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Pacific Ocean killer whale and other cetaceans Distribution survey, March 2006 (PODs 2006) conducted aboard the NOAA ship McArthur II

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Introduction

In 2001 the Southern resident killer whale (SRKW) population was petitioned for listing under the ESA. A series of workshops were held in 2003 and 2004 to identify data gaps and risk factors associated with the 20% decline this population experienced in the late 1990s. The primary data gap identified with this population was its winter distribution. Although the population has been identifiable since 1976, only 12 documented sightings in the winter in coastal waters existed in 2001, ranging form central California to the Queen Charlotte Islands, British Columbia. With the 2005 listing of the population under the ESA, Critical Habitat designation was required but in the initial designation none of the coastal U.S waters were included due to a paucity of sighting data. In order to obtain location data to improve the Critical Habitat designation, as well as obtain other information on behavior and prey selection, annual winter cruises to locate SRKWs have been conducted annually from 2004, except for the year 2005 (no sea days were allocated to this task in FY05). Here we report on the sighting and acoustic data collected for killer whales and other cetacean species and sea birds, as well describe the oceanographic data collected during the Pacific Ocean killer whale and cetaceans Distribution survey, March 2006 (PODs 2006) conducted aboard the NOAA ship McArthur II.

Survey Objectives

The overall objective of this cruise was to locate southern resident killer whales (SRKWs) in order to better document their winter range as well as improve our understanding of their behavior and habitat use in these areas. In addition, other biological and oceanographic data were collected to better characterize their environment. Other objectives included photo-identification, behavioral observations, and acoustic study of sounds produced by other cetaceans in this area during the winter.

Study Area

The survey tracklines for the project included the waters of the continental shelf from southern Vancouver Island to central Oregon. This region is within the range of most of the documented sightings of SRKW during the late March timeframe.

Itinerary

The survey began on 13 March 2006 in Astoria, Oregon and ended on 30 March 2006 in Port Angeles, Washington. A set of predetermined tracklines were established prior to the survey to cover the portion of the study area with the highest probability of encounter of SRKW based on previous sightings. In general, the ship was to initially follow the tracklines from the Columbia River north to Tofino, Vancouver Island. If no southern resident killer whales were encountered the ship followed a set of tracklines south, potentially as far as central Oregon, depending on weather and whale detections. The ship would then return north repeating these tracklines. Tracklines were modified during the cruise due to weather or other considerations. In addition, modifications were made by transiting directly to areas where recently reported sightings of killer whales were likely to be southern resident killer whales. Four days (22 March – 25 March) were limited to operations in the Strait of Juan de Fuca due to inclement weather. The final ship track is shown in Figure 1.

Methods and Materials

Surveys were conducted for marine mammals and seabirds during this cruise. Two survey methods for marine mammals were used, visual and acoustic. In addition, oceanographic data were collected. Scientific Personnel that collected these data are listed in Table 1.

Visual Surveys

Marine Mammals

Line-transect survey methods were the primary visual survey method. This approach was consistent with Southwest Fisheries Science Center approach for use in estimating abundance (Kinzey et al. 2001). The *McAurthur II* traveled at 9-10 knots (through the water) along the designated trackline. A daily watch for marine mammals was maintained during daylight hours by scientific observers on the fly-bridge (approximately 0700 to 1800), except when the ship was stopped to conduct other sampling operations, or when precluded by weather. A team of three observers searched with 25x150 binoculars, 7X binoculars, and unaided eye. The two outboard observers scanned from 10 degrees across the trackline to 90 degrees abeam with the Big eyes. The observers reported sighting angle using the azimuth incorporated into the binocular mount (this azimuth was calibrated to zero at the beginning of the cruise). The recorder monitored the entire 180 degree field of view with 7x 50 binoculars and unaided eye. Sighting conditions, watch effort, sightings, and other required information were entered into a computer, using the program WinCruz (written by R. Holland, SWFSC), hooked up to the ship's GPS (for course, speed and position information). Observers worked for 30 minutes at each of the three stations and rotated through the three positions for a total of 1.5 hours on the fly-bridge, with an hour break between sets of rotations.

If weather (Sea State greater than Beaufort 4, rain, or fog) precluded observations with the 25x binoculars, a two observer watch was manned on either the flybridge or bridge with 7x50 binoculars or unaided eye. The observers scanned with unaided eye and 7x50 binoculars for marine mammals. Sighting conditions, watch effort, sightings, and other required information were also entered into a computer, using the program WinCruz (written by R. Holland, SWFSC), hooked up to the ship's GPS (for course, speed and position information), but this was done by the observer.

On sighting a marine mammal or other feature of biological interest, the marine mammal observer team on watch occasionally requested the vessel be maneuvered to approach the cetacean school or feature for investigation. During these occasions, the team went off-effort to allow the ship to approach the group of marine mammals. During this time, the observers made estimates of group size. During certain sightings, behavioral data were collected and photographs were taken. Furthermore, in some instances, a small boat was deployed for biopsy, behavioral data collection, photographic and other operations will occur. Depending on the duration and end location of the encounter the trackline was either resumed at the point of departure or intersected at the closet point, while ensuring that the line was not repeated.

Seabirds

Surveys of marine bird distribution were recorded by trained observers during all daylight hours when ship speed exceeded 2.5 m/s (5 knots). Three observers rotated through watches of two observers each, so that every observer had an opportunity to eat meals and rest as necessary to avoid fatigue. Observations began at dawn each morning. A primary observer counted and identified all flying or sitting birds within a strip transect extending 300 m out from the bow to the beam of the ship (90° arc). During mild weather, observations were collected from the flying bridge (deck height = 12.6 m) on the side of the vessel with the best viewing conditions for each survey. In the event of precipitation exceeding a light drizzle, observations were collected from the bridge wing that was most in the lee of the wind (deck height 10.3 m).

Binoculars (8x magnification) were used to aid in counting and species identification. Data were called out to a secondary observer who immediately entered them into a laptop computer running the "See-Bird" data acquisition program v 2.3.0 (Southwest Fisheries Science Center, La Jolla, CA). The computer was linked to GPS satellite data input so that each observation was associated with a time stamp and a latitude/longitude position. Standard behavior codes were noted and recorded (e.g.sitting, feeding, flight direction, etc). Marine mammals or large aggregations of seabirds observed beyond the observation zone were also recorded in the comments.

<u>Acoustic survey</u> - Two different types of acoustic monitoring systems were available during the cruise, a dual towed array system and sonobouys.

Towed Arrays - hydrophones

The towed array system consisted of 2 hydrophones arrays: a 2 element array (array A); and a 5 element array (array B). Array A consisted of 2 elements with 3.15 spacing and approximately 330m of lead in cable. The 2 elements for array A had an effective (i.e. flat) frequency response of 100 Hz – 40 kHz. Array A was the primary array deployed (i.e. day and night) during normal survey mode. Array B consisted of 5 elements consisting of two paired phones at either end with 3m spacing between each element in the pair, and a single hydrophone near the middle (330 from the end pair and 130m from the first pair) for a total aperture of 660m (between the first and last pair). The last element of array B consisted of a broad-band, high-frequency element with a flat frequency response up to 200 kHz. Array B was intended to complement array A during nighttime encounters with resident killer whales in order to improve tracking capabilities. Each array was spooled on its own hydraulically powered winch for deployment and retrieval. Usually, array A was deployed at lengths of 200-300m from the fantail of the ship, depending on the bottom depth and other factors. Approximately 10 lbs of lead weight was attached to each array approximately 180m from the end of the array to sink it to a suitable depth. Array B was deployed with 200m of cable from the first pair of elements (for a total length of ~ 660m).

The deck cable was connected to the dry end of the array after deployment via a weather-proof electronic connector. The deck cable led from the winch into the dry-lab where the array power supply, signal conditioning, and signal processing, and signal recording system were located on the McArthur II. Array A was powered by two 12V DC batteries using a differential power (positive, negative & ground) configuration. Array B was powered by a 16V gel-cell.

Towed Arrays - Signal conditioning system

Six channels from both arrays (2 elements from array A, and the first 4 elements from array B) were passed to a 6-channel low pass filter (Alligator Filter Tech. model AAF) set at a fixed 48 kHz corner frequency. The seventh channel (from hydrophone 5 of array B) was sent to a low-pass filter with a corner frequency set at 100 kHz. The signal was then split between a National Instruments 6062E DAQ card for (for high-frequency recordings) and a programmable band-pass filter (Krohn-Hite model 3362) with a corner frequency set at 48 kHz. The high pass filter was adjusted as needed between 500 Hz and 4 kHz (default set at 500Hz) and used to reduce and low-frequency engine and flow noise. All seven channels (i.e. all hydrophones from both arrays) were fed into a MOTU Traveler PC digital interface. The MOTU interface was used to digitize all seven channels of array signals and then sent to ISHMAEL via a fire-wire cable.

