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Final Contract Report
February 3, 1999
Sakhalin Marine Mammal
Monitoring and Research Program

Gray Whales Summering off Sakhalin Island, Far East Russia: July-October 1997. A Joint U.S.-Russian Scientific Investigation

by

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INTRODUCTION

Numerous species of whales, dolphins, porpoises, fur seals, and seals inhabit the Sea of Okhotsk (Fig. 1). Three of the most critically endangered populations of large whales; the Okhotsk bowhead (*Balaena mysticetus*), the western North Pacific right whale (*Eubalaena glacialis*), and the western Okhotsk/Korean gray whale (*Eschrichtius robustus*) are known to occur in this sea (Brownell *et al*. 1997, Clapham *et al*. in press). Concerns regarding the status of these whale populations have been intensified by the recent onset of large scale U.S.-Russian oil and gas development programs in Okhotsk waters. Anthropogenic activities related to oil and gas exploration, including geophysical seismic surveys, drilling operations, vessel and aircraft traffic, and oil spills pose potential new threats to the marine ecosystem, and may impact populations of endangered species, including whales (for reviews see Richardson *et al*. 1995 and Geraci and St. Aubin 1990). However, a properly designed biological monitoring and Habitat Conservation Plan (U.S. Fish and Wildlife Service 1998) can provide the requisite information needed to prevent significant impacts, and help to mitigate unavoidable impacts to acceptable levels. Therefore, it has been mandated by the Russian and U.S. governments that biological investigations of potential industry-related ecosystem impacts be conducted for such oil and gas development projects to proceed (Anonymous 1997a).

Detailed information on responses of marine mammals to industrial activities and noise can help to gauge potential ecosystem effects (Richardson *et al*. 1995, Richardson and Würsig 1997). Results from studies on the reactions of cetaceans to underwater noise and other human related activities are highly variable, ranging from no apparent response to active avoidance (for review see Richardson *et al*. 1995). While many of these studies have documented no or only subtle short-term changes in behavior, it is important to recognize that tolerance of noise does not necessarily mean that it has no deleterious effects (Richardson and Würsig 1997). Long-term effects of noise and disturbance at the individual and population levels are presently little understood. Gray whales currently provide the best example of long-term behavioral changes as a result of industrial activities. Several studies on eastern gray whales have documented distributional shifts or complete abandonment (Bryant *et al*. 1984) of known wintering areas in relation to increased anthropogenic activity (for review see Richardson *et al*. 1995).

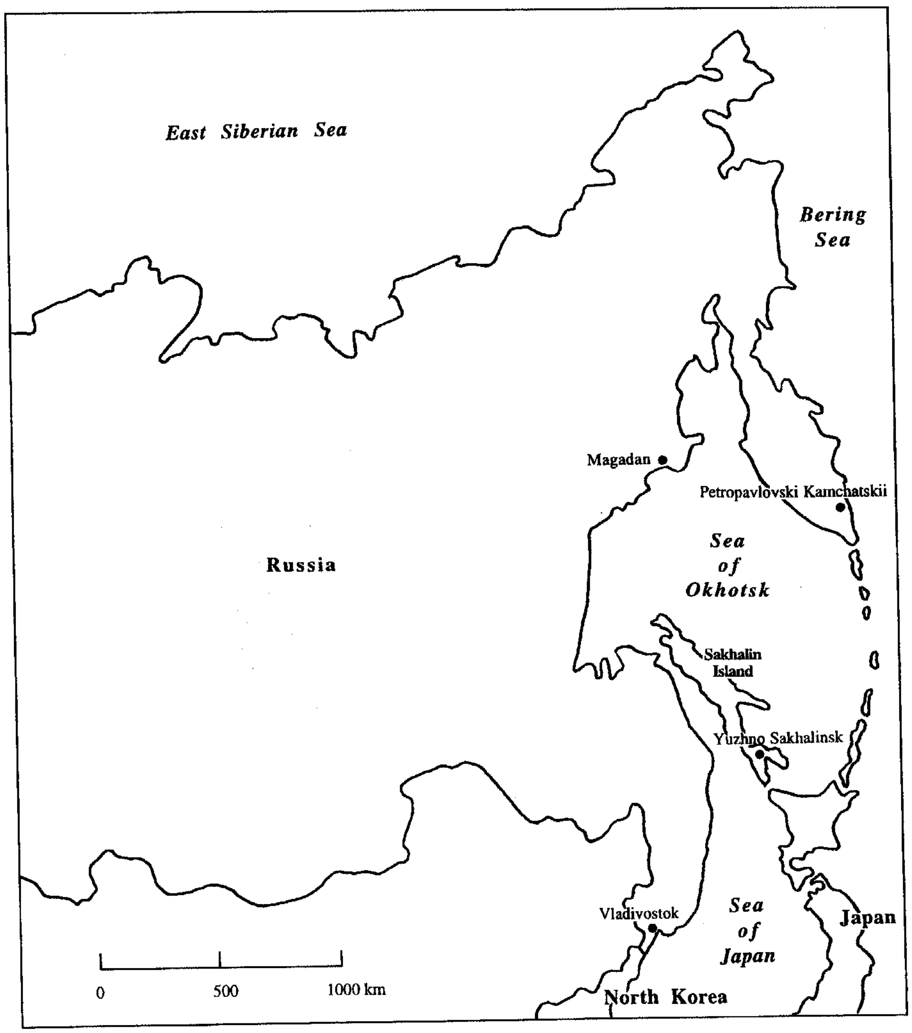


Figure 1. Far East Russia, showing Sakhalin Island in the southwestern Okhotsk Sea.

Rationale

Extensive oil and gas exploration and development is currently underway off the northeastern coast of Sakhalin Island, Russia (Fig. 2). During summer of 1997, 3-D geophysical surveying of a feature named “Piltun-Astokhskoye” (PA) on the northeastern Sakhalin coast was conducted (Fig. 2). At the same time, plans were finalized for the 1998 installation of the temporary drilling rig “Sakhalinskaya” (52°54’ N, 143°29’ E) and permanent offshore production platform “Molikpaq” (52°43’ N, 143°34’ E) in the PA field. This oil field overlaps in latitude with the waters adjacent to Piltun Lagoon. Sighting records from Russian aerial and vessel surveys in the Okhotsk Sea between 1979 and 1989, and recent aerial surveys by Würsig *et al*. (1998) suggest that gray whales aggregate predominately along the shallow-water shelf region located off Piltun Lagoon (Blokhin *et al*. 1985, Votrogov and Bogoslovskaya 1986, Berzin *et al*. 1988, 1990, 1991, Berzin in press, Würsig *et al*. 1998). This region of the Okhotsk Sea is characterized by high benthic biomass densities of 1,000,000 kg/km^2 (V. N. Koblikov unpublished data), and is the only currently known feeding ground for western stock gray whales (Blokhin *et al*. 1985, Brownell *et al*. 1997). Given the endangered status of western gray whales (Anonymous 1997b, Clapham *et al*. in press), and the new potential for increased industry-related disturbance on their feeding grounds, a joint U.S.-Russian multi-year research, monitoring, and mitigation program was initiated to monitor gray whales (and other marine mammals) off the northeastern Sakhalin coast.

Oil development involves industrial activities that could pose threats to western gray whales, as has been documented for marine mammals elsewhere (review by Geraci and St. Aubin 1990). Potential problems include those associated with oil spills, ship strikes, entanglements in cables or lines, pollution from drilling muds or similar materials, and physical habitat changes such as those caused by dredging (review by Richardson *et al*. 1989, and Clapham *et al*. in

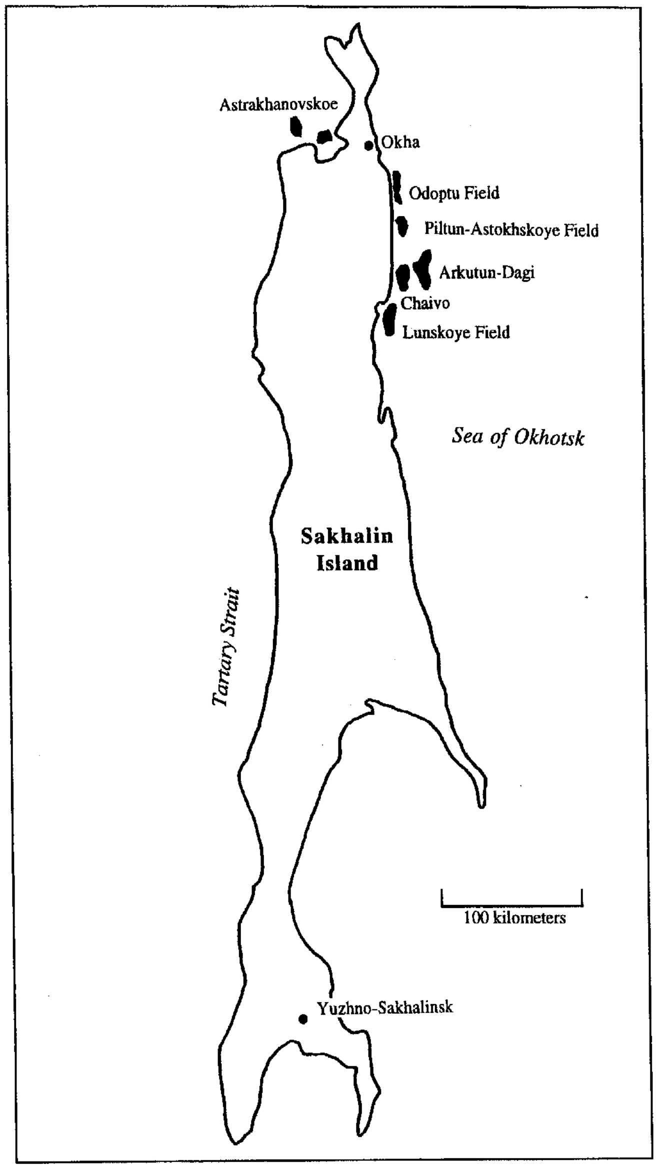


Figure 2. Sakhalin Island, with major oceanic oil fields along the northeastern coast.

press). In addition, displacement of whales from critical feeding and migratory habitat is possible due to the disturbance from noise, seismic surveys, or other industrial activities. For example, strong acoustic sources like the open-water seismic exploration conducted in the PA field during 1997 are probably audible to gray whales at distances exceeding 100 km (Richardson *et al*. 1995). Previous studies in the U.S. and Canadian arctic or near-arctic, on bowhead, white (*Delphinapterus leucas*), and gray whales have demonstrated that knowledge of habitat use and behavioral reactions can help to plan industrial activities in a fashion that allows both animals and humans to coexist (summaries in Würsig 1990, Richardson and Würsig 1995, 1997).

Preliminary findings from research conducted during July-September of 1997 indicate that the near-shore waters close to Piltun Lagoon play an important role in the feeding ecology for at least part of the western gray whale population. This report represents first-year findings from a multi-year program to: 1) examine potential short- and long-term behavioral changes of whales exposed to industrial activities related to development of the northeastern Sakhalin Shelf; 2) determine population numbers and habitat use patterns of whales in the area; and 3) develop potential mitigation policies allowing industrial activities and marine mammals to coexist. While this report is complete for 1997 data, further analyses of inter-year trends and a minimum population estimate for 1997 will be presented in a similar report for the now completed 1998 field season.

Background and Research Summary

The Okhotsk-Korean or western gray whale is one of the most endangered and little known populations of large whales in the world (Brownell and Chun 1977, Berzin *et al*. 1995, Brownell *et al*. 1997, Clapham *et al*. in press). This population was intensively hunted from at least the late 16th century by Japanese net whalers, European and American whalers during the late 1840's, and Korean whalers as recently as 1966 (Omura 1984, Brownell *et al*. 1997). In 1974, the western gray whale was considered by many to be extinct (Bowen 1974). However, in 1977 the scientific "re-discovery" of this population was described (Brownell and Chun 1977). Russian sighting records from sporadic aerial and vessel surveys conducted between 1979 and 1989 (Blokhin *et al*. 1985, Votrogov and Bogoslovskaya 1986, Berzin *et al*. 1988, 1990, 1991, Berzin in press), and photographic identification studies in 1994, 1995, and 1997 (Brownell *et al*. 1997, this report) suggest that western gray whales summer (May-November) along the shallow-water shelf of northeastern Sakhalin Island, where they feed on benthic and near-benthic organisims. Although no truly systematic or quantitative data are available, current population size estimates suggest that fewer than 250 animals now exist (Vladimirov 1994, Blokhin 1996). Basic information regarding the life history and population biology of the western gray whale is also sparse, and only recently has this cetacean come under concerted study (Brownell *et al*. 1997).

In August of 1995, a long-term research project on the conservation status, distribution, and behavior of gray whales off the northeastern coast of Sakhalin Island was initiated under the U.S.-Russian Environmental Agreement (Marine Mammal Project). In early July of 1997, the first follow-up to the 1995 work was undertaken by a collaborative research effort between Texas A&M University and the Kamchatka Institute of Ecology and Nature Management. The principal components of the 1997 research effort were: 1) shore-based observations to describe general behavior and near-shore movement patterns in relation to geophysical seismic survey activity; 2) photo-identification of individual whales to examine occurrence patterns, site fidelity, and habitat use; 3) acoustic monitoring of the ambient environment, industrial/seismic sounds, and gray whale vocalizations; and 4) surveys of the near-shore area to describe basic distribution patterns.

Intensive fieldwork was carried out from early July to early September, 1997, in the near-shore waters off Piltun Lagoon. In addition, general monitoring in the form of daily shore-based whale counts were maintained until early November to further document southward migratory timing and departure from the Okhotsk Sea feeding grounds. From July to September, 69 days were spent in the field, with 36 of these shore observation days; 21 boat-based photo-identification days; and 17 acoustic monitoring days. Baseline data collected during the study were analyzed by the Marine Mammal Research Program at Texas A&M University, and by Russian scientists at the Pacific Research Institute of Fisheries and Oceanography (TINRO), Vladivostok and the Kamchatka Institute of Ecology and Nature Management, Far Eastern Branch of the Russian Academy of Sciences. Results presented here provide the first systematic assessment of habitat use, distribution, numbers, individual site fidelities, and behavior of western stock gray whales relative to geophysical seismic operations.

Summer 1997 findings clearly indicate that relative to the estimated total population of only several hundred whales, large numbers of feeding gray whales inhabit the northeastern Sakhalin Shelf during ice-free periods. Photo-identification of individually recognizable whales documented a fidelity to the area for numerous individuals, including two mother/calf pairs. The relatively constant number of whales using the Piltun study area during the summer of 1997, combined with regular observations of feeding behavior, suggest that this coastal habitat is an important feeding area for at least part of this endangered population.

METHODS

Study Area

Zaliv Pil'tun (referred to in this report as Piltun Lagoon) is located on the northeastern shore of Sakhalin Island, Russia (Fig. 3). The lagoon is approximately 90 km long and 15 km across at its widest point. A single entrance connecting the inner lagoon ecosystem with the Okhotsk Sea occurs at 52°50' N, 143°20' E, and appears to have considerable biological influence on the surrounding coastal waters. The near-shore marine environment of this region is characterized by shelf waters generally less than 20 m deep, over a predominately sand substrate (Fig. 3). Water temperature during the summer varies from about 4-15 °C, and salinity ranges are typically between 29 to 30 ppt. Periods free of sea ice occur between May and December, however, significant annual variability exists. With the exception of seismic survey vessels working in the near vicinity, the Piltun study area was essentially free of any regular anthropogenic disturbance.

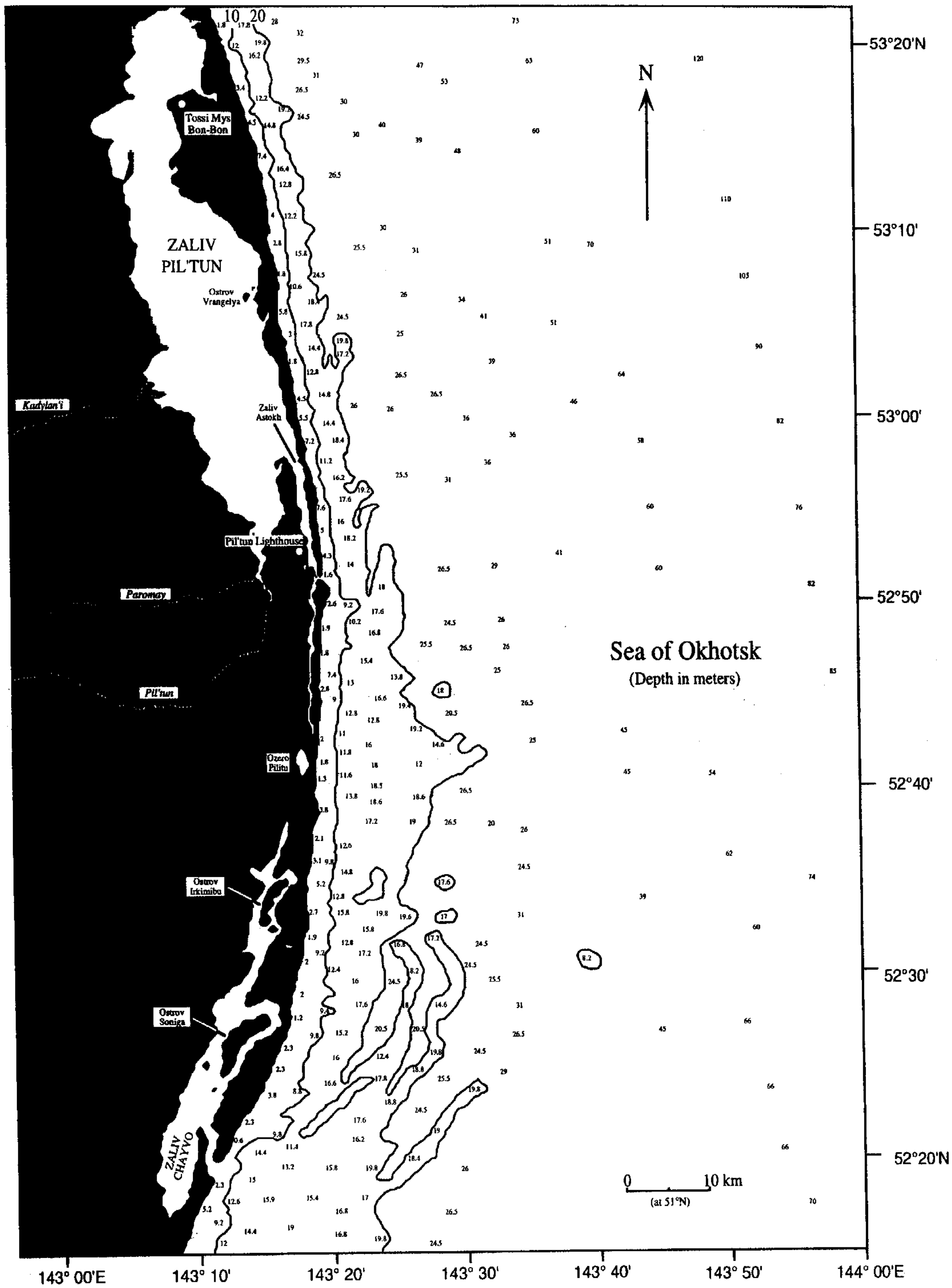


Figure 3. Near-shore waters near Piltun, the main research site of the present study. Depths are represented in meters.

The Piltun lighthouse is situated just north of the lagoon mouth, and is separated from the sea by a narrow channel in the lagoon and an outer barrier spit. Thus, the 35 m lighthouse sits approximately 1.4 km inland of the seashore. The field camp is highly remote and primitive, with access only by helicopter, boat, or four-wheel drive tundra truck making for a variety of logistical constraints.

Aerial Surveys

Our plan to carry out systematic aerial surveys throughout the 1997 field season did not materialize due to unforeseen logistical problems, largely related to the remoteness of the field camp and limited communication capabilities. However, one survey was conducted between 1527 and 1800 hours on 19 August along the northern and northeastern shore of Sakhalin Island. The survey flight path was from Nikolayevsk-na-Amur to the Piltun field camp. Aerial observations were conducted from a MI-8 helicopter, traveling within 0.5 km of the shoreline, at an altitude of 400 m, and approximate air speed of 170 km/h. The Beaufort State ranged from 2 to 5, but was 4 (making for marginal observation conditions) for most of the flight along the northeastern shore of Sakhalin, from Cape Elizabeth to Piltun. Observational protocol during this flight consisted of stationing one experienced observer on each side of the helicopter cockpit to look for whales and to log sighting information onto data sheets. On-board GPS positional information was not available during the flight, so sighting positions were determined by shore-based recognition points and by interpolating some sightings from speed of travel between points. Observation methods and analyses of groups and subgroups of whales followed techniques developed for other gray whale studies (Rugh 1984, Rice *et al*. 1981).

Vessel Surveys

Sightings from our small Zodiac-type outboard research vessel generally coordinated with shore observations, and alternated with behavioral studies and photographic identification (see below and Würsig *et al*. 1986, for gray whales feeding off St. Lawrence Island, northern Bering Sea). However, we obtained a basic strip-transect count (of a strip width of 2 km on either side of the vessel) of gray whales from a larger 15 m vessel on 1-3 August. Sighting conditions were excellent, with Beaufort State ranging from 0 to 1. During daylight hours, the survey vessel traveled south to north from Chaivo Lagoon (with the survey starting at 52°00'N) to approximately 60 km north of Piltun (53°25'N), at a distance of 2 km from shore and a speed of 7-9 km/h. A single observer equipped with 7x50 binoculars and a GPS maintained nearly continuous watch to document all marine mammal sightings.

Acoustic Monitoring

Acoustic studies of the environment and whales are necessary to describe potential disruption of whale activities by industrial sounds. Although gray whales are not highly vocal, they do emit sounds believed to be important for communication (Dahlheim 1987, Crane 1992). It has even been suggested that gray whales can alter the tonal frequencies of their calls in response to human noise (Dahlheim *et al*. 1984), and that this acousto-behavioral shift might mitigate against anthropogenic masking of important communicatory sounds. Eastern stock gray whales are known to react to human industrial activities (Malme and Miles 1985, Malme *et al*. 1988), making it important to also collect acoustic information for western gray whales.

The same vessel used for photo-identification work was also used for acoustic recording. Recordings were made opportunistically between photo-identification sessions, and when weather allowed. Basic protocol consisted of recording ambient noises with and without human activities, and whale vocalizations with calibrated hydrophones and sound recorders. This approach allowed for descriptions of received sound levels at different frequencies (Richardson and Greene 1995). Recording locations were chosen pseudo-randomly within the general vicinity of consistent gray whale sightings. Salinity and surface temperature measurements were taken at each recording location and GPS positions and depth measurements were recorded regularly throughout sessions. During recordings, the vessel was allowed to drift with the engine turned off.

From 6 July through part of 31 July, recordings were made using a single-element hydrophone and a Marantz analog tape recorder. Thereafter, the recording system included a four-element vertical array of hydrophones maintained and calibrated by Cornell University's Bioacoustics Laboratory. However, due to the shallow water depth of the near-shore shelf region (recording depths ranged from 4.5-24.0 m), only the bottom element of the array could ever be deployed for recording. Hydrophone depth was generally about mid-water, but was varied to also include near-bottom and near-surface recording positions.

The hydrophone cable was connected to a Shure FP-11 preamp that controlled signal strength, and sounds were recorded with a TEAC RD-101T digital audio tape (DAT) deck, also calibrated by Cornell University. Spoken descriptive commentary was entered at the start of each recording on a separate designated channel. Input was monitored *via* headphones throughout recording sessions, and the occurrence of audible seismic activity, biological sounds, or anything unusual was noted.

Acoustic Data Analysis

Digitally-recorded sounds were analyzed following a systematic protocol developed by Cornell University, and by using their specialized acoustic processing workstation and "Canary" software. This workstation consisted of a Macintosh Quadra 650 equipped with a digital interface, used for data input from the sound recorder, and a digital sound processing board that allowed implementation of a Fast Fourier Transform algorithm. Waveform files were acquired using a TEAC RD 135, at a sampling rate of 4.8 kHz.

Two signal types were analyzed: seismic pulses, and ambient noise. Although gray whale vocalizations were audible on one day of digital recording, the signal to noise ratio was too low for proper measurements of sound level or frequency. More detailed descriptive analyses may be possible with further spectrogram analysis of the original recordings.

Of the 53 min of seismic recordings with good signal-to-noise ratio recorded on 1 August in Beaufort State 1 conditions, 66 undistorted seismic pulses were selected for analysis. These pulses were measured for received sound levels (in dB re. 1 μPa), averaged over 0.15 and 0.5 sec, as well as peak-to-peak, and zero-to-peak levels as obtained from the waveforms.

Shore-Based Observations

Shore-based observations were particularly valuable for this study, as whales were regularly observed feeding within 3 km of shore. The 35 m high lighthouse near the entrance of Piltun Lagoon was used as the main 1997 observation post. From this vantage point, we employed three observation methods: scan sampling, focal observations, and theodolite tracking. In addition, this platform allowed observers to direct the research vessel to select whale groups for photo-identification purposes. Each shore observation day began at sunrise when appropriate weather conditions were present. The observation crew consisted of three people: a behavioral observer, theodolite operator, and computer operator. On arrival to the lighthouse, research equipment was assembled and environmental conditions (visibility, Beaufort State, swell, wind, glare, etc.) were recorded. All behavior and theodolite data were entered real-time on a laptop computer running a time-synchronized data-collection program, named "Aardvark," developed by Cornell University for shore-based whale studies. Data collection protocols are detailed in Appendix I, including descriptions of whale behavior, weather, sea condition, data confidence ratings, and potential disturbance categories.

The main components of shore-based behavioral work were dedicated to data collection during different times of day, for non-seismic, seismic, and post-seismic conditions, and varying pod-to-survey vessel distances. Seismic conditions were determined by inspection of survey vessel activity logs. Non-seismic periods were defined as times when the survey vessel was not active and when no other potential sources of disturbance (other vessels, aircraft, killer whales, etc.) were observed within the scan area. Seismic periods were times when survey operator records indicated array gun activity. Post-seismic conditions were defined as up to one hour after seismic activity ceased, and when no other potential sources of disturbance were noted (see above conditions for non-seismic periods). In addition, pod-to-vessel distances were obtained by taking survey vessel positional data and theodolite-obtained pod locations and calculating the distance between them. Three basic data collection methods were used: 1) systematic 15-min scans; 2) theodolite tracking of pods; and 3) focal pod observations. Each of these methods are described in the following sections.

