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U.S. DEPARTMENT OF COMMERCE
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by
B. K. Rone[1], A. B. Douglas[2], A. N. Zerbini[1,2], L. Morse[1],
A. Martinez[3], P. J. Clapham[1], and J. Calambokidis[2]

[1]Alaska Fisheries Science Center
7600 Sand Point Way N.E.
Seattle, WA 98115
www.afsc.noaa.gov

[2]Cascadia Research Collective
218 ½ W Fourth Ave.
Olympia, WA 98501

[3]Southeast Fisheries Science Center
75 Virginia Beach Drive
Miami, FL 33149

U.S. DEPARTMENT OF COMMERCE
Gary F. Locke, Secretary
National Oceanic and Atmospheric Administration
Jane Lubchenco, Under Secretary and Administrator
National Marine Fisheries Service
Eric C. Schwaab, Assistant Administrator for Fisheries

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ABSTRACT

Little is known about the present-day occurrence of cetaceans found in offshore waters in the Gulf of Alaska; however, whaling records and a few recent surveys have shown this area to be important habitat. The U.S. Navy maintains a maritime training area in the central Gulf of Alaska, east of Kodiak Island, and has requested additional information on marine mammal presence and use of this area. To describe the occurrence and distribution of marine mammals in and around the U.S. Navy training area, a line transect visual and acoustic survey was conducted 10-20 April 2009 from the NOAA ship *Oscar Dyson*. The primary survey area encompassed nearshore and offshore pelagic waters of the central Gulf of Alaska. Survey lines were designed to provide equal coverage of the nearshore and offshore habitat.

During this project, the visual survey covered a total of 760 km (410 nautical miles, nmi) on-effort (visible horizon, Beaufort sea state 5 or less, and survey speed of 10 knots through the water) while transit (visible horizon, Beaufort sea state 5 or less, and survey speed of 12 knots) and fog effort (no horizon, Beaufort sea state 5 or less) legs accounted for 553 km (298 nmi). There were a total of 96 sightings (453 individuals) of 11 confirmed marine mammal species; these included fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), gray (*Eschrichtius robustus*), minke (*B. acutorostrata*) whales, and killer whales (*Orcinus orca*), Dall's (*Phocoenoides dalli*) and harbor (*Phocoena phocoena*) porpoise, Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), Steller sea lions (*Eumetopias jubatus*), harbor seals (*Phoca vitulina*), and sea otters (*Enhydra lutris*). Additionally, there were 36 sightings (46 individuals) of unidentified large whales, dolphins, and pinnipeds. Passive acoustic operations were conducted 24 hours/day surveying a total of 3,519 km (1,900 nmi) and recorded 49 acoustic

detections of sperm whales (*Physeter macrocephalus*) and killer whales. Photographs of 19 individual killer whales and 4 fin whales were obtained on this cruise and compared to existing photo-identification catalogs.

Density and abundance estimates were calculated for fin and humpback whales by stratum using line transect methods with and without covariates in detection probability models. Additional sightings from a previous cruise on a comparable vessel were used for improving estimation of detection probability. All results were fairly similar given the constraints of the sample sizes involved. Estimates of abundance in the inshore and offshore strata were 594 (CV = 0.29) and 889 (CV = 0.57) for fin whales, and 219 (CV = 0.57) and 56 (CV = 0.57) for humpback whales, respectively. A small proportion of large whales were not identified to species but were probable fin or humpback whales based on observations, and estimates of these unidentified whales were assigned to these species based on the proportion of fin and humpback whales identified in each stratum. This raised fin whale estimates of abundance to 666 (CV = 0.3) and 938 (CV = 0.57) and humpback whale estimates to 265 (CV = 0.48) and 63 (CV = 0.51, inshore and offshore strata, respectively).

Despite a number of logistical and time limitations, the survey provided new information on the occurrence and abundance of marine mammals in the region. Sighting sample sizes were adequate to provide density and abundance estimates for fin and humpback whales. Identification photographs obtained on this cruise also verify the seasonal presence of individual fin and killer whales in a study area that is rarely surveyed.

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INTRODUCTION

The U. S. Navy uses a maritime training area (144,560 km^2) in the Gulf of Alaska located south of Prince William Sound and east of Kodiak Island. The training area encompasses various marine habitats, both shelf and pelagic, that support most species of marine mammals found in the Gulf of Alaska. Twenty-six species of marine mammals are known to reside in or seasonally frequent the Gulf of Alaska. Although marine mammals are present year-round in the Gulf of Alaska, the greatest number of animals occurs during the spring and summer. Three of the whale species present in the Gulf of Alaska, humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*) and right *(Eubalaena japonica)* whales, feed in the outer continental shelf and slope waters during the summer into early fall, while blue (*B. musculus*), sei (*B. borealis*), and sperm (*Physeter macrocephalus*) whale species are thought to be more pelagic (Berzin and Rovnin 1966, Rice 1974). Gray whales (*Eschrichtius robustus*) are thought to migrate along the shore of the Gulf of Alaska (Rice and Wolman 1982) as well as maintain a summer-long presence off Kodiak Island (Moore et al. 2007). From sea otters (*Enhydra lutris*) to blue whales, some species of marine mammals found in the Gulf of Alaska were aggressively hunted from land and/or vessel until the passage of the Marine Mammal Protection Act of 1972 and the U.S. Endangered Species Act of 1973 (Rice and Wolman 1982, Scheffer 1972). In 1980, a survey conducted and described by Rice and Wolman (1982) determined that the populations of all great whales in the Gulf of Alaska had been severely depleted. Since that time some of these species have shown signs of recovery; however, only the eastern North Pacific gray whale has experienced a seemingly complete population recovery (Rugh et al. 2005). Historically, distribution of cetaceans in the Gulf of Alaska has been based on commercial catch records (Nishiwaki 1966, Townsend 1935) and whaling-related scouting vessel data (Berzin and Rovnin 1966, Wada 1979). For pinnipeds and sea otter, species that are found seasonally close to shore, current abundance and distribution estimates are available (Angliss and Allen 2009); however, for most cetacean species in the Gulf of Alaska, marine mammal survey effort has not generated sufficient sighting data to create abundance estimates. Absence/presence data is available from the 2004 Southwest Fisheries Science Center vessel-based marine mammal survey for humpback whales that crossed through the U.S. Navy's Gulf of Alaska training area (Barlow and Henry 2005). In addition, bottom-mounted hydrophones in the offshore Gulf of Alaska have been used to record calls from blue, humpback and fin whales throughout the year (Stafford et al. 2007).

Despite the challenges of studying marine mammals in the Gulf of Alaska, information on these populations is necessary for management, particularly for populations that inhabit pelagic waters where minimal survey effort has occurred. To determine marine mammal distribution and abundance in the Gulf of Alaska training area, the U.S. Navy provided funds for a vessel-based line transect survey in the Gulf of Alaska during April 2009.

The Gulf of Alaska Line Transect Survey (GOALS) had three main objectives: (1) to visually assess the distribution and occurrence of marine mammals in the Gulf of Alaska with specific focus on the U.S. Navy maritime exercise area, (2) to conduct 24-hour acoustic operations to record the presence of marine mammals in the U.S. Navy training area in coordination with and in addition to visual operations, and (3) to document individual animals through photo-identification and biopsy sampling.

METHODS

Survey Design and Visual Survey Methods

The survey was conducted from 10 to 20 April 2009 aboard the NOAA ship *Oscar Dyson,* a 63 m fisheries research vessel. Two strata, inshore and offshore, were proposed and tracklines were designed to provide a uniform spatial coverage of the study area (Table 1, Fig. 1). The inshore stratum encompassed the continental shelf/slope region of the training area and the offshore stratum contained the pelagic zone. This proposed design allowed for the computation of abundance estimates.

Rotating teams of three scientists collected sighting data using standard line transect methods during on-effort status. Operations began at 07:20 and ceased at 20:00, or as long as conditions would allow. A full observation period lasted 2 hours (40 minutes in each position) and was followed by a 2 hour rest period. All three observers (starboard and port observers and data recorder) were stationed on the ship's flying bridge. Starboard and port observers used 25× 'big-eye' binoculars with reticles to scan from 10° on the opposite side to 90° abeam. The data recorder surveyed the trackline with 7 × 50 binoculars while scanning through the viewing areas of the two primary observers. In addition, an independent observer positioned on the flying bridge scanned for animals using 7 × 50 binoculars and recorded marine mammal sightings in a notebook, silently providing the information to the recorder if it was not detected by the primary observers. When a sighting was made, the primary observer conveyed to the recorder the horizontal angle and number of reticles from the horizon to the initial sighting. Additional information collected was sighting cue, course and speed, species identity, and best, low, and high estimates of group size. The computer program WINCRUZ (available at http://swfsc.nmfs.noaa.gov/PRD/softwares/software.html) was used to record all sighting and environmental data (e.g., cloud cover, wind speed and direction, and sea conditions).

