Western Gray Whale Behavior, Movement, and Occurrence Patterns off Sakhalin Island, 2006

Photo taken from shore at South Station, O. Sychenko.

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INTRODUCTION

The western stock of the gray whale (*Eschrichtius robustus*) is one of the most endangered large baleen whale populations in the world. The current population estimate is approximately 120 individuals that habitually feed off the northeastern area of Sakhalin Island in summer-fall of every year (Cooke *et al.* 2006, IISG Report 2006, Jones and Swartz 2002). The small number of whales remaining in the population in combination with fewer than 50 reproductive females served as the basis for The World Conservation Union (IUCN) listing the western gray whale as Critically Endangered (Hilton-Taylor 2000, Red Book of Russian Federation 2000, Weller and Brownell 2000). Continued human-related mortality south of the Okhotsk Sea (Brownell 1999), poses potential threats to the future survival of this population. In the past two years alone, four female western gray whales were incidentally caught in fishing gear near Japan. The western stock of gray whales face other threats such as direct and incidental catches (generally outside the Sea of Okhotsk), ship strikes, and physical habitat changes such as those caused by dredging (Richardson *et al*. 1989, Brownell 1999). Displacement or abandonment of whales from critical feeding and migratory habitat is possible, due to disturbance from noise of seismic surveys, vessel activity, other industrial activities, and the cumulative impact of all anthropogenic activity being conducted in a region. The shallow water inshore distribution of gray whales makes them particularly susceptible to environmental fluctuations and anthropogenic activity.

For the past eight years, research on distribution and abundance patterns, foraging ecology, population dynamics, and behavior, both in their natural environment as well as to industrial activities, has taken place to understand and monitor the western gray whale population during their summer-fall (June – October) foraging period (summaries in Blokhin *et al.* 2003 a, b, Fadeev 2002, 2003, 2004, 2005, 2006, 2007, LeDuc *et al.* 2002, Meier *et al.* 2002, Vladimirov *et al* 2005, 2006, 2007, Weller *et al.* 1999, 2002 a, b, Würsig *et al.* 2002, 2003, Yakovlev and Tyurneva 2003, 2004, 2005, 2006, 2007, Yazvenko *et al.* 2002, Gailey *et al.* 2004, 2005, 2006, 2007). It is currently unknown where western gray whales spend winter and spring, but it is assumed that mating, calving, and early calf rearing take place to the south of Sakhalin Island, in or near coastal waters of the South China Sea (Jones and Swartz 2002).

The feeding grounds of western gray whales are in the vicinity of existing and planned oil and gas developments by the operators of the Sakhalin-1 [Exxon Neftegas Limited (ENL)] and Sakhalin II [Sakhalin Energy Investment Company (SEIC)] projects. Sakhalin-1 and Sakhalin II have sponsored several monitoring programs to understand natural variation and the potential impacts their activities may have on western gray whale behavior, movement, abundance, distribution, benthic communities, and population trends. The conservation and management approach involves continual monitoring of western gray whales during their summer and fall (June – October) foraging period to obtain additional understanding of the population, and active mitigation of potential industrial impacts on the population. The approach attempts to ensure that the western gray whale foraging period is not disrupted, and that they are able to continue to feed in preferred areas to gain the food requirements needed to sustain them during their north and south bound migration, as well as on their breeding grounds.

While western gray whales face several threats during their annual north-south migration along the east coast of Asia, a concern in both short- and long-term is the amount and levels of sound 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.* 1999; Richardson *et al.* 1986), humpback whales (McCauley *et al.* 2000; McCauley *et al.* 1998), 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 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. in Press*; Johnson *et al. in Press*; Weller *et al.* 2002a; Würsig *et al.* 1999; Yazvenko *et al. in Press*). 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. in Press*). Similarly, Weller *et al.* (2005) 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.

During the summer of 2005, SEIC initiated construction of the Piltun Astokh-B (PA-B) platform with the placement of a Concrete Gravity Based Structure, or CGBS. The PA-B platform is located near-shore (~13 km from shore in 30 m water depth) and in close proximity to the Piltun gray whale feeding area. With the exception of distance from shore, both univariate and multivariate analyses found no significant effects in relation to gray whale movement and behavior for most of the subtle indicators of response. This could be a result of the noise mitigation strategy employed to minimize sound exposure levels above 120 dB within the Piltun feeding area during industrial/construction operations, and actively mitigating and monitoring sound levels in the field (SEIC 2005, Rutenko 2006). 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 in this study were confounded with nearshore research vessels and CGBS related activity and therefore we were unable to test the effects of one or the other sound source directly. Gray whales were observed to be particularly sensitive to nearshore research vessels approaching within 0.5 km of the whale, and this response could potentially have led to the offshore movement observed in relation to sound levels. Gailey *et al.* (2007) argued that some of the highest sound levels were those due to nearshore research vessels as opposed to the construction activity.

In 2006, pipeline construction activity was initiated from Piltun Astokh-B (PA-B) and Molikpaq (PA-A) platforms. The route of the pipeline is illustrated in Figure 4, coming ashore south of the previously known (Piltun Area) nearshore feeding grounds of gray whales. We term this region as "Chaivo Area" for this report. The PA-A and PA-B platforms are located near-shore (~13-16 km from shore in 30 m water depth). Pipeline placement consisted of multiple phases and predictive acoustic models were conducted prior to construction and used as a mitigation measure to minimize sound levels within the known foraging habitat of western gray whales. Sound levels were monitored in the field in real-time to ensure that levels were below criteria levels (see Rutenko 2007). Prediction of sound levels generated by dredging, pipeline placement, and backfilling activities was part of a noise management strategy, initiated prior to the construction activity, and acoustic and behavior monitoring programs were employed during construction to monitor the potential impacts on western gray whales.

Behavioral responses are likely to be the first signs of disturbance that could lead to diminished feeding activity. Therefore, we believe that evaluating subtle indicators of behavioral response in relation to potential anthropogenic activity (i.e. sound level, vessel presence) is a good management approach towards understanding threshold levels and activities that could lead to disruption of "normal" activity of gray whales on the feeding grounds. A more detailed multivariate analysis is currently being conducted to examine these indicators of response, which will incorporate environmental, temporal, whale behavior, vessel activity and sound level information to investigate potential impacts the construction activity may have had on western gray whales and these analyses will be presented in a separate report. In this report, analyses are presented on whale locations, movements, and behaviors relative to presumably undisturbed as well as potentially affected conditions.

Behavioral monitoring effort in 2006 was a continuation of research conducted in 2001-2005, that aims to provide long-term observations of habitat use, distribution, abundance, movement, and behavior of individuals and groups of western gray whales in the Piltun feeding area. The duration of the 2006 study was extended compared to previous years and took place from late June to late September. In addition, an extra behavior team monitored gray whales in the vicinity of the pipeline landfall location at three stations in the Chaivo Area, outside of the known Piltun feeding area. Behavioral research was conducted from onshore locations that were some distance from the whales. The use of onshore locations has the advantage of avoiding the possibility that the observing station(s) would be a source of disturbance. We conducted three primary observation methods: 1) scan sampling to obtain relative abundance estimates, distribution, and group size information; 2) theodolite tracking of individuals or groups to describe spatial movement, orientations, speeds, and habitat use; and 3) focal animal observations to monitor surfacing-respiration-dive parameters and other surface-visible behaviors. Data were analyzed by parametric and nonparametric statistical methods. Ultimately, it is our intent to describe the basic biology, behavior, and habitat utilization of western gray whales in the Piltun feeding area, and the amount of natural variability that exist annually, seasonally, and geographically. Such information will be used during project design and implementation to help realize effective management strategies to protect the whales and their foraging habitat.

METHODS

Research methods used in 2006 were consistent with those implemented in 2001-2005, and therefore much of this section is repeated from Würsig *et al.* (2002, 2003) and Gailey *et al.* (2004, 2005, 2006, 2007). Data analyses followed similar protocols as used before, but with inclusion of three additional stations and a third behavior team to monitor nearshore dredging activity that was approximately 40 km south of the observation stations employed from 2001-2005 (Chaivo Area).

Study Area

Shore-based observations were conducted along 86 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, one of the two currently known feeding grounds off northeastern Sakhalin Island utilized by the western (or Korean-Okhotsk) stock of gray whales, with an apparent nutrient-rich habitat that may be influenced by a local lagoon ecosystem, known as Piltun Bay (see also Johnson 2002). The nearshore waters of the Sea of Okhotsk are characterized by sand substrate with a gradually sloping continental shelf.

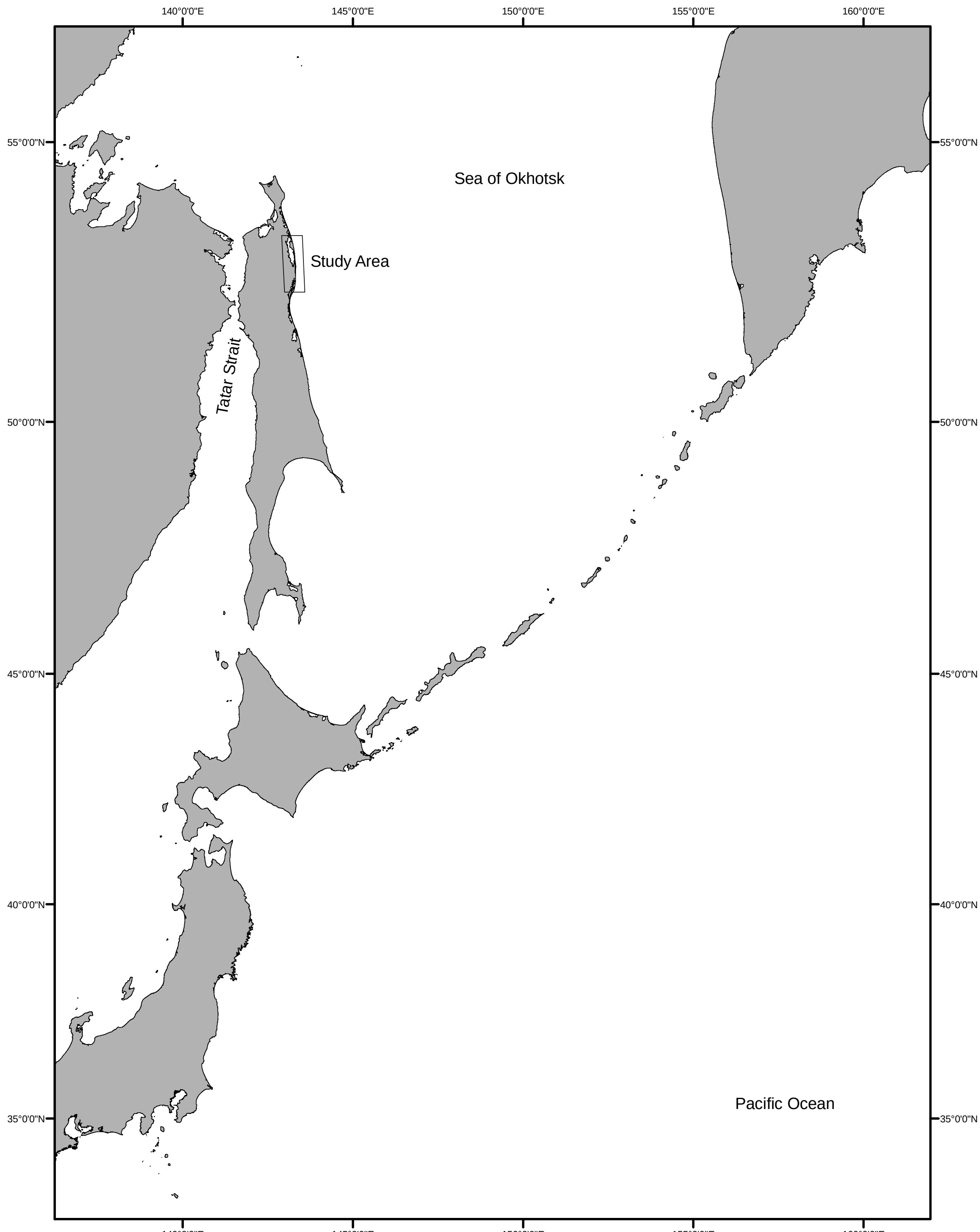

Figure 1. Study area in the northeastern portion of Sakhalin Island in Far East Russia. Figure 2 shows details of the study area.

Shore-Based Observations

Nine geographic locations were chosen to conduct behavioral observations on western gray whales in summer 2006 (Table 1). Each station was selected based on its height above sea level relative to the generally low dunes of the area (Table 1). Three separate behavioral teams (two teams at the six most northern stations and one team at the three most southern stations) conducted research on every possible good weather day. For the northern teams (Piltun Area), station selection proceeded systematically from south to north. For the southern team (Chaivo Area), the two most southern (Chaivo and Pipeline) locations where alternated between at the onset of the field season to monitor the northern gray whale migration, then later in August a third station (Camp station) was incorporated and observations proceeded from south to north. These protocols for the southern based team were in accordance with recommendations suggested by the Interim Independent Scientists Group (IISG 2006). Once the northern-most station was reached (North Station & Odoptu Station/Camp station), then the next day of effort continued at the most southern stations (South Station & 1st Station/ Chaivo Station). Therefore, the observation teams conducted research at each station after three favorable weather days. Two stations (2nd Station and Station 07) had been used since the 2001 seismic study; 1st Station and Odoptu Station were incorporated in 2002, and North Station and South Station were added in 2004. The three new southern stations in the Chaivo region were added this season to monitor nearshore dredging activity.

Table 1. Nine shore-based vantage points along the northeastern coast of Sakhalin Island, Russia. Station height is at mean low water.

Station Name	Latitude	Longitude	Height (m)
North Station	53º18'22.8"	143º12'35.3"	18.64
Odoptu Station	53º12'33.1"	143º14'51.2"	15.61
Station 07	53º07'29.9"	143º16'12.3"	8.14
2nd Station	53º03'08.9"	143º17'04.6"	10.16
1st Station	52º58'27.5"	143º18'06.6"	6.80
South Station	52º53'23.9"	143º19'05.6"	4.92
Campsite Station	52º34'48.8"	143º18'53.5"	5.12
Pipeline Station	52º31'52.7"	143º18'17.4"	7.15
Chaivo Station	52º29'09.3"	143º17'28.3"	6.78

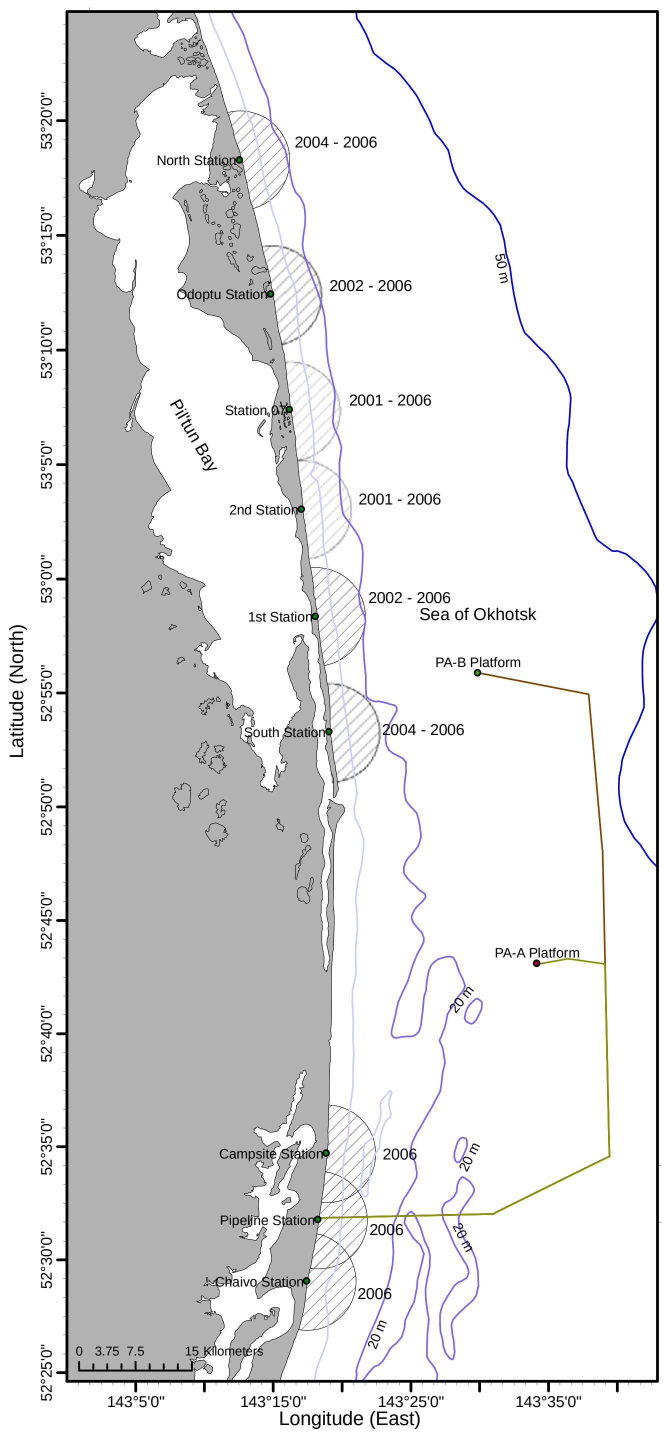

Figure 2. Geographic positions of nine shore-based stations in the northeastern coastal region of Sakhalin Island, Russia. Semi-circular grids illustrate approximate viewable range (4 km) from each shore-based station. Dates indicate years when data were collected at each station.

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, 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), wind speed, wind direction, cloud cover, and swell heights were recorded. Hand-held weather stations (Kestrel 4000) were utilized 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.

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) to progressively scan a predetermined section of the study area ranging from 0° to 180° magnetic North (magnetic declination relative to true North = 11.98° West in summer of 2006). 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 - 2006 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 two 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.

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 within a relatively close distance (4-5 km) from the station. Each individual was continually tracked until the animal was lost, moved beyond the 4 km critical distance, or when environmental conditions hampered further tracking. 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). Due to the relatively low elevations of each station, a maximum of 4 km distance from the station was used for a critical distance 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).

Focal Behavior Observations

Focal behavior sessions of behavior and respiration event (*sensu* Altman 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 known individuals, due to our low vantage point and distance from whales. A focal session would be terminated once the whale moved out of the study area or when the above conditions were not met. At least one behavioral observer would follow individuals with the aid of hand-held binoculars (7x50). 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 provided by theodolite tracking of the focal animal.

Data Analysis

Scan Data – For a broad overview, the relative number of whales and pods were analyzed. All scan-based data were evaluated for the entire coastal region observed throughout the nine shore-based stations and within and between each station. An estimation of the distribution using the fixed kernel method was conducted to graphically evaluate potential areas where animals were most frequently seen along the coastal region during scans (Worton 1989). The number of whales/pods per station were evaluated at different time periods for each day of effort and for different seasons. Season for this 2006 study consists of periods of June – July and August – September. This temporal selection was based on a natural break point due to three weeks of continual absence of information due to foggy conditions from the onset of August to late August. Due to non-normal distribution of scan data, both number of whales and pods were transformed (log (# whales or pods +1)) for analytical purposes. Based on the observed height above sea level, geographic bearing, and reticle readings of each sighting, distance from observer and geographic location were calculated (see Lerczak and Hobbs 1998 for distance equations). In addition, a refraction index was used to correct for potential errors in line-of-sight estimation within the distance approximation (Leaper and Gordon 2001). The refraction correction required known temperature and pressure information which were recorded automatically at 10 minute intervals by a hand-held (Kestrel 4000) environmental device at each observation station. Due to differences in observation heights at the nine stations, a threshold, determined by evaluating the frequency distribution of sightings in relation to distance from station and the station's relative height, of ≤ 6 km distance from the station was used for some analyses (i.e. comparing relative abundance values between stations) to fairly compare between different stations (Figure 3). In other words, stations at higher elevations (i.e. 18.6 m at North Station) allowed observers to see further and therefore potentially more whales, while stations at lower elevations (i.e. 4.9 m at South Station) could potentially see fewer whales compared to higher elevations simply as a function of observable area. For other analyses that were dependent on geographic location, such as distance from shore, a threshold of 10 km from the observation station was taken. 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 at North Station, then these offshore (> 6 km) sightings are included in distance from shore estimates. We believe that sightability among the different stations would be more prevalent for abundance estimates compared to distributional patterns and therefore increased distance thresholds for these distributional analyses.

A.