Scan Samples

To determine the number of pods, number of whales, and pod locations within the study area, scan samples were collected each hour when not following focal pods. As a rule, each observation day began with a 15-min scan which covered a predetermined and constant portion of the study area. This viewing "arena" consisted of a 110° arc divided so that 55° of the arena was to the north of the lighthouse, and 55° to the south. Offshore viewing range was determined by visibility, but no scans were conducted in which offshore visibility was less than 0.5 km. Hand-held binoculars (7 x 50) were used for all shore-based scans. During each scan, the behavioral observer scanned from north to south, counting and sequentially numbering each pod, and detailing pod composition. Simultaneously, the theodolite operator marked each pod's location and verified pod composition. In addition, any vessels in the area were noted, and tracked *via* theodolite.

Theodolite Tracking

Whale movement patterns, including travel speed, angular change in course direction, linearity, and reorientation rates were monitored by theodolite. Similarly, seismic survey ships and other vessel traffic within the study area were also tracked by theodolite. This line of investigation has been especially useful in other whale studies (summaries by Richardson and Würsig 1995, 1997) by providing meaningful information on natural behavior and possible disturbance effects. A Lietz/Sokkisha Model DT5A theodolite, with 10-sec precision and 30-power monocular magnification, was used to track whale and vessel locations. The theodolite measured the exact horizontal and vertical angles of target locations in degrees, minutes, and seconds from the lighthouse observation platform. Horizontal bearings were referenced to True north with a relative angle set consistently on a map-located GPS mark. Vertical angles were automatically referenced to gravity by the theodolite. To determine locations of targets, theodolite angles were converted into Cartesian coordinates with correction for curvature of the earth and theodolite height. Tidal variation, an important variable in determining the accuracy of theodolite tracks, was directly measured from a tide stake within the Piltun

Lagoon and indirectly measured by extrapolation from 1997 tide charts for the more southern Chaivo Bay region.

Focal Observations

To obtain behavior and respiration information on select individuals and pods, focal observations were conducted (Altmann 1974). Focal observations were done with 7 x 50 or 10 x 35 hand-held binoculars and began when a pod was sighted within reliable viewing range of the lighthouse. In general, the behavioral observer initiated a focal session and continued observations until the focal pod traveled out of viewing range, or environmental conditions hampered reliable behavioral observation. Focal observations were conducted on only one pod at a time. In contrast, the theodolite operator attempted to track multiple pods and all vessels within view during a session, while also closely monitoring the focal pod. Definitions of whale behavior, respiration variables, and other parameters measured by theodolite are given in Appendix I.

Dataset Partitioning

Data partitioning was necessary for a number of analyses presented here. These restrictions are outlined in the following sections. The period for which comparisons relating whale behavior to seismic activity was 23 July-12 August. These dates represent the start of our 1997 shore-based data collection (23 July) and the final geophysical survey records (12 August) provided to us by seismic operators.

Scan Data - A total of 397 pods counted during scans between 23 July-8 September were used to examine the number of pods, whales, and whales per pod in the study area. No dataset restrictions were employed for these analyses. Pod locations and descriptions of overall distribution were limited to the 343 pods fixed by theodolite during scans between 23 July and 8 September. Analyses examining the number of pods, whales, and whales per pod in relation to non-seismic, seismic, and post-seismic periods were restricted to the 23 July-12 August period. Scans included in all of the above analyses were restricted to sessions in which no other source of potential disturbance (e.g. other vessels, aircraft, etc.) were visible from the lighthouse.

Theodolite Data - Theodolite tracking data collected between 23 July-12 August were used for comparison of leg delta, leg speed, linearity, and reorientation for all pods during non-seismic, seismic, and post-seismic conditions. Analyses which considered pod-to-vessel distance were restricted to one-whale pods during "seismic-on" periods. The rationale for this dataset restriction was based on the lack of seismic vessel records during non-active periods, and the overall limited number of days for which vessel locations and pod locations could be simultaneously plotted. The occurrence of pods >1 during these occasions was unusual. Therefore, to prevent spurious contributions from unusually large pods (considered here to be outliers), and to minimize potential confounding effects of pod composition, this analysis was limited to single-adult whale pods. Tracks included in these analyses were restricted to sessions in which no other source of potential disturbance (e.g. other vessels, aircraft, etc.) were visible from the lighthouse.

Focal Observation Data - Focal observation data collected between 23 July-12 August were used for comparisons of surfacing-respiration-dive variables during non-seismic, seismic, and post-seismic conditions, and with respect to pod-to-vessel distance. In order to minimize possible confounding effects of pod composition, vessel traffic, and viewing conditions, focal observation sessions included in these analyses were restricted to those conducted on single-adult whale pods, in which no vessels other than seismic vessels were visible from the lighthouse, and in which the behavioral observer confidence rating was three or lower (see Appendix I).

Statistical Procedures and Considerations

Frequency distributions for scan, theodolite, and focal observation data were of a generally uni-modal and near-normal nature (Zar 1984). Because of the robustness of parametric analyses for these types of distributions (for example, see Dorsey *et al.* 1989), we analyzed these data by parametric Analysis of Variance (using an alpha level for significance of $p < 0.05$) followed by Fisher's *post hoc* comparisons (Zar 1984).

As is true for most other studies on large whales using similar methodological approaches (for example Würsig *et al*. 1986, Malme *et al*. 1987), the potential for pseudo-replication and/or lack of data independence is of potential concern. As a partial solution to this problem, we have followed the suggestion of Dr. W. John Richardson (personal communication), and used mean rather than raw values for all variables potentially influenced by this consideration. For example, blow interval was calculated by using the mean interval for each surfacing rather than using the interval between each blow. However, for the purposes of this report, blow interval was also analyzed and presented to allow for direct comparisons with previous studies on gray whale surfacing-respiration-dive patterns which were based on raw score data (Würsig *et al*. 1986, Malme *et al*. 1988). Other parameters for which mean rather than raw scores were used included leg speed, and leg delta. For these theodolite-determined variables, raw scores were averaged into a single mean value per track.

Graphic Representations

Graphic representations of the data reported here are consistent in the use of Standard Error of the Mean (SEM) for all error bars on histograms. Box plots display the 10th, 25th, 75th, and 90th percentiles, along with mean and median values. Value labels provided in individual plots are identified by the associated legend, x- and y-axis titles, or descriptive figure captions.

Photo-Identification

Photographic identification has proved extremely useful for whale studies, and gray whales are particularly well-marked along their sides, backs, and flukes (Darling 1984, Jones 1990). Boat-based photo-identification surveys were conducted on all good weather days during the study period. Identical methodology was employed during each survey, with the primary objective of encountering and photographically identifying as many whales as possible. Previous photo-identification data gathered in the Piltun area in 1994 and 1995 used mainly right-side dorsal flank markings for identification (Brownell *et al.* 1997), and for the sake of intra- and inter-annual reliability, we continued this methodological approach.

Photographic surveys involved slow travel in a 4.5 m outboard powered inflatable boat. The research team consisted of a boat driver, data recorder, digital video camera operator, and 35-mm camera photographer. Systematic search from the survey vessel was maintained until a whale sighting was made. At this point, the survey vessel was slowed to idle speed, and maneuvered to a vantage point approximately 50 m from the whale pod. From this vantage, observations on pod location, time, behavior, and number of whales were recorded. A pod was defined as any whales observed in close spatial proximity, and usually moving in the same direction while often engaged in similar behavior.

The research vessel was then moved within 3-12 m of the whale pod and individuals were photographed. During the photographic effort, a running commentary regarding the film frame and video counter number as related to particular whales was recorded onto data sheets. Measures of water depth, location (as determined by GPS), and environmental conditions were recorded on average every 3-5 min throughout the entire photographic session. In all cases, attempts were made to simultaneously photograph and video tape the right dorsal flank of each whale, followed then by photos of the left dorsal flank and flukes. Photographs were taken with a Nikon F5 35-mm camera equipped with a 100-300 mm zoom telephoto lens, high-speed motordrive, and databack. Video footage was recorded on a Sony DCR-VX1000 digital video camera. Two 35-mm film types were used: Kodachrome 200 ISO color slide film, and T-Max 400 ISO black and white negative film.

Contact with whale pods was maintained until photographic effort was completed. The boat was then motored away from the pod, where initial field estimates of pod size and group composition were revised if necessary, and all film and written records reviewed for completeness. These procedures were repeated as the research vessel resumed travel and additional whale pods were encountered. Pod size estimates were based on field observations, and were the product of a consensus among all trained observers on board the survey vessel. Calves were identified by their small body size and constant association with a particular adult whale.

Photo-Identification Analysis

A total of 72 rolls of film (2600 frames) were taken during the 1997 field season. Images of individual gray whales consisted of various aspects of the body, including head, back, dorsal flanks, and flukes. Based on the photographic methodology developed by Brownell *et al*. (1997) during a 1995 field effort in the Piltun area, the 1997 research team also targeted the right dorsal flank of each whale as the primary body aspect for identification purposes. Attempts were made in all cases to follow this standard approach, however, it was not always possible. Therefore, to maximize the collection of data, whales were photographed sequentially from head to fluke on either the left or right side, and the top and bottom of their flukes. Written observations collected at the time of each photographic session were used to link inter-individual aspects together whenever possible.

Photographic images were first examined on a light table using an 8x loupe. To prevent cataloging different sides and aspects of the same whale as more than one individual, the right flank was always used as the basis for initial identification. A whale was not given a permanent subject identification number unless its right dorsal flank was photographed at some point during the field season. Additional aspects of the body were used as identification tools, only if they were first matched with their respective right flank. Of course, it was our ambition to identify as many whales as possible, therefore all images of acceptable quality (even if unmatched) were archived for subsequent identification purposes.

Photographic "matching" was done by comparing a "new" individual to all images of already cataloged whales. If a prospective match was determined, the current slide was repeatedly compared to previous slides, and was required to match before being confirmed as a reidentification of a known individual. If a photograph could not be matched, then photographs of remaining individuals were inspected. Although labor intensive, this systematic search process ensured that all previously sighted whales would be resighted. If a match was not found after this comprehensive inspection, the individual was considered a new sighting. Upon completion of the 1997 photo-identification catalog, comparisons were made with whales first identified in the Piltun study area during week-long field efforts in 1994 and 1995 and a database containing information on each whale identified between 1994-1997 was established.

Digital Video Analysis

Digital video footage was collected simultaneously to still photography during all photo-identification surveys. Each video session was subsequently reviewed frame by frame to verify and enhance the already established 35-mm photographic catalog. A data code containing date and running time information allowed easy separation of whale pods. When analyzing each pod session, video frames of marked whales were compared to the corresponding 35-mm slides for that group. If the video image(s) matched a whale already cataloged, a note was made in the video log and the next surfacing sequence was examined. If the video images did not match a previously known whale, then a print was made on a digital video color printer. Such prints were set aside for later comparison with the 35-mm photographic catalogs. If the videographer recorded a previously unphotographed aspect of an identified whale, then a print was made of that aspect. The print was labeled with the appropriate identification number and added to the identification catalogs.

After all digital video footage was analyzed and necessary prints made, images of whales not accounted for by 35-mm photographs were systematically “matched” following the same procedure as that described for photo-identification analysis. Only two video prints (of right-side dorsal flanks) were not matched in the 35-mm catalog of identified individuals. Although these prints contained the “standard” side and aspect for permanent identification, both prints showed a minimal amount of pigmentation and marking information. Thus, the two video prints of right-side dorsal flanks were added to the temporary identification catalog for comparison with photographs taken during future field seasons.

The use of digital video proved to be a valuable tool in creating the photo-identification catalogs. Although the quality of the video images was generally slightly lower then the 35-mm photographic images, the resulting footage nevertheless provided additional aspects for identified whales. Also, use of video-based recognition increased the sighting frequencies of eight identified whales by one or two observations, and by four for one additional whale.

RESULTS AND DISCUSSION

Aerial Surveys

Five whales were seen during the 19 August aerial survey. No whales were seen between Nikolayevsk to Cape Elizabeth, one (at 53°41’ N) from Cape Elizabeth to the port city of Okha (53°35’ N) on the northeastern coast, and four sightings between Okha and the northern tip of Piltun Lagoon (53°24’ N). All sightings were of single non-calf whales within 300-800 m of shore. During this rapid transit past the northern part of gray whale distribution in rather inclement weather and only marginal viewing conditions, we observed three whales oriented south and two south-east, indicating a possible general movement south, along shore. The first (northern-most) whale seen had mud trailing from its last surfacing location, indicative of feeding. Movement speed was slow for that first whale, and slow to medium speed (without whitewater along the flanks) for the other four. The brief views as we passed by gave one of us (B. Würsig, experienced with dedicated airplane surveys) the impression that more whales than were counted, were missed due to marginal sighting conditions. Nevertheless, the single and sporadic sightings indicated the lack of any large concentrations of animals.

While this brief survey was certainly not enough to characterize details of gray whale occurrence patterns in the area, it indicated that the northern most area of gray whale distribution may have been approximately 90 km north of Piltun on that day. Further, it is apparent that whales occur throughout that northern range, but that no great concentrations, as commonly seen directly off Piltun, were likely to have been present to the north at that time. These findings support previous results from TINRO surveys in the Okhotsk Sea between 1979 and 1989 which reported that the only major concentrations of gray whales in coastal waters of Sakhalin were observed near Piltun Lagoon (Blokhin *et al.* 1985, Votrogov and Bogoslovskaya 1986, Berzin *et al*. 1988, 1990, 1991, Berzin in press).

Vessel Surveys

During the 1-3 August large vessel survey, five pods consisting of 10 whales were encountered to the south and within 18 km of the mouth of Piltun Lagoon. In addition, 16 pods composed of 26 whales were encountered north of the lagoon mouth, and as far north as 53°24' N (Table 1 and Fig. 4).

Table 1. Gray whale sighting locations collected 1-3 August, 1997, from the Russian research vessel.

Whale location	Number of whales	Whale location	Number of whales
52°34’N 143°24’E	2	53°11’N 143°18’E	1
52°36’N 143°23’E	3	53°11’N 143°18’E	1
52°40’N 143°22’E	1	53°12’N 143°18’E	3
52°42’N 143°22’E	3	53°14’N 143°19’E	1
52°45’N 143°22’E	1	53°14’N 143°17’E	1
52°58’N 143°20’E	2	53°14’N 143°15’E	1
52°58’N 143°20’E	1	53°15’N 143°19’E	3
52°59’N 143°19’E	3	53°17’N 143°15’E	1
53°01’N 143°19’E	1	53°18’N 143°15’E	1
53°09’N 143°20’E	1	53°23’N 143°14’E	4
53°10’N 143°18’E	1		

All whale sightings were within 4 km of shore, a trend likely to be related to the limited sightability from the relatively low sighting platform of the ship. During this same three-day period, approximately 23 whales were observed from the lighthouse. Thus, it is possible that as many as 59 gray whales were present between 52°00’ N and 53°30’ N during this survey, but we have no information on what proportion this represented of the entire instantaneous-use area and numbers on 1-3 August.

Acoustic Studies

Digital acoustic recordings were made on 27 occasions, from 31 July to 5 September, at depths ranging from 4.5-24.0 m (Table 2 and Fig. 5). Eleven of these recordings were clearly free of seismic sounds, 13 contained measurable seismic noise, and three may have contained

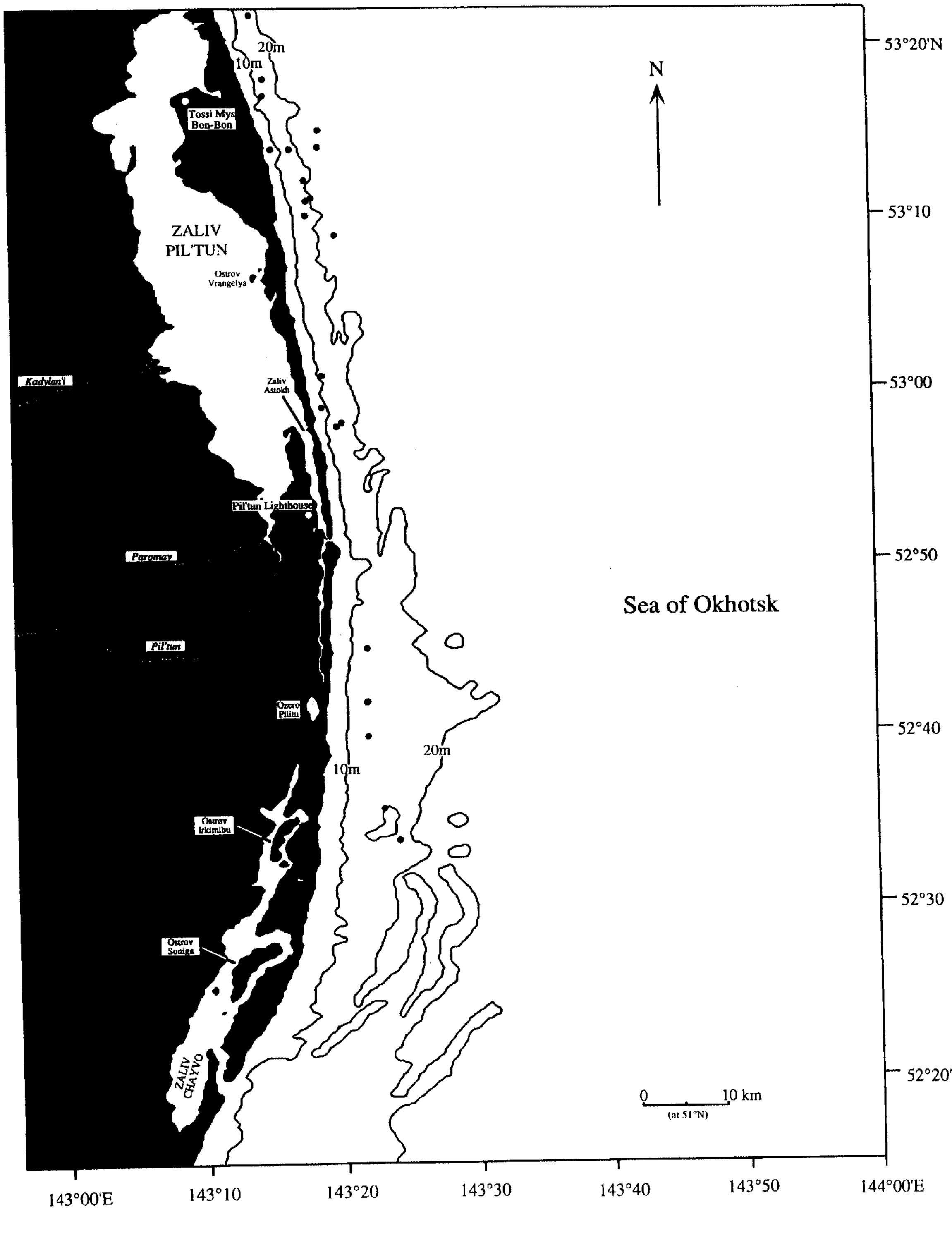


Figure 4. Gray whale sighting locations during 1-3 August, 1997, large vessel transect Along the northeastern Sakhalin coast.

Table 2. Summary of 1997 acoustic recording sessions.

Date (mm/dd/yy)	Recording time (local) start	end	Latitude at start (degrees north)	Longitude at start (degrees east)	Water depth (m)	Hyd. depth (m)	Seismic activity audible (Yes/No)	Whale sounds audible (Yes/No)
07/31/97	14:56:54	15:07:44	52.845	143.360	15.0	10	No	No
07/31/97	15:08:04	15:18:04	52.843	143.360	15.5	5	No	No
08/01/97	12:28:54	12:38:54	52.909	143.372	21.0	15	Yes	No
08/01/97	12:39:24	12:49:54	52.912	143.372	21.0	10	Yes	No
08/01/97	12:51:44	13:01:54	52.916	143.372	21.0	5	Yes	No
08/01/97	13:22:54	13:28:10	52.919	143.341	12.0	6	Yes	No
08/01/97	13:32:54	13:42:54	52.920	143.343	12.0	3	Yes	No
08/11/97	13:21:51	13:33:13	52.841	143.382	19.5	14	Yes	No
08/11/97	13:33:51	13:48:21	52.840	143.382	19.0	10	Yes	No
08/11/97	14:11:39	14:17:59	52.859	143.347	6.5	2	?	No
08/11/97	14:18:51	14:23:31	52.858	143.334	4.5	1	?	No
08/11/97	14:44:51	15:03:11	52.868	143.369	18.5	13	?	No
08/11/97	15:03:51	15:14:51	52.866	143.369	19.0	7	No	No
08/11/97	15:15:51	15:26:02	52.867	143.368	19.5	4	No	No
08/13/97	10:19:51	10:33:51	52.866	143.340	14.5	9	No	No
08/13/97	10:35:51	10:58:26	52.871	143.373	18.0	4	No	No
08/14/97	10:07:21	10:24:31	52.854	143.359	13.5	8	No	No
08/14/97	10:26:01	10:41:36	52.859	143.359	14.0	4	No	No
08/15/97	12:20:51	12:29:21	52.886	143.352	13.5	9	No	No
08/26/97	12:59:57	13:14:17	52.813	143.391	19.0	14	Yes	Yes
08/26/97	13:15:27	13:25:57	52.814	143.392	19.0	8	Yes	Yes
08/30/97	10:39:57	10:51:38	52.849	143.355	13.0	8	Yes	No
08/30/97	10:52:57	11:02:42	52.851	143.355	13.0	5	Yes	No
09/04/97	12:12:55	12:26:25	52.877	143.377	16.0	9	No	No
09/04/97	12:27:55	12:35:55	52.880	143.374	18.0	6	No	No
09/05/97	11:23:54	11:35:39	52.829	143.407	24.0	19	Yes	No
09/05/97	11:37:24	11:50:54	52.828	143.406	24.0	10	Yes	No

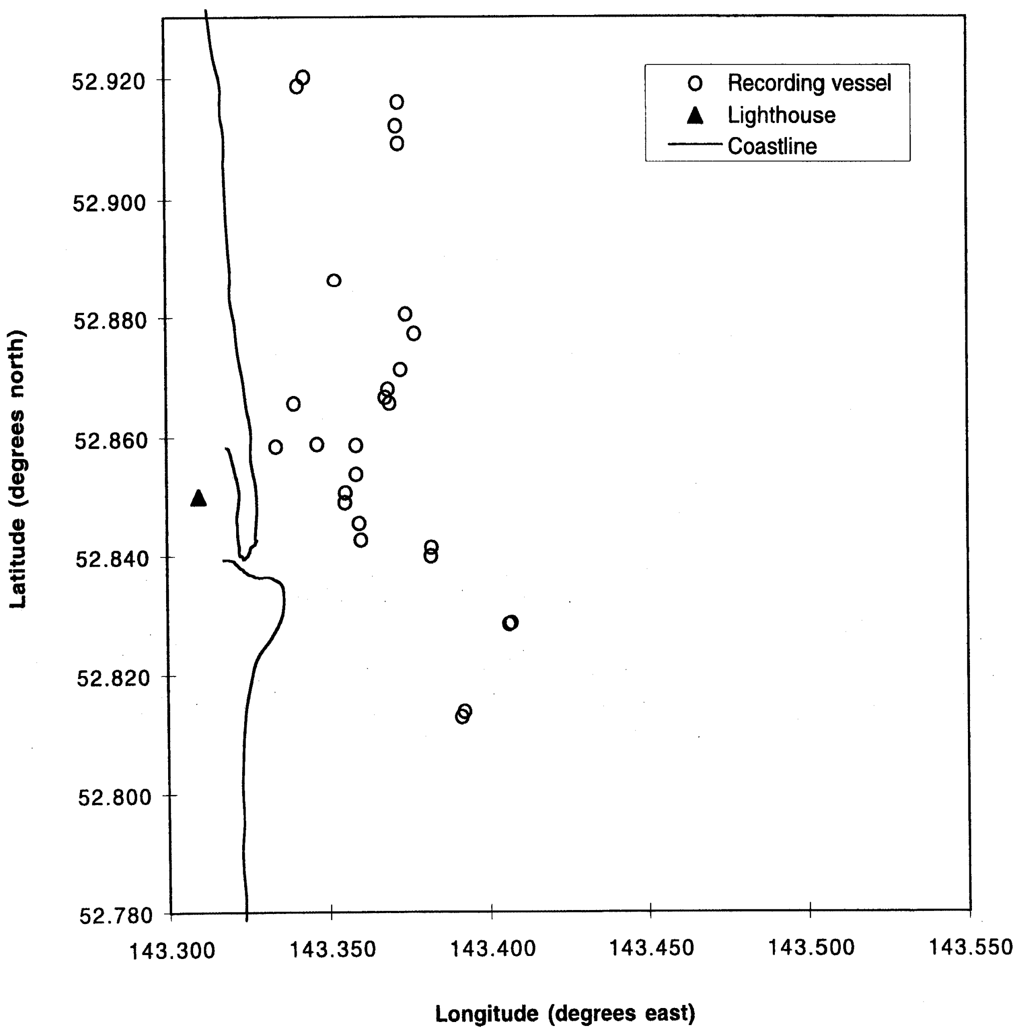


Figure 5. Acoustic recording locations for July-September, 1997.

audible but weak seismic pulses. Whale sounds were only recorded on two occasions on 26 August, during active seismic periods (Table 2). The sounds consisted of stereotypic "knock" sounds commonly emitted by gray whales (for example, Dahlheim *et al*. 1984). In this case, the knocks came from one whale, approximately 300 m from the recording vessel, as the animal traveled slow to medium speed. Because the sounds were of low intensity relative to ambient noise on that day, a detailed sound frequency analysis was not possible.