On-effort status was defined as a visible horizon, Beaufort sea state 5 or lower, and survey speed of 10 knots through the water. Lines connecting the end/start points of designated tracklines as well as lines to and from the survey area were classified as 'transit lines' and were surveyed using on-effort protocols whenever possible; however, typically they were conducted at a speed of 12 knots. Fog effort corresponded to observations conducted under poor visibility (no horizon) but with a Beaufort sea state 5 or less and was conducted on both designated tracklines and transit lines. Under unacceptable weather conditions (visibility $\leq$ 0.5 nautical miles (nmi) and/or sea state $\geq$ 6), off-effort watches on the bridge were conducted. Two observers were positioned on the bridge to record off-effort sightings and environmental data. At the cruise leader's discretion, line transect survey effort was temporarily suspended to allow closer approaches to sightings for photo-identification. Although a biopsy sampling plan was established, no sampling occurred due to the limited survey time and opportunities. Given the limited time to cover the tracklines and because acoustic operations could be conducted despite weather conditions, the ship continued along the transect lines and visual operations were conducted when possible.

Ship-based Passive Acoustics

Passive acoustic operations were conducted continuously throughout the survey area. During periods of favorable daytime conditions, the passive acoustic survey was conducted in concert with the visual survey effort. The towed acoustic array was used to collect high quality examples of vocalizations and to determine the presence of acoustically active cetaceans at times when no visual survey effort was possible due to high sea states or darkness.

Passive acoustic data were monitored using a two-element towed hydrophone array. This towed array was a 400 m long, Kevlar reinforced, multi-conductor armored cable assembly with an oil-filled tow section at the end of the cable. The array could be towed at any speed up to 12 knots. For this survey, the array was deployed 200 m astern of the vessel. The tow section contained two Teledyne Benthos AQ-4 high-gain hydrophones with a designed frequency response of 10 Hz to 15 kHz. These hydrophones, along with their associated signal conditioning and line drive electronics, were separated by 3 m within the oil-filled tow section.

The analog acoustic signal was passed into the acoustics lab for filtering, amplification, recording and monitoring. These acoustic signals were continuously monitored in real-time by an acoustics operator. The analog signal was digitized via a National Instruments DAQCard-6062E at a sample rate of 96 kHz. Continuous recordings were copied to hard disk in real time as .WAV files 10 minute in duration. The software package *Ishmael,* a program designed to analyze acoustic data sets (Mellinger 2001), was used to monitor signals and make high bandwidth recordings. The relative bearing of manually selected signals of interest could be calculated by *Ishmael* utilizing the difference in the time of arrival of a signal at each hydrophone. These relative bearings could then be sent to a second computer for display. This computer was connected to a GPS receiver and loaded with the *WhalTrak2* software package (created by Glen Gailey at Texas A&M University). *WhalTrak2* displayed the ship's current position and track in a graphic display window, overlaying lines of bearings as instructed by the operators. This provided the acoustics team with a picture of how acoustic detections related to visual sightings of cetaceans and other possible sources of sound, such as ship traffic. *WhalTrak2* was also programmed to record ship position, effort, weather, and general comments to a Microsoft Access data file.

Due to flow noise, we expected to lose an approximate range of 0-1,000 Hz, resulting in the loss of low frequency calls (i.e., baleen whales). A cursory review of acoustic recordings for low frequency baleen whales was conducted at the start of the cruise, particularly when fin whales were sighted, and confirmed the absence of these calls. As a result, real-time monitoring on *Ishmael* occurred only for upper frequency, audible calls.

Photo-identification

Identification photographs of target species were obtained to allow evaluation of movements of animals during the survey and comparison to existing catalogs. Highest priority species for photo-identification on the Gulf of Alaska survey were North Pacific right, blue, and fin whales. Other high priority species were humpback, killer, sperm, minke (*Balaenoptera acutorostrata*), Baird's beaked whale (*Berardius bairdii*) and Stejneger's beaked whale (*Mesoplodon stejnegeri*). When the observers located a target species, the visual survey effort was suspended and the primary survey vessel was directed to obtain photographs of the animals. The vessel was positioned for the best lighting and angle so that photographs could be obtained of the dorsal fin as well as the chevron on fin whales, flukes of humpback whales and saddle patches of killer whales. Photographs were taken using Nikon D-200 and Canon 20D autofocus digital cameras equipped with a 70-300 mm or a 100-400 mm zoom lens. All photographs were reviewed, and the highest quality identification photograph(s) of each animal were selected to be compared to existing photo-identification catalogs from the northeastern Pacific and the Gulf of Alaska.

Line Transect Analysis of Large Whale Data

Line transect analysis (Buckland et al. 2001, 2004) was conducted to estimate density and abundance of fin, humpback, and unidentified large whales only. Detection functions were fit using data from all three species categories. Line transect analysis combined effort conducted under appropriate survey conditions in on-effort, on-transect, and transit lines with good visibility and sea conditions. Sighting data collected during transect and transit lines were used to estimate detection probability, but only data from transect lines were used in estimation of density and abundance. We also evaluated whether acoustic detections of sperm whales could be used to estimate a line transect density, but this did not appear possible because many acoustic detections could not be localized.

Initially, estimation of detection probability was conducted using only sighting data from GOALS 2009. Due to the relatively small sample size (Table 2), perpendicular distance data were left untruncated and only two conventional distance sampling (CDS, Buckland et al. 2001) models were used for fitting a detection function: the hazard rate and the half normal.

In order to increase sample size to estimate detection probability, fin (n = 57), humpback (42), and unidentified large whale (1) sightings collected during a research cruise conducted by the National Marine Mammal Laboratory (NMML) in the Gulf of Alaska from 26 June to 15 July 2003 aboard the NOAA ship *Miller Freeman* (Fig. 2) were included in the analysis (Table 2). This cruise was carried out on a similar platform within the general area and followed similar searching methodology employed during GOALS 2009; therefore, sighting data were expected to be comparable. The addition of such sightings not only provided additional data for estimating detection probability with better precision, but also allowed the use of multiple covariate distance sampling methods (MCDS, Marques and Buckland 2003). Exploratory analysis indicated that truncation at 5 km was the most appropriate for estimation of detection probability as it provided relatively good model fits and allowed for most of the sighting data (94%, n = 138) to be used in the analysis.

Five covariates (Table 3) were proposed to estimate detection probability with MCDS methods. Only single covariate models were used in the estimation of detection probability and those that did not conform to this detection probability hypothesis were excluded from the analysis. For example, detection probability is expected to increase as group size increases; models that indicated otherwise were excluded.

Encounter rate and its variance were empirically estimated from the data (Buckland et al. 2001). For CDS models, size bias regressions were computed to investigate whether group size was influencing detection probability (Buckland et al. 2001). If the regression was significant to an $\alpha = 0.15$ level, then the size bias regression coefficients were used to estimate average group size. Otherwise, a simple mean was computed. For MCDS models, group sizes were estimated by dividing the estimated density of individuals by the estimated density of groups in the study area (Marques and Buckland 2003).

For density estimation, stratum-specific abundance estimates were calculated using the detection probability model that received most support from the data (the "best" model) according to the Akaike Information Criterion (AIC). For the purpose of this analysis, detection probability on the trackline was assumed to be (g[0] = 1). All parameter estimates were computed using the software *Distance 5.0,* release 2 (Thomas et al. 2006).

RESULTS

Visual Survey Effort and Sightings

The survey covered a total of 760 km (410 nmi) on-effort while transit and fog effort legs accounted for 553 km (298 nmi) (Table 4, Fig. 3). The offshore stratum was not surveyed in its entirety due to limited survey time resulting from delayed departure.

There were a total of 96 sightings (453 individuals) of 11 confirmed marine mammal species; these included fin, humpback, gray, and minke whales, as well as killer whales, Dall's and harbor porpoise, Pacific white-sided dolphins, Steller sea lions, harbor seals and sea otters. Additionally, there were 36 sightings (46 individuals) of unidentified large whales, dolphins, and pinnipeds (Table 5, Figs. 4-7).

Ship-based Passive Acoustics

Acoustic effort covered approximately 3,519 km (1,900 nmi) with 760 km (410 nmi) conducted during full visual effort (Fig. 8).

There were a total of 49 acoustic detections, 9 during full visual effort, and 40 during "acoustics only" effort periods (Table 6, Fig. 8). Of these detections, eight were localized to a position located equidistant right or left of the trackline. This towed array configuration and methodology did not allow for resolution of the right/left ambiguity of relative bearings without purposely altering the ship's heading during the detection period. Constraints on survey time did not allow for this resolution throughout the survey. Three detections were matched to visual sightings of killer whales.

Killer whales (16) and sperm whales (28) were the only identified species acoustically detected. The unidentified odontocetes (5) are likely killer whales but the calls were too weak or indistinct to classify with certainty. Acoustic identification was based on published call type descriptions. Due to limitations of available sound processing software, group size estimates were not possible for the killer whale detections.

As expected, low frequency baleen whale calls were not detected due to the masking effect of flow noise as the array was towed through the water.

Photo-identification

Photographs for photo-identification purposes were collected on three separate days (Table 7). There were a total of 721 photographs collected during encounters with fin whales and killer whales. See Appendix for photo-analysis results.

The four fin whale identification photographs (left sides) were compared to photographs of approximately 100 fin whales from the Gulf of Alaska (catalog maintained by Bree Whitteveen; University of Alaska Fairbanks), 79 fin whales from Southern California (catalog maintained by Cascadia Research Collective) and an additional 25 animals from the Gulf of Alaska (collected by NMML). Many photographs from existing catalogs showed only right sides. No matches were made between the fin whale photographs collected on this survey and the two collections. The 19 individual killer whales were compared to photographs from a catalog maintained by NMML that contains 1,237 western Alaska resident killer whales from the Gulf of Alaska, Aleutian Islands and Bering Sea as well as 400 transient killer whales collected from those same areas. No matches were found between individuals identified on this survey and the existing catalogs.