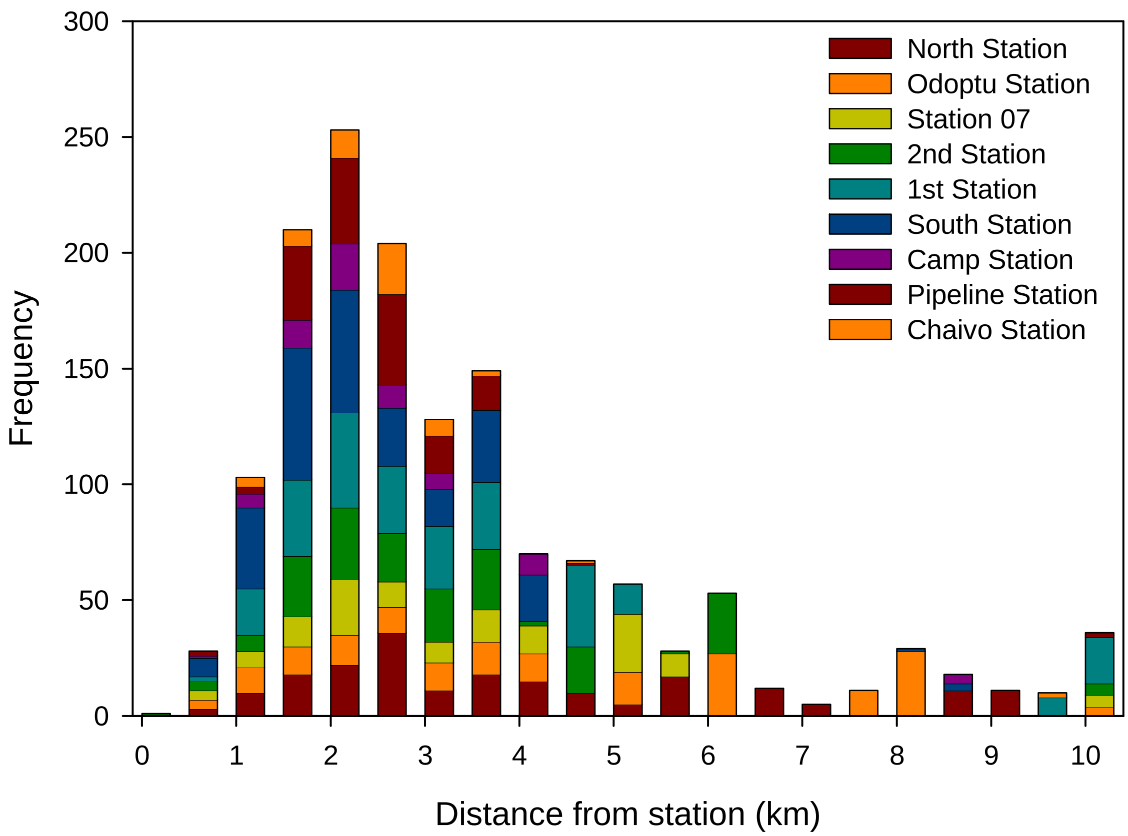

Figure 3. Frequency of sighting distances of western gray whales from (A) nine shore-based vantage points, and (B) two high elevation (North and Odoptu Station) stations and two low elevation (South and Camp) stations (continued on next page).

B.

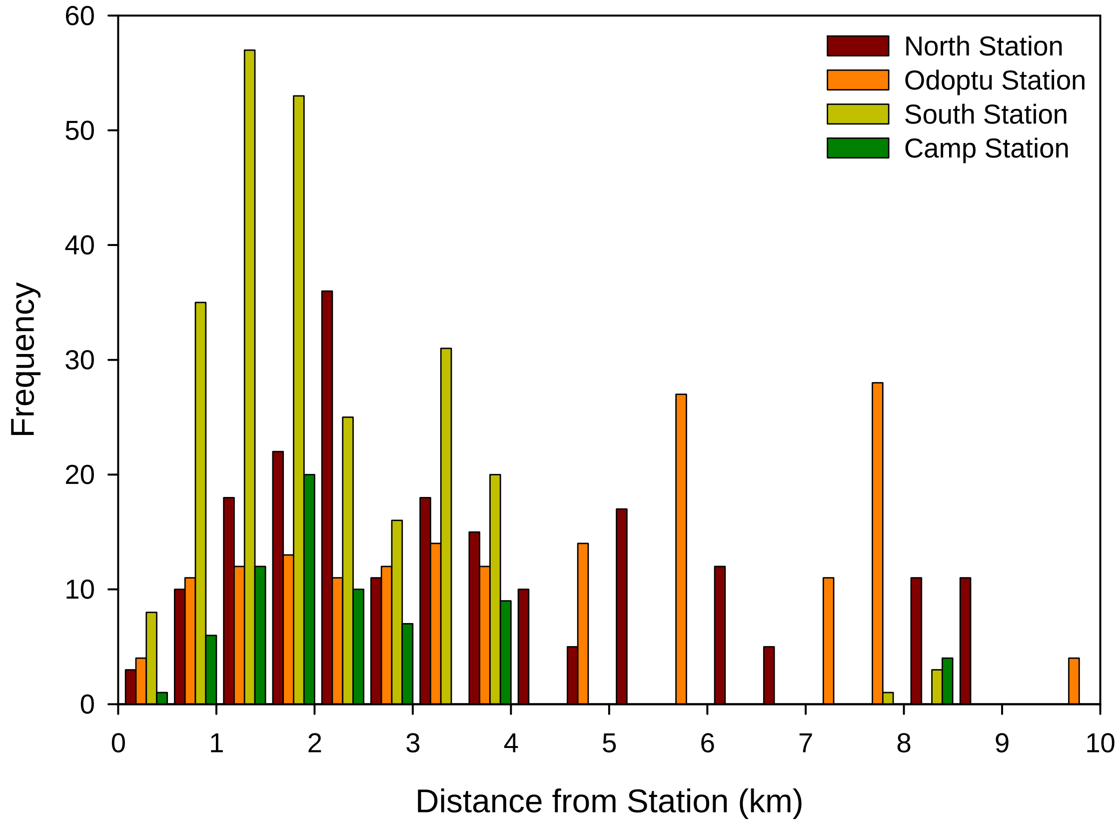

Figure 3 continued.

<u>Theodolite Data</u> – Theodolite tracking information was evaluated in terms of each animal's relative speeds, orientations, and displacement. Due to potential issues of 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 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 due to its dependence on 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 a 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). Furthermore, a "displacement" analysis was conducted to evaluate natural movement patterns among different behavioral states of western gray whales. 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 based on bootstrap methods. The bootstrap was conducted by randomly selecting (with replacement) i_n paths (where i_n was defined as the number of paths that have n moves), and calculating the mean squared displacement. After 1000 iterations of the bootstrap, the 95% confidence interval for each step were 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 greater error bars at higher n steps (Turchin 1998).

<u>Behavioral/Respiration Data</u> – 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.

	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

<u>Theodolite and Focal Behavior Data Bins</u> – 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 bin representative per trackline or focal behavior 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. 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, or unrecognized behaviors comprising a substantial portion of the bin.

Transformations - Histograms were evaluated for each of the response 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 distribution of leg speed was transformed using the square root. The distributions of reorientation rate, range, respiration interval, blows per surfacing, and surface time were non-normal. Each of these variables was log-transformed.

RESULTS

Effort

The 2006 field season commenced on 20 June 2006 and ended on 29 September 2006. A total of 64 (with both stations, 32 actual) days (413 hrs) of effort was spent at the six most northern-based shore stations, the Piltun Area (Table 3, Appendix 1). A total of 33 days (203 hrs) of effort was spent at the three most southern-based shore stations, in the Chaivo Area (Table 3). The first day of data collection started on 23 June at Chaivo Station for the southern team and 26 June at 1st Station for the northern teams. The last field day of effort for all teams was 26 September at Odoptu, North Station, and Pipeline Station.

Table 3. Total amount of effort at nine shore-based stations during 23 June to 26 September 2006.

Station name	Days	Effort (hrs)
North Station	9	41.57
Odoptu Station	9	52.00
Station 07	11	74.54
2nd Station	10	79.69
1st Station	15	100.95
South Station	10	65.08
Campsite Station	6	43.64
Pipeline Station	13	75.37
Chaivo Station	14	84.05
All Stations	97	616.89

Scan Data

General – A total of 376 scans with 1513 whales from 1195 sightings were accumulated for the duration of the study (Table 4). Distribution of gray whale sightings from the nine stations is illustrated in Figure 7 and shown in Figure 4-6; although whales could be sighted up to about 10 km distance from the station with the highest elevation (North Station, 18.9 m), they were generally < 5 km from shore (**Error! Reference source not found.**; Table 5). Gray whales were observed to initially (June - July) occur more frequently in the northern portion of the study area. Later in the season (August – September), there appeared to be a distributional shift with increased numbers of whales and pods near dredging activity to the south (Figure 6).

Gray whales were present on almost each day of effort, with a mean of 3.6 ± 3.32 SD (Median = 3, Range: 0-17, N = 376) whales and 2.8 ± 2.52 (2, 0-12, 376) pods in the study area per scan. The mean pod size detected was 1.3 ± 0.52 (1, 1-4, 1063) whales per pod throughout the duration of this study (Figure 7).

Table 4. Summary of scans during 2006 at nine shore-based stations.

Station	# Scans	# Sightings	# Individuals
North Station	21	139	194
Odoptu Station	23	118	155
Station 07	39	103	122
2nd Station	56	161	195
1st Station	69	236	307
South Station	48	229	291
Campsite Station	32	63	70
Pipeline Station	43	99	124
Chaivo Station	45	47	55
All Stations	376	1195	1513

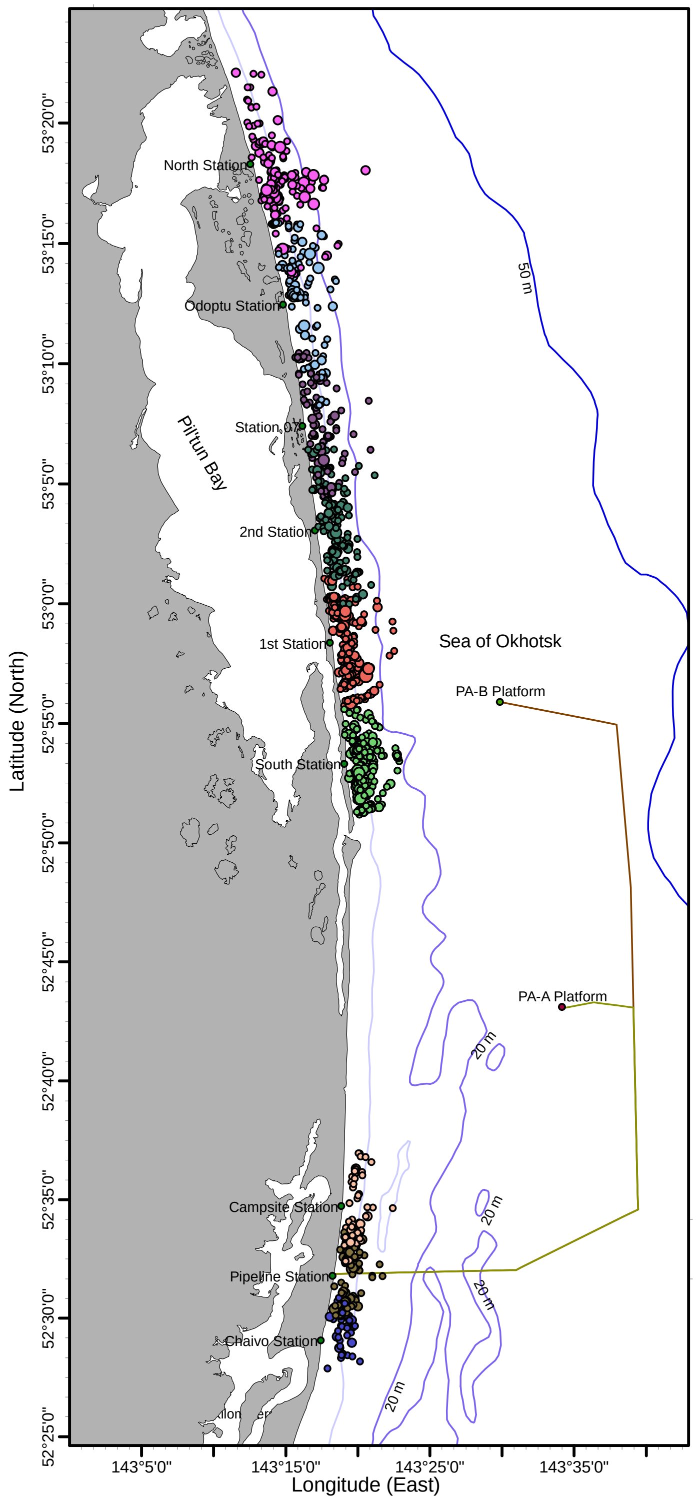

Figure 4. Geographic positions of sightings of western gray whales at nine shore-based stations on Sakhalin Island, summer 2006.

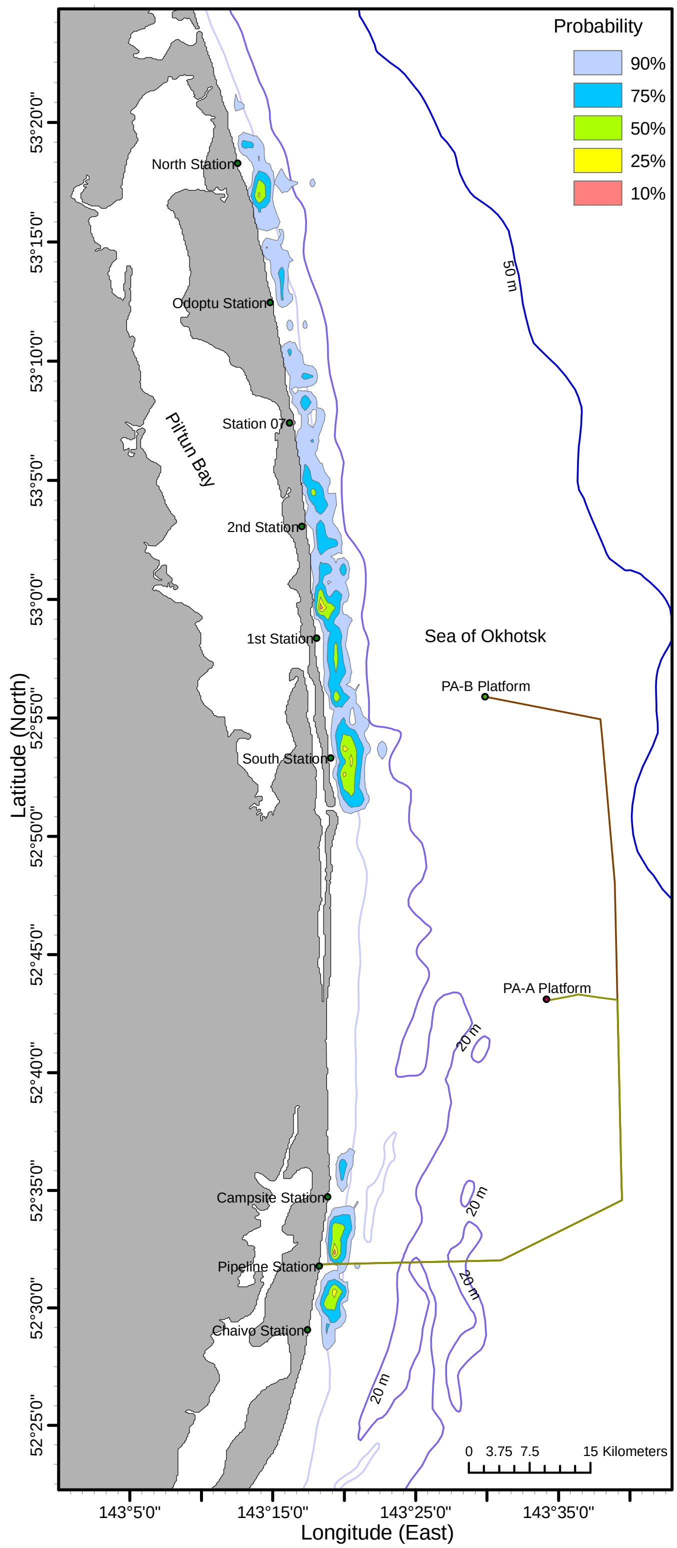

Figure 5. Distribution of western gray whales from nine shore-based positions during the summer of 2006. Blue – red represents the kernel density probability contours.

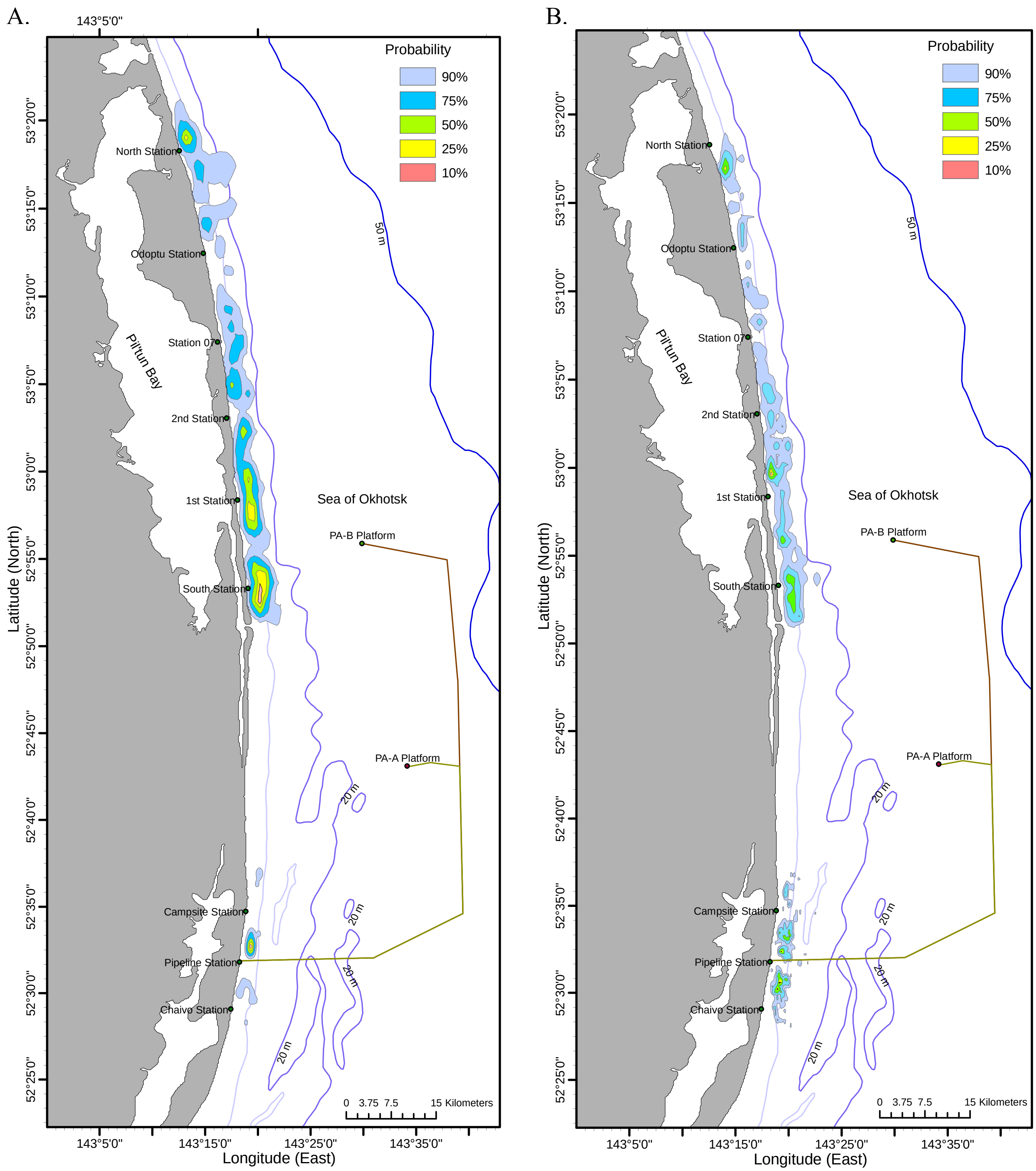

Figure 6. Seasonal distribution of western gray whales from nine shore-based positions from (A) June - July and (B) August - September of 2006. Blue – red represents the kernel density probability contours.

A.

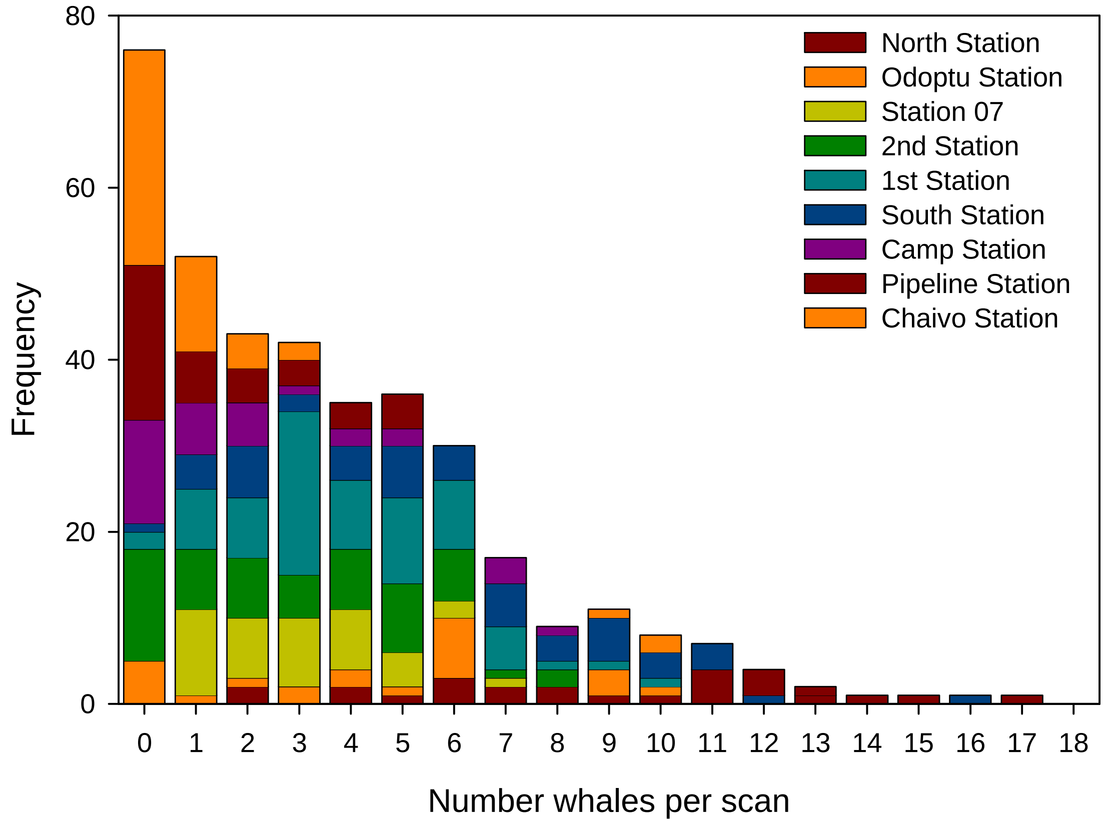

Figure 7. Frequency histograms of numbers of whales (A) and pods (B) detected per scan throughout the study period, and pod size (C) (continued on next two pages).

