Western Gray Whale Occurrence Patterns and Behavior:
Shore-Based Observations off Sakhalin Island,
August-September 2002

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25 March 2003

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INTRODUCTION, RATIONALE, AND BRIEF OVERVIEW OF RESULTS

The western population of gray whale (*Eschrichtius robustus*) is remnant and in danger of extinction (USFWS 1997, Red Book of the Russian Federation 2000, Hilton-Taylor 2000). Approximately 100 individuals habitually feed off the northeastern area of Sakhalin Island in summer-fall of every year; and considerable research on occurrence patterns, foraging and other behaviors, behavior relative to industrial activities, and genetics has taken place in the past 6 years (summaries in LeDuc et al. 2002; Weller et al. 1999, 2002a,b).

In 2002, we investigated occurrence patterns and some aspects of behavior of near-shore gray whales in proximity to the Odoptu Block of potential oil/gas development by Exxon Neftegas Limited (ENL). In 2002, there was considerably less boating and other human activity in the sea than had been the case in 2001, when a 3-dimensional seismic project occurred throughout a portion of our observation period (Würsig et al. 2002). As for the preceding effort in 2001, it was again decided that one platform to gauge whale behaviors would be from shore. This platform had the advantage that it was removed from the whales, thereby avoiding the possibility of the observing station(s) to be a source of disturbance. We chose three main observation techniques: 1) scan sampling to obtain relative abundance estimates and group sizes of gray whales along shore; 2) theodolite tracking of focal groups to describe locations, orientations, and speeds of movements; and 3) focal group or focal animal observations to describe 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 basic habitat use and behavior of western gray whales in relation to naturally-occurring (generally environmental) variables, petroleum industry activities, and other potential influences on the whales. We understand that this information will be used during project design and implementation to help design effective strategies to protect the whales.

The 2002 field season was hampered by many unusually poor weather days, consisting of storms, rain squalls, and fog. Despite the poor weather, however, the 2002 field season was successful in providing information about movement patterns, behavioral observations, and relative numbers of whales at four geographic locations. The field season commenced on 12 August 2002 and ended on 5 October 2002. Due to weather conditions, the first day of data collection began on 17 August 2002 and the last day of effort was 28 September 2002. The season ended with 26 days of effort (192 hrs), 117 scan samples with 369 sightings, 94 tracks, and 46 focal follows of individual gray whales.

No killer whales (*Orcinus orca*) were observed in our near-shore study area during the entire 2002 field season.

METHODS

Methods used in 2002 were similar to those of 2001, and much of this section is repeated from Würsig et al. (2002), with variations in stations and some analyses, as given below.

Study Area

Shore-based observations were conducted along 32 kilometers of coastal region in the northeastern portion of Sakhalin Island, Russia (Figure 1). The study area encompasses one near-shore part of the only known feeding ground off northeastern Sakhalin Island for 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 Zaliv Pil'tun (see also Johnson 2002). The near-shore waters of the Sea of Okhotsk are characterized by sand substrate with a gradually sloping continental shelf.

Shore-Based Observations

Four geographic locations were chosen to conduct behavioral observations on western gray whales during summer 2002 (Table 1). Each station was selected based on its height above sea level relative to the generally-low dunes of the area (Table 1), and overlapping distance (approx. 4 km) to other shore-based stations (Figure **2)**. The position of each station allowed the shore-based team to monitor gray whale behavior along 32 km of coastal region. Due to the logistic difficulty of moving between stations, one day of effort was usually dedicated to one of the four shore-based stations. A station was selected systematically to proceed from south to north. Once the northern-most station was reached (Odoptu Station), then the next day of effort would continue at the most southern station (1st Station). Two stations (2nd Station and Station 07) had also been used during the 2001 seismic study. An additional station (1st Station) was incorporated into the study due to previous data indicating that more gray whales might be to the south. However, during the first few weeks of the study, most whales were observed to be traveling north, with fewer whales at the southern-most station. Based on field observations, we explored a new station (Odoptu Station) further north than Station 07. The Odoptu Station proved rather successful, with a number of gray whales in the area.

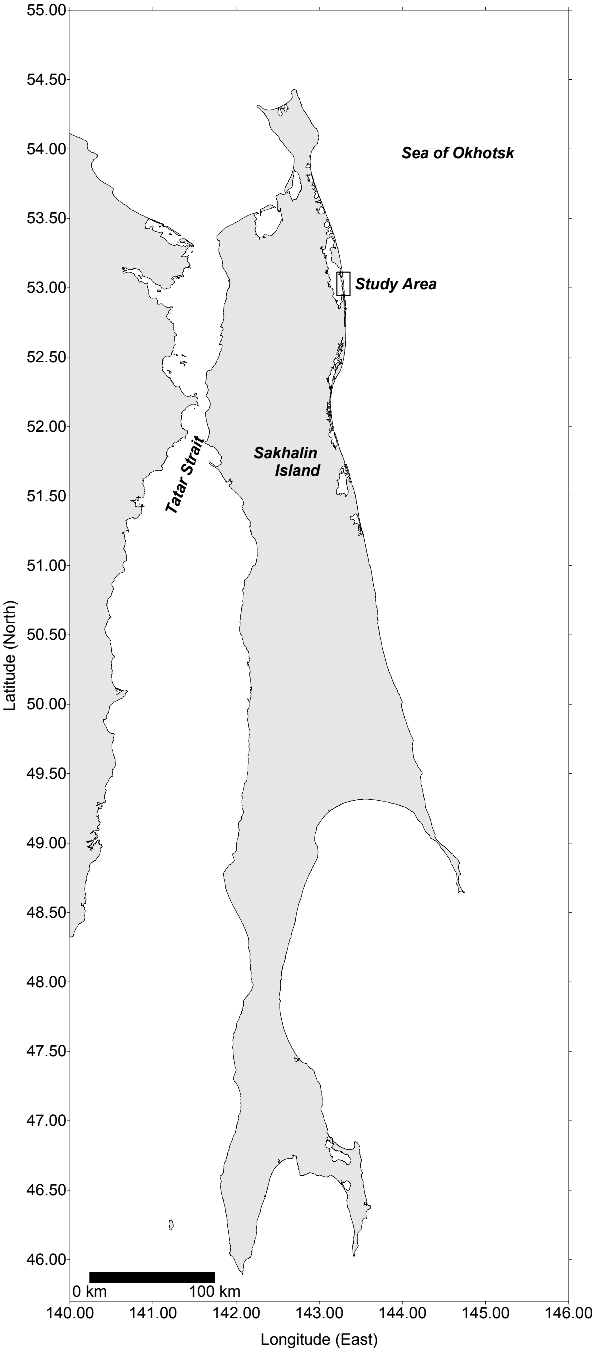

Figure 1. Study area in the northeastern portion of Sakhalin Island in Far East Russia.

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

Station Name	Latitude (N)	Longitude (E)	Station Height (m)
1st Station	52° 58' 27"	143° 18' 07"	10.1
2nd Station	53° 03' 08"	143° 17' 04"	8.6
Station 07	53° 07' 29"	143° 16' 12"	8.1
Odoptu Station	53° 12' 33"	143° 14' 51"	17.2

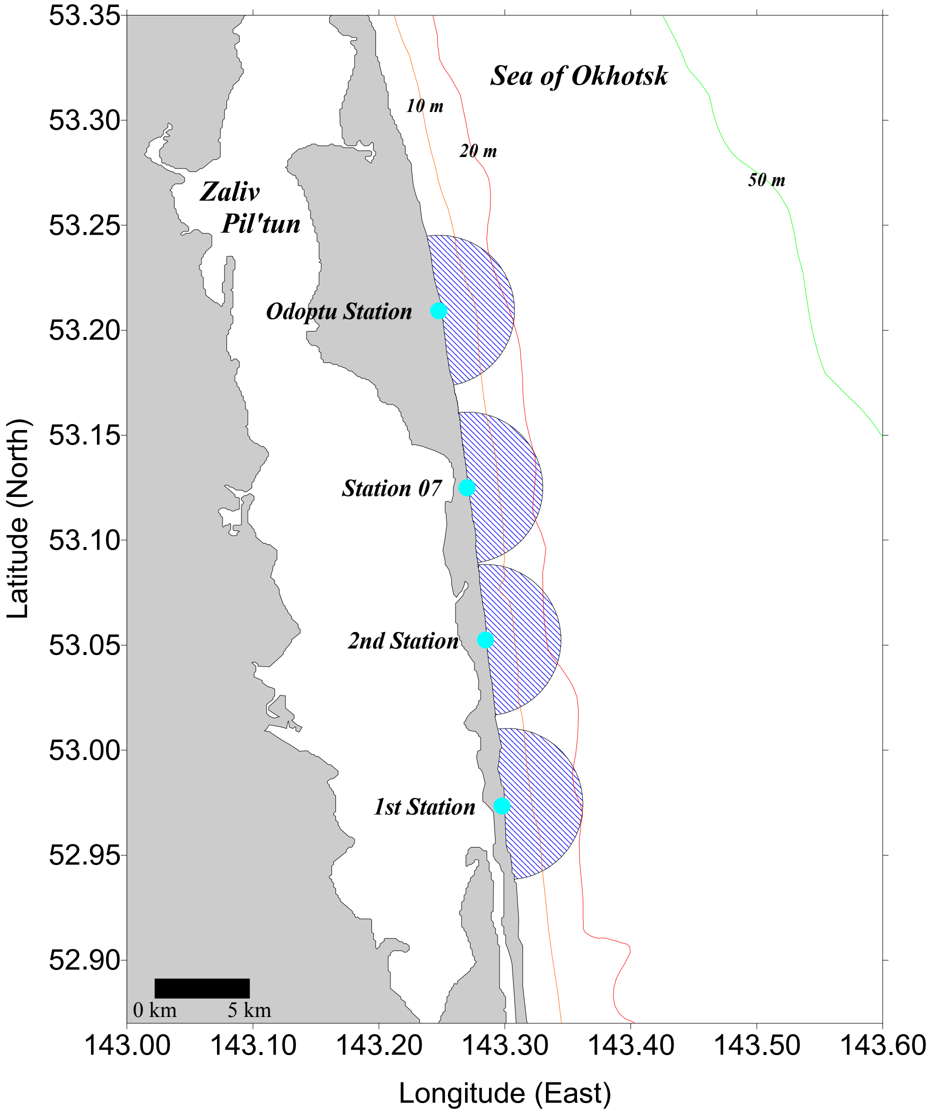

Figure 2. Geographic positions of four shore-based stations along the Odoptu Block in the northeastern coastal region of Sakhalin Island, Russia. Semi-circular grids illustrate approximate viewable range (4 km) from each shore-based station.

Environmental Considerations

Environmental conditions were recorded several times/day to ensure consistent and reliable results for all three methodological techniques employed by the shore-based monitoring team (see below). The relative visibility, glare concentration and horizontal angles, sea state (Beaufort scale values of 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 direction, cloud cover, and swell environmental conditions were recorded. If these environmental parameters hampered observations, then research effort was discontinued until conditions were acceptable.

Scan Sampling

To monitor the relative number 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 (10x50) to scan a predetermined section of the study area ranging from 20° to 160° magnetic North (magnetic declination relative to true North =12.27°West). Each scan was initiated from the northern portion of the study area and proceeded to the southern portion. The duration of each scan was 15 minutes, with a maximum of one scan per hour. Once an observer sighted a whale or whales, we recorded the number of whales, magnetic bearing, reticules (etchings inside the binoculars used to estimate distances by known sizes of objects in view, or angle below horizon), and the observer's impression of distance from the study site.

Theodolite Tracking

The spatial and temporal movement patterns of gray whales were monitored with a Lietz/Sokkisha Model DT5A theodolite with 30-power monocular magnification and 5-sec precision. This technique converts horizontal and vertical angles into geographic positions (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, and Appendices 1 and 2 for further description and mathematical calculations used in this methodological technique). A theodolite tracking session was initiated when a single or an individually recognizable gray whale could be identified and the individual was within a relatively close distance (< 4 km) from the shore-based 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. Because individuals were generally chosen for tracking, we have few movement data on whale groups >1, and therefore cannot make conclusions about movements of non-single whales. 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 (see Würsig et al. 1991 for height-related errors).

Focal Behavior Observations

Focal behavior sessions (Altmann 1974, Martin and Bateson 1993) were conducted on individual gray whales to determine if any behavioral or respiration changes occurred in relation to environmental variables. However, a complete set of environmental data was not available for analysis in this report, and such analysis is not conducted here. 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 whale was that, due to our low vantage point and distance from whales, it was generally impossible to distinguish individuals. We therefore biased our data towards singles, and cannot adequately discuss the behavior of groups of 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 (10x50). The behavioral observer would call out each behavioral event that occurred, and this information along with information about date and time were recorded by a computer operator into a laptop computer and analyzed with Pythagoras. To minimize inter-observer variability, the behavioral observer's observations were periodically evaluated by other observers. In most focal follow sessions, behavioral/respiration events could be recorded simultaneously with spatial and temporal movements of the focal animal.

Data Analysis

Scan Data – For a broad overview, the relative number of whales and number of pods were analyzed. All scan-based data were evaluated for the entire coastal region observed throughout the four shore-based stations and within and between each station. The number of whales/pods per station were also evaluated during morning (before 12:00 a.m.) and afternoon (after 12:00 a.m.) periods of each day of effort, and non-statistically evaluated for different months of observation (before and after 10 September 2002, as an approximate division into first and second halves of this year's study; this division has the added advantage of potential comparison to "during" and "after" industrial seismic in the preceding year, 2001) to investigate potential changes. Due to non-normal distribution of the scan data, both the number of whales and pods were transformed (log(# whales or pods +1)) for analytical purposes.

Theodolite Data – Theodolite tracking information was evaluated in terms of each animal's relative speeds, orientations, and displacement. Due to potential issues of oversampling and/or undersampling 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 (**Figure** 3), turning angles (**Figure** 4), number of fixed data points (Figure 5), and fix rate (number of fixed data points per minute, Figure 6). A 90-sec interpolation criterion was based on autocorrelation analysis performed on movement patterns during the 2001 analysis. 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. After an interpolated position was found, all data between the two positions were discarded to provide even steps for analysis. When completed, interpolation ensured that all locations in a track were equal to the interpolation interval. The result of the interpolation procedure described above yielded tracklines with pairs of fix points (steps) separated by time intervals of approximately 90 sec. The fix rate in Figure 6 illustrates a high resolution data set provided to yield accurate interpolation positions along a given trackline.