Line Transect Analysis of Large Whale Data

Line transect analysis was conducted using the two strata, an inshore (area = 47,411 km^2) and an offshore stratum (area = 98,253 km^2) (Fig. 1). On-effort visual survey included six lines totaling 460 km in the inshore stratum, and three full or partial lines totaling 300 km in the offshore stratum (other sections of lines were completed in either limited visibility or with acoustics only). In addition, 384 km were surveyed in transit and 169 km under foggy conditions. A total of 19 fin whale sightings were observed on-effort within the survey area. Eleven were documented in transects on the inshore stratum and seven on the offshore stratum. One sighting was recorded during transit. Eight humpback whale sightings were recorded on-effort, seven in the inshore and one in the offshore stratum. Six sightings were made of unidentified large whales, five in the inshore and one in the offshore, and these most likely represented fin or humpback whales based on the identified sightings.

GOALS 2009 Data Only

For the dataset using only the GOALS 2009 data for the detection probability, only CDS models with or without series expansions were fit to these data because of the relatively small sample size of sightings. Model 1 had the lowest AIC value. Model parameter and density estimates for this model is summarized in Tables 8 and 9, respectively.

GOALS 2009 and *Miller Freeman* 2003 Data

For the combined detection function (GOALS 2009 and *Miller Freeman* 2003 data), results from best CDS and MCDS models (those within Δ AICs = 3) are summarized in Table 10. Overall the best model (Model 3) was the half normal with Method as covariate (Table 10). The combined detection function resulted in a slightly lower (but not statistically different) calculation of effective search half-width than that using the GOALS 2009 data alone and a slightly lower CV (0.08 for Model 3 versus 0.15 for Model 1, Tables 8, 10). Estimates of density and abundance for the best model (Model 3) are shown in Table 11. Density and abundance estimates were approximately 15% higher (but not statistically different) for detection probability Model 3 when compared to estimates with Model 1. Density and abundance CVs were slightly lower due to the larger sample size used in the estimation of Model 3.

All results are fairly similar given the constraints of the sample sizes involved. Because the results of Model 3 have the lower CV and the lowest AIC scores, we recommend them as the best estimates of density and abundance. Resulting estimates are 594 (CV = 0.29) and 889 (CV = 0.57) fin whales for the inshore and offshore strata, respectively, and 219 (CV = 0.57) and 56 (CV = 0.57) humpback whales in the inshore and offshore strata, respectively.

Unidentified large whales were most likely fin or humpback whales and estimates of unidentified large whales[1] could be assigned to these species based on the proportion of fin and

[1] CVs of pooled (fin/humpback + unidentified large whales) estimates of abundance were computed assuming species-specific estimates were independent.

humpback whales identified in each stratum. This would raise fin whale estimates of abundance to 666 (CV = 0.3) and 938 (CV = 0.57) and humpback whale estimates to 265 (CV = 0.48) and 63 (CV = 0.51, inshore and offshore strata respectively).

DISCUSSION

This survey faced several challenges including limited survey time, a large survey area, and inclement weather. Despite these limitations, the survey was successful and provided an unexpectedly large number of visual sightings and acoustic detections. The visual sightings generated density and abundance for fin, humpback, and unidentified large whales. Although a density estimate may be produced for harbor and Dall's porpoise in the future, both these species are known to have reactive movement to ships that will need to be considered in the analysis. Although this survey produced the highest number of acoustic detections and localizations of sperm whales in comparison with previous surveys, there were not enough positive range and bearings to provide a density estimate at this time. Acoustic detection of baleen whales was not possible with the towed array because their lower frequency calls cannot be detected due to flow noise and sonobuoys were not available for this cruise. This did not alter our ability to estimate density and abundance since these were based on visual sighting rates.

Fin whales were the most common large cetacean sighted visually on this cruise. Fin whales are encountered seasonally off the coast of North America and in the Bering Sea. Based on data from bottom-mounted offshore hydrophone arrays, there were peaks in call rates occurring during fall and winter in the central North Pacific and the Aleutian Islands. Fewer calls were recorded during the summer months (Moore et al. 1998, Stafford et al. 2007, Watkins et al.

2000). Presence or absence of recorded calls may not reflect the actual presence or absence of fin whales since there may be a seasonal pattern to their call rates or difference in oceanographic properties. Current reliable estimates for fin whales do not exist for the entire Gulf of Alaska; however, sighting data from coastal surveys between the Kenai Peninsula and Amchitka Pass conducted July-August 2001-2003 have generated a population estimate of 1,652 (95% CI: 1,142 - 2,389) (Zerbini et al. 2006). Density estimates of fin whales vary in the Pacific Ocean off the California coast. Fin whales are observed year-round with an estimated 1.1 fin whales per 1,000 km^2 (Barlow 1995, Forney et al. 1995). In Hawaiian waters where sightings of fin whales are extremely rare, passive acoustic monitoring has been used to estimate a density of 0.081 fin whales per 1,000 km^2 (McDonald and Fox 1999).

Sperm whales are distributed widely throughout the North Pacific. Although the visual observers never sighted sperm whales, they were the most common acoustically detected species during the survey. High acoustic detections of this species and absence of visual sightings can be explained by their long dive times and loud, expansive echolocation clicks. While sperm whale females and young generally remain in the tropical and temperate waters year-round, males are thought to move north in the summers to feed in the Gulf of Alaska and Bering Sea (Kasuya and Miyashita 1988), and sperm whales have been acoustically detected year-round in the Gulf of Alaska (Mellinger et al. 2004). Although a minimum population estimate is not available for sperm whales in the Gulf of Alaska, results from data collected during visual surveys conducted by NMML during summer months between 2001 and 2006 have shown that sperm whales were the most frequently sighted large cetacean (NMML unpublished data in Angliss and Allen 2009).

Sightings of humpback whales on GOALS 2009 provide important data on spring-time distribution in the Gulf of Alaska. Humpback whales were the second most common whale encountered on the survey. Other than a single sighting in the offshore stratum, humpback whales were found exclusively within the inshore stratum and this is reflected in the higher density and abundance estimates for the inshore stratum. Our findings of higher humpback whale abundance in the inshore stratum coincides with past line transect surveys of the area that found 93% of humpback whale groups were observed in water depths between 46 and 183 m (Brueggeman et al. 1988). Humpback whales encountered during the summer along southeast Alaska and the northern Gulf of Alaska migrate primarily to the Hawaiian Islands and Mexico (Calambokidis et al. 2008). Current estimates of abundance for humpback whales based on photo-identification and line transect surveys in the western and northern Gulf of Alaska during summers 2004, 2005 and 2006 is 3,000-5,000 animals (Calambokidis et al. 2008). Because humpback whales generally spend the winter months in lower latitudes and would just be returning to their feeding grounds in early spring when the GOALS cruise occurred, our estimates represent only a portion of the summer abundance in the study area.

Gray whales were the third most common large whale sighted on the GOALS 2009 cruise and while this provides important data on spring-time distribution, it is not adequate for an abundance or density estimate. Gray whales pass through the Gulf of Alaska twice each year as they migrate to feed in the northern Bering and Chukchi seas and migrate back down to calving and breeding lagoons along Baja California (Braham 1984). In recent years, a large aggregation of gray whales has inhabited the Kodiak Island area throughout the entire summer (Moore et al. 2007). Reflecting their more inshore distribution, gray whales were only sighted in the inshore stratum.

Although small boat operations were not possible during this cruise, we were able to obtain photographic identifications of fin and killer whales from the ship (see Appendix). Photographs obtained on this cruise provide seasonal identifications of fin and killer whales in a difficult study area. Due to survey limitation, we were unable to document both sides of the fin whales. Therefore, matching to existing catalogs was limited to the one available side of the animal. However, due to the distinct dorsal fins of these four whales, there is a high probability that each animal could be matched if it existed in the catalogs. The 19 killer whales identified from two encounters on the GOALS cruise did not match the available catalog of photographs managed by NMML; however, in the months to come there may be an opportunity to compare these photographs to the catalog managed by Graeme Ellis at Canada's Pacific Biological Station, British Columbia. Research (including collection of identification photographs) on resident and transient killer whales commenced in Prince William Sound in the 1970s (Hall 1981), and is ongoing in the southeastern Bering Sea, the eastern/central Aleutian Islands region, and the western and central Gulf of Alaska (Dahlheim 1997; Ellis 1984, 1987; Leatherwood et al. 1984).

Overall the cruise provided valuable new data about the presence of marine mammals in the Gulf of Alaska during the spring in relation to the U.S. Navy training area and surrounding areas. Analyses of the visual data provided abundance and density estimates for fin and humpback whales in a region where scant data on these species exist. Although limitations on acoustic software prevented obtaining group size estimates, results provided information on the presence of killer and sperm whales in the study area, valuable information given that the latter was never sighted by the visual team.

