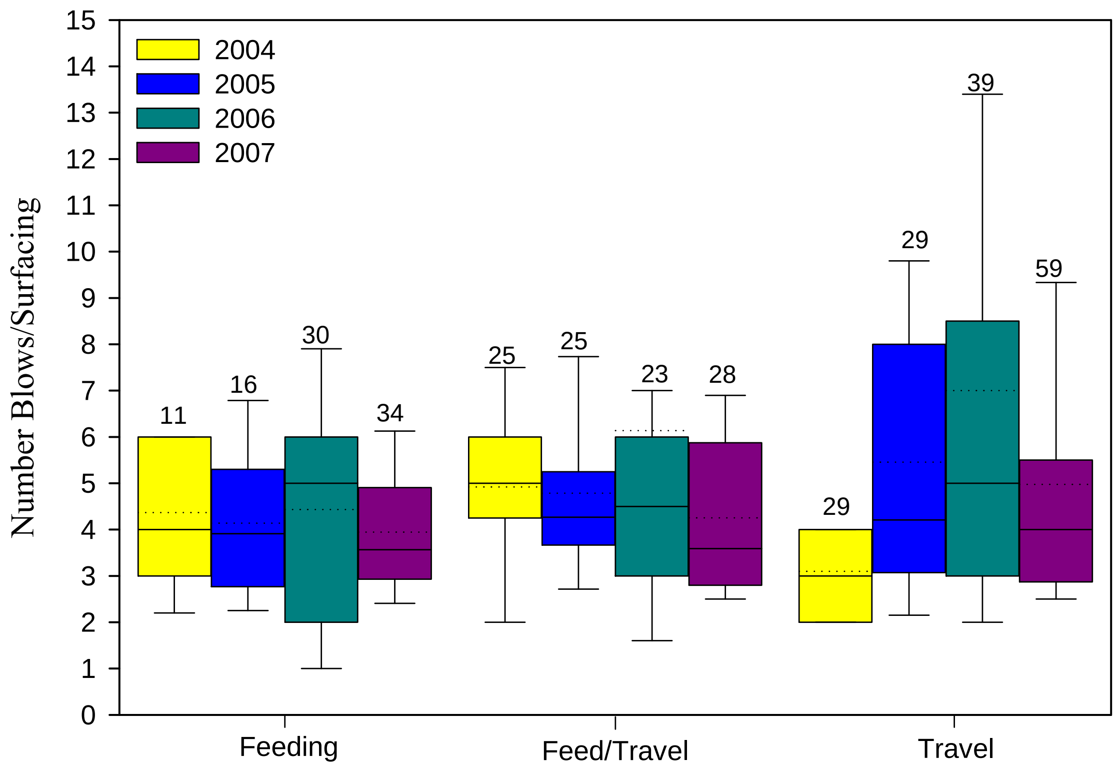

Figure 32. Number of blows per surfacing of western gray whales during three behavioral states, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

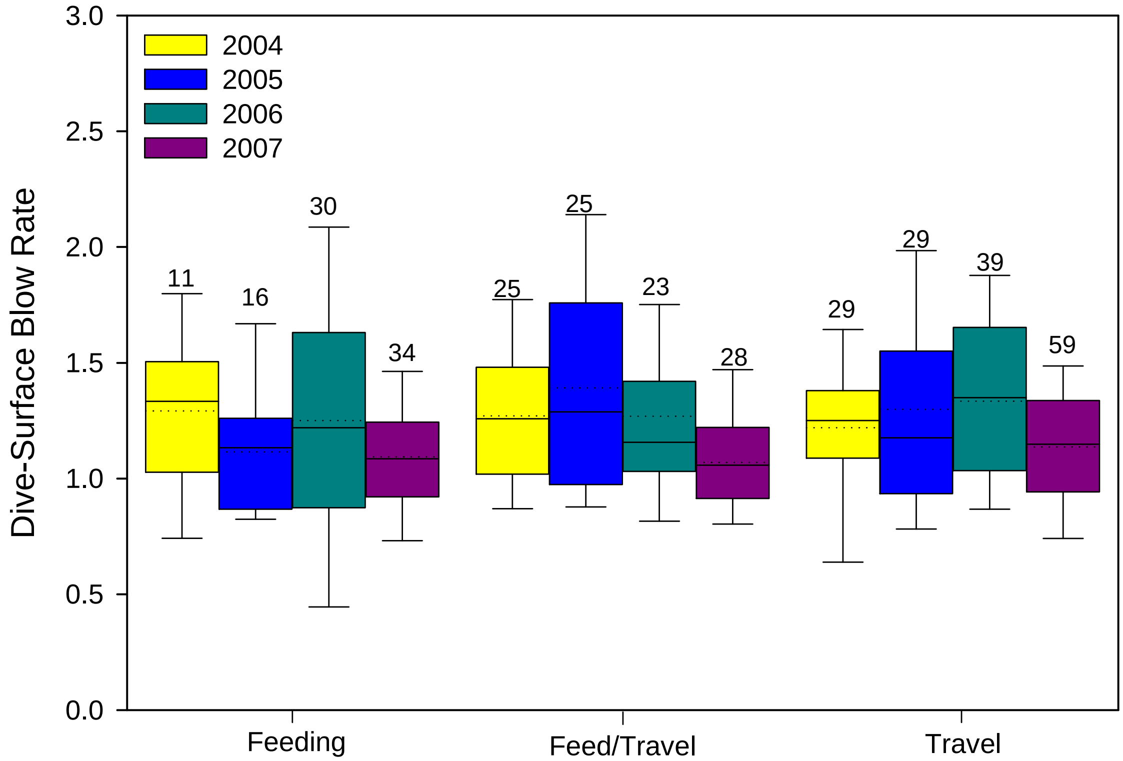

Figure 33. Dive-surface blow rate of western gray whales during three behavioral states, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