Records provided to us by the seismic operators surveying the Piltun-Astokhskoye field indicated that the 3-D seismic array used consisted of 27 active sleeve guns, with a total volume of 2620 cu. in. The average pressure was listed as 2000 psi with primary amplitude of 35.70 bar-m (~242-246 dB re 1 μPa) and a peak-to-peak amplitude of 79.90 bar-m (~252 dB re 1 μPa) (see Richardson *et al*. 1995 pp. 137 for bar-m to dB conversions). Received levels of 165 seismic pulses were measured through waveform analysis. Seismic pulses were generally separated by about 7.5 sec from each other, and energy from each pulse lasted no longer than approximately 0.5 sec. (Fig. 6). An example of strength over time of a seismic pulse recorded on 1 August is presented in its sound waveform (Fig. 6).

Distribution of sound level as a function of frequency for this same pulse is represented in its spectrum (Fig. 7). The overall broadband received level values for this pulse, as measured from the waveform, were approximately 153 dB re 1 μPa, zero-to-peak; 159 dB re 1 μPa, peak-to-peak; and 139 dB re 1 μPa, averaged over one second. Zero-to-peak and peak-to-peak values are simply the algebraic differences between zero and the positive and negative extremes, respectively, as determined from the highest-amplitude portion of the waveform. The averaged value of 139dB re 1 μPa represents the average received level over a one-second interval (taking into account the logarithmic nature of decibel scales), and, as with the "peak" levels, encompasses the energy in all measured frequencies. At the time of this recording our vessel was in 12 m of water with the hydrophone at 6m depth, while the seismic vessel was approximately 30.4 km to the southeast, traveling 170° (True), and surveying in water 37 m deep.

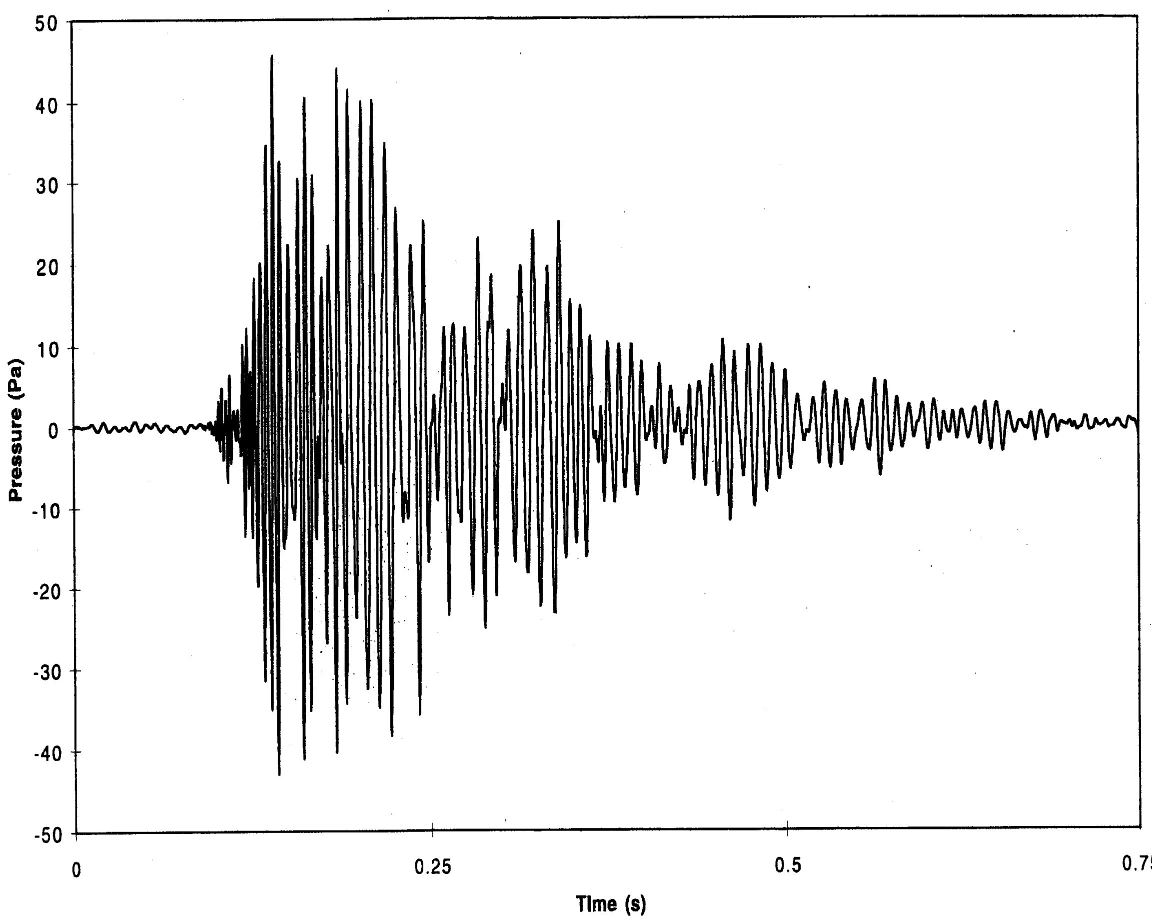


Figure 6. Waveform of a seismic pulse recorded on 1 August, 1997, depicting the distribution of sound level as a function of frequency.

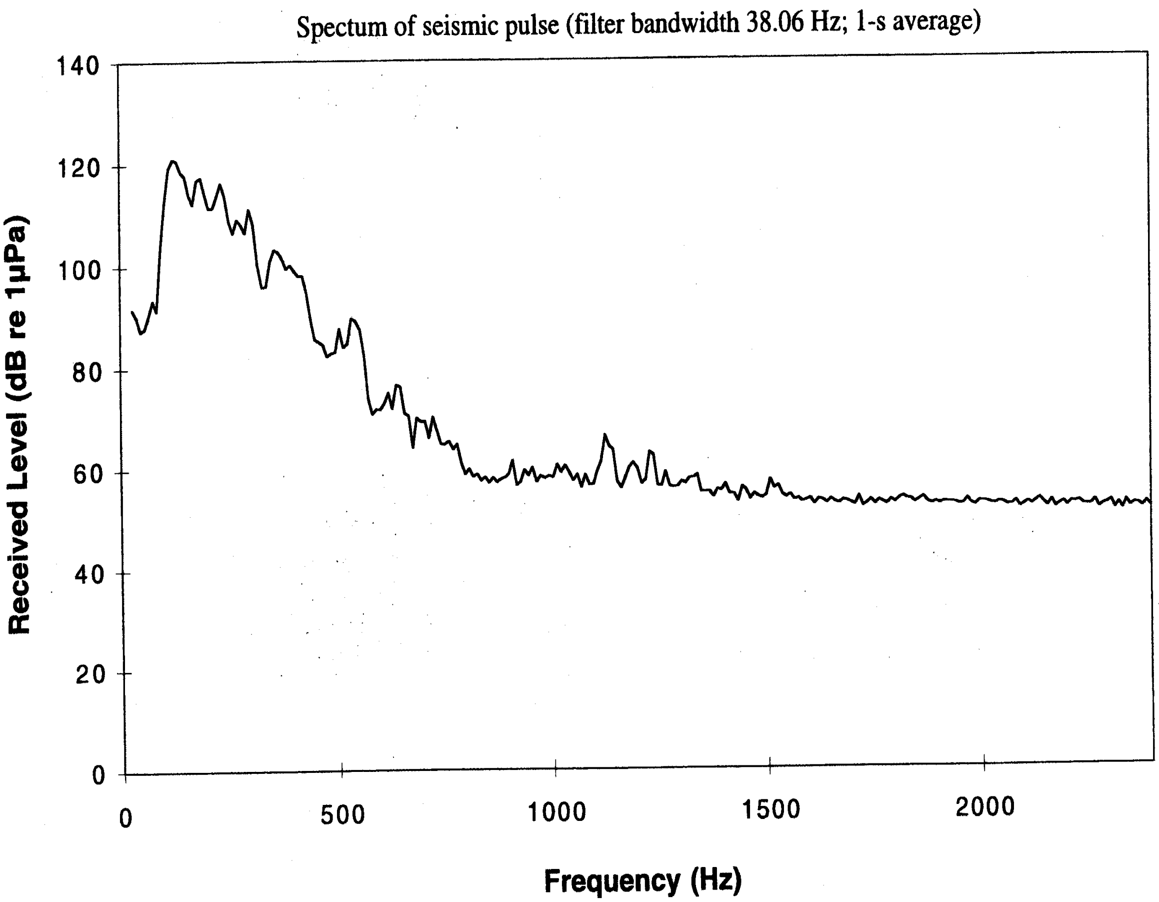


Figure 7. Spectrum of a seismic pulse recorded on 1 August, 1997, depicting the distribution of sound level as a function of frequency.

Gray whales migrating northward off California showed clear behavioral reactions and shifts in travel due to received seismic sounds of about 160 dB, by slowing travel, re-orienting, and increasing their respiration rates (Malme *et al.* 1984). In the northern Bering Sea, summering gray whales (in the same seasonal phase as during the present study) showed behavioral avoidance 10.0% of the time when received levels of seismic pulses were about 163 dB, and 50.0% of the time when pulses were about 173 dB (Malme *et al.* 1988). Potential impacts of seismic activities off Piltun were observed from our limited 1997 data set, and a comparative discussion will be presented in the following scan, theodolite tracking, and surface-respiration-dive sections.

Shore-Based Observations

Scans

Eighty-two 15-min scans were made from shore on 33 days between 23 July and 8 September, with 39 conducted in the morning (before 1200 hrs) and 43 in the afternoon. During that time, a total of 397 pods consisting of 689 whales were sighted. The overall mean number of pods detected per scan was 4.8 ± s.d. 2.91. The overall mean number of whales per scan was 8.4 ± s.d. 4.96, and the overall mean number of whales per pod was 1.7 ± s.d. 1.02. Twenty-seven (7.0%) of these pods, many of which certainly represented resightings of the same whales over time, contained at least one calf. This percentage may be slightly low however, as some calves may have been missed due to sighting conditions and distance of whales from the lighthouse sighting platform. See results presented in the photo-identification section for further details regarding mother-calf pods present during the study period.

The overall mean number of pods and whales detected per scan during the morning period was 4.3 s.d ± 2.44 and 7.8 s.d. ± 5.27, respectively (Fig. 8-9). Afternoon scans were characterized by means of 5.3 s.d. ± 3.24 pods per scan, and 8.9 s.d. ± 4.67 whales per scan (Fig.

8-9). Relative numbers and general distribution of pods and whales detected during morning and afternoon sampling periods did not appear to change greatly throughout the season (Fig. 10).

The number of pods per scan and number of whales per scan indicated that whales were present throughout the research period, but with an apparent seasonal pulse of fewer whales from about 8 to 24 August than before and after this two-week period (Figs. 11-12). Of the 397 pods detected during scans, 86.4% (n = 343) were accurately fixed by theodolite. The major concentration of pods (as determined by theodolite) was within approximately 6 km of the coast, with the farthest sightings 12 km offshore during optimal viewing conditions (Fig. 13). Nevertheless, because our offshore sighting distance was often hindered by atmospheric conditions, a reliable assessment of whale numbers greater than about 6-9 km from shore was prevented.

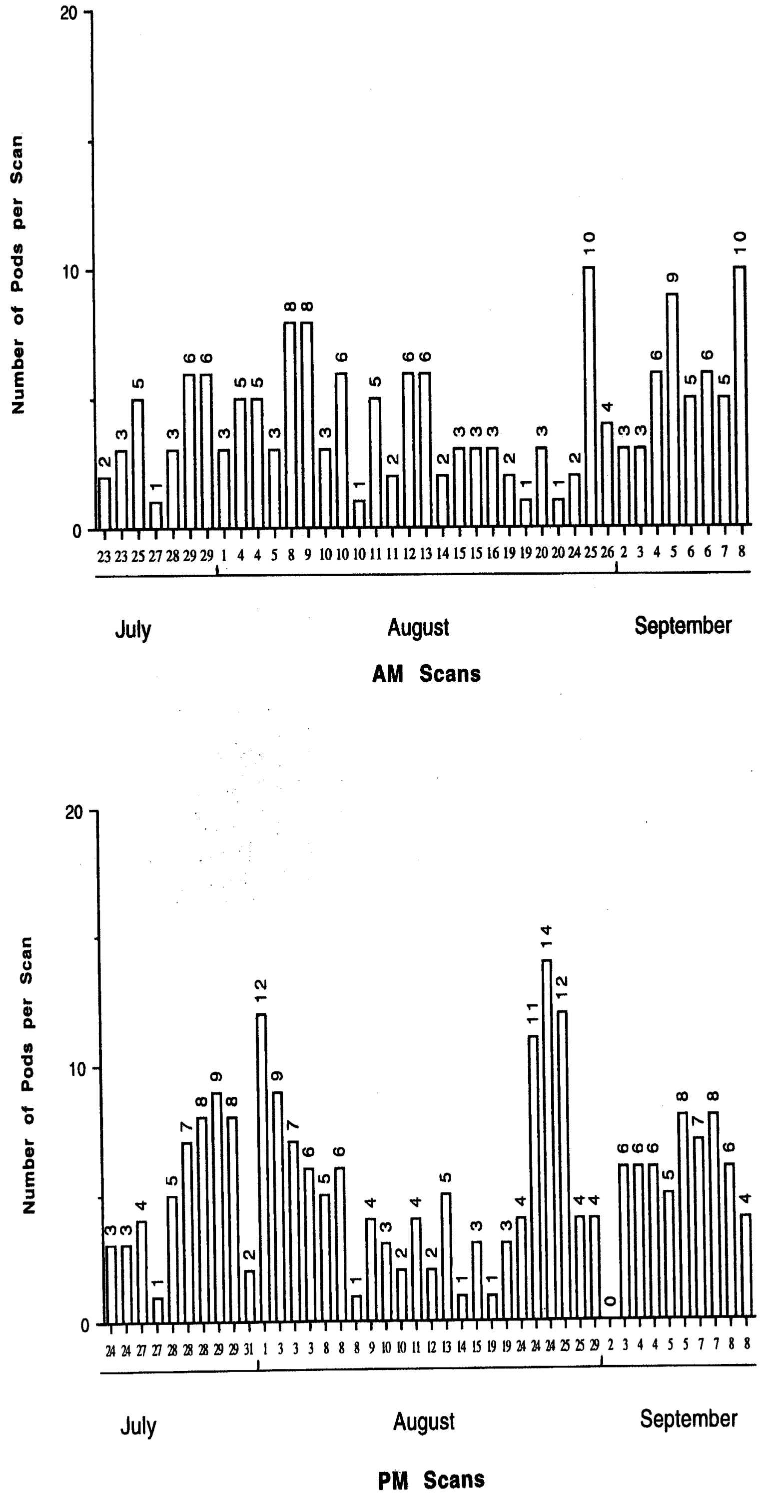


Figure 8. Number of pods detected per scan during morning and afternoon sampling periods, and by month. Days on which more than one scan was conducted are represented by repeated dates on the x-axis.

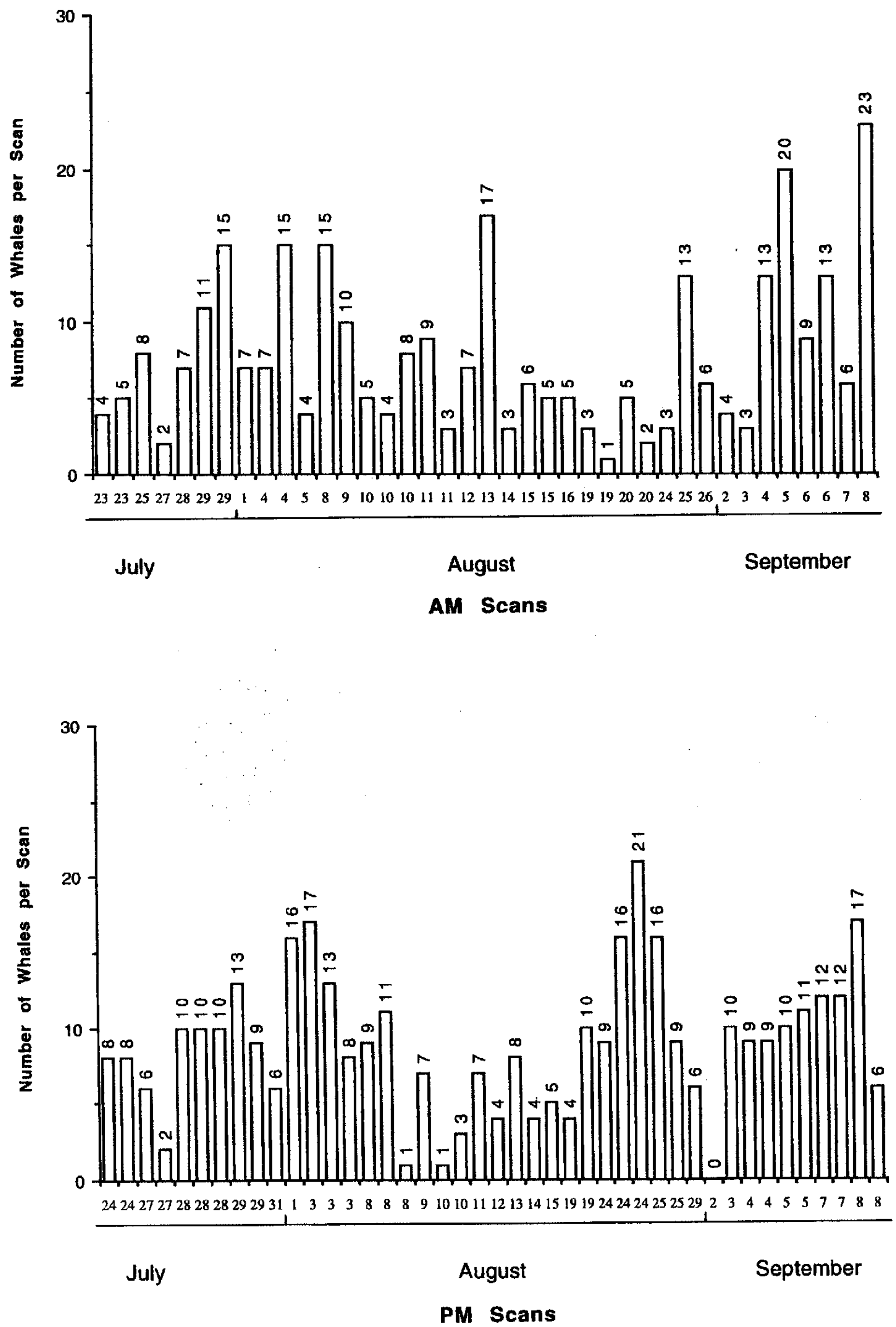


Figure 9. Number of whales detected per scan during morning and afternoon sampling periods, and by month. Days on which more than one scan was conducted are represented by repeated dates on the x-axis.

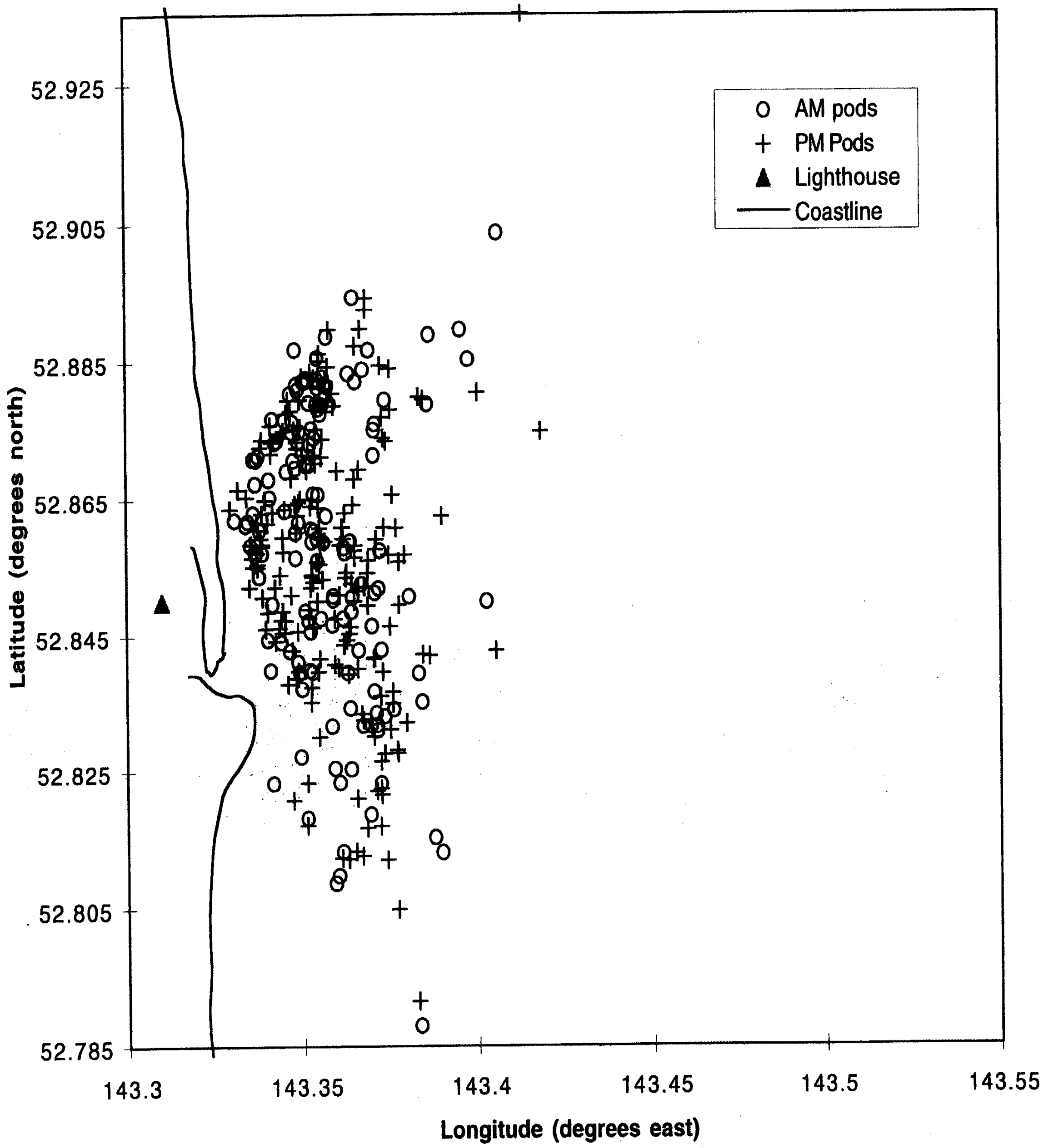


Figure 10. Theodolite-determined pod locations collected during shore-based scan samples. Symbols represent morning and afternoon sighting trends.

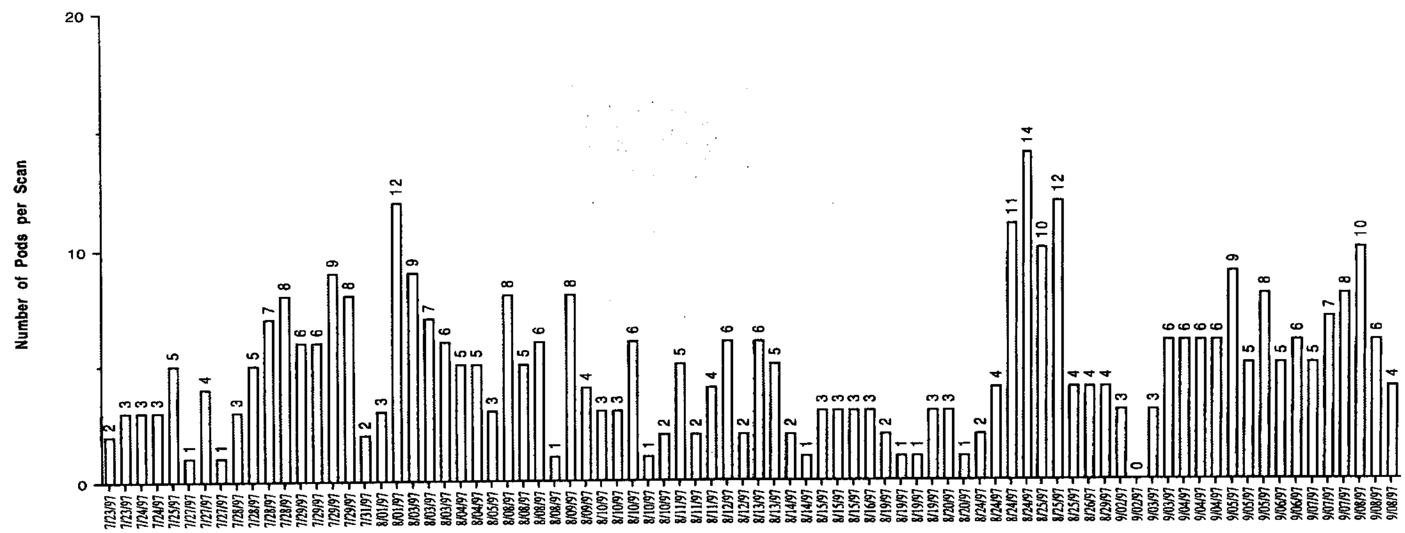


Figure 11. Number of pods per scan from 23 July to 8 September, 1997. Days on which more than one scan was conducted are represented by repeated dates on the x-axis.