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We would like to thank the Pacific Fleet Commander (CPF) and the Chief of Naval Operations Environmental Readiness (OPNAV N45) for supporting this cruise. Robin Brake (CAPT OASN) and Frank Stone (CIV) helped arrange for funding. The Naval Postgraduate School made contractual arrangements on short notice thanks to the efforts of Curt Collins (CIV). George Hart (CIV CNRNW, N40BA) pushed for and helped design the survey. Jeff Leonard (CTR NSWC Crane) worked on sonobuoy supplies. Commander Chief Pittman and the U.S. Coast Guard Kodiak assisted with sonobuoy receiving logistics. Thank you to the officers and crew of the NOAA ship *Oscar Dyson* and the visual and acoustic observers who participated on this cruise: Suzanne Yin, Ernesto Vázquez Morquecho, Greg Fulling, Carol Keiper, Cynthia Christman, Kelly Cunningham and Sean Suk. Thank you to Holly Fearnbach and Dave Ellifrit for conducting the killer whale photo-identification analysis. Tarry Rago provided helpful suggestions on the report. Special thanks to Catherine Berchok, Tom Norris, and Greg Falxa who advised and helped with the set-up and design of the cruise. Thank you to the Southeast Fisheries Science Center for the use of their towed array. Many thanks for the thoughtful reviews by Janice M. Waite (NMML) and Kathleen M. Stafford (Applied Physics Lab, University of Washington). Technical edits were provided by Gary Duker and James Lee of the Alaska Fisheries Science Center's Publications Unit. This survey was conducted under MMPA Scientific Research Permit No. 782-1719.

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Table 1. -- Strata and proposed effort allocation in the study area.

Stratum	Area (km^2)	Number of tracklines	Total effort (km)
Inshore	47,411	12	1,905
Offshore	98,253	10	1,944
Total		**22**	**3,849**

Table 2. -- Sample sizes for estimation of detection probability using the GOALS 2009 and *Miller Freeman* 2003 sighting data.

Species	GOALS 2009	*Miller Freeman* 2003
Fin whale	19	57
Humpback whale	9	42
Unidentified large whale	10	1
Total	**38**	**100**

Table 3. -- Covariates used in the multiple covariate distance sampling (MCDS) models using GOALS 2009 and *Miller Freeman* 2003 sighting data.

Covariate	Type	Levels
Method	Factor	Naked eye, Big eye binoculars
Ship	Factor	*Oscar Dyson* (2009), *Miller Freeman* (2003)
Group size	Factor	Group size estimate for each sighting
Beaufort scale	Factor	0, 1, 2, 3, 4, and 5
Species	Factor	Fin, humpback and unidentified large whale

Table 4. -- Completed visual effort for the GOALS 2009 research cruise.

Stratum	Effort (km)
Inshore	460
Offshore	300
Total on-effort	760
Transit	384
Fog effort	169
Total	**1,313**

Table 5. -- Marine mammal sightings (individuals) from the GOALS 2009 research cruise.

Species	On-effort	Off-effort	Total
Cetaceans			
Fin whale	20(56)	4(8)	24(64)
Humpback whale	10(19)	1(1)	11(20)
Gray whale	1(2)	2(6)	3(8)
Minke whale	2(3)	0	2(3)
Killer whale	6(119)	0	6(119)
Dall's porpoise	10(59)	0	10(59)
Harbor porpoise	30(89)	0	30(89)
Pacific white-sided dolphin	1(60)	0	1(60)
Unid large whale	22(31)	6(7)	28(38)
Unid. small whale	2(2)	0	2(2)
Unid. dolphin/porpoise	2(2)	0	2(2)
Total cetacean	106(442)	13(22)	119(464)
Pinnipeds and Otters			
Steller sea lion	6(28)	0	6(28)
Harbor seal	2(2)	0	2(2)
Sea otter	1(1)	0	1(1)
Unid. pinniped	4(4)	0	4(4)
Total pinniped	13(35)	0	13(35)
Total	**119(477)**	**13(22)**	**132(499)**

Table 6. -- Acoustic detections from the GOALS 2009 research cruise using two-element towed array.

Species	**Detections during visual effort**	**Detections during acoustic only effort**	**Total**
Killer whale	8(3*)	8	16
Sperm whale	1	27	28
Unidentified odontocete	0	5	5
Total	**9**	**40**	**49**

* Acoustic detections matched to visual sightings.

Table 7. -- Number of photo-identified individuals collected during the GOALS 2009 research cruise.

Species	**11 April 09**	**12 April 09**	**18 April 09**	**Total**
Fin whale	4	0	0	4
Killer whale	0	5	14	19
			Total	**23**

Table 8. -- Model parameter of detection probability estimation for the GOALS 2009 large whale sighting data only.

Model No.	**Model**	**No. par**	**Δ AIC**	**ESW (km)**	**ESW CV**
1	Half normal without series expansions	1	0.00	2.91	0.15
2	Hazard rate without series expansions	2	1.54	3.17	0.17

No. par – number of parameters, AIC – Akaike Information Criterion, ESW – effective search half-width, CV – coefficient of variation

Table 9. -- Estimation of density and abundance of fin, humpback, and unidentified large whales in inshore (area = 47,411 km^2) and offshore (area = 98,253 km^2) strata using the GOALS 2009 data only.

	Fin whale		**Humpback whale**		**Unidentified large whale**	
	Inshore	**Offshore**	**Inshore**	**Offshore**	**Inshore**	**Offshore**
No. sightings	11	7	7	1	5	1
Encounter rate	0.067	0.050	0.024	0.003	0.013	0.003
Encounter rate CV	0.29	0.57	0.61	0.56	0.50	0.57
Group Size	2.81	2.14	1.57	1	1.2	1
Group Size CV	0.23	0.07	0.12	0	0.17	0
Model 1						
Density (ind/km^2)	0.011	0.009	0.004	0.0005	0.002	0.0005
Density 95% CI	(0.005, 0.024)	(0.001, 0.068)	(0.000, 0.017)	(0.000, 0.005)	(0.000, 0.008)	(0.000, 0.005)
Abundance	548	843	194	56	106	56
CV	0.33	0.59	0.63	0.59	0.53	0.59

Table 10. -- Model parameter of detection probability estimation for the GOALS 2009 and *Miller Freeman* 2003 large whale sighting data.

Model No.	**Model**	**No. par**	**Δ AIC**	**ESW (km)**	**ESW CV**
3	Half normal with Method covariate	2	0.00	2.69	0.08
4	Half normal without covariate	1	0.38	2.72	0.07
5	Half normal with Ship covariate	2	2.03	2.71	0.07
6	Half normal with Species covariate	3	2.57	2.70	0.08

No. par – number of parameters, AIC – Akaike Information Criterion, ESW – effective search half-width, CV – coefficient of variation.

Table 11. -- Estimation of density and abundance of fin, humpback and unidentified large whales in inshore (area = 47,411 km^2) and offshore (area = 98,253 km^2) using the GOALS 2009 and *Miller Freeman* 2003 data.

	Fin whale		**Humpback whale**		**Unidentified large whale**	
	Inshore	**Offshore**	**Inshore**	**Offshore**	**Inshore**	**Offshore**
No. sightings	11	7	7	1	5	1
Encounter rate	0.067	0.050	0.024	0.003	0.013	0.003
Encounter rate CV	0.29	0.57	0.61	0.56	0.50	0.57
Group Size	2.81	2.14	1.57	1	1.2	1
Group Size CV	0.23	0.07	0.12	0	0.17	0
Model 3						
Density (ind/km^2)	0.012	0.009	0.004	0.0005	0.003	0.0005
Density 95% CI	(0.006, 0.025)	(0.000, 0.083)	(0.001, 0.017)	(0.000, 0.005)	(0.000, 0.009)	(0.000, 0.005)
Abundance	594	889	219	56	118	56
CV	0.29	0.57	0.57	0.57	0.52	0.57