B.

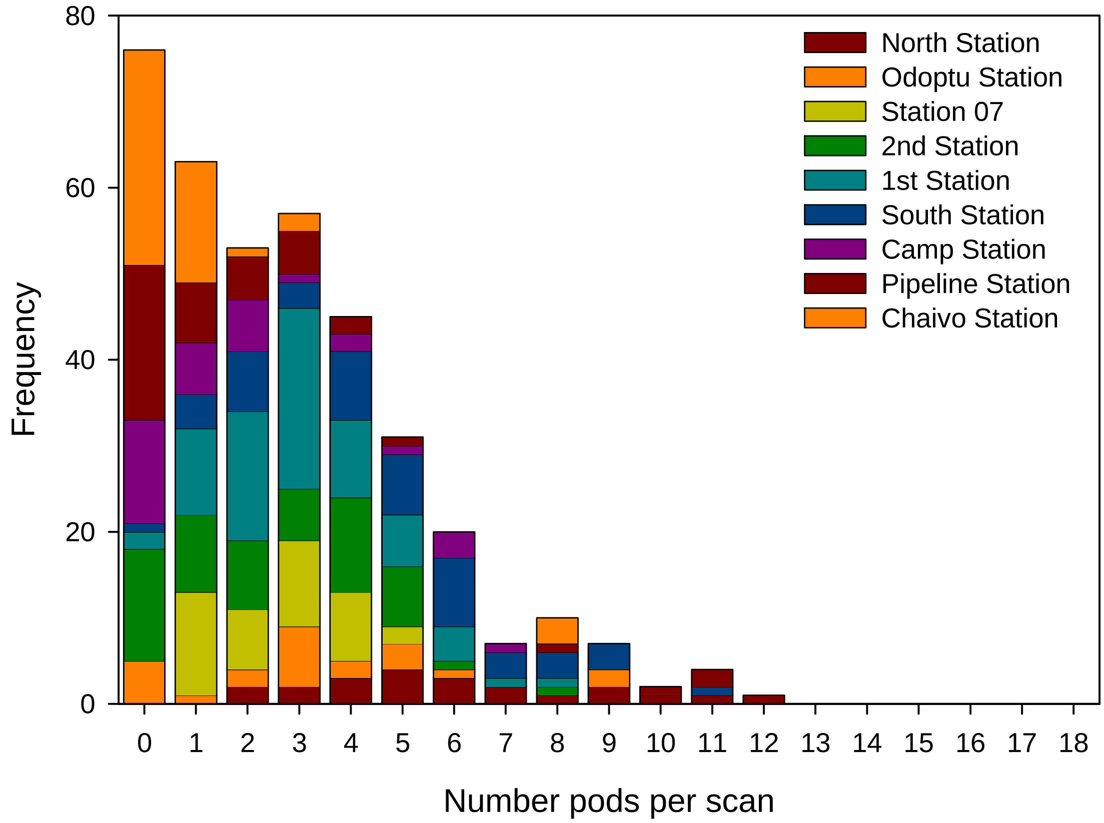

Figure 7…continued…

C.

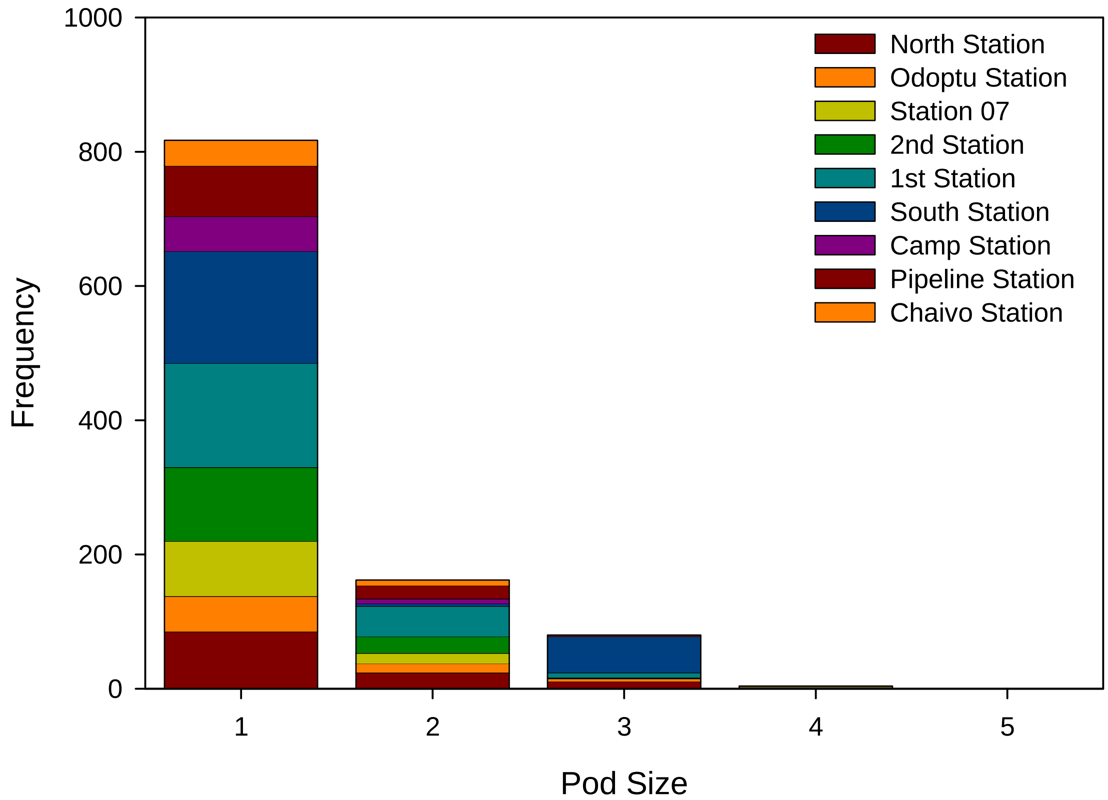

Figure 7 continued.

Distance from shore – Western gray whales were observed on average 1.5 ± 1.03 km from shore among the different stations (**Error! Reference source not found.** and Table 5). Whales at the most northern location (North Station) tended to be slightly further from shore (1.9 km). In addition, the distance from shore at North Station was significantly ($F = 5.28$, df = 8, $P < 0.0001$) higher than 1st Station and Station 07. Gray whales at Station 07 were observed to be significantly closer to shore compared to all other stations, except 1st Station. There were no temporal differences among the different months of observation ($F = 2.45$, df = 2, $P = 0.09$) or season (June - August and August to September; $F = 1.18$, df = 1, $P = 0.2774$) in relation to gray whale distribution from the shore.

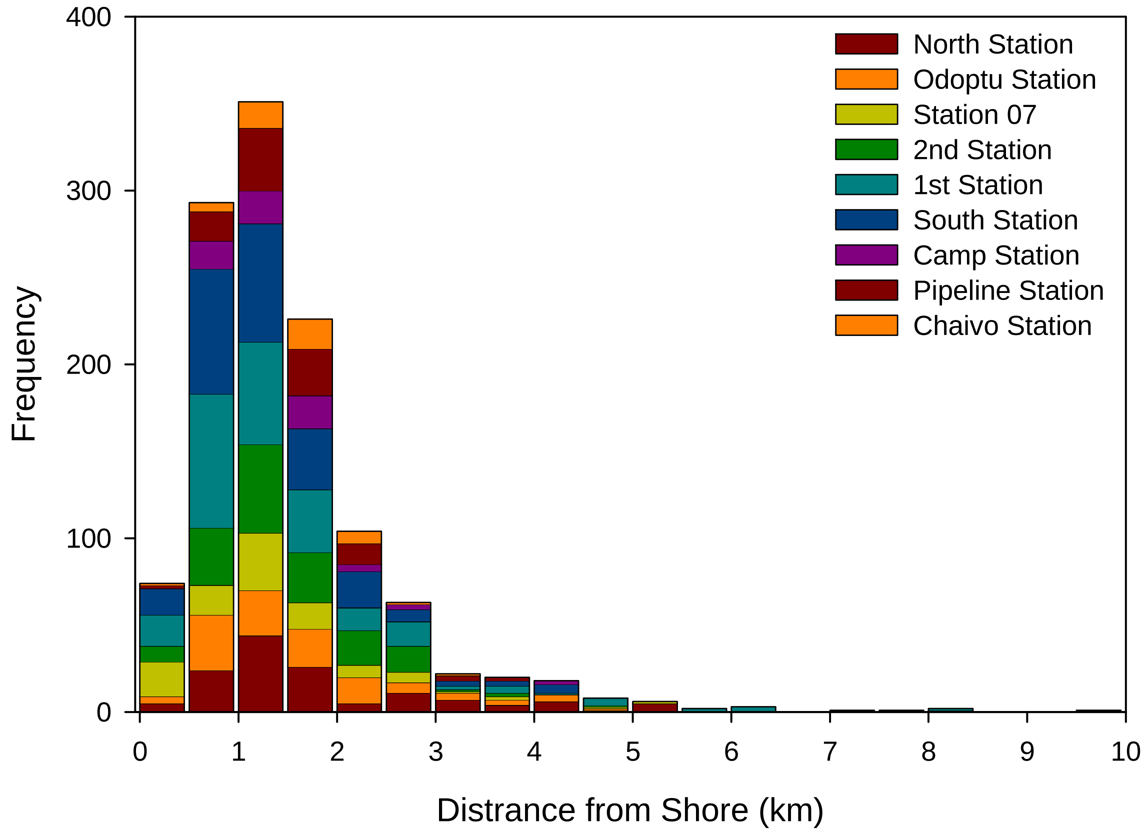

Figure 8. Distance of western gray whale sightings from shore off Sakhalin Island, summer 2006.

Table 5. Distance of western gray whales from shore at nine shore-based stations. Sample size represents number of sightings of gray whales.

Stations	Mean(km)	Median (km)	SD (km)	N
North Station	1.9	1.4	1.31	139
Odoptu Station	1.7	1.4	1.12	118
Station 07	1.3	1.2	0.93	103
2nd Station	1.5	1.4	0.79	161
1st Station	1.5	1.2	1.37	236
South Station	1.4	1.2	0.79	229
Camp	1.5	1.3	0.71	63
Pipeline	1.5	1.4	0.63	99
Chaivo	1.6	1.6	0.56	47
Total	1.5	1.3	1.03	1195

Morning vs. Afternoon - No significant difference in the number of whales ($\chi^2 = 0.85$, P = 0.36) or pods ($\chi^2 = 0.55$, 0.46) were detected in the morning and afternoon periods of each day (

). In the morning, the mean number of whales was 3.4 ± 3.37 SD (Median = 3, Range: 0-17, N = 172); and in the afternoon, the mean number of whales was 3.7 ± 3.28 (3, 0-15, 204). In the morning, the mean number of pods was 2.8 ± 2.59 (2, 0-12, 172); and in the afternoon, the mean number of pods was 2.9 ± 2.46 (3, 0-11, 204).

A.

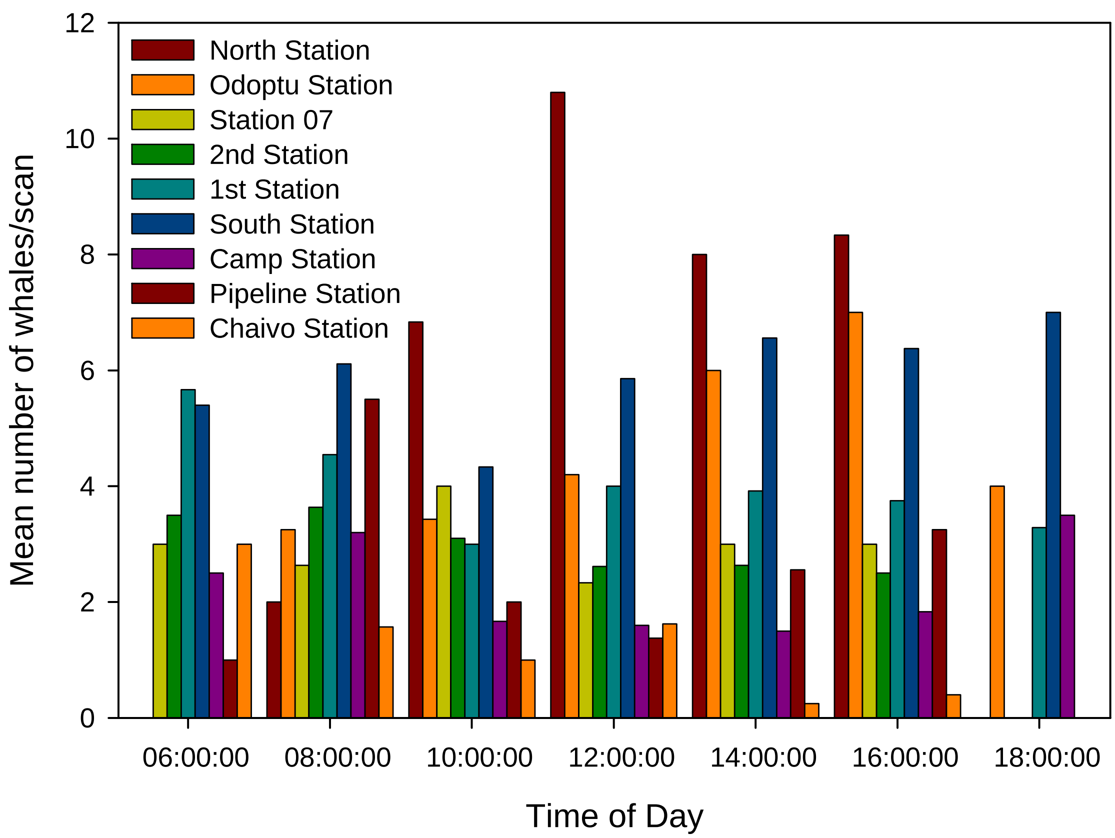

Figure 9. Mean number of whales (A) and pods (B) per time of day at nine shore-based stations (continued on next page).

B.

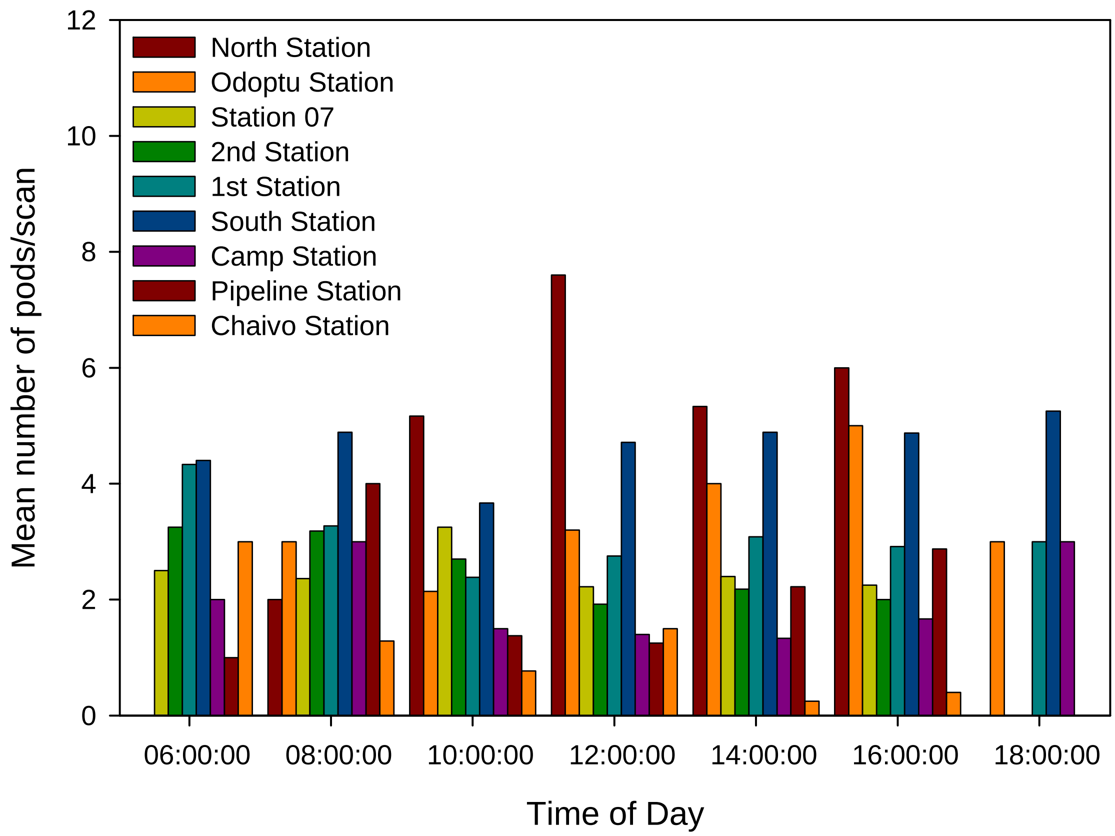

Figure 9 continued.

Stations – The mean numbers of whales and pods observed for the season among stations were significantly different (whales F = 111.1, df = 8, P < 0.001; pods 105.6, 8, <0.001), with more whales and pods at the northern most shore station (North Station, $\overline{\chi}$ = 8.1 ± 3.73 SD whales and 5.8 ± 2.55 pods) on average for the season (Table 7). Season was included as a covariate to explain variation for different temporal periods (see below). Post-hoc comparisons found that:

- All southern stations (Camp Station, Pipeline station, and Chaivo Station) were not significantly different among one another;
- Chaivo Station was significantly different from all northern stations;
- Odoptu Station, Station 07, 2nd Station, 1st Station, Campsite, and Pipeline stations had similar number of whales and pods among each other;

- North Station was significantly higher in numbers of whales and pods than all other stations except South Station; and
- South Station had significantly higher number of whales than all other stations except North and Odoptu Station.

Although there tended to be more whales to the northern regions, there was also a great degree of temporal variability. In late June through July, few whales were observed at the southern locations near the dredging activity; however, later in the season (August through September) there were more whales observed in the southern region. In general, the northern six locations (Piltun Area) had significantly ($\chi^2 = 68.6$, $P < 0.001$) more whales than the three southern locations (Chaivo Area). The overall number of whales observed in the Piltun Area was a mean of 4.3 ± 3.10 (median = 4, range = 0-16, N = 256), while the mean number of whales at the Chaivo Area was 2.0 ± 3.25 (1, 0-17,120). Temporally, there were significant ($F = 82.1$, df = 1, $P < 0.0001$) season affects with more whales observed at almost all stations later in the season (August – September) than during the early part of the season. However, North Station, South Station, and Station 07 had non-significant changes in number of whales for the entire season (Table 6). Despite the seasonal affects and shifts of higher abundance in the Chaivo Area later in the season, whales remained significantly ($F = 64.5$, df = 3, $P < 0.001$) higher in the northern regions for both seasons (June – July and August – September).

Table 6. Relative abundance of western gray whales from June-July and August-September.

Station	June - July	August - September
North Station	8.4 ± 5.13 (8)	7.9 ± 2.78 (13)
Odoptu Station	2.4 ± 3.13 (10)	5.9 ± 2.47 (13)
Station 07	2.7 ± 2.09 (15)	3.1 ± 1.33 (24)
2nd Station	1.7 ± 2.12 (25)	3.9 ± 2.12 (31)
1st Station	2.7 ± 1.75 (30)	4.9 ± 1.88 (39)
South Station	6.1 ± 2.37 (15)	5.9 ± 4.01 (33)
Campsite Station	0.6 ± 1.51 (7)	2.5 ± 2.57 (25)
Pipeline Station	0.8 ± 1.42 (24)	5.4 ± 5.1 (19)
Chaivo Station	0.4 ± 0.8 (27)	2.4 ± 3.45 (18)

Table 7. Number of whales (A) and pods (B) detected at nine shore-based stations. Sample size is represented by the number of scans per station.

A.

Station	Mean	Median	SD	Range	N
North Station	8.1	8	3.73	2-15	21
Odoptu Station	4.4	5.5	3.24	0-10	23
Station 07	2.9	3	1.65	1-7	39
2nd Station	2.9	3	2.38	0-8	56
1st Station	3.9	3.5	2.12	0-10	69
South Station	6.0	6	3.55	0-16	48
Campsite Station	2.1	1	2.49	0-8	32
Pipeline Station	2.8	1	4.22	0-17	43
Chaivo Station	1.2	0	2.44	0-10	45
Total	3.6	3.0	3.3	0-17	376

B.