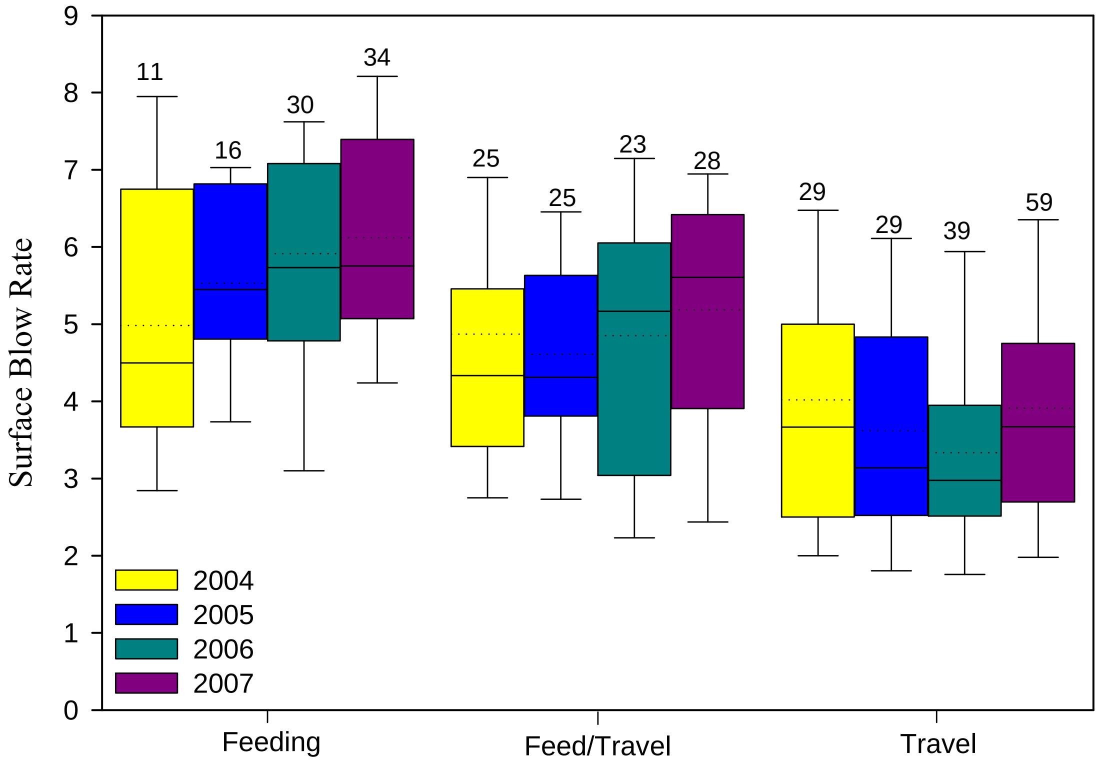

Figure 34. Surface blow rate of western gray whales during three behavioral states, Sakhalin Island, Russia, 2004-2007. Display as in Figure 14.

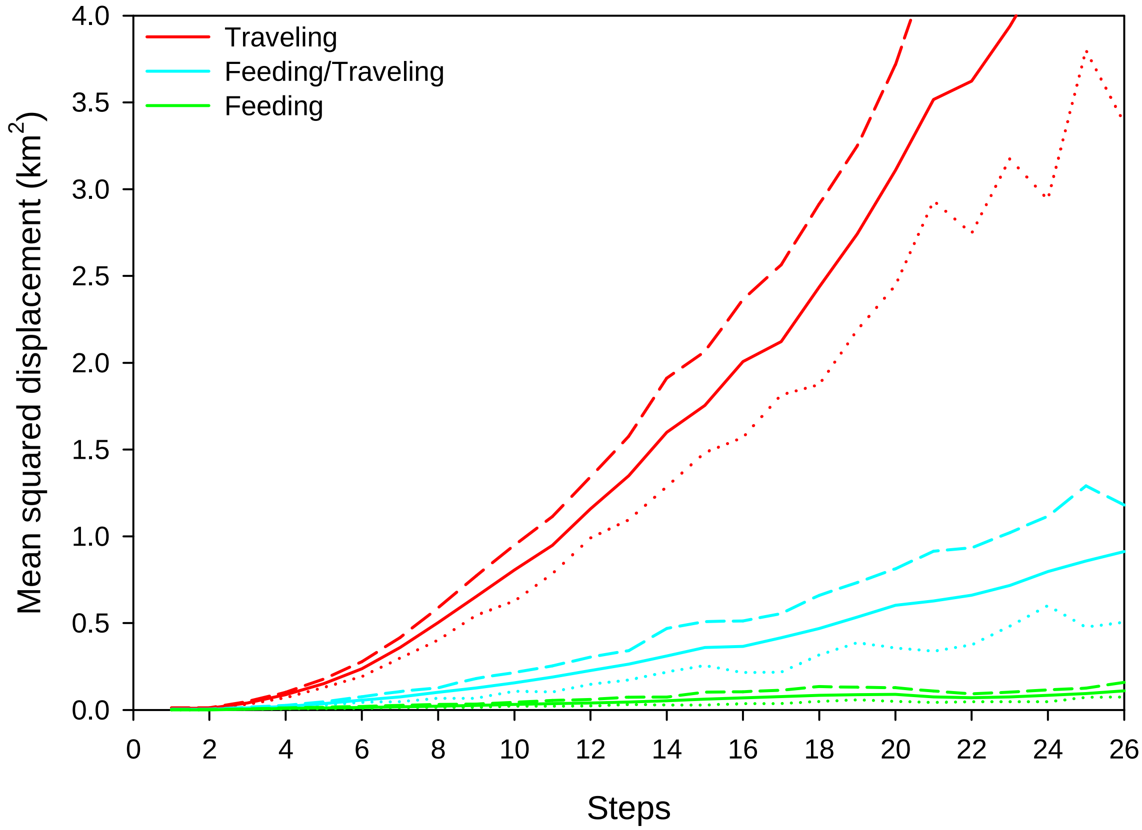

Figure 35. Mean squared displacement of western gray whales during three behavioral states, Sakhalin Island, Russia, 2007. The upper and lower 95% confidence intervals are represented by dashed and dotted lines, respectively.