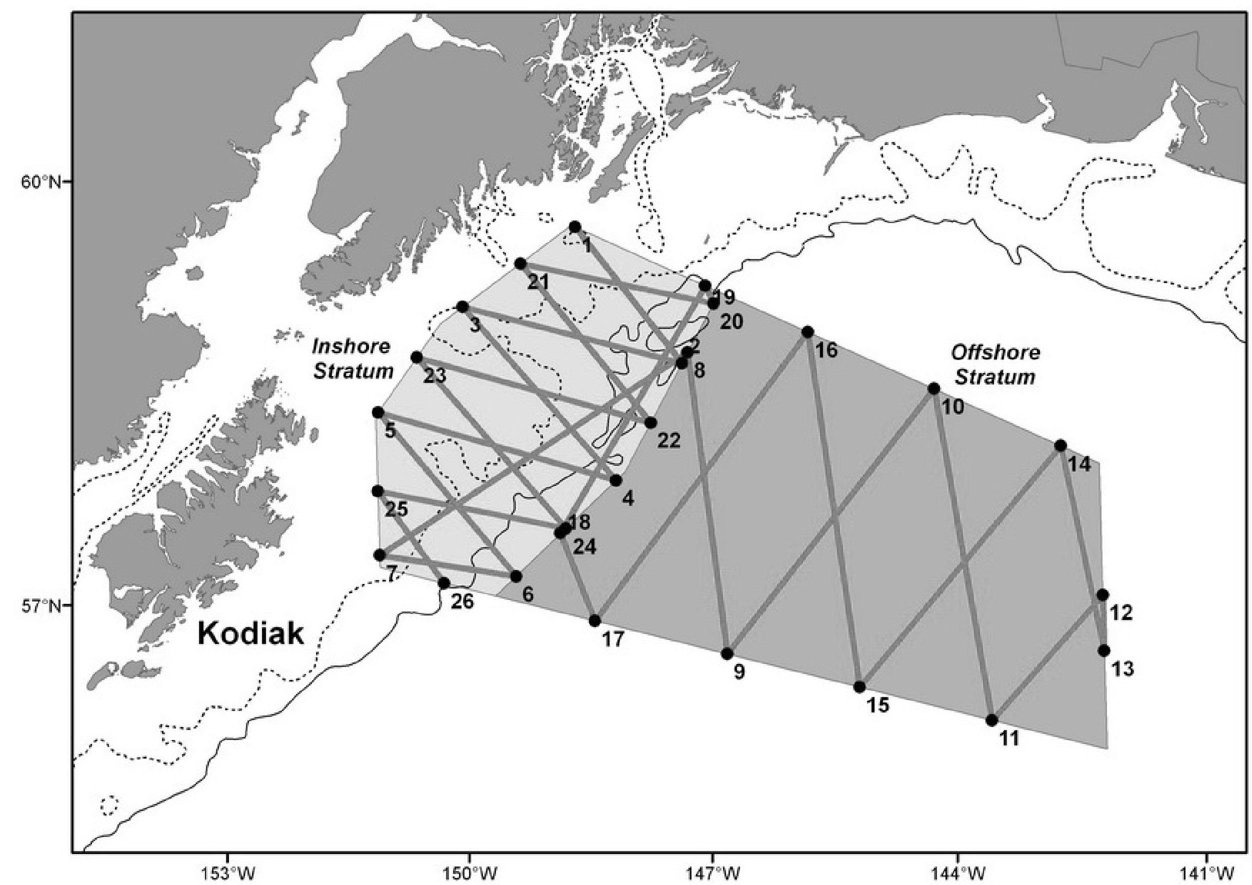


Figure 1. -- Tracklines for the GOALS 2009 research cruise.

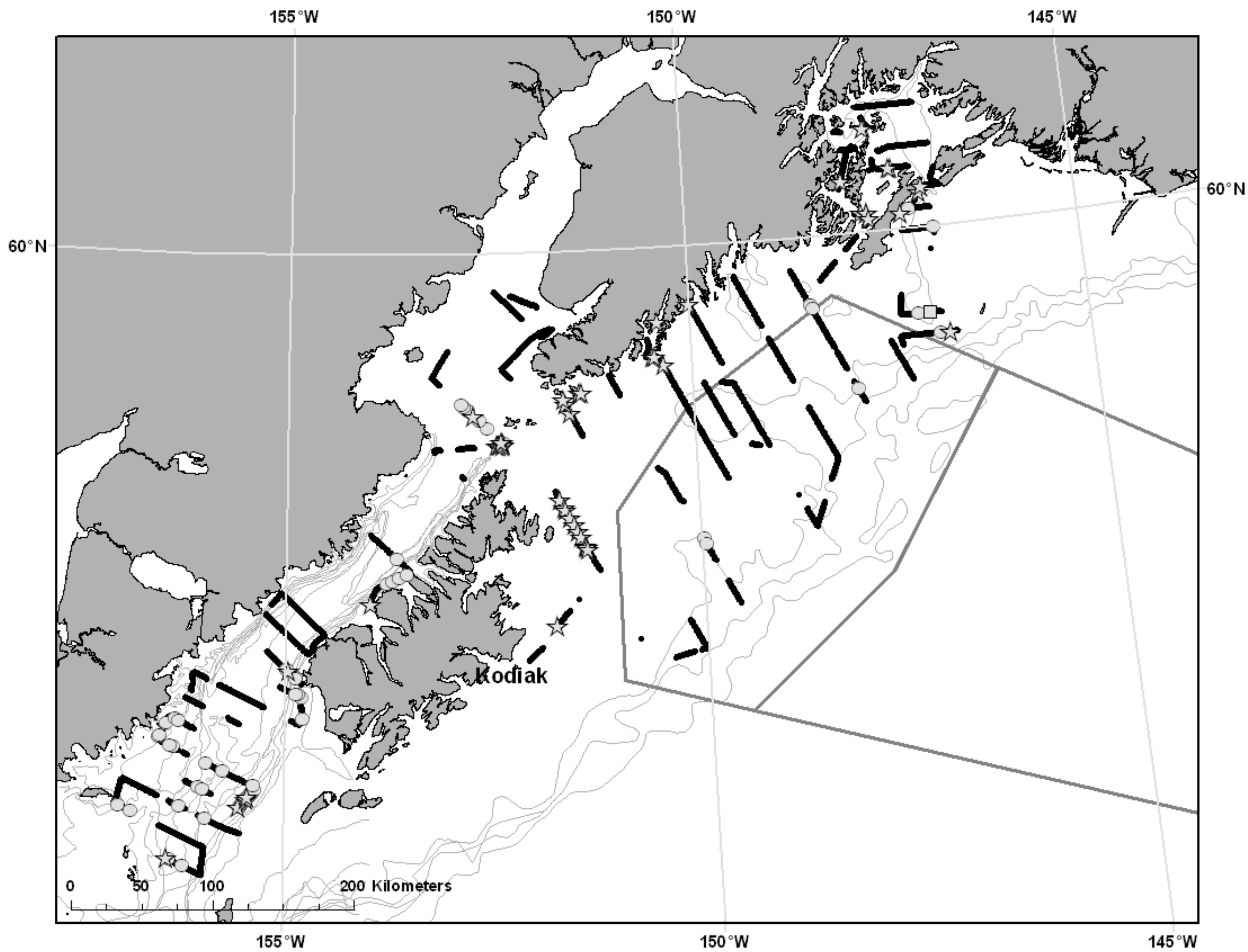


Figure 2. -- Completed visual effort and baleen whale sightings from the NOAA ship *Miller Freeman* 2003 research cruise used in combination with the GOALS 2009 data for analysis (circle = fin whale; star = humpback whale, square = unidentified large whale). Inshore and offshore strata for the 2009 GOALS survey (gray) are shown here for geographic reference.

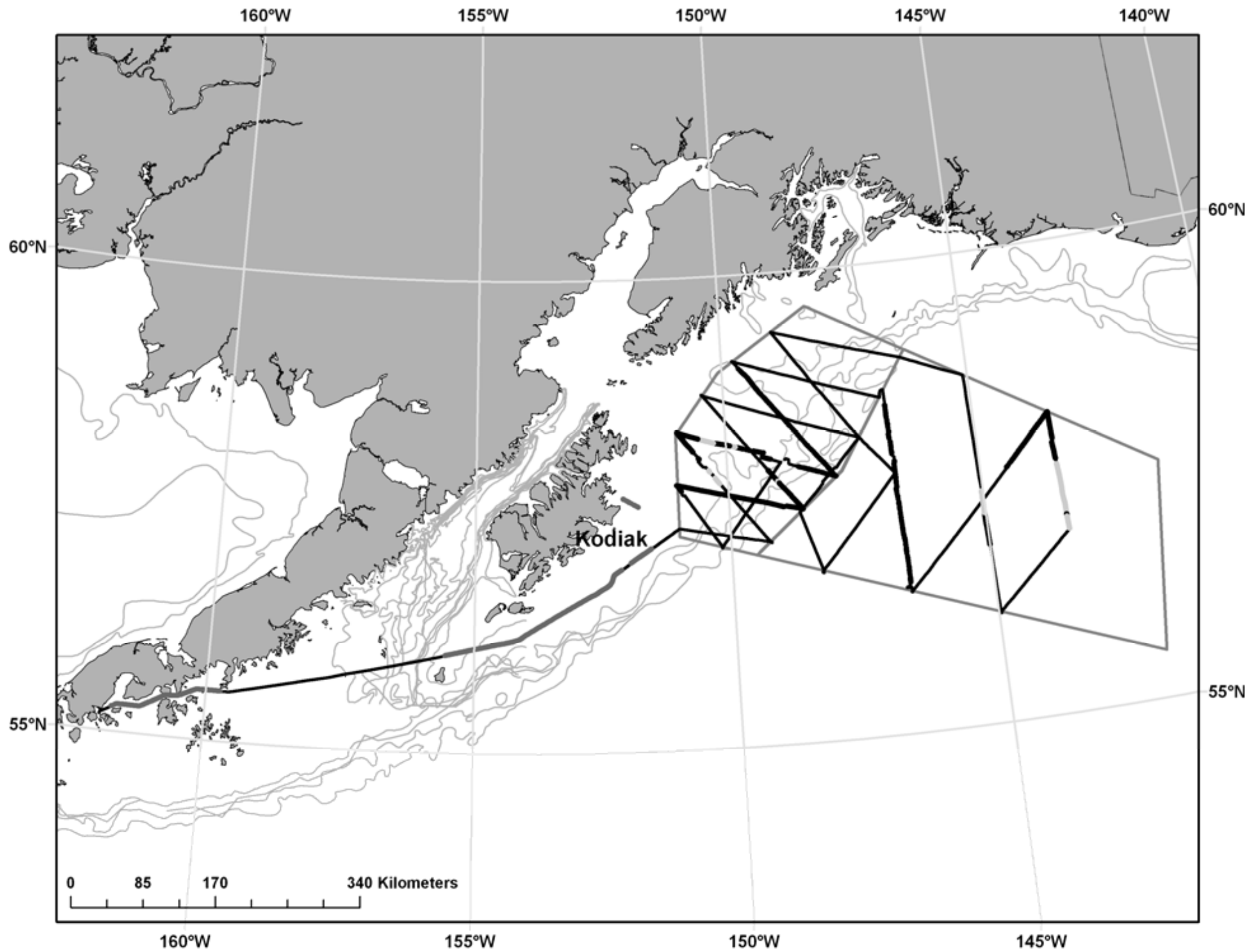


Figure 3. -- Completed visual and acoustic effort for the GOALS 2009 research cruise (visual and acoustic on-effort – bold black; transit and acoustic effort – dark gray; fog and acoustic effort – light gray; acoustic effort only – thin black).