Station	Mean	Median	SD	Range	N
North Station	5.8	5.5	2.55	2-11	21
Odoptu Station	3.2	3.0	2.57	0-9	23
Station 07	2.5	3.0	1.27	1-5	39
2nd Station	2.4	2.0	1.98	0-8	56
1st Station	3.0	3.0	1.64	0-8	69
South Station	4.7	5.0	2.52	0-11	48
Campsite Station	1.8	1.0	2.16	0-11	32
Pipeline Station	2.3	1.0	3.31	0-11	43
Chaivo Station	1.0	0.0	2.03	0-12	45
Total	2.8	2.0	2.52	0-12	376

Theodolite Tracklines

Gray whales were tracked for at total of 235 hrs ($\overline{\chi}$ = 53 min/track), ranging from 5 min to 7 hrs of continuous monitoring of movement patterns (Table 8). We recorded a total of 263 different tracklines with 12,536 geographic positions (Figure 10).

Table 8. Summary of trackline data gathered at nine shore-based stations.

Station	# Tracklines	Mean Duration (min.)	Range (min)
North Station	26	47.5	6 - 119
Odoptu Station	25	67.9	6 - 197
Station 07	31	70.0	5 - 290
2nd Station	33	60.8	10 - 176
1st Station	49	45.4	6 - 258
South Station	31	43.2	5 - 178
Campsite Station	17	41.1	9 - 174
Pipeline Station	37	35.1	5 - 79.9
Chaivo Station	14	88.1	6 - 421
Total	263	53.0	5 - 421

The analytical data set, consisting of only recognizable or single individuals, yielded 140 tracklines that were suitable for analysis (Table 9). On average, gray whales were observed moving 2.6 ± 2.12 SD km/h (Median = 1.7, Range = 0.2 - 9.3; Figure 11), accelerating 0.03 ± 0.268 km/h (0.01,-0.57 – 1.03; Figure 12), reorienting 19.5 ± 15.92 °/min (14.8, 1.0 – 64.2; Figure 13), and ranging 39.6 ± 35.91 m/min (25.8, 2.1 – 153.1; Figure 16). The mean vector length and linearity index were 0.78 ± 0.246 (0.89, 0.09 – 1.00; Figure 14) and 0.82 ± 0.236 (0.92, 0.09 – 1.00; Figure 15), respectively. These directional indices indicate a more straight-line path movement as opposed to a non-directional feeding type behavior.

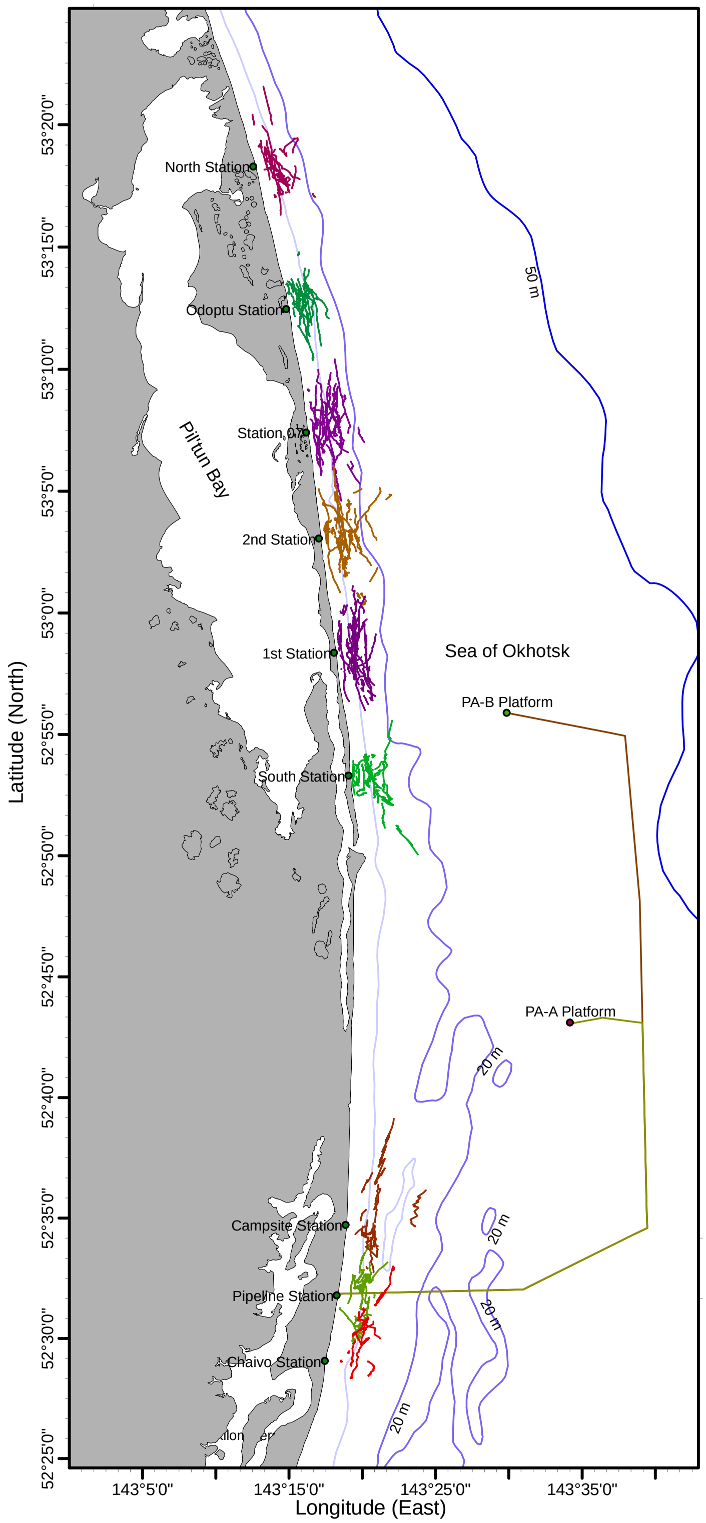

Figure 10. Tracklines of western gray whales at nine shore-based positions on Sakhalin Island during summer 2006 (N = 263).

Table 9. Summary data for trackline analysis of western gray whales during summer 2006.

N = 140	Mean	Median	Min	Max	SD
Leg Speed (km/h)	2.6	1.7	0.2	9.3	2.12
Reorientation Rate (°/min.)	19.5	14.8	1.0	64.2	15.92
Acceleration (km/h)	0.03	0.01	-0.57	1.03	0.268
Mean Vector Length	0.78	0.89	0.09	1.00	0.246
Linearity Index	0.81	0.92	0.09	1.00	0.236
Ranging Index (m/min.)	39.6	25.8	2.1	153.1	35.91

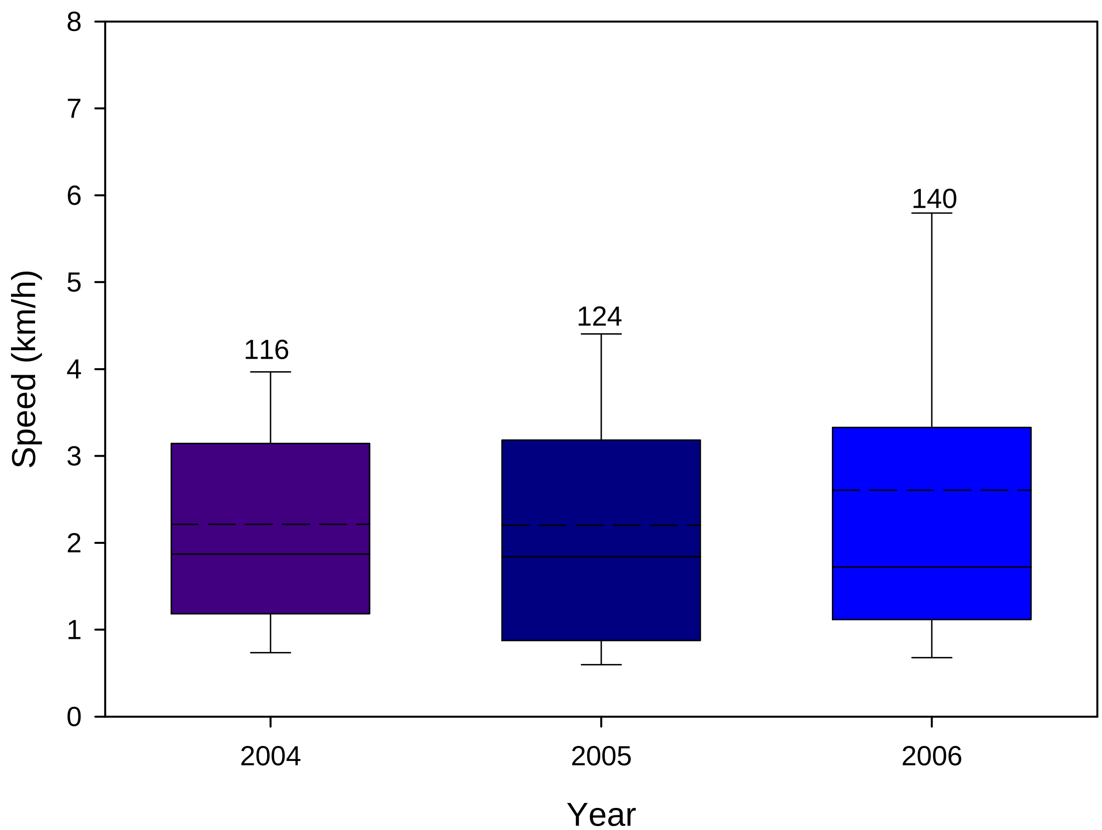

Figure 11. Leg Speed for all single or recognizable individual gray whales observed at six (2004-2005) to nine (2006) shore-based stations. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

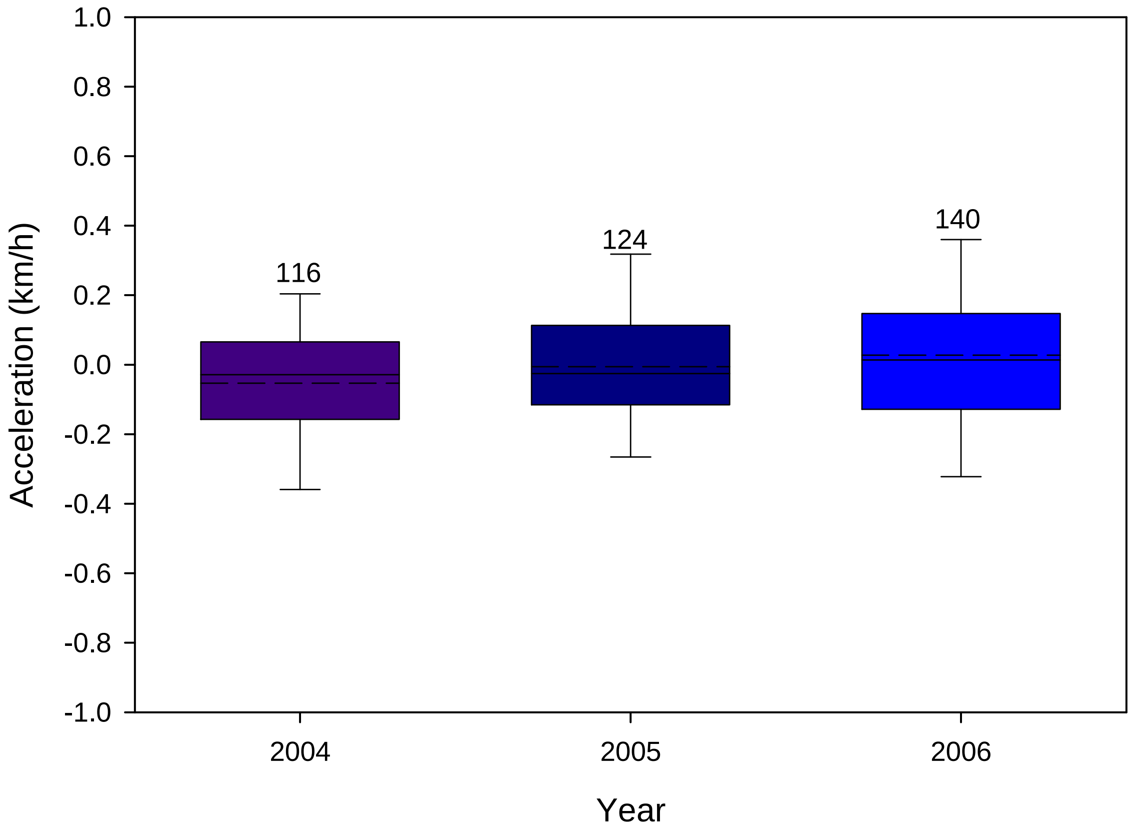

Figure 12. Acceleration for all single or recognizable individual gray whales observed at six (2004-2005) to nine (2006) shore-based stations. The negative values of acceleration represent deceleration. Display as in Figure 11.

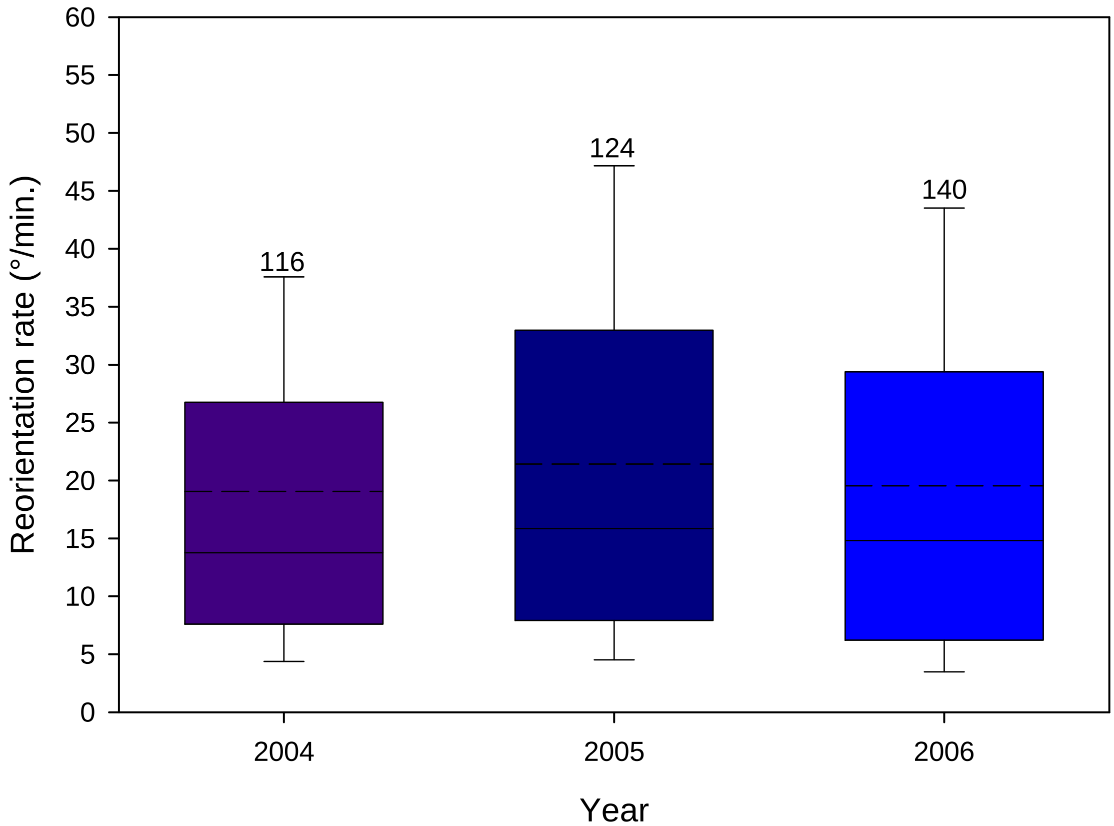

Figure 13. Reorientation rate for all single or recognizable individual gray whales observed at six (2004-2005) to nine (2006) shore-based stations. Display as in Figure 11.

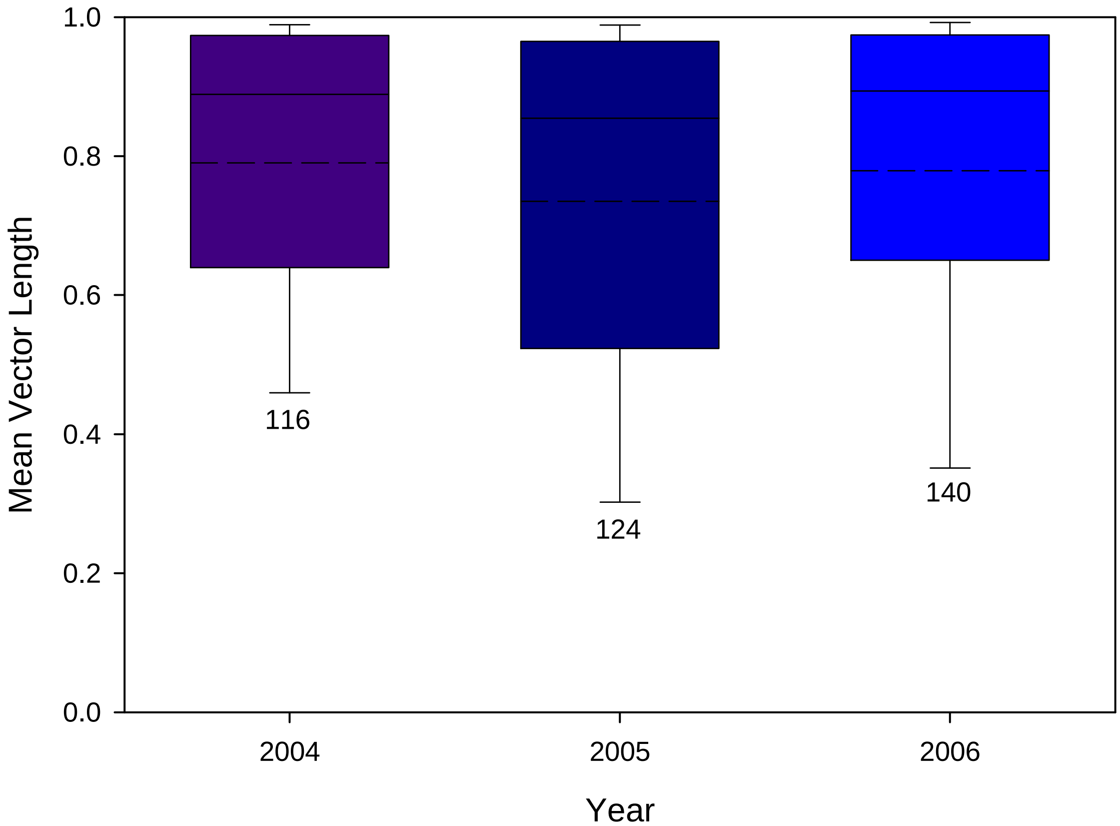

Figure 14. Mean vector length for all single or recognizable individual gray whales observed at six (2004-2005) to nine (2006) shore-based stations. Display as in Figure 11.

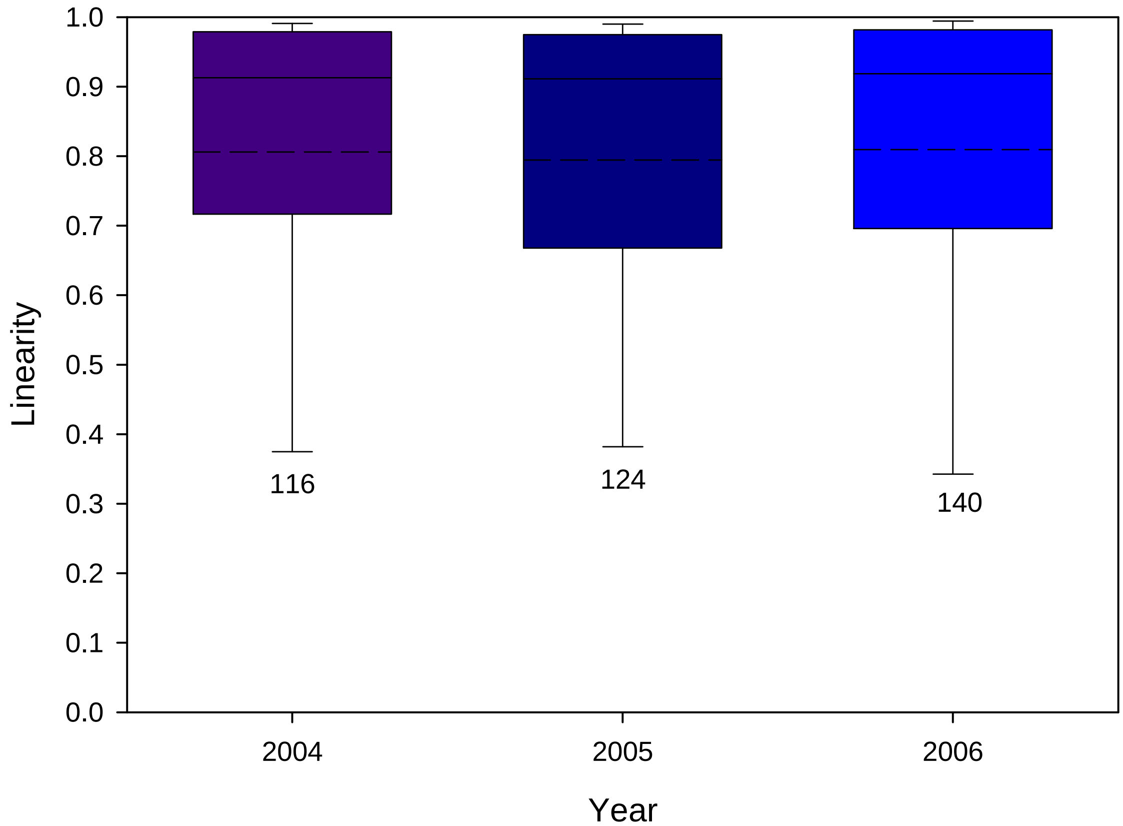

Figure 15. Linearity index for all single or recognizable individual gray whales observed at six (2004-2005) to nine (2006) shore-based stations. Display as in Figure 11.