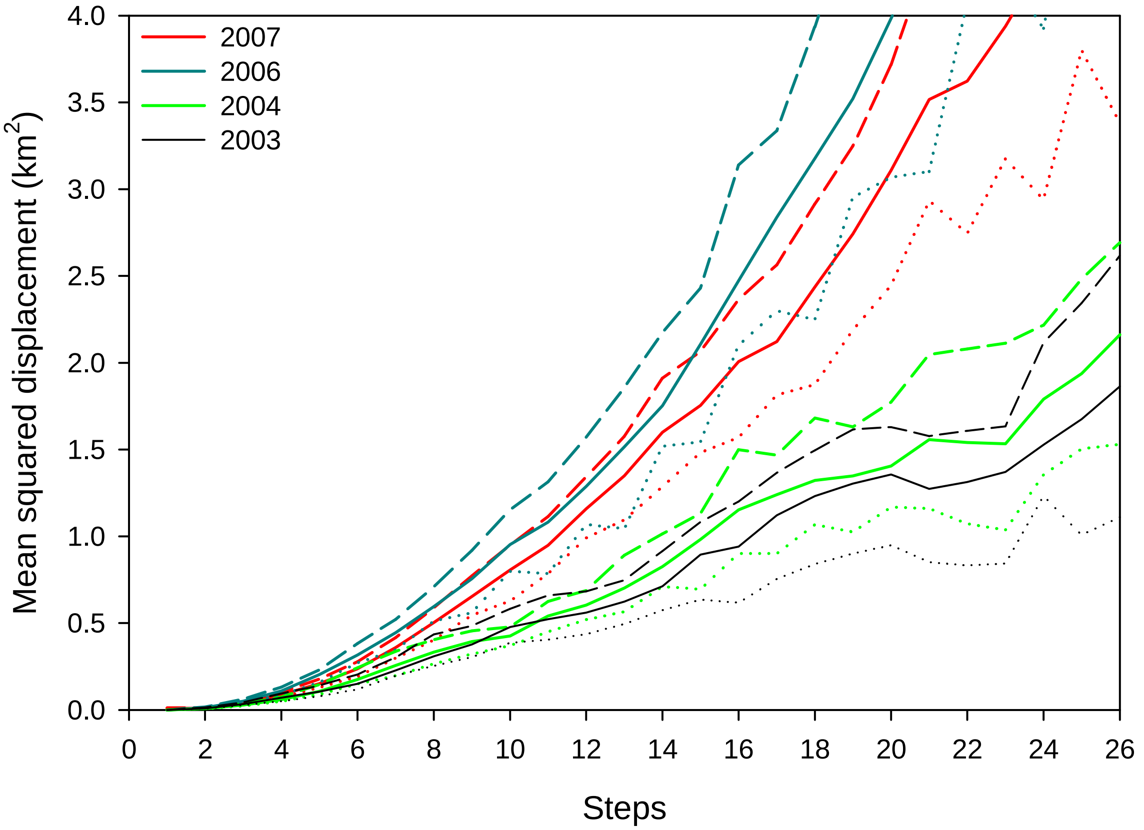

Figure 36. Displacement of western gray whales while exhibiting traveling behavior during 2003-2004 and 2006-2007.

Social Activity – Observations of social activity typically occurs towards the late end of August through September. During each of these occasions, the animals' behavior and movement activities were similar. There were periods of surface-activity with flukes, pectorals, heads, and other parts of an animal's body above the surface of the water, and periods of apparent "chasing", where one animal rapidly moved away from the group and the rest of the social group then "chase" this animal. Once the other individuals "caught up" with the individual that moved away, the surface activity continued and similar active events were repeated. In 2004-2006, relatively few occasions of social activity (4 in 2004, 3 in 2005, and 2 in 2006) were observed. In 2007, a total of six occasions of social activity were observed. The timing of these observations range from 30 August to 20 September. Social activities were observed from all stations, except North Station. Three occurrences were in the morning, and three were in the afternoon. Each social event is briefly described below:

- 30 August (Station 07). A group of five individuals was tracked nearshore (0.7 km) in the morning and continued to socialize further from shore (2 km) for two hours.
- 1 September (South Station). Two to four whales, sighted at distance of 400 m from the shore, were surface-active and breaching, but no apparent “chasing” type behavior. The group was tracked for only 15 minutes, and chasing could have occurred later.
- 7 September (2nd Station). Four individuals were tracked for 50 minutes traveling and socializing at 1.7 – 2 km from the shore
- 14 September (Odoptu Station). A group of two animals was tracked for one hour at 1 – 1.5 km from the shore. Both social and traveling behaviors were observed during this period. Towards the end of the observation, one individual continued traveling north, and the second individual joined another group of two whales that were feeding.
- 20 September (1st Station). Four gray whales were tracked for about five hours at 2.7 – 3.7 km from the shore. Social activity was recorded at the beginning of tracking and the majority of the time the whales were observed feeding.
- 21 September (2nd Station). At least four gray whales were observed for 40 minutes socializing at a distance of 3 km from the shore.

Killer Whales

Nine groups of killer whales were observed in the study area during the 2007 field season. One group of killer whales was observed on the evening of 9 July from the camp site location ~500 m north of 1st Station. The group consisted of one male, three other individuals of unknown sex, and one calf. The pod was traveling south approximately 0.3 – 0.5 km from the shore.

On 4 August, one killer whale was observed at Odoptu Station (3.3 km from the shore) during a scan. The minimal distance between killer whale and gray whales sighted within the same scan was 1 km. The killer whaler approached within 1 km of a group of three gray whales (including a mom-calf pair) that was traveling southward. Later in the same day, a group of five killer whales was sighted at North Station (4.2 km from the shore) during the scan with a minimal distance to gray whales of 3.1 km. The next killer whale sighting occurred on 6 August at 2nd Station. A single individual was sighted during three consecutive scan sessions (1.5, 1.3, and 1.7 km from the shore), with the closest recorded approach to gray whales of 0.5, 1.4, 1.2 km, respectively. Another group of five killer whales (including a calf) was tracked for 30 minutes on 28 August at North Station (traveling south at 1.8 – 2.4 km from the shore). It approached within 0.5 km from a group of 2-3 gray whales that were feeding in the area, and 1.2 km from a traveling group of 5-7 gray whales. The same group of killer whales was observed one hour later at Odoptu Station 2.8 km from the shore. The minimal distance to gray whales was 3.3 km. On 9 September, two groups of killer whales were sighted. A single killer whale sighting was recorded during a scan at South Station (2.2 km from the shore). The minimal distance between killer whale and gray whales sighted within the same scan was 0.7 km. Another group of four individuals (including a calf) was tracked for 20 minutes at 1st Station and later for 40 minutes at South Station. The group was traveling 0.7 – 0.3 km from the shore. The closest approach to a gray whale (single individuals traveling in the area) was 1.7 at 1st Station and 1.6 km at South Station. Five killer whales were sighted on 10 September at Station 07 during a scan (2.2 km from the shore). Only one scan was conducted that day, and no gray whales were observed in the area. The last sighting of killer whales (group size of six individuals) was on 18 September at 2nd Station (2.5 km from the shore). No gray whales were observed within the area.

For each of the above observations, no obvious changes were observed in gray whale behavior related to the presence of the killer whales.

DISCUSSION

Since 2001, western gray whale behavioral observations have been conducted in the nearshore Piltun feeding area during each summer-fall period. The first year of observations resulted in initial descriptions of western gray whale behavior as well as assessing the potential influences of a seismic survey that occurred in close proximity to the nearshore feeding habitat (Würsig *et al.* 2002, Gailey *et al.* 2007b). With the exception of a seismic survey late in the 2004 field season, the 2002-2004 field seasons were relatively free of anthropogenic activity, and these years provided "baseline" information to better understand these whales in an area where feeding is the primary activity. With some understanding of the amount of “natural” variability that can exist, this study has continued to examine indicators of behavioral response that could potentially be affecting the animals’ ability to feed. In 2005, this knowledge assisted in understanding potential impacts of nearshore research vessels and construction activity related to the placement of a concrete gravity based structure (Gailey *et al.* 2007c). In 2006 and 2007, construction activity related to pipeline placement and top-sides installation at the PA-B site occurred in the vicinity of the Piltun feeding area. Analyses are currently being conducted to examine potential distribution and behavioral disturbance affects these activities may have had. In this report, we compare 2007 behavioral observations to the results of previous studies.