Towed Arrays - Signal processing and recording system

One laptop was dedicated for running ISHMAEL sound localization and digital recording software (developed by D. Mellinger, OSU-PMEL, Newport, OR). A second laptop was dedicated to running Whaletrack II (developed by Glenn Gailey, TAMUG, TX). These two computers were connected via a network connection to an Ethernet router which was used to pass information from ISHMAEL to Whaletrack II (see Appendix II for setup procedures).

ISHMAEL was used to record acoustic data and process calls for localization. Generally, data were sampled and recorded at 96 kHz for both arrays. Two-channels were recorded when array A was deployed and 7 channels (2 from array A, and 5 from array B) when both arrays were deployed. In some instances other sample rates and channels were recorded as needed. Recordings were made continuously at 10 minute intervals with times with most start-times aligned on the hour and every ten minutes after the hour.

Animal vocalizations were manually selected in ISHMAEL for localization by windowing the signal with a pointing device (e.g. a trackball or touchpad). Depending on localization method selected n ISHMAEL either a left-right ambiguous bearing, an un-ambiguous bearing, or a relative location was estimated. All bearings and locations were estimated relative to the ships location. Instantaneous estimates of locations were possible using a newly developed “crossed-pair” localization method in ISHMAEL. The bearing or location estimate and additional information were automatically passed to Whaletrack II via the network connection.

Whaletrack II was used to plot bearings and/or location estimates passed from ISHMAEL. Whaletrack II also acquired and plotted ship position via a serial GPS connection. Ship track history, current heading and speed as well as an estimated position of the array were calculated and stored in an MSAccess database created by Whaletrack II. Information about effort, acoustic contacts and settings of acoustic equipment (e.g. gain and filter cutoffs) were also recorded in Whaletrack II.

Bearings plotted in Whaletrack II were used to estimate the animals location using a “sequential-bearing fix” technique. This technique involved sequentially plotting several bearings to the target while steadily moving past it. The locations of animal(s) were estimated visually by the computer operator who subjectively assessed the point where the bearing lines intersect. Bearings and estimated locations of animal calls were saved in a Whaletrack II database file. Screen dumps of bearing and ship plots were occasionally saved.

Sonobuoy System

Type AN/SSQ-57B USN sonobuoys (effective audio frequency response 10 Hz – 20 kHz) transmitting at various radio frequencies (164-167 MHz range) were deployed as conditions warranted. Sonobuoys are self-contained units that automatically power-up upon contact with water and transmit sounds via radio waves. All sonobuoys were set at 90m hydrophone deployment depths and 8 hour operating life (auto-scuttle setting). The sonobuoy radio signals were received by a mast mounted antennae connected to an ICOM IC-PCR1000 receiver that was controlled through a PC-based software interface. Acoustic signals from the receiver were recorded to a hard-drive using ISHMAEL and a NI 6062E DAQ card or the internal PC sound card.

Towed Arrays - Monitoring

Array A was monitored 24/7 weather permitting as the ship proceeded on the tracklines. The vessel slowed from survey speed to approximately 3 knots at the midpoint of each line in order to provide improved acoustic monitoring conditions. If killer whales were detected a second five element towed array on a separate hydraulic powered winch was simultaneously deployed for more efficient tracking. Sonobuoys were deployed on an opportunistic basis, at the discretion of the Acoustics team to aid in tracking whales that had been detected.

When southern resident killer whales were detected, every effort was made to remain with these animals for as long as possible. Visual sightings as well as acoustic data from the towed acoustic array or sonobouys were used to track the whales. Behavioral data were collected during visual observations, and if weather permitted, a small boat was deployed in order collect, behavioral data, predation event remains, and photographs.

<u>Photo-ID</u> Photographs of marine mammals were taken on an opportunistic basis. The animals were either approached by the research vessel during normal survey operations, approached the research vessel on their own, or were approached by a small boat. Photographs of individuals were taken with digital 35 mm SLR cameras using 300 and 400 mm lenses for those species that have photo-ID existing catalogs.

<u>Biopsy Sampling</u> - Biopsies for genetic analyses of killer whales were collected on an opportunistic basis in U.S. waters. Samples collected for killer whales were only taken form small boats using the method outlined by Barrett-Leonard et al. (1996). Biopsy samples taken from the research vessel were collected from animals within 10m to 30m of the bow of the vessel using a dart fired from a dart rifle (S. Claussen per.comm.).

<u>Prey remains collection</u> – Prey remains from predation events of marine mammals were collected on an opportunistic basis. These samples were collected from animals that were approached by the small boat.

<u>Behavioral Observations</u> – Behavioral observations of marine mammals were taken on an opportunistic basis. The animals to be observed were approached by the research vessel during normal survey operations, approached the vessel on their own, or were approached by a small boat.

<u>Oceanography</u>

Thermosalinograph Sampling

The ship's Sea-bird Electronics Thermosalinograph (TSG) sampled surface water temperature and salinity continuously during the entire cruise track. The data from the TSG and from a GPS were continuously recorded by the ship's Scientific Computing System (SCS). The TSG information was also used in the field by the oceanographer to record latitude, longitude, surface water temperature, and salinity during expendable bathyothermograph (XBT) casts, surface water sampling, and CTD casts.

Expendable Bathyothermographs (XBTs) Deployment

Expendable bathyothermographs (XBTs) were deployed at 0900, 1200, and 1500 hours, and surface water samples were collected at 0600, 0900, 1200, 1500, and 1800 hours local ship time, and at other times, under the discretion of the Chief Scientisit (e.g., surface water samples are also taken every hour when in the presence of Southern Resident killer whales). For XBT deployments, Sippican Deep Blue probes were used and data were transmitted to the Shipboard Environmental data Acquisition System. After each

XBT drop, a surface water sample for chlorophyll a analysis was collected in a bucket deployed over the side of the ship. Immediately following bucket sampling, a 50 ml sample of the water was filtered onto a 2.5 cm GF/F filter. All filters were wrapped in foil, labeled, and stored frozen in a Ziploc freezer bags until sample analysis, which occurred on the ship within <1-2 weeks of collection. For extraction, the filters were placed in culture tubes with 8 ml of 90% (v/v) acetone and stored in the freezer for a minimum of 2 hours. The tubes were then allowed to equilibrate with room temperature, and fluorescence was measured using a Turner Designs 10-AU Digital Field Fluorometer.

CTD Casts

A CTD (conductivity-temperature-depth) station was occupied each evening one hour after sunset, weather and sufficient depth permitting. In the event that a CTD cast was cancelled due to inclement weather or because the ship was tracking killer whales, an XBT was also deployed when the surface water sample was collected at 1800 hours. CTD data and seawater samples were collected using a SeaBird 9/11+ CTD with a 12-place rosette and Niskin bottles. All casts were to 1000m (depth permitting) with the descent rate set at 30 m/min for the first 100m of the cast, then 60 m/min after that, including the upcast between bottles. Niskin bottle water samples were collected at 12 standard depths (0, 10, 20, 30, 40, 50, 75, 100, 150, 200, 500, 1000) between the surface and 1000 meters, or to within 10 m of the bottom. For each cast, water samples were collected for chlorophyll a analysis at all depths to 200 m. Immediately following sampling, a 50 ml sample of the water was filtered onto a 2.5 cm GF/F filter. All filters were wrapped in foil, labeled, and stored frozen in a Ziploc freezer bags until sample analysis, which occurred on the ship within <1-2 weeks of collection. Chlorophyll a extraction and analysis were conducted using the same protocol as above. Water samples for salinity analysis were collected at 100, 500, and 1000 m (or to within 10 m of bottom). Three additional salt samples were collected every other day so that the depths sampled were 30 m, 100m, 150m, 200 m, 500 m, and 1000 m. Water samples for salinity analysis were stored upright at ambient room temperature. Salinity samples were processed within a few months after the cruise at the University of Washington Marine Chemistry Laboratory in Seattle. Water samples (approximately 40 ml) for nutrient analysis from each of the 11 depths up to 500 m were transferred into pre-rinsed (10% HCl and H_2O) vials and frozen upright. Nutrient samples were processed within 1 year after the cruise, at the University of Washington Marine Chemistry Laboratory in Seattle.

Results and Discussion

Search Effort and Sightings – Marine mammals

A total of 2227.8 km were surveyed in the 16 days with suitable weather, yielding an average of 139.2 km/day (Table 2, Figure 2). However, only 956.3 km were considered on effort, and of the 1100 km total off–effort, 260.8 km were conducted on the flybridge and 960.7 were conducted on the bridge. Most of the sightings were collected in BFT 3 or greater (81%).

A total of 94 sightings were made during all effort categories (Table 3). The majority of sightings were made while on effort (56) although a substantial numbers were observed while off –effort (38) (Table 4). Eight identifiable cetacean species were sighted (Figures 3, 4). The most commonly sighted species were gray whales, followed by Dall’s porpoise, and harbor porpoise. Only one group of killer whales (transients) was initially sighted without an acoustic cue (see Acoustics section). Only one ship-based biopsy attempt was made, on a Dall’s porpoise in U.S. waters, but no sample was collected.