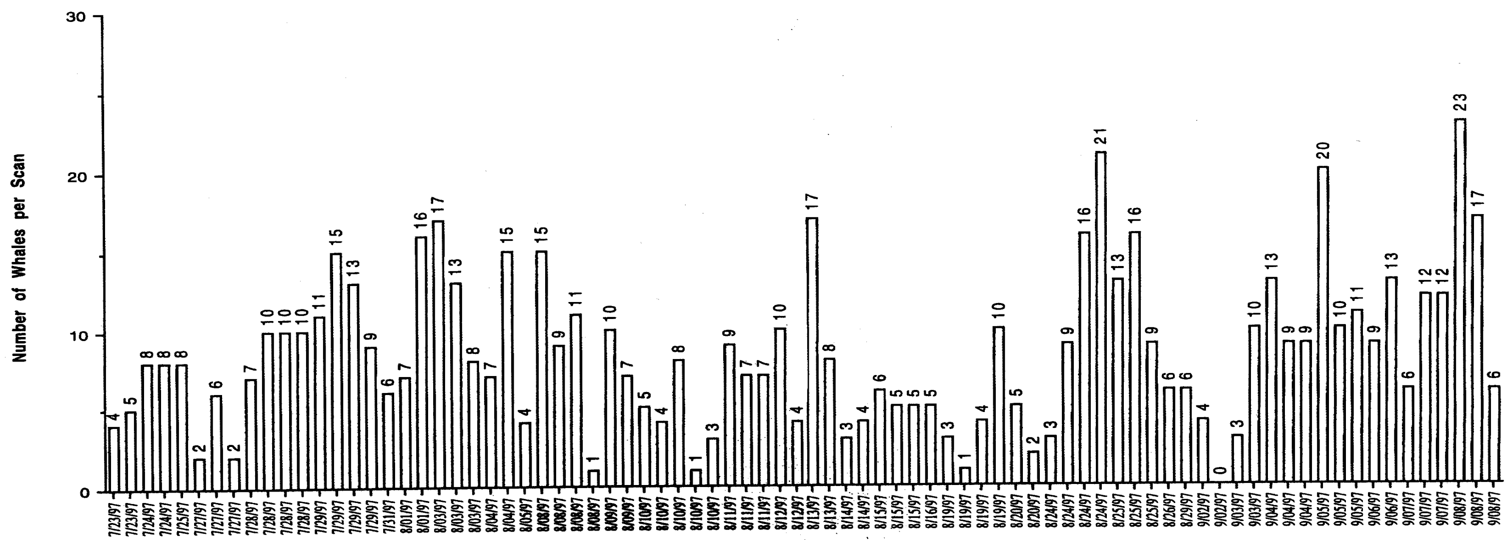


Figure 12. Number of whales per scan from 23 July to 8 September, 1997. Days on which more than one scan was conducted are represented by repeated dates on the x-axis.

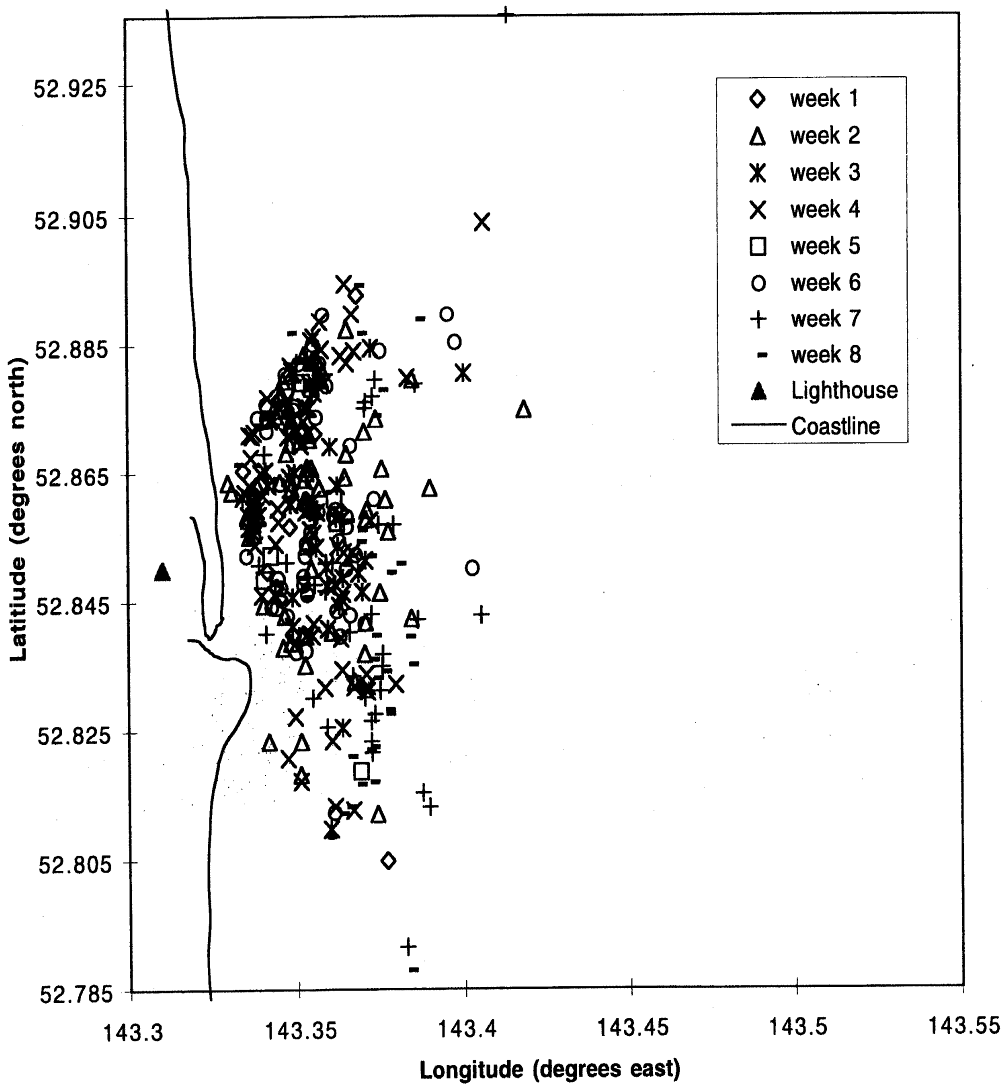


Figure 13. Theodolite-determined pod locations collected during shore-based scan samples. Symbols represent weekly sighting trends.

Overall, 95.3% (n = 327) of the 343 pods located by theodolite were sighted within 4 km of shore, with the majority of pods (68.2%) occurring between 1-3 km (Fig. 14). However, a month-by-month analysis showed that the mode of pod distribution occurred from 1-2 km in July, 1-3 km in August, and 3-4 km in September (Fig. 15). This pattern indicated a procession of pods into deeper water as the summer season progressed.

Although there were daily differences in distances that pods could be sighted due to fog, sunglare, or Beaufort State, there was no apparent overall seasonal change in visibility that could account for the monthly increase in sightings further from shore later in the season. As well, the fact that fewer pods were sighted close to shore in September helps to argue against an interpretation of the reported shift in seasonal distribution being solely an artifact of sighting conditions. Therefore, it appears that the shift to a more offshore distribution later in the season was real. It is not known at this time whether changes in seasonal distribution were due to biological changes such as the distribution and density of prey items, or perhaps migratory restlessness, or were related to anthropogenic factors such as seismic activity. While additional data are clearly required to better understand the apparent late season offshore movement of these whales, one potential explanation is that the shallow water and shelving nature of the near-shore area off Piltun may have had considerably less energy (or loudness) from anthropogenic noise, mainly seismic for the 1997 season, resulting from sound absorption by the bottom and surface (Richardson *et al*. 1995). Support for this hypothesis is provided by the apparent change in seafloor structure from rock bottom in waters 35-40 m deep to sand bottom at 25-35 m depth (Sakhalin Energy Investment Company 1997). Since seismic survey activities in the Piltun-Astokhskoye field continued until 12 August, whales may have remained closer to shore during

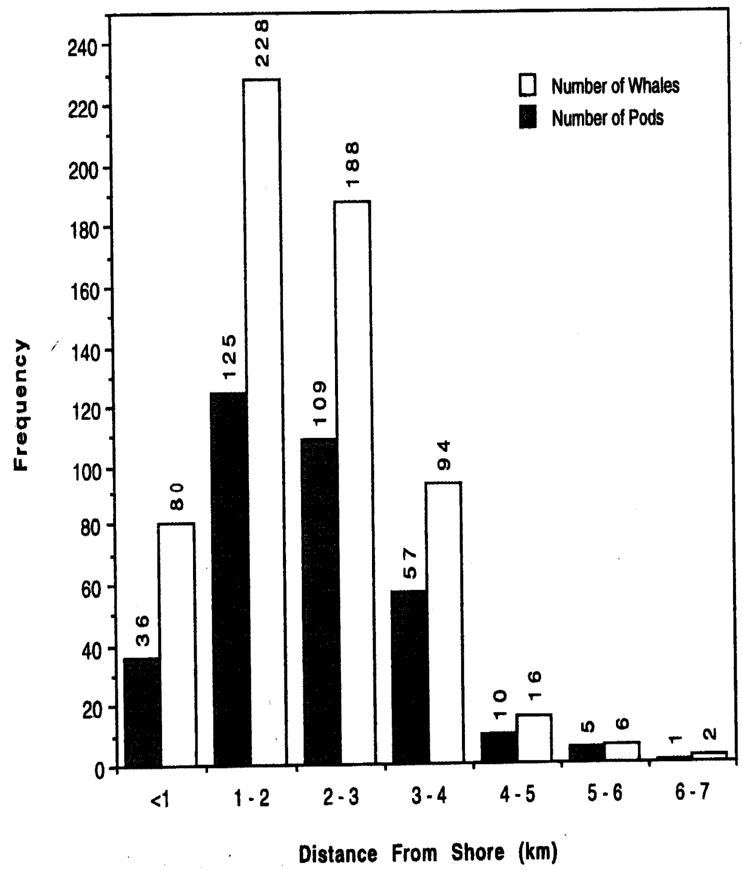


Figure 14. Overall number of pods and number of whales observed during shore-based scans with corresponding distances from shore as determined by theodolite.

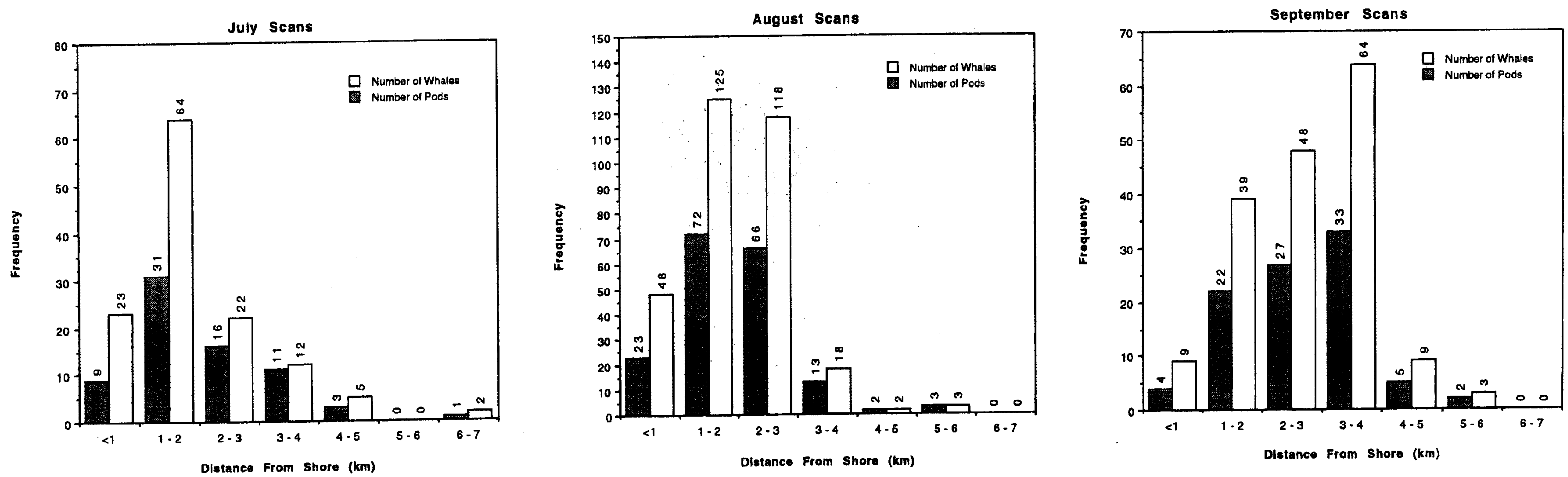


Figure 15. Monthly plots of the number of pods and number of whales observed during scans with corresponding distances from shore as determined by theodolite.

seismic periods (July - mid August) and shifted to more offshore waters in late August and early September once seismic surveying was terminated. However, our underwater recordings indicated that seismic sounds from an unknown source occurred to at least 5 September, confounding any further attempts at a potential correlation of gray whale inshore-offshore distribution and seismic activity.

The overall distribution of whales within the scan area was highly skewed to the north of our observation post. Over the entire season, 66.5% (n = 228) of the 343 pods located by theodolite during the study were initially detected north of the lighthouse, while only 33.5% (n = 115) of all pods were detected to the south (Fig. 16a). During July, 70.0% (n = 89) of all pods were located to the north while 30.0% (n = 39) were first sighted to the south (Fig. 16b). A similar trend was also apparent during the August sample, with 73.2% (n=230) of all pods to the north and 26.8% (n = 84) to the south (Fig. 16b). This pattern changed dramatically in the September sample, when 52.3% (n=90) of all pods were located north of the lighthouse, while 47.7% (n = 82) were detected to the south (Fig. 16b). At present, we do not know what may have caused this shift. A potential explanation may be an increase in late season (September) migratory unrest, characterized by increased movement to the south in advance of the fall southward migration. Alternately, biological changes in the near shore ecology and prey availability may also help to account for the patterns in longshore distribution presented here. We hypothesize that the entrance to Piltun Lagoon and the northward flow of nutrient rich lagoon waters to the sea during low tides may have a significant effect on the near-shore benthic community of the region. While additional data are needed, it is plausible that the tendency for whales to aggregate north of the lighthouse during July-August, which based on our observations is approximately the latitude where lagoon water fully mixes with seawater, may be related to north-south differences in prey density.

There was a strong tendency for the number of whales per pod (pod size) to be larger within the first 1-2 km of shore, with the < 1 km distance being the only one with pods of more than two whales on average (Fig. 17a). This later result may relate to the regular occurrence of mother-calf pods in the near-shore area. Indeed, data from our shore-based scans indicated that, of the pods with calves for which theodolite determined positions were obtained, 24 were seen within 2 km of shore, and only one outside of that distance. Although these data indicate a clear tendency for pods with calves to stay near shore, they must not be regarded as comparative absolutes, as it becomes more difficult to identify calves at greater distances.

While overall pod sizes were largest in the 0-2 km zone, in September, when the mode in pod numbers was 3-4 km from shore, the mean pod size of 1.9 was also large (Fig. 17b). Future work, especially involving radio- and satellite-tracking of known individuals, may provide further insight into the apparent seasonal shifts in the number of pods, pod size, and both inshore-offshore and north-south distribution during late summer/early autumn.

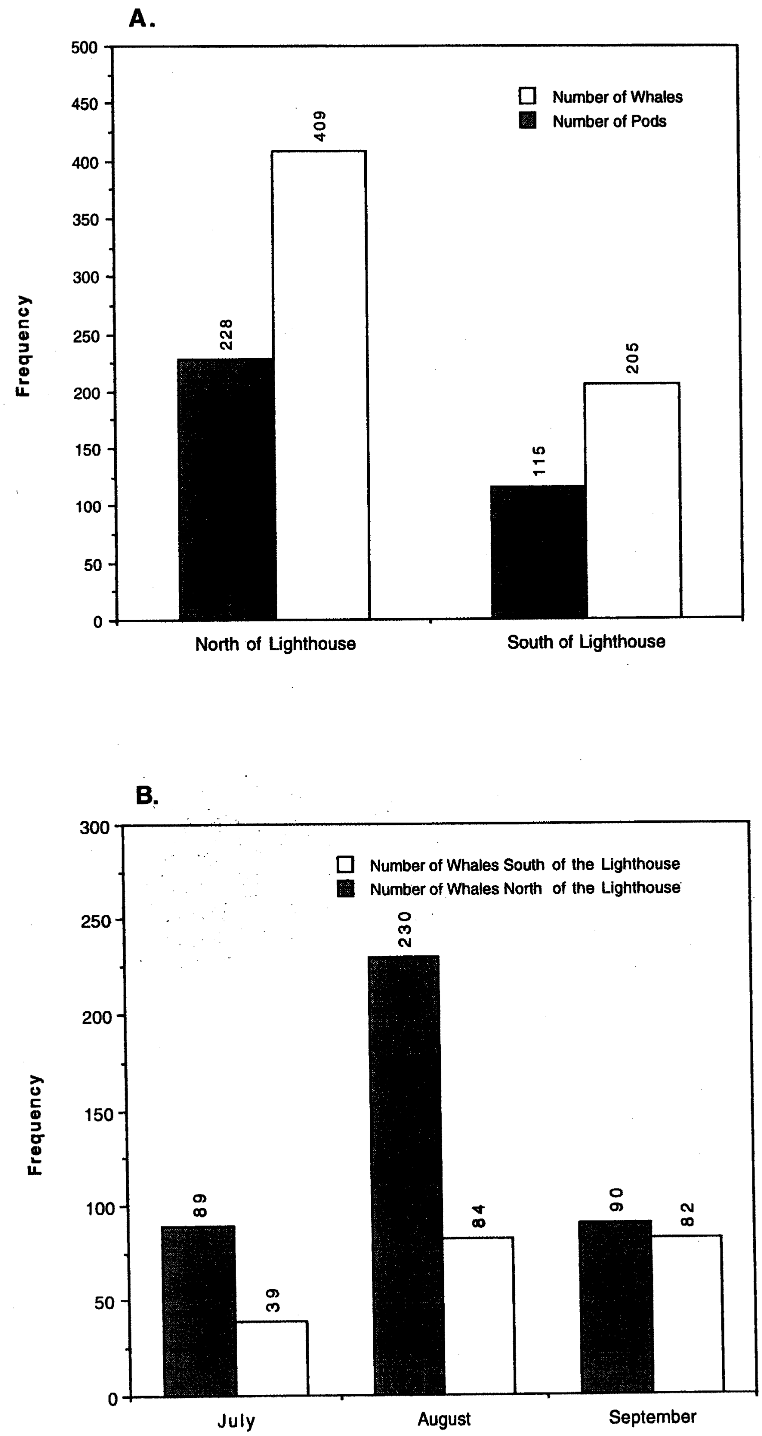


Figure 16. Overall (A) and monthly (B) number of pods and number of whales observed north and south of the lighthouse during shore-based scans.

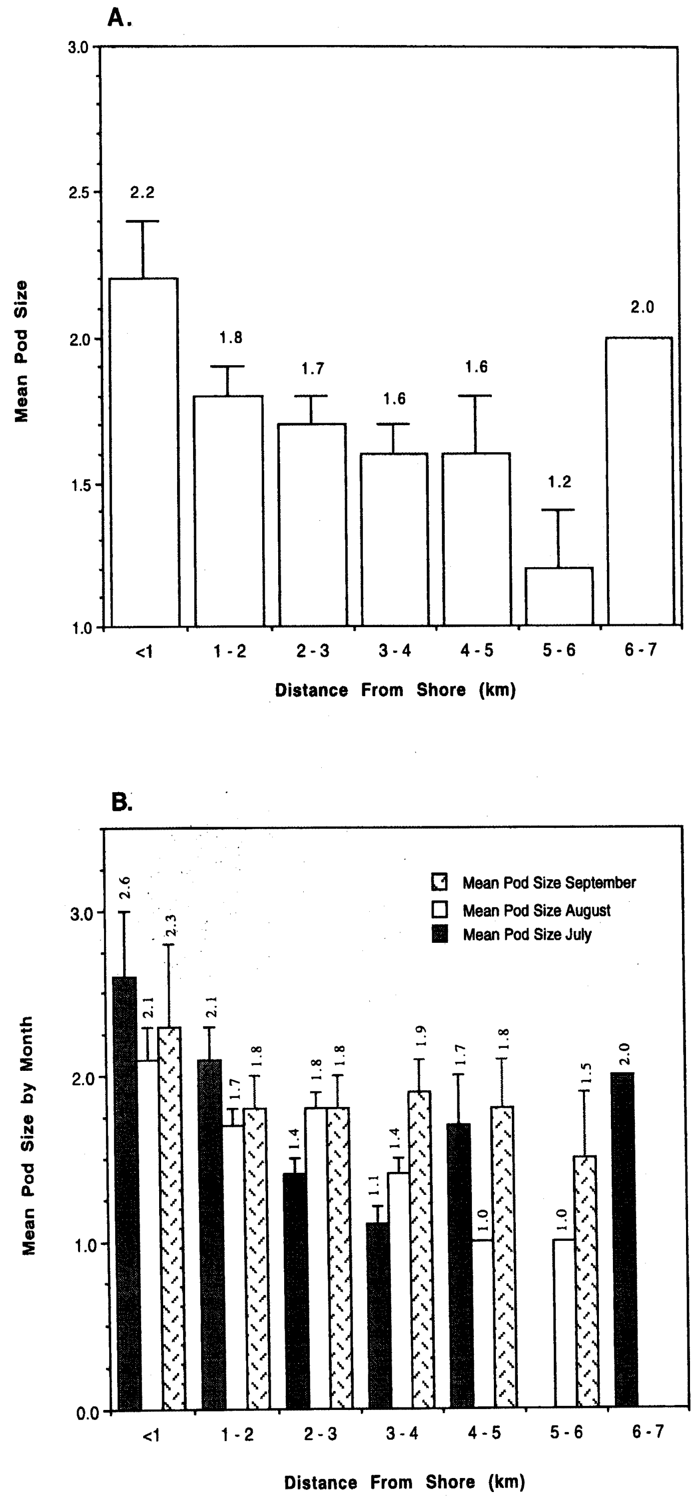


Figure 17. Overall (A) and monthly (B) mean pod sizes as a function of distance from shore as determined by shore-based scans. Error bars represent standard error of the mean.

No significant differences were detected in the number of whales per scan (Fig. 18a) or in the number of whales per pod as a function of non-seismic, seismic, and post-seismic conditions (Fig. 18b). However, the overall analysis of pods per scan revealed a marginally significant effect of seismic condition ($F(2,29) = 2.924$, $p = 0.0697$). The mean number of pods detected per scan for the three conditions were: non-seismic-- 5.6 $\pm$ s.d. 1.76 ($n = 15$); seismic-- 4.7 $\pm$ s.d. 2.92 ($n = 12$); post seismic-- 2.8 $\pm$ s.d. 1.48 ($n = 5$) (Fig. 18c). Fisher's *post hoc* comparisons indicated a significant difference ($p < 0.05$) in the number of pods detected per scan between non-seismic and post-seismic conditions (Fig. 18c). This result, shows a trend of fewer pods being detected immediately after seismic periods than during non-seismic periods and may indicate that pods began to shift their distribution out of the study site during periods of seismic noise, resulting in the lower whale numbers during the subsequent post-seismic condition. The apparent change in overall whale occurrence could be related to individual whales reacting differently to seismic sound, by, for example, increasing travel speed, changing directions differently from whales, or changing basic behavior patterns of feeding, travel, and socializing. Changes in speeds and orientations relative to seismic sound were found by Malme *et al.* (1984, 1986, 1988) for migrating and feeding eastern stock gray whales, and by Richardson *et al.* (1986) and Ljungblad *et al.* (1988) for bowhead whales. However, we emphasize that our data represent relatively small sample sizes collected during a short time within only one season. The fact that whales continued to occur near shore throughout the study period may argue against overt

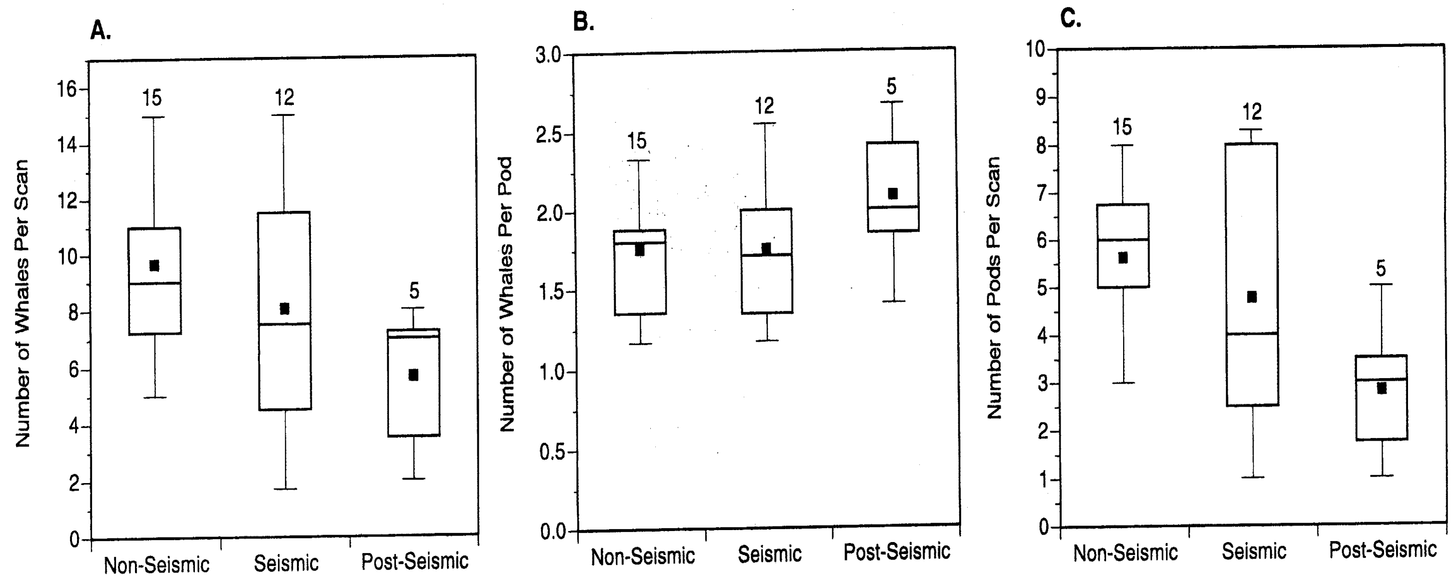


Figure 18. The number of whales (A), number of whales per pod (B), and number of pods (C) detected per scan and as a function of seismic category. The lowest, second lowest, middle, second highest, and highest box points represent the 10th percentile, 25th percentile, 75th percentile, and 90th percentile, respectively. Means are represented by black squares. Value labels represent number of scans.

longer-term behavioral disruptions by the seismic activity that occurred generally greater than 10 km to the east.

Theodolite Tracking

Eighty-four pod tracks, some of which overlapped in time, totaling approximately 36 h were used in the overall analysis. Tracks ranged from 8 min to 92 min in length, with a overall mean track length of 25.6 min. Pod tracks which spanned across two conditions (i.e. a track which started in non-seismic conditions but ended under seismic conditions) were appropriately partitioned into each respective category. Tracks stopped when whales moved out of reliable sighting distance, as night descended, or (more often) due to inclement weather such as high winds and fog. In general, whales often meandered in areas approximately 500 m in diameter for up to several hours, with most activity being apparent feeding behavior (see Appendix I). Whales tended to show no preferred direction of movement, as might be the case during directional travel or as a result of migratory unrest.