Gray whales have consistently utilized the Piltun feeding habitat and offshore feeding grounds throughout the past eight years of observations. Such site fidelity to these relatively small geographic feeding areas (Weller *et al.* 1999) is likely due to high concentrations of prey (Fedeev 2008). Similar fidelity to feeding areas has also been noted for gray whales of the eastern population (for example, Pike 1962, Hatler and Darling 1974, Würsig *et al.* 1986, Dunham and Duffus 2002). Although there has been consistent use of the region, distribution and abundance patterns within the Piltun and offshore feeding area have considerable amount of seasonal (within the feeding season), annual, and, sometimes, daily variability. In 2001, considerably more whales occurred at the southern-most station, Mt. Kiwi, than at the four other more northerly stations. However, in 2002 - 2004, it was the more northerly stations that had substantially more whales than any other station. The northerly-occurring trend continued for three years, but in the past three years there has been another trend of increasing number of whales observed towards the southern portion of the study area (South station) that is near the mouth of Piltun Bay. During the 2007 field season, there was a notable decrease in abundance of western gray whales in the northern areas (Figure 37, Table 15). It has been suggested that changes in prey types and concentrations have led to these annual shifts in gray whale abundance and distribution (Fadeev 2008). Other regions, such as the central part of the study area where whales were observed mainly traversing, have been relatively consistent in the number of whales over the years.

As in previous years, there can be great daily variability in the numbers of whales and pods. For example, initial scans at 08:30 on 9 September 2007 at South station recorded a total of 16 whales utilizing the habitat. These whales remained in the area until mid-day when whales were apparently moving out of the area. By 16:30, only three whales remained. Gray whales are highly mobile animals, and can traverse several observation areas within one day. Despite some degree of daily variability, there are consistent trends (Table 15).

Within feeding season shifts in gray whale abundance and distribution have occurred. In 2006, for instance, observations were conducted south of the present study area to monitor pipeline dredging activity. Western gray whale abundance in this region was suspected to be low based on previous surveys (Vladimirov 2005, 2006). However, later in the feeding season (August-September) the abundance of whales increased significantly. In 2007, the distribution of gray whales was more uniform in the Piltun feeding area during August. In September, there appeared to be an almost total abandonment of the northern region and higher concentrations of whales in the southern portion of the study area (Table 6; Figure 10).

Patterns of gray whale abundance and distribution have also changed in relation to their use of the two known feeding areas (Piltun and Offshore) off the northeast coast of Sakhalin Island (Vladimirov 2008). In 2004-2006, more whales utilized the Piltun feeding habitat compared to 2001-2003 (Table 15; Figure 37). During these years, the increase in utilization of the Piltun feeding area corresponded to a decrease in utilization of the offshore feeding area (Vladimirov 2005, 2006, 2007). The relative abundance of western gray whales observed in this study found that whales occurred in similar numbers compared to those observed in 2004-2006. However, Vladimirov (2008) found an estimated 20% reduction of western gray whales utilizing the entire Piltun feeding habitat. These two studies cover two different observation ranges. Vladimirov (2008) observe the relative number of whales at a larger spatial scale that is approximately twice that observed in this study. The combination of these results between these two studies indicate that western gray whales were utilizing some areas within the Piltun feeding grounds to a greater and lesser extent than previous field season, but overall had lower relative abundance throughout the nearshore feeding habitat. For example, western gray whales were noted to utilize the northern portion of the observation range in the study less in 2007, but had relatively higher abundance than has been observed in any previous field season in the southern portion of the observation range. The overall average, however, throughout the observation range in this study was consistent with previous field season. Vladimirov (2008) had lower density of western gray whales in observation regions that are further north than the present study area and potentially in other areas that were not within the geographic range of the present study. The lower observed densities in these other regions may have contributed to the observed decrease of the overall utilization of western gray whales throughout the feeding grounds.

Gray whales were on average 1.6 km from shore during June - September of 2007. This east-west distribution pattern is comparable to an average distance of 1.5 km from shore in 2005 and 2006. However, in 2003 and 2004, the average distances from shore were slightly higher (2.3 and 2.1 km, respectively); kernel density probability contours illustrated a consistent feeding area in waters greater than 1.5 km from shore and greater than 20 meters deep during the 2003-2004 field season. This slightly further offshore feeding area had a high abundance of sand lance (Fedeev 2004, 2005). Gray whales are known to be highly adaptable and to exploit seasonal abundance of different prey items and likely were exploiting sand lance for the past few years. However, in 2007, this more distant from shore feeding area was less extensively utilized. This lower abundance of whales in the northern part of the Piltun feeding area slightly further from shore area corresponded with a decrease in sand lance abundance in 2007 (Fadeev 2008).

There were no significant, consistent patterns in daily variation in the number of whales among the different regions. Although little evidence of daily trends has been found to-date, annual sample sizes may be too small to detect these variations, and/or other factors may contribute to daily changes in abundance and distribution patterns. A re-analysis of all available abundance and distribution information while taking into account tide, weather conditions, seasonal, temporal, and prey availability data may yield further insights and understanding of the variability in western gray whale habitat use patterns.

Table 15. Summary of number of whales and pods per scan for 2001-2007. Stations are arranged from highest latitude (North Station) to lowest latitude (South Station). Sightings between magnetic bearings of 0-20° and 160°-180° where removed from 2004 - 2007 data sets to conform to methods used to determine relative abundance of gray whales in 2001-2003 (see 'METHODS' section). Sightings in 2006-2007 were summarized for the period mid-July to September since this period was more typical of past field seasons.