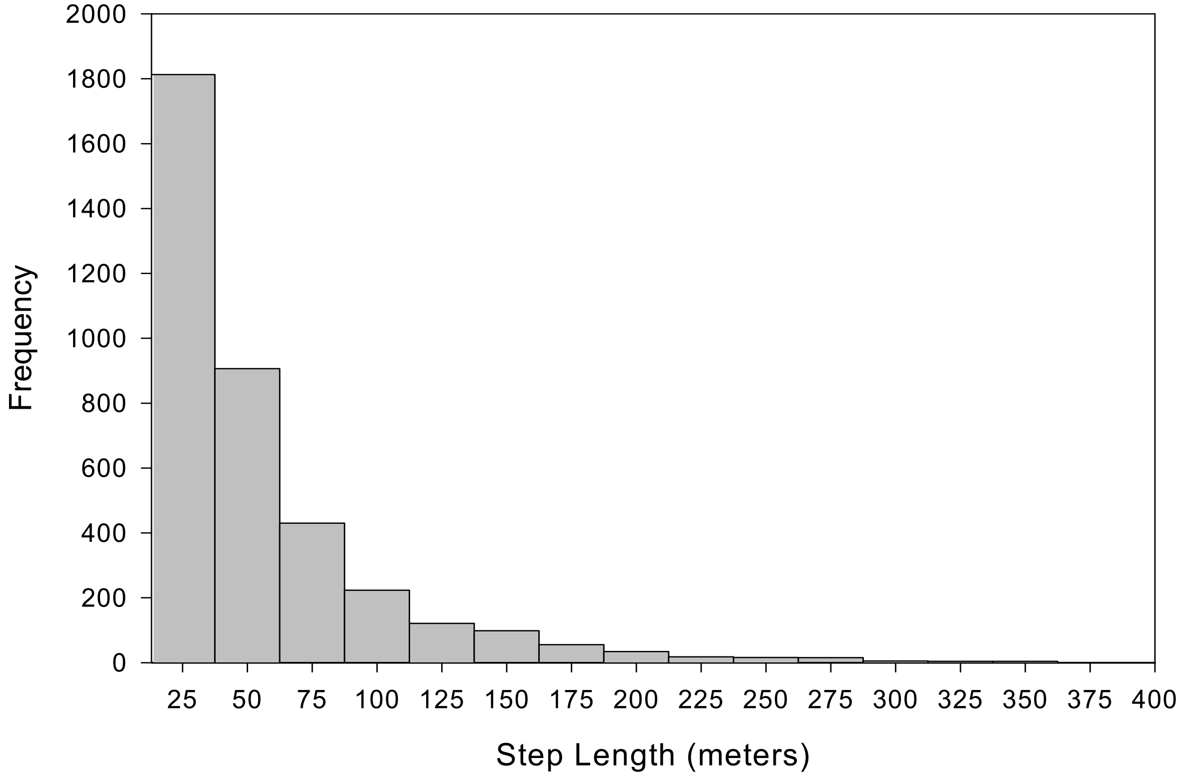

Figure 3. Frequency distribution of step length of the entire theodolite trackline dataset.

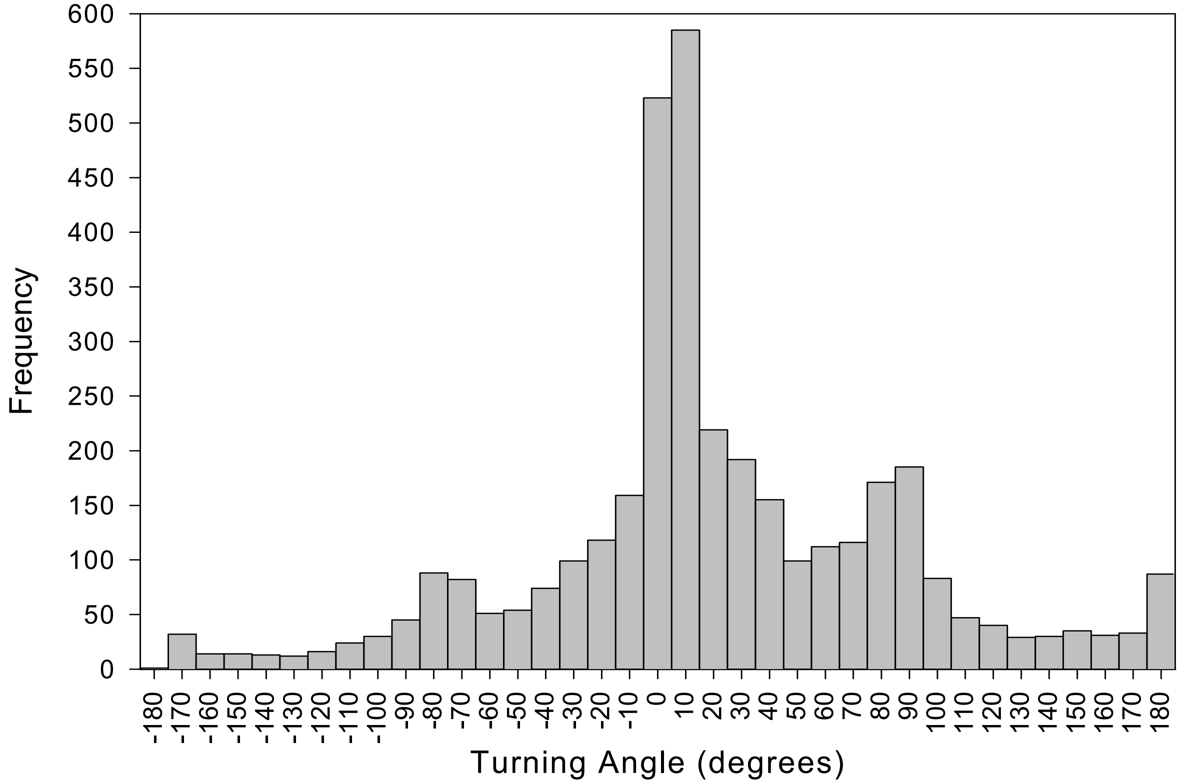

Figure 4. Frequency distribution of turning angles of the entire theodolite trackline dataset.

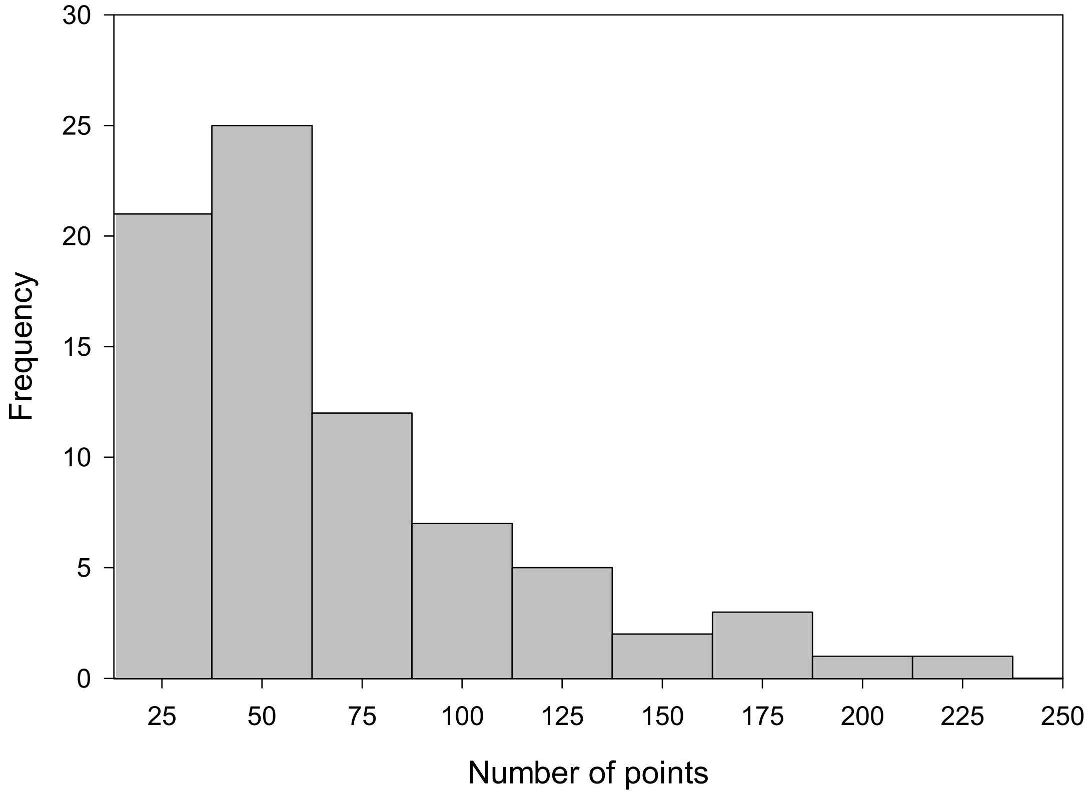

Figure 5. Frequency distribution of the number of fix data points for tracklines with more than 10 data points in the entire theodolite trackline dataset.

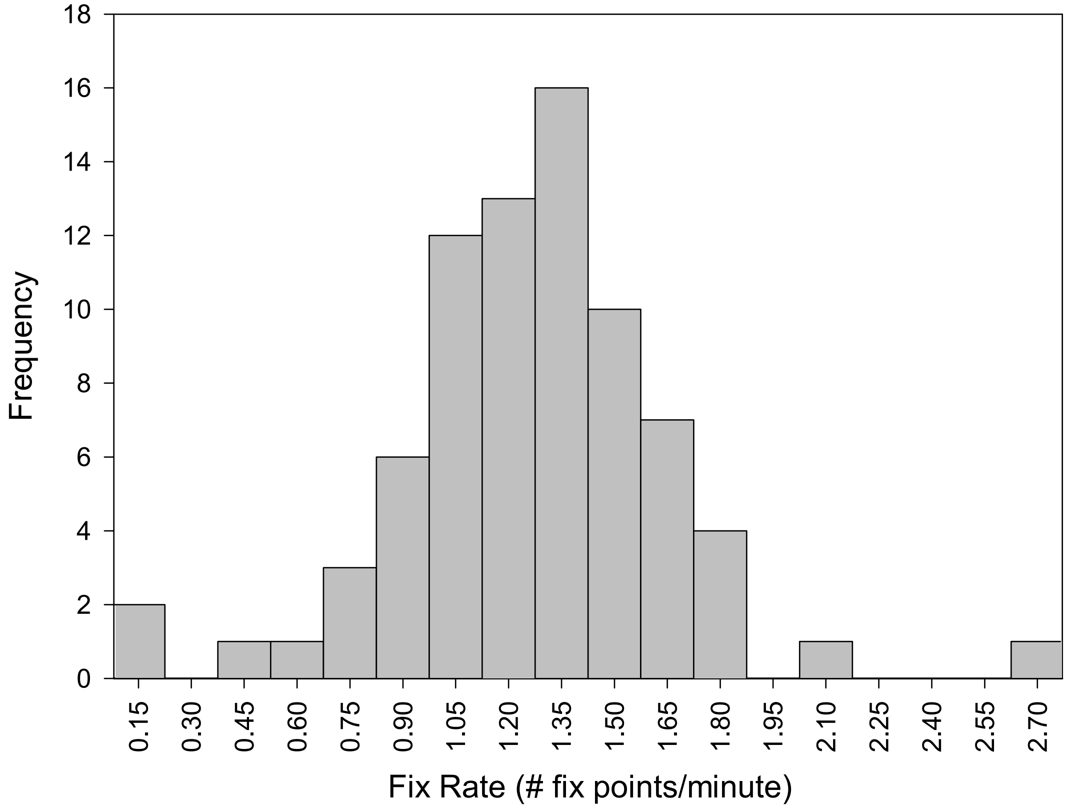

Figure 6. Frequency distribution of the fix rate (number of recorded geographic positions per minute) for tracklines.

For each interpolated trackline, the calculated leg speed, acceleration, linearity, reorientation rate, and mean vector length were analysed (see Appendix 1). 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 the deviation of a trackline from that of a straight line and is calculated by dividing the net geographic distance between the first and last fix of a trackline by the cumulative distances along the track. Linearity values range between 0 and 1, where a linearity score close to one represents a straight trackline and a value close to zero represents a track with little or no observed directional movement (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).

Behavioral/Respiration Data – To evaluate potential behavioral changes, focal behavioral data were quantified by six variables: 1) blow interval (time between subsequent exhalations per surfacing), 2) number of blows per surfacing, 3) surface time (duration of individuals remaining at or near the surface), 4) dive time (duration of individuals remaining submerged), 5) surface blow rate (mean number of exhalations per minute while the individual is at the surface), and 6) surface-dive blow rate (number of exhalations per minute averaged over the duration of a surfacing-dive cycle). One approximately 10 minute long bin was randomly selected per each behavioral observation session, and one mean calculated per each of the six variables per 10 minute bin (see next section).

Theodolite and Focal Behavior Data Bins – Due to variation in track duration between tracklines, all tracks were binned into 10-minute intervals per tracking/focal follow session. "Binning" involved combining locations within intervals of time lasting approximately 10 minutes, and viewing the interval of time as the basic observation unit upon which responses and explanatory variables were measured. Each interval of time was called a *bin*, and ended at an actual or interpolated location. Therefore, bins may vary in length. 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, one 10-minute bin was randomly selected from each trackline or focal behavior session. Therefore, the sampling unit used was one 10-minute bin per trackline or focal behavior session.

Transformations - Histograms were evaluated for each of the response variables. Transformations for each of non-normal distributions were performed to approximate normal distributions for analysis 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* using the following equation,

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

where Y_i' was the transformed response for observation *i*, and Y_i was the original response. The constant 0.003 was subtracted from each observation to avoid division by zero when the original response was 1.0. Back-transformation to the scale of the original response was accomplished using the equation,

$$Y_i = \frac{1.003 \times \exp\{Y_i'\} + 0.003}{1 + \exp\{Y_i'\}}.$$

The distributions of *Leg Speed*, *Reorientation Rate, Blows per Surfacing,* and *Surface Time* were also highly non-normal. Each of these variables were log-transformed using the equation,

$$Y_i' = \log_e(Y_i).$$

Again, Y_i' was the transformed response for observation *i*, and Y_i was the original response. Back-transformation to the scale of the original response was accomplished by raising *e* to the Y_i' power.

RESULTS

Effort

A total of 26 days (192 hrs) of effort was spent at the four shore-based stations (Table 2). Less effort was conducted at the Odoptu Station because it was added in the middle of the field season. The majority of the effort per station was spent at 1st Station and 2nd Station. This was mainly a result of poorer weather conditions while at these stations and conducting many half days of effort. Station 07 had fewer half-days of effort than did 1st and 2nd Stations (see Appendix 3).

Table 2. Total amount of effort at four shore-based stations during 17 August to 28 September, 2002.