Four descriptive parameters of whale movement patterns obtained by theodolite were compared for tracks collected during periods for which seismic survey records and pod-to-vessel distances were available. These parameters were: 1) Leg Speed - speed between subsequent theodolite fixes of the same pod; 2) Leg Delta - angular change between three consecutive legs; 3) Linearity - the ratio between total distance traveled and distance between beginning and end points of a track or "distance made good"; and 4) Reorientation - the sum of changes in a pod's bearing between legs, divided by the number of seconds for the entire track, or in other words, the average number of degrees that are passed through in one second. Leg speed and leg delta data were analyzed by averaging raw scores into a single mean value per track, and linearity data (consisting of ratios) were arcsine transformed prior to analysis (Zar 1984).

Movement Patterns as a Function of Pod-to-Vessel Distance

Working under the hypothesis that the distance of the survey vessel from a pod would potentially influence behavior differentially, we examined pod tracks as a function of distance. This analysis consisted only of "seismic-on" data because our records of seismic activity were limited to periods when the survey vessel was active, and therefore the only times when pod-to-vessel distances could be calculated. Theodolite data for periods of known vessel activity fell into two discrete pod-to-vessel classes; 20-30 km and 30-40 km.

The analyses of mean leg speed ($F(1,11) = 0.625$, $p = 0.4458$), mean leg delta ($F(1,9) = 0.438$, $p = 0.5246$), linearity ($F(1,9) = 0.057$, $p = 0.8171$), and reorientation ($F(1,9) = 0.259$, $p = 0.6229$) during seismic-on conditions and as a function of pod-to-vessel distance revealed no significant differences (Fig. 19a-d). Based on these results, we speculated that pod-to-vessel distance was not in itself eliciting detectable differences in whale movement patterns, at least during seismic-on conditions. However, the presence or absence of seismic sounds, regardless of distance, could not be ruled out as potentially producing discernible behavioral effects and this possibility was investigated in the following analysis.

Movement Patterns as a Function of Seismic Condition

In this analysis, the same movement parameters as described above were compared for pods tracked during non-seismic, seismic, and post-seismic periods without taking the covariate of pod-to-vessel distance into account. The overall analysis of mean leg speed revealed a significant effect of seismic condition ($F(2,81) = 6.574$, $p = 0.0023$). The mean leg speed for each of the three conditions were: non-seismic-- 1.5 $\pm$ s.d. 0.973 (n = 39); seismic-- 2.5 $\pm$ s.d. 1.26 (n = 30); post seismic-- 2.3 $\pm$ s.d. 1.35 (n = 15) (Fig. 20a). Fisher's *post hoc* comparisons indicated a significant difference ($p < 0.05$) in mean leg speed between non-seismic and both seismic and post seismic conditions. These findings indicate that whales traveled more rapidly during and after seismic activity than in its absence.

The analysis of mean leg delta showed a marginally significant overall effect of seismic condition ($F(2,58) = 2.851$, $p = 0.0659$). The mean leg delta for each of the three conditions were: non-seismic-- 65.2 ± s.d. 38.26 (n = 25); seismic-- 40.2 ± s.d. 34.38 (n = 23); post seismic-- 44.4 ± s.d. 44.19 (n = 13) (Fig. 20b). Fisher's *post hoc* comparisons revealed a significant difference ($p < 0.05$) in mean leg delta between non-seismic and seismic conditions. These findings suggest that whales decreased angular changes in movement patterns during seismic periods.

The overall analysis of linearity revealed a significant effect of seismic condition ($F(2,58) = 5.546$, $p = 0.0062$). The average distance made good ratio for the three conditions were: non-seismic-- 0.75 ± s.d. 0.378 (n = 25); seismic-- 1.1 ± s.d. 0.383 (n = 23); post seismic-- 1.1 ± s.d. .391 (n = 13) (Fig. 20c). Fisher's *post hoc* comparisons indicated a significant difference ($p < 0.05$) in linearity between non-seismic and both seismic and post-seismic conditions. These findings suggest that whales covered a larger linear area per time during seismic and post seismic conditions. Finally, the analysis of reorientation revealed a non-significant effect of seismic condition ($F(2,58) = .638$, $p = .5092$) (Fig. 20d).

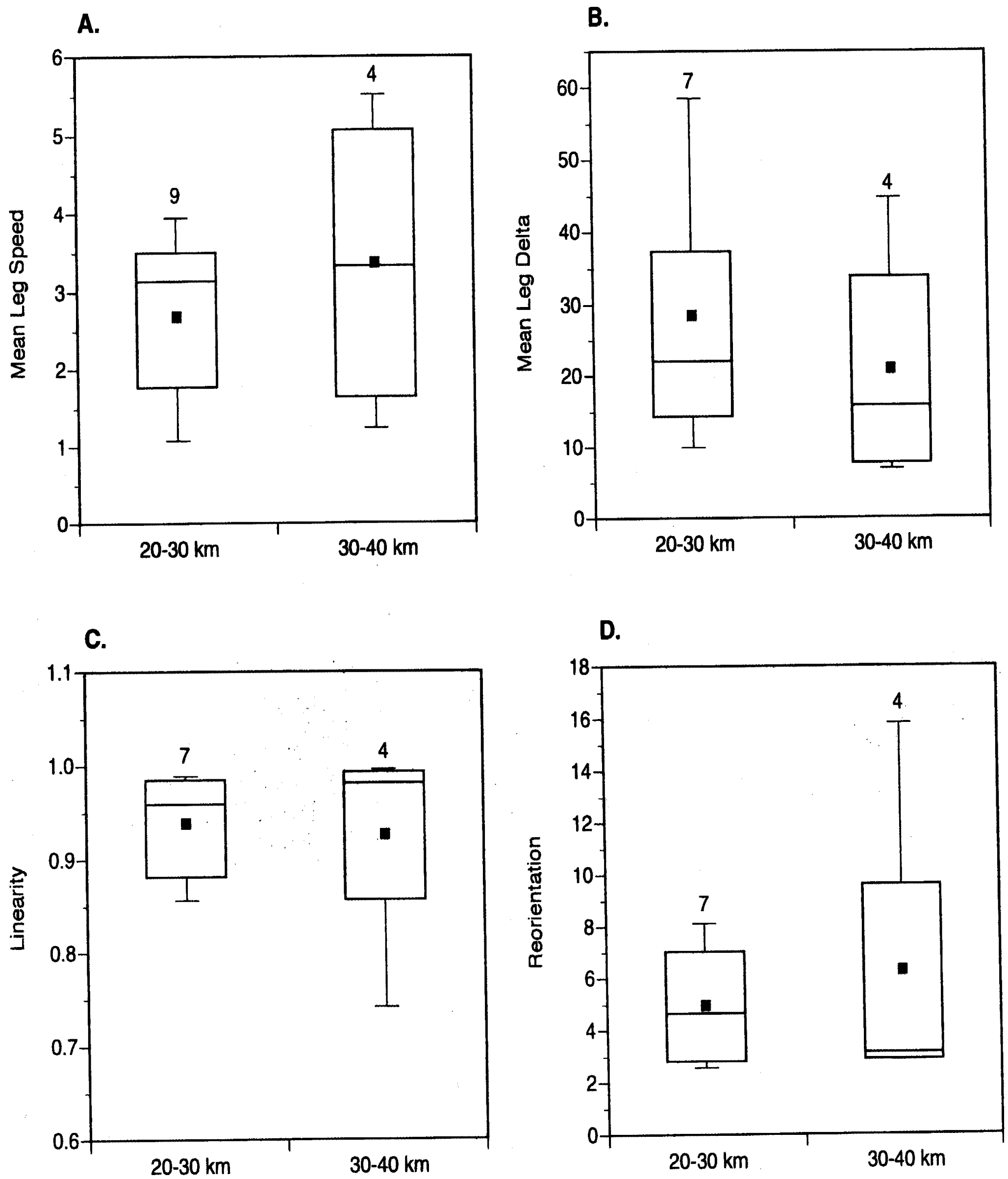


Figure 19. Mean leg speed (A), mean leg delta (B), linearity (C), and reorientation (D) statistics for theodolite-tracked, one whale pods during seismic conditions and as a function of pod-to-vessel distance. The lowest, second lowest, middle, second highest, and highest box points represent the 10th percentile, 25th percentile, median, 75th percentile, and 90th percentile, respectively. Means are represented by black squares. Value labels represent number of pod tracks.

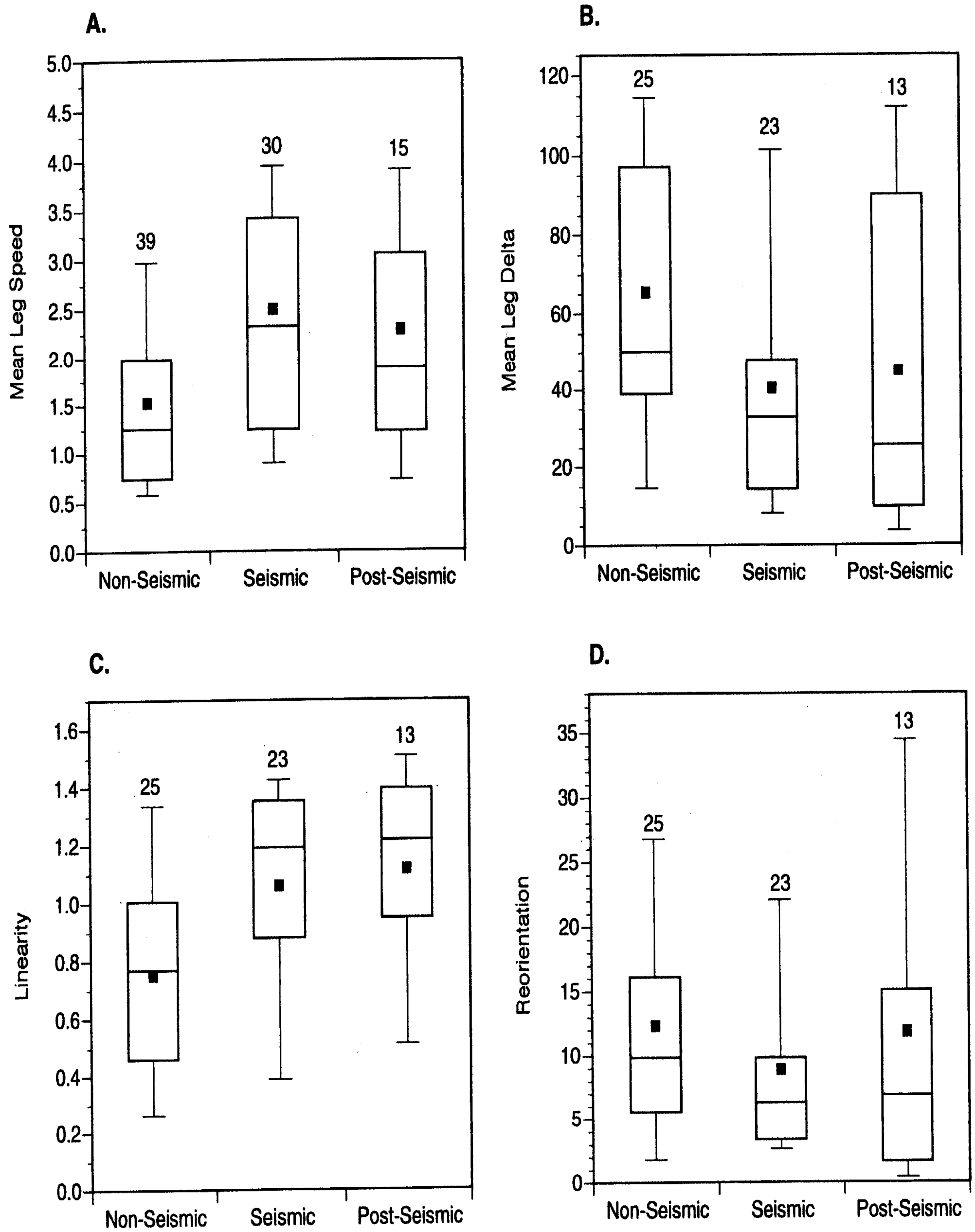


Figure 20. Mean leg speed (A), mean leg delta (B), linearity (C), and reorientation (D) statistics for theodolite-tracked whale pods during non-seismic, seismic, and post-seismic conditions. The lowest, second lowest, middle, second highest, and highest box points represent the 10th percentile, 25th percentile, median, 75th percentile, and 90th percentile, respectively. Means are represented by black squares. Value labels represent number of pod tracks.

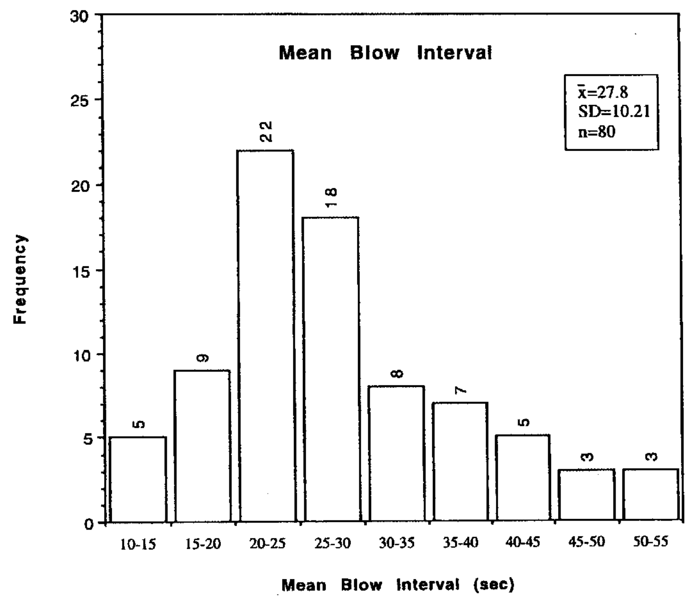
In sum, overall changes in mean leg speed, mean leg delta, and linearity were detected in the presence of seismic activity. These three findings together indicate a trend of faster and straighter swimming over larger areas during seismic periods. While additional data are needed, the present results show that seismic activity does elicit a behavioral change in overall whale movement patterns. We do not presently know how to relate these findings to a possible "nervousness factor," but hypothesize that it may be indicative of disturbance to feeding behavior which is generally characterized by limited linear movement and a high degree of angular change between surfacings (Würsig *et al*. 1986).

Surfacing-Respiration-Dive Parameters

Twelve focal sessions, conducted between 19 July and 12 August, were available for analysis. These focal observations ranged from approximately 8 min to 75 min, with a mean focal follow of 33 min. The overall frequency distributions of surfacing-respiration-dive (SRD) parameters for single whale pods are presented in Fig. 21. Similar to the analyses conducted on theodolite-obtained data, two analyses were conducted on five discrete SRD parameters (see Appendix I for detailed descriptions of these variables). These parameters were: Blow Interval; Dive Time; Surface Time; Blows Per Surfacing; and Surface-Dive Blow Rate. Blow interval data were analyzed in two manners; as the mean of all blow intervals during a single surfacing and as raw scores, taking each blow interval into account. However, only mean blow interval data are plotted here.

SRD Behavior as a Function of Pod-to-Vessel Distance

Working under the hypothesis that the distance of the survey vessel from a pod would potentially influence behavior differentially, we examined SRD parameters as a function of distance. This analysis consisted of only "seismic on" data because our records of seismic activity were limited to periods when the survey vessel was active, and therefore the only times when pod-to-vessel distances could be calculated.



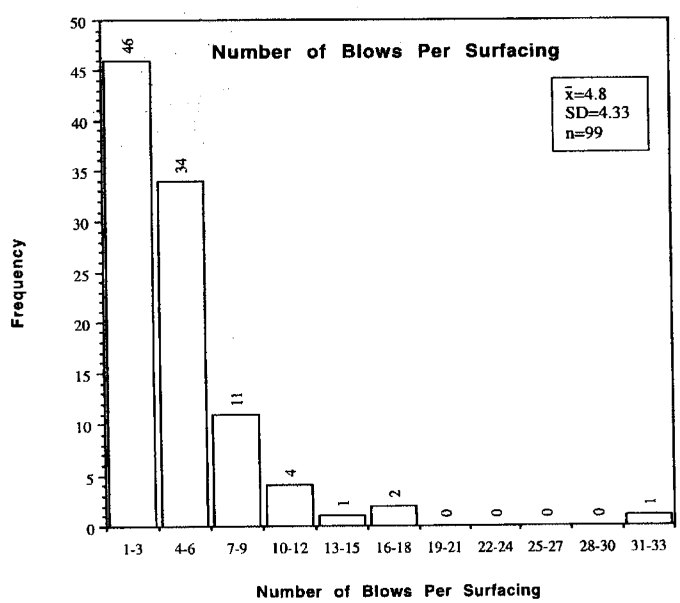
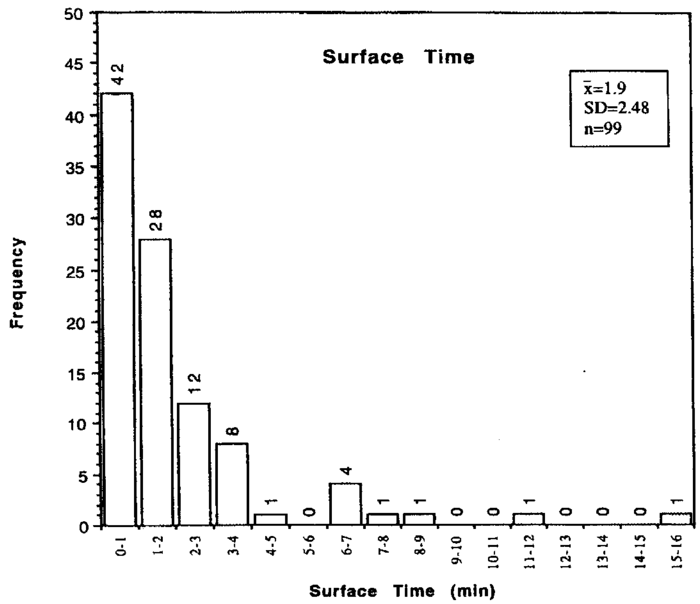


Figure 21. Frequency distribution of five surfacing-respiration-dive variables measured during focal observations on one-whale pods.



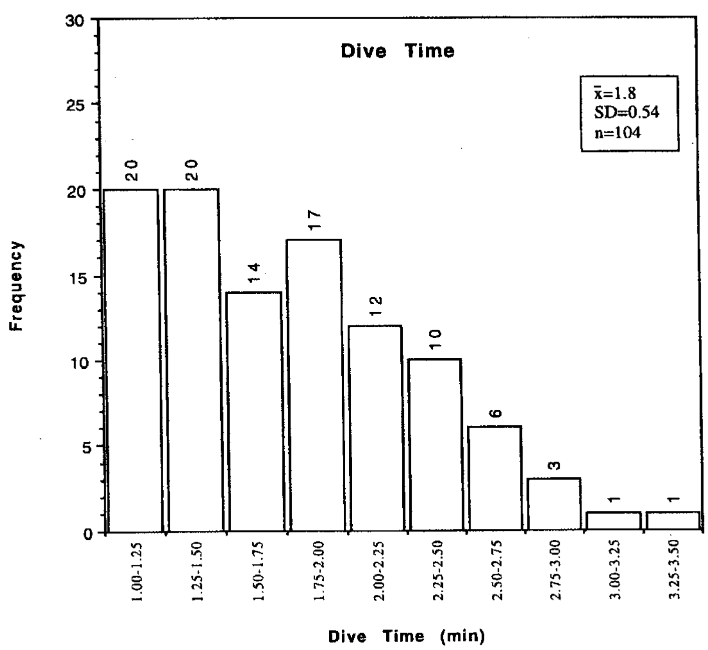


Figure 21 (cont.) Frequency distribution of five surfacing-respiration-dive variables measured during focal observations on one-whale pods.

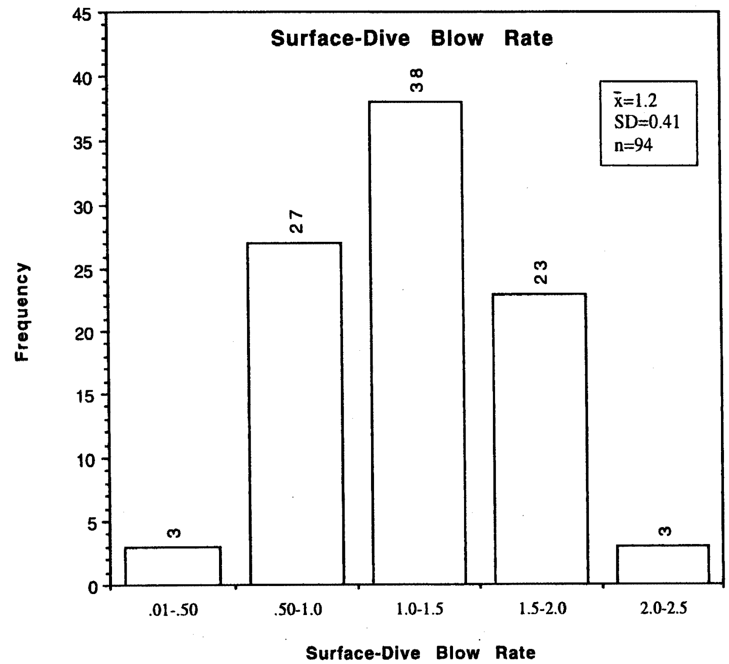


Figure 21 (cont.) Frequency distribution of five surfacing-respiration-dive variables measured during focal observations on one-whale pods.

SRD data for periods of known vessel activity fell into three discrete pod-to-vessel classes; 10-20 km, 20-30 km, and 30-40 km. In this analysis, data collected during seismic-on conditions were compared as a function of pod-to-vessel distance. No significant differences in raw score blow interval ($F(2,274) = 0.249$, $p = 0.7794$); mean blow interval ($F(2,49) = 0.996$, $p = 0.3768$); blows per surfacing ($F(2,60) = 0.401$, $p = 0.6716$); surface time ($F(2,60) = 0.37$, $p = 0.692$); dive time ($F(2,60) = 0.584$, $p = 0.5607$); or surface-dive blow rate ($F2,56) = 0.478$, $p = 0.6225$) were detected when examined by the three distance categories (Fig. 22a-e). Again, as was suggested for the theodolite data, it also appeared that pod-to-vessel distance was not in itself eliciting detectable differences in whale surfacing-respiration-dive patterns, at least during seismic-on conditions. However, the presence or absence of seismic sounds, regardless of distance, could not be ruled out as potentially producing discernible behavioral effects and was therefore investigated in the following analysis.

SRD Behavior as a Function of Seismic Condition

In this analysis, the same surfacing-respiration-dive variable described above were compared for all one-whale pods observed during non-seismic, seismic, and post-seismic conditions without taking the covariate of pod-to-vessel distance into account. The overall analysis of blow interval for raw scores revealed a significant effect of seismic condition ($F(2,425) = 14.218$, $p = 0.0001$) . The mean blow interval for the three conditions were: non-seismic-- 34.5 $\pm$ s.d. 13.21 ($n = 118$); seismic-- 29.12 $\pm$ s.d. 10.44 ($n = 278$); post-seismic-- 24.78 $\pm$ s.d. 7.35 ($n = 32$). Fisher's *post hoc* comparisons indicated a significant difference ($p < 0.05$) in raw blow interval between non-seismic and both seismic and post-seismic and also between seismic and post-seismic conditions.

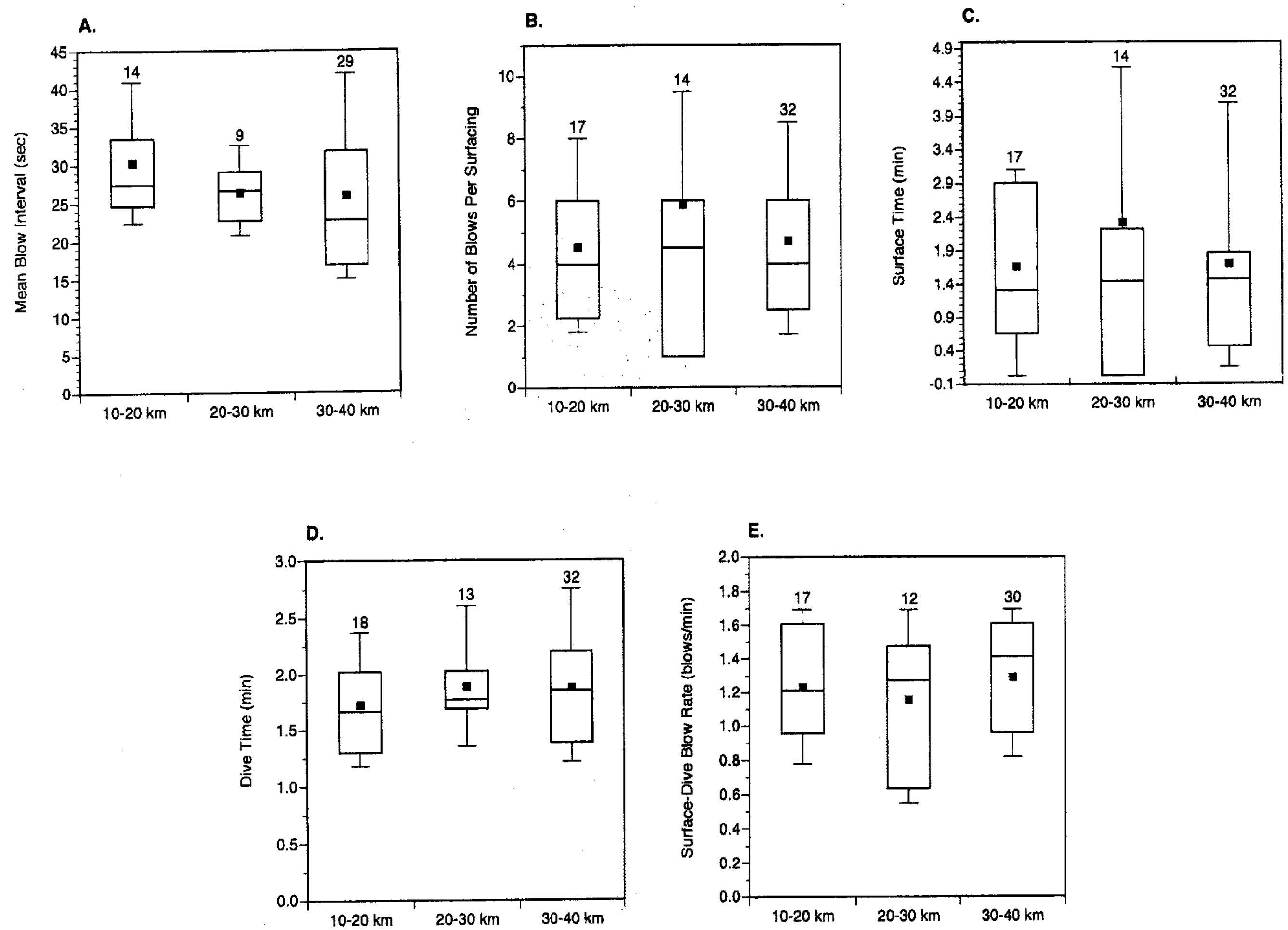


Figure 22. Mean blow interval (A), number of blows per surfacing (B), surface time (C), dive time (D), and surface-dive blow rate (E) statistics collected during focal observations of one-whale pods and as a function of pod-to-vessel distance. The lowest, second lowest, middle, second highest, and highest box points represent the 10th percentile, 25th percentile, median, 75th percentile, and 90th percentile, respectively. Means are represented by black squares. Value labels represent sample sizes.