Search effort and sightings - Seabirds

A total of 112.7 hours of on-effort survey observations were collected between 14 March 2006 and 31 March 2006; total effort for each day is shown in Table 5. The three numerically dominant seabird species observed were common murres (*Uria aalge*, 58.2%), black-legged kittiwakes (*Rissa tridactyla*, 10.2%), and hybrids between western and glaucous-winged gulls (*Larus occidentalis* x *glausecens*, 7.9%; Table 6). Total daily counts of the seven most common bird species encountered are shown in Table 7. It is worth noting here that survey effort appeared to capture the migration of winter resident birds such as black-legged kittiwakes and Cassin's auklets from the survey area, and the arrival of spring migrants or summer residents such as gulls, sooty shearwaters, and surf scoters (Table 7).

Acoustic detections

The hydrophone array was monitored for approximately 370 hours (85%) of the 433 hours the ship was at sea. Of the total time the hydrophone array was deployed, 290 hours of recordings were made (67% of the time the ship was at sea). Only two sonobuoys were deployed, but signals from both were weak, sound quality was poor, and no killer whale sounds were detected, thus no recordings were made.

Sixteen acoustic detections were made during the cruise. Killer whales detections were the most numerous, occurring on eight occasions with 6 allowing localization to get a visual sighting (Table 8, Figure 5). The other detections were 3 sperm whale detections, 3 Pacific white-sided dolphins, and two unidentified delphinids. The acoustic detection of J pod on 18 March and K and L pods were each a result of reports from previous visual sightings which allowed us to focus our effort in the local region of the sighting relatively soon after its report.

Killer whale encounters

Two of the three ecotype of killer whales found in the North Pacific Ocean, transients and residents, were encountered during the cruise (Table 9). For the resident type, pods from both the both the northern and southern communities were observed. Northern residents were encountered on 4 occasions over a period of 11 days. During each encounter group composition varied slightly, although this may have been due to the whales being spread out and potentially because of the differences in time they were able to be monitored. The 28 March sighting west of Willapa Bay is of note in that this is the furthest south that northern residents have been documented. All three pods of SRKW were encountered during this cruise. The occurrence of J pod near the west entrance of the Strait of Juan de Fuca was within their known winter range. Although small boat operations were conducted with J pod in U.S. waters, no feeding was observed. Later in the day when the ship entered Canadian waters, feeding by J pod was observed, however small boat operations were not feasible at that time. The sighting of K and L pods was the second recent occurrence of Southern residents in close proximity to the Columbia River in spring (Zamon et al. 2007). Although we were able to conduct small boat operations with the whales for about two hours, no foraging was observed and no biopsy attempts were made.

Oceanography

Fifty-three XBT deployments and 7 CTD deployments were made during the cruise (Table 10, 11, 12, Figure 6). Ninety-six surface chlorophyll samples, sixty-seven CTD chlorophyll samples, twenty-four salinity samples, and sixty-seven nutrient samples were collected.

Acknowledgements

We are grateful to the Officers and crew of the McArthur II for their support and expertise was essential to the success of this cruise. The accomplishments of the cruise would not have been possible dedication and hard work of the research team participants. Thanks to John Calambokidis, Gretchen Steiger and Greg Schorr from Cascadia Research Collective for their assistance with staffing the cruise and Ann Zoidis from Cetos Research Organization with other cruise staffing. Cruise Logistics were assisted by NWFSC staff - Christel Martin, Jeff Hard, and staff from Vera Trainer's program. We appreciate the support and assistance of several colleagues at the SWFSC. Don Norris, Dave Mellinger and Glen Gailey each played key roles in the development of the Acoustic tracking system. We greatly appreciate Bruce Jonasson and Tim Nesseth emergency patch up of our acoustics array, and John Hildebrand for his generous contribution of sonobouys. Thanks to Ken Balcomb for the tip on J pod's location and direction of travel and to Susan Berta of Orca Network and the whale watch naturalists at the Lewis and Clark Interpretive Center at Cape Disappointment State Park for the killer whale sighting that lead to the detection of K and L pods. Special thanks to Damon Holzer, NWFSC for expert development of the figures. Marine mammal research in the U.S. was conducted under NMFS Permit No. 774-1714 issued to the SWFSC and in Canada under DFO Marine Mammal License 2006-02 and SARA License 24.

Literature Cited

Barrett-Lennard, L. G., T. G. Smith, and G. M. Ellis. 1996. A cetacean biopsy system using lightweight pneumatic darts, and its effect on the behavior of killer whales. Marine Mammal Science 12:14-27.

Kinzey, D., Gerrodette, T., Dizon, A., Perryman, W., Olson, P. and Rankin, S. 2001. Marine Mammal Data Collected During a Survey in the Eastern Tropical Pacific Ocean Aboard the NOAA Ships McArthur and David Starr Jordan, July 28 – December 09, 2000.

Zamon, J.E., T.J Guy, K. Balcomb, and D.Ellifrit. 2007. Winter observations of southern resident killer whales (O*rcinus orca*) near the Columbia River plume during the 2005 spring chinook salmon (*Oncorhynchus tshawytscha*) spawning migration. Northwestern Nat. 88:193–198.

Table 1. Participating scientists from14-31 March 2006 during PODs 2006.

Name[1]	**Position**	**Org**
Brad Hanson	Chief Scientist, Mammal Observer	NWFSC
Dawn Noren	Co-Cruise Leader, Mammal Observer	NWFSC
Michael Richlen	Marine Mammal ID Specialist	CRC
Candi Emmons	Killer whale ID Specialist	CRC
Stephen Claussen	Mammal Observer	CRC
Tom Norris	Acoustician	Ind.
Liz Zele	Acoustician	CRC
Hisham Qayum	Acoustician	PMEL
Tina Yack	Acoustician	CRC
Shelly Nance	Oceanographer	NWFSC
Scott Mills	Seabird Observer	NWFSC
Alan Richards	Seabird Observer	NWFSC
Jon Plissner	Seabird Observer	NWFSC

Table 2. Visual survey effort summary for cetaceans (kms) by sea state from 14-31 March 2006 during PODs 2006

Effort type	Sea State							
	0	1	2	3	4	5	6	Total
On Effort Flying Bridge	0	55.0	189.0	278.5	217.4	193.4	23.0	956.3
Off Effort Blying bridge	0	12.5	36.8	191.1	27.8	12.5	10.1	290.8
Off Effort Bridge	0	17.0	107.8	120.9	343.6	164.8	226.6	960.7
Total	0	84.5	336.6	590.5	588.8	370.6	259.7	2227.8

Table 3. Visual sightings summary - Cetaceans - 14-31 March 2006 during PODs 2006.

Code	Species	Total Sightings	Average group size
20	*Lissodelphis borealis*	5	17
37	*Orcinus orca*	9	*
40	*Phocoena phocoena*	10	1.4
44	*Phocoenoides dalli*	14	3.4
46	*Physeter macrocephalus*	1	1
69	*Eschrichtius robustus*	40	2
71	*Balaenoptera acutorostrata*	2	1.0
76	*Megaptera novaeangliae*	5	1.8
78	Unid. small whale	2	1
79	Unid. large whale	6	1
	Total	94	

* see Table 4

Table 4. Cetacean sightings from14-31 March 2006 during PODs 2006.