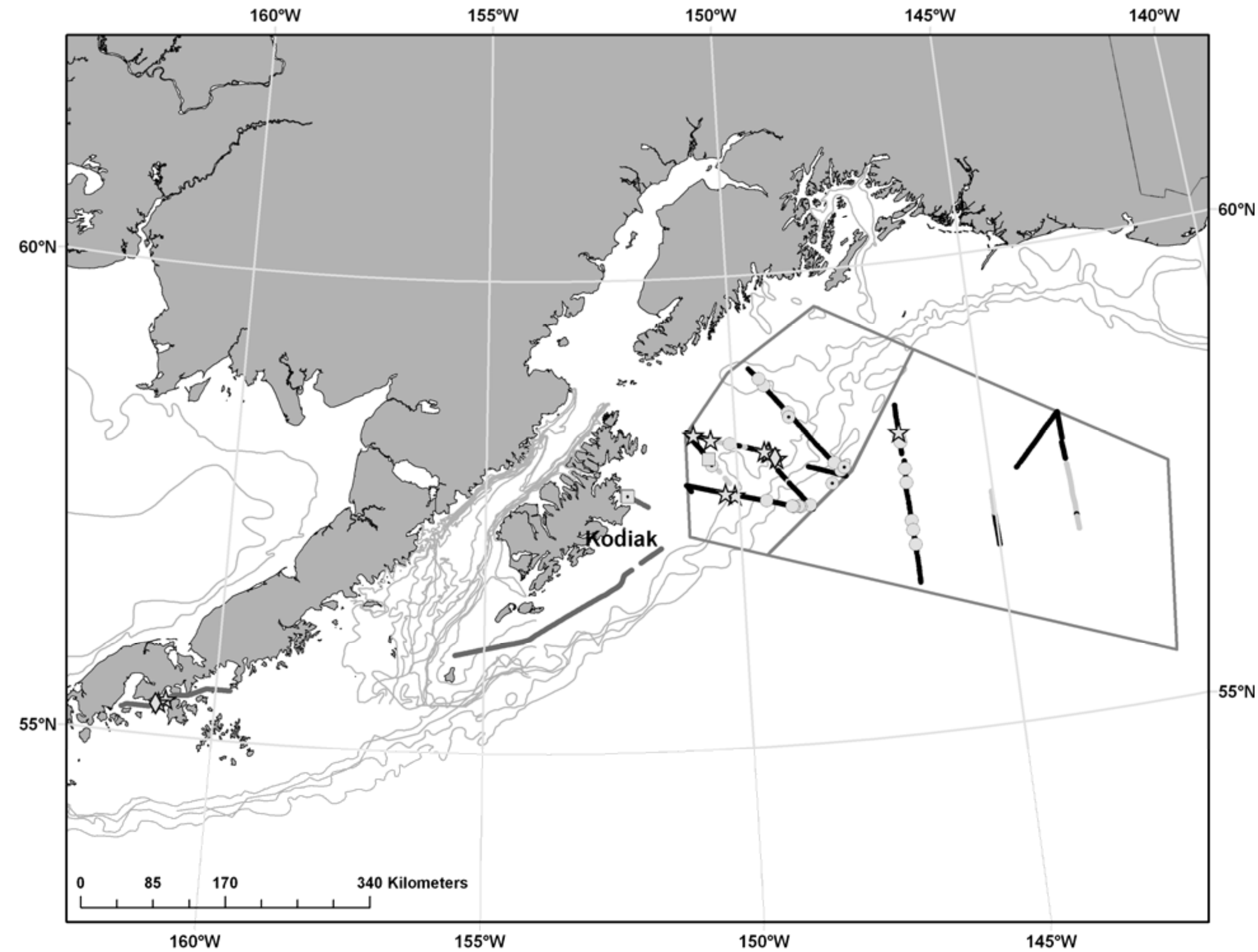


Figure 4. -- Baleen whale sightings from the GOALS 2009 research cruise (circle = fin whales, square = gray whale, star = humpback whale, diamond = minke whale; open symbol = on-effort sightings, dotted symbol = off-effort sightings).

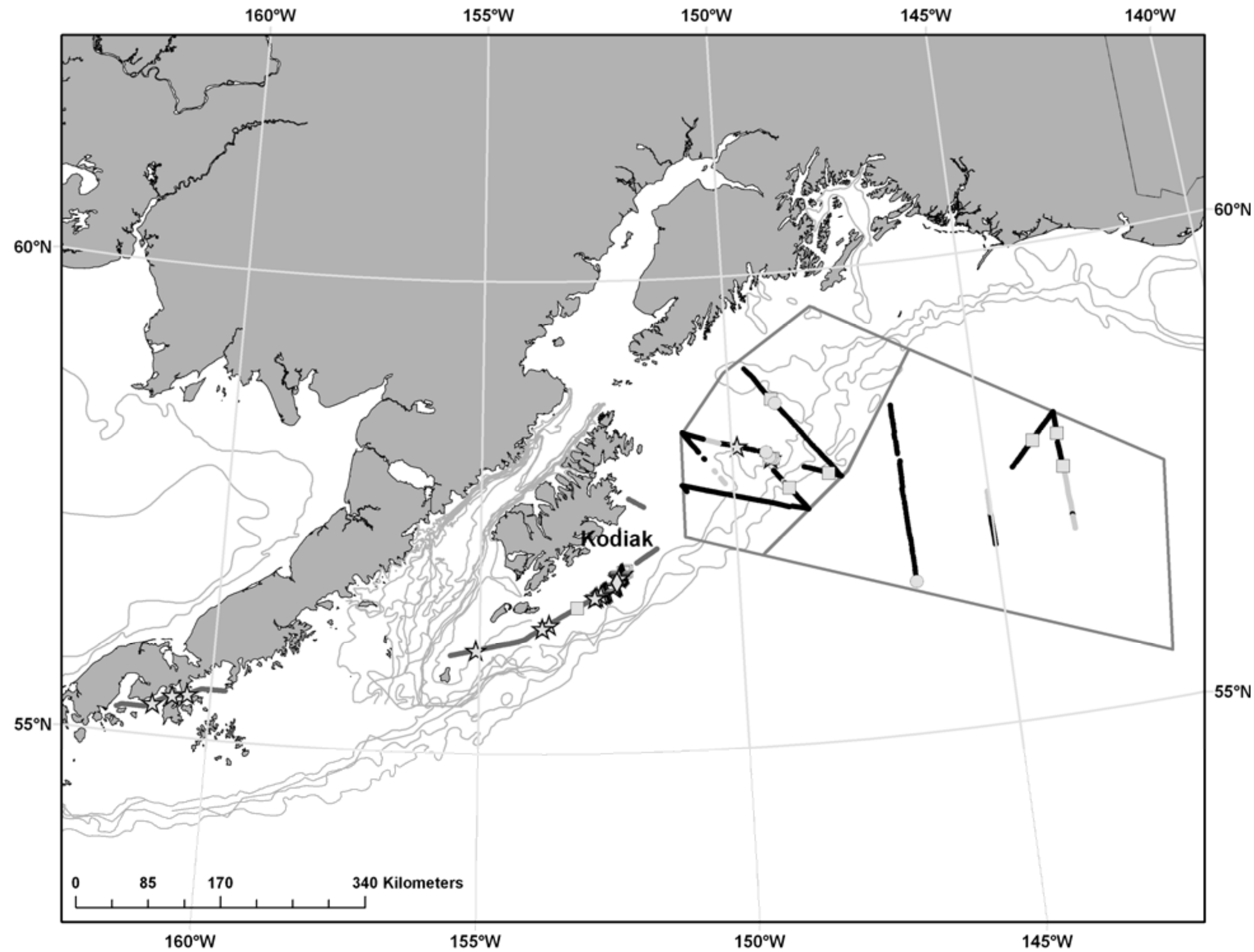


Figure 5. -- Toothed whale sightings from the GOALS 2009 research cruise (star = harbor porpoise, square = Dall's porpoise, circle = killer whale, diamond = Pacific white-sided dolphin; open symbol = on-effort sightings).