				Number Whales			
Station	2001	2002	2003	2004	2005	2006	2007
North Station	-	-	-	5.7 ± 3.49 (23)	9.1 ± 4.70 (10)	7.2 ± 2.99 (19)	2.3 ± 2.00 (38)
Odoptu Station	-	8.4 ± 4.59 (16)	5.6 ± 4.31 (29)	12.2 ± 5.77 (24)	5.6 ± 4.52 (11)	4.2 ± 2.63 (20)	2.1 ± 1.92 (46)
Muritai	2.3 ± 1.49 (34)	-	-	-	-	-	-
Station 07	1.8 ± 1.35 (41)	3.3 ± 2.74 (29)	2.3 ± 3.32 (55)	5.9 ± 4.13 (31)	3.6 ± 1.96 (21)	1.9 ± 1.67 (32)	1.5 ± 1.52 (33)
Midway	2.7 ± 1.87 (40)	-	-	-	-	-	-
2nd Station	2.3 ± 1.88 (34)	2.0 ± 1.83 (37)	1.8 ± 1.75 (37)	3.7 ± 2.95 (28)	3.94 ± 2.18 (18)	2.8 ± 2.02 (46)	2.7 ± 2.24 (36)
Mt. Kiwi	4.0 ± 2.7 (42)	-	-	-	-	-	-
1st Station	-	1.9 ± 1.98 (35)	1.2 ± 1.84 (46)	3.1 ± 3.00 (45)	2.8 ± 1.83 (16)	2.6 ± 2.09 (58)	3.7 ± 2.75 (45)
South Station	-	-	-	2.3 ± 2.35 (37)	5.5 ± 3.77 (16)	4.8 ± 3.00 (44)	6.8 ± 3.93 (38)

				Number Pods			
Station	2001	2002	2003	2004	2005	2006	2007
North Station	-	-	-	3.8 ± 2.10 (23)	6.1 ± 3.44 (10)	4.7 ± 2.23 (19)	1.4 ± 1.18 (38)
Odoptu Station	-	5.7 ± 2.85 (16)	4.4 ± 3.01 (29)	8.4 ± 3.83 (24)	3.9 ± 2.55 (11)	2.9 ± 1.94 (20)	1.5 ± 1.38 (46)
Muritai	1.6 ± 1.05 (34)	-	-	-	-	-	-
Station 07	1.3 ± 0.94 (41)	2.2 ± 1.75 (29)	1.7 ± 2.22 (55)	4.1 ± 2.35 (31)	2.4 ± 1.47 (21)	1.6 ± 1.36 (32)	1.1 ± 1.06 (33)
Midway	2.0 ± 1.25 (40)	-	-	-	-	-	-
2nd Station	1.7 ± 1.29 (34)	1.5 ± 1.37 (37)	1.3 ± 1.22 (37)	2.4 ± 1.47 (28)	2.9 ± 1.67 (18)	2.3 ± 1.66 (46)	1.8 ± 1.64 (36)
Mt. Kiwi	2.6 ± 1.43 (42)	-	-	-	-	-	-
1st Station	-	1.5 ± 1.40 (35)	1.0 ± 1.50 (46)	2.2 ± 1.89 (45)	2.5 ± 1.75 (16)	2.0 ± 1.57 (58)	2.5 ± 1.78 (45)
South Station	-	-	-	1.7 ± 1.61 (37)	2.6 ± 2.68 (16)	3.9 ± 2.21 (44)	5.0 ± 3.37 (38)

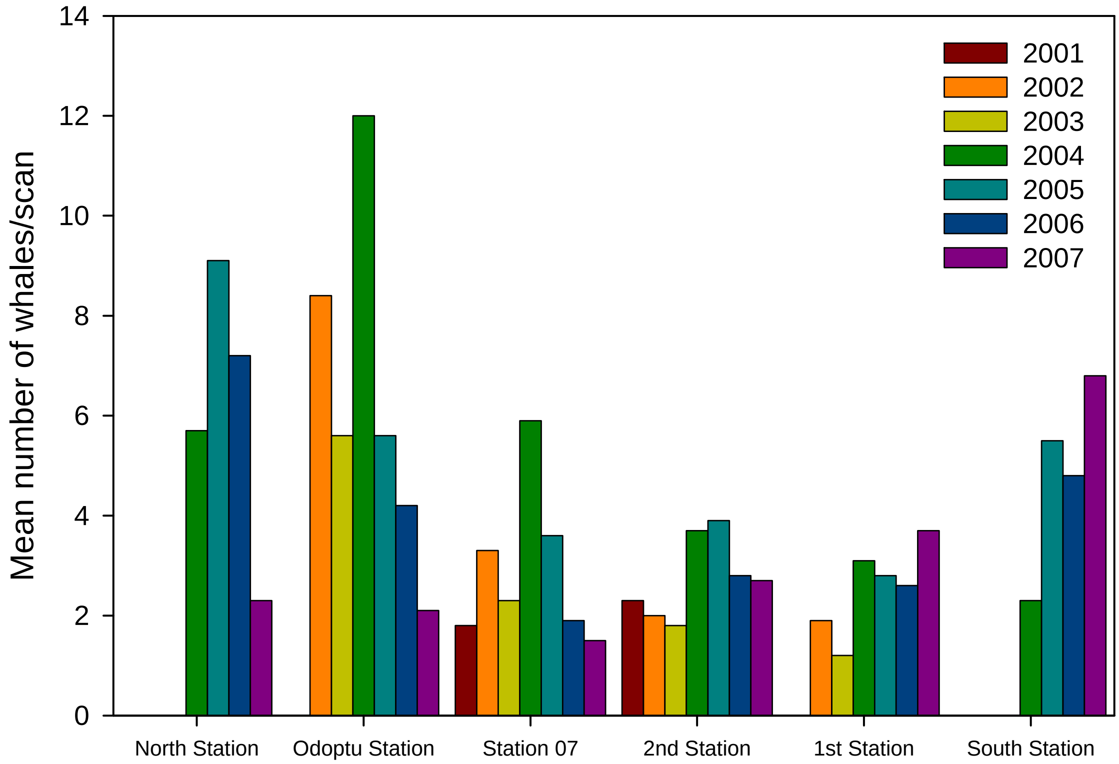

Figure 37. Annual relative abundance of western gray whales at six shore based stations from 2001-2007. Sightings between 0-20 and 160-180 were removed from 2004 - 2007 data sets to properly compare relative abundance of gray whales to the methods of 2001-2003 (see methods). Sightings from 2006-2007 were summarized from mid-July to September since this period was more typical of past field seasons.

Due to the relative "good" weather in 2007 (particularly in August and September), the 2007 field season resulted in the highest sample size of theodolite tracks for any year of 2001-2007. In addition, the longest track (> 7 hrs) was recorded for a mother-calf pair that was initially traveling then feeding 1.5 km from shore at the most northern station.

With the exception of 2002, the movement patterns of western gray whales in 2007 were similar to those observed in previous years. In 2002 (a non-construction year), gray whales were observed to be traveling more throughout the study area. In fact, the overall speed in 2002 was very similar to the behavioral traveling speeds of 3.2 to 3.6 km/h observed in 2003-2007. We hypothesized that this could be representative of a different foraging strategy, such as feeding more on prey in the water column as opposed to benthic foraging. Gray whales could potentially be feeding more on "clouds" of water column prey, potentially distributed in a somewhat poisson fashion. Similar travel between locations was evident for eastern gray whales feeding on mysids off Vancouver Island, Canada (Guerrero 1989).