Sighting #	Date	Time	Lat	Long	Species code	Species	# of animals	Effort
1	14-Mar	1439	N46:15.26	W124:23.34	37	Oo	6	On
2	14-Mar	1651	N46:16.12	W124:15.37	69	Er	3	On
3	15-Mar	902	N46:38.01	W124:41.34	37	Oo	?	Off
4	15-Mar	1140	N46:42.45	W124:16.66	69	Er	1	On
5	16-Mar	709	N47:19.82	W124:31.28	78	unid whale	1	Off
6	16-Mar	751	N47:21.85	W124:41.25	22	Lo	5	Off
7	16-Mar	1345	N48:07.71	W124:51.66	69	Er	1	Off
8	16-Mar	1353	N48:08.94	W124:53.19	40	Pp	1	Off
9	16-Mar	1717	N48:31.43	W124:38.19	40	Pp	2	Off
10	16-Mar	1719	N48:31.46	W124:38.32	40	Pp	2	Off
11	16-Mar	1734	N48:31.96	W124:40.73	40	Pp	1	On
12	16-Mar	1742	N48:32.34	W124:42.34	69	Er	3	On
13	17-Mar	700	N48:27.54	W125:55.86	22	Lo	8	Off
14	17-Mar	1035	N48:45.97	W125:32.47	44	Pd	2	On
15	17-Mar	1041	N48:46.70	W125:31.17	76	Mn	2	On
16	17-Mar	1202	N48:54.00	W125:45.26	79	unid lg whale	1	On
17	18-Mar	643	N48:18.02	W124:16.01	37	Oo – J pod	*	Off
18	18-Mar	1238	N48:28.92	W124:28.02	37	Oo – J pod	*	On
19	18-Mar	1259	N48:29.41	W124:29.67	71	Ba	1	Off
20	19-Mar	830	N48:21.20	W124:26.32	40	Pp	2	On
21	19-Mar	1016	N48:25.73	W124:53.14	79	unid lg whale	1	On
22	19-Mar	1040	N48:23.11	W124:58.11	69	Er	4	On
23	19-Mar	1043	N48:22.72	W124:58.81	69	Er	2	On
24	19-Mar	1702	N48:02.43	W125:32.04	44	Pd	6	On
25	19-Mar	1715	N48:03.16	W125:28.99	44	Pd	3	On
26	19-Mar	1749	N48:05.66	W125:20.85	40	Pp	1	On
27	19-Mar	1744	N48:06.02	W125:19.70	44	Pd	2	On
28	20-Mar	819	N48:06.80	W125:04.72	40	Pp	1	On
29	20-Mar	903	N48:02.96	W124:56.07	69	Er	3	On
30	20-Mar	952	N47:55.26	W124:54.39	69	Er	2	On
31	20-Mar	1052	N47:47.56	W124:51.75	69	Er	3	On
32	20-Mar	1123	N47:44.31	W124:49.98	79	unid lg whale	1	On
33	20-Mar	1126	N47:44.19	W124:49.94	69	Er	1	Off
34	20-Mar	1135	N47:43.82	W124:49.78	40	Pp	2	Off
35	20-Mar	1143	N47:43.67	W124:49.70	69	Er	1	Off
36	20-Mar	1207	N47:41.13	W124:48.72	40	Pp	1	On
37	20-Mar	1222	N47:38.71	W124:47.34	40	Pp	1	On
38	20-Mar	1311	N47:38.11	W124:51.46	76	Mn	2	On
39	20-Mar	1326	N47:39.01	W124:54.78	22	Lo	20	On
40	20-Mar	1419	N47:43.93	W125:01.89	44	Pd	4	Off
41	20-Mar	1423	N47:44.06	W125:01.69	79	unid lg whale	1	Off
42	20-Mar	1442	N47:44.68	W125:01.08	44	Pd	4	Off
43	20-Mar	1454	N47:45.24	W125:01.95	44	Pd	3	Off
44	20-Mar	1457	N47:45.34	W125:02.12	46	Pm	1	Off
45	20-Mar	1509	N47:45.78	W125:02.83	37	Oo – No. Res.	25	Off
46	21-Mar	753	N46:54.18	W124:34.96	78	unid sm whale	1	On
47	21-Mar	903	N46:49.57	W124:19.24	69	Er	1	On

* Complete estimates of group size were not be made

Table 4. Cetacean sightings during PODs 2006, cont.

Sighting #	Date	Time	Lat	Long	Species code	Species	# of animals	Effort
48	21-Mar	904	N46:49.50	W124:18.91	69	Er	1	On
49	21-Mar	909	N46:49.29	W124:17.85	69	Er	2	On
50	21-Mar	919	N46:48.81	W124:15.48	69	Er	1	On
51	21-Mar	923	N46:48.61	W124:14.54	69	Er	4	On
52	21-Mar	938	N46:46.26	W124:14.18	69	Er	1	On
53	21-Mar	942	N46:45.62	W124:14.17	69	Er	1	On
54	22-Mar	718	N48:17.43	W125:00.17	78	unid sm whale	1	Off
55	22-Mar	852	N48:27.28	W124:46.61	69	Er	4	Off
56	22-Mar	1400	N48:15.63	W124:05.57	44	Pd	6	Off
57	22-Mar	1411	N48:14.88	W124:03.12	44	Pd	2	Off
58	23-Mar	1016	N48:30.52	W123:35.20	44	Pd	2	Off
59	25-Mar	1350	N48:15.07	W123:30.53	44	Pd	1	Off
60	26-Mar	1719	N48:23.64	W125:43.34	79	unid lg whale	1	On
61	27-Mar	723	N48:04.86	W125:12.08	37	Oo– No. Res.	42	Off
62	27-Mar	1656	N47:33.67	W124:47.73	69	Er	4	On
63	27-Mar	1729	N47:30.67	W124:41.00	69	Er	2	On
64	27-Mar	1741	N47:28.82	W124:40.48	69	Er	1	On
65	27-Mar	1755	N47:26.49	W124:40.60	69	Er	1	On
66	27-Mar	1808	N47:24.34	W124:40.69	69	Er	3	On
67	28-Mar	959	N46:34.06	W124:35.60	76	Mn	2	Off
68	28-Mar	1500	N46:39.71	W124:31.68	37	Oo– No. Res.	*	Off
69	29-Mar	740	N45:54.65	W124:14.29	22	Lo	35	On
70	29-Mar	1025	N45:46.50	W124:41.31	44	Pd	7	On
71	29-Mar	1317	N45:39.35	W124:15.26	69	Er	1	On
72	29-Mar	1438	N45:35.92	W124:07.21	69	Er	1	On
73	29-Mar	1541	N45:31.84	W124:18.82	44	Pd	2	On
74	29-Mar	1633	N45:28.01	W124:28.10	71	Ba	1	On
75	29-Mar	1725	N45:23.59	W124:19.59	44	Pd	4	On
76	29-Mar	1809	N45:20.10	W124:12.48	69	Er	2	On
77	30-Mar	1032	N45:55.25	W124:11.58	69	Er	1	Off
78	30-Mar	1033	N45:55.34	W124:11.28	69	Er	2	Off
79	30-Mar	1045	N45:56.14	W124:08.49	69	Er	1	On
80	30-Mar	1049	N45:56.40	W124:07.58	69	Er	1	On
81	30-Mar	1107	N45:57.55	W124:09.16	76	Mn	1	Off
82	30-Mar	1159	N46:01.28	W124:19.61	22	Lo	15	On
83	30-Mar	1233	N46:06.72	W124:17.59	69	Er	3	On
84	30-Mar	1246	N46:08.94	W124:16.89	69	Er	1	On
85	30-Mar	1247	N46:09.15	W124:16.89	69	Er	1	On
86	30-Mar	1248	N46:09.31	W124:16.77	69	Er	5	On
87	30-Mar	1251	N46:09.64	W124:16.67	69	Er	2	On
88	30-Mar	1421	N46:10:48	W124:12.62	69	Er	4	Off
89	30-Mar	1424	N46:10.43	W124:12.61	69	Er	3	Off
90	30-Mar	1426	N46:10.38	W124:12.60	69	Er	2	Off
91	30-Mar	1527	N46:09.92	W124:17.09	37	Oo - K,L pods	*	Off
92	31-Mar	945	N46:54.50	W124:25.10	76	Mn	2	Off
93	31-Mar	1011	N46:59:02	W124:26.70	69	Er	2	Off
94	31-Mar	1632	N48:00.22	W124:57.43	37	Oo– No. Res.	10	Off

* Complete estimates of group size were not be made

Table 5. Marine bird survey effort, in hours per day, 14-31 March 2006 during PODs 2006.

Date	**Survey effort, in hours, minutes**
14 Mar 2006	5:34
15 Mar 2006	7:13
16 Mar 2006	2:21
17 Mar 2006	8:36
18 Mar 2006	1:40
19 Mar 2006	10:45
20 Mar 2006	5:35
21 Mar 2006	8:50
22 Mar 2006	2:11
23 Mar 2006	6:21
24 Mar 2006	2:56
25 Mar 2006	4:38
26 Mar 2006	9:37
27 Mar 2006	2:16
28 Mar 2006	6:54
29 Mar 2006	10:22
30 Mar 2006	6:35
31 Mar 2006	10:11
Total effort	**112. 7 hours**

Table 6. Total counts of species recorded during marine bird survey effort, in descending numerical order, 14-31 March 2006, during PODs 2006.

Common Name	**Scientific name**	**Total count**	**Percentage of total**
Common Murre	*Uria aalge*	9402	58.2%
Black-legged Kittiwake	*Rissa tridactyla*	1654	10.2%
Western x Glaucous-winged Gull	*Larus spp.*	1279	7.9%
Rhinoceros Auklet	*Cerorhinca monocerata*	934	5.8%
Dark Shearwater	*Puffinus spp.*	500	3.1%
Cassin's Auklet	*Ptychoramphus aleuticus*	400	2.5%
Sooty Shearwater	*Puffinus griseus*	354	2.2%
Surf Scoter	*Melanitta perspicillata*	281	1.7%
Ancient Murrelet	*Synthliboramphus antiquus*	171	1.1%
Northern Fulmar	*Fulmarus glacialis*	169	1.0%
Fork-tailed Storm-petrel	*Oceanodroma furcata*	153	0.9%
California Gull	*Larus californicus*	119	0.7%
Herring Gull	*Larus argentatus*	106	0.7%
Mew Gull	*Larus canus*	97	0.6%
Black-footed Albatross	*Phoebastria nigripes*	86	0.5%
Unidentified Gull	*Larus spp.*	77	0.5%
Red-breasted Merganser	*Mergus serrator*	66	0.4%
Brandt's Cormorant	*Phalacrocorax penicillatus*	47	0.3%
Glaucous-winged Gull	*Larus glaucescens*	44	0.3%
Pacific Loon	*Gavia pacifica*	37	0.2%
Short-tailed Shearwater	*Puffinus tenuirostris*	26	0.2%
Pigeon Guillemot	*Cepphus columba*	24	0.1%
Bonaparte's Gull	*Larus philadelphia*	20	0.1%
Thayer's Gull	*Larus thayeri*	18	0.1%
Brant	*Branta bernicla*	14	0.1%
Red-throated Loon	*Gavia stellata*	13	0.1%

Table 6 (con't). Total counts of species recorded during marine bird survey effort, in descending numerical order, 14-31 March 2006, during PODs 2006.