Station Name	Days of Effort	Effort (hrs)
1st_Station	8	62.05
2nd_Station	9	60.13
Station_07	5	44.58
Odoptu_Station	4	25.50
Total	26	192.26

Scan Data

General – A total of 117 scans were accumulated for the duration of the study, with a mean of 4.2 ± 2.72 SD scans conducted per day of effort. Distribution of sightings from the four stations is shown in Figure 7; this demonstrates graphically that although whales could be sighted up to about 5 km distance from a station, they were rarely >2.5 km from shore. Gray whales were present on each day of effort, with a mean of 3.2 ±3.38 SD (Median = 2, Range: 0-18, N = 117) whales and 2.2 ±2.23 (1, 0-10, 117) pods in the study area per scan. The mean pod size detected was 1.4 ±0.57 (1, 1-4, 261) whales per pod throughout the duration of this study (Figure 8 and **Figure** 9).

Morning vs. Afternoon – There were no significant differences in number of whales (U = 1586.500, P = 0.496) or pods (1542.500, 0.349) detected in the morning and afternoon. Figure 10 illustrates similar frequency distributions for the number of whales and pods per scan for both morning and afternoon periods of the day. In the morning, the mean number of whales was 2.9 ±3.21 SD (Median = 2, Range: 0-14, N = 57); and in the afternoon, the mean number of whales was 3.4 ± 3.54 (2, 0-18, 60). In the morning, the mean number of pods was 2.0 ± 2.15 (1, 0-9, 57); and in the afternoon, the mean number of pods was 2.4 ± 2.30 (1.5, 0-10, 60).

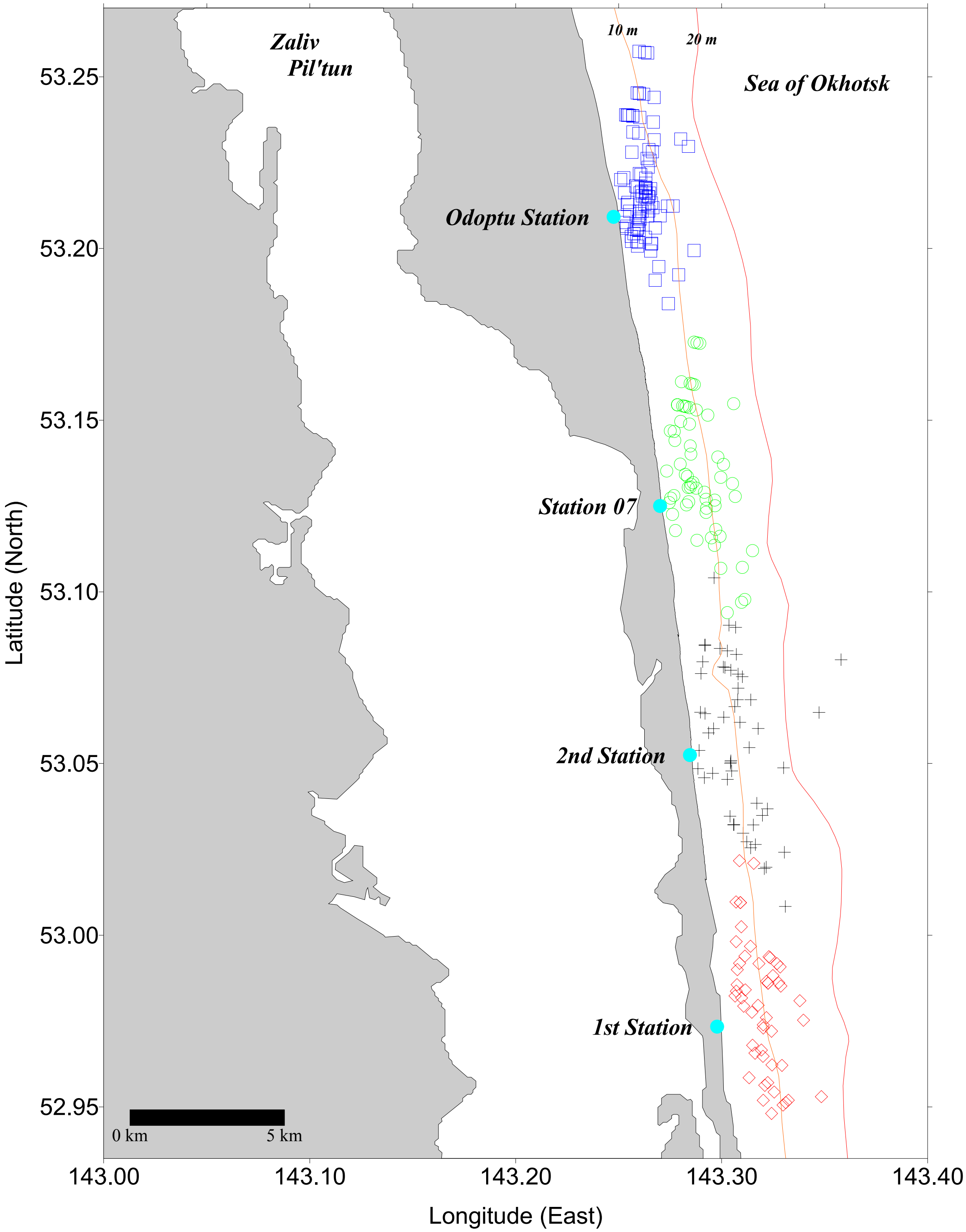

Figure 7. Geographic positions of sightings of western gray whales at four shore-based stations on Sakhalin Island, summer 2002.

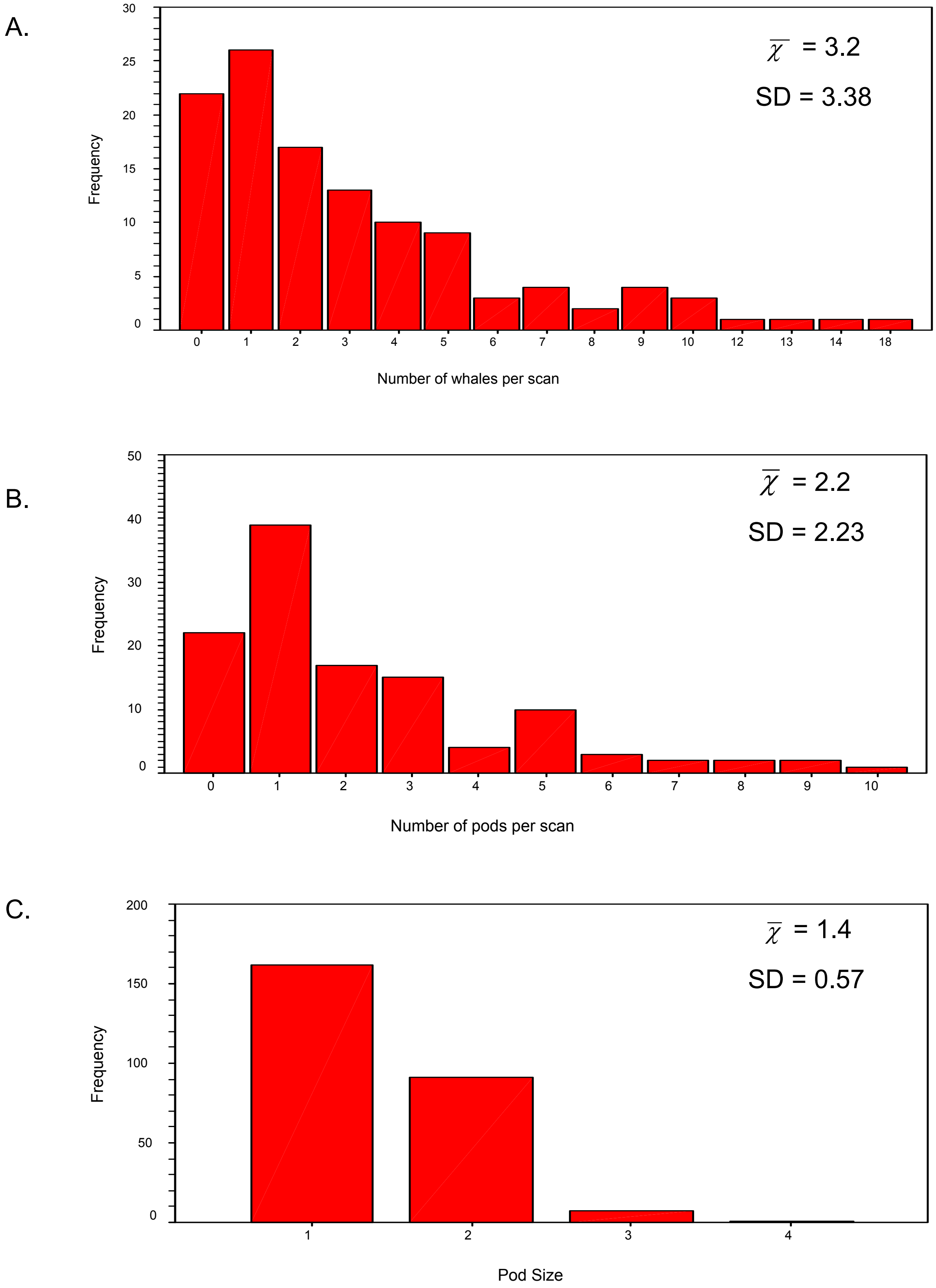

Figure 8. Frequency histograms of numbers of whales (A) and pods (B) detected per scan throughout the study period, and pod size (C).

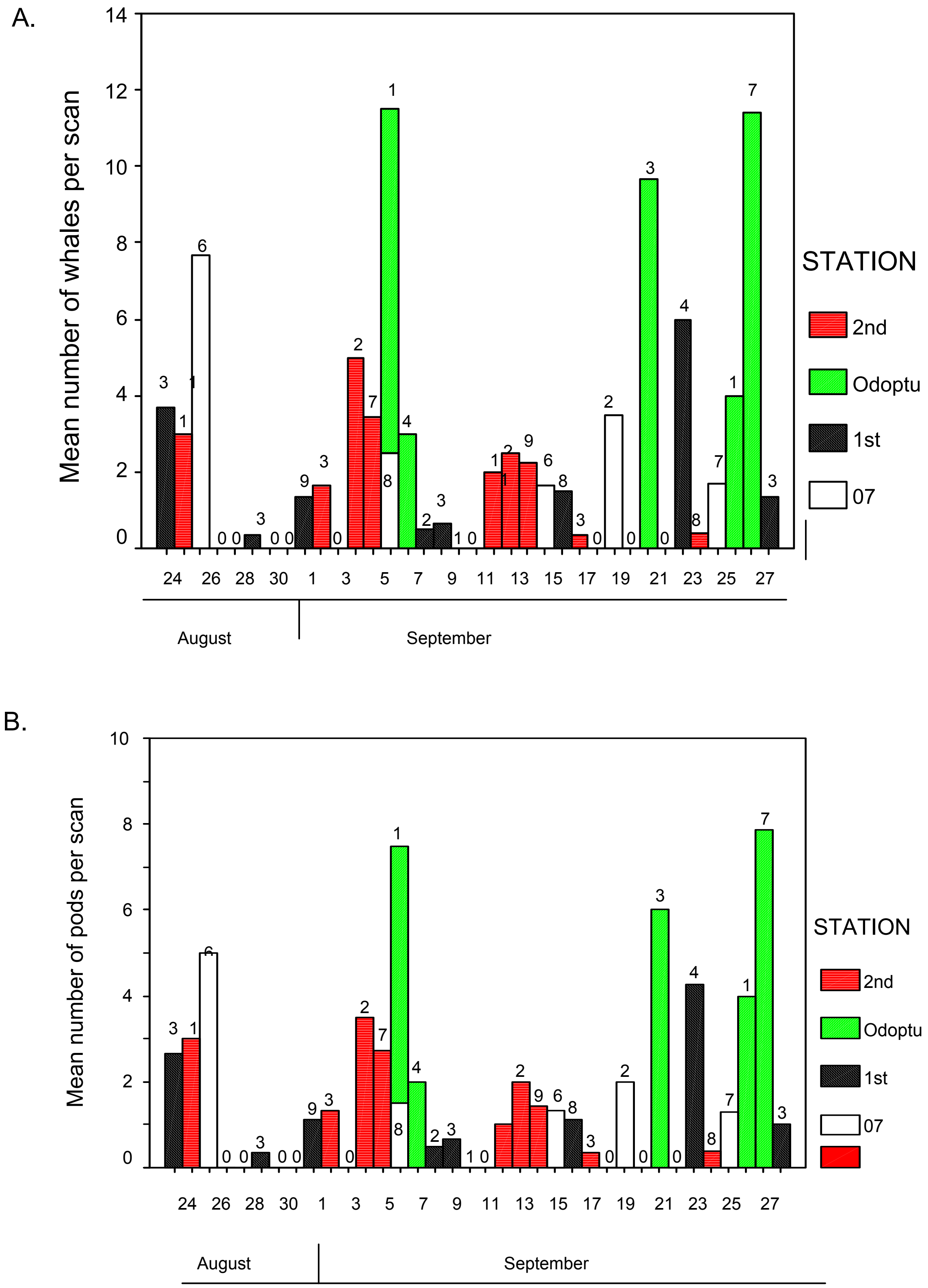

Figure 9. Mean numbers of whales (A) and pods (B) detected per scan at each of the four shore-based stations. The number of scans performed per day at each station is indicated at the top of each bar.

