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FINAL REPORT

MARINE MAMMAL RESEARCH AND MITIGATION IN CONJUNCTION WITH AIR GUN OPERATION FOR THE USGS 'SHIPS' SEISMIC SURVEYS IN 1998

Prepared for

U.S. Geological Survey,

National Marine Fisheries Service, and

Minerals Management Service

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A number of people and organizations assisted in the completion of this project. Lisa Schlender, Darcy Bristow, Dianna Lambourn, Jen Quan, and Annie Douglas conducted observations from the *Thompson*. Tamara Gunther, Todd Chandler, Kristin Rasmussen, and Renee Mensing conducted the marine mammal observations from the *Tully*. Joe Evenson, Steve Jeffries, Kristin Rasmussen, Greg Falxa, and Rob Schick conducted the aerial surveys. The Washington Department of Fish and Wildlife provided the aircrafts used for the aerial surveys; Val Jutkins and Steve Jeffries was helpful in setting these up. Dave Bain conducted acoustic monitoring and supplemental observations from the *Tully* and a launch. Mark Pearson and Renee Mensing assisted in this work. The captain and crews of the *Thompson* and *Tully* were extremely helpful throughout the surveys. Mark Sears provided supplemental marine mammal observations of relevance to the project. Joe Evenson, Heather Harding, Todd Chandler, Nicole Stegman, Annie Douglas, Hannah Smith, and Heather Medic assisted in conducting special surveys for gray whales in the study area. Gretchen Steiger helped prepare the report.

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INTRODUCTION

In March 1998, the U.S. Geological Survey, in collaboration with a number of other government and academic institutions, conducted seismic surveys in the greater Puget Sound area to investigate earthquake hazards. The project was named SHIPS (Seismic Hazards Investigations in Puget Sound) and was conducted from 10 to 24 March 1998. The surveys consisted of measuring responses to a towed array of 12-16 air guns with a total volume of 5,500-6,500 cubic inches. Maximum theoretical source levels for such an array were calculated to be on the order of 260 dB (re 1 µP at 1m).

Although seismic tests and other applications of loud low-frequency sound in waters have been used for many years, there has been a heightened concern in recent years about the impacts of these sounds on marine mammals. In the last year for example, the HESS (High Energy Seismic Surveys) team has been organized to evaluate the impacts of seismic exploration primarily off California. This team includes the Minerals Management Service, National Marine Fisheries Service, other regulating state and federal agencies, representatives of the oil industry and fishing groups and environmentalists.

We report here the results of a marine mammal mitigation and monitoring program conducted in conjunction with the SHIPS surveys. This effort was originally designed by the authors in conjunction with USGS and NMFS. The mitigation requirements and safety zones employed in these surveys and reported on here were the result of negotiations between USGS and NMFS and were incorporated into the permit issued by NMFS to USGS for the incidental taking of marine mammals.

OBJECTIVES

The objectives of the study were as follows:

- Mitigate impacts on marine mammals by monitoring the presence of these species from the survey ship and requesting shut-down of the air gun array when marine mammals were seen within specified safety zones representing distances close enough to potentially cause physical injury.

- Mitigate impacts by identifying potentially sensitive areas to marine mammals that should be avoided or surveyed only during daylight hours

- Document the number of animals of each species present in the vicinity of sound transmissions.

- Evaluate the reactions of marine mammals to the sound transmissions at different distances from the air gun array.

- Examine the received sound levels at different distances from the survey ship and examine potential reactions in relation received sound level.

METHODS

General approach

The research effort included a number of components:

1. Observations made directly from the seismic survey vessel (*Thompson*) to provide mitigation, document marine mammals exposed to the air guns, and monitor reactions of marine mammals close to the seismic survey vessel.

2. Observations from a scout vessel (*Tully*) to document the presence of marine mammals farther from the seismic survey vessel and obtain data on reactions of marine mammals to a similar seismic survey vessel that was not firing air guns. The *Tully* had a variety of support roles related to the seismic surveys and therefore its schedule and operations could only partly be designed for marine mammal monitoring.

3. Aerial surveys to document the presence of marine mammals in the study area prior to the seismic surveys and to examine shifts in marine mammal distribution in a small area before during and after passage of the seismic survey vessel.

4. Special small boat operations to make supplemental observations of marine mammals. These included photographic identification of gray whales present in the study area.

5. Acoustic monitoring conducted from a launch deployed from the *Tully* to measure the levels to which marine mammals were being exposed to sound and monitor their reactions. This component was conducted by Dr. David Bain and will be reported on separately from this report (see below).

Observations from seismic and scout vessels

Observations were conducted from the seismic vessel (*Thompson*) 24 hours a day when seismic operations were underway and from the scout vessel during daylight hours (Table 1, Figures 1-13). Six observers were placed aboard the seismic vessel to provide both the mitigation described above and gather data on the species, number, and reaction of marine mammals to the seismic vessel. Three observers were on duty during daylight hours and two during night operations. During daylight observations observers used *Tasco* 7x50 binoculars with internal compasses and reticles to record the horizontal and vertical angle to sightings.

Night time operations and observations were conducted with the aid of two night vision scopes. The primary scope was a mounted thermal imagining scope loaned to the project by the Navy. Two smaller hand-held commerical light magnification scopes were also used. The primary mounted scope was placed at the center of the observation deck and was used to scan forward and to the sides. A second observer used the smaller scopes to alternately search the area close to either side of the ship that was blocked from view of the center-mounted scope.

Four marine mammal observers plus the acoustical monitoring personnel worked on board the scout vessel (*Tully*) during daylight operations. These provided information on sightings of any sensitive species in the area, reactions of marine mammals to the survey vessel at larger distances, and provide data on sighting rates and behaviors of marine mammals to compare to those from the seismic vessel.

Data on survey effort and sightings from both the survey and scout vessel were recorded on one similar data sheet. These included information to track survey effort including observers on duty and weather conditions (Beaufort sea state, wind speed, cloud cover, precipitation, visibility, etc.). For each sighting, the time, bearing and reticle reading to sighting, species, group size, surface behavior, and orientation were recorded.

The vertical angle to the animal was based on the reticle reading and the distance above the water were used to evaluate whether a sighting was within the safety zone.

Mitigation safety zones

Three safety zones were proposed by USGS and were incorporated into NMFS's permit for this project. These were:

1. For pinnipeds, seismic operations would be shut down when a pinniped was seen close to a distance of 100 m. A provision was also made for all pinnipeds (except Steller sea lions), allowing continued operations if the pinnipeds were deemed to have actively approached the survey vessel on their own.

2. For odontocetes (toothed cetaceans), the safety zone was 200 m

3. For mysticetes (baleen whales), the safety zone was 500 m

These safety zones were based on potential received levels by marine mammals, so the distances were interpreted as indicating distance from the center of the array. Because the observers were located on the seismic vessel, well ahead of the array being towed behind the vessel, determining the distance from the sighted marine mammal to the array was complicated. We calculated the distance marine mammals were from the array using the distance of the sighting from the observer to the marine mammal and the angle off the ships orientation to the sighting. For each angle, a cut-off distance was calculated representing the three safety zones.

Observers were instructed to call for a shut-down when a marine mammal was seen inside the safety zone or close enough to the safety zone that given measurement error it could be within the safety zone. Shut-down was also considered when animals were ahead of the vessel path outside the safety zone but it appeared likely the direction of travel of the vessel would result in their shortly being within the safety zone.

For effective mitigation, the observers needed to know very quickly whether a sighting was within the safety zone. We used a board with an arrow for observers to estimate the angle to the sighting. Also on this board was the cut-off vertical angle which represented each of the

safety zones, allowing a quick determination of whether a sighting was close to the safety zone. After use in the initial portion of the survey, a new system was designed to provide a greater measure of safety for animals ahead of the vessel and also to allow more rapid determination of whether a shut-off was warranted. This new system is discussed in detail in the results (see also Table 2) and was utilized starting on 15 March.

Mitigation during operations within Canadian waters was also modified slightly as a result of both negotiations with the Department of Fisheries and Oceans (DFO) and the requests of a DFO observer that was placed on the vessel. These changes are discussed in Results.