Pomarine Jaeger	*Stercorarius pomarinus*	10	0.1%
Long-tailed Duck	*Clangula hyemalis*	9	0.1%
Western Gull	*Larus occidentalis*	9	0.1%
Parakeet Auklet	*Cyclorrhynchus psittacula*	8	0.0%
Black Scoter	*Melanitta nigra*	6	0.0%
Harbor Seal	*Phoca vitulina*	6	n/a
Stellar Sea Lion	*Eumetopias jubatus*	4	n/a
Harlequin Duck	*Histrionicus histrionicus*	3	0.0%
Glaucous Gull	*Larus hyperboreus*	2	0.0%
Parasitic Jaeger	*Stercorarius parasiticus*	2	0.0%
Pelagic Cormorant	*Phalacrocorax pelagicus*	2	0.0%
Thick-billed Murre	*Uria lomvia*	2	0.0%
Unidentified Alcid	*Family Alcidae*	2	0.0%
White-winged Scoter	*Melanitta fusca*	2	0.0%
Bald Eagle	*Haliaeetus leucocephalus*	1	0.0%
Canada Goose	*Branta canadensis*	1	0.0%
Common Loon	*Gavia immer*	1	0.0%
Double-crested Cormorant	*Phalacrocorax auritus*	1	0.0%
Elephant Seal	*Mirounga angustirostris*	1	n/a
Horned Puffin	*Fratercula corniculata*	1	0.0%
Laysan Albatross	*Diomedea immutabilis*	1	0.0%
Ring-billed Gull	*Larus delawarensis*	1	0.0%
Sea Otter	*Enhydra lutris*	1	n/a
TOTALS		**16167**	**100.0%**

Table 7. Total daily counts of the eight most common marine bird species during survey effort, 14-31 March 2006, during PODs 2006.

Day in March	**Common Murre**	**Black-legged Kittiwake**	**Western x Glaucous-winged Hybrid**	**Rhinoceros Auklet**	**Dark shearwater**	**Cassin's Auklet**	**Sooty Shearwater**	**Surf Scoter**
14	1118	18	69	5	3	27		3
15	220	113	49	11	17	103	8	6
16	62	4	8	7		12		
17	405	327	32	70	6	131	1	1
18		7	7	2				2
19	82	344	52	40	9	20	2	
20	192	219	39	48	34	47	7	3
21	1670	125	95	39	28	27	7	20
22	22	25	12	18			3	
23	10	7	78	127				5
24	2		17	40				
25	7	16	21	44		1		
26	421	301	44	105	31	14	41	2
27	94	36	23	55	301		45	
28	200	16	135	23	8	1	5	2
29	1280	53	194	70	79	5	51	95
30	1665	8	251	60	19		121	81
31	1952	35	230	170		14	71	63
Total	**9402**	**1654**	**1356**	**934**	**535**	**402**	**362**	**283**

Table 8. Acoustic detections of marine mammals from 14-31 March 2006 during PODs 2006.

Date	Time	Latitude	Longitude	Species	Ecotype
14-Mar-06	14:39	N 46:15.26	W124:23.34	O.o.	Transients
14-Mar-06	14:39	N 46:15.26	W124:23.34	L.o.	
15-Mar-06	15:12	N 46:36.05	W124:23.62	P.m.	
17-Mar-08	7:10	N 47:19.9	W124:31.55	L.o.	
18-Mar-06	7:10	N 48:18.02	W124:16.01	O.o.	So. Resident
18-Mar-06	12:38	N 48:28.92	W124:28.02	O.o.	So. Resident
20-Mar-06	14:00	N 47:39.97	W124:56.82	P.m.	
20-Mar-06	15:08	N 47:45.78	W125:2.83	O.o.	No. Resident
23-Mar-06	5:30	N 48:14.4	W123:39.96	P.m.	
26-Mar-06	14:55	N 48:40.04	W125:33.74	Unid Dolp.	
27-Mar-06	7:23	N 48:4.86	W125:12.08	O.o.	No. Resident
28-Mar-06	15:00	N 46:39.71	W124:31.68	O.o.	No. Resident
29-Mar-06	7:46	N 45:55.53	W124:11.54	L.o.	
29-Mar-06	8:49	N 45:51.96	W124:22.43	Unid Dolp.	
30-Mar-06	7:46	N 46:9.92	W124:17.09	O.o.	No. Resident
31-Mar-06	16:32	N 48:0.22	W124:57.43	O.o.	No. Resident

Table 9. Killer whale encounters from 14-31 March 2006 during PODs 2006

Date	Duration of encounter	Latitude	Longitude	Ecotype	Whales Present
14-Mar-06	1:21	46-15.26	124-23.34	Transients	Transients
18-Mar-06	5:07	48-18.02	124-16.01	Resident	J pod
18-Mar-06	6:33	48-28.92	124-28.02	Resident	J pod
20-Mar-06		47-45.78	125-02.83	Resident	I11 Pod (Ill and I31 matrilines)
27-Mar-06	8:37	48-04.86	125-12.08	Resident	I11s,C10s,C6s,G2s,G27s,G45,G20s,G17s
28-Mar-06	2:59	46-39.71	124-31.68	Resident	C10s,C6s,G45,G27s,G34s,G48,G17s,I47
30-Mar-06	3:03	46-09.92	124-17.09	Resident	K, L pods
31-Mar-06		48-00.22	124-57.43	Resident	C10s

Table 10. Summary of environmental data from 14-31 March 2006 during PODs 2006

Sample type	Cruise total
CTD casts	7
CTD chlorophyll samples	67
Surface chlorophyll samples	96
Nutrient samples	67
Salinity samples	24
XBT drops	53

Table 11. XBT deployment locations from 14-31 March 2006 during PODs 2006.

XBT #	Serial #	Max depth (m)	Sea surface temp (°C)	PST Date	PST time	Latitude	Longitude
1	937264	78	8.8	14-Mar	914	N46:09.15	W124:12.54
2	973263	135	9.7	14-Mar	1200	N46:11.44	W124:29.66
3	973267	220	8.9	14-Mar	1514	N46:17.15	W124:22.00
4	973262	380	9.7	15-Mar	900	N46:37.87	W124:42.07
5	973261	178	9.6	15-Mar	1500	N46:46.89	W124:48.73
6	973266	542	9.3	15-Mar	825	N47:23.64	W124:49.66
7	973265	75	9.6	16-Mar	1200	N47:49.32	W124:48.25
8	973269	175	8.8	16-Mar	1500	N48:20.14	W124:52.10
9	973270	78	8.7	17-Mar	900	N48:34.39	W125:51.28
10	973268	100	8.4	17-Mar	1200	N48:53.64	W125:44.45
11	973271	160	8.9	17-Mar	1500	N48:49.09	W126:16.51
12	973272	135	8.3	17-Mar	1800	N48:41.16	W125:46.33
13	97325	196	8.4	18-Mar	1200	N48:27.50	W124:25.15
14	973286	150	8.7	18-Mar	1900	N48:32.32	W124:43.80
15	973287	80	8.6	19-Mar	900	N48:23.38	W124:33.73
16	973288	118	9.2	19-Mar	1200	N48:20.29	W125:18.69
17	973289	887	9.2	19-Mar	1500	N48:06.07	W125:49.41
18	973290	300	9.3	19-Mar	1925	N48:08.84	W125:07.29
19	973291	120	8.7	20-Mar	900	N48:03.64	W125:00.30
20	973292	92	9.9	20-Mar	1200	N47:42.18	W124:49.28
21	973296	154	9.6	20-Mar	1500	N47:45.35	W125:02.15
22	973295	355	10.3	20-Mar	1800	N47:43.35	W125:05.60
23	973294	54	9.1	21-Mar	900	N46:49.99	W124:21.20
24	973293	570	9.8	21-Mar	1200	N46:33.31	W124:39.23
25	973372	80	8.9	21-Mar	1526	N46:19.74	W124:17.83
26	973371	175	9.9	20-Mar	1801	N46:08.99	W124:37.63
27	973270	280	8.7	22-Mar	857	N48:27.33	W124:45.13
28	973373	145	8.2	22-Mar	1206	N48:22.43	W124:27.55
29	973373	133	8.5	22-Mar	1510	N48:12.53	W123:50.40
30	973374	150	8.4	22-Mar	1745	N48:19.92	W123:57.54
31	973375	177	8.3	23-Mar	900	N48:25.52	W124:17.66
32	973376	250	8.6	23-Mar	1200	N48:26.35	W124:33.02
33	973380	250	8.6	23-Mar	1200	N48:26.35	W124:33.02
34	973379	175	8.4	23-Mar	1447	N48:15.23	W124:04.28
35	973378	171	8.3	23-Mar	1800	N48:17.99	W123:42.80
36	973377	168	8.5	25-Mar	1500	N48:18.55	W123:46.00
37	973360	132	8.5	25-Mar	1800	N48:26.74	W124:19.44
38	973364	112	9.2	26-Mar	900	N48:39.81	W126:01.01
39	973368	93	8.5	26-Mar	1230	N48:56.39	W125:43.35
40	973359	193	9.0	26-Mar	1500	N48:39.69	W125:33.95
41	973363	125	9.5	27-Mar	847	N47:59.82	W125:03.35
42	973367	130	9.0	27-Mar	1200	N47:52.28	W125:02.19
43	973362	143	9.7	27-Mar	1500	N47:41.88	W124:58.94
44	973362	167	9.7	28-Mar	900	N46:35.40	W124:33.28
45	973358	319	9.9	28-Mar	1200	N46:34.79	W124:37.46
47	973361	152	10.0	29-Mar	900	N45:51.00	W124:25.73
48	973365	194	10.3	29-Mar	1200	N45:42.07	W124:29.29
49	973353	126	10.5	29-Mar	1500	N45:34.40	W124:11.79
50	973349	160	10.1	30-Mar	900	N45:49.86	W124:30.71
51	973345	125	10.1	30-Mar	1200	N46:01.32	W124:19.56
52	973354	90	10.1	30-Mar	1500	N46:09.14	W124:14.06
53	973350	92	10.2	30-Mar	1800	N46:07.04	W124:14.27