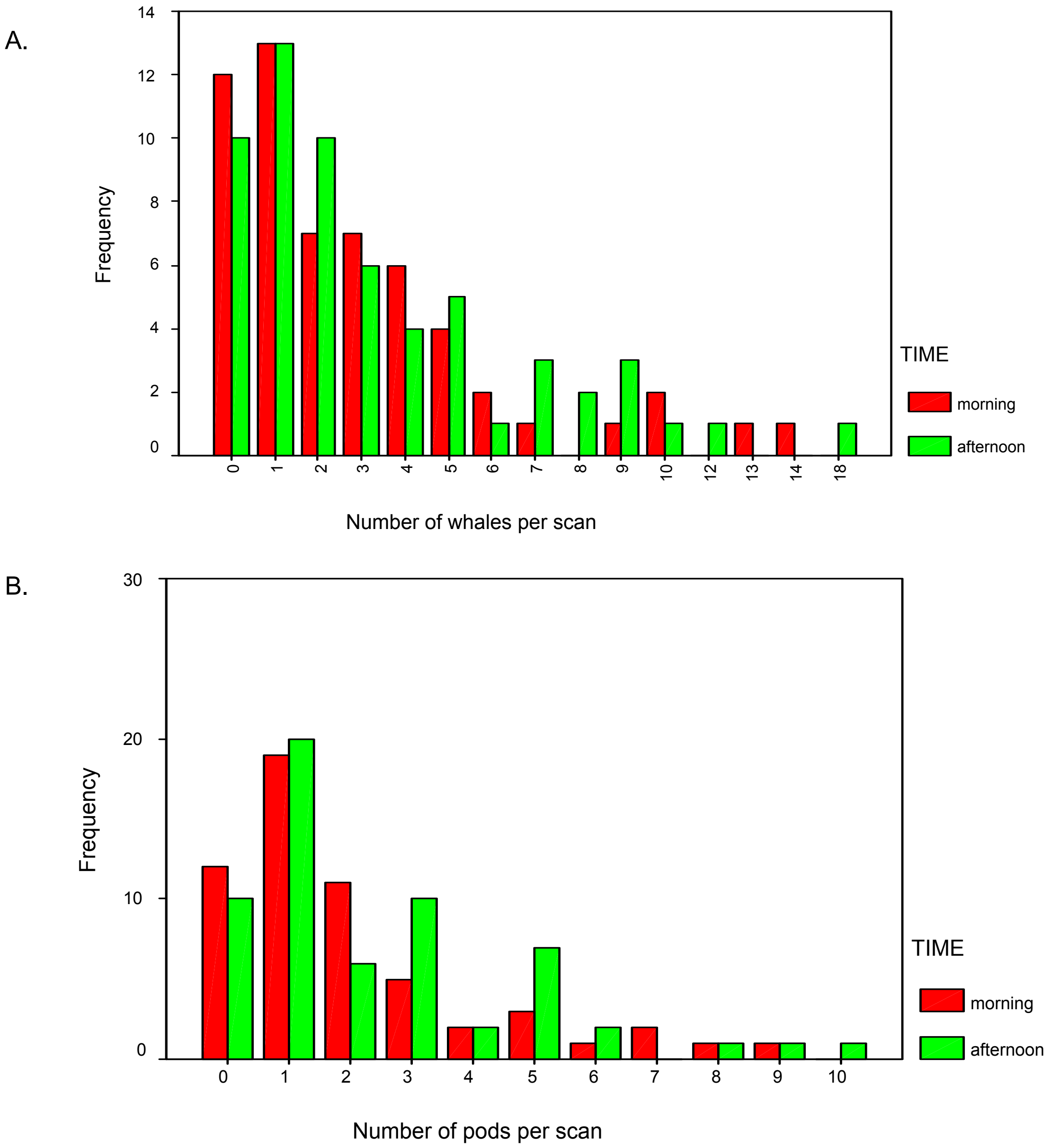

Figure 10. Frequency distributions of the data sets for number of whales (A) and pods (B) per scan.

Stations – The mean numbers of whales and pods observed for the season among stations were significantly different (whales F = 15.760, df = 3, P < 0.001 ; pods F = 15.155, df = 3, P < 0.001), with more whales and pods at the northern-most shore-based station (Odoptu Station, $\overline{\chi}$ = 8.4 ± 4.59 SD whales and 5.7 ± 2.85 SD pods) on average for the season, compared to the other three stations (see **Figure** 9, **Table** 3). The numbers of whales and pods at the other three shore-based stations were similar (1.9 ± 1.98 to 3.3 ± 2.74 whales and 1.5 ± 1.40 to 2.2 ± 1.75 pods), with 1st Station having the lowest number of whales and pods per scan.

During the period 10 through 28 September 2002 (Table 4), the mean numbers of whales and pods observed at each station were significantly different (whales F = 18.871, df = 3, $p < 0.001$; pods F = 20.106, df = 3, $P < 0.001$), with more whales and pods at the northern-most shore-based station (Odoptu Station, mean = 8.4 ± 4.59 SD whales and 5.69 ± 2.85 SD pods) on average for the season, than at the other three stations. The numbers of whales and pods at the other three shore-based stations were similar (1.3 ± 1.46 to 2.2 ± 2.35 whales and 0.9 ± 0.93 to 1.6 ± 1.64 pods), with 2nd Station having the fewest whales and pods per station.

Table 3. Number of whales (A) and pods (B) detected from four shore-based stations along the Odoptu Block during the entire season.

A.

STATION	Mean	SD	Median	Range	N
1st Station	1.9	1.98	1	0-7	35
2nd Station	2.0	1.83	2	0-7	37
Station 07	3.3	2.74	3	0-9	29
Odoptu Station	8.4	4.59	9	2-18	16

B.

STATION	Mean	SD	Median	Range	N
1st Station	1.5	1.40	1	0-5	35
2nd Station	1.5	1.37	1	0-5	37
Station 07	2.2	1.75	2	0-5	29
Odoptu Station	5.7	2.85	6	1-10	16

Table 4. Number of whales (A) and pods (B) detected from four shore-based stations along the Odoptu Block from 10 through 28 September 2002.

A.

STATION	Mean	SD	Median	Range	N
1st Station	2.2	2.35	1	0-7	20
2nd Station	1.3	1.46	1	0-5	24
Station 07	2.1	1.60	2	0-5	23
Odoptu Station	8.4	4.59	9	2-18	16

B.

STATION	Mean	SD	Median	Range	N
1st Station	1.6	1.64	1	0-5	20
2nd Station	0.9	0.93	1	0-3	24
Station 07	1.4	1.08	1	0-4	23
Odoptu Station	5.7	2.85	6	1-10	16

Theodolite Tracklines

Gray whales were tracked for at total of 74 hours ($\bar{\chi}$ = 47.6 min./track), ranging from 7 min to 4.3 hrs of continuous monitoring of movement patterns (Table 5). We recorded a total of 94 different tracklines with 5,638 geographic positions (Figure 11).

Table 5. Summary of trackline data gathered at four shore-based stations.

Station Name	# Tracklines	Avg Duration (min.)	Range (min.)
1st Station	26	51.6	15 - 148
2nd Station	30	40.8	7 - 158
Station 07	25	47.4	8 - 257
Odoptu Station	13	56.3	11 - 128

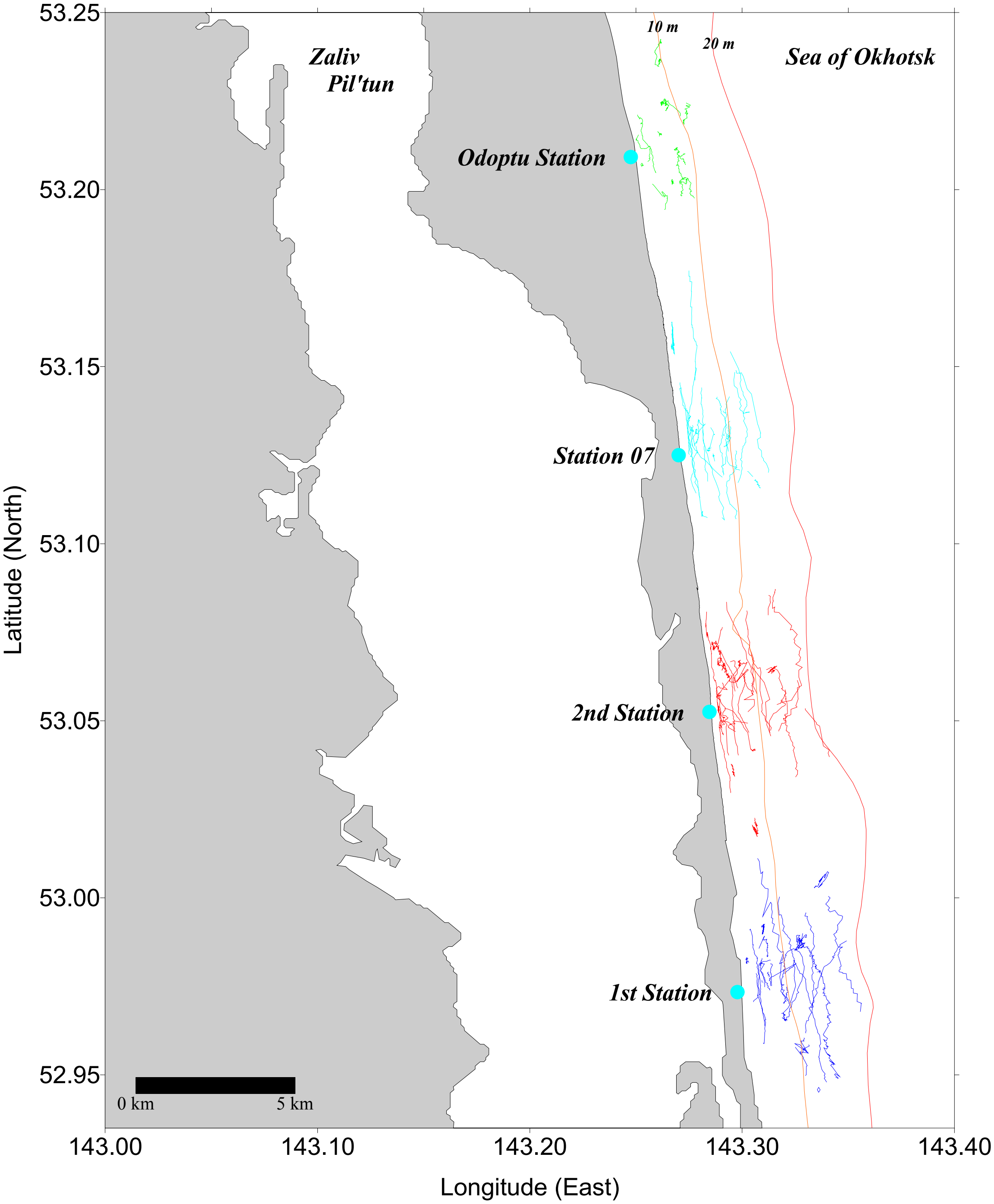

Figure 11. Tracklines (N = 94) of western gray whales at four shore-based positions on Sakhalin Island during summer 2002.

The analytical data set, consisting of only recognizable or single individuals, yielded 74 tracklines that could be used for analysis (Table 6). On average, gray whales observed during the duration of the study were moving 3.17±2.059 SD kph (Median = 2.96, Range = 0.37-7.95; Figure 12), accelerating 0.08±0.495 kph (0.00,-0.75 – 2.62; Figure 13), and reorientating 21.05±19.317 °/min (13.02, 1.43 – 83.26; Figure 14). The mean vector length and linearity index was 0.77±0.271 (0.90, 0.08 – 1.00; Figure 15) and 0.82±0.242 (0.94, 0.14 – 1.00; Figure 16), respectively. These directional indices indicate more straight-line path movement as opposed to non-directional feeding type behavior.

Table 6. Summary data for trackline analysis of western gray whales during summer 2002.

N = 74	Mean	Median	Min	Max	SD
Leg Speed (kph)	3.17	2.96	0.37	7.95	2.059
Acceleration (kph)	0.08	0.00	-0.75	2.62	0.495
Mean Vector Length	0.77	0.90	0.08	1.00	0.271
Reorientation Rate (°/min.)	21.05	13.02	1.43	83.26	19.317
Linearity Index	0.82	0.94	0.14	1.00	0.242

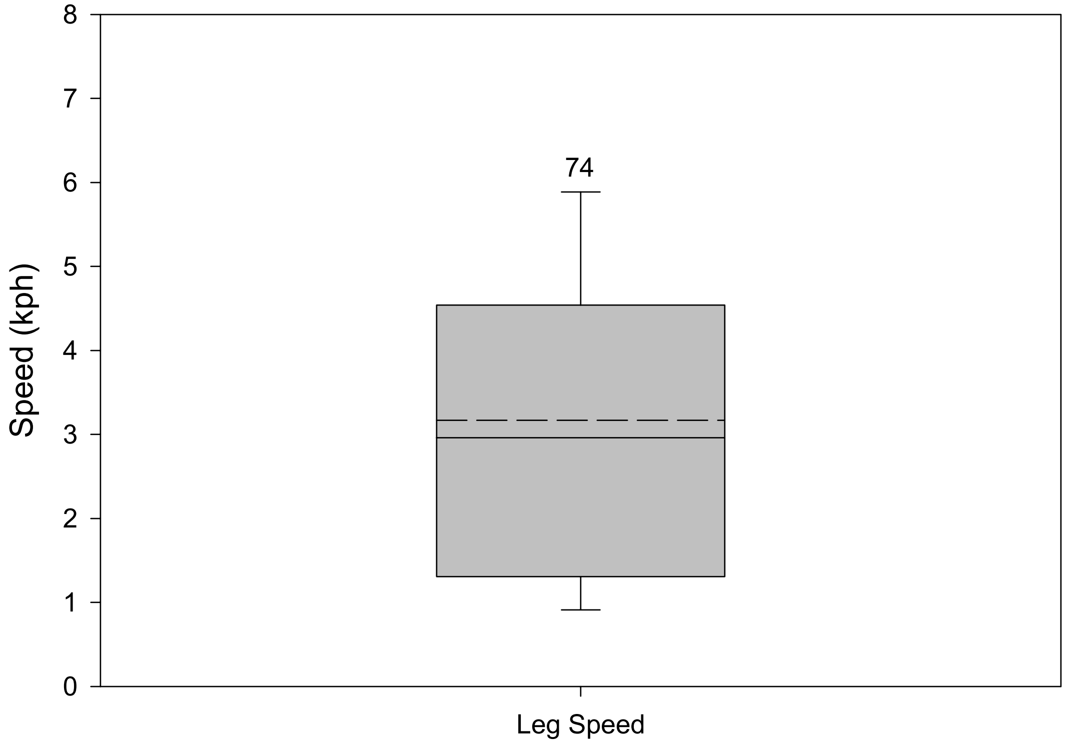

Figure 12. Leg Speed for all single or recognizable individual gray whales observed at four shore-based stations. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