Acoustic monitoring

Acoustic measurements were made primarily from a launch deployed from the *Tully* in conjunction with the surveys. These provided direct measurements of the levels to which marine mammals were being exposed to sound. In addition to measurement of received levels at different distances from the seismic survey ship, measurements were also made near marine mammals in conjunction with observations of their behavior.

The acoustic component of the research is being conducted by Dr. David Bain. Results of this component were not yet available at the time of this report. Results of this work will be provided in a separate supplemental report.

Aerial surveys

Three aerial surveys were flown: one prior to the seismic operations and two during the operations (Table 3, Figures 14-16). The number of aerial surveys flown was less than anticipated because of problems obtaining permission to fly surveys in Canadian airspace and cancellation of several flights due to poor weather.

The initial aerial survey was conducted on 6 March 1998 and searched most of the entire study area to identify species present and potential sensitive areas. The second and third flights were conducted on 11 and 12 March and involved repeated surveys of the region immediately around the seismic operations.

Surveys using ship's launches

Special surveys using ships launches were conducted in several areas. Primary activities included:

- Making observations of gray whales migrating past the west entrance to the Strait of Juan de Fuca when seismic operations were conducted in this area.
- Documenting the presence of "summer-resident" gray whales primarily near Whidbey Island and obtaining identification photographs of individual animals using the area (see section on photographic identification below).
- Sampling marine mammal distribution and abundance by traveling the route of the seismic vessel (approach-mode observations)

Photographic identification of gray whales

Gray whale photographic identification was conducted whenever possible after gray whales were sighted using launches from the *Thompson* and *Tully*. Cascadia's 5.3m RHIB was also for some additional surveys immediately after the end of the seismic surveys. Gray whale photographic identification was based on tracking individual animals using photographs of distinctive markings on both the left and right sides of the dorsal region around the dorsal hump. This is a method that has been used successfully in past research on gray whales in Washington State (Calambokidis *et al*. 1994, Calambokidis and Quan 1997) as well as in other regions (Darling 1984).

Ilford HP-5 negative film was shot using 35mm cameras with 300mm f4.5 lenses. We also photographed the ventral surface of the flukes for identification when possible. From the photographs, individuals could be distinguished by comparing the natural markings around the dorsal region of the whale. The markings included pigmentation of the skin, mottling, scarring, and barnacles, which varies between individuals. The negatives of gray whales were examined and the best shot of the right and left sides of whales (for each sighting) selected and printed (7 by 2.5 inch). To determine the number of whales seen during the season, the prints were then compared to one another to identify whales seen during multiple days. Each individual whale was then compared to the catalog of gray whales photographed off Washington in previous years.

Data processing

Data acquired from the *Thompson*, *Tully*, and aircraft data were entered in to *MS-Excel* files and error checked. Clinometer angles and binocular reticle angles collected from the *Thompson* were changed to 0.2 and 4.8 when the minimum and maximum values reported by observers were 0 or 5, respectively.

Checks of orientation (*i.e*., right, left, away and towards) for each marine mammal sighting were made by comparing the "observer-assigned orientation" with the "calculated orientation". Calculated orientation was derived by multiplying the observer-assigned "travel" direction (*i.e*., hour of the clock, with 12 o'clock being equal to animal(s) that are paralleling the ship's course) by 30 and subtracting the bearing to the sighting (*i.e*., 0 or 360 degrees being equal to a sighting located off the bow of the ship). These calculated values ranged from approximately -200 to + 400 degrees and were subsequently grouped in to 4 categories based on their relative orientation to the ship (e.g., away=-45 to +45 degrees, right=+45 to +135, etc.). The orientation for a given sighting was compared for "perfect" agreement (e.g., observer left=calculated left) and "satisfactory" agreement (*e.g*. observer travel direction=any but the exact opposite direction).

The results of the comparisons were encouraging with rate of agreement exceeding 75% for the "perfect agreement" category and 100% for the "satisfactory category". Of the sightings between the observer-assigned and calculated orientation and was generally found to exceed 75% in all observers from both the *Tully* and the *Thompson*.

RESULTS

Modifications to the safety zones and shut-down criteria

The distances used for shut-down were modified slightly in the field in consultation with USGS personnel beginning 15 March. These changes were made for two reasons:

1. The system for determining whether an animal was approaching the safety zone, remained somewhat cumbersome and could delay calling for the shut-down. Not until both the vertical angle and horizontal bearing to the sighting was determined and looked up on a matrix table or the values on the angle board could it be determined if the sighting was within the safety zone.

2. Because distances for the safety zone were from the array, a sighting directly ahead of the vessel would need to be considerably closer to the vessel to be within the array safety zone. A pinniped directly on the course of the boat would not be within the 100 m safety zone until it was almost under the bow of the ship. This was problematic because most seals would dive before allowing a vessel to be so close and therefore would out of sight of the observers but not necessarily out of danger.

To deal with these problems and add a greater measure of safety, the zones were expanded to be both simpler to use and to extend farther from the array along the intended path of the ship. Instead of a matrix of cut-off distances based on every possible sighting angle, angles were grouped into three categories: 1) those ahead of the vessel (0-60 degrees off the ship's course), 2) those to the side of the vessel (60-120 degrees off the ship's course), and 3) those behind the ship (120-180 degrees off the ship's course). Within each of these zones a single vertical angle was computed that completely encompassed the old safety zone and extended the safety zone out in front of the ship, instead of just around the array (Table 2).

Mitigation within Canadian waters

The initial plan was to these employ safety zones in both U.S. and Canadian waters. Some confusion emerged about the status of the permit for operations within Canadian waters (handled by the Department of Fisheries and Oceans, DFO); despite original DFO approval of the operations, the plan was not reviewed by the marine mammal program personnel within DFO. This resulted in additional negotiations with DFO during the surveys to develop a marine mammal mitigation procedures within Canadian waters that were acceptable.

Mitigation and shut-down procedures within Canadian waters were more complex and somewhat ambiguous. The guidelines provided by DFO included a request to avoid a number of areas near large pinniped concentrations and shutting down operations when marine mammals were seen within 3 nautical miles (nmi) of the seismic vessel. Additionally, a DFO observer was placed aboard the seismic vessel and provided guidance on when to shut-down due to proximity of marine mammals. The observers continued the monitoring effort when in Canadian waters and enforced the NMFS guidelines as a safety precaution.

Shut-downs for marine mammal mitigation

Seismic operations were requested to be shut down on five occasions related to the presence of marine mammals (Table 4). Three of these were because animals (minke whale, California sea lion, and Steller sea lion) were in close proximity to the seismic vessel. In only the case of the minke whale was the initial sighting actually inside the NMFS-designated safety zone. The California sea lions were slightly outside the zone but because they were ahead of the vessel, it was deemed there was a good chance they might shortly approach the 100 m of it. The Steller sea lion was the only proximity shut-down made using the new safety zones employed after 15 March; the shut-down was called for when the sighting was 112 m away from the observers.

The two additional times that the operations were shut down related to marine mammals were not due to the proximity of animals but were decided upon in consultation with USGS personnel and made as an extra precautionary step. The first instance was when the seismic vessel was at the mouth of Carr Inlet and was preparing to head north into the inlet. Because this was a narrow inlet with a known large concentration of harbor seals, it was decided to shut down while headed into the inlet and only conduct seismic operation while exiting the inlet, to avoid any danger of trapping animals without a means of escape. A precautionary shut-down was also conducted at night while returning southbound down Saratoga Passage. Gray whales had been seen at the south end of the passage that day and this has been an area frequently used by gray whales previously. Thus, the shut down avoided conducting seismic operations in this area at night when observer visibility was limited.

All five shut-downs were within U.S. waters. On one occasion while in Canadian waters, a harbor seal was seen within 100 m of the observers and just over 100 m from the center of the array. Normally this would have resulted in a shut-down but the DFO observer specifically advised against shut-down in this situation. By the time this confusion was resolved, the ship had already passed the location of the sighting, although the harbor seal was not resighted. Despite the DFO observer not feeling that a shut-down was warranted, the observers confirmed their strategy that should the situation arise again, that the NMFS requirements should be used as a minimum and that the DFO observer could request additional shut-downs as necessary. No shut-downs were requested by the DFO observer on board.