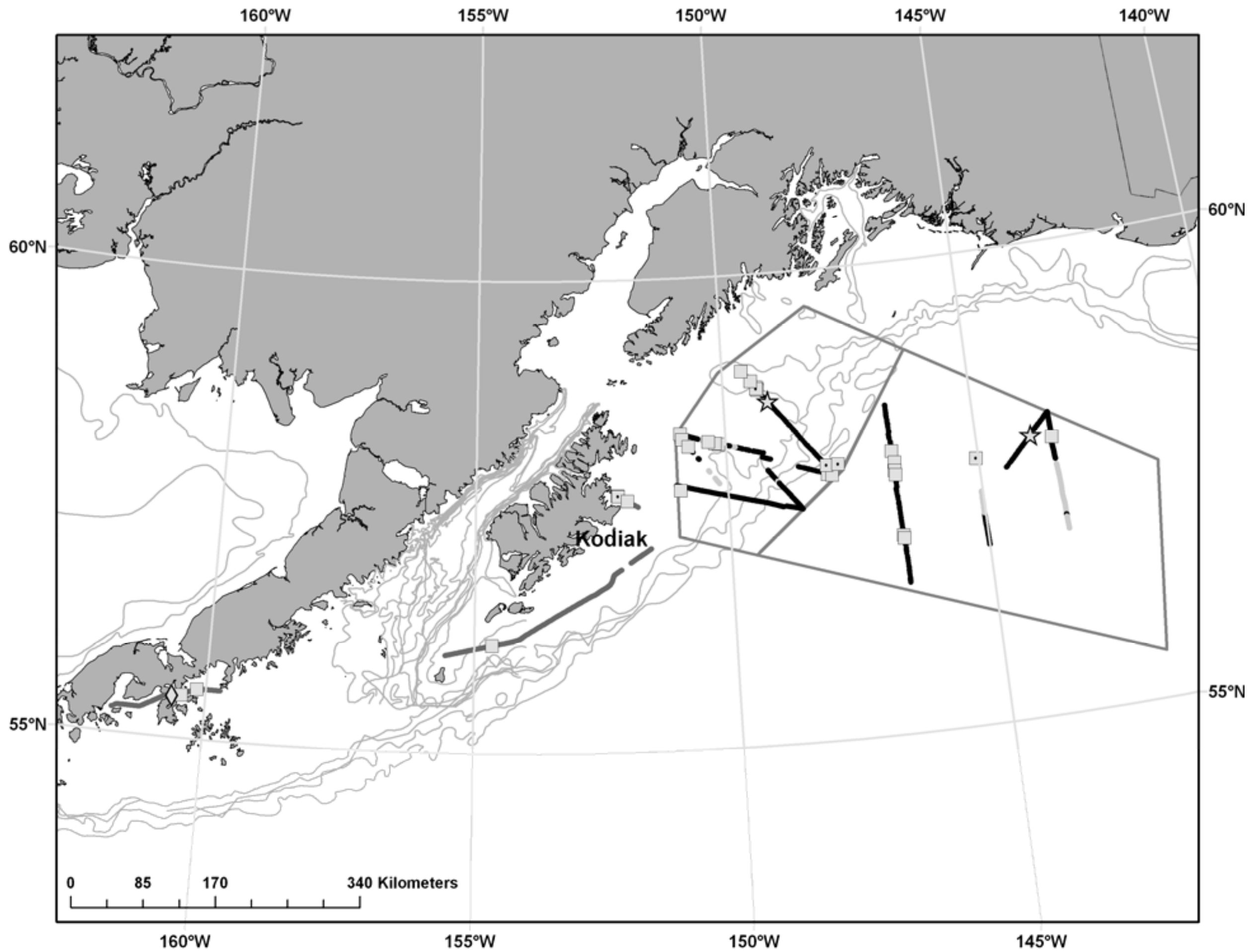


Figure 6. -- Unidentified cetacean sightings from the GOALS 2009 research cruise (square = large whale, star = dolphin/porpoise, circle = small whale; open symbol = on-effort sightings, dotted symbol = off-effort sightings).

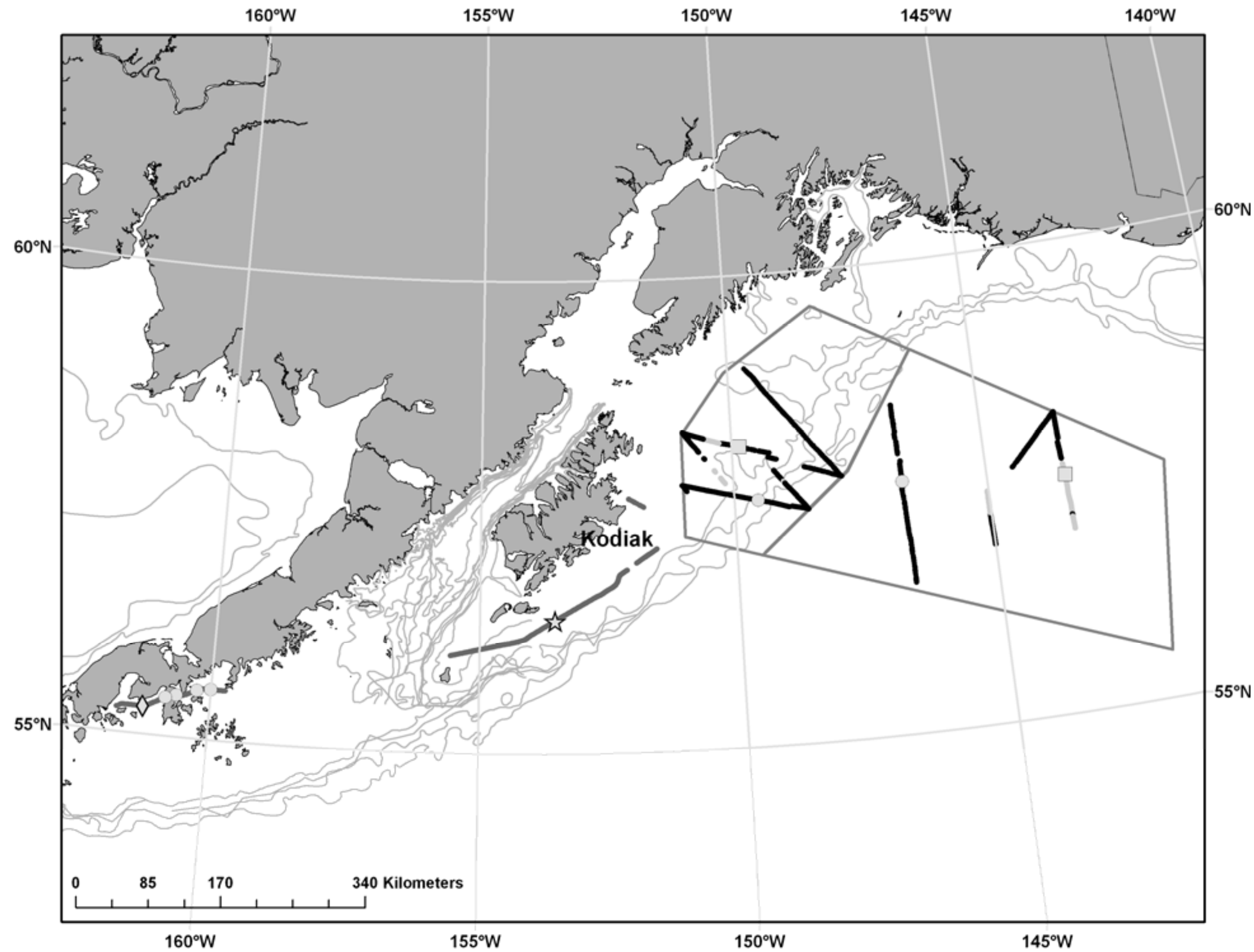


Figure 7. -- Pinniped and otter sightings from the GOALS 2009 research cruise (circle = Steller sea lion, star = sea otter, square = harbor seal, diamond = unidentified pinniped; open symbol = on-effort sightings).