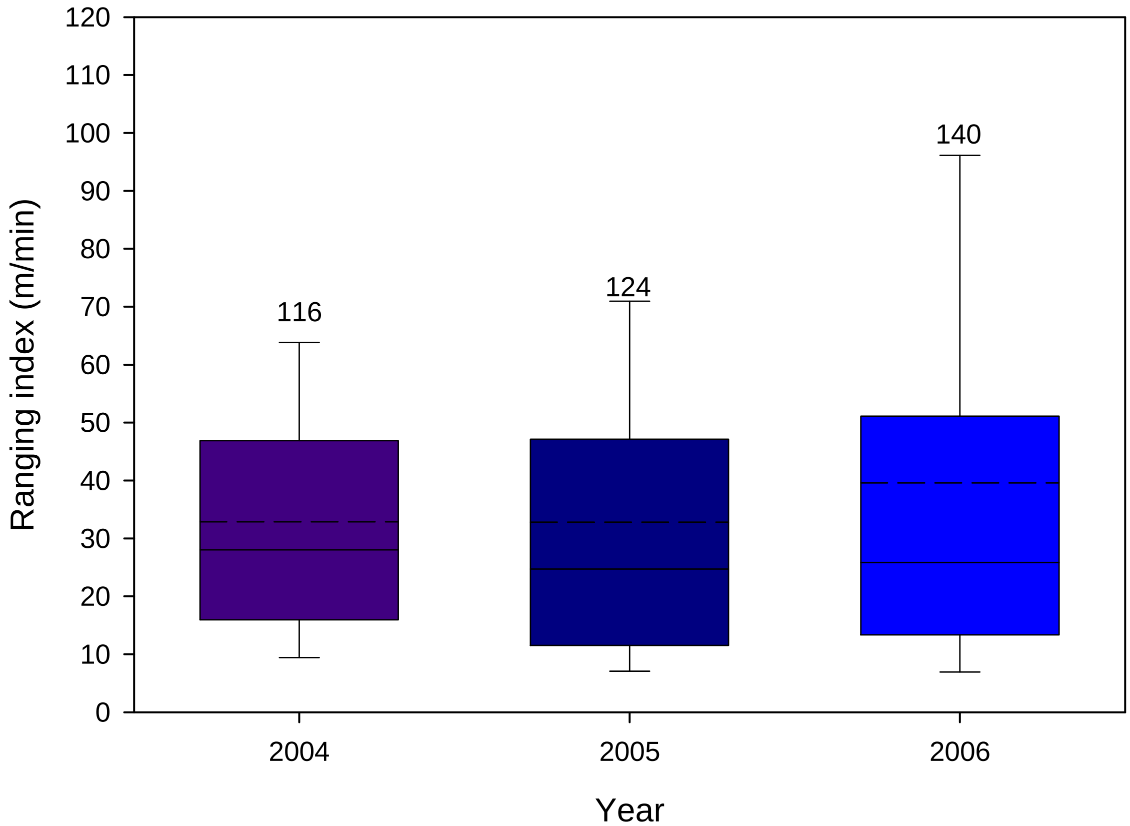

Figure 16. Ranging index for all single or recognizable individual gray whales observed at six (2004-2005) to nine (2006) shore-based stations. Display as in Figure 11.

Focal Behavior Observations

Focal behavioral observations were conducted for a total of 62 hrs, on 81 individual gray whales from 29 June to 25 September 2006 (Table 10). The mean duration of a focal session lasted approximately 55 min, and a total of 6614 behavior events were recorded.

Table 10. Summary of focal behavior data gathered at six shore-based stations.

Station	# Focals	Mean Duration (min.)	Range (min)
North Station	6	38.3	14 - 108
Odoptu Station	8	49.1	19 - 77
Station 07	15	80.3	20 - 265
2nd Station	13	47.3	14 - 113
1st Station	13	46.1	10 - 167
South Station	11	53.5	12 - 164
Campsite Station	4	80.4	33 - 215
Pipeline Station	7	33.2	16 - 63
Chaivo Station	4	64.8	33 - 88
Total	81	54.85	10 - 265

The analytical data set yielded 81 focal follows. On average, individual gray whales had a blow interval of 0.40 ± 0.209 SD blows per minute (Figure 17), with 6.15 ± 6.726 (Figure 18) blows per surfacing. The time that individuals were observed at the surface was 1.99 ± 3.133 (Figure 17) minutes, while individuals dove for 2.37 ± 1.126 (Figure 17) minutes. The dive surface blow rate and surface blow rate were 1.26 ± 0.476 (Figure 18) blows per minute and 4.39 ± 1.937 (Figure 18) blows per minute, respectively (Table 11).

Table 11. Summary statistics for surface-respiration-dive parameters of individual western gray whales.

N = 81	Mean	Median	Min	Max	SD
Blow Interval (per min.)	0.40	0.33	0.10	1.00	0.209
Blows/Surfacing	6.15	5.00	1.00	44.00	6.726
Surface Time (min.)	1.99	1.03	0.05	15.55	3.133
Dive Time (min.)	2.37	2.07	1.05	6.02	1.126
Surface Blow Rate	4.39	3.96	1.50	12.00	1.937
Dive-Surface Blow Rate	1.26	1.21	0.25	2.75	0.476

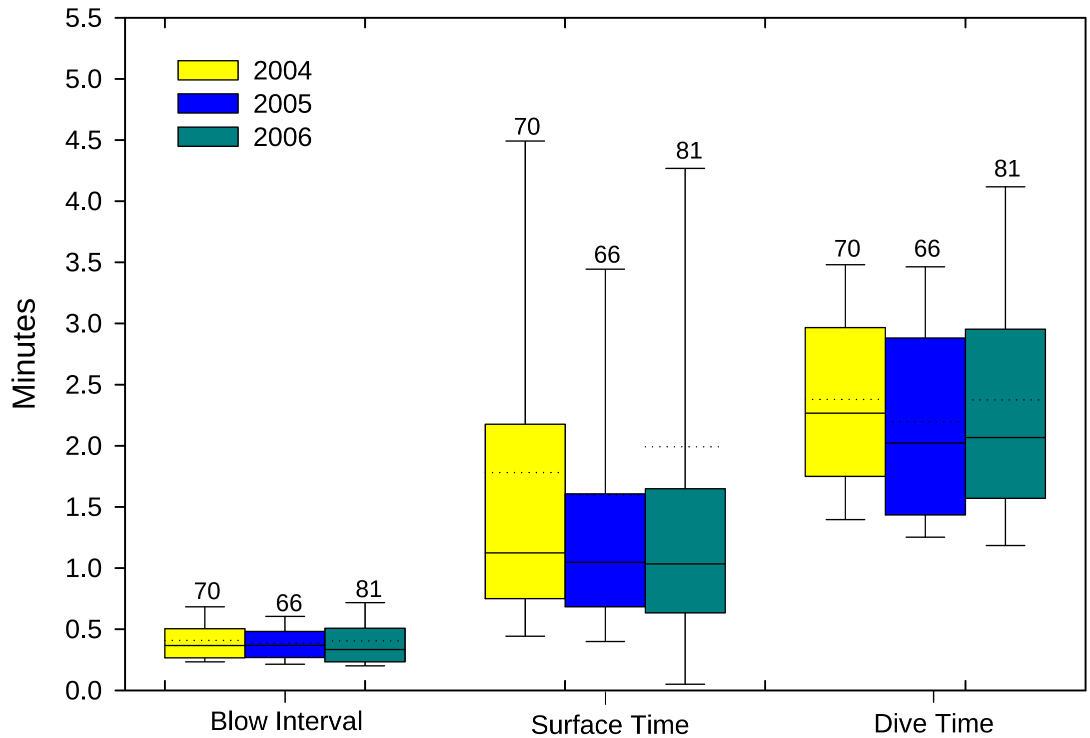

Figure 17. Blow interval, surface time, and dive time parameters of western gray whales. Display as in Figure 11.

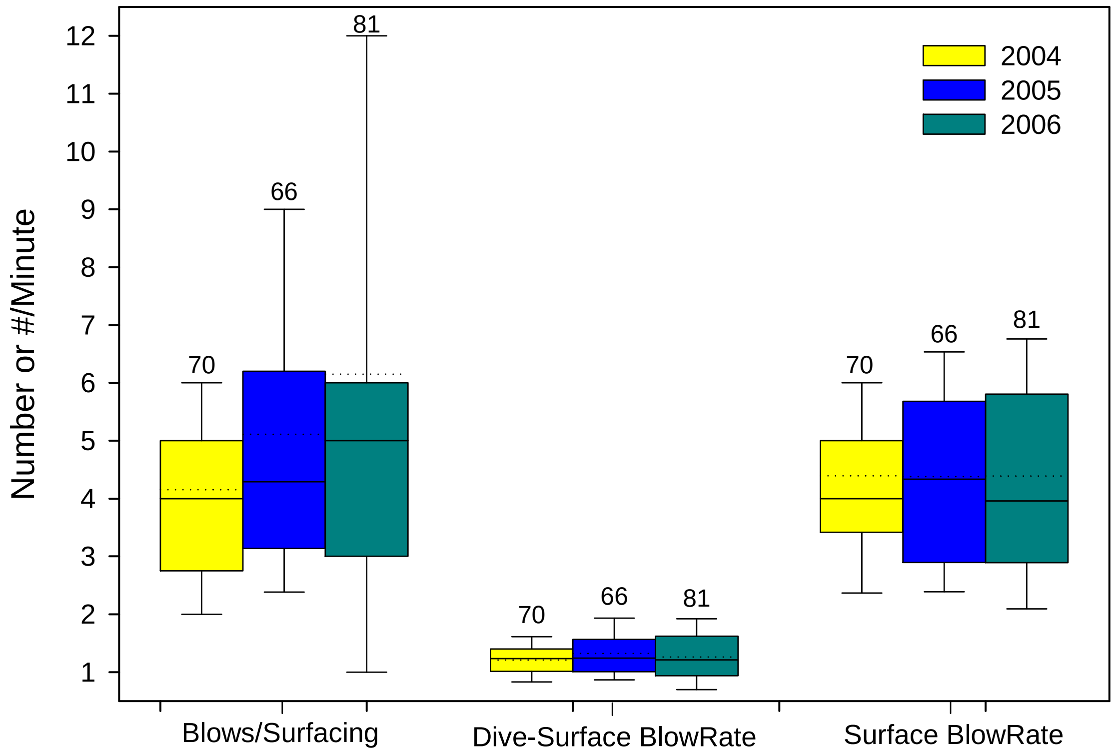

Figure 18. Number of blows per surfacing, dive-surface blow rate, and surface blow rate of western gray whales. Display as in Figure 11.

Behavior

Three main behavioral states were observed during the 2006 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. Although other behavioral states were observed, such as milling, socializing, and resting, there are too few occurrences of these behavioral states to provide a detailed analysis.

The gray whales' speeds (F = 72.2, df = 2, P = <0.001), reorientation rates (104.9, 2, <0.001), ranging indices (93.7, 2, <0.01), linearity (93.3, 2, <0.001) and mean vector length (80.4, 2, <0.001) were significantly different among the three behaviors. Respiration interval (22.0, 2, <0.001) was significantly lower during feeding than traveling and between feeding/traveling and traveling; but not between feeding/traveling and feeding. Gray whales were observed to spend significantly less time at the surface (8.66, 2, <0.01) while feeding compared to traveling behavior. The surface-blow rate was also found to be significantly different (19.7, 2, <0.01) among all three behaviors. Acceleration, distance-from-shore, dive time, and dive-surface blow rate were all non-significant among the three behavioral states (Table 12, Figure 19 - Figure 31). The "displacement" of whales among the three behavioral states also revealed significant differences with individuals displacing 0.05 km^2 (95% Confidence interval: 0.03 – 0.06 km^2), 0.55 km^2 (0.31 - 0.79 km^2), and 3.98 km^2 (3.07 – 4.78 km^2) during feeding, feeding/traveling, and traveling behavioral states, respectively, after 20 steps (i.e. 30 minutes) (Figure 32). In comparison to previous years, feeding and feeding/traveling "displacement" behavior appear to be within the same confidence intervals observed in 2004 and 2005. However, traveling behavior was significantly higher than those observed in 2004 and 2005.

Table 12. Movement and respiration variables of western gray whales during feeding, feeding/traveling, and traveling behavioral states. 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/hr)	1.0 ± 0.64 (40)	1.7 ± 1.08 (43)	4.1 ± 2.15 (78)	72.22	< 0.001	F-T, FT-T, FT-F
Reorientation rate (/min)	38.3 ± 13.82 (40)	19.8 ± 12.66 (43)	9.2 ± 6.65 (78)	104.95	< 0.001	F-T, FT-T, FT-F
Linearity Index	0.5 ± 0.26 (40)	0.8 ± 0.21 (43)	0.9 ± 0.10 (78)	93.33	< 0.001	F-T, FT-T, FT-F
Mean vector length	0.5 ± 0.21 (40)	0.8 ± 0.23 (43)	0.9 ± 0.10 (78)	80.37	< 0.001	F-T, FT-T, FT-F
Acceleration (km/hr)	0.0 ± 0.13 (40)	0.0 ± 0.25 (43)	0.1 ± 0.3 (78)	1.64	0.200	
Ranging index (m/min)	11.1 ± 9.23 (40)	24.1 ± 16.75 (43)	65.5 ± 35.01 (78)	93.73	< 0.001	F-T, FT-T, FT-F
Distance to shore	1.4 ± 0.57 (40)	1.5 ± 0.62 (43)	1.5 ± 0.71 (78)	1.11	0.332	
Respiration Interval (min)	0.27 ± 0.176 (30)	0.35 ± 0.210 (23)	0.55 ± 0.230 (39)	22.00	< 0.001	F-T, FT-T
Surface Time (min)	0.82 ± 0.576 (30)	1.61 ± 2.961 (22)	2.80 ± 3.251 (37)	8.66	< 0.001	F-T
Dive Time (min)	2.57 ± 1.116 (30)	2.44 ± 1.078 (22)	2.13 ± 1.041 (37)	1.72	0.185	
Dive-surface blow rate	1.25 ± 0.565 (30)	1.27 ± 0.430 (22)	1.33 ± 0.354 (37)	0.31	0.731	
Surface blow rate	5.91 ± 2.090 (30)	4.85 ± 1.722 (22)	3.33 ± 1.407 (37)	19.74	< 0.001	F-T, FT-T
Number Blows/Surface	4.43 ± 2.487 (30)	6.14 ± 8.609 (22)	7.00 ± 5.745 (37)	2.67	0.075	

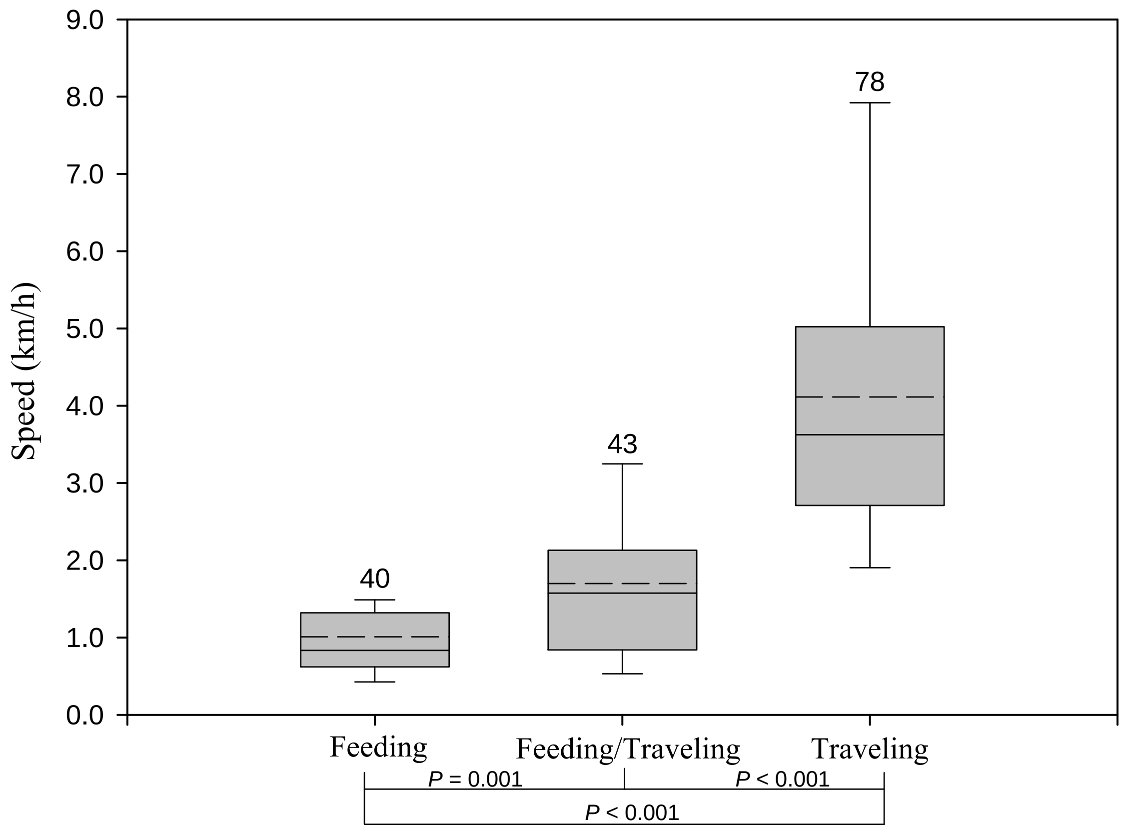

Figure 19. Speed of western gray whales during three behavioral states. Display as in Figure 11.

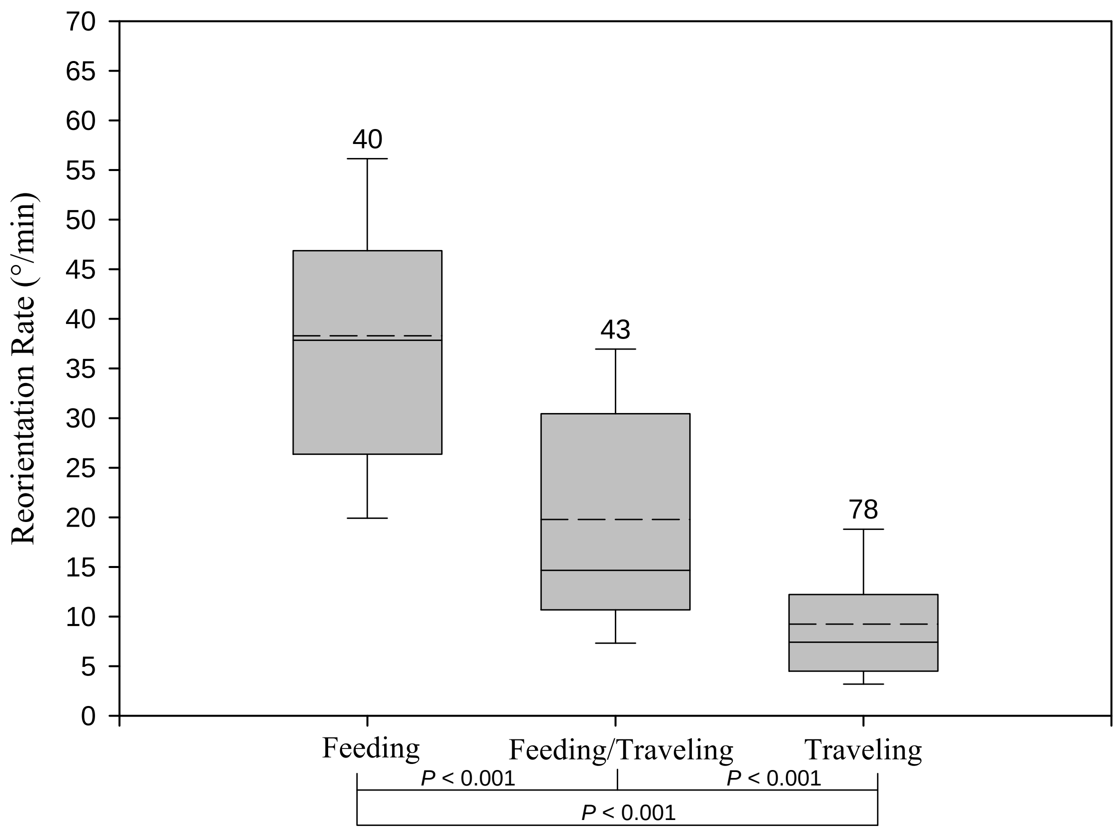

Figure 20. Reorientation rate of western gray whales during three behavioral states. Display as in Figure 11.