Aerial surveys

The initial aerial survey flight on 6 March 1998 covered a broad portion of the study area and resulted in 205 sightings of 862 marine mammals (Table 5, Figure 14). Six different species were seen; four pinnipeds and two small cetaceans. The majority of the sightings (72%) were of harbor seals (Table 5) and although they were seen throughout the study area, the highest densities occurred in southern Puget Sound (Case and Carr Inlet) and in northern Puget Sound, especially in the Port Susan area (Figure 14). California sea lions were also frequently seen (15 sightings) with most sightings in central and northern Puget Sound. Of the eight Steller sea lion sightings, most were made in the Strait of Juan de Fuca and Strait of Georgia. Three sightings were made of elephant seals hauled out on Protection and Minor Islands in the Strait of Juan de

Fuca. Sightings of harbor and Dall's porpoise were frequent and were primarily in the Strait of Juan de Fuca, Strait of Georgia, and San Juan Islands area.

Aerial survey flights conducted on 11 and 12 March 1998 repeatedly surveyed the two areas with the highest concentrations on pinnipeds on the scouting flight (portions of southern and northern Puget Sound). These surveys were designed to be conducted during the time period that the seismic survey ship was operating in these areas. The difficulty in coordinating the exact timing of the aerial survey during optimum daylight conditions (along with the availability of aircraft, pilot, and observers) and the seismic survey ship in the proper area made it hard to obtain the samples at the optimum times and locations. The survey on 11 March in southern Puget Sound yielded 68 sightings of harbor seals on the two passes made over the area, however, most of the sightings were made prior to passage of the ship through the area (Figure 15). A similar situation occurred on 12 March, when the aerial survey made three passes of an area of high harbor seal density in northern Puget Sound, but most of the sightings were in an area that was still ahead of the ship's path by the end of the survey. Limitations in the availability of the survey aircraft and pilot prevented extending the flights later.

The distribution of harbor seals seen on the three aerial survey passes covering the areas transited by the seismic survey ship on 12 March did not noticeably change from before to after the passage of the *Thompson* (Figure 16). Only a small proportion of the sightings can be compared, but these indicate the presence of harbor seals near the trackline after passage of the boat. In the region transited by the vessel from 1044 to 1310, for example, three sightings of harbor seals were made within about 3 km of the ship trackline, all after passage of the ship. The one indication of a possible shift in harbor seal presence is at the entrance of Port Susan where harbor seal density was highest. A large concentration of animals right at the entrance to the bay seen on the first two passes, was not present on the third pass when the vessel is in that area.

Additional flights which were planned were not conducted due to two factors. Further surveys were not allowed in Canada at the request of the Department of Fisheries and Oceans and weather conditions were not suitable for flying on several days when flights were scheduled after operations returned to U.S. waters.

Sightings made by vessel

Eight species of marine mammals were sighted from the *Thompson* during the surveys (Table 6, Figures 2-7). Harbor seals, California sea lions and Dall's porpoise were most frequently sighted. There were a total of 498 sightings of 1,326 animals. There were also 193 resightings of marine mammals. Sightings at night were far less common than in the day and consisted primarily of hauled out pinnipeds that could be seen with the thermal night scope.

There was a similar distribution of sightings from the *Tully* (Table 7, Figures 8-13). During daylight operations from the *Tully,* 360 sightings of 564 animals of seven species were made with an additional 30 resightings. The mix and proportion of sightings by species from the *Thompson* and *Tully* were similar to each other and to aerial surveys.

Distances that animals were sighted

The initial sighting locations of marine mammals in relation to the survey platform varied by species, survey platform, day/night, and whether air guns were operating (Table 8). These generally indicated that although sightings made from the *Thompson* were generally closer to the ship than those from the *Tully* due to viewing conditions, operation of the air guns did result in sightings being farther from the *Thompson*.

Sightings made from the *Tully* were generally at greater distances than from the *Thompson* (regardless of whether air guns were operating or not). This is apparent from the average sighting distances (Table 8) as well as from the plot of sighting locations in relation to the vessel (Figures 17-18). Locations of sightings made from the *Tully* also included a greater proportion initially made behind the vessel (Figure 18).

The greater distances at which sightings were made and higher proportion behind the vessel are likely the result of differences in the viewing conditions from the two vessels. Most of the observations from the *Tully* were made from the flying bridge which provided almost complete visibility in all directions and was considerably higher (17.5 m including eye height) than the primary observation platform from the *Thompson*. The primary observation area aboard the *Thompson* provided a view about 11.8 m above the water line and did not allow good visibility to the rear due to the superstructure.

Sighting distances from the *Thompson* did not show any large area with a clear absence of sightings and the presence of sightings close to the vessel did not appear to differ from the *Tully*. Nevertheless, sighting distances from the *Thompson* tended to be greater when seismic operations were underway than when they were not. Sightings distances for all species (pooled) were significantly greater from the *Thompson* when seismic operations were underway than when they were not (t-test, $p<0.001$). The same pattern of greater distances during seismic operations was also significant for two of the common species: harbor seals and California sea lions (t-test, $p<0.05$ for both cases).

Sightings during night time operations were limited and consisted primarily of hauled out pinnipeds. Of 51 sightings made during night operations, 34 where of hauled out pinnipeds and the rest of pinnipeds in the water. The thermal/infrared scope used for night observations was extremely effective in sighting the warm bodies of hauled out pinnipeds. These stood out dramatically and were easier to see far away than using conventional means in the daytime. For this reason the distance at which sightings were made at night were on average greater than those during the day. The 34 sightings of hauled out animals averaged 1,661 m away compared to only 561 m for sightings made at night of animals not hauled out. Six of the 17 sightings of non-hauled animals made at night were at dusk (1800-1900).

Orientation behavior of animals seen

There were patterns in the orientation in relation to the vessel for the most commonly seen species (Table 9). In most cases, marine mammals were most likely to be oriented away from the survey platform when sighted or resighted. This was the case for all three common species (harbor seal, California sea lion, and Dall's porpoise) for both vessels whether seismic operations were underway or not. In general, marine mammals were almost twice as likely to be oriented away from the survey platform than towards it. Marine mammals tended to be oriented away even at distances greater than 500 m. Some of this pattern may be the result of observer bias tending to score an animal as heading away rather than towards the survey vessel, since it was such a consistent a finding. The result is somewhat surprising for Dall's porpoise which generally have a reputation for approaching vessels. Marine mammals tended to be oriented away from the *Thompson* (whether air guns were operating or not) to a greater extent than was the case with sightings from the *Tully*.

Sightings from the *Tully* were also examined for their orientation to the *Thompson* when air guns were firing (Table 10). This suggested that sightings of the most common species were moving away from the *Thompson* even when it was miles away. Dall's porpoise were more than twice as likely to be moving away from the *Thompson* than toward it at distances of 2 to 10 nmi. This same pattern was true for harbor seals and California sea lions. Only at distances of greater than 10 nmi did the proportion of animals heading toward the *Thompson* become similar to those heading away.

Gray whale photographic identification

Five photographically identified gray whales were tracked over the course of the study (Table 11). All of these were in northern Puget Sound around the south end of Whidbey Island. Photographic identification of these animals was made from launches deployed from the *Thompson* and *Tully* and Cascadia Research's RHIB. We received a report from a member of our sighting network of a whale in Useless Bay on 12 March, a day that the *Thompson* was firing and operating in northern Puget Sound in Port Susan and Saratoga Passage. A launch was deployed and two gray whales were found and identified off Possession Point within about a nautical mile of where the ship had passed earlier in the day.

These whales likely arrived into the Whidbey Island area during the time of the SHIPS surveys. March is usually when Cascadia receives initial sighting reports of gray whales from this region. The 12 March sighting was the first reported in 1998 from the south Whidbey Island area. There had been occasional sightings reported sporadically over the winter from other parts of Puget Sound, including sightings of gray whales off the west side of Whidbey Island in the Strait of Juan de Fuca on 5 March.

Four of the five whales identified during the study were known individuals that had been identified in this region in past years through 1990 (IDs 21 & 22) and 1991 (IDs 49 & 56) (Calambokidis *et al*. 1994). These whales typically stay until May or June. Sightings during and after this study revealed that four of the five whales remained in the northern Puget Sound area until at least mid-April, well after the end of the seismic surveys on 24 March.