Similarly, the analysis of blow interval for mean values revealed a marginally significant effect of seismic condition ($F(2,77) = 2.814$, $p = 0.0662$). The mean blow interval for the three conditions were: non-seismic-- 31.93 $\pm$ s.d. 12.23 ($n = 20$); seismic-- 26.98 $\pm$ s.d. 9.56 ($n = 53$); post-seismic-- 22.66 + s.d. 3.69 ($n = 7$) (Fig. 23a). Fisher's *post hoc* comparisons indicated a significant difference ($p < 0.05$) in mean blow interval between non-seismic and post-seismic conditions. The remaining surfacing-respiration-dive variables of blows per surfacing ($F(2,96) = 0.076$, $p = 0.9271$), surface time ($F(2,96) = 0.408$, $p = 0.6664$), dive time ($F(2,101) = 1.669$, $p = 0.1936$), and surface-dive blow rate ($F(2,91) = 0.398$, $p = 0.6728$) showed no significant differences by non-seismic, seismic, and post-seismic conditions (Fig. 23b-e).

These analyses of raw and mean data show similar results, and reveal that whales had longer intervals between exhalations during non-seismic periods. It is especially interesting that blow interval, which has been shown to be a relatively unchanging parameter for eastern stock gray whales (Würsig et al. 1986) and bowhead whales (Richardson *et al*. 1986, 1990), showed a seismically-related change in the present case. When links between blow intervals and occurrence of seismic activity have been noted in previous studies, the effect has been in the opposite direction to the results reported here; that is, longer not shorter blow intervals during seismic exposure (for review see Richardson *et al*. 1995). We caution that although the data indicate a significance, we presently do not know what potentially confounding factors may enter into this interpretation, and await further analyses and gathering of additional data for a more robust assessment.

Photo-Identification

Twenty-two photo-identification surveys totaling 85 h of effort were conducted 9 July through 8 September. Approximately 33 h hours were spent in direct observation of whale groups, during which time 72 rolls of film (2600 images) and three hours of digital video tape were used. Whales were always present in the study area, and sighted on each of the 22 surveys.

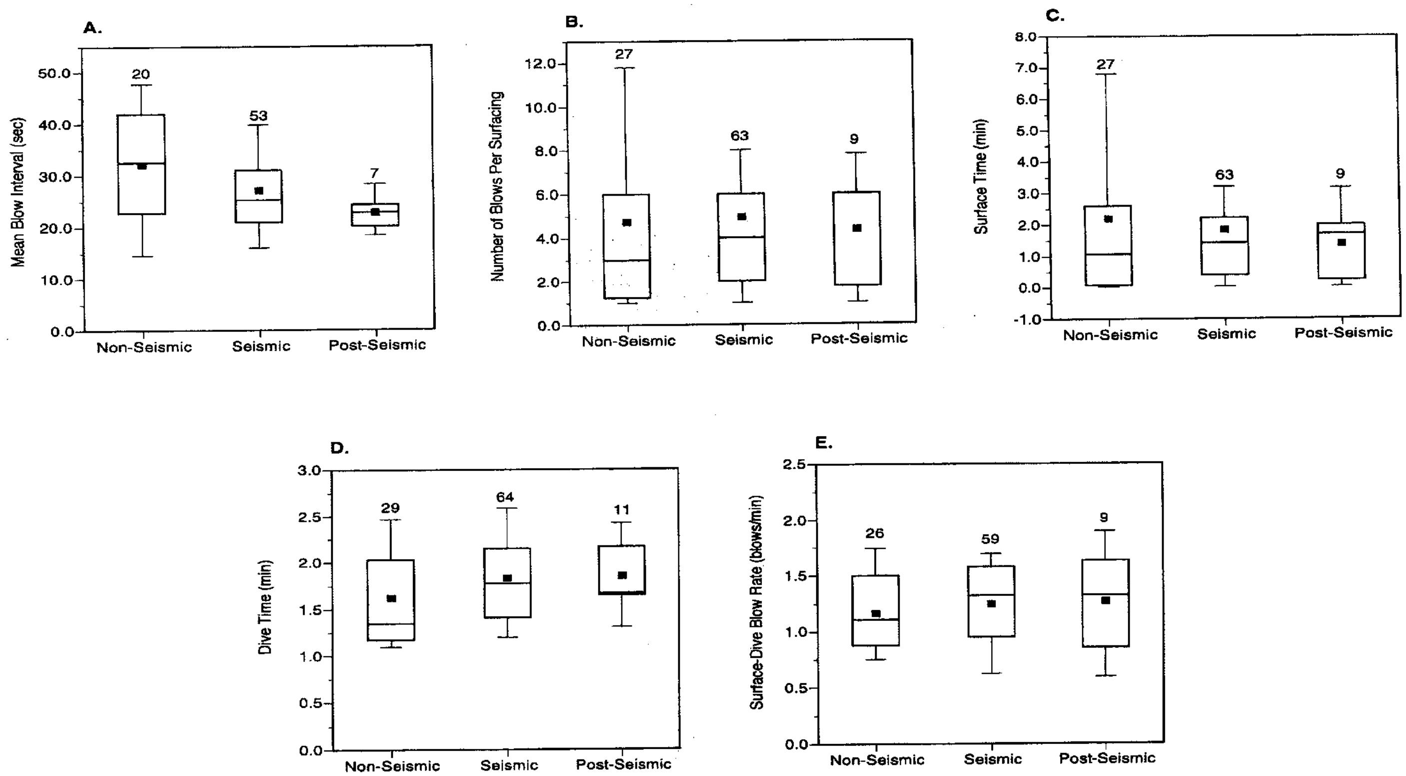


Figure 23. Mean blow interval (A), number of blows per surfacing (B), surface time (C), dive time (D), and surface-dive blow rate (E) statistics collected during focal observations of one-whale pods and as a function of seismic condition. The lowest, second lowest, middle, second highest, and highest box points represent the 10^{th} percentile, 25^{th} percentile, median, 75^{th} percentile, and 90^{th} percentile, respectively. Means are represented by black squares. Value labels represent sample sizes.

A total of 114 pods were encountered, with a mean pod size of 1.8 $\pm$ s.d. 1.33. Pod sizes ranged from 1-9 whales, with a majority of pods (97.4%) composed of four whales or less (Fig. 24).

A total of 43 naturally marked individual whales (Fig. 25) were identified by the end of the sampling season. The rate at which individual whales were first identified during the study is presented in Fig. 26. This figure displays the cumulative number of whales identified over time. The rapid increase in the slope of the curve represents the initial identification of previously unrecognized whales. This curve indicates that sightings of new animals had not yet leveled off by the end of the photographic effort, and it is likely that not all whales had been identified. Approximately one month into the study; however, the rate at which new whales were identified slowed and fewer "new" whales were being observed.

The presence or absence of identified whales during each of the three 1997 study months, and for the previous 1994 and 1995 photographic efforts, is presented in Fig. 27. Fourteen whales (32.6%) were sighted in only one month, while 16 (37.2%) were sighted in two months, and 13 whales (30.2%) were sighted in all three months (Fig. 28). Of the 28 whales first identified in July of 1997, 71.4% (n=20) were also sighted in August, and 46.4% (n=13) were again sighted in September. A similar trend was apparent for the 11 whales first sighted in August of 1997, with six of these individuals (54.6%) also sighted in September. All but three of the 16 whales sighted in two months were observed in consecutive months, as opposed to having an absence in their sighting pattern (i.e. July sighting and September sighting with no August sighting). Finally, of the 22 whales identified in August of 1995, 12 (54.6%) were also sighted in August of 1997. These findings suggest that some whales move into and out of the Piltun area during the

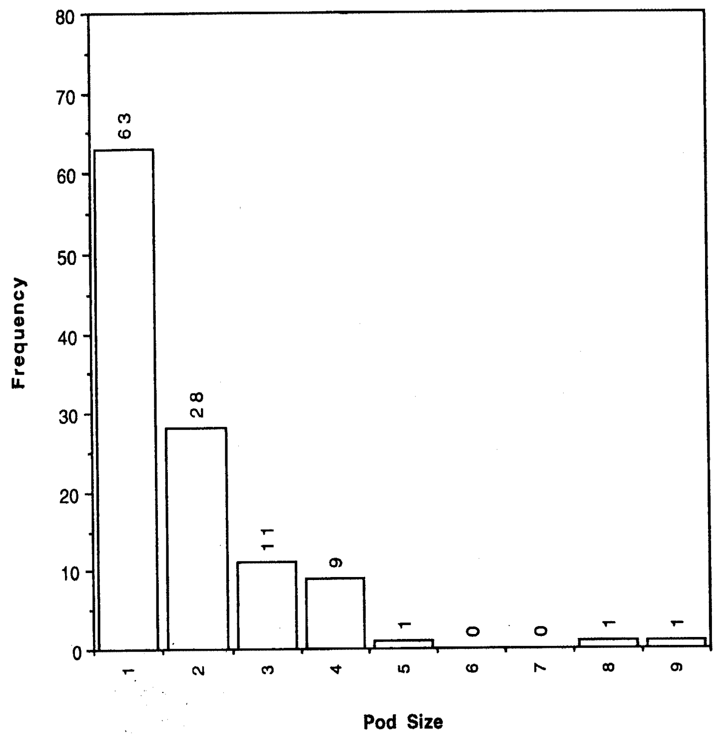


Figure 24. Pod sizes for whales identified during photo-identification surveys in 1997.

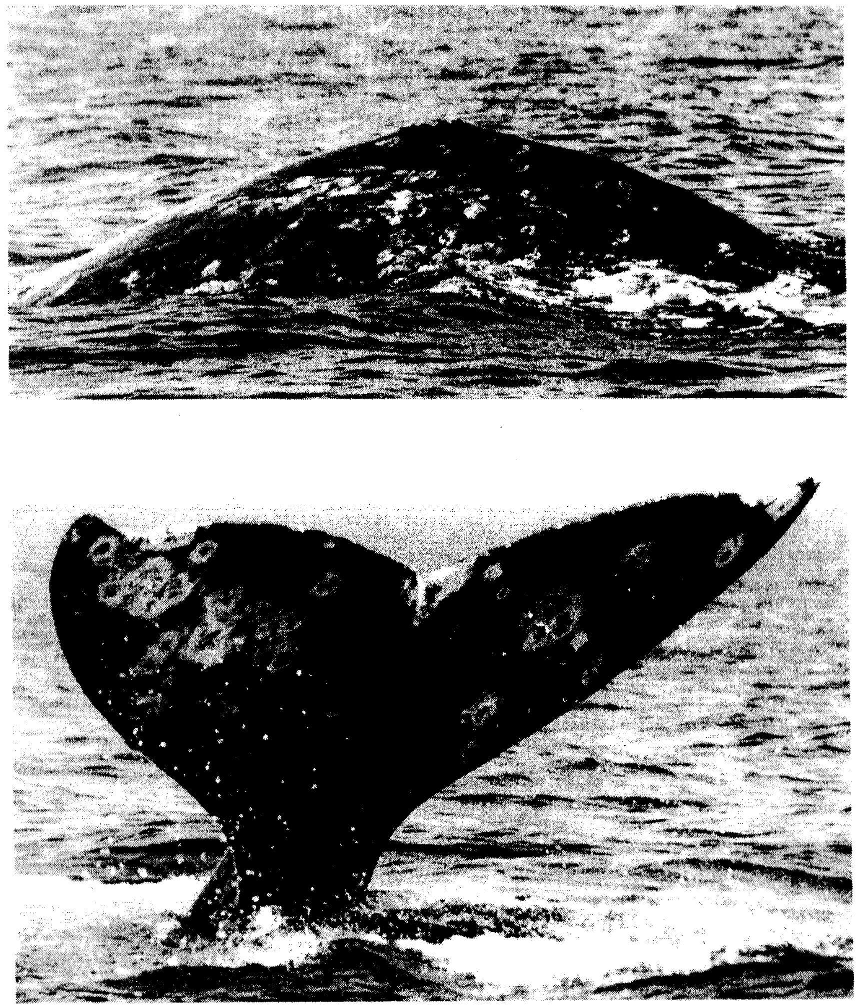


Figure 25. Whale 001, first sighted 9 July, 1997, off Piltun, Sakhalin Island. Spot and other mark patterns on gray whales are caused by pigmentation differences, holdfasts of barnacles, whale lice (Cyamidae), and other unknown factors. All whales are individually distinguishable by high quality photos.

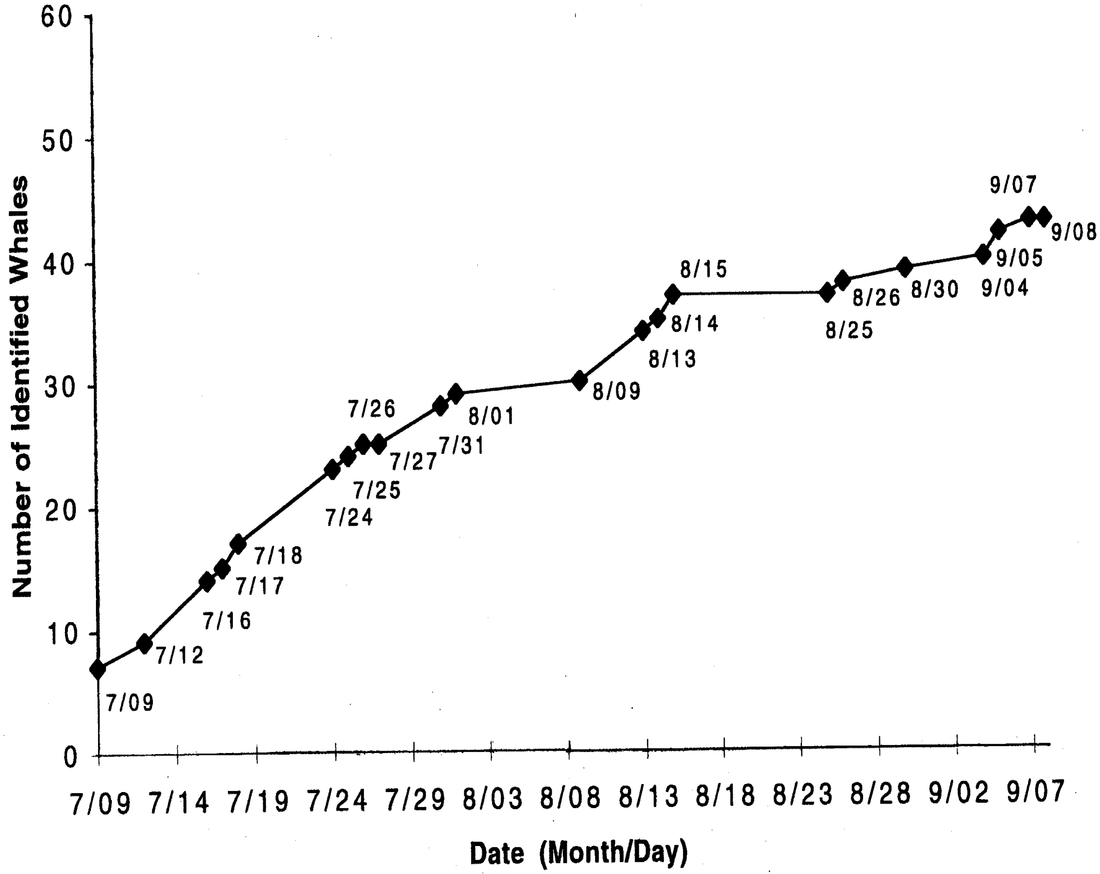


Figure 26. Rate of discovery curve for whales identified during 1997. Plotted dates represent survey days.

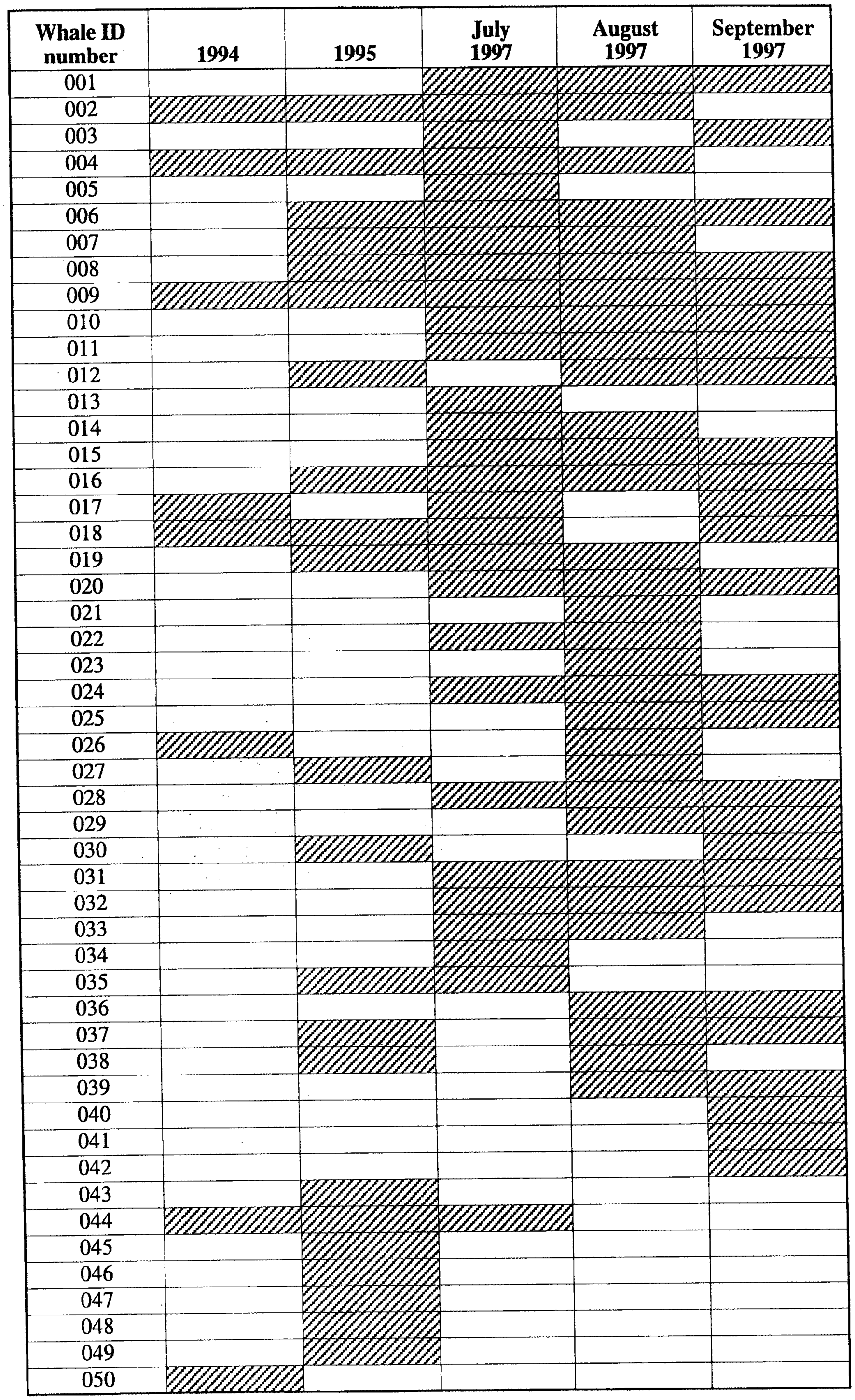


Figure 27. Occurrence patterns for whales identified in 1994, 1995, and 1997.

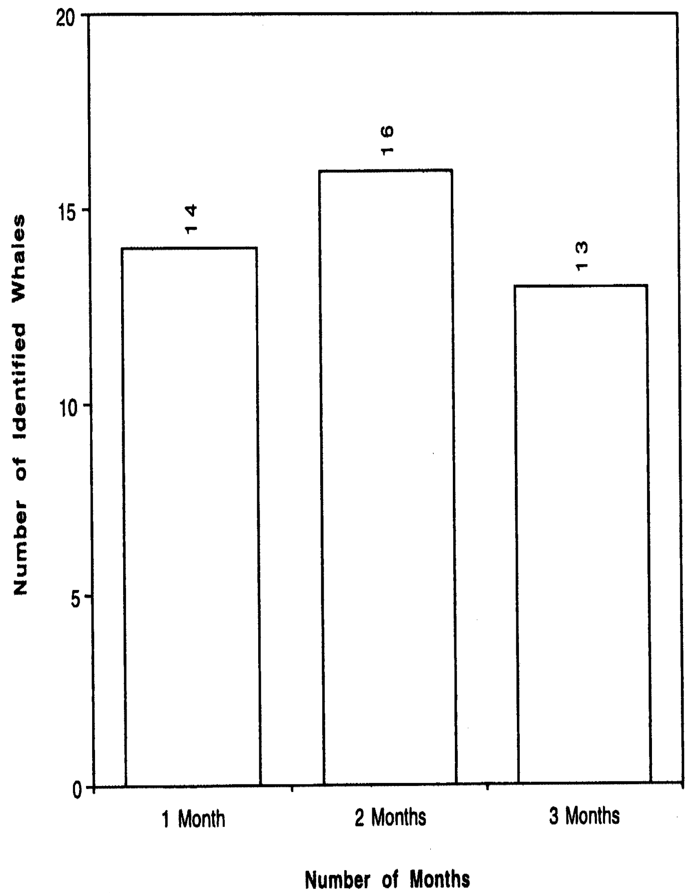


Figure 28. Seasonal sighting patterns for whales identified in 1997.

summer months, while other whales show apparent fidelity to the region (at least over several weeks to months).

Of the 43 whales identified during the 1997 field season, 58.1% (n = 25) were newly-identified animals (Table 3). Sighting frequencies for recognized individuals ranged between 1-8, based on a one-sighting-per-day criterion (Fig. 29, see Table 4 for further detail). Overall, 41.9% (n = 18) of the whales identified in 1997 had been previously identified in Piltun during 1994 and/or 1995 photographic efforts (see Table 3 and Fig. 27).

Table 3. Sighting data for gray whales identified in the Piltun study area, 1994-1997.

Year	Number of whales identified	Number of new whales identified that year	Percentage of whales reidentified from previous years	Number of whales seen only in that year
1994	8	8	0.0%	1
1995	22	17	22.7%	6
1997	43	25	41.9%	25

Five of the eight whales first identified in 1994 were also sighted in 1995 and 1997, while two whales first sighted in 1994 were not seen in 1995 but were again sighted again in 1997. Seven whales identified in 1994 or 1995 were not resighted in 1997. Therefore, the minimum number of known animals at this time is 43, but may be as high as 50 if the seven whales identified in previous years but not subsequently resighted are assumed to be living (Table 3). These sighting patterns indicate that many whales return to the Piltun area on a seasonal and annual basis (Fig. 30). This pattern of annual return to the same geographic area follows what has been observed for eastern gray whales (Würsig *et al*.

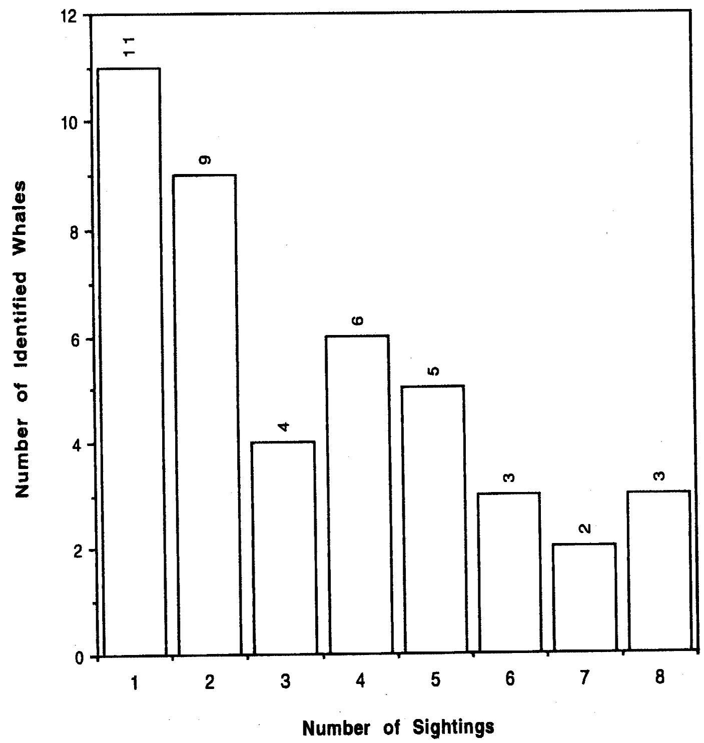


Figure 29. Sighting frequencies for whales identified in 1997.