Observations in 2007 indicated that gray whale feeding activity had a patchy distribution, being concentrated in the northern portion of the study area (primarily up to the month of August) and southern portion of the study area. Little concentrated feeding was observed from Station 07, between the northern and southern areas. Whales observed in the area around Station 07 were generally traversing, either in feeding/traveling or in traveling modes (Figure 12). After August, little to no feeding was observed in the northern region and gray whales were concentrated primarily in the southern part of the study area.

Sample sizes of focal follows were also record high in 2007 with the longest focal recorded (~7 hrs). With the exception of differences in 2002, the derived surface-respiration-dive parameters were comparable to those collected during field seasons when no construction activity occurred (2003-2004 baseline data). In 2002, blow interval and dive time tended to be higher and lower, respectively, than observed in other years, indicative of the greater amount of travel in that year (Gailey *et al.* 2005, Table 16). The general blow interval and dive time in 2007 were more similar to those of 2003-2006, which are comparable to those of bottom-feeding eastern gray whales in the northern Bering Sea (Würsig *et al.* 1986) and off Vancouver Island, Canada (Guerrero 1989). Dive times are generally lower than those reported for eastern gray whales, which is likely because of the shallow depth of the Piltun study area. For example, Würsig *et al.* (1986) found a general increase in dive time in deeper (> 20 m) water. In addition, Gailey *et al.* (2007c) found that water depth was significantly associated with dive time, indicating that whales had longer durations of dives in deeper waters.

While western gray whales remain in the feeding grounds, three predominant behaviors were observed: 1) feeding, 2) feeding/traveling, and 3) traveling. Movement and respiration patterns were found to be significantly different when whales engaged in these different modes of activity. Gray whales tended to move faster, were more directional, and covered a larger range while traveling compared to that of feeding/traveling and feeding. Movement patterns were also different between the two different modes of observed feeding behavior (feeding/traveling and feeding). Differences in movement patterns during feeding and feeding/traveling behavior may be representative of the different foraging strategies, such as feeding in one area with high concentration of food, while feeding/traveling in areas of lower prey availability or on different prey types. Feeding/traveling behavior could be related to a "search" mode where whales are investigating the bottom and feeding on lower density of prey in order to find larger high density patches of prey. Observations of whales feeding in one localized area for several hours suggest that the prey availability at that location was likely higher than in surrounding areas.

Respiration parameters were only found to be significantly different between two modes of activity: traveling and feeding. When whales were traveling, the duration between subsequent blows at the surface tended to be longer with shorter durations of diving and longer surface times compared to the two feeding activities (feeding and feeding/traveling). When whales were engaged in feeding or feeding/traveling, there was no difference in respiration patterns between these modes of feeding activity.

"Displacement" analyses in the past two years have indicated significantly different patterns for traveling whales than those found in previous years (2002-2005). However, while animals were feeding and feeding/traveling, displacement patterns were within the confidence intervals of past analyses. This could be related to a more patchy distribution of prey availability where animals were traveling more directionally between known patches of prey. Alternatively, anthropogenic activity, such as close vessel approaches and response to "noisy" activity could have influenced these patterns. Additional analyses are currently being conducted to fully understand these changes in movement and separate out observations where anthropogenic activity could potentially be affecting western gray whale behavior.

There is some circularity between the definitions of behavioral states as a natural predictor for variables of movement, such as speed, directionality, and range indices. For example, we would expect a lower linearity (i.e. less linear movement) and range indices for whales observed to be feeding ("remains in one localized area with non-directional movement and consistent periods of dives") compared to those animals that are classified as traveling ("swimming in one general direction and often remaining at the surface without consistent dives"). Behavioral states of the animal are important to provide context to help understand and monitor, despite some circularity in its definition, because these activities are “normal” for western gray whales and we were interested in explaining/identifying “normal” and aberrant behavior associated with natural and anthropogenic events. In other words, we could estimate that traveling whales normally do so at a speed of *X* km/h, then in effect check for association between higher (or lower) speeds for traveling whales in the presence of higher (or lower) anthropogenic sound levels. In addition, marine mammals have been noted to respond differently in relation to their current behavioral state. Resting whales, for example, are more likely to be disturbed by sounds than animals engaged in foraging and social activity (NRC 2003, Richardson and Würsig 1995).

Other behavioral states, such as resting, milling, socializing, playing, etc., were less frequently observed. This leads to low statistical power for analyzing these states which obviously limits quantitative interpretation. In addition, behavioral states such as socializing often consist of more than one individual, which increases the difficulty of reliably tracking or conducting a focal follow unless one distinctive individual can be recognized within the group. In 2007, observed socializing behavior occurred during a similar time period as in previous years (end of August and September). The increase in social bouts in the latter part of the summer has similarly been described for eastern gray whales off St. Lawrence Island (Würsig *et al.* 1986). It is unknown why gray whales engage in these activities more in the latter part of the feeding season. One hypothesis is that such increases in social activity may be indications that animals have successfully fed and are engaging in more energetic activities. The descriptions of social behavior are similar to those described for the eastern population of gray whales on their feeding grounds and are akin to descriptions of courting and mating behavior (Sauer 1963, Fay 1963, Jones and Swartz 2002). In fact, the majority of the social behavior observations during 2001-2007 included sexual activity, as indicated by an exposed penis. Although sexual-related activity continues to be observed on the feeding grounds, it likely serves some unknown social purpose that is ultimately non-reproductive (Jones and Swartz 2002).

Killer whales are one of the few known predators of gray whales. Predation on gray whales has been documented for the eastern population (Baldridge 1972, Goley and Straley 1994, George and Suydam 1998) and it is likely to occur to some degree on the smaller population of western gray whales. Indirect evidence of killer whale interactions with western gray whales is apparent by the tooth rake marks on the bodies of some individuals.

Such interactions may at times result in successful predation, especially on calves or recently weaned calves. Transient killer whales have been sighted infrequently (~2-5 times per field season) in the Piltun feeding grounds. Western gray whales have generally not been observed to respond to the presence of killer whales. In 2007, nine groups of killer whales were observed. This number is slightly higher than any previous season since 2001, but it is likely a result of the extended field season with increased effort. None of the gray whales observed in 2007 in the vicinity of killer whales were observed to respond to their presence. It is unknown if gray whales are unaware of the killer whales in the region or whether they simply remain unconcerned by their presence. In 2006, however, interactions between two adult gray whales and a group of 4-6 killer whales indicated obvious harassment by the killer whales and movement (high speed inshore movement) response by the gray whales to their presence (Gailey *et al.* 2007a).