Sighting reports from other sources

In March 1998 during the seismic surveys, Mark Sears a long-time marine mammal observer based at Point Williams in West Seattle just south of Alki Point, made some interesting observations of Dall's porpoise potentially related to the seismic surveys. He had been seeing Dall's porpoise regularly off Point Williams from January to early March typically in groups of 5 to 8 animals. On 11 March, however, he saw an unusually large number of groups. Between 1400 and 1700, he saw five separate groups of five to eight animals pass Point Williams all headed north. On 12 and 13 March, no animals were seen in the area, which was somewhat unusual for the period. From 14 to 19 March he again saw Dall's porpoise on most days. They were again absent from 20-26 March.

These observations may indicate a broader regional response of Dall's porpoise to the air gun operations. The seismic vessel began air gun operations early on 11 March off Seattle and then proceeded south and continued operations in southern Puget Sound all that day, returning past Seattle early on 12 March. Dall's porpoise were repeatedly seen during these operations in southern Puget Sound on 11 March and off Whidbey Island on 12 March. If these movements were linked to the seismic operations (which is not possible to be certain), it may have been possible that animals left the area during operations and returned a few days after operations ended in the area.

Although killer whales were not sighted on any of the vessel or aerial surveys, they were present in the study area. Sightings of killer whales were reported in the San Juan Islands during the course of the study. Additionally, killer whales were also in Puget Sound during the surveys. Mark Sears reported seeing J pod at 1725 on 15 March between Pt. Williams and Blake Island. This is shortly after the *Thompson* completed the first leg of surveys in Puget Sound.

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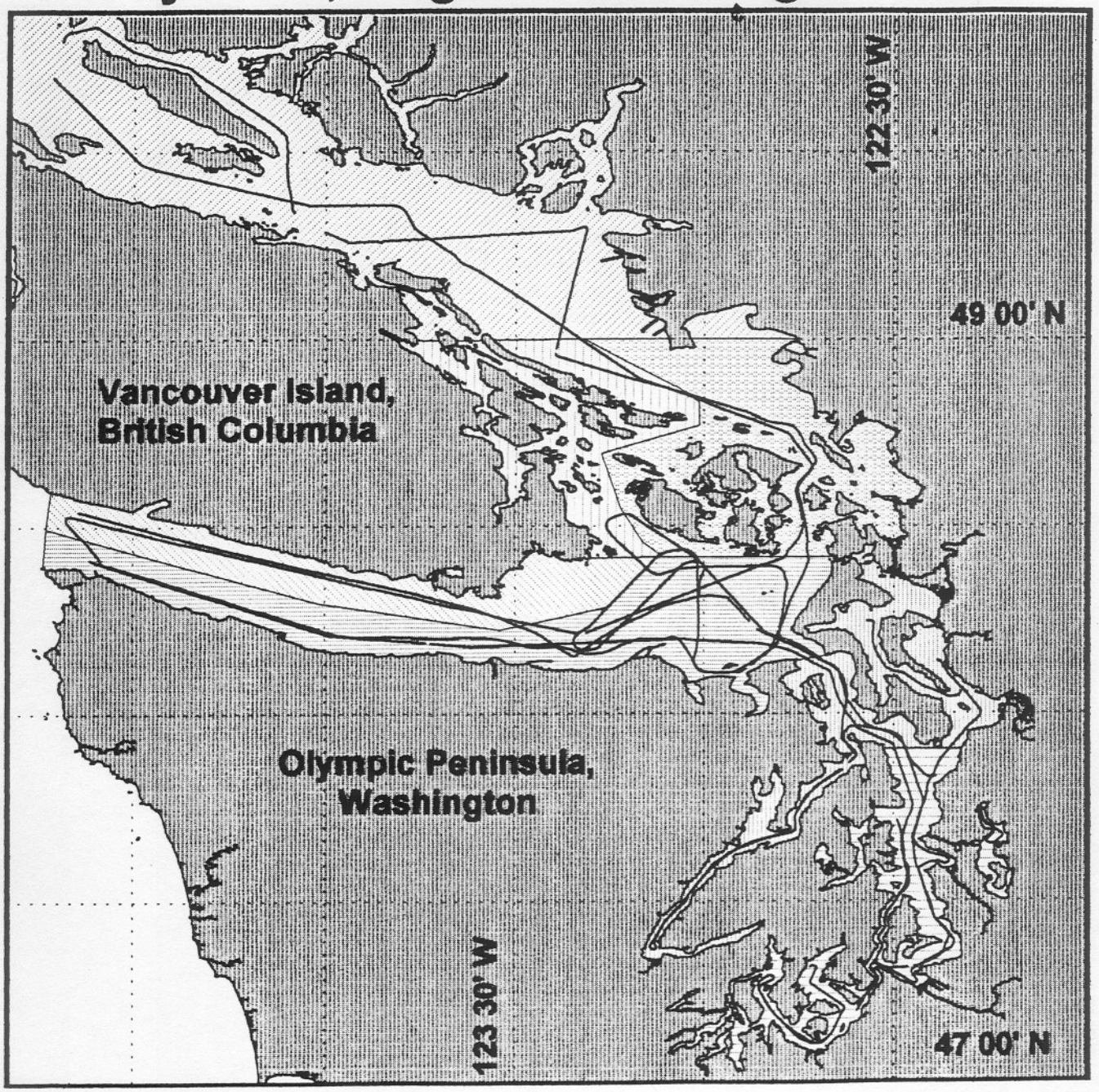
Study Area, Regions and Airgun Shots



0 40 Kilometers

N
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Multiple airgun shots from the Thomas G. Thompson

Regions

- Puget Sound, proper
- Admiralty Inlet, Hood Canal
- US Strait of Juan de Fuca
- Canadian Strait of Juan de Fuca
- US San Juan Islands
- Canadian Gulf Islands
- Strait of Georgia