Table 4. Sighting histories of gray whales identified in 1997.

Whale ID number	Aspect	Date	Group number	Initial sighting location (degrees north and east)		Initial sighting depth (m)	Sea surface temperature
001	R,L,F	09/07/97	1	52°49.473	143°21.763	18.5	8.7 °C
001	R,L,F	26/07/97	5	52°55.153	143°20.774	14.5	
001	R,F	31/07/97	2	52°51.100	143°21.633	13.5	
001	R,L,F	01/08/97	7	52°55.569	143°20.836	11.5	
001	R	08/09/97	6	52°50.157	143°22.090	13.5	
002	R,L,F	09/07/97	2	52°51.089	143°22.232	14.0	
002	R,L,F	12/07/97	2	52°50.658	143°22.214	14.0	7.8 °C
002	R	17/07/97	2	52°51.310	143°22.254	15.0	6.0 °C
002	L	17/07/97	3	52°50.308	143°22.383	14.0	
002	R,L	17/07/97	4	52°49.549	143°22.249	12.5	
002	R,L	09/08/97	1	52°50.529	143°21.556	16.0	
002	R,L	13/08/97	4	52°52.650	143°22.288	14.5	
003	R	09/07/97	3	52°51.299	143°22.300	14.5	
003	R	31/07/97	2	52°51.100	143°21.633	13.5	
003	R	08/09/97	4	52°50.329	143°22.704	21.0	
004	R,L	09/07/97	4	52°51.945	143°21.492	19.0	
004	L	25/07/97	2	52°51.518	143°20.953	13.0	13.3 °C
004	R	01/08/97	7	52°55.569	143°20.836	11.5	
004	R,L,F	01/08/97	8	52°56.837	143°21.345	18.0	
004	R,L	13/08/97	1	52°51.376	143°21.064	12.0	
004	R,L	13/08/97	2	52°51.374	143°20.997	11.0	
004	R	13/08/97	6	52°51.724	143°20.761	10.5	
004	R	13/08/97	8	52°51.923	143°20.668	9.5	
004	R,L	15/08/97	4	52°52.969	143°20.859		
005	R,L	09/07/97	5	52°50.488	143°22.098	15.5	
006	R,L	09/07/97	5	52°50.488	143°22.098	15.5	
006	R	01/08/97	11	52°55.764	143°20.980		
006	R	09/08/97	1	52°50.529	143°21.556	16.0	
006	R,L	08/09/97	6	52°50.157	143°22.090	13.5	
007	R,L,F	12/07/97	1	52°50.010	143°22.161	12.5	
007	R,L,F	13/08/97	3	52°51.431	143°22.916	15.5	9.8 °C
007	F	25/08/97	2	52°50.817	143°21.957	15.5	

Table 4 (cont.). Sighting histories of gray whales identified in 1997.

Whale ID number	Aspect	Date	Group number	Initial sighting location (degrees north and east)		Initial sighting depth (m)	Sea surface temperature
007	L,F	26/08/97	8	52°50.730	143°22.186	14.5	
008	R	12/07/97	1	52°50.010	143°22.161	12.5	
008	L	17/07/97	4	52°49.549	143°22.249	12.5	
008	R,L,F	01/08/97	4	52°51.721	143°21.467	14.0	
008	R,L,F	26/08/97	4	52°49.643	143°22.029	13.0	
008	R	26/08/97	9	52°50.088	143°21.674	17.0	
008	R,L,F	04/09/97	4	52°50.061	143°22.232	15.0	
008	R	05/09/97	6	52°49.625	143°23.986	22.0	
008	R,L,F	05/09/97	9	52°50.785	143°22.882	14.0	
009	R,L,F	16/07/97	2	52°53.156	143°21.150	11.5	
009	R,L,F	26/07/97	4	52°53.365	143°21.135	14.5	
009	R,L,F	27/07/97	1	52°53.317	143°21.469	16.0	15.4 °C
009	R,F	01/08/97	5	52°52.843	143°21.508	14.5	
009	R,L,F	26/08/97	2	52°49.695	143°21.325	15.5	
009	R,L,F	26/08/97	7	52°51.162	143°21.736	17.0	
009	R,L,F	04/09/97	3	52°51.418	143°22.011	17.5	
009	R,F	05/09/97	9	52°50.785	143°22.882	14.0	
010	R	17/07/97	2	52°51.310	143°22.254	15.0	6.0 °C
010	L	18/07/97	1	52°51.842	143°21.414	14.5	7.0 °C
010	R,L	26/08/97	1	52°50.635	143°21.444	14.5	
010	R,L,F	04/09/97	2	52°50.440	143°21.772	17.0	
010	R,L	05/09/97	8	52°50.267	143°22.188	13.5	
010	R	05/09/97	10	52°50.175	143°22.251		
010	R,L	08/09/97	6	52°50.157	143°22.090	13.5	
011	R,L,F	18/07/97	1	52°51.842	143°21.414	14.5	7.0 °C
011	L	18/07/97	2	52°52.666	143°21.360	15.0	
011	R,L	26/07/97	2	52°53.151	143°21.187	15.0	
011	R,L	31/07/97	1	52°51.250	143°20.417	6.7	
011	R,L	31/07/97	3	52°51.002	143°20.978	8.7	9.4 °C
011	R,L	31/07/97	4	52°50.976	143°20.614	8.0	
011	R,L,F	01/08/97	3	52°51.025	143°21.404	13.5	
011	L	13/08/97	3	52°51.431	143°22.916	15.5	9.8 °C

Table 4 (cont.). Sighting histories of gray whales identified in 1997.

Whale ID number	Aspect	Date	Group number	Initial sighting location (degrees north and east)		Initial sighting depth (m)	Sea surface temperature
011	R,L,F	26/08/97	5				
011	L,F	07/09/97	2	52°50.543	143°22.222	15.0	
012	R,L,F	14/08/97	5	52°51.917	143°21.200	12.0	
012	R,L,F	04/09/97	1	52°51.185	143°22.537	13.0	
012	R,L,F	04/09/97	4	52°50.061	143°22.232	15.0	
013	R,F	16/07/97	1	52°50.931	143°21.685	14.5	
014	R,L,F	16/07/97	2	52°53.156	143°21.150	11.5	
014	R,L,F	14/08/97	5	52°51.917	143°21.200	12.0	
015	R,L	16/07/97	3	52°50.658	143°21.440	16.5	
015	R,L	25/07/97	1	52°50.964	143°20.227	7.5	13.3 °C
015	L	09/08/97	1	52°50.529	143°21.556	16.0	
015	L	07/09/97	1	52°51.136	143°21.927	17.5	
016	R,L,F	16/07/97	2	52°53.156	143°21.150	11.5	
016	L,F	18/07/97	3	52°53.114	143°21.679	21.0	
016	R,L	09/08/97	1	52°50.529	143°21.556	16.0	
016	L	08/09/97	6	52°50.157	143°22.090	13.5	
017	R,L	26/07/97	4	52°53.365	143°21.135	14.5	
017	R,L	04/09/97	4	52°50.061	143°22.232	15.0	
018	L	09/07/97	5	52°50.488	143°22.098	15.5	
018	R,L	04/09/97	4	52°50.061	143°22.232	15.0	
019	R,L	24/07/97	1	52°51.738	143°20.139	9.0	4.3 °C
019	R,L	26/07/97	1			6.0	12.2 °C
019	L	31/07/97	1	52°51.250	143°20.417	6.7	
019	R,L	31/07/97	7	52°50.654	143°20.776	6.8	
019	R,L	14/08/97	3	52°51.334	143°20.170	4.7	
019	R	15/08/97	2	52°51.020	143°20.275	5.2	
019	R,L	26/08/97	6	52°51.274	143°20.128	5.1	
020	R,L	24/07/97	1	52°51.738	143°20.139	9.0	4.3 °C
020	R,L	26/07/97	1			6.0	12.2 °C
020	L	31/07/97	1	52°51.250	143°20.417	6.7	
020	R,L	31/07/97	7	52°50.654	143°20.776	6.8	
020	R,L	14/08/97	3	52°51.334	143°20.170	4.7	

Table 4 (cont.). Sighting histories of gray whales identified in 1997.

Whale ID number	Aspect	Date	Group number	Initial sighting location (degrees north and east)		Initial sighting depth (m)	Sea surface temperature
020	R	15/08/97	2	52°51.020	143°20.275	5.2	
020	R,L	26/08/97	6	52°51.274	143°20.128	5.1	
020	L	05/09/97	12	52°52.212	143°19.772	4.7	
020	R	08/09/97	5	52°49.973	143°22.045	13.5	
021	F	01/08/97	5	52°52.843	143°21.508	14.5	
021	R,F	01/08/97	6	52°53.350	143°21.573	16.0	10.9 °C
021	L,F	01/08/97	7	52°55.569	143°20.836	11.5	
021	R,L,F	01/08/97	9	52°56.651	143°20.400	13.0	
022	R,L,F	31/07/97	2	52°51.100	143°21.633	13.5	
022	R,L,F	13/08/97	1	52°51.376	143°21.064	12.0	
023	R,L	13/08/97	3	52°51.431	143°22.916	15.5	9.8 °C
023	R,L,F	13/08/97	5	52°51.518	143°21.493	13.5	
024	R,L	24/07/97	1	52°51.738	143°20.139	9.0	4.3 °C
024	R	24/07/97	2	52°52.404	143°20.015	7.8	
024	L	24/07/97	3	52°52.170	143°20.295	9.5	
024	L	01/08/97	2	52°50.937	143°21.163	8.2	
024	L	14/08/97	1	52°51.058	143°20.501	7.6	
024	R	14/08/97	2	52°51.462	143°20.265	6.5	
024	L	14/08/97	3	52°51.334	143°20.170	4.7	
024	R,L	14/08/97	4	52°51.321	143°20.628	8.5	6.1 °C
024	L	05/09/97	11	52°50.666	143°20.851	7.5	
024	R	08/09/97	1	52°50.809	143°20.818	7.7	
024	R,L,F	08/09/97	5	52°49.973	143°22.045	13.5	
024	R,L	08/09/97	9	52°50.955	143°20.600	7.5	
025	R,L	13/08/97	1	52°51.376	143°21.064	12.0	
025	R	08/09/97	2	52°51.392	143°21.577	14.5	
025	R,L	08/09/97	6	52°50.157	143°22.090	13.5	
025	R,L	08/09/97	8	52°50.861	143°21.366	13.5	
026	R	15/08/97	5	52°53.044	143°21.278	15.0	
027	R,L,F	15/08/97	1	52°50.136	143°21.545	16.0	
027	R,L,F	25/08/97	1	52°49.974	143°21.709	16.0	7.4 °C
027	L	26/08/97	8	52°50.730	143°22.186	14.5	

Table 4 (cont.). Sighting histories of gray whales identified in 1997.

Whale ID number	Aspect	Date	Group number	Initial sighting location (degrees north and east)		Initial sighting depth (m)	Sea surface temperature
028	R,L	31/07/97	1	52°51.250	143°20.417	6.7	
028	R,L,F	15/08/97	1	52°50.136	143°21.545	16.0	
028	R,L,F	25/08/97	2	52°50.817	143°21.957	15.5	
028	R,L,F	05/09/97	4	52°50.517	143°21.771	17.0	
029	L,F	13/08/97	3	52°51.431	143°22.916	15.5	9.8 °C
029	L,F	26/08/97	8	52°50.730	143°22.186	14.5	
029	R,L,F	05/09/97	3	52°51.924	143°21.855	17.5	
029	R,L,F	07/09/97	6	52°53.037	143°21.806	16.5	
030	R,L	07/09/97	3	52°50.784	143°22.229	14.0	
030	L,F	08/09/97	2	52°51.392	143°21.577	14.5	
030	R,L	08/09/97	3	52°51.355	143°21.554	14.0	
030	R	08/09/97	7	52°50.940	143°21.621		16.9 °C
031	R,L,F	24/07/97	1	52°51.738	143°20.139	9.0	4.3 °C
031	R,L	24/07/97	2	52°52.404	143°20.015	7.8	
031	L	24/07/97	3	52°52.170	143°20.295	9.5	
031	R,L,F	25/07/97	1	52°50.964	143°20.227	7.5	13.3 °C
031	R,L	27/07/97	2	52°50.839	143°20.609	6.7	
031	R,F	31/07/97	1	52°51.250	143°20.417	6.7	
031	L	31/07/97	5	52°51.354	143°20.408	6.6	
031	R,L	31/07/97	6	52°51.159	143°20.401	6.5	
031	R	31/07/97	7	52°50.654	143°20.776	6.8	
031	R	01/08/97	1	52°50.216	143°21.085	7.1	
031	R,L	14/08/97	1	52°51.058	143°20.501	7.6	
031	R,L	26/08/97	6	52°51.274	143°20.128	5.1	
031	R,L	05/09/97	1	52°50.788	143°20.460	6.2	13.5 °C
031	R	05/09/97	12	52°52.212	143°19.772	4.7	
032	R,L,F	24/07/97	1	52°51.738	143°20.139	9.0	4.3 °C
032	R,L,F	24/07/97	2	52°52.404	143°20.015	7.8	
032	L	24/07/97	3	52°52.170	143°20.295	9.5	
032	R,L,F	25/07/97	1	52°50.964	143°20.227	7.5	13.3 °C
032	L,F	27/07/97	2	52°50.839	143°20.609	6.7	
032	R	31/07/97	1	52°51.250	143°20.417	6.7	

Table 4 (cont.). Sighting histories of gray whales identified in 1997.

Whale ID number	Aspect	Date	Group number	Initial sighting location (degrees north and east)		Initial sighting depth (m)	Sea surface temperature
032	L	31/07/97	5	52°51.354	143°20.408	6.6	
032	R,L	31/07/97	6	52°51.159	143°20.401	6.5	
032	R	31/07/97	7	52°50.654	143°20.776	6.8	
032	R,L	01/08/97	1	52°50.216	143°21.085	7.1	
032	R,L	14/08/97	1	52°51.058	143°20.501	7.6	
032	R,L	26/08/97	6	52°51.274	143°20.128	5.1	
032	R,L	05/09/97	1	52°50.788	143°20.460	6.2	13.5 °C
032	R,L	05/09/97	12	52°52.212	143°19.772	4.7	
033	R,L	24/07/97	3	52°52.170	143°20.295	9.5	
033	R	31/07/97	1	52°51.250	143°20.417	6.7	
033	R,L	31/07/97	5	52°51.354	143°20.408	6.6	
033	R,L	01/08/97	2	52°50.937	143°21.163	8.2	
033	L	13/08/97	7	52°52.027	143°20.973	11.5	
033	L	15/08/97	3	52°52.995	143°20.798	11.5	
034	R,L	25/07/97	2	52°51.518	143°20.953	13.0	13.3 °C
035	R,L,F	31/07/97	1	52°51.250	143°20.417	6.7	
036	R	09/08/97	1	52°50.529	143°21.556	16.0	
036	R,F	25/08/97	3	52°50.936	143°21.468	13.5	
036	R,L,F	07/09/97	2	52°50.543	143°22.222	15.0	
037	R,L	13/08/97	4	52°52.650	143°22.288	14.5	
037	R	25/08/97	3	52°50.936	143°21.468	13.5	
037	R	04/09/97	5	52°51.173	143°23.487	23.0	
038	R	30/08/97	1	52°49.509	143°21.599	13.0	4.4 °C
039	R,L,F	26/08/97	7	52°51.162	143°21.736	17.0	
039	R,L	05/09/97	9	52°50.785	143°22.882	14.0	
040	R,F	04/09/97	5	52°51.173	143°23.487	23.0	
041	R,L	05/09/97	2	52°51.084	143°21.558	14.5	
041	R,L	05/09/97	6	52°49.625	143°23.986	22.0	
041	L	07/09/97	5	52°51.776	143°22.021	14.5	
042	R,L,F	05/09/97	2	52°51.084	143°21.558	14.5	
042	L,F	05/09/97	6	52°49.625	143°23.986	22.0	
044	R,F	18/07/97	4	52°53.585	143°22.658		

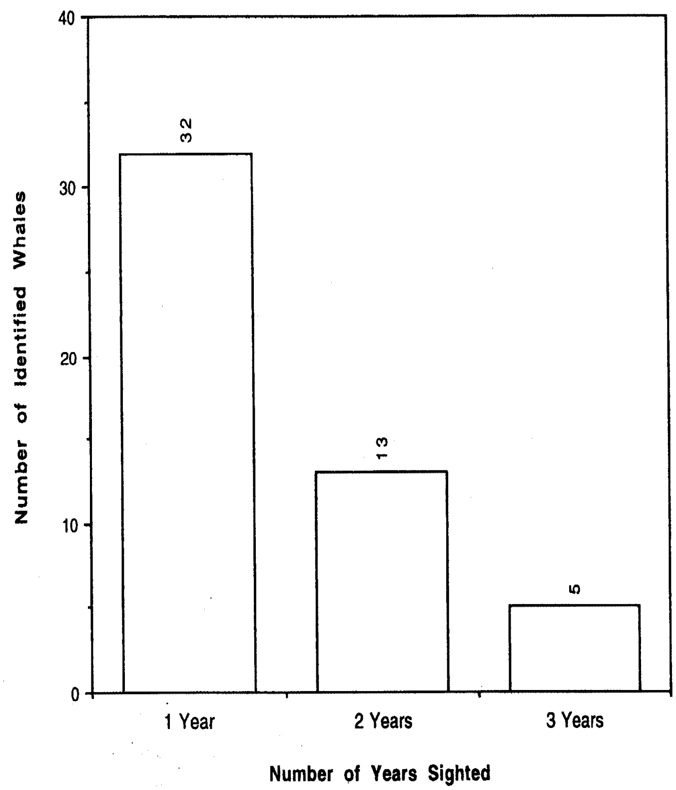


Figure 30. Annual sighting records for photographically identified whales.

1986, Jones 1990), and emphasizes the potential importance of the Piltun region as a major feeding ground for at least part of the western gray whale population.

Two mother-calf pairs were identified during the study, and ranked among the most frequently sighted whales. These mothers and calves were closely bonded throughout the study, and often the two pairs interacted with each other. Only late into the final month of the study did we suspect that one of the calves had separated from its mother. Observations indicated that this newly-independent calf had joined the other mother-calf pair (at least temporarily). The regular sightings of these two mother-calf pairs corresponded with a noticeable increase in "friendliness" (*sensu* Jones and Swartz 1984) toward our research vessel. In particular, one mother and calf often approached the vessel to within several meters. In addition to photo-recognition of these pairs, on good sighting days we could identify both mother-calf pairs from the shore station by use of a 25-40x-power spotting scope. The combined boat-based and shore-based sighting records suggested that these mother-calf pairs remained in the Piltun study area over the duration of the study. One of these identified mothers had been previously identified with a calf in Piltun during 1995, possibly indicating an annual return to this region by reproductive females.

CONCLUSIONS

Results presented here represent a significant step in advancing our basic understanding of the biology and behavior of western gray whales along northeastern Sakhalin Island. Nevertheless, this research is only of a baseline nature, with more detailed information becoming available only after several additional years of dedicated effort. While whales did not appear to be displaced by industrial seismic activity; we documented changes in distribution, movements, and respiration parameters correlated with the presence of seismic-related noise. Major results from each research method employed during the 1997 field effort are summarized here:

- Aerial and vessel surveys suggested that while gray whales were detected to the north and south of Piltun Lagoon, the only major concentrations observed were located near the study site. These findings are in support of previous TINRO aerial and ship-based survey results which also reported that major concentrations of gray whales in the coastal waters of Sakhalin were observed predominately near Piltun Lagoon.

- Acoustic monitoring of geophysical survey activity revealed received sound levels from seismic pulses of approximately 153 dB re 1 μPa, zero-to-peak; 159 dB re 1 μPa, peak-to-peak; and 139 dB re 1 μPa, averaged over one second while the seismic survey vessel was 30-35 km from shore. These findings indicated that even at relatively large distances, seismic noise was detectable within the nearshore area that gray whales were typically located.

- Theodolite tracking determined that most pods were sighted within 6 km of shore. Intra-seasonal changes in pod distribution indicated that whales moved into deeper water as the summer season progressed. This distributional change suggested that pods may have remained closer to shore during seismic periods (July to mid-August) and shifted to more offshore waters (late-August to early-September) once seismic surveying was terminated.

- Shore-based scans counted 397 pods, with an average of 4.8 pods and 8.4 whales per scan. Scans collected during non-seismic, seismic, and post-seismic periods showed a trend of fewer pods being detected immediately after seismic periods than during non-seismic periods. This pattern suggested that pods began to shift their distribution out of the study site during periods of seismic noise, resulting in the lower whale numbers counted during the subsequent post-seismic condition.

- Photo-identification surveys identified 46 whales, and revealed high levels of seasonal site fidelity, and annual return of previously identified individuals. These occurrence patterns, in combination with the regular observation of several mother-calf pairs, emphasizes the importance of the Piltun area as a major feeding ground for at least part of the population.

Data regarding movement patterns and surfacing-respiration-dive patterns were examined at two levels; with respect to pod-to-vessel distance; and as a function of non-seismic, seismic, and post-seismic conditions. The presence or absence of seismic activity rather than pod-to-vessel distance appeared to be of greater importance in eliciting behavioral changes. The following alterations in movement and respiration patterns were detected:

- Theodolite tracks during focal observations detected changes in whale swim speeds and orientations relative to seismic sound. Alterations in leg speed, leg delta, and linearity indicated a trend of faster and straighter swimming over larger areas during seismic periods. We hypothesize that these behavioral changes may be indicative of disturbance to feeding behavior which is generally characterized by limited linear movement and a high degree of angular change between surfacings.

- Focal pod observations revealed that whales had the longest intervals between exhalations during non-seismic periods. The more rapid breathing rate detected during seismic and post-seismic periods is difficult to interpret but clearly indicates a fundamental physiological change which may or may not prove deleterious to individual whales.

Although several features of the data presented here indicated a relationship between whale behavior and seismic sound, none of the reactions observed appeared to have been overtly dramatic (i.e. immediately detectable by visual observers). Instead, behavioral changes consisted mostly of what appeared to be short-term responses. The cumulative effects of short-term responses over extended periods of time (e.g. year after year) are presently unresolved, and can only be assessed by additional long-term study.

Similarly, long-term responses to disturbance such as gradual abandonment of an area (see Bryant *et al*. 1984), or overall diminished annual return and site fidelity patterns also cannot be discerned without longitudinal data.

Industrial activities on the continental shelf off northeastern Sakhalin Island have steadily increased in the past several years, and are scheduled to continue into the next millennium. The nearly constant drilling and production activities, in addition to the associated increase in aircraft and shipping traffic now occurring off Piltun Lagoon have introduced new and presently under-studied sources of potential disturbance to western gray whales on their feeding grounds. Therefore, we strongly recommend that the current research effort be continued, while at the same time expanding to incorporate studies on: reactions of whales to increased aircraft and vessel traffic; nearshore benthic habitat and prey communities; distribution and occurrence patterns of whales at broader spatial scales along the eastern Sakhalin coast; and migratory routes and timing to and from the Piltun area.

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SCIENTIFIC REVIEW BOARD

The scientific Review Board established for the present project consists of well-known researchers who are dedicating their time, *gratis*, to advising on all research aspects. Board members are:

Dr. Phillip Clapham. Marine Mammalogist, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, Massachusetts.

Dr. James Darling. West Coast Whale Research Foundation, Tofino, British Columbia, Canada.

Dr. Douglas DeMaster. Chief of Marine Mammal Science, Marine Mammal Laboratory, National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

Dr. Stephen Reilly. Marine Mammal Biologist. National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California.

Dr. Toshio Kasuya. Professor of Marine Biology, Mie University, Mie, Japan.

Dr. Steven L. Swartz. Marine Mammal Biologist. National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, Florida.

Dr. Alexey Yablokov. Chairman, Center for Russian Environmental Policy, Moscow, Russia.

APPENDIX I

Data collection protocols and definitions of variables regarding: behavior, respiration, environment, visibility, vessels, and disturbance.

Western Stock Gray Whale: Daily Shore Station Schedule

Arrival at Shore Station

Begin each day at sun rise, set-up theodolite, data collection computer, and additional equipment. Record environmental conditions, theodolite position and eye piece height, researcher roles, and tide height.

Scan Sample

Once equipment is ready, initiate a systematic scan of the designated study area (arena). During each scan, the behavioral observer scans from North to South, counting each pod and detailing pod composition. Simultaneously, the theodolite operator "fixes" each pods location and verifies pod composition.

Active Search

Occurs when not in focal session. One observer scans inshore area left to right, alternating between binoculars and naked eye (and acts as computer operator/notetaker when necessary). The theodolite operator fixes vessels and non-focal pods. Active search requires a minimum of 2 observers.

Focal Observation Sessions (*see focal observation protocol*)

Focal observations should begin when a pod is sighted within reliable viewing range of the lighthouse shore station. The behavioral observer will initiate a focal session and continue observations until the pod travels out of viewing range, or environmental conditions hamper reliable behavioral calls. The observer will concentrate on the focal pod only. The theodolite operator will track all pods and vessels within view during the focal session, enlisting help from other crew when possible. The closest point of approach and associated information for boats, planes and helicopters will be called by the theodolite operator (see theodolite protocol). The computer operator/notetaker will record all information and verify that necessary details have been described.

When to Leave Shore Station

- No whales
- Poor sighting conditions (e.g., Beaufort ≥ 6, fog, rain, low light, etc.)