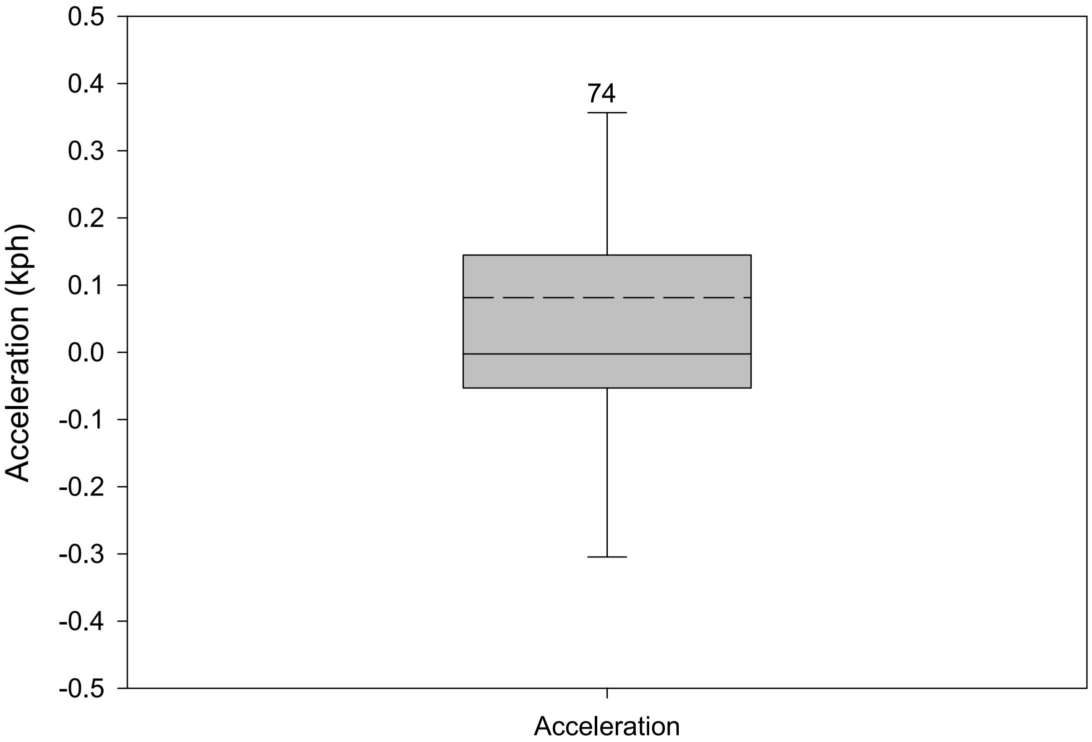

Figure 13. Acceleration for all single or recognizable individual gray whales observed at four shore-based stations. The negative values of acceleration represent deceleration. For each box-plot, the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

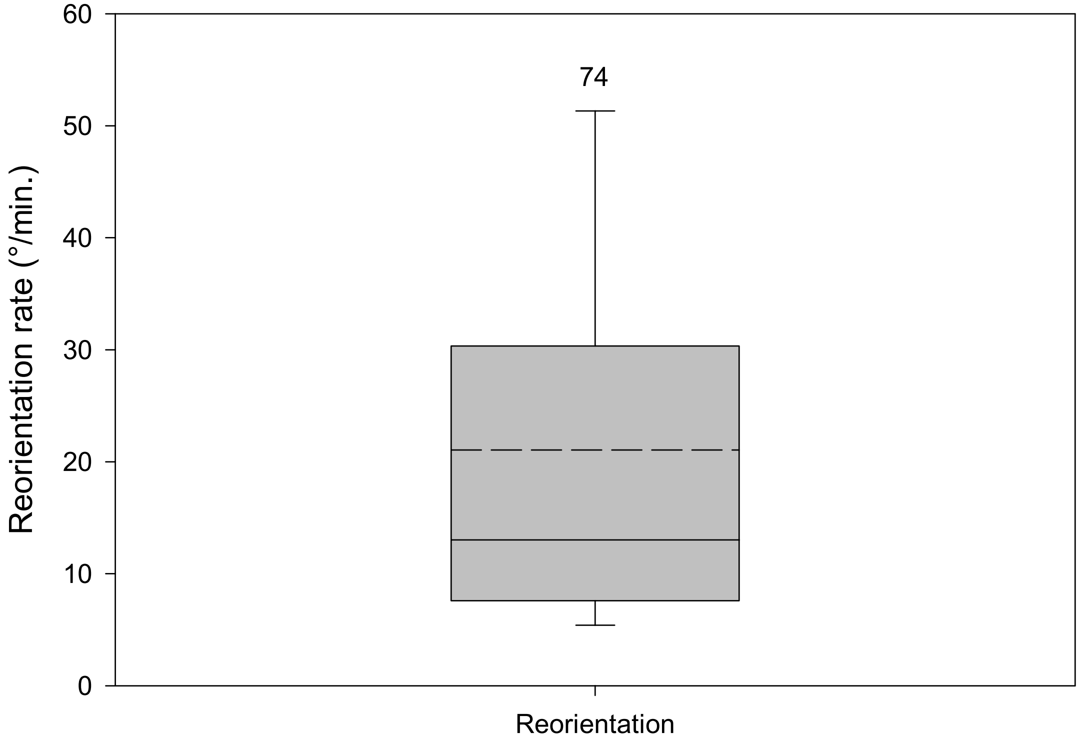

Figure 14. Reorientation rate for all single or recognizable individual gray whales observed at four shore-based stations. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

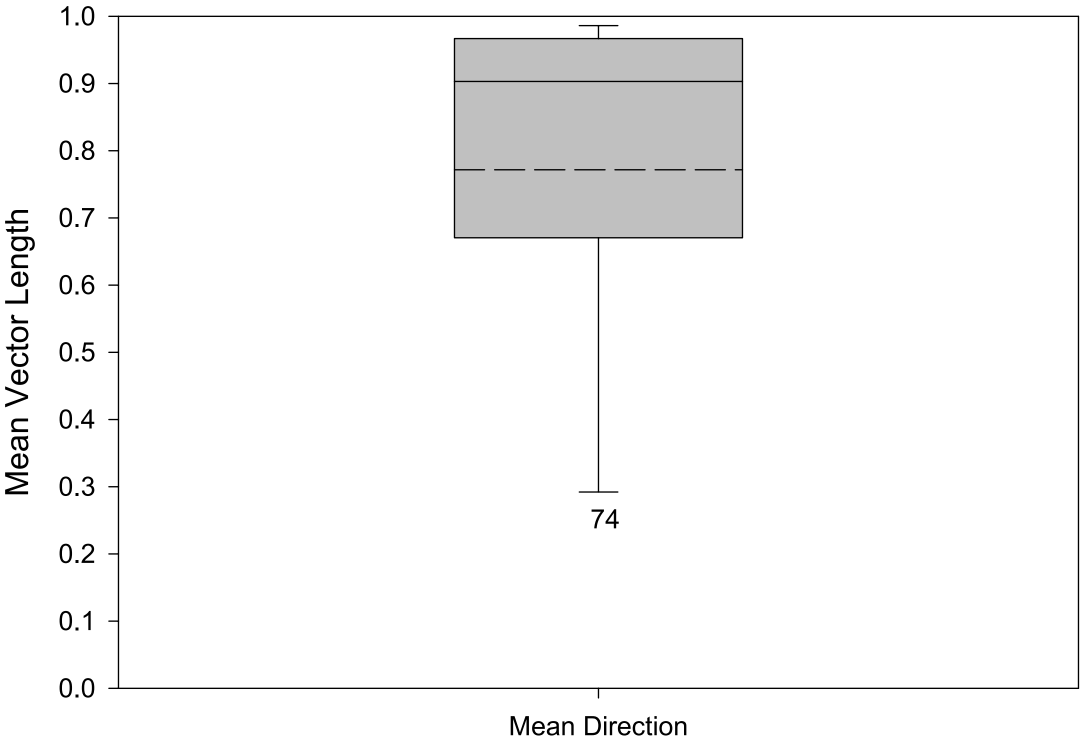

Figure 15. Mean vector length for all single or recognizable individual gray whales observed at four shore-based stations. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

Figure 16. Linearity index for all single or recognizable individual gray whales observed at four 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.

To evaluate potential seasonal changes within the duration of the study, trackline variables were compared from before and after 10 September. There were no significant differences in any variables between these two periods (Table 7, Figure 17, Figure 18, Figure 19, Figure 20, and Figure 21).

Table 7. Summary statistics of trackline variables before and after 10 September.

		Mean	Median	Min	Max	SD	N
Leg Speed (kph)	Before	3.36	3.20	0.37	7.95	2.067	31
	After	3.03	2.64	0.66	10.07	2.066	43
Acceleration (kph)	Before	0.14	0.02	-0.56	2.13	0.535	31
	After	0.04	-0.03	-0.75	2.62	0.465	43
Mean Vector Length	Before	0.81	0.96	0.10	0.99	0.279	31
	After	0.74	0.83	0.08	1.00	0.265	43
Reorientation Rate (°/min)	Before	18.63	9.54	3.15	76.73	19.606	31
	After	22.79	14.51	1.43	83.26	19.146	43
Linearity	Before	0.86	0.95	0.21	1.00	0.225	31
	After	0.79	0.93	0.14	1.00	0.252	43

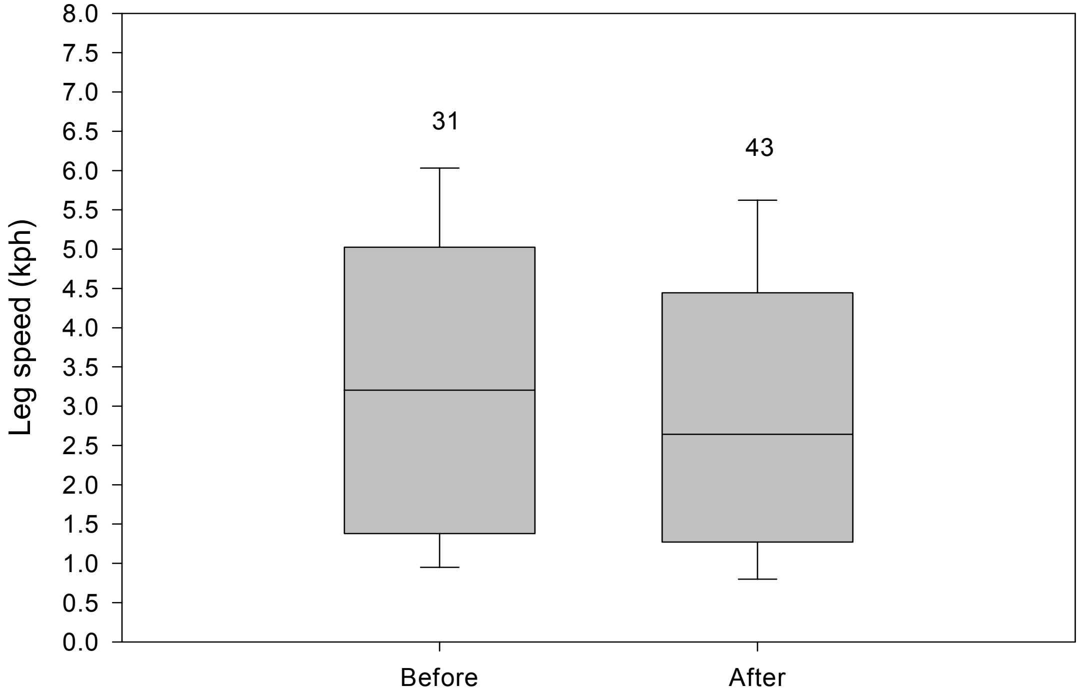

Figure 17. Leg Speed of single or recognizable gray whales before and after 10 September (t = 0.571, df = 72, P = 0.570). For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

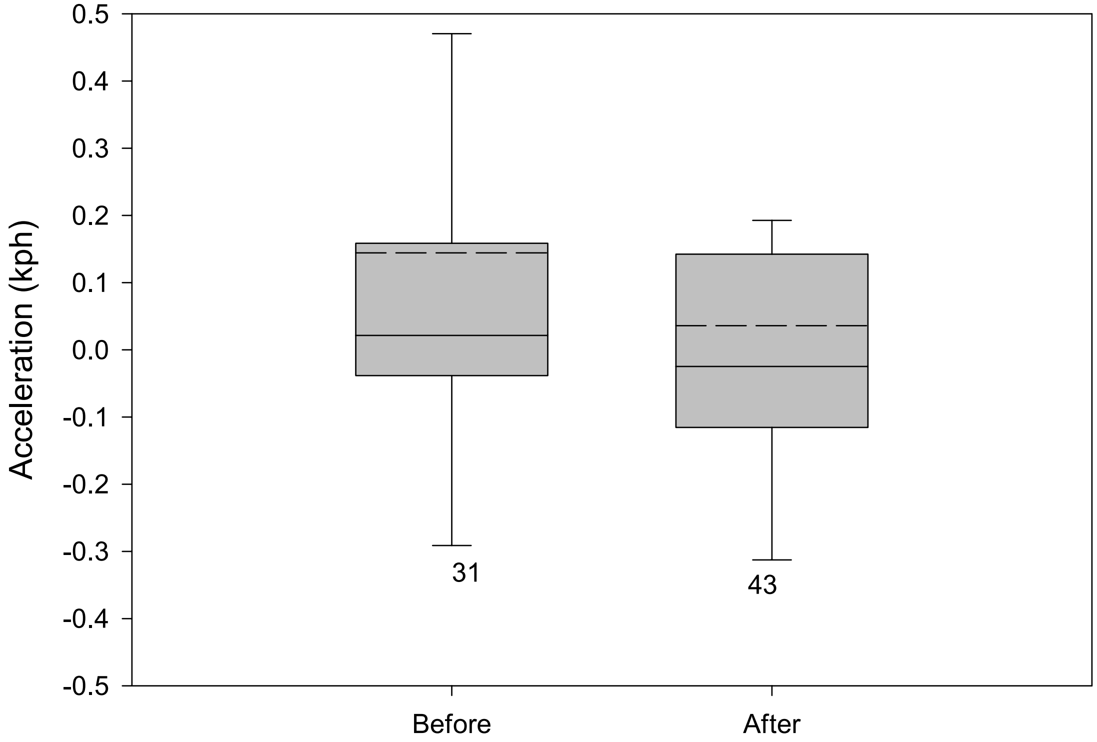

Figure 18. Acceleration of single or recognizable gray whales before and after 10 September (t = 0.992, df = 72, P = 0.324). Negative acceleration values indicate deceleration. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