Table 16. Summary statistics for theodolite and focal behavior data collected during 2001 - 2007. Dashes (-) separate numbers that indicate ranges; plus/minus (±) separate means and standard deviations, and numbers in parentheses are sample sizes.

Variable	2001	2002	2003	2004	2005	2006	2007
Leg Speed (km/h)	1.9 ± 1.49 (510)	3.2 ± 2.06 (74)	2.3 ± 1.04 (47)	2.2 ± 1.30 (116)	2.2 ± 1.84 (124)	2.6 ± 2.12 (140)	2.4 ± 1.76 (176)
Linearity	0.8 ± 0.23 (482)	0.8 ± 0.24 (74)	0.8 ± 0.29 (47)	0.8 ± 0.23 (116)	0.8 ± 0.91 (124)	0.8 ± 0.24 (140)	0.8 ± 0.23 (176)
Acceleration (km/h^2)	0.0 ± 0.71 (506)	0.1 ± 0.50 (74)	0.0 ± 0.23 (47)	0.0 ± 0.22 (116)	0.0 ± -0.03 (124)	0.0 ± 0.27 (140)	0.0 ± 0.23 (176)
Reorientation Rate (°/min.)	17.4 ± 13.72 (506)	21.0 ± 19.32 (74)	26.0 ± 18.76 (47)	19.1 ± 15.17 (116)	21.4 ± 15.85 (124)	19.5 ± 15.92 (140)	17.3 ± 14.52 (176)
Distance to Shore (km)	1.1 ± 0.66 (510)	-	2.3 ± 1.23 (283)	2.1 ± 1.45 (984)	1.5 ± 1.19 (502)	1.5 ± 0.66 (140)	1.4 ± 0.72 (176)
Mean Vector Length	0.8 ± 0.26 (482)	0.8 ± 0.27 (74)	0.7 ± 0.29 (47)	0.8 ± 0.22 (116)	0.7 ± 0.85 (124)	0.8 ± 0.25 (140)	0.8 ± 0.24 (176)
Ranging Index	-	-	31.1 ± 18.06 (47)	32.9 ± 22.31 (116)	32.8 ± 24.71 (124)	39.6 ± 35.91 (140)	36.2 ± 29.87 (176)
Blow Interval (blows/min.)	0.4 ± 0.14 (271)	0.5 ± 0.19 (46)	0.4 ± 0.13 (34)	0.4 ± 0.17 (64)	0.4 ± 0.15 (66)	0.4 ± 0.21 (81)	0.4 ± 0.18 (105)
Blows per Surfacing	5.2 ± 3.93 (234)	4.9 ± 4.45 (42)	4.2 ± 1.38 (34)	4.2 ± 1.63 (64)	5.1 ± 2.86 (66)	6.2 ± 6.73 (81)	4.9 ± 3.22 (105)
Surface Time (min.)	1.6 ± 1.84 (241)	1.7 ± 1.50 (42)	1.7 ± 1.78 (34)	1.8 ± 1.73 (64)	1.6 ± 1.73 (66)	2.0 ± 3.13 (81	1.6 ± 1.97 (105)
Dive Time (min.)	2.5 ± 0.92 (239)	1.8 ± 0.80 (44)	2.2 ± 0.77 (34)	2.4 ± 0.80 (64)	2.2 ± 0.84 (66)	2.4 ± 1.13 (81)	2.5 ± 0.94 (105)
Dive-Surface Blow Rate	1.2 ± 0.34 (236)	1.3 ± 0.32 (42)	1.3 ± 0.42 (34)	1.2 ± 0.32 (64)	1.3 ± 0.42 (66)	1.3 ± 0.48 (81)	1.1 ± 0.33 (105)

In summary, this report examines behavioral observations that were collected during the 2007 field season off northeast Sakhalin Island, Russia. The current analyses do not consider the potential effects of anthropogenic activity, such as installation of the PA-B platform top-sides, and the activities of nearshore vessels, which may influence the behavior of western gray whales. These analyses will be the subject of a separate report. We believe that behavioral studies in combination with acoustic data, data on vessel distance and benthic /prey information provides an excellent basis to understand observed changes in western gray whale abundance, behavior, and distribution. This multivariate approach has been extremely useful in previous studies that examined potential impact (Gailey *et al.* 2002, Gailey *et al.* 2007b, Gailey *et al.* 2007c). If affects on behavior become evident, this knowledge can be used to suggest mitigation measures to avoid biologically significant impacts on this critically endangered population of gray whales, while filling in basic information on their life history, behavior, and habitat utilization.

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APPENDIX 1. Daily summary of theodolite, focal behavior, and scan data collected off northeast Sakhalin Island, Russia, during the summer of 2007.

Station	Date	Start Day	End Day	Effort(hrs)	# Tracklines	# Focal Follows	# Scans
1st Station	20-Jun-07	6:45:39	17:12:07	10.44	1	0	8
1st Station	21-Jun-07	6:47:47	18:11:46	11.40	4	2	9
South Station		7:24:36	17:16:01	9.86	0	0	9
2nd Station	23-Jun-07	11:35:46	13:46:05	6.45	1	1	3
		15:01:14	19:17:49				
Station 07		11:43:27	17:52:04	6.14	0	0	5
1st Station	24-Jun-07	9:50:33	17:51:11	8.01	1	0	6
South Station		10:31:06	10:35:16	4.48	1		4
		12:52:53	17:17:35			0	
2nd Station	25-Jun-07	9:25:51	19:27:13	10.02	1	0	5
Station 07		10:28:36	19:07:25	8.65	3	3	7
1st Station	26-Jun-07	7:41:16	9:40:48	1.99	1	0	2
South Station		8:00:33	9:39:00	1.64	0	0	1
1st Station	28-Jun-07	7:18:46	7:44:25				
1st Station		8:36:35	11:57:36	4.67	2	0	3
1st Station		12:30:36	13:23:53				
South Station		8:57:26	13:25:03	4.46	4	0	2
1st Station	29-Jun-07	13:32:24	18:14:13	4.70	4	0	3
South Station		13:43:11	18:03:32	4.34	2	1	2
1st Station	1-Jul-07	7:21:55	18:33:19	11.19	1	1	7
South Station		7:59:56	17:47:03	9.79	1	0	9
1st Station	9-Jul-07	15:59:40	17:43:45	1.74	0	0	2
1st Station	10-Jul-07	10:28:41	18:07:52	7.65	4	2	1
South Station		10:41:41	17:53:16	7.19	4	2	1
2nd Station	11-Jul-07	7:57:36	12:54:23	4.95	0	0	4
Station 07		8:04:20	12:24:12	4.33	0	0	3
2nd Station	14-Jul-07	11:50:33	17:20:32	5.50	2	1	0
Station 07		11:58:34	17:47:32	5.82	3	2	2
North Station	17-Jul-07	9:08:47	13:04:02	3.92	1	1	2
Odoptu Station		8:54:34	12:30:15	3.60	1	1	2
1st Station	27-Jul-07	9:16:08	11:46:23	2.50	0	0	1
South Station		10:00:41	11:17:00	1.27	2	0	1
1st Station	28-Jul-07	12:15:06	14:29:20	2.24	1	0	0
1st Station	29-Jul-07	11:49:28	19:31:22	7.70	3	3	2
South Station		12:39:16	18:54:29	6.25	5	0	1
2nd Station	30-Jul-07	7:49:56	13:23:17	5.56	1	1	2
Station 07		8:29:41	12:33:34	4.07	3	0	0
2nd Station	3-Aug-07	12:08:33	18:55:37	6.78	3	2	1
Station 07		12:36:20	12:40:20	0.07	2	0	0
Station 07		15:50:20	18:30:20	2.67			
North Station	4-Aug-07	9:33:00	18:11:13	8.64	4	2	5
Odoptu Station		8:58:17	18:44:03	9.76	3	2	5
1st Station	5-Aug-07	7:52:16	15:09:03	7.28	2	2	3
South Station		8:55:21	16:08:37	7.22	5	1	3
2nd Station	6-Aug-07	8:24:09	13:00:11	4.60	4	2	3
Station 07		8:47:04	15:06:49	6.33	3	3	2