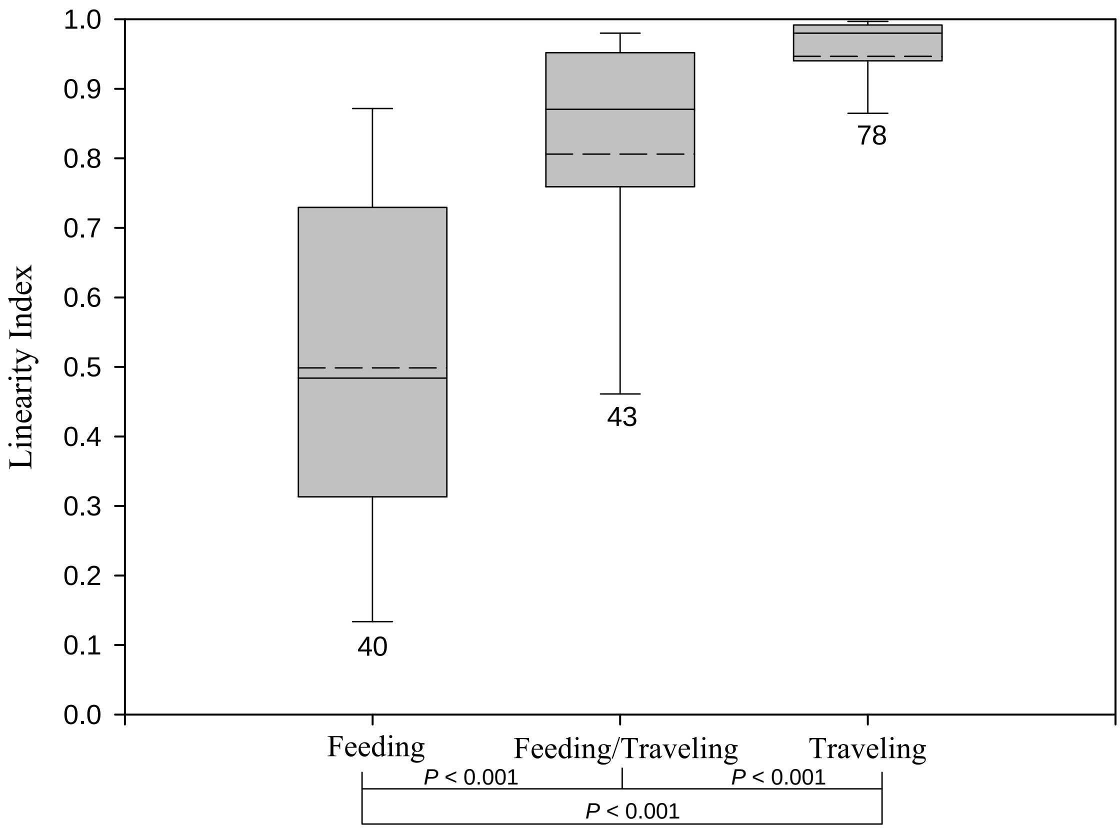

Figure 21. Linearity index of western gray whales during three behavioral states. Display as in Figure 11.

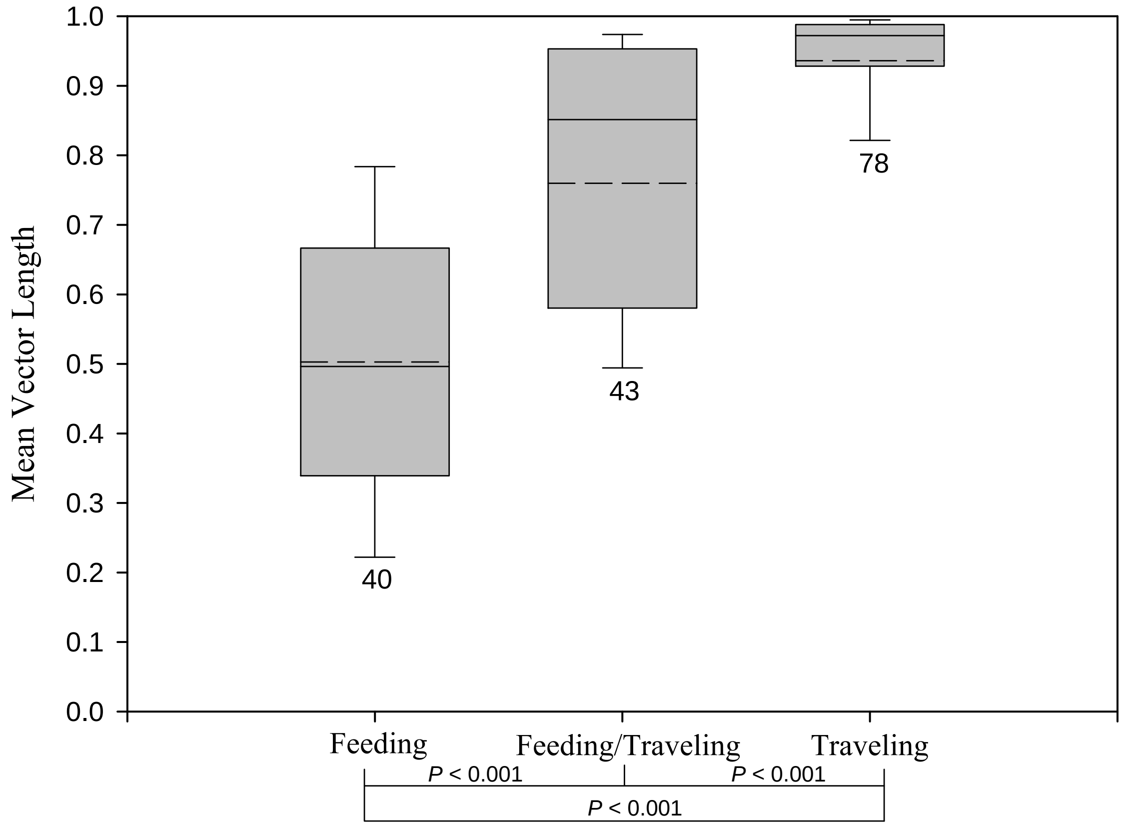

Figure 22. Mean vector length of western gray whales during three behavioral states. Display as in Figure 11.

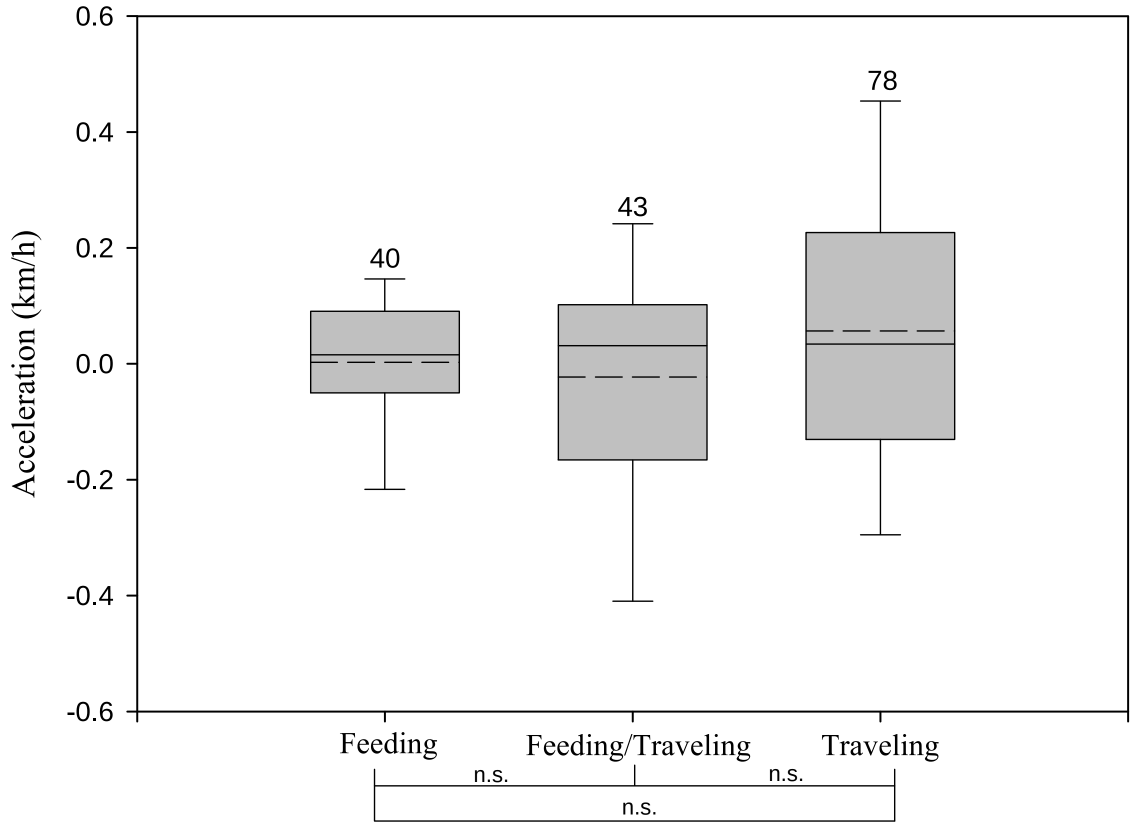

Figure 23. Acceleration of western gray whales during three behavioral states. Display as in Figure 11.

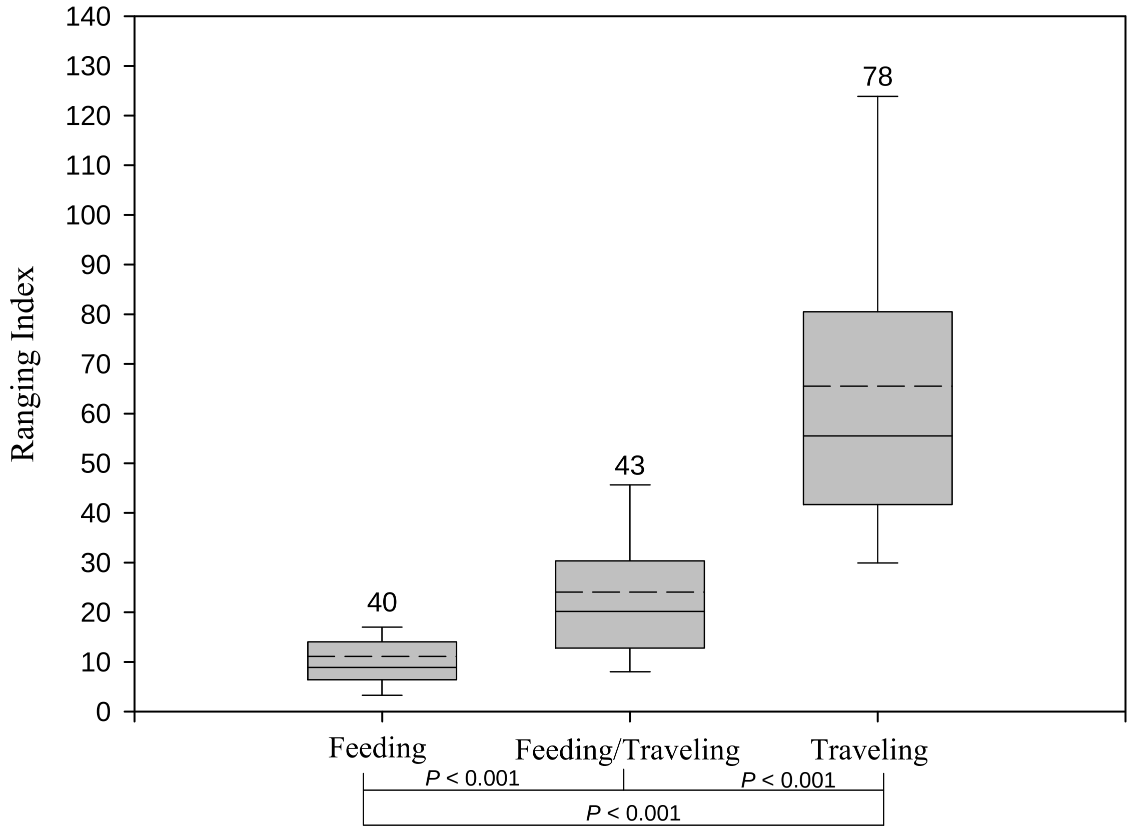

Figure 24. Ranging index of western gray whales during three behavioral states Display as in Figure 11.

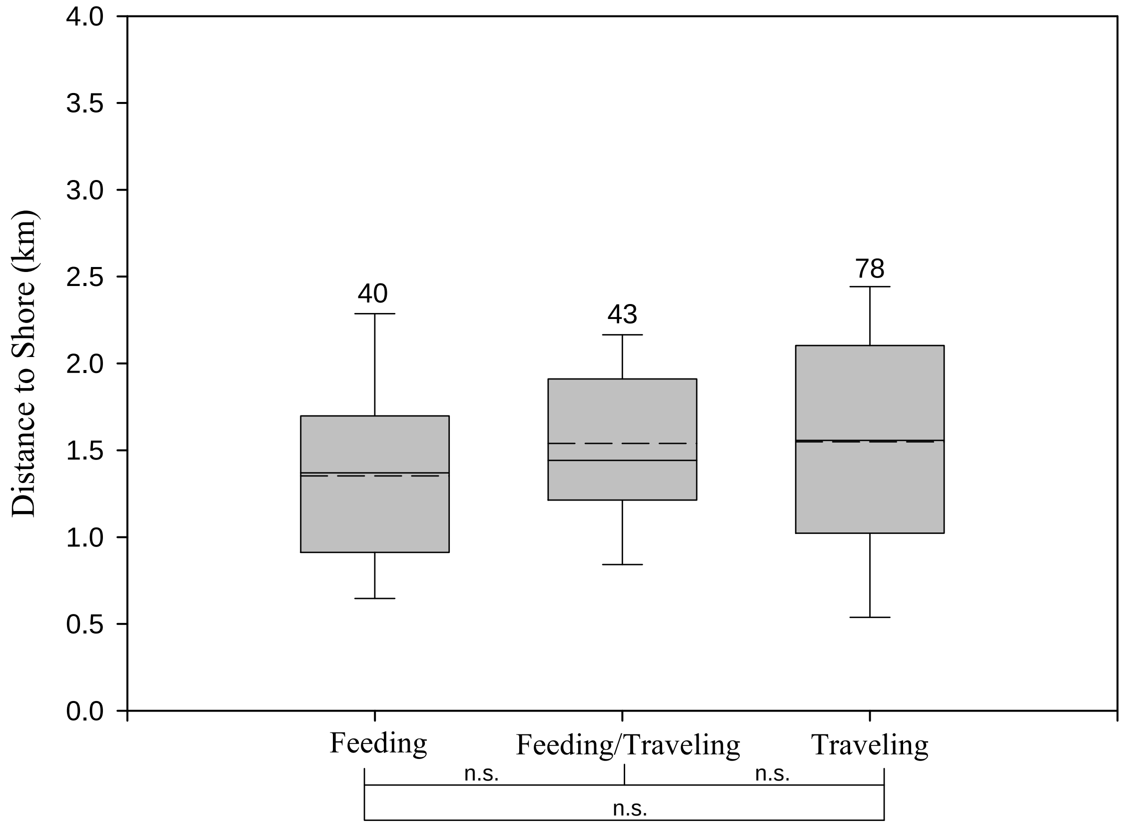

Figure 25. Distance to shore of western gray whales during three behavioral states. Display as in Figure 11.

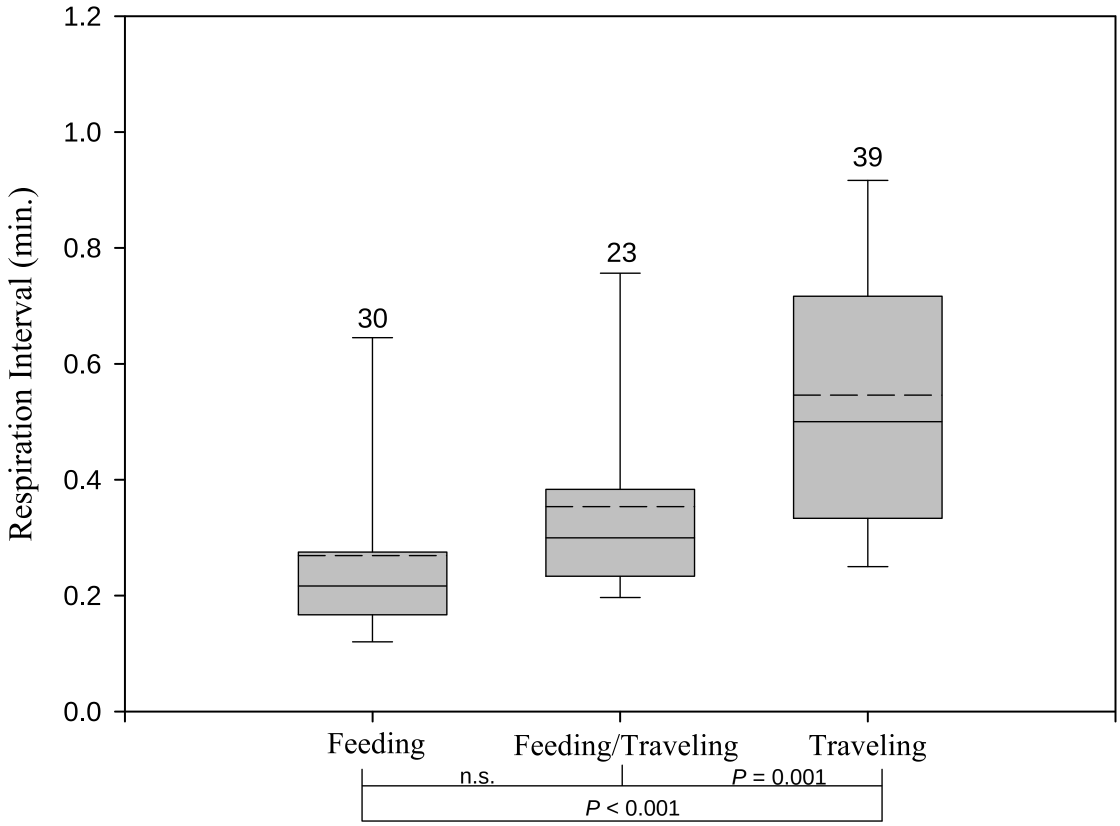

Figure 26. Respiration interval of western gray whales during three behavioral states. Display as in Figure 11.

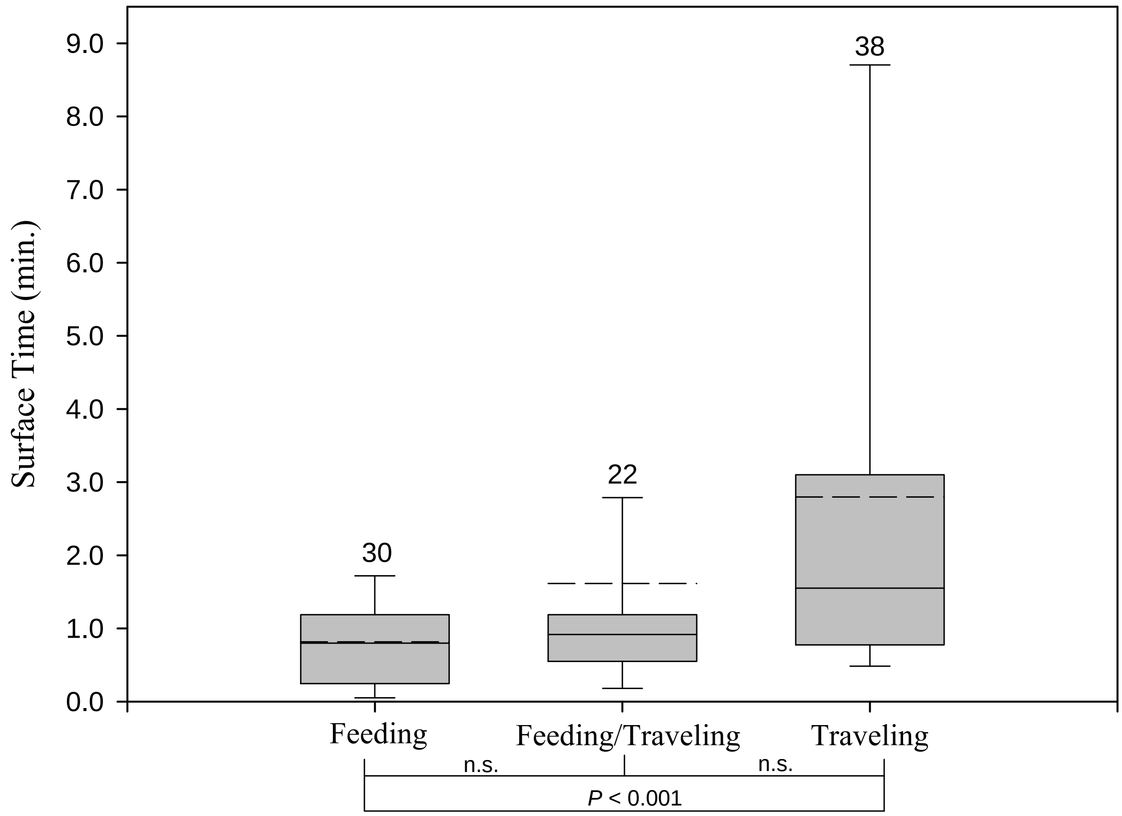

Figure 27. Surface time of western gray whales during three behavioral states. Display as in Figure 11.