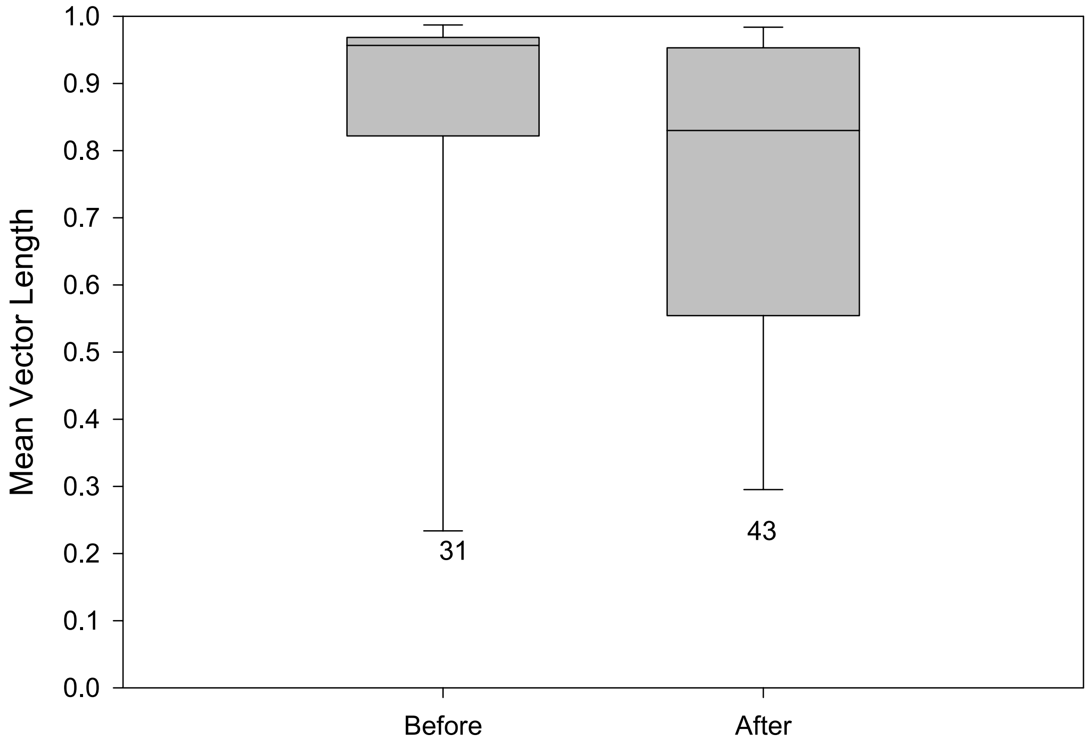

Figure 19. Mean Vector Length of single or recognizable gray whales before and after 10 September (t = 0.889, df = 72, P = 0.377). For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

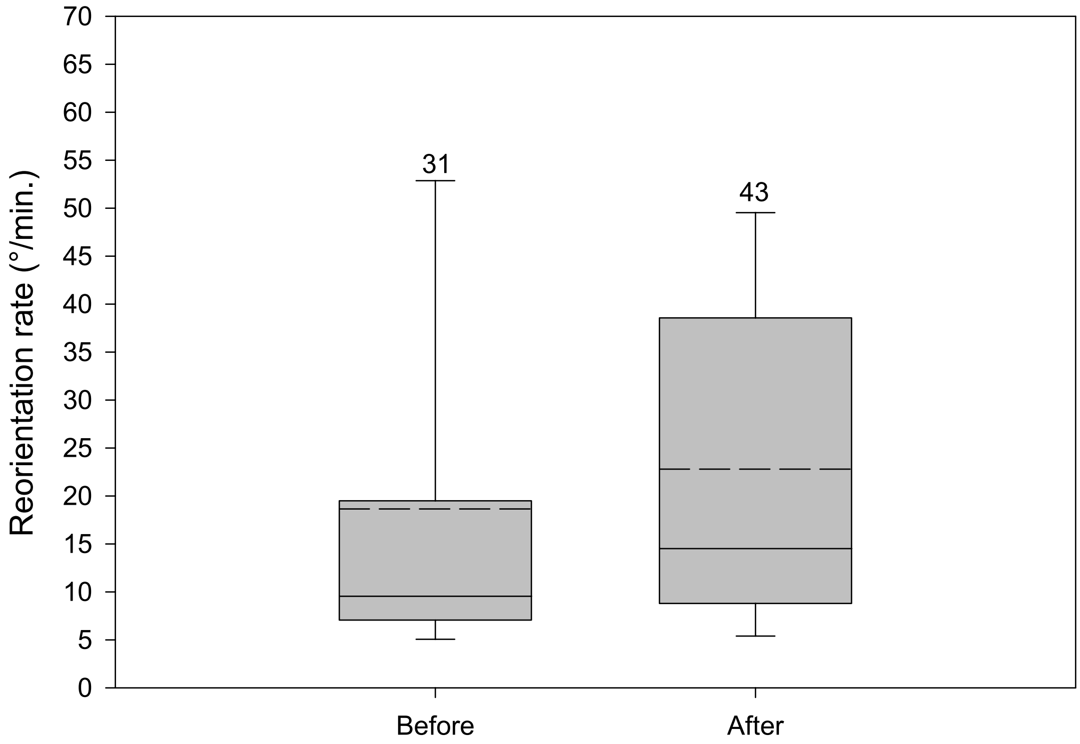

Figure 20. Reorientation rate of single or recognizable gray whales before and after 10 September (t = -0.815, df = 72, P = 0.418). For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

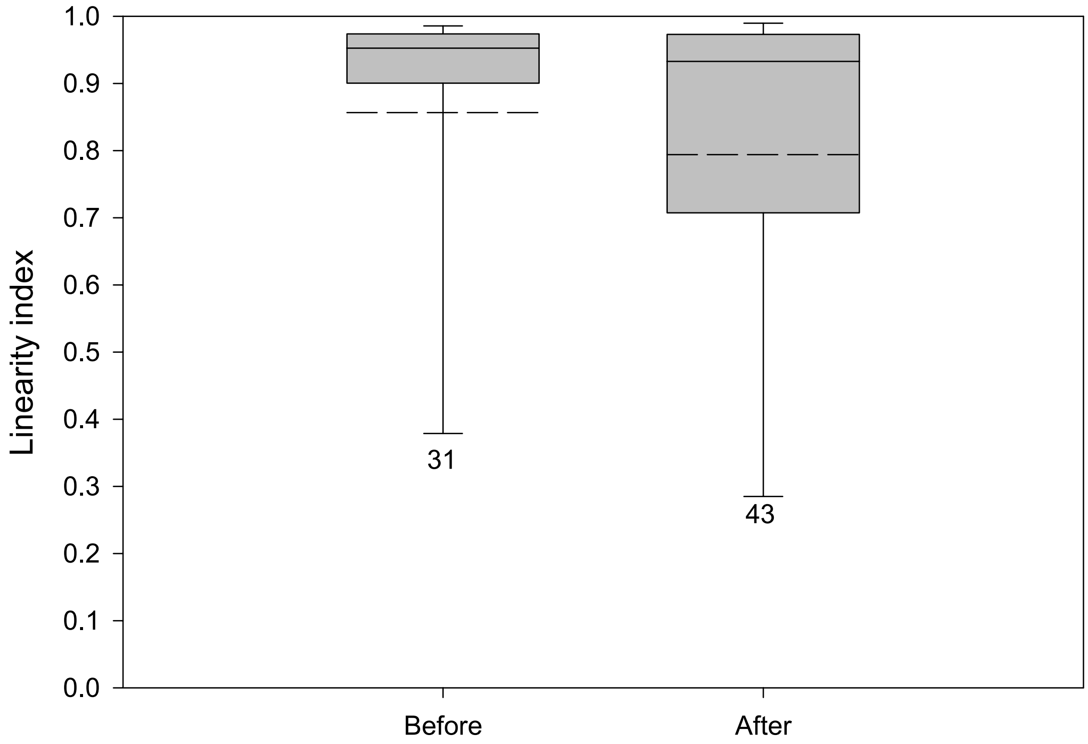

Figure 21. Linearity index of single or recognizable gray whales before and after 10 September (t = 0.665, df = 72, P = 0.508). For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

Focal Behavior Observations

Focal behavioral observations were conducted for a total of 30 hrs, on 46 individual gray whales from 17 August to 28 September 2002 (Table 8). The mean duration of a focal session lasted approximately 47 min, and a total of 3,004 behavior events were collected.

Table 8. Summary of focal behavior data gathered at four shore-based stations.

Station Name	# Focals	Mean Duration (min.)	Range (min.)
1st Station	13	65.61	26 - 145
2nd Station	14	30.64	8 - 74
Station 07	13	46.61	9 - 250
Odoptu Station	6	49.77	17 - 91
Total	46	47.46	8 - 250

On average, individual gray whales had a blow interval of 0.46±0.194 SD blows per minute (Median = 0.43, Range = 0.22 – 0.88; Figure 22), with 4.88±4.451 (3.67, 1 – 27; Figure 23) blows per surfacing. The time that individuals were observed at the surface was 1.65±1.503 (1.63, 0.33 – 7.08; Figure 22) minutes, while individuals dived for 1.84±0.805 (1.63, 1.03 – 4.60; Figure 22) minutes. The surface blow rate and surface-dive blow rate were approximately 3.64±1.630 (3.38, 1.63 – 7.23) blows per minute and 1.28±0.317 (1.26, 0.69 – 2.22) blows per minute, respectively (Table 9; Figure 23).

Table 9. Summary statistics for surface-dive-respiration parameters of individual western gray whales.

	Mean	Median	Min	Max	SD	N
Blow Interval (per min.)	0.46	0.43	0.22	0.88	0.194	46
Blows/Surfacing	4.88	3.67	1.00	27.00	4.451	42
Surface Time (min.)	1.65	1.18	0.33	7.08	1.503	42
Dive Time (min.)	1.84	1.63	1.03	4.60	0.805	44
Surface-Dive Blow Rate	1.28	1.26	0.69	2.22	0.317	42
Surface Blow Rate	3.64	3.38	1.63	7.23	1.630	42

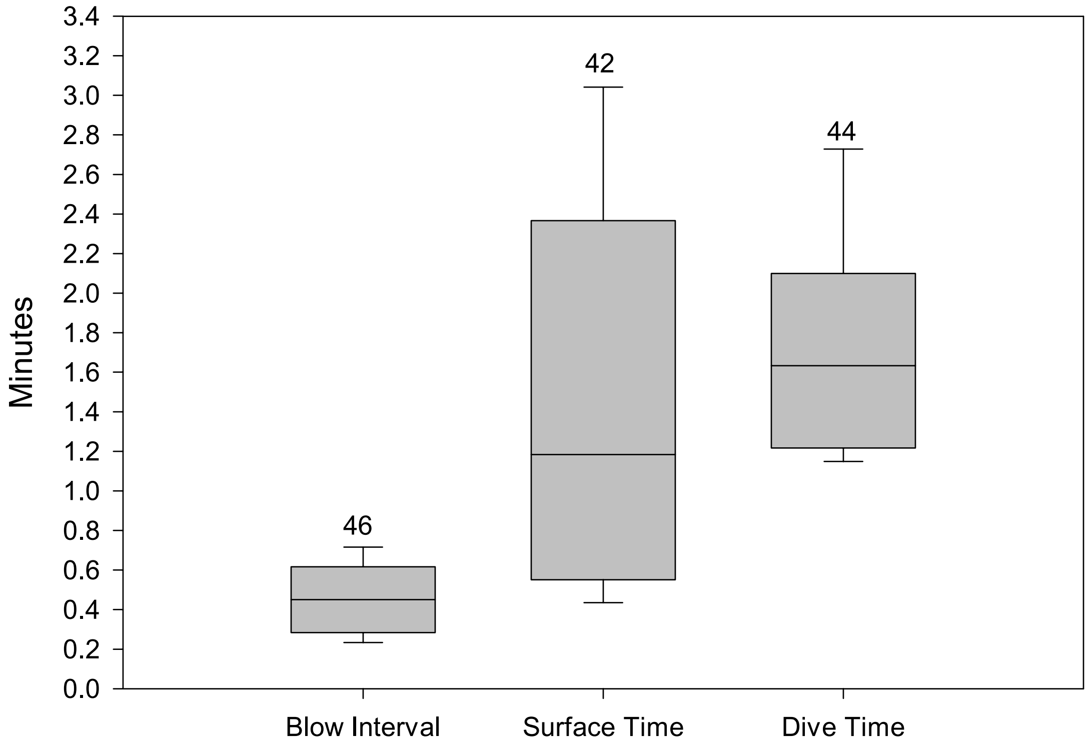

Figure 22. Blow interval, surface time, and dive time parameters of western gray whales. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

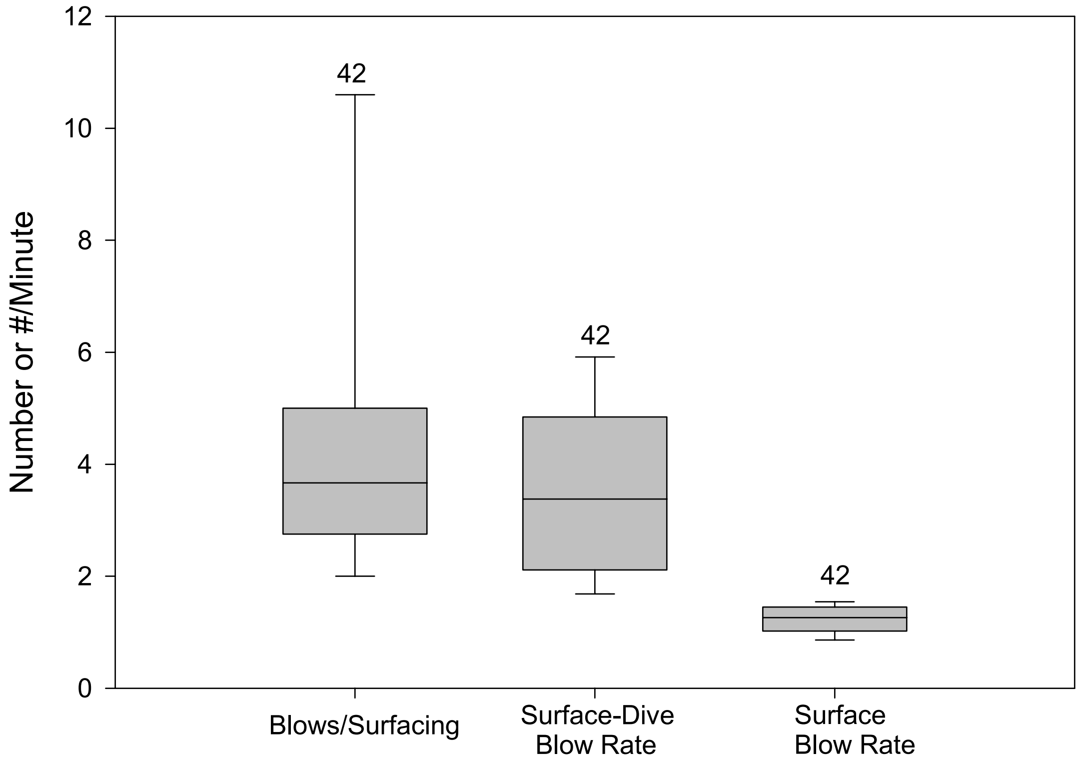

Figure 23. Number of blows per surfacing, surface-dive blow rate, and surface blow rate of western gray whales. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

Before and after 10 September periods were not significantly different for any behavioral variables evaluated (Table 10; Figure 24 and Figure 25).

Table 10. Summary statistics of behavioral parameters for the periods before and after 10 September 2002 .