North Station	7-Aug-07	8:59:57	12:07:41	3.13	0	0	1
Odoptu Station		8:38:09	12:54:00	4.26	1	0	2
1st Station	8-Aug-07	15:10:29	15:52:09	0.69	1	0	0
1st Station	15-Aug-07	12:29:11	16:56:15	4.45	2	0	4
South Station		12:54:01	17:37:37	4.73	2	0	4
2nd Station	16-Aug-07	8:12:06	17:08:36	8.94	2	1	2
Station 07		8:41:41	16:55:18	8.23	2	1	2
North Station	17-Aug-07	9:04:09	18:16:45	9.21	3	3	3
Odoptu Station		8:17:55	18:38:37	10.35	3	1	2
1st Station	18-Aug-07	7:03:08	17:34:19	10.52	4	2	7
South Station		7:16:05	17:35:19	10.32	5	4	5
2nd Station	19-Aug-07	11:43:14	12:35:05	5.94	4	3	0
2nd Station		13:12:00	14:57:40				
2nd Station		15:42:15	19:01:20				
Station 07		11:48:32	18:00:40	6.20	2	0	2
North Station	21-Aug-07	8:13:48	15:00:00	6.77	2	1	2
Odoptu Station		8:04:10	15:20:34	7.27	6	2	3
1st Station	24-Aug-07	6:43:25	18:51:53	12.14	8	5	8
South Station		7:15:33	18:54:19	11.65	8	1	4
2nd Station	25-Aug-07	7:08:57	15:38:57	8.50	2	2	5
Station 07		7:33:10	11:48:46	7.26	2		4
Station 07		12:11:33	15:11:25			1	
North Station	26-Aug-07	10:04:20	11:00:30	0.94	0	0	1
Odoptu Station		9:28:35	11:33:20	2.08	1	0	0
North Station	28-Aug-07	8:53:18	18:54:23	10.02	4	2	6
Odoptu Station		8:14:30	19:26:11	11.20	4	1	11
1st Station	29-Aug-07	7:06:56	9:15:36	5.98	1	0	1
1st Station		10:30:37	14:20:35				
South Station		7:41:08	9:29:38	5.13	3	0	2
South Station		10:09:50	11:46:21				
South Station		12:06:04	13:48:36				
2nd Station	30-Aug-07	7:37:11	14:31:00	6.90	3	1	3
Station 07		7:57:42	18:08:18	10.18	6	3	7
North Station	31-Aug-07	8:46:30	18:23:42	9.62	4	1	9
Odoptu Station		8:15:52	19:10:19	10.91	5	3	5
1st Station	1-Sep-07	7:03:46	10:49:51	10.69	6	5	3
1st Station		11:35:28	18:30:28				
South Station		7:30:32	8:45:30	9.16	7	0	2
South Station		10:47:58	18:42:45				
1st Station	5-Sep-07	15:25:00	15:45:14	0.34	0	0	1
2nd Station	7-Sep-07	7:46:40	15:36:04	7.82	5	4	4
Station 07		8:09:19	15:12:02	7.05	2	1	4
North Station	8-Sep-07	8:38:06	17:37:48	9.00	5	3	3
Odoptu Station		8:34:43	18:39:23	10.08	3	2	7
1st Station	9-Sep-07	6:57:39	7:18:26	6.78	7	0	6
1st Station		9:53:45	16:19:50				
South Station		8:21:23	16:45:59	8.41	3	1	6
2nd Station	10-Sep-07	8:50:10	12:18:01	3.46	1	1	0
North Station		14:05:57	14:28:53	0.38	0	0	0
Odoptu Station		13:22:38	13:42:38	0.33	0	0	0

Station 07		8:26:50	12:40:03	4.22	1	1	1
2nd Station	13-Sep-07	10:35:12	16:13:41	5.64	2	0	4
Station 07		10:56:15	15:42:33	4.77	1	1	3
North Station	14-Sep-07	9:29:32	13:36:17	4.11	0	0	4
Odoptu Station		9:05:30	14:14:34	5.15	2	0	4
North Station	16-Sep-07	9:30:51	10:20:00	0.82	0	0	0
Odoptu Station		9:12:09	11:10:16	1.97	0	0	1
1st Station	17-Sep-07	7:54:47	18:42:35	10.80	2	2	3
South Station		8:20:07	18:20:12	10.00	7	1	6
2nd Station	18-Sep-07	8:15:17	18:05:03	9.83	3	2	8
Station 07		8:31:57	17:30:57	8.98	4	1	7
North Station	19-Sep-07	9:14:50	9:42:50	0.47	0	0	0
Odoptu Station		9:05:44	11:30:13	2.41	1	1	1
1st Station	20-Sep-07	10:53:00	18:58:10	8.09	5	1	5
South Station		11:19:13	17:59:49	6.68	6	4	4
2nd Station	21-Sep-07	12:54:22	15:30:34	2.60	2	0	3
Station 07		13:07:52	15:00:18	1.87	1	1	1
North Station	25-Sep-07	9:54:21	11:11:52	1.29	0	0	2
Odoptu Station		9:27:14	11:47:20	2.34	0	0	3
2nd Station		12:30:00	12:50:00	0.33	0	0	1
1st Station		13:57:45	14:17:45	0.33	0	0	1
TOTAL				625.5	249	105	334