Western Stock Gray Whales: Protocol and Behavioral Ethogram Codes

Aardvark File Header ***(entered automatically when file is opened)***

station (id/name/latDeg/latMin/lonDeg/lonMin/el/magDec)	Observation station description
observer (id/name)	Observer description
theodolite (id/name/azOffset/decOffset)	Theodolite description
reference (id/name/azimuth)	Azimuth reference description

Observations - Start/End

start
end

Observer Roles

role (observer/role)

Oberservation Comments

c(text/id)	Comment
l (lag)	Lag in calling last observation (default 3
sec)	
x	Delete last entry
xx	Delete last sequence

Observed Object Descriptions

pc (id/# whales/ # calves)	Pod composition
vt (id/type)	Vessel type

Scan Sampling

ssc (id/visibility/beaufort/swell/vessels/pods)	Start scan
sws	Start whale scan
esc	End Scan

Focal Sampling

sfs (session/pod/or/speed/vis/beaufort/swell/vessels/aircraft/Dist)	Start focal session
efs	End focal session
or (orientation/speed)	Focal pod orientation
env (visibility/beaufort swell)	Environment
cnf (confidence)	Observer confidence
pl	Pod lost

Vessel and Aircraft Closest Approaches

cpav (vessel/pod)	Vessel
cpaa (airplane/pod)	Airplane
cpah (helicopter/pod)	Helicopter

Pod Affiliations and Disaffiliations

paf (old1/old2/new)	Pod affiliation
pds (old/new1/new2)	Pod disaffiliation

Theodolite Calibration

eh (height)	Eyepiece Height
tbc	Bubble check
rbt	Rebalance

Protocol and Behavioral Ethogram Codes (Continued)

INDIVIDUAL WHALE BEHAVIORS

All commands take two arguments, an individual code (1 = adult, 2 = mom, 3 = calf, 4 = escort) and a pod id.

Respiration

fs First surface with no blow
f First surface blow
nf Not first surfacing (whale seen at surface)
b Blow
n No blow rise (surface w/ no visible blow)
m Missed blow(s)? (breaks resp. sequence)

Submergence

s Slip under (terminates rest bout)
a Peduncle arch (arching w/out lifting flukes)
d Fluke down dive (arch & lifting flukes < 45 deg)
u Fluke up dive (arch & lifting flukes > 45 deg)
sq Unidentified submergence > 60 sec

Non-respiratory markers

nr Missed non-resp beh(s)? (breaks sequence)
ub Unidentified behavior

Subsurface exhalations

bc Bubble cloud (single burst of bubbles)
bt Linear bubble trail (stream of bubbles)

Body contact

sb Strike with body part
wc Whale body contact (non-strike)

Head and leaping behaviors

hr Head rise (Spyhop)
hl Head lunge (forward thrust < 45 deg with splash)
mb Motorboating (sustained head lunge)
hs Head slap (forward thrust > 45 deg & slap)
br Breach (non-forward leap)
us Unidentified large splash
oh Other head behavior

Tail behaviors

te Tail extension (holds in air > 3 sec)
ts Tail slap (slapping water surface with tail)
ls Lateral tail slap (peduncle slap)
sw Tail swish (side-to-side motion)
lt Lateral tail display (no need to call with ps)
ot Other tail behavior

Pectoral fin behaviors

pe Pec extension (1 or both fins > 3 sec)
ps Pec slap (form unspecified)
rp Rolling pec slap (rotating rostro-caudal axis)
op Other pec behavior

POD BEHAVIORAL STATES

All commands take one argument, a pod id.

1 Resting (rest)
2 Feeding (feed)
3 Milling (mill)
4 Travelling (trav)
5 Surface active (sact)
6 Unknown (unkn)

POD BEHAVIORAL STATE MODIFIERS

Modifier commands take no arguments.

sync Behaviors synchronous
asyn Behaviors asynchronous

Theodolite Fixes

State arguments are behavioral state numbers: see above.

z	Read theodolite
p (id/state)	Pod
v (id/state)	Vessel
hp (id/state	Harbor Porpoise
mw (id/state)	Minke Whales
kw (id/state)	Killer Whales
r (id/state)	Azimuth reference
o (id/state)	Other (note object type in comment or use fx)
fx (type/id/state)	Fix with object type specified
bf (observer /azimuth/type/id/state)	Binocular fix
st (observer/type/id/state)	Naked eye sighting

POD EVENTS

All commands take one argument, a pod id.

pd Pod decreases speed
pi Pod increases speed
px Pod stops
p45 Pod changes direction 45 to 90 degrees
p90 Pod changes direction 90 to 180 degrees
p 80 Pod changes direction 180 degrees

VESSEL EVENTS

All commands take one argument, a vessel id.

vs Vessel starts
vc Vessel changes speed
vx Vessel stops

Western Stock Gray Whales: Behavioral State Definitions

Code	Name	Abbrev.	Definition
1	REST	rest	indicated when a whale(s) lies horizontal and motionless near the surface in the same location for 5 sec or more.
2	MILLING	mill	swimming with no obvious orientation (non-directional) characterized by asynchronous headings, circling, changes in speed, and no surface activity.
3	TRAVELING	trav	swimming with an obvious orientation (directional), no surface activity.
4	FEEDING	feed	swimming in varied directions often in a localized region and characterized by lateral tail displays or lateral rolls, with occassional mud or sand expelled from whales mouth.
5	STATIONARY	stat	little or no forward movement (<1 km/hr) between surfacing sequences, staying in the same general location.
6	SURFACE ACTIVE	sact	aerial behavior that creates a conspicuous splash (include all head, tail, pec fin, and leaping behavior).
7	UNKNOWN	unkn	behavioral state undetermined/unknown.

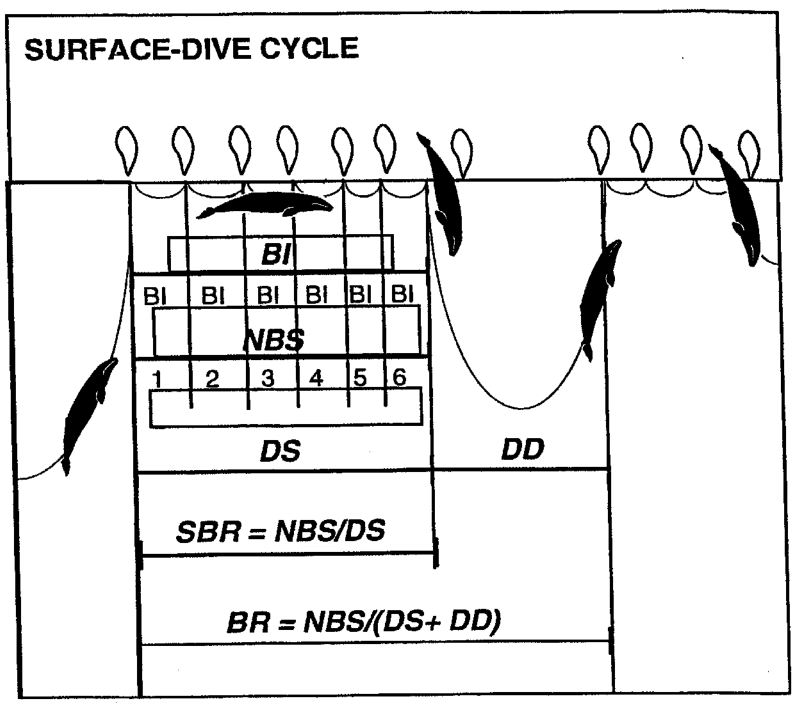
***Note:** record approx. speed and compass direction when possible.
0 = not moving forward
1 = slow (no wake, 1-2 km/hr)
2 = medium (small wake, 3-5 km/hr)
3 = fast (large wake, > 6 km/hr)

Events are instantaneous, while states have appreciable duration (Altmann 1974).

Western Stock Gray Whales: Respiration Variables

Surface-dive cycles were used as primary means of quantifying differences in behavioral states. The following six variables of respiration were measured:

1. **Blow Interval** ***(BI)*** **:** time interval of 60 sec or less between exhalations at (or near) the surface.
2. **Number of Blows per Surface Duration** ***(NBS)*** **:** number of exhalations during a surface period.
3. **Duration at Surface*(DS)*** **:** period of time spent at (or near) the surface between successive dives. Surface duration was terminated by a submergence with blow interval exceeding 60 seconds.
4. **Duration of Dive** ***(DD)*** **:** period of time during a dive to first surfacing. First exhalation exceeding 60 sec in length marked the beginning of a surface duration.
5. **Surface Blow Rate** ***(SBR)*** **:** total number of exhalations divided by surface duration from each complete surface-dive cycles.
6. **Surface-Dive Blow Rate** ***(SDBR)*** **:** total number of exhalations divided by surface duration and dive duration from each complete surface-dive cycles.



Western Stock Gray Whales: Focal Observation Protocol

Pod Type Priorities

1) Mom/calf (MC)
2) Mom/calf/escort (MCE)
3) 1 adult
4) 2 adults
5) 3 adults
6) more than 3 adults

Pods within a reliable viewing distance (generally < 5 km using 7X - 10X binoculars) of the shore station will be selected as focal pods. Collection of accurate behavioral data, particularly surface-dive blow rate (or blow rate) which is regarded as an important index of disturbance, should dictate selection and duration of focal sessions.

WHEN TO INITIATE SESSION

Focal sessions should be initiated after assessing the pods within view of the shore station unless an "ideal" situation is immediately discovered at the discretion of the behavioral observer (e.g., a mother/calf pod entering the study area).

Prior to recording any behaviors on a focal pod, the following information should be entered in the computer:

- **sfs (start focal session)**
  session pod or speed vis beaufort swell vessels aircraftDist playback

- **env (environment)**
  give the vis/beaufort/swell conditions near the focal pod, not for the entire arena

- Prior to the session (if known) or as soon as possible after the focal session has begun and the information is known, enter:

  - **cnf (observer confidence)**
    Indicates confidence rating of focal session; should be given after every surfacing of the focal pod.

- The following should be entered during the session, if applicable:

  - **env (environment)** - only need to enter if conditions near the focal pod change from initial conditions
  - **paf (pod affiliation)**
  - **pds (pod disaffiliation)**
  - **sync (synchronous)** - default (only need to call if asyn called previously)
  - **asyn (asynchronous)** - indicate how many whales are at the surface

- Before terminating a session, enter the following:

  - final **env** (even if it has not changed since last entered)
  - final **cnf**

  (In addition, make sure that theodolite operator fixes all vessels.)

Focal Observation Protocol (Continued)

WHEN TO TERMINATE SESSION

• If the pod is lost - i.e., whales pass beyond a reliable viewing distance (approximately 5 km), are lost from view (e.g., obstructed by land, not sighted for > 40 min), conditions are such that behaviors and/or respirations can no longer be observed reliably (e.g., poor visibility or Beaufort number > 5), ID confusion with other pods, or an affiliation/disafiliation occurs.

MISCELLANEOUS FOCAL SESSION INFORMATION

• Binoculars will be used to track whale behaviors; the power of the binoculars used will depend on sighting distance, observer preference, and utility/applicability. Binoculars of different power may be switched within a session.

• A pod is defined as one whale or more swimming together within 5 body lengths of each other and exhibiting synchrony in behaviors such as respiration, surfacing, and diving (Baker et al. 1983; Würsig et al. 1984). It is generally not possible to consistently distinguish individual whales within pods from shore with the exception of single whales and calves.

• Focal pod behaviors will be classified according to a behavior ethogram. Specific behavior events and states and associated information will be dictated by the primary behavioral observer and entered into the lap-top computer by the computer operator as alpha/numeric codes. The note-taker will manually record any notes which may be necessary to describe events or highlight changes to be applied to the data during the subsequent editing phase.

• When a pod composition changes (i.e., a whale(s) joins or leaves a pod), the pod will be given a new identification number and will be treated as a new pod. If focal observations continue on the "new" pod, a PAF or PDS code will be entered to flag when the affiliation/disaffiliation occurred, followed by a blank SFS in the computer. The notetaker will write down the SFS information, which will be filled into the computer during the editing phase at the end of the day.

VESSEL AND AIRCRAFT OBSERVATIONS

• All small vessels (< 75 feet) are tracked out to 10 km by the theodolite operator when possible.
• All large vessels (> 75 ft) are tracked by the theodolite operator as long as they remain in view.
• Theodolite operator is responsible for calling CPAs of vessels and aircraft during focal sessions (see theodolite protocol).
  • CPAs and associated info on vessels are called when < 1 km from focal pod
  • CPAs and associated info on aircraft are called when < 2000 ft altitude and < 1 km horizontal distance from focal pods

Western Stock Gray Whales: Behavioral Observer Confidence Ratings

BEHAVIORAL OBSERVATION CONFIDENCE RATINGS

CODE	DEFINITION
1	Excellent respiration (blows and no-blow rises) and behavioral data (confident that you are missing none).
2	Excellent respiration data (reliable for calculating respiration rates) and "soft" behavioral data (confident you are seeing blows and no-blow rises, but you may be missing some behaviors (<10%), usually due to distance or environmental conditions).
3	Okay respirations (you think you're getting most blows and no-blow rises) but shaky behavior (you feel you are unable to discern some (<25%) behaviors, generally due to distance or conditions).
4	Shaky respirations (the data will probably be useful only for surface and dive times) and only very obvious/conspicuous behaviors visible.
5	Theodolite tracking only due to inability to discern blows and behaviors usually due to distance or conditions.
6	Shaky blow data, good behavior data. Usually occurs in poor lighting conditions with pods that are close enough for most or all behaviors to be visible (including no blow rises), but blows are not seen reliably.

Western Stock Gray Whales: Theodolite Protocol

Theodolite Fixing Priorities:

1) Focal Pods
2) Vessels <1 km from focal pod
3) Non-focal pods and other marine mammals
4) Other Vessels (prioritized by):
    a) proximity to focal pod (particularly up to 4 km from focal pod)
    b) large vessels (particularly if < 5 km from focal pod)
    c) proximity to non-focal pods or other marine mammals

Theodolite Operation

General set-up

1) Horizontal readings should increase left to right (there should be a right-pointing arrow displayed)
2) Vertical readings should read 090° at horizon and increase below the horizon
3) The bottom number displayed when first turning on theodolite tells you how much battery life (hours) is left: battery symbol = *CHANGE BATTERY*, bat 0 = <0.5 hrs, bat 1 = 1.5-10 hrs, bat 2 = 10-15 hrs, bat 3 = >15 hrs
4) *ALWAYS* carry the theodolite with 2 hands, supporting the bottom
5) *NEVER* change alignment screws, etc.
6) Do not lean on or bump the theodolite, as it is easily knocked out of balance. After balancing the theodolite initially, only rebalance when it gives you an error message, or if it is out of balance after a focal session
7) Measure the theodolite height above (at eyepiece) ground every day (round to nearest 0.5 in)

Balancing the Theodolite

1) Center (approximately) the theodolite leg plate over the station ground-marker
2) Firmly set theodolite legs into the ground by putting your weight onto each leg step with one foot; set the legs in the same spot every day and label the legs accordingly. Set-up the legs so that the area where the theo operator stands most often is between 2 theo legs to allow maneuverability.
3) By eye, level the leg plate using the horizon line (or use a carpenter's level)
4) Screw the theodolite onto the tripod
5) Turn the theodolite on to check the battery level, then turn it off while balancing. If it reads "bat 0" or "bat 1", change the batteries before balancing
6) Attach the Powerbook computer lead to the theodolite prior to balancing
7) Balance the little circular bubble by adjusting the legs (if bubble > 1/2 out) or by using the leveling screws

Western Stock Gray Whales: Theodolite Protocol (Continued)

8) Align the eyepiece between 2 legs. Use the 2 leveling screws over the 2 legs to balance the front oval bubble between the 2 darkest hash marks

9) Balance the 2nd oval bubble (90° to the right of 1st bubble) with the 3rd leg's leveling screws

10) Turn the eyepiece 180° and repeat the oval bubble balancing procedure if necessary (in reverse)

11) Rotate the theodolite all the way around--it should now be leveled on 4 planes. If you have lots of trouble balancing the bubbles, the theo may be out of alignment. Check with Dave - he may be able to realign it

12) Rotate the eyepiece vertically until you hear a beep = vertical reading is leveled relative to gravity

"Zeroing" the Theodolite

1) Rotate theo horizontally until the desired "zero-reference" angle is found

2) "Lock" this angle reading so that when you turn the theo, the angle doesn't change (lock/unlock symbol on theo = SHFT + illuminate key)

3) Align the crosshairs with the "zero-reference" landmark (R1 = white marker) and "unlock" the horizontal reading

4) Take a fix of the zero-reference landmark at the beginning & end of each day. Take a fix of the zero-reference marker whenever you rebalance and rezero the theodolite

Checking Theodolite Balance and Level:

- Check the 2 oval leveling bubbles (perpendicular to each other) at the end of every focal session by rotating theo into 4 quadrant planes(e.g., turn 90° x 4). Rebalance theo if the bubbles are more than one hash-mark off center in any one plane

- Rebalance the theodolite whenever "E 115" or "E 117" is displayed on the theo measurement panel. These codes indicate that the theodolite cannot compensate for being unbalanced (i.e., the theo is > or < 3 minutes out of balance)

- If the theodolite needs to be rebalanced: 1) Take a zero reference fix (unless E 115 or E 117 is displayed, in which case you cannot take any fixes); 2) Rebalance theodolite and tell computer operator (RBT); 3) Reset zero reference angle and take a fix

Fixing pods and other marine mammals (out to 5 km if feasible)

- Always fix on waterline/whale intersection; try to fix at front of *leading* animal in pod when possible

- Focal pods: fix at least once per surface duration and every 60 seconds, and when changes in travel headings or speeds occur

- Non-focal pods and other marine mammals: Fix once per surface duration or every 3 minutes if staying at surface, and whenever a change in heading or speed occurs

- Fluke-print fixes: lag fix from when animal was last seen in water slick. It is not necessary to say that a fluke-print fix was taken in the notes

Western Stock Gray Whales: Theodolite Protocol (Continued)

Fixing vessels (out to 5 km for vessels <75' long, near horizon for large (>75') vessels)

- Fix all vessels (stationary or traveling) at least 3x times if they make no major changes in heading (approx. 45°) or speed (> approx 10 km/h), including (1) as they enter into view, and (2) as they pass out of view. If theodolite person is not busy, fix vessels more frequently but try not to compromise pod fixes for vessel fixes. If possible, fix vessels whenever a major change in heading or speed occurs. Don't worry about fixing vessels at the far edges of the arena
- Fix all vessels at beginning and end of each focal session (efs = end of focal session and should be called after this is done)
- Call vx/vs/vc codes on all vessels, particularly those near the focal pod. Remember to call changes in vessel type for vessels that start/stop their engines. If you are unsure whether or not the engines are still running, be conservative and assume that they are. Take a fix of the vessel as soon as possible after calling vx/vs/vc codes.
- Always record whether a vessel is actively following whales (pod ID #__). This should be entered as a comment in the notes.
- Vessels that pass out of view but return again later should be given a new ID # (so the theodolite analysis program doesn't connect all of the points). However, make a comment that it is the same vessel sighted earlier (e.g., V5=V1).

The theo operator is responsible for calling the closest point of approach (CPA) for all vessels <1 km from the focal pod and on aircraft <2000 ft vertically and <1 km horizontally from the focal pod.

The procedure is as follows:

(1) Vessel fix (i.e. call "Vessel 3 fix", etc.)

(2) CPA ("cpav", "cpaa", or "cpah" - followed by the vessel or aircraft ID#)

(3) Focal pod fix if possible (Should call "Pod 1 fix", etc.)

(4) For aircraft CPA's, tell the notetaker what the estimated altitude & horizontal distance to the focal pod was at the time of the CPA, the orientation (deg. mag.) of the aircraft, and the aircraft flight behavior (e.g., linear pass, c circling, up/down or zig-zag/erratic). Incidences of aircraft harassing pods should be described in detail. Large aircraft passes < 1 km horizontal and < 5000 ft altitude from focal pods should be noted/described (they will be rare events)

- CPA's should also be called on vessels > 75 ft long (Vessel Type 3) passing < 5 km from a focal pod as feasible (their sounds travel farther)

VESSEL DESCRIPTIONS

Describe when first sighted. Descriptions should be refined as boat comes into better view.

- Vessel type (see list of Vessel Types)
- Length (ft)
- Engine size/type (single, twin, outboard, inboard/outboard, inboard, # Horsepower)
- Name and/or registration #, if possible
- General description
- Unique identifying features (color, stripes, canopy...)

Western Stock Gray Whales: Notetaker Protocol

Notetaker Responsibilities:

1) Ensuring that all information is collected, including prompting theodolite & behavioral observer [e.g., for **pod comp (this information if very important--check for confirmation of pod compositions of minimum (+) pods frequently)**, vessel descriptions, etc.]

2) Recording all notes/comments on the Field Notes form

3) Summarizing all pods on the Pod Summary form

4) Operating the VHF radio

Upon Arrival At Station:

Fill-out information on top of Field Notes page and Pod Summary form: station name, date, page #, theo height (inches), crew & positions (use 3 initials), watch synchronized? (denoted by check (√), effort start & end time (= start and end time in Aardvark file).

Pods

A description of each pod should be done when first fixed by the theodolite operator. This information should then be transcribed from the Field Notes form to the Pod Summary form. Each pod description should include:

1) ID # (e.g., P2)

2) PC = pod comp = # whales: A = adults, M = mom, C = calf, E = escort, and + indicates a minimum pod size. (e.g., MCE=mom/calf, escort, 1A=1 adult, 1A+=at least 1 adult, MC+=at least a mom/calf.) Notetaker is responsible for ensuring that pod size is confirmed on "minimum" pods by prompting theodolite or behavioral observer for this information.

3) Line # or time = line # or time in Aardvark when pod was first fixed with theodolite (optional)

4) Initial description = behavior state, orientation (deg. mag.) (optional), speed (optional)

5) If the pod becomes a focal pod, be sure to indicate it as a focal pod on the Pod Summary Form.

Vessels

1) A description of each vessel should be made when first fixed with the theodolite. The description should include:

   (a) length (ft)
   (b) engine size/type (e.g., single, twin, inboard, outboard, inboard/outboard)
   (c) name and/or registration #, if possible
   (d) general description
   (e) unique identifying features (color, stripes, canopy, sails)
   (f) vessel type (see list of Vessel Types)

2) The theodolite person should call closest point of approach) between focal pods & vessels if ≤ 1 km [preceded by a theodolite fix of the vessel (and a focal pod fix if possible)]. The notetaker should make an entry in the notes with the time of the CPA and the vessel ID. Put an asterisk (*) in the margin to the left of the CPA entry.

Western Stock Gray Whales: Notetaker Protocol (Continued)

Aircraft (Airplanes & Helicopters)

1) CPA (Closest Point of Approach) will be called by theodolite operator for all aircraft passing < 2000 ft vertical & < 1 km horizontal from focal pods. An entry in the notes should indicate the time of the CPA, the aircraft ID#, the estimated altitude & distance from the aircraft to the focal pod at the time of the CPA, the orientation of the aircraft, and a description of the type of aircraft (for airplanes, record how many engines, if known). In addition, put an asterisk (*) in the margin to the left of the CPA entry.

2) Describe *any* aircraft harassment of any marine mammals.

Notes/Comments

Notes indicate:

- Changes/corrections to be made when editing data
- Describe situations/events that cannot be adequately described by computer
- Describe pods and vessels when they are first fixed with the theodolite
- Start and end of focal sessions (sfs, efs) & reason focal session ended (e.g., affiliation/disaffiliation, distance, visibility/Beaufort, lost from view, disappeared, etc.)
- If disaffiliation/affiliation occurs, note which pod ID# affiliates/disaffiliates and the new pod #'s. Note the new pod compositions, behavior states, etc. as with any first fix of a "new" pod. Ask the behavioral observer when the paf/pds occurred so that there is no confusion later over where the code should be inserted in the data stream.
- "Official" comments (i.e., those entered in Aardvark) 1) describe a change to be made to the data in the editing process, or 2) contain text to be added to the data stream
- Remember, Aardvark codes can't describe everything. Notes help clarify confusing situations, changes, etc. It's better to have more than not enough. But try to limit the # of "official" comments.

Western Stock Gray Whales: Visibility & Sea State Codes

VISIBILITY:

CODE	NAME	DEFINITION
1	EXCELLENT	Surface water calm (Beaufort 0-1) with no sun glare or other environmental factors impeding ability to sight whales. Visibility > 5 km
2	VERY GOOD	May be slightly uneven lighting or light chop (Beaufort 0-2) but still relatively easy to sight whales. Visibility > 5 km
3	GOOD	Light chop with scattered whitecaps (Beaufort 0-3), swell (2-4 m) or some sun glare or other impediment (e.g., haze) in ≤10% of the study area. Whales can still be detected fairly easily.
4	FAIR	Choppy waves with fairly frequent whitecaps, low-light conditions (e.g., heavy overcast, dawn, dusk), swell 4-6 m or sun glare in ≤50% of study area. Some animals in study area likely to be missed
5	POOR	Numerous whitecaps (Beaufort 5), sun glare or haze in >50% of the study area, or swell > 6 m, impeding ability to sight whales. Many (>50% ?) animals in study area are likely to be missed
6	UNACCEPTABLE	Beaufort ≥6, or glare, haze, or other visibility impediment in >75% of study area. Detection of whales unlikely unless the observer is looking directly at the place where the animals surface. Time to go home!

SEA STATE (BEAUFORT WIND SCALE):

CODE	DESCRIPTION (*abbreviated*)	WIND SPEED (kts)		WAVE (m)
0	Smooth and mirror-like	Calm	(0-1)	--
1	Light ripple	Light air	(1-3)	0.3
2	Small wavelets, not breaking	Light Breeze	(4-6)	0.6
3	Scattered whitecaps	Gentle Breeze	(7-10)	1.2
4	Small waves, frequent whitecaps	Mod. breeze	(11-16)	1.8
5	Moderate waves, many whitecaps	Fresh breeze	(17-21)	2.0
6	All whitecaps, some spray	Strong breeze	(22-27)	3.0
7	Breaking waves, spindrift begins	Near gale	(28-33)	4.3
8	Medium high waves, foamy	Gale	(34-40)	5.5

SWELL HEIGHT

Estimated in meters

Western Stock Gray Whales: Vessel Type Definition

TYPE	DESCRIPTION
0	unpowered
1	outboard, < 30 ft.
2	inboard or inboard/outboard, ≥ 25 ft.
3	> 75 ft.

- The primary factor determining vessel description is engine type. The secondary factor is vessel length. If in doubt about the vessel type, base it on the engine type.

- Vessel type may change if a sailboat changes from sail power to engine power (or vice versa). If you can determine that a sailboat has changed its power source, then enter a new vessel type in the computer. If you cannot determine the power source (e.g., sail is up but you cannot tell if engines are also running) be conservative and classify it as powered (i.e., type 1 or 2).