		Mean	Median	Min	Max	SD	N
Blow Interval (per min.)	Before	0.44	0.42	0.23	0.73	0.169	24
	After	0.48	0.50	0.22	0.88	0.221	22
# Blows/Surfacing	Before	5.76	3.83	2.00	27.00	5.621	20
	After	4.09	3.17	1.00	13.00	2.949	22
Surface Time (min.)	Before	1.53	1.22	0.47	4.83	1.129	20
	After	1.77	1.08	0.33	7.08	1.796	22
Dive Time (min.)	Before	1.84	1.83	1.03	3.75	0.664	22
	After	1.84	1.58	1.03	4.60	0.942	22
Surf-Dive Blow Rate (#/min.)	Before	1.28	1.26	0.69	2.22	0.388	20
	After	1.27	1.28	0.85	1.86	0.246	22
Surf-Blow Rate (#/min.)	Before	3.61	3.28	1.76	6.67	1.532	20
	After	3.68	3.63	1.63	7.23	1.749	22

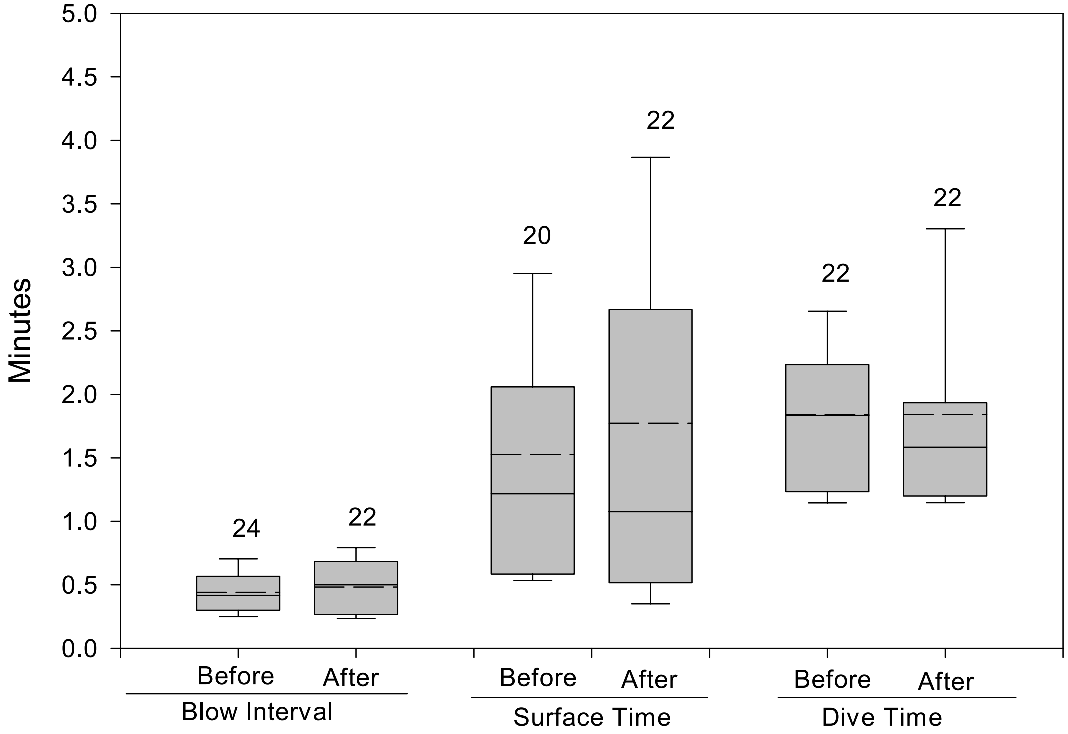

Figure 24. Box plot of blow interval (t=-0.721, df = 44, P = 0.475), surface time (0.142, 40, 0.888), and dive time (0.003, 42, 0.998), before and after 10 September. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

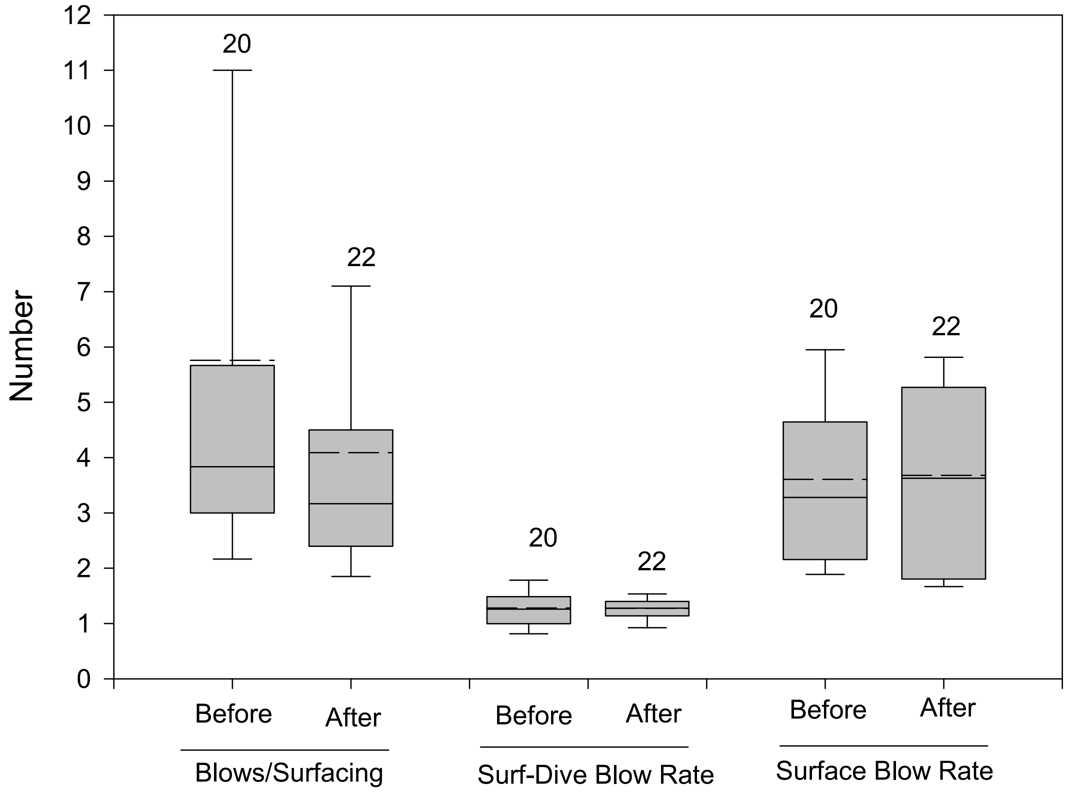

Figure 25. Box plot of blows/surfacing (1.454, 40, 0.154), surface-dive blow rate (0.141,40,0.928), and surface blow rate (0.360,40,0.890), the latter two in number per minute; before and after 10 September. For each box-plot the whiskers represent the 10th and 90th percentile, the box represents the 25th and 75th percentile, the solid bar represents the 50th percentile, and dashed bars represent mean values.

DISCUSSION

The observation season of 2002 was markedly free of water-based industrial exploration and development activities to the north of the mouth of Piltun Lagoon, and we therefore believe that this year presented a good "baseline" of information on positional/behavioral information of western gray whales. As in summer 2001 (see Würsig et al. 2002 for all comparisons to 2001 data), gray whales were present on every day of the 26 days of observations, once again indicating strong site fidelity to the near-shore area. 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), as well as the present one (Weller et al. 1999). The mean of 3.2 whales per scan was somewhat higher than the 2.6 mean per scan of 2001, indicating that, on average for the late summer season, there appeared to be more whales near-shore off the Odoptu Block than in the previous year. As well, the 2.2 pods per scan of 2002 was slightly higher than the 1.9 pods per scan of 2001. Mean pod size was as in 2001, at 1.4 whales per pod, with a range of 1-4 (in 2001, one pod was of 6 whales). This small pod size is usual for bottom or near-bottom feeding gray whales, and is slightly less than the mean and median of 2 whales per pod reported for this population by Weller et al. (1999). Their data were gathered generally 10-25 km south of the present study area, where whales in the late 1990's tended to be more numerous near the mouth of Piltun Lagoon; and it is possible that pod size is slightly larger due to more whales aggregated there.

In 2001, considerably more whales occurred at the southern-most station, Mt. Kiwi, than at the four other more northerly stations. However, in 2002, it was the northern-most station, Odoptu (just north of the 2001 northern station, Muritai) that had substantially more whales than did the other three to the south. We do not know why this was so, although surmise (with no data, however) that prey distribution was a likely factor in determining whale distribution. In the earlier part of the 2001 season, seismic surveys were conducted in the Odoptu Block, and some whales may have avoided this area during that period (Johnson 2002).

While statistical analyses were not possible for whale and pod distribution intra-seasonally, an examination of **Figure** 9 indicates that the overall distribution did not change dramatically between late August and late September. By the last day, 27 September 2002, there was no indication that whales were moving south, i.e. that the fall migration had begun. As in 2001, approximately equal numbers of whales and pods were seen in the morning and afternoon, so there was no consistent movement into or out of the area on a diel basis.

Theodolite tracking demonstrated two major behavioral types: feeding in an area, where animals remained within about 300 to 500 m for up to several hours; and traveling through the area, most often approximately parallel with the coastline. As in 2001, very little social behavior was noted during this study, unlike the apparent seasonally increasing social activity reported by several authors for August to September eastern gray whales in the northern Bering Sea, summarized by Würsig et al. (1986). It is possible (but we consider it unlikely) that our attention to tracking and behavioral analyses of single whales rather than groups of whales biased us to see less social activity than actually occurred. Overall speed of travel of whales was at a median of about 3.0 and mean of 3.2 kilometers per hour (kph), somewhat faster than the 2001 median of about 1.5 to 2.5 kph, mean = 1.7, and comparing reasonably well with the 2.3 to 2.8 kph found from a limited set of three tracks in the northern Bering Sea (Würsig et al. 1986). The slightly faster speed compared to earlier years and to the eastern population data indicates that whales may not have been feeding as much, and traveling between sites more, when observed in 2002. 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). Linearity, acceleration, reorientation rate, and mean vector length were all remarkably similar to the data of 2001, gathered in nearly the same area (Table 11). Although Table 11 also presents data from off Piltun from two earlier years, we do not regard these to be closely comparable, since they were taken from a very different vantage point (the Piltun lighthouse), by different people than those who collected the data for the most recent two years, and by slightly different categorizations and analyses.

Blow intervals, blows per surfacing, and surface time were similar to these parameters for bottom-feeding eastern gray whales in the northern Bering Sea (Würsig et al. 1986) and off Vancouver Island (Guerrero 1989). Dive times of 2001 were approximately 1.0 min shorter than for bottom feeding eastern gray whales, possibly in part due to the very shallow nature of the Sakhalin Island near-shore areas. In 2002, dive times were even less than in 2001, at a mean of 1.8 min per dive. Würsig et al. (1986) found a general increase in dive time in deeper (> 20 m) water. Guerrero (1989) found that gray whales feeding on mysids in the water column have fewer number of blows per surfacing and shorter blow intervals, surface times, and dive times than bottom-feeding whales. For 2002, the shorter dive times are consistent with greater movement and potential water column feeding, as noted above. The surface-dive blow rate was also closer to mysid feeders (Guerrero 1989) than eastern gray whale bottom feeders, but this – as well – may be due to the shallowness of the Piltun feeding area, fewer observed feeding bouts (and more traveling behavior), or some other factor(s).

Table 11. Summary statistics for theodolite and focal behavior data collected during 1997, 1998, 2001 and 2002. Dashes (-) separate numbers that indicate ranges; plus/minus (±) separate means and standard deviations, and numbers in parentheses are sample sizes.

Variable	1997 (Würsig et al. 1999)	1998 (Würsig et al. 2000)	2001 (Würsig et al. 2002)	2002 (Present Report)
Leg Speed (kph)	1.5-2.0	1.7± 1.4	1.9 ± 1.49 (510)	3.2 ± 2.06 (74)
Linearity	0.70 - 0.90	0.78± 0.40	0.8 ± 0.23 (482)	0.8 ± 0.24 (74)
Acceleration (kph)	-	-	0.0 ± 0.71 (506)	0.1 ± 0.50 (74)
Reorientation Rate (°/min.)	8 – 13	7.0± 6.12	17.4 ± 13.72 (506)	21.0 ± 19.32 (74)
Distance to Shore (km)	1 – 3	<1 – 2	1.1 ± 0.66 (510)	
Mean Vector Length	-	-	0.8 ± 0.26 (482)	0.8 ± 0.27 (74)
Blow Interval (blows/min.)	0.46± 0.17	0.37± 0.196	0.4 ± 0.14 (271)	0.5 ± 0.19 (46)
Blows per Surfacing	4.7± 4.33	3.7± 2.24	5.2 ± 3.93 (234)	4.9 ± 4.45 (42)
Surface Time (min.)	1.8± 2.48	1.0± 1.03	1.6 ± 1.84 (241)	1.7 ± 1.50 (42)
Dive Time (min.)	1.7± 0.53	2.3± 0.99	2.5 ± 0.92 (239)	1.8 ± 0.80 (44)
Surface-Dive Blow Rate (blows/min.)	1.2± 0.40	1.1± 0.43	1.2 ± 0.34 (236)	1.3 ± 0.32 (42)

In summary, there is some "natural" variability among western gray whales while on the feeding grounds, and we urge further exploration of the complex suite of natural and anthropogenic variables that can affect the whales. Two important missing items for the present work are: 1) a complete environmental data set as supplied to us for the 2001 analysis; and 2) knowledge of whale prey. Since there is the possibility of cumulative impacts on the whales as oil/gas industrial projects develop in the future, it is important to conduct studies to fill in the missing information on life history and behavior. In addition, monitoring to identify problems and suggest alternatives to practices that may be impacting the whales need to continue.

ACKNOWLEDGEMENTS

We gratefully acknowledge the logistic help of Sergei Blokhin, Sergei Balystok, Maria Esengalieva, Mike Jenkerson, Alexander Lysenko, Anna Rybka, David Weller, BridgetWatts, and Sergei Yazvenko. Rodger Melton, Caroline Martin, and Steve Johnson helped with all phases of the study, from inception to logistics, communication in the field, and editing of this manuscript. W. John Richardson helped with study design and editing. Daryl Lorenz made sure that invoices were paid in a timely manner, and drivers Alexander Lysenko and Alexander Kostin were excellent companions and helpers in the field.

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APPENDIX 1.

Theodolite Calculations of Distance, Bearing, and Geographic Positions (taken from Gailey and Ortega-Ortiz 2002).