Table 12. CTD deployment locations for CTDs from 14-31 March 2006 during PODs 2006.

CTD #	Number of depth sampled	Max depth (m)	PST Date	PST start time	Latitude	Longitude
1	10	200	14-Mar	2001	N46:19.4	W124:37.88
2	8	100	16-Mar	2002	N48:34.97	W125:05.42
3	11	500	20-Mar	2051	N47:45.69	W125:09.71
4	10	200	26-Mar	2048	N48:09.08	W125:42.08
5	8	100	27-Mar	1938	N47:13.21	W124:43.53
6	12	1000	28-Mar	1943	N46:30.57	W124:50.84
7	10	170	29-Mar	1955	N45:10.96	W124:17.00

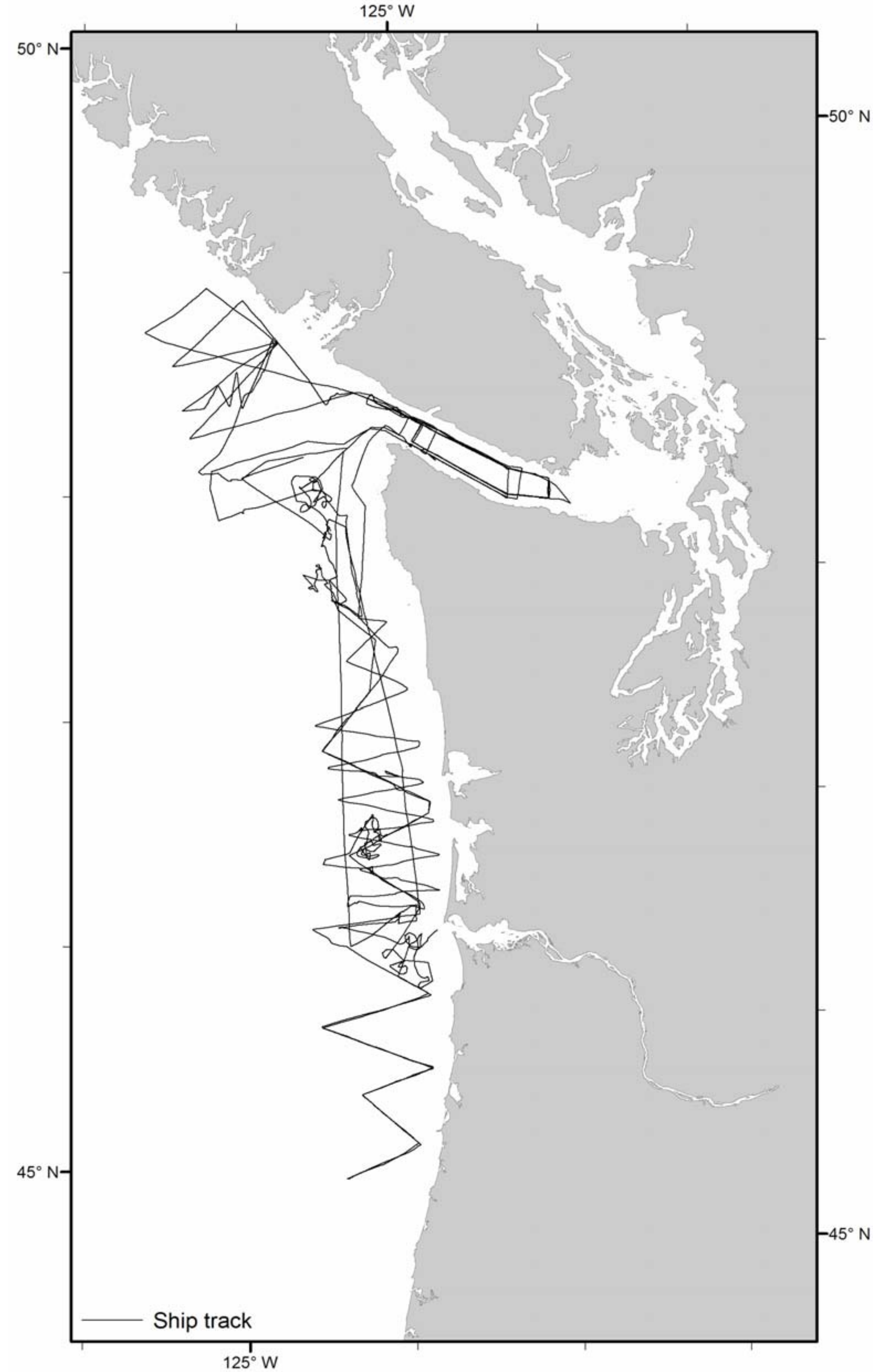

Figure 1. Cruise track of the McArthur II from 14 - 31 March 2006 for PODs 2006.