Figure 1

Pinnipeds Sighted from the Thomas G. Thompson

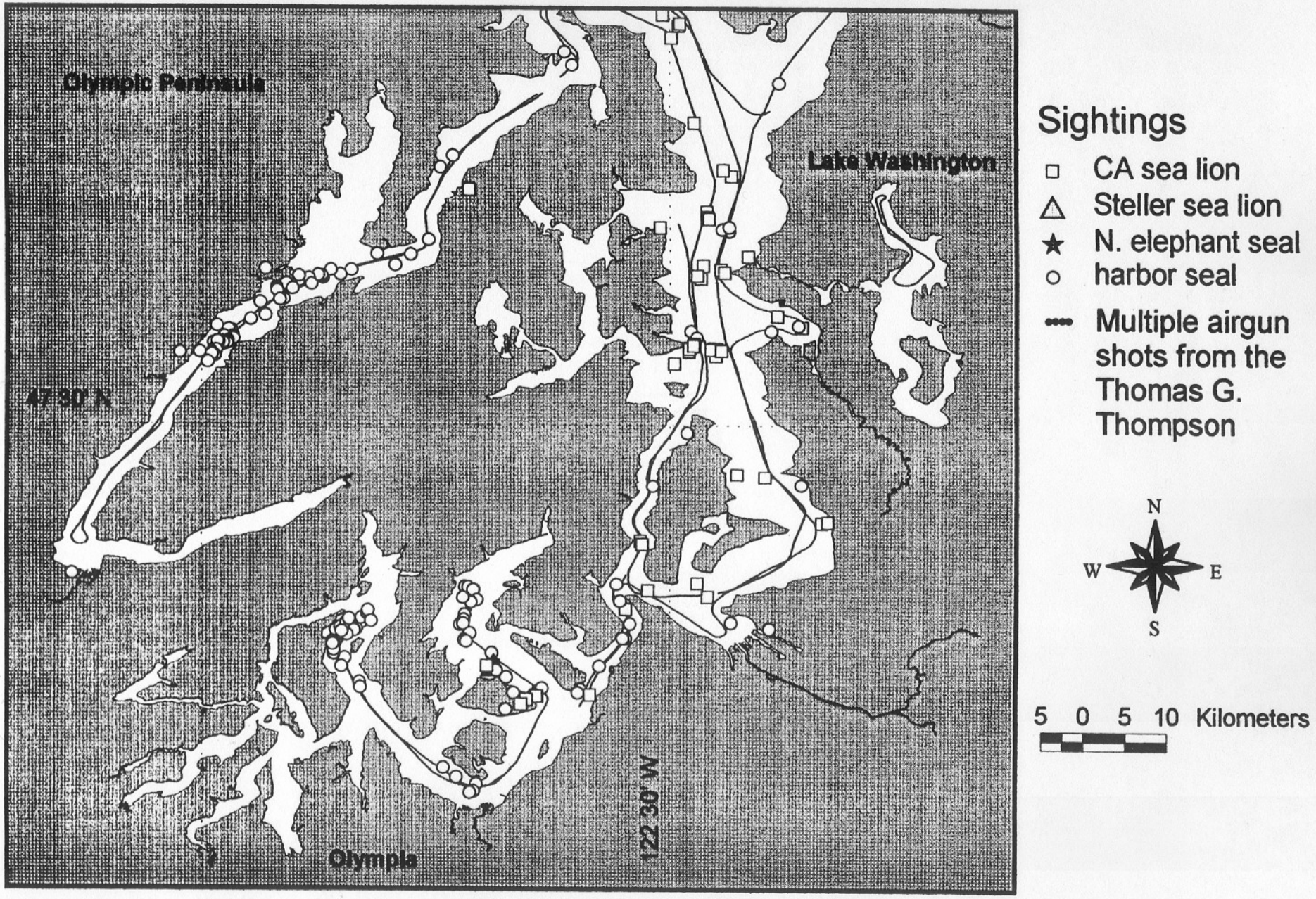


Figure 2

Cetaceans Sighted from the Thomas G. Thompson

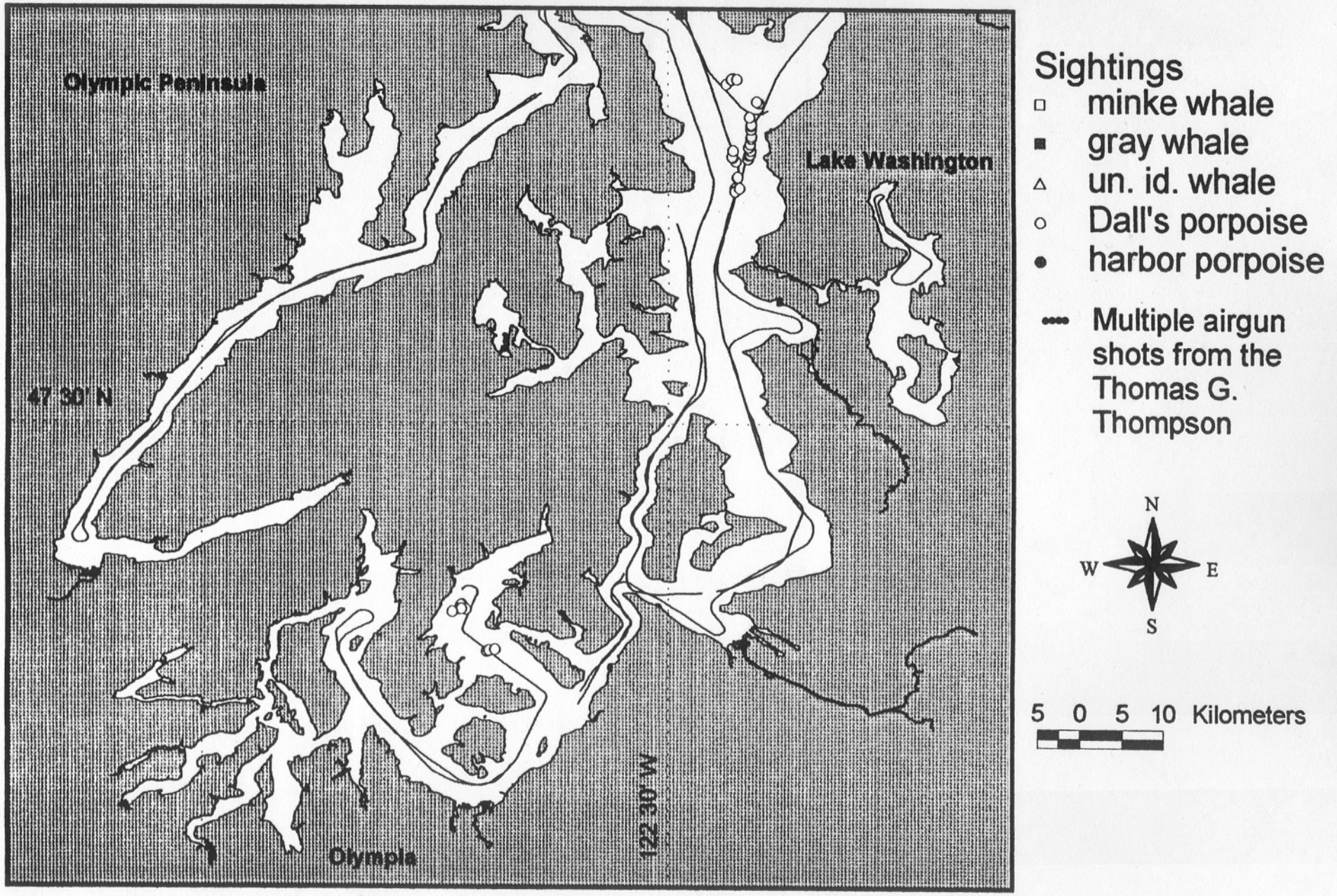


Figure 3

Pinnipeds sighted from the Thomas G. Thompson

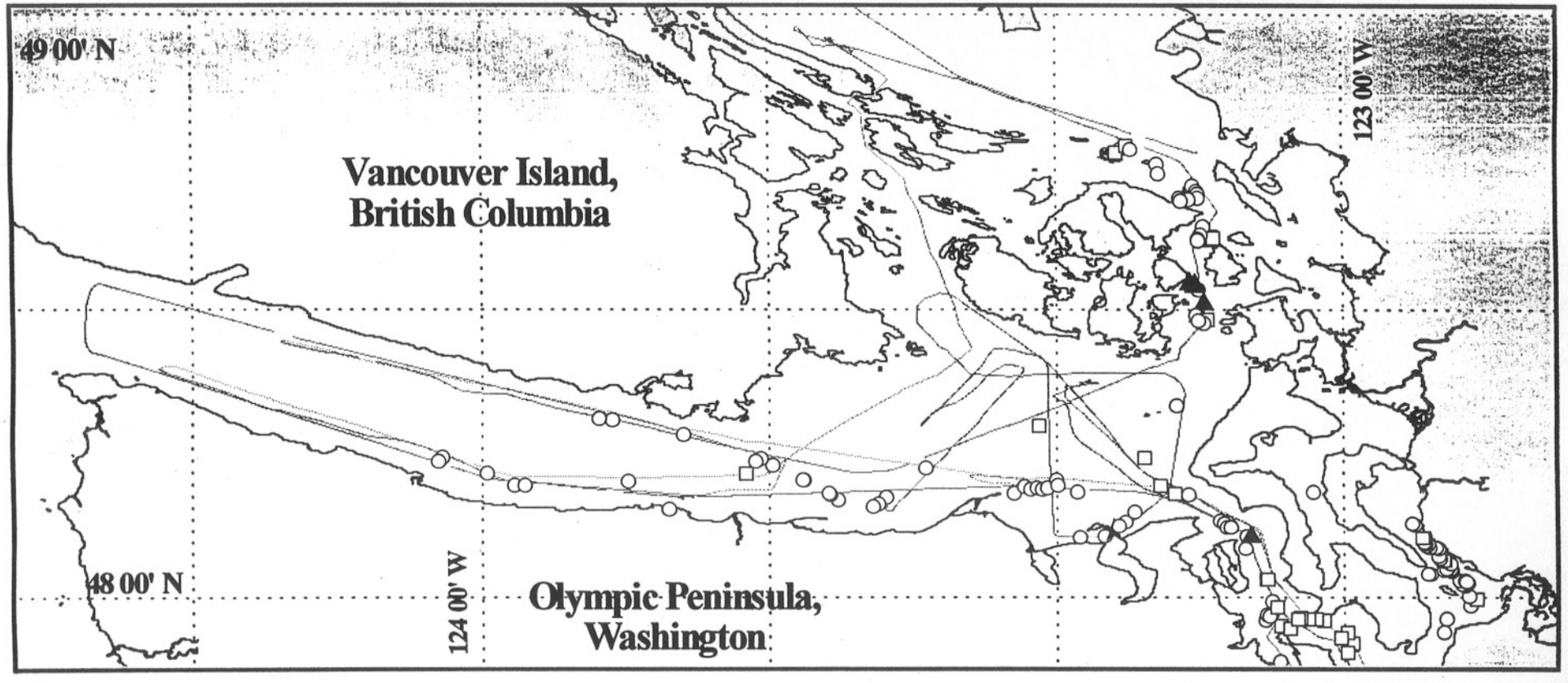


Figure 4

Cetaceans sighted from the Thomas G. Thompson