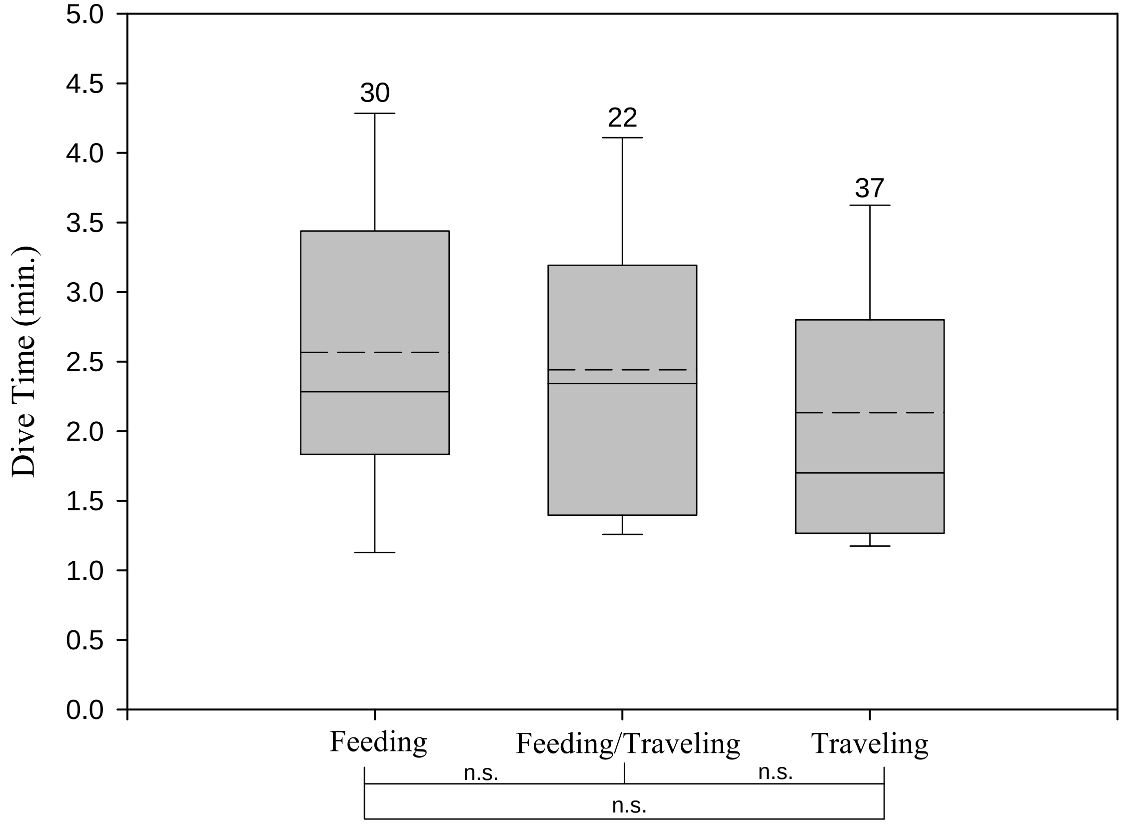

Figure 28. Dive time of western gray whales during three behavioral states. Display as in Figure 11.

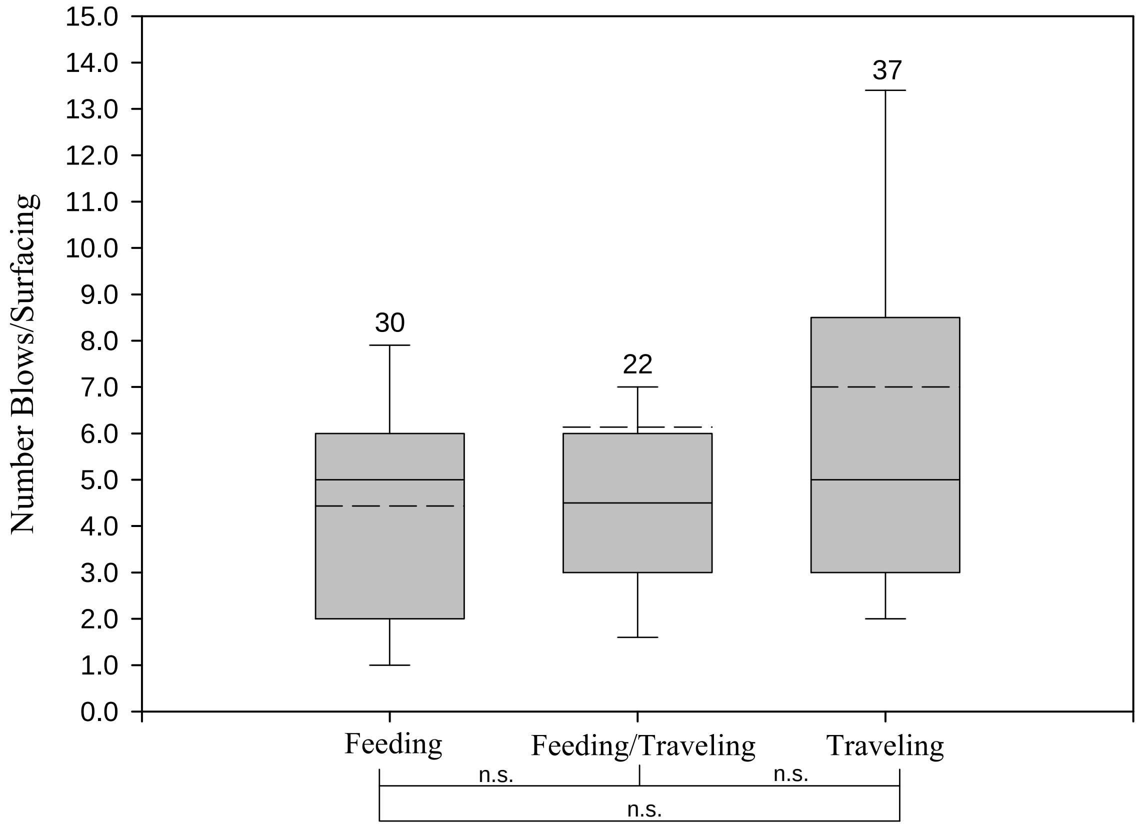

Figure 29. Number of blows per surfacing of western gray whales during three behavioral states. Display as in Figure 11.

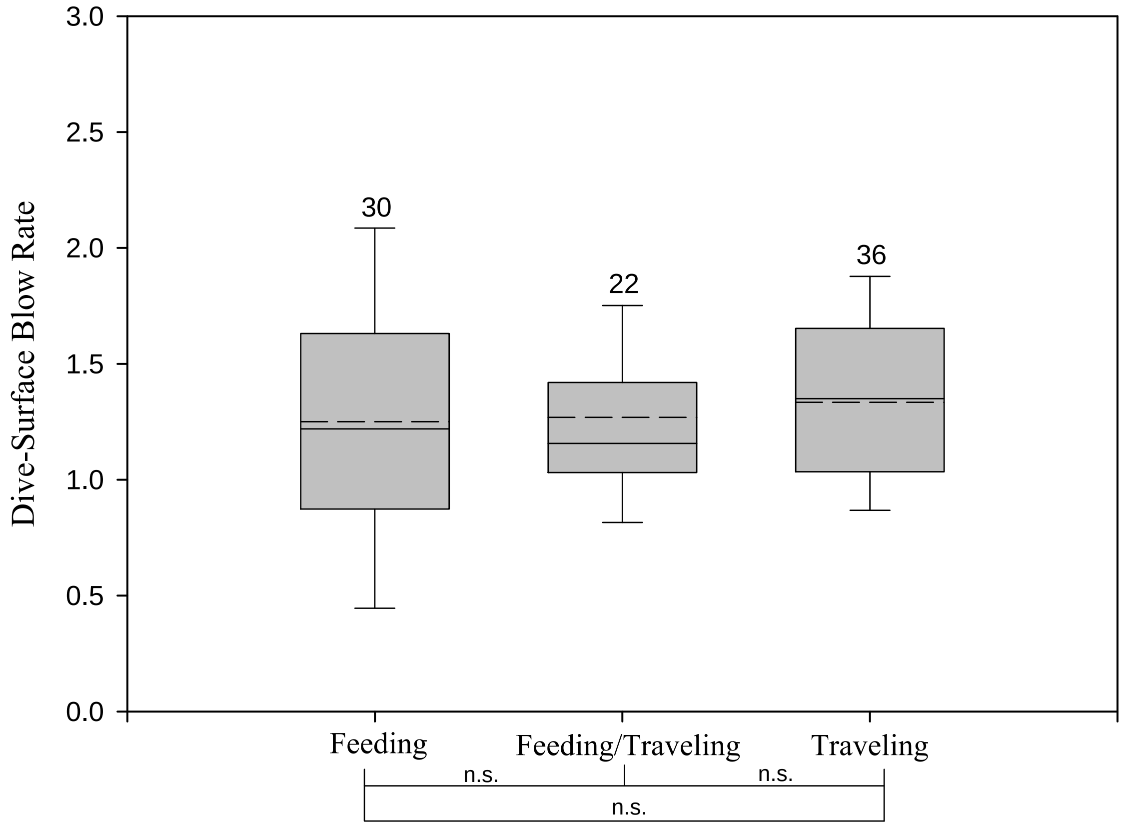

Figure 30. Dive-surface blow rate of western gray whales during three behavioral states. Display as in Figure 11.

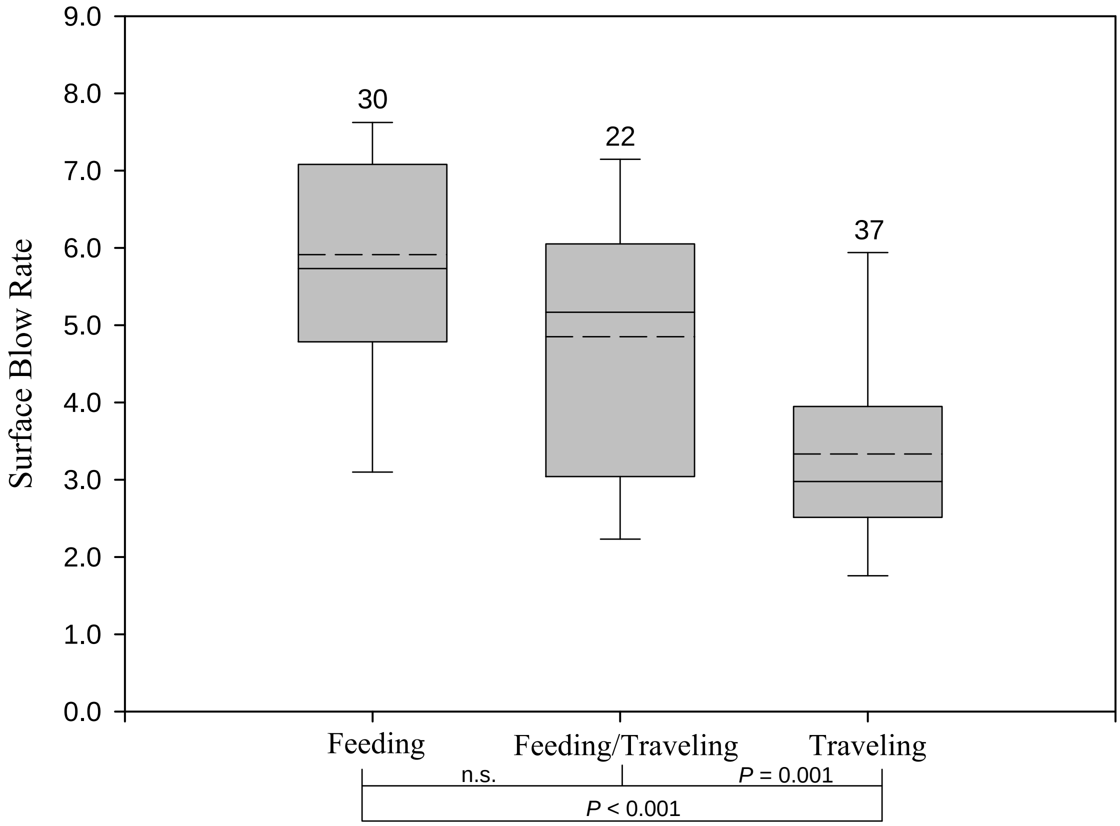

Figure 31. Surface blow rate of western gray whales during three behavioral states. Display as in Figure 11.

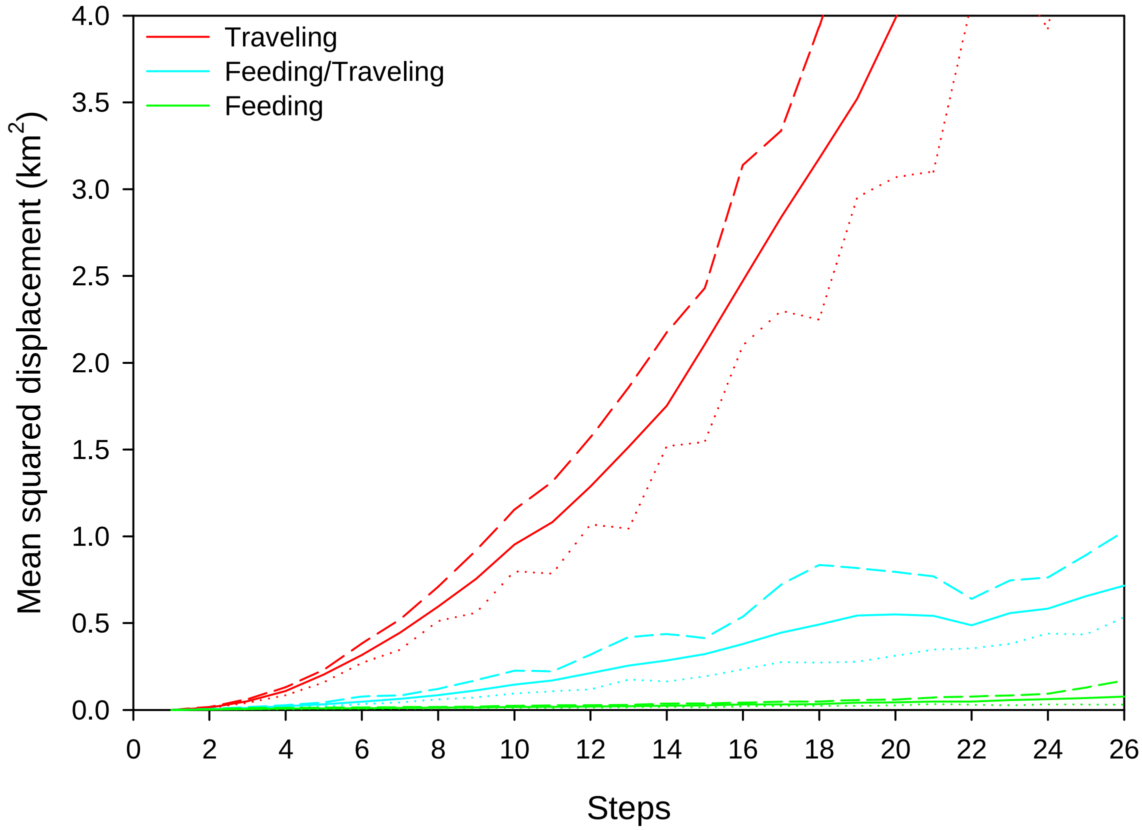

Figure 32. Mean squared displacement of western gray whales during three behavioral states. The upper and lower 95% confidence intervals are represented by dashed and dotted lines, respectively.

Social Activity – In comparison to previous years (but similar to 2005), very few occasions of social activity were observed during the 2006 field season. The first observation of social activity occurred on 23 August (North Station). A group of 3-4 individuals was tracked for 1.5 hrs at 2.4 – 3.8 km from the shore. Playing/social behaviors with breaching (six times) were observed during this period. Another social bout was observed on 16 September at South Station. A group of at least four individuals was sighted at distance more than 4 km from shore. 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.

Killer Whales

Three groups of killer whales were observed during the 2006 field season. On 6 September, a group of two individuals was observed at South Station (2.5 km from shore) during the scan. The minimal distance between killer whales and gray whales was 2.2 km. Another group of two individuals was sighted during two consecutive scans at North Station (2.7 and 3.0 km from shore) on 15 September. During each killer whale sighting, gray whales were present in the study area. Killer whales approached within 2 km of a group of gray whales (6-9 individuals) feeding in the area. The closest approaches during two consecutive scan sessions were 2.6 and 2.2 km, respectively. During the above observations, no obvious changes were observed in gray whale behavior due to the presence of killer whales in the area. Mother calf pairs were not observed during the killer whales’ presence.

On 15 September, a group of 4-6 killer whales was observed from Odoptu Station to be within 20 m of a group of two adult gray whales. This group of killer whales is likely to have been the same group observed at the northern station several hours prior to this observation. The sighting occurred at the beginning of the trackline as the gray whales were moving into shore. Multiple blows of killer whales occurred alongside the gray whales for approximately 15 minutes of observations. The two adult gray whales were traveling alongside one another at an average speed of 6 km/h during the interaction. The group of killer whales then changed their movement and started to travel south, as the gray whales continued to travel northwest towards the shoreline (Figure 33). As the group of gray whales approached to approximately 1.5 km from shore, their speed of movement decreased to about 1 km/h and the two individuals were further spaced apart (approximately 50-200 m). Approximately two hours after the interaction with killer whales, the group of gray whales started traveling offshore in a northeast direction. This observation was the first obvious disturbance reaction of western gray whales to the presence of killer whales in the nearshore area.

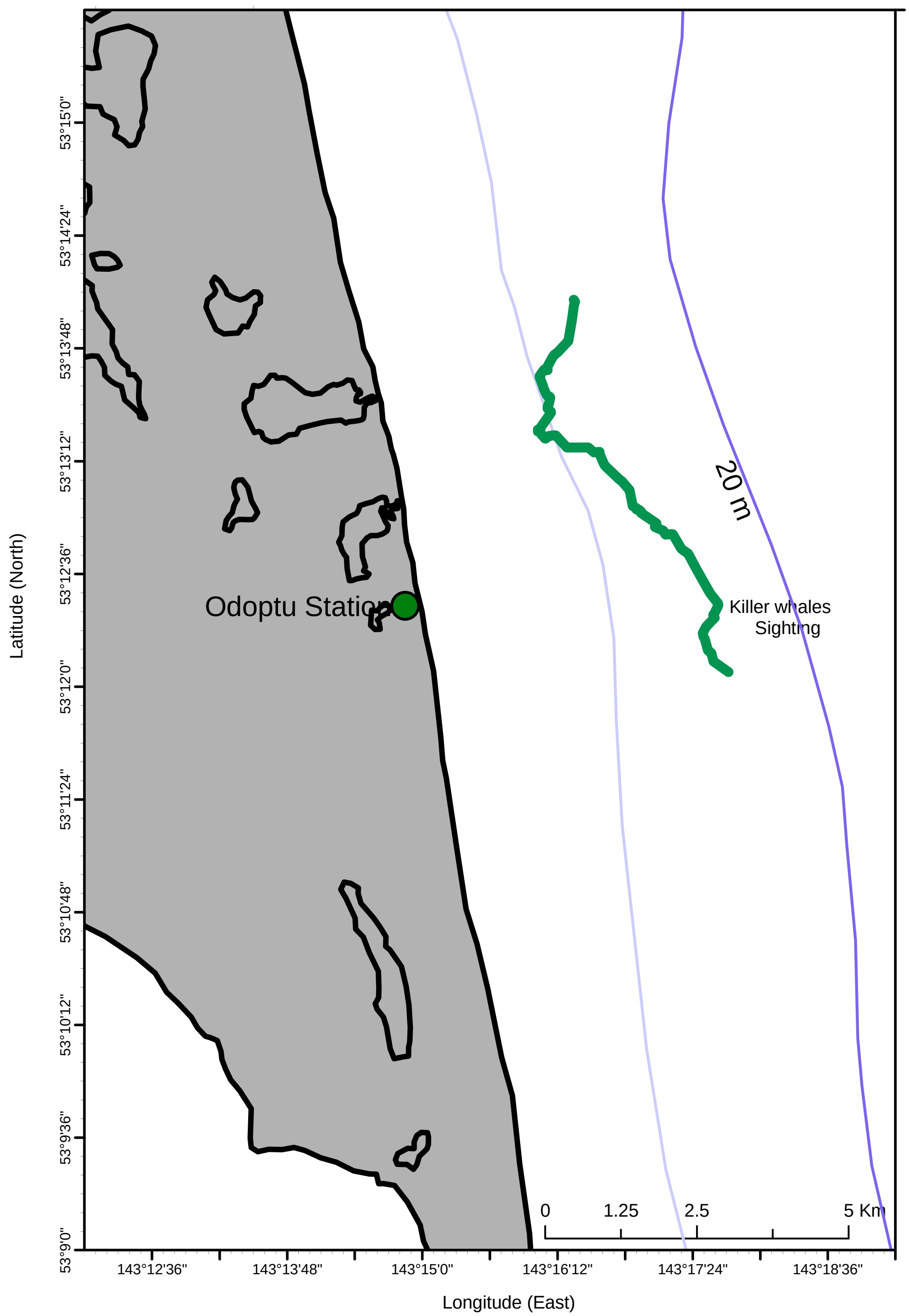

Figure 33. Trackline (duration = 2.4 hrs) of two adult gray whale movements during a killer whale interaction on 15 September 2006. "Killer whale sighting" marks the observation period of the killer whales near the gray whales.

DISCUSSION

The objective is this study is to better understand the behavior, distribution, abundance, habitat use, and movement patterns of western gray whales on their foraging grounds. In 2001, our first year of dedicated shore-based observations (with five stations, spaced closer together than in later years) resulted in initial baseline descriptions as well as behaviors potentially affected by a seismic survey in that summer (Würsig *et al.* 2002, Gailey *et al. in Press*). With the exception of a seismic survey late in the 2004 field season, the 2002-2004 observations were relatively free of anthropogenic activity, which provided needed "baseline" information to be used towards better understanding of western gray whales in an area where feeding is the primary activity. With some understanding of “natural” variability, we examine subtle indicators of behavioral response that could potentially affect 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. In this report, we compare 2006 information to previous years; however, these data have not been completely analyzed in relation to vessel and sound level information from pipeline construction and nearshore vessel activity that occurred. These analyses will be presented in a subsequent report.