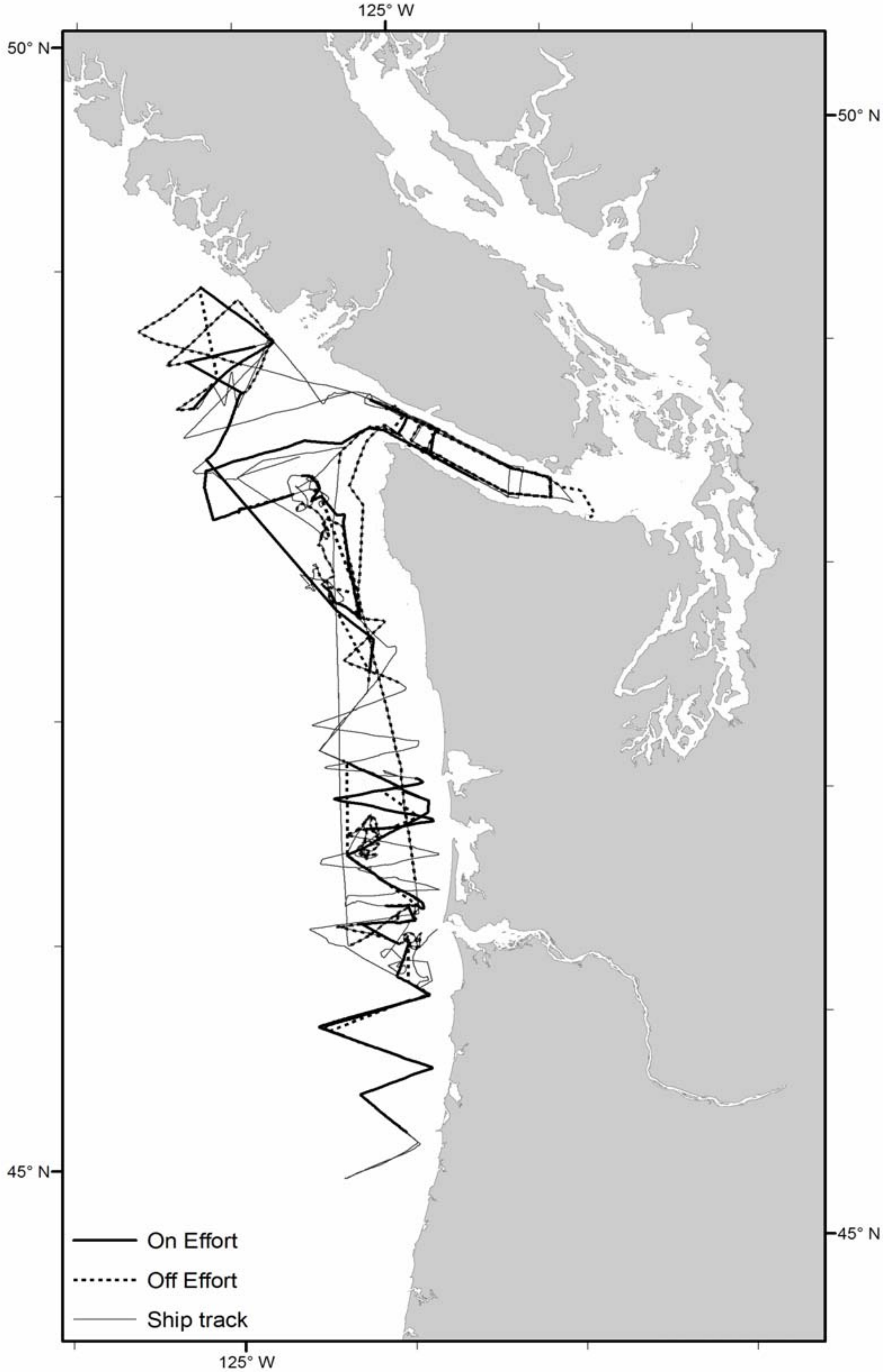

Figure 2. Visual On and Off –effort monitoring of marine mammals from 14-31 March 2006 for PODs 2006

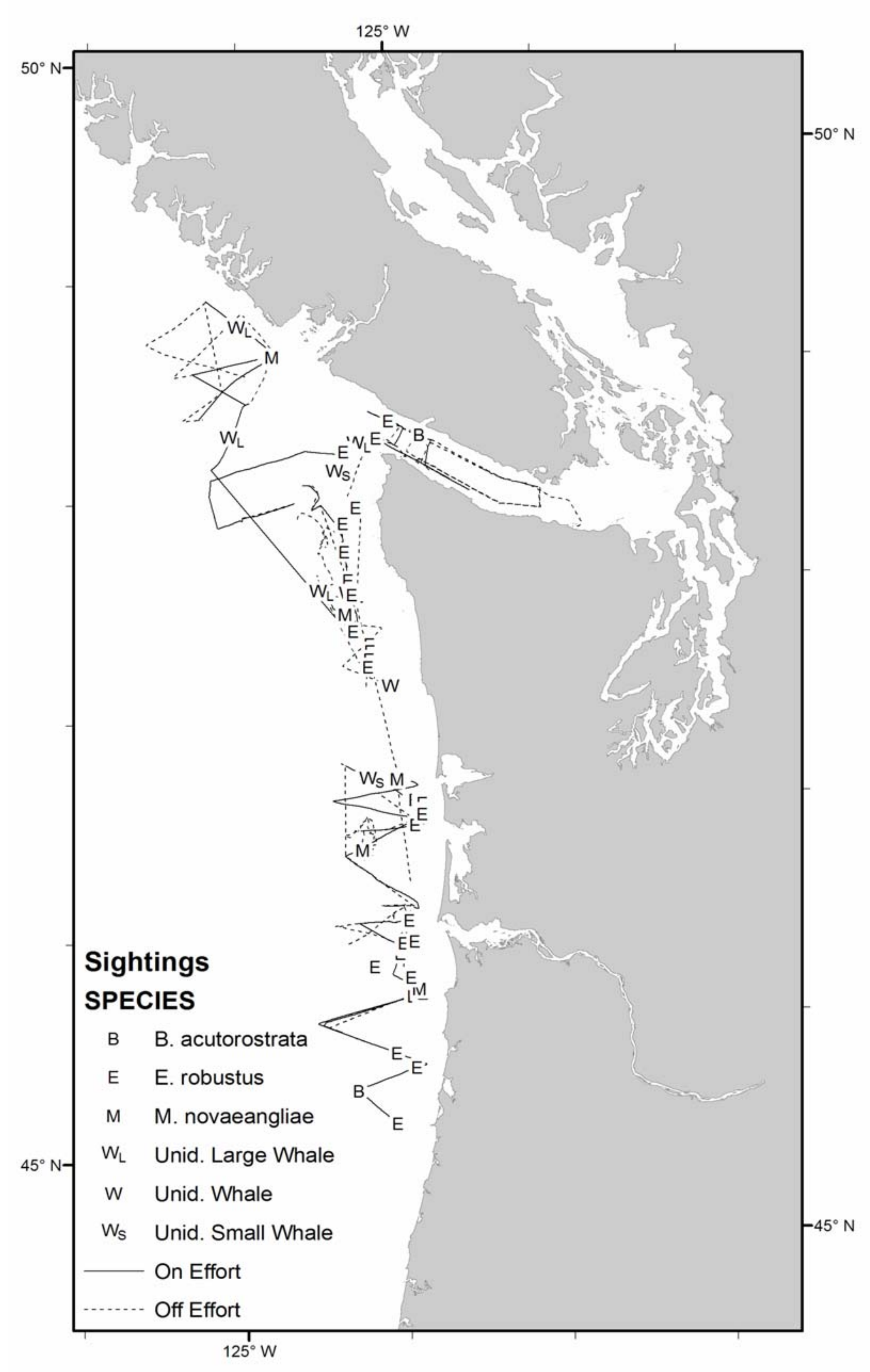

Figure 3. On and Off -effort sightings of baleen whales from 14-31 March 2006 for PODs 2006.

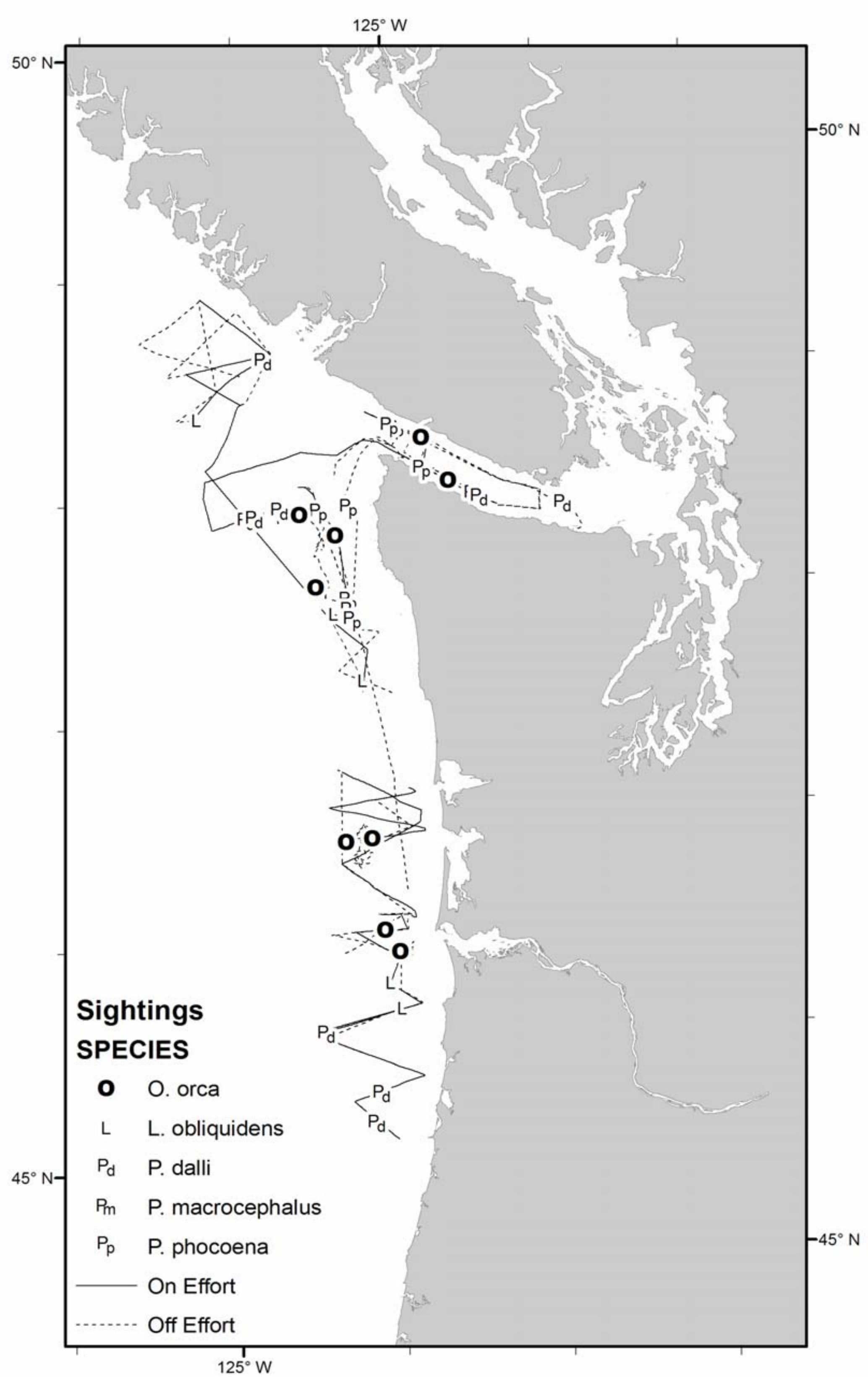

Figure 4. On and Off -effort sightings of toothed whales from 14-31 March 2006 for PODs 2006.