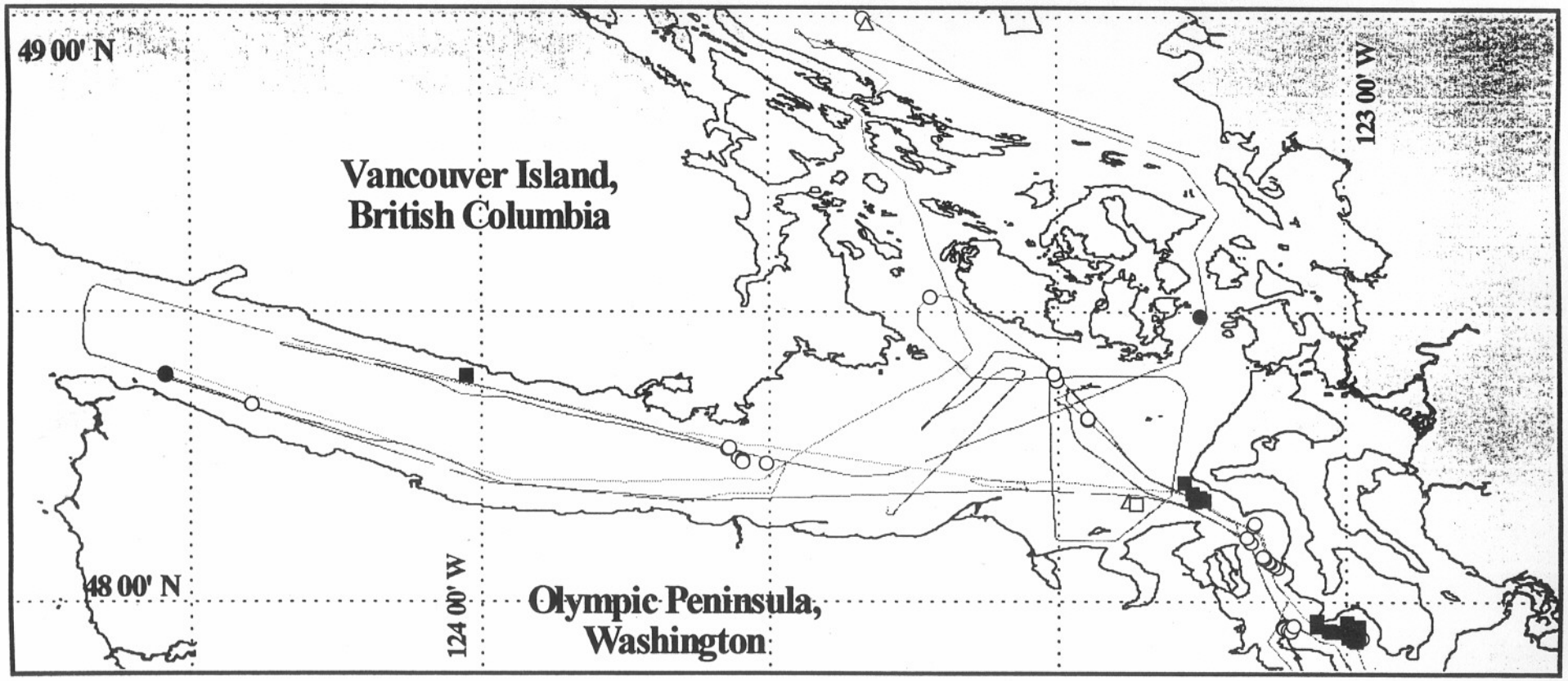


Figure 5

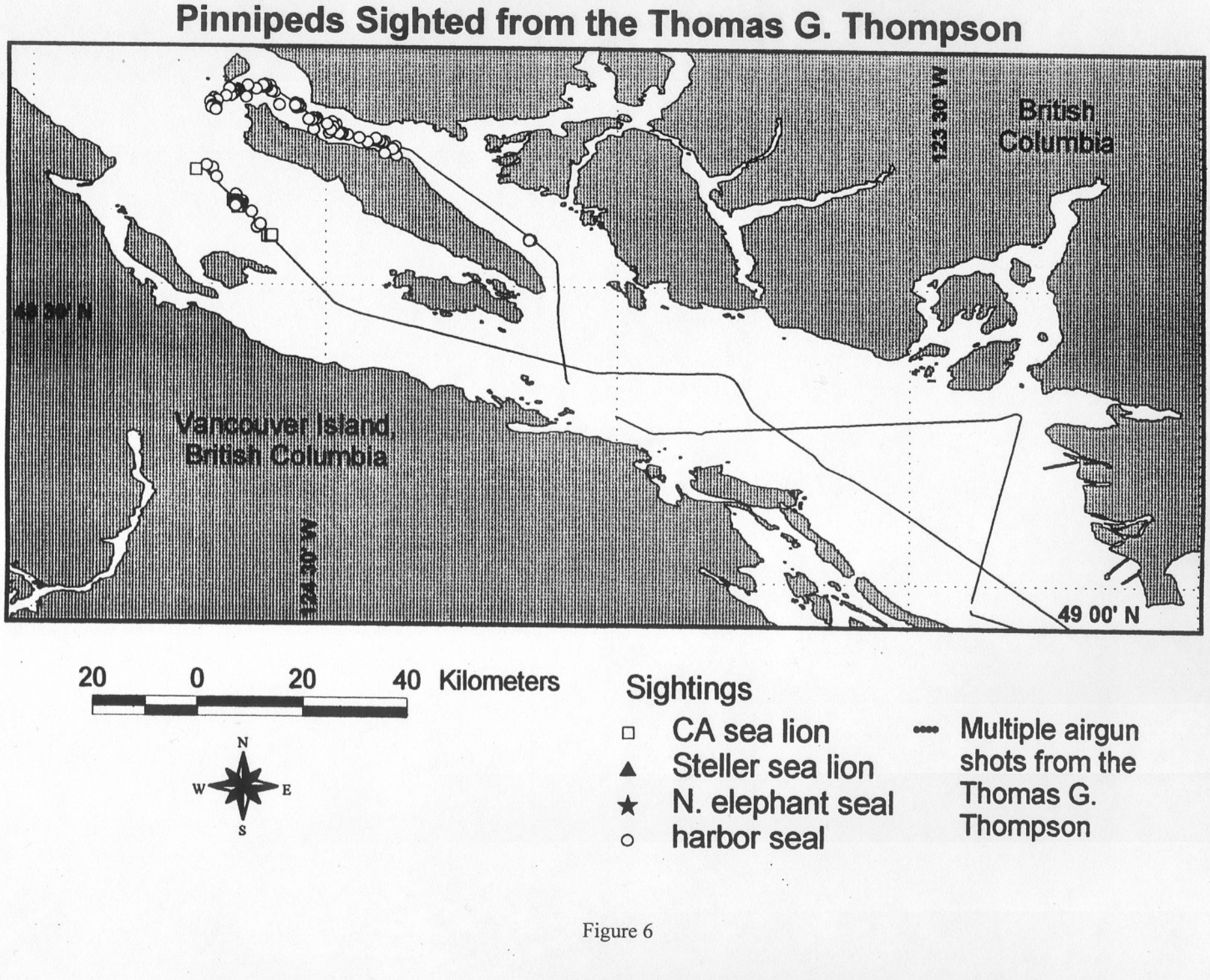

Pinnipeds Sighted from the Thomas G. Thompson
British Columbia
123 30' W
Vancouver Island, British Columbia
49 00' N
20 0 20 40 Kilometers
N
W
E
S
Sightings
CA sea lion
Steller sea lion
N. elephant seal
harbor seal
Multiple airgun shots from the Thomas G. Thompson