Gray whales were present on almost every day of the 32 days of observations, indicating strong site fidelity to the Piltun and Chaivo feeding areas, most likely due to high concentrations of prey availability (114.1 g/m^2 concentrations for Amphipods; Fedeev 2002, 2003). Such fidelity for feeding gray whales has also been described for the eastern population (for example, Pike 1962, Hatler and Darling 1974, Würsig *et al.* 1986, Dunham and Duffus 2002), as well as the present one (Weller *et al.* 1999). Mean distance from shore in 2006 was 1.5 km, as compared to 2.1 km and 1.5 km in 2004 and 2005, respectively. Overall, whales on average were closer to shore in 2005 and 2006 than in all years except for 2001. One exception was at the northernmost station, where kernel density probability contours show a consistent feeding area in waters >1.5 km and >20 m deep. This feeding area has been apparent for the past three years when observations were initiated in this region. However, in 2006, this further from shore feeding area seemed to be utilized early in the season more than later on (August - September).

As in previous years, there can be great daily variability in the numbers of whales and pods in different regions. Gray whales are highly mobile animals, and can traverse several observation areas within one day. Nevertheless, there have been consistent trends. North and South Station had significantly more whales and pods than stations in between these two regions, as well as the Chaivo Area (Camp, Pipeline, and Chaivo Station) (Table 17). In addition, North and South Station were two of the few areas that did not appear to change in numbers of whales seasonally. This consistent pattern of utilization may indicate that these areas are especially vital as a feeding habitat. We expected to observe relatively few numbers of whales in the Chaivo region since past observations had yielded low relative abundance of whales and, therefore, the region was believed to be slightly outside of the known nearshore feeding habitat (Vladimirov 2005, 2006). From late June through July, the Chaivo Area had a relatively low abundance of approximately 0.6 whales per scan, but later in the season (August through September) the mean number of whales per scan was 3.4, with the highest mean number of whales (5.4 whales/scan) at Pipeline Station near the dredging activity.

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 (presently second-to northernmost) station, Odoptu (~5 km north of the 2001 northern station, Muritai) that had substantially more whales than any other station. Therefore, the northerly-occurring trend has now been ongoing for the past four years, but in the past two years there has been an increase in number of whales at South Station that is near the mouth of Piltun Lagoon. In the earlier part of the 2001 field season, seismic surveys were conducted in the Odoptu Block, in the more northern part of our study area, and some whales may have avoided this area during that period (Yazvenko *et al.* 2002).

There was no significant daily variation (AM vs. PM) in number of whales or pods, which has been consistent with previous years. However, sample sizes may be too small to detect daily variations, and other factors may contribute towards changes in abundance and distribution patterns. It would be informative to conduct a multivariate analysis, taking tide, weather conditions, seasonal, and temporal considerations into account. As Table 13 indicates, there has been a tendency in the past three years of an overall increase in number of whales and pods near-shore compared to observations conducted in 2001-2003. This increase could be related to the corresponding decrease of gray whales observed in the offshore feeding area (Vladimirov 2005, 2006, 2007).

Table 13. Summary of number of whales and pods per scan for 2001-2006. Stations proceed from highest latitude (North Station) to lowest latitude (Chaivo Station). Sightings between 0-20 and 160-180 where removed from 2004 - 2006 data sets to properly compare relative abundance of gray whales to the methods of 2001-2003 (see methods). Sightings from 2006 were also summarized from mid-July to September since this period was more typical of past field seasons; June contained lower numbers of whales, probably because they were still migrating to the feeding grounds in that early summer month.

	Number whales						
Staion	2001	2002	2003	2004	2005	2006	2006 -mid-July to September
North Station	-	-	-	5.7 ± 3.49 (23)	9.1 ± 4.70 (10)	6.6 ± 3.31 (21)	7.2 ± 2.99 (19)
Odoptu Station	-	8.4 ± 4.59 (16)	5.6 ± 4.31 (29)	12.2 ± 5.77 (24)	5.6 ± 4.52 (11)	3.7 ± 2.84 (23)	4.2 ± 2.63 (20)
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)	1.8 ± 1.61 (39)	1.9 ± 1.67 (32)
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)	2.3 ± 2.11 (56)	2.8 ± 2.02 (46)
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)	2.5 ± 2.03 (69)	2.6 ± 2.09 (58)
South Station	-	-	-	2.3 ± 2.35 (37)	5.5 ± 3.77 (16)	4.9 ± 2.91 (48)	4.8 ± 3 (44)
Campsite Station	-	-	-	-	-	1.2 ± 1.39 (32)	1.4 ± 1.32 (25)
Pipeline Station	-	-	-	-	-	2.2 ± 2.98 (43)	2.6 ± 3.12 (35)
Chaivo Station	-	-	-	-	-	1.2 ± 2.42 (45)	1.6 ± 2.76 (32)
	Number pods						
North Station	-	-	-	3.8 ± 2.10 (23)	6.1 ± 3.44 (10)	4.4 ± 2.34 (21)	4.7 ± 2.23 (19)
Odoptu Station	-	5.7 ± 2.85 (16)	4.4 ± 3.01 (29)	8.4 ± 3.83 (24)	3.9 ± 2.55 (11)	2.5 ± 2.06 (23)	2.9 ± 1.94 (20)
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)	1.5 ± 1.31 (39)	1.6 ± 1.36 (32)
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)	1.9 ± 1.74 (56)	2.3 ± 1.66 (46)
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)	1.9 ± 1.54 (69)	2.0 ± 1.57 (58)
South Station	-	-	-	1.7 ± 1.61 (37)	2.6 ± 2.68 (16)	3.8 ± 2.14 (48)	3.9 ± 2.21 (44)
Campsite Station	-	-	-	-	-	1.1 ± 1.24 (32)	1.3 ± 1.22 (25)
Pipeline Station	-	-	-	-	-	1.7 ± 2.36 (43)	2.1 ± 2.47 (35)
Chaivo Station	-	-	-	-	-	1.0 ± 2.01 (45)	1.4 ± 2.28 (32)

In 2006, we had the highest number of theodolite tracks of focal whales, and also the longest ever track (7 hrs) of two individuals feeding approximately 3 km north of Chaivo Station. This observation occurred while nearshore dredging activity was operating approximately 7 km north of these whales. Despite an increase in the overall numbers of whales in the study area in the past three years compared to 2001-2003, the animals' movement patterns in 2006 were relatively similar to previous observations. However, the general speed of movement, range, and surface time tended to be slightly higher in 2006 compared to previous years, with the exception of 2002. This could potentially be a result of having approximately twice as many traveling representatives in the dataset compared to other behaviors. In 2002 (a non-construction year), gray whales were observed 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 - 2005, respectively. 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. The slightly faster speed compared to other years may indicate that whales are not feeding as much in the Piltun-Chaivo feeding area, and traveling more between sites. These increased speeds could also have been a part of feeding more on "clouds" of water column prey, potentially distributed in somewhat poisson ("rare and random") fashion. Similar travel between locations was evident for eastern gray whales water column feeding on mysids off Vancouver Island, Canada (Guerrero 1989). The seasonal shifts observed in the study found higher abundance of whales to the southern regions (Chaivo Area) later in the field season, which could have contributed to these results. As animals traveled out of the northern regions, they would be observed by two behavioral teams, and potentially the same individuals were seen feeding in the southern region, by one behavioral team. In other words, if the pattern of individuals traveling out of the Piltun Area and feeding in the Chaivo Area existed, then there would likely be more representative traveling behavior observed compared to feeding behavior since two behavioral teams were monitoring the Piltun Area versus the one team monitoring the Chaivo Area.

The surface-respiration-dive parameters observed in 2006 appear to be within the range of normal behaviors observed from 2002-2004, with the exception of differences in 2002. In 2002, blow interval and dive time appear 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 14). Despite the similar patterns observed for movement variables compared to 2002 and increased frequency of traveling behavior, the general blow interval and dive time in 2006 are more similar to those of 2003 and 2004, 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 were generally lower than those of eastern gray whales reported to date, which is likely a factor of the shallow depth of the present 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.* (2007) found that water depth explained a significant amount of variation in dive time. As duration of dives was found to increase as the water depth increased.

Behavioral observations illustrated three primary behavioral types: 1) feeding; 2) feeding/traveling; and 3) traveling through the area, often parallel to the coastline. Unlike 2003-2004 but similar to 2001-2002 and 2005, in 2006 there was relatively little social activity. The few socializing occasions observed were consistent with time periods of previous years, generally occurring later in the season (end of August and September). Observations of increased social behavior in late summer are similar to what was described off St. Lawrence Island, with eastern gray whales socializing more in September than in July (Würsig *et al.* 1986). It is presently unknown whether observations of this behavior later in the season is due to gray whales having successfully fed and are now able to engage in other activities (such as social/sexual "play", perhaps as a precursor to physiological sexual readiness), this marks the early beginning of the mating season, or for some other unknown reason. Given the gestation period of gray whales (11-13 months), it is likely that such social/sexual behavior in the feeding grounds serves some unknown non-reproductive purpose.

In the past six years, observations of killer whale presence have been infrequent (approximately 2-5 times per field season), and gray whales did not appear to respond to their presence. We do not know whether the whales were unaware of the killer whales, or were simply unconcerned by their presence. However, in 2006 we observed a short-term interaction between two adult gray whales and a group of 4-6 killer whales, with the individual gray whales moving rapidly inshore. Indications of killer whale interactions are apparent by the tooth rake marks on the bodies of some gray whales, and such interactions may at times result in successful predation, especially on calves or recently weaned calves. Such predation has been witnessed on gray whales of the eastern population (Baldridge 1972, Goley and Straley 1994, George and Suydam 1998), and it is likely that it occurs at times in the far smaller western population as well.

Focal behavior studies showed that the respiration parameters of blow interval, surface time, dive time, blows per surfacing, dive/surface blow rate, and surface blow rate were generally within the range of those observed during seasons of non-anthropogenic activity (2002-2004). There were significant differences in relation to movement parameters of speeds of travel, reorientation rates, ranging indices, linearity, mean vector length, and several of the respiration parameters among the three primary behaviors observed: feeding, feeding/traveling, and traveling. These differences have been consistent with the past analyses of movement and respiration. Differences in movement and respiration patterns during feeding and feeding/traveling behavior may also represent 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.

We acknowledge that some (unquantified) circularity may exist between the definitions of behavioral states as a natural predictor for variables such as speed, reorientation rate, and linearity. 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"). We evaluate behavioral states of the animal in relation to movement and respiration, 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 *et al.* 1995).

Gray whales observed to be traveling in 2006 had higher overall speeds (4.1 km/h) than observed in previous years. "Displacement" analyses indicated traveling behavior to be significantly different than that found in previous studies, while feeding and feeding/traveling behaviors were consistent with past analyses. This pattern appears to be dominated by five of the six most northern stations (of the Piltun Area), furthest from nearshore dredging activity, as opposed to the three southern based stations in the Chaivo Area, closest to the nearshore dredging activity. This could be related to the observed seasonal shift to the southern stations later in the field season or alternatively related to anthropogenic activity in the area. We believe that further analyses are needed to understand these changes in movement patterns.

The results presented here do not address the potential effects of anthropogenic activity, and therefore may be confounded by these potential influences. Analyses are currently being conducted with variables such as water depth, swell, tide, and whale behavioral variables, to determine if these "natural" predictors explain a significant amount of variation in the response variables of speed, linearity, respiration interval, etc. Once these natural models have been developed, we intend to evaluate the influence of anthropogenic variables, such as received sound levels, vessel distance, etc. This approach is similar to the multivariate analyses conducted by Gailey *et al.* (2007) with modifications that have been suggested by the Western Gray Whale Advisory Panel (WGWAP 2006).

Observations of western gray whales on their feeding grounds in 2004-2006 showed an increase in the number of whales and pods throughout the study area, compared to data collected in 2001-2003. Some movement and respiration indicators, such as speed, dive time, and respiration interval, appear to be different in 2002 and 2006, potentially indicating a different foraging strategy or change in prey availability in the study area. Since the primary reason that gray whales migrate to this area each summer is to forage, our interpretation of behavioral observations would be greatly enhanced by analyzing prey concentrations in the study area, gathered since 2002 (Fadeev 2003, 2004, 2005, 2006, 2007). Furthermore, due to the continued anthropogenic activity related to oil/gas development and the concern of possible cumulative impacts, acoustic information is essential towards evaluating potential behavioral disturbances of gray whales. We believe that behavioral studies in combination with acoustic data, data on vessel distance and information on benthic/prey provides an excellent basis to examine observed changes in behavior. This knowledge can be used to suggest alternatives to management practices that may be impacting this critically endangered population of gray whales, while filling in basic information on their life history, behavior, and habitat utilization.

Table 14. Summary statistics for theodolite and focal behavior data collected during 2001 - 2006. 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
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)
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)
Acceleration (km/h)	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)
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)
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)
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)
Ranging Index	-	-	31.1 ± 18.06 (47)	32.9 ± 22.31 (116)	32.8 ± 24.71 (124)	39.6 ± 35.91 (140)
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)
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)
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
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)
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)

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APPENDIX 1. Daily summary of theodolite, focal behavior, and scan data collected during the summer of 2006.

Station	Date	Start Day	End Day	Effort(hrs)	# Tracklines	# Focal Follows	# Scans
Chaivo Station	23-Jun-06	12:54:09	16:58:26	4.07	0	0	3
Chaivo Station	24-Jun-06	8:03:19	16:12:38	8.16	0	0	8
Chaivo Station	25-Jun-06	8:00:00	8:05:00	0.08	0	0	5
		9:40:00	15:30:30	5.84			
1st Station	26-Jun-06	9:47:05	12:29:52	2.71	3	0	3
Pipeline Station		10:26:13	15:27:29	5.02	0	0	3
1st Station	29-Jun-06	11:27:29	12:18:22	0.85	1	0	1
		12:23:40	14:15:18	1.86			
		15:12:44	17:20:41	2.13			
Pipeline Station		14:15:51	19:02:50	4.78	0	0	5
South Station		11:25:22	12:44:30	1.32	0	0	4
		14:33:54	17:09:59	2.60			
1st Station	30-Jun-06	10:17:50	18:23:42	8.10	5	0	6
Campsite Station		7:25:14	18:55:45	11.51	1	0	9
2nd Station	1-Jul-06	7:32:00	17:08:51	9.61	0	0	10
Chaivo Station		12:09:04	17:39:51	5.51	1	1	1
Station 07		7:44:52	16:30:43	8.76	4	1	8
1st Station	2-Jul-06	7:53:19	12:38:38	4.76	1	0	5
Chaivo Station	5-Jul-06	10:12:14	10:55:19	0.72	0	0	1
North Station		9:45:08	12:20:50	2.60	2	0	2
Odoptu Station		9:22:45	11:50:38	2.47	0	0	2
North Station	8-Jul-06	11:07:00	12:07:00	1.00	0	0	1
Odoptu Station		10:51:48	12:24:28	1.54	0	0	2
1st Station	16-Jul-06	6:56:21	18:33:49	11.62	6	3	9
Chaivo Station		7:40:33	18:06:37	10.43	0	0	9
South Station		7:18:15	18:30:47	11.21	10	4	8
2nd Station	17-Jul-06	7:51:44	18:29:19	10.63	8	3	9
Pipeline Station		8:04:28	18:00:11	9.93	0	0	9
Station 07		8:00:46	18:24:47	10.40	4	1	7
Chaivo Station	18-Jul-06	7:55:34	18:00:02	10.07	0	0	8
North Station		10:00:15	17:27:06	7.45	7	2	6
Odoptu Station		9:27:47	18:27:52	9.00	3	1	7
Pipeline Station	22-Jul-06	11:30:12	14:43:36	3.22	2	0	0
1st Station	23-Jul-06	11:58:22	18:13:59	6.26	4	2	3
South Station		12:46:40	18:29:53	5.72	5	2	4
2nd Station	24-Jul-06	6:39:21	14:34:11	7.91	2	2	7
Pipeline Station		7:52:08	19:00:02	11.13	4	1	7
Station 07		6:43:14	14:52:03	8.15	5	5	5
1st Station	25-Jul-06	13:53:59	20:12:08	6.30	5	1	7
Chaivo Station	26-Jul-06	7:51:50	18:16:36	10.41	2	1	3
North Station	27-Jul-06	8:09:34	12:10:52	4.02	3	0	3
Odoptu Station		7:46:34	12:21:36	4.58	3	1	3
Pipeline Station		7:58:59	9:52:17	1.89	1	0	2
Pipeline Station	14-Aug-06	7:55:23	9:05:56	1.18	1	0	0

1st Station	19-Aug-06	7:03:41	19:33:19	12.49	7	2	12
South Station		7:35:26	18:30:40	10.92	5	4	8
2nd Station	20-Aug-06	7:29:17	18:06:03	10.61	5	3	9
Pipeline Station		7:25:32	17:42:52	10.29	6	2	8
Station 07		8:05:56	18:00:10	9.90	6	3	6
North Station	22-Aug-06	10:01:29	14:02:29	4.02	3	1	2
Odoptu Station		9:14:25	14:31:09	5.28	3	1	3
Campsite Station	23-Aug-06	7:20:35	18:31:21	11.18	7	2	8
North Station		11:38:46	16:44:32	5.10	5	1	4
Odoptu Station		10:02:54	17:14:17	7.19	3	0	7
Station 07		8:17:45	8:44:00	0.44	0	0	1
1st Station	24-Aug-06	8:20:58	11:10:49	2.83	2	1	2
Chaivo Station		7:57:41	16:34:31	8.61	1	0	7
South Station		9:01:52	11:08:06	2.10	2	0	2
1st Station	25-Aug-06	7:30:33	8:00:00	0.49	3	1	5
		14:55:01	18:49:51	3.91			
Pipeline Station		8:53:27	10:02:55	1.16	6	1	7
		12:11:45	17:55:00	5.72			
1st Station	26-Aug-06	6:58:09	12:53:24	5.92	1	1	4
Campsite Station		7:04:13	8:35:30	1.52	1	1	1
South Station		7:35:08	13:02:23	5.45	5	0	5
1st Station	27-Aug-06	12:03:32	18:32:40	6.49	3	0	1
South Station		12:38:56	17:42:18	5.06	2	0	5
2nd Station	1-Sep-06	12:18:43	18:24:46	6.10	2	1	5
Campsite Station		13:28:54	14:48:58	1.33	2	0	5
		15:28:52	18:49:13	3.34			
Station 07		12:29:35	17:49:50	5.34	1	0	3
2nd Station	2-Sep-06	9:08:37	17:41:05	8.54	5	0	7
Station 07		9:23:15	17:46:52	8.39	3	2	2
Chaivo Station	3-Sep-06	8:04:11	10:12:56	2.15	4	2	5
		13:43:56	18:14:35	4.51			
North Station		10:00:15	18:10:49	8.18	3	1	6
Odoptu Station		9:10:54	18:34:25	9.39	6	3	7
1st Station	4-Sep-06	7:49:15	10:37:28	2.80	0	0	2
South Station		7:47:40	10:16:52	2.49	0	0	2
1st Station	6-Sep-06	7:29:03	19:06:39	11.63	6	2	9
Pipeline Station		8:04:07	15:42:35	7.64	6	0	6
South Station		7:51:10	18:43:35	10.87	2	1	7
2nd Station	7-Sep-06	8:43:04	14:54:53	6.20	2	2	2
Campsite Station		10:29:46	17:56:37	7.45	1	0	8
Station 07		9:05:16	13:56:14	4.85	2	0	5
Chaivo Station	12-Sep-06	8:31:16	10:16:23	1.75	0	0	2
2nd Station	13-Sep-06	9:01:42	17:51:20	8.83	4	2	3
Chaivo Station		8:18:23	15:29:09	7.18	5	0	3
Station 07		9:29:30	17:24:23	7.92	3	1	5
North Station	15-Sep-06	10:05:00	17:10:04	7.08	3	1	6
Odoptu Station		9:30:47	18:27:33	8.95	4	2	1
Pipeline Station		8:50:50	10:56:15	2.09	1	0	2

1st Station	16-Sep-06	8:01:49	17:49:24	9.79	2	0	6
Pipeline Station		8:44:52	18:39:57	9.92	7	2	4
South Station		8:43:06	9:05:31	0.37	0	0	7
		9:43:29	16:41:09	6.96			
2nd Station	17-Sep-06	8:29:04	12:47:15	4.30	3	0	4
Campsite Station		8:10:06	15:28:27	7.31	5	1	5
Station 07		8:36:07	12:27:09	3.85	2	1	2
Chaivo Station	23-Sep-06	10:45:49	13:28:37	2.71	0	0	3
Chaivo Station	24-Sep-06	8:47:02	10:37:00	1.83	0	0	2
2nd Station	25-Sep-06	11:15:03	18:12:23	6.96	2	0	7
Station 07		11:28:12	18:00:41	6.54	1	1	5
North Station	26-Sep-06	9:44:43	11:52:44	2.13	0	0	1
Odoptu Station		9:23:46	12:59:35	3.60	3	0	1
Pipeline Station		8:07:04	9:31:03	1.40	1	1	1
TOTAL				616.9	260	81	453