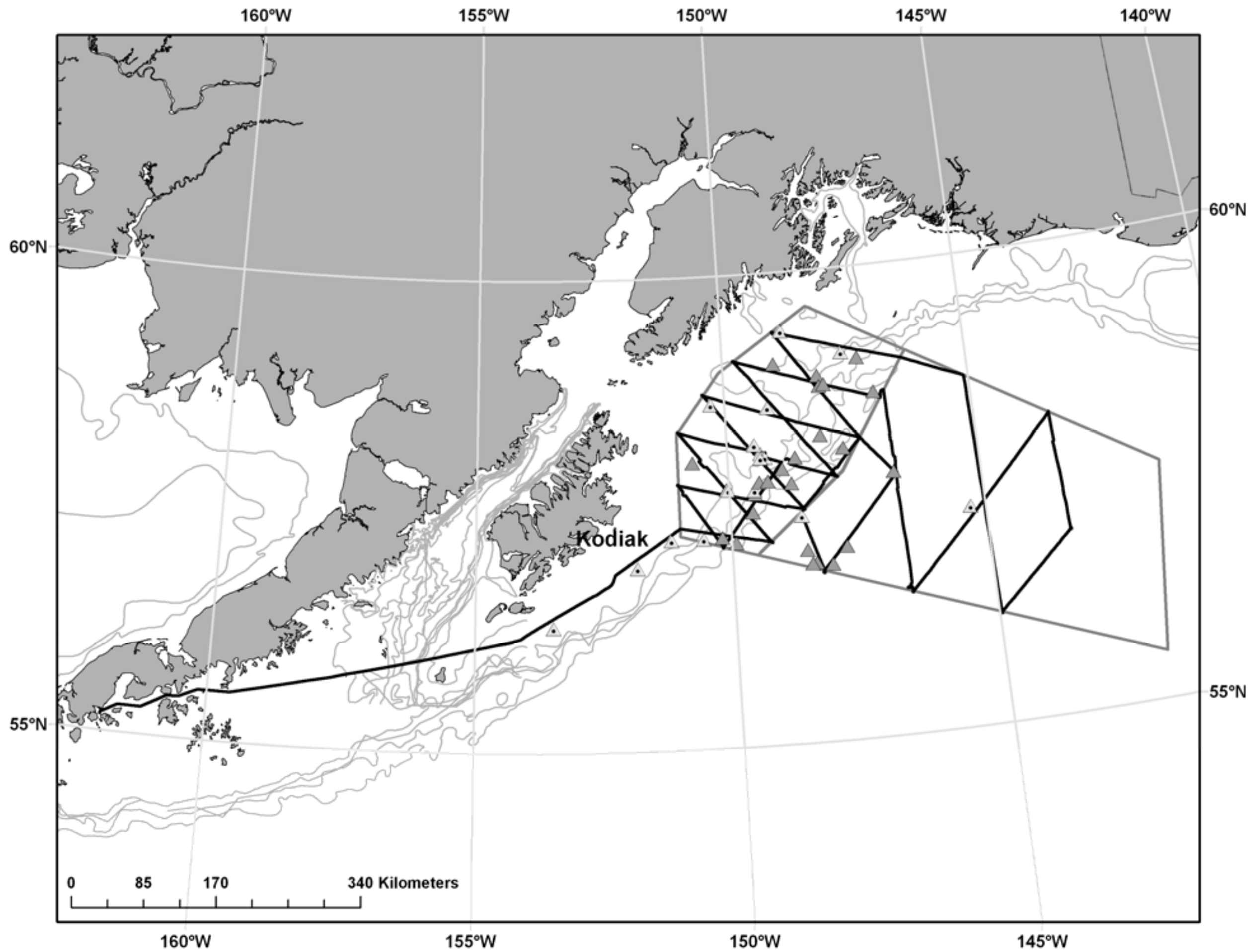


Figure 8. -- Acoustic effort and detections from the GOALS 2009 research cruise (light, dotted triangle = killer whale, dark, open triangle = sperm whale).

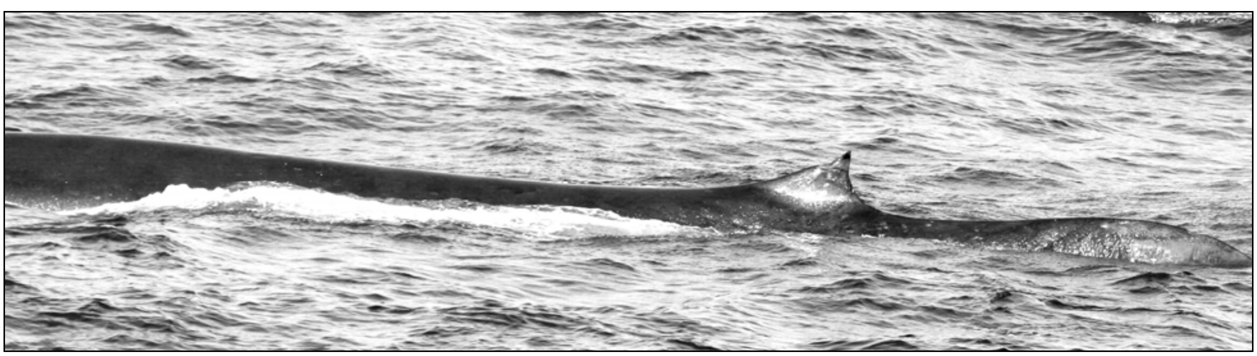
APPENDIX

Catalog of photo-identified individuals during the GOALS 2009 research cruise.

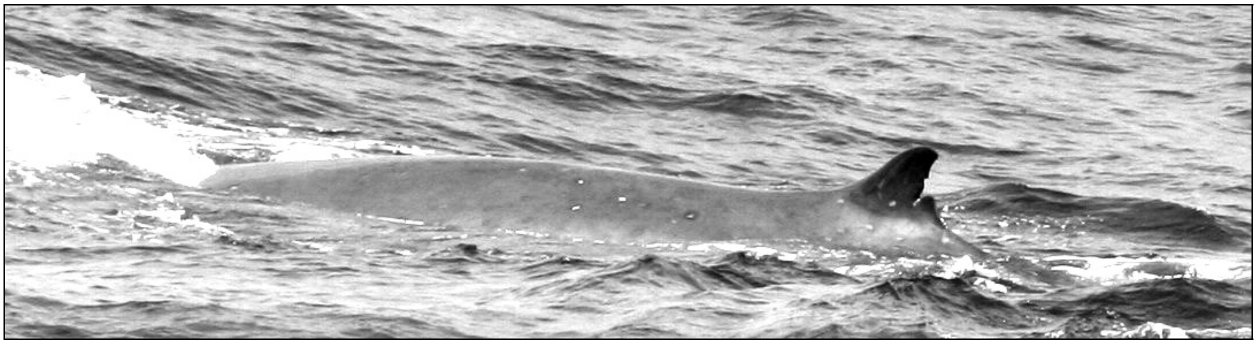
Fin Whales

CRC-BP-temporary-001-20090411-D6-0011edit; Cascadia Research Collective, Annie B. Douglas

CRC-BP-temporary-002-20090411-D6-0019edit; NMML, Brenda K. Rone



CRC-BP-temporary-003-20090411-D6-0027edit; Cascadia Research Collective, Annie B. Douglas



CRC-BP-temporary-004-20090411-D6-0037edit; Cascadia Research Collective, Annie B. Douglas

Killer Whales

CRC-OO-temporary-001-20090412-30D-0164edit-OOh (r); Cascadia Research Collective, Annie B. Douglas

CRC-OO-temporary-001-20090412-30D-0184edit OOh(l); Cascadia Research Collective, Suzanne Yin

CRC-OO-temporary-002-20090412-30D-0181edit OOg; Cascadia Research Collective, Annie B. Douglas

CRC-OO-temporary 003-20090418-30D-0066edit OOc; Cascadia Research Collective, Annie B. Douglas

CRC-OO-temporary-004-20090412-30D-178edit OOc;
Cascadia Research Collective, Suzanne Yin

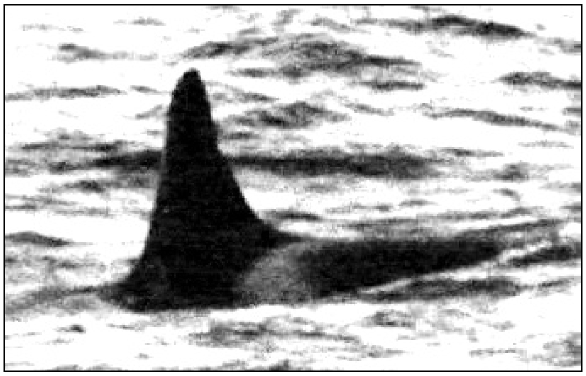
CRC-OO-temporary 005-20090418-30D-0066edit OOd;
Cascadia Research Collective, Annie B. Douglas

CRC-OO-temporary 006-20090418-30D-0060edit OOg;
Cascadia Research Collective, Annie B. Douglas

CRC-OO-temporary 007-20090418-30D-0073edit OOk;
(right) Cascadia Research Collective, Annie B. Douglas

CRC-OO-temporary 008-20090418-30D-0060edit Ooh;
Cascadia Research Collective, Annie B. Douglas

CRC-OO-temporary 009-20090418-30D-0076edit OOl;
Cascadia Research Collective, Annie B. Douglas



CRC-OO-temporary-010-20090412-30D-0172edit OOa; Cascadia Research Collective, Suzanne Yin

CRC-OO-temporary 011-20090418-30D-0071edit OOe; Cascadia Research Collective, Annie B. Douglas

CRC-OO-temporary 012-20090418-30D-0080edit(l) OOm; Cascadia Research Collective, Annie B. Douglas

CRC-OO-temporary 012-20090418-30D-0089edit OOm(r); Cascadia Research Collective, Annie B. Douglas

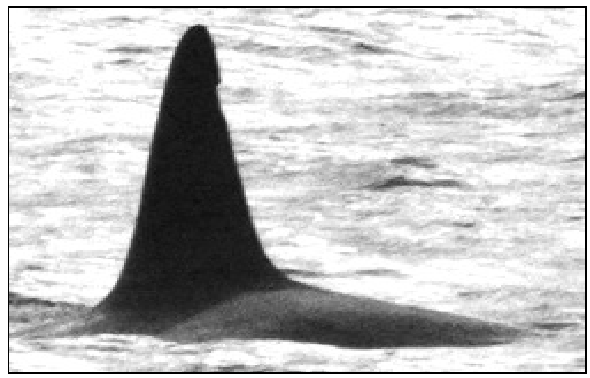
CRCRC-OO-temporary 013-20090418-30D 0120edit OOn; Cascadia Research Collective, Annie B. Douglas

CRC-OO-temporary 014-20090418-30D-0127edit OOp; Cascadia Research Collective, Annie B. Douglas

CRC-OO-temporary 015-20090418-30D- 0083edit OOq(r)
Cascadia Research Collective, Annie B. Douglas

CRC-OO-temporary 016-DY0905_18-Apr-09_S57 60 63_BKR_8441 OOa; NMML, Brenda K. Rone

CRC-OO-temporary -017-20090418R-30D-0069edit OOb; Cascadia Research Collective, Annie B. Douglas



CRC-OO-temporary-018-20090418-D6-0086edit OOs; Cascadia Research Collective, Suzanne Yin

CRC-OO-temporary-019-20090412-D6-0048 OO1; Cascadia Research Collective, Annie B. Douglas

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