Figure 6

Cetaceans Sighted from the Thomas G. Thompson

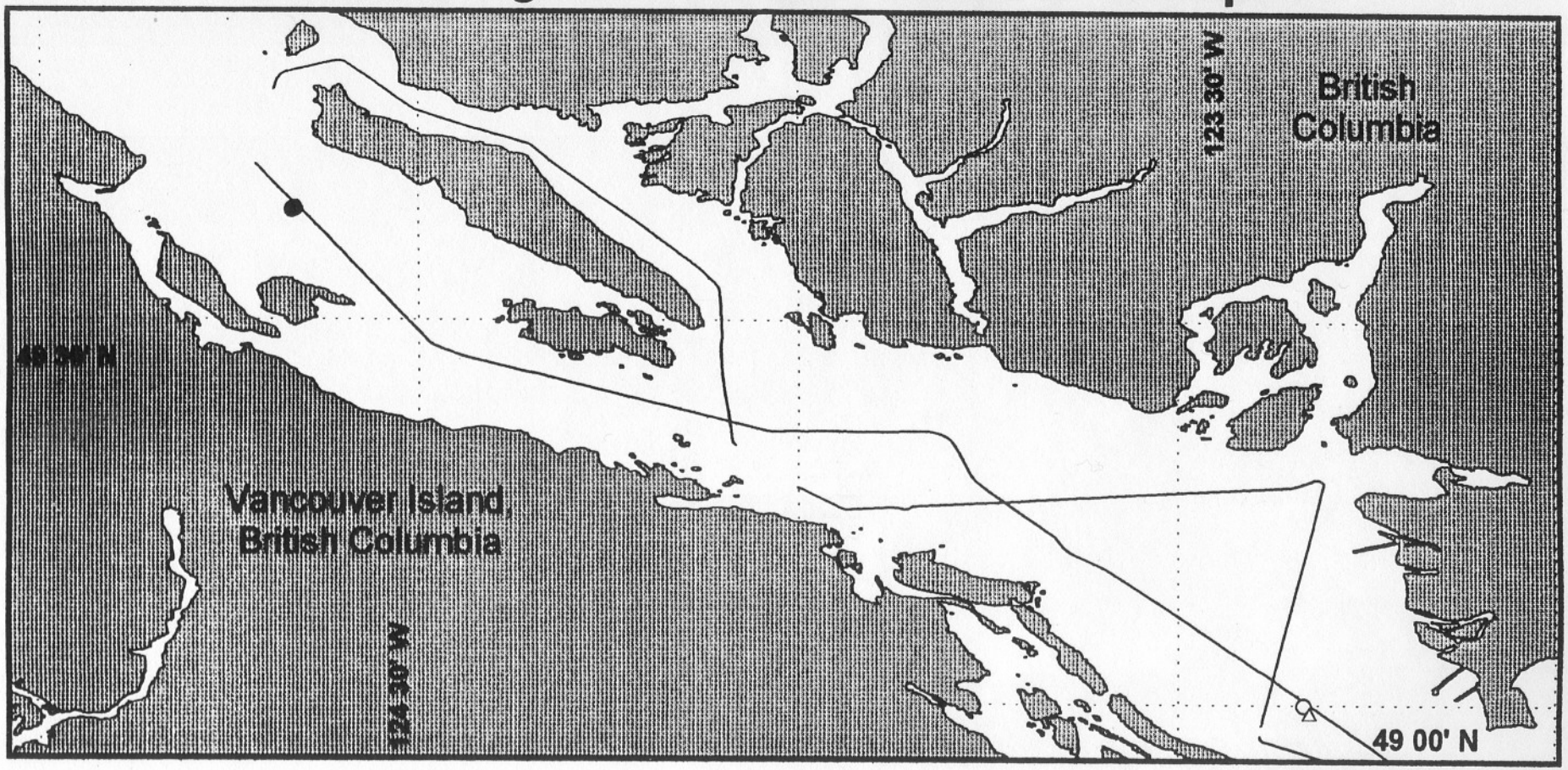


Figure 7

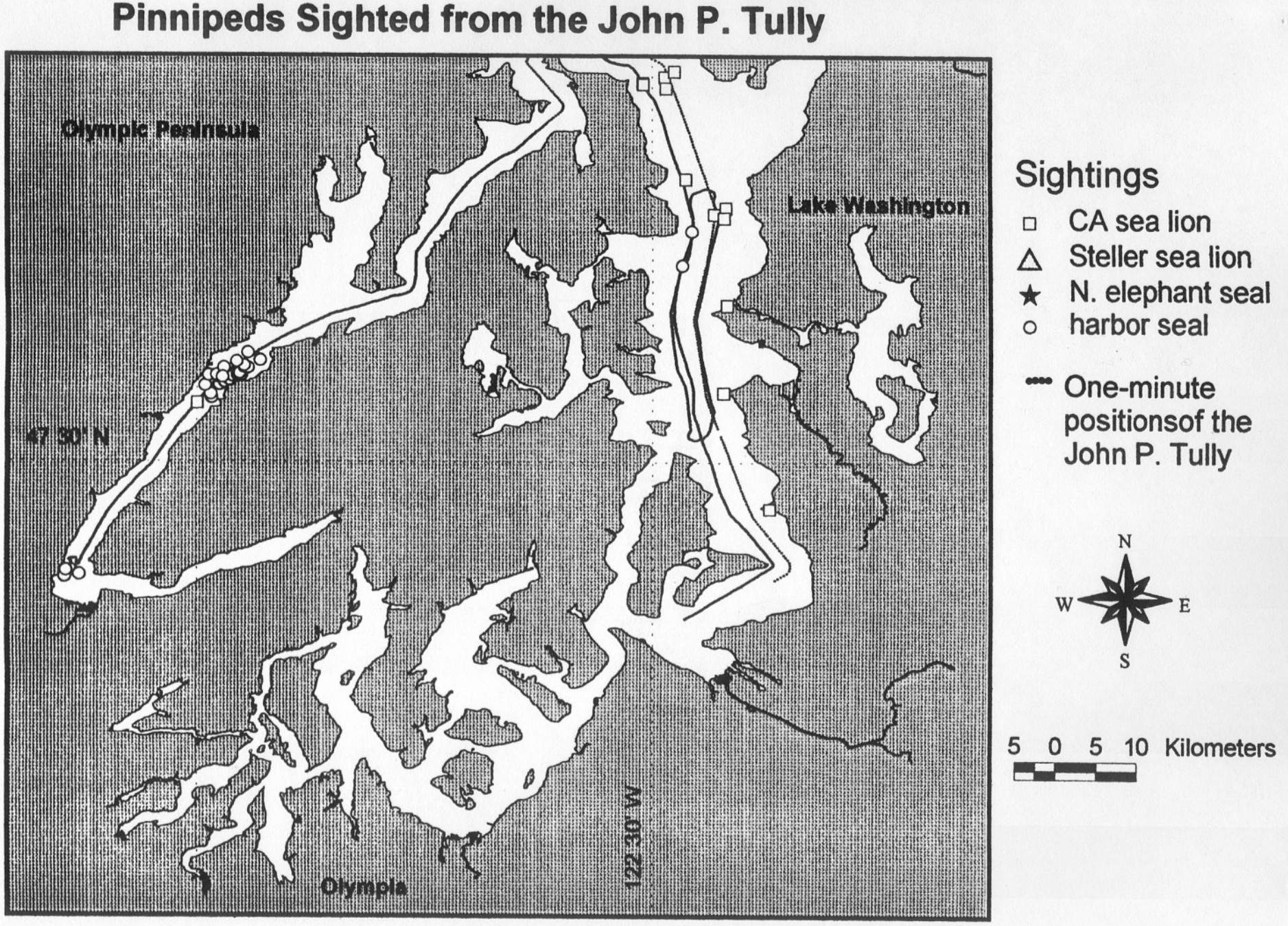

Pinnipeds Sighted from the John P. Tully
Olympic Peninsula
Lake Washington
47 30' N
Olympia
122 30' W
Sightings
CA sea lion
Steller sea lion
N. elephant seal
harbor seal
One-minute positionsof the John P. Tully
N
W
E
S
5 0 5 10 Kilometers