The distance calculation performed for each fixed object incorporates the station's geographic position (latitude, longitude), theodolite angle readings, observer's height above sea level, and tide height. We used a modified version of the distance approximation proposed by Lerczak and Hobbs (1998) to calculate sighting distances from angular readings of shore-based marine mammal surveys, which corrects for the curvature of the earth,

$$\beta = \frac{\pi}{2} - \alpha - \theta = 180 - \varpi$$

$$D_0 = (R_E + h) \cdot \cos(\beta) - \sqrt{(R_E + h)^2 \cdot \cos(\beta)^2 - (2hR_E + h^2)}$$

$$\delta = \arcsin\left(\sin(\beta) \frac{D_0}{R_E} \right)$$

$$D = \delta \cdot R_E$$

where,

α = angle from horizontal (90°) to horizon and central arc angle from horizon to station

β = angle from object being fixed to station

δ = central arc from object being fixed to station

θ = angular drop from horizon to object being fixed

ϖ = vertical angle estimated with the theodolite

h = station height or altitude

R_E = radius of the Earth $(6.371 \times 10^6 \text{ m})$

D_0 = line-of-sight distance to object being fixed

D = distance to object being fixed along the surface of the earth/ocean

Once the distance to the object along the surface of the ocean (D) is known, the great circumference equation is used to determine geographic position of the fixed object,

$$\tau = \eta - \rho$$

$$Lat_F = \sin^{-1}\left(\cos(\tau)\cdot\sin(D/60/1852)\cdot\cos(Lat_S) + \left[\sin(Lat_S)\cdot\cos(D/60/1852)\right]\right)$$

$$Lon_F = \cos^{-1}\left(\frac{\cos(D/60/1852) - \left[\sin(Lat_S)\cdot\sin(Lat_F)\right]}{\cos(Lat_S)\cdot\cos(Lat_F)}\right) + Lon_S$$

where,

D = distance in meters between the two points along the surface of the Earth

τ = bearing from station to object

η = azimuth or horizontal angle estimated with the theodolite

ρ = reference azimuth (bearing from station to reference point)

Lat_S = latitude of the station

Lon_S = longitude of the station

Lat_F = latitude of the fixed object

Lon_F = longitude of the fixed object

The great circumference equation is also used to determine distance between two geographic points along the surface of the Earth when the geographic coordinates (latitude and longitude) of both points are known.

$$D = \left(60\cdot\cos^{-1}\left[\left(\sin(Lat_1)\cdot\sin(Lat_2)\right) + \left(\cos(Lat_1)\cdot\cos(Lat_2)\right)\cdot\cos(Lon_2 - Lon_1)\right]\right)\cdot 1852$$

$$\varphi = \cos^{-1}\left[\frac{\sin(Lat_2) - \left[\sin(Lat_1)\cdot\cos(D/60)\right]}{\sin(D/60)\cdot\cos(Lat_1)}\right]$$

where,

D = distance in meters between the two points along the surface of the Earth

φ = bearing from point 1 to point 2

Lat_1 = latitude of point

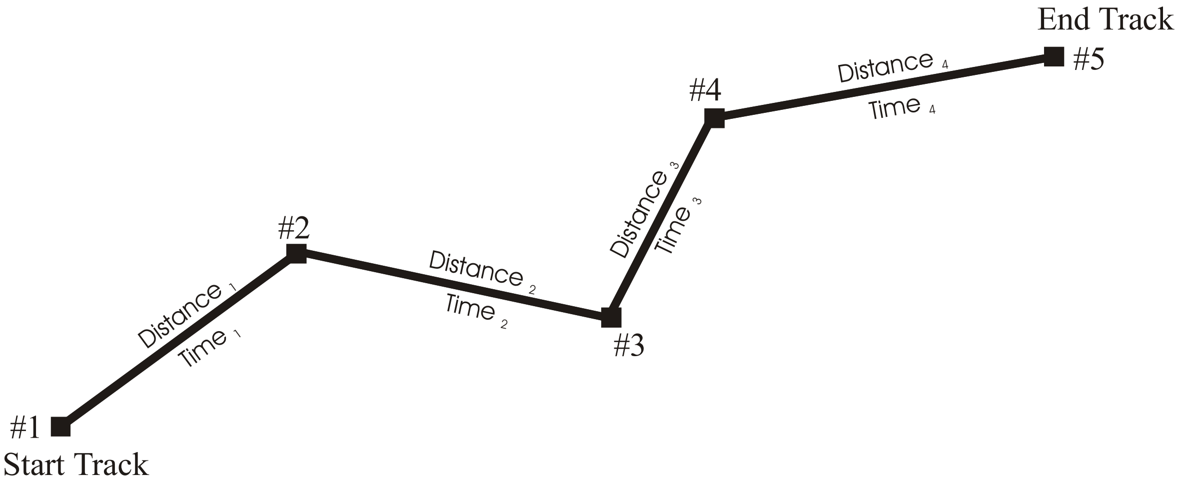
Lon_1 = longitude of point 1

Lat_2 = latitude of point 2

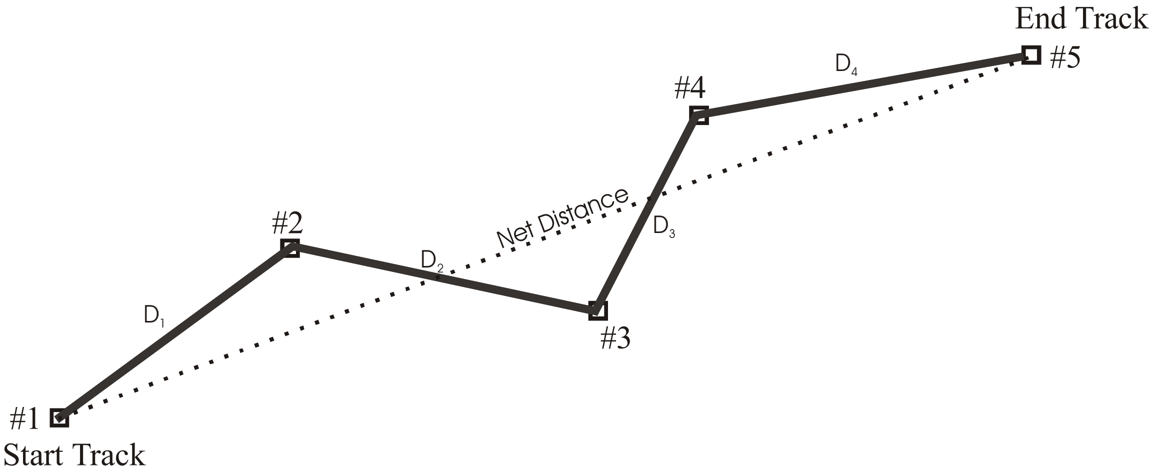
Lon_2 = longitude of point 2

APPENDIX 2.

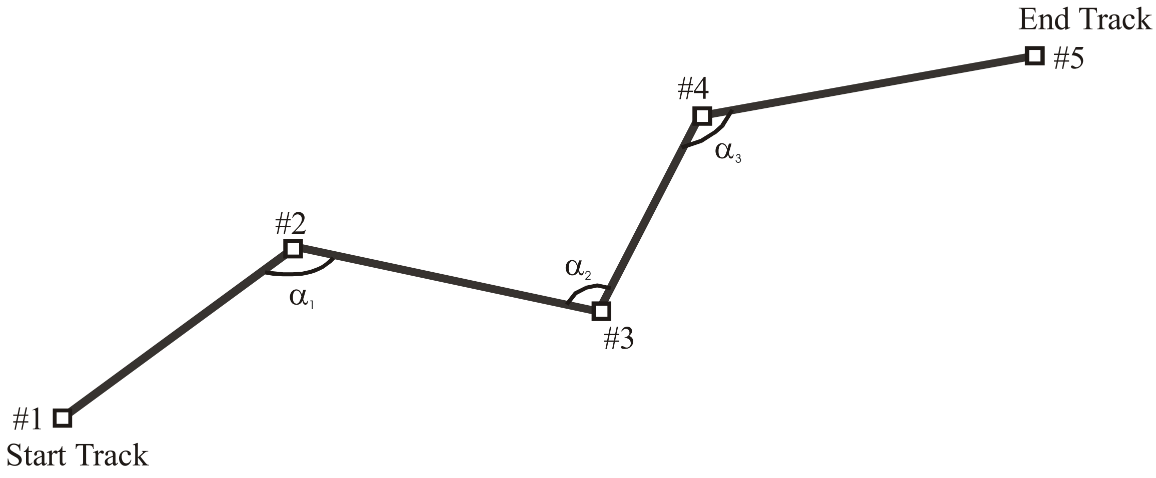
Examples of Trackline Calculations for Leg Speed, Linearity, Reorientation Rates, and Relative Orientation (taken from Gailey and Ortega-Ortiz 2002).



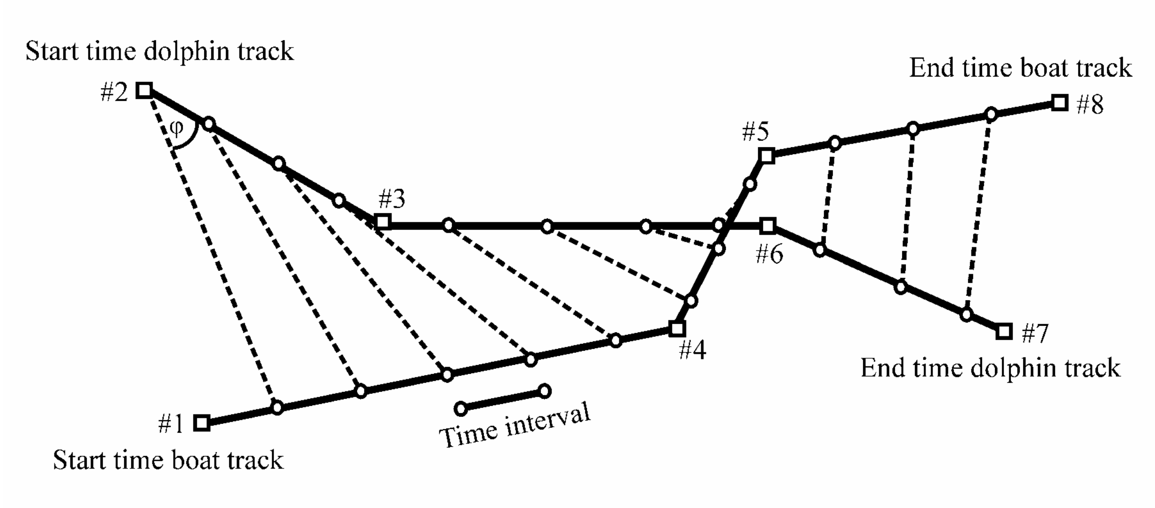
An example illustrating the calculated leg speed by dividing the geographic distance traveled between two sequential fixed positions by time. Numbers indicate actual fix points along the trackline ($Leg\ Speed = Distance_i / Time_i$, where Distance$_i$ is the distance between fix number i and i+1 and Time$_i$ is the time difference between fix number i and i+1).



An example illustrating the calculated linearity by dividing the net geographic distance by the cumulative distances along a trackline. Numbers indicate actual fix points along the trackline ($Linearity = Net_D \Big/ \sum_{i=1}^{k-1} D_i$, where D$_i$ is the distance between fix number i and i+1, k is the maximum number of fix points, and Net_D is the net distance between the first and last fix points).



An example illustrating the calculated reorientation rate. ($RR = \sum_{i=1}^{k-1} |\alpha_i - \alpha_{i+1}| / Time_D$, where RR is the reorientation rate, $Time_D$ is the duration of the trackline (minutes), and k is the total number of angles). Numbers indicate actual fix points along the trackline.



Positions used to estimate distance between a dolphin/whale trackline and a boat trackline. Location is estimated by interpolating position at specified time intervals. Numbers indicate the sequence of actual fixes. The angle φ indicates the relative orientation of reference trackline (dolphin/whale) to trackline selected for comparison (vessel).

APPENDIX 3.

Daily summary of theodolite, focal behavior, and scan data collected during the summer of 2002.

Station	Date	Start Day	End Day	Effort (Hrs)	# Tracklines	# Focal Follows	# Scans
2nd_Station	17-Aug-02	13:42:18	16:50:40	03.14	1	0	0
1st_Station	23-Aug-02	13:00:16	18:04:02	05.06	1	0	0
1st_Station	24-Aug-02	11:10:50	18:05:16	06.91	4	3	3
2nd_Station	25-Aug-02	10:10:21	15:42:25	05.53	6	3	1
Station_07	26-Aug-02	09:34:58	17:36:35	08.03	9	4	6
1st_Station	29-Aug-02	11:51:51	16:09:56	04.30	1	1	3
1st_Station	01-Sep-02	06:55:47	18:23:00	11.45	6	3	9
2nd_Station	02-Sep-02	07:16:37	12:51:02	05.57	1	0	3
2nd_Station	04-Sep-02	07:09:56	09:21:29	02.19	1	0	2
2nd_Station	05-Sep-02	06:51:19	18:44:30	11.89	8	5	7
Station_07	06-Sep-02	07:07:32	17:48:34	10.68	6	3	9
Odoptu_Station	07-Sep-02	07:35:42	12:54:38	05.32	1	1	4
1st_Station	08-Sep-02	07:10:00	07:10:00	00.00	0	0	2
1st_Station	09-Sep-02	07:46:53	15:19:56	07.55	1	1	3
2nd_Station	10-Sep-02	07:48:54	07:48:54	00.00	0	0	1
2nd_Station	12-Sep-02	18:08:00	18:08:00	00.00	0	0	1
2nd_Station	13-Sep-02	12:13:46	13:17:00	01.05	1	0	2
2nd_Station	14-Sep-02	08:02:36	18:53:59	10.86	7	3	9
Station_07	15-Sep-02	07:29:23	17:40:21	10.18	5	4	6
1st_Station	16-Sep-02	07:39:27	18:11:19	10.53	3	1	8
2nd_Station	17-Sep-02	07:45:47	17:48:02	10.04	2	1	3
Station_07	19-Sep-02	07:49:37	14:25:10	06.59	4	1	2
Odoptu_Station	21-Sep-02	07:55:54	13:58:14	06.04	3	0	3
1st_Station	23-Sep-02	11:08:48	18:16:38	07.13	7	3	4
2nd_Station	24-Sep-02	07:52:39	17:44:10	09.86	2	2	8
Station_07	25-Sep-02	07:42:57	16:48:32	09.09	2	1	7
Odoptu_Station	26-Sep-02	09:54:53	14:36:05	04.69	1	1	1
Odoptu_Station	27-Sep-02	07:48:34	17:15:50	09.45	8	4	7
1st_Station	28-Sep-02	08:16:05	17:22:53	09.11	3	1	3
TOTAL	26 Days			192.26	94	46	117