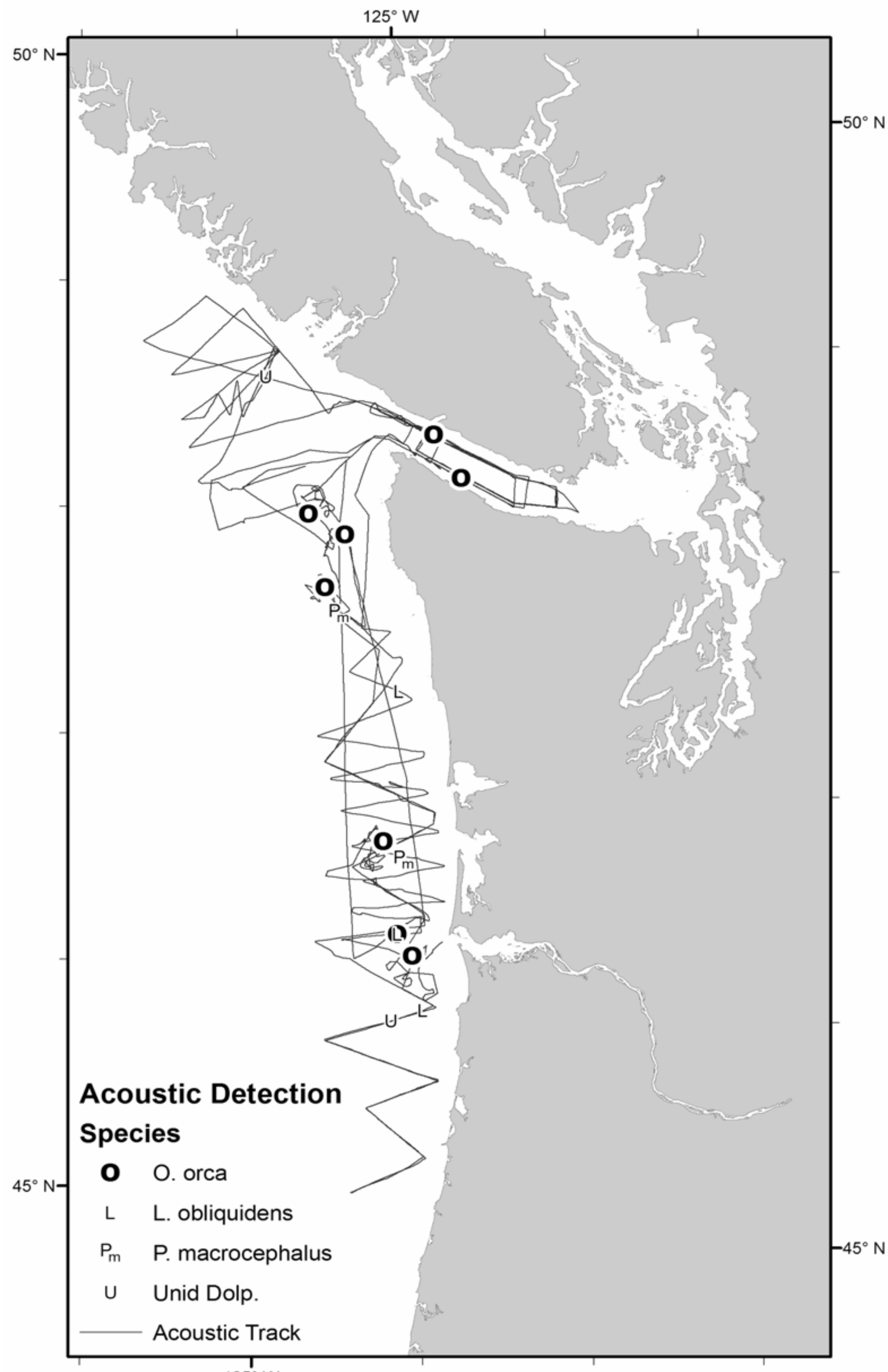

Figure 5. Acoustic detections of marine mammals from 14-31 March 2006 for PODs 2006.

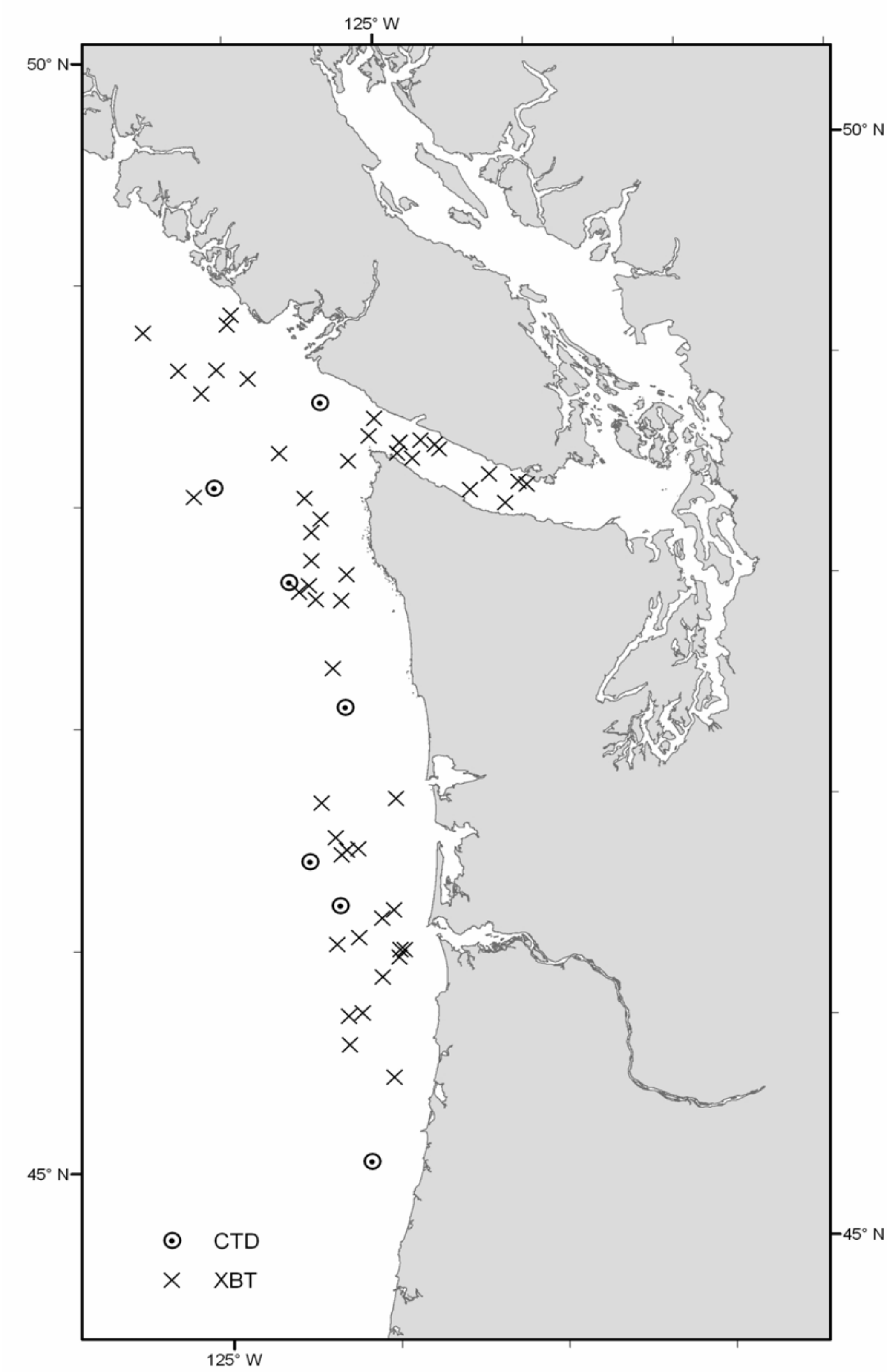

Figure 6. XBT and CTD deployments from 14-31 March 2006 for PODs 2006.