Figure 8

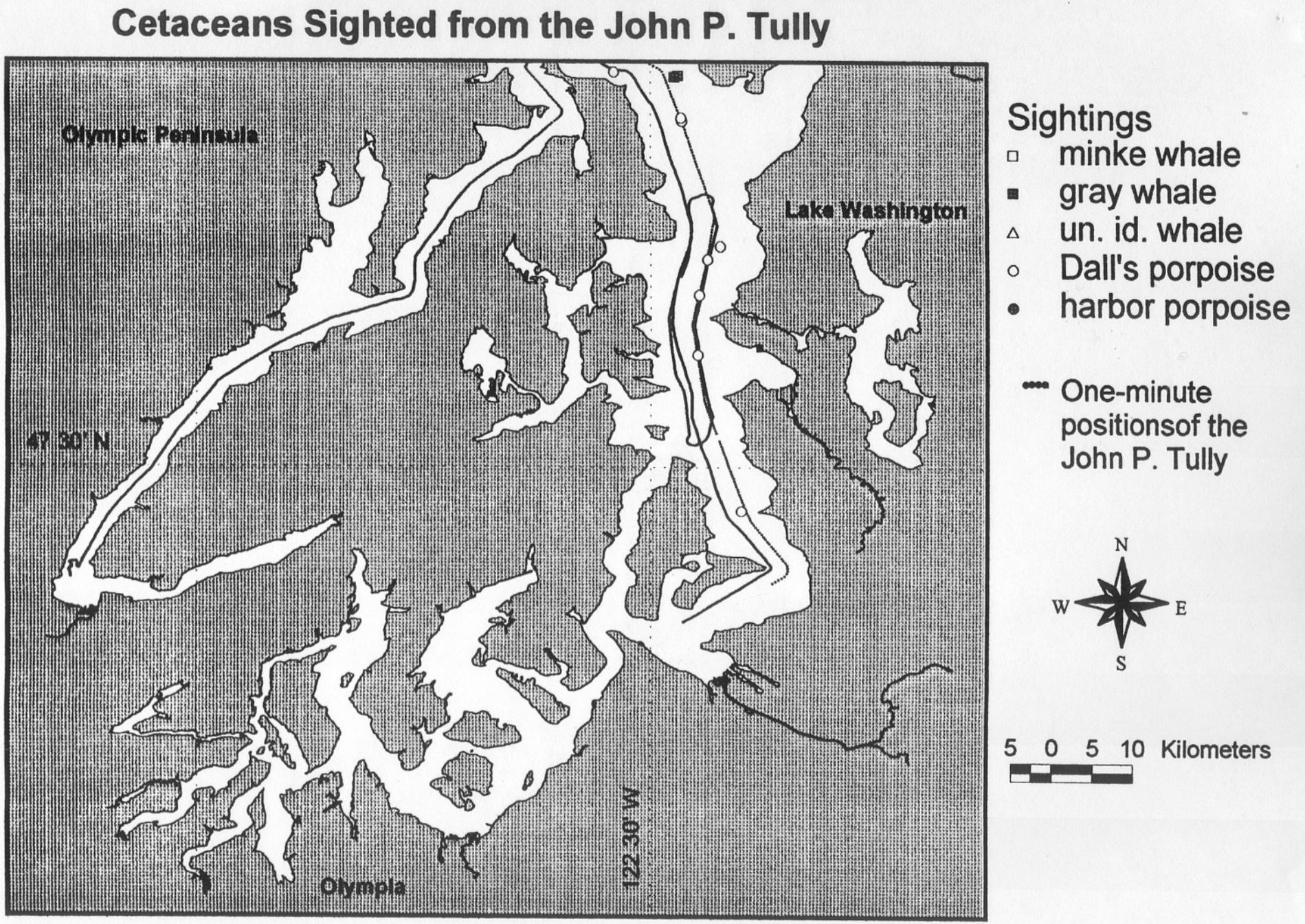
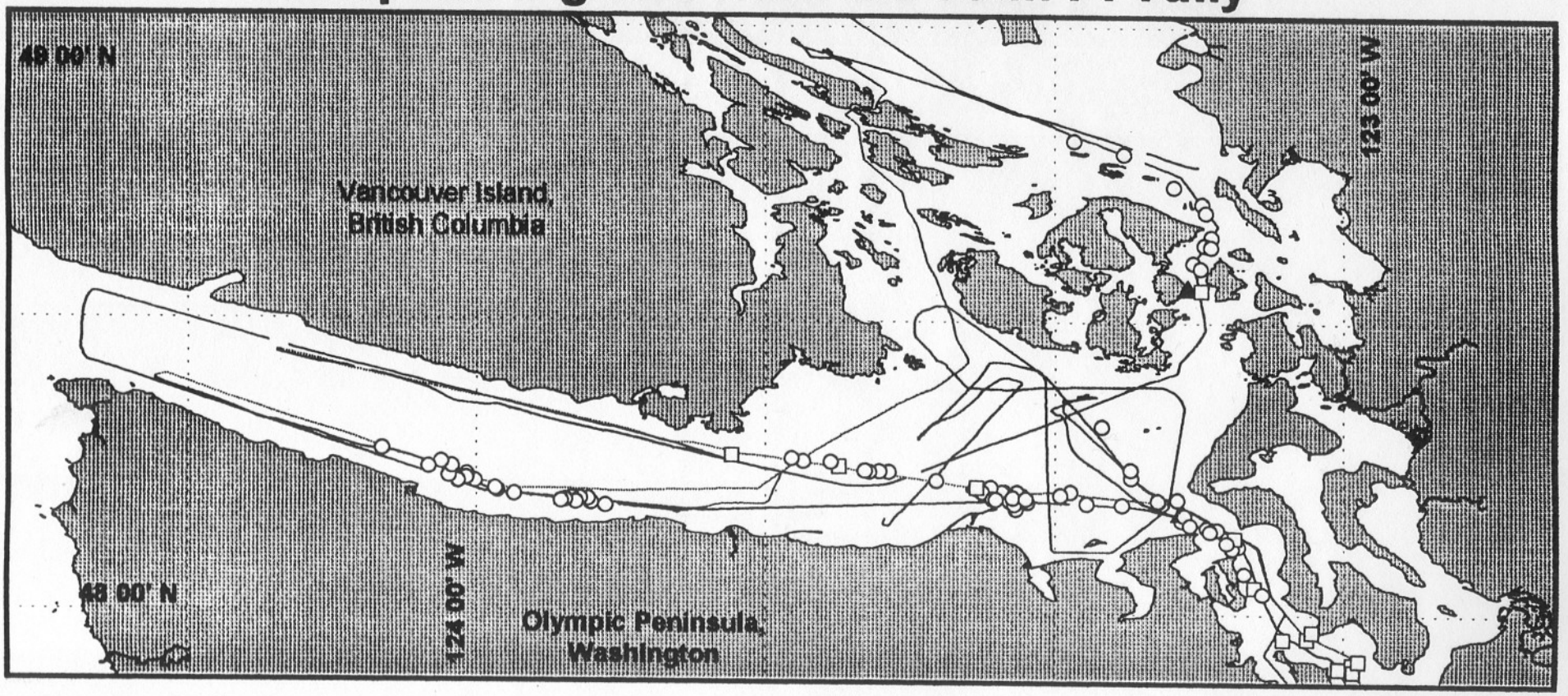

Cetaceans Sighted from the John P. Tully
Olympic Peninsula
Lake Washington
47 30' N
Olympia
122 30' W
Sightings
minke whale
gray whale
un. id. whale
Dall's porpoise
harbor porpoise
One-minute positionsof the John P. Tully
N
W
E
S
5 0 5 10 Kilometers

Figure 9

Pinnipeds Sighted from the John P. Tully



20 0 20 40 60 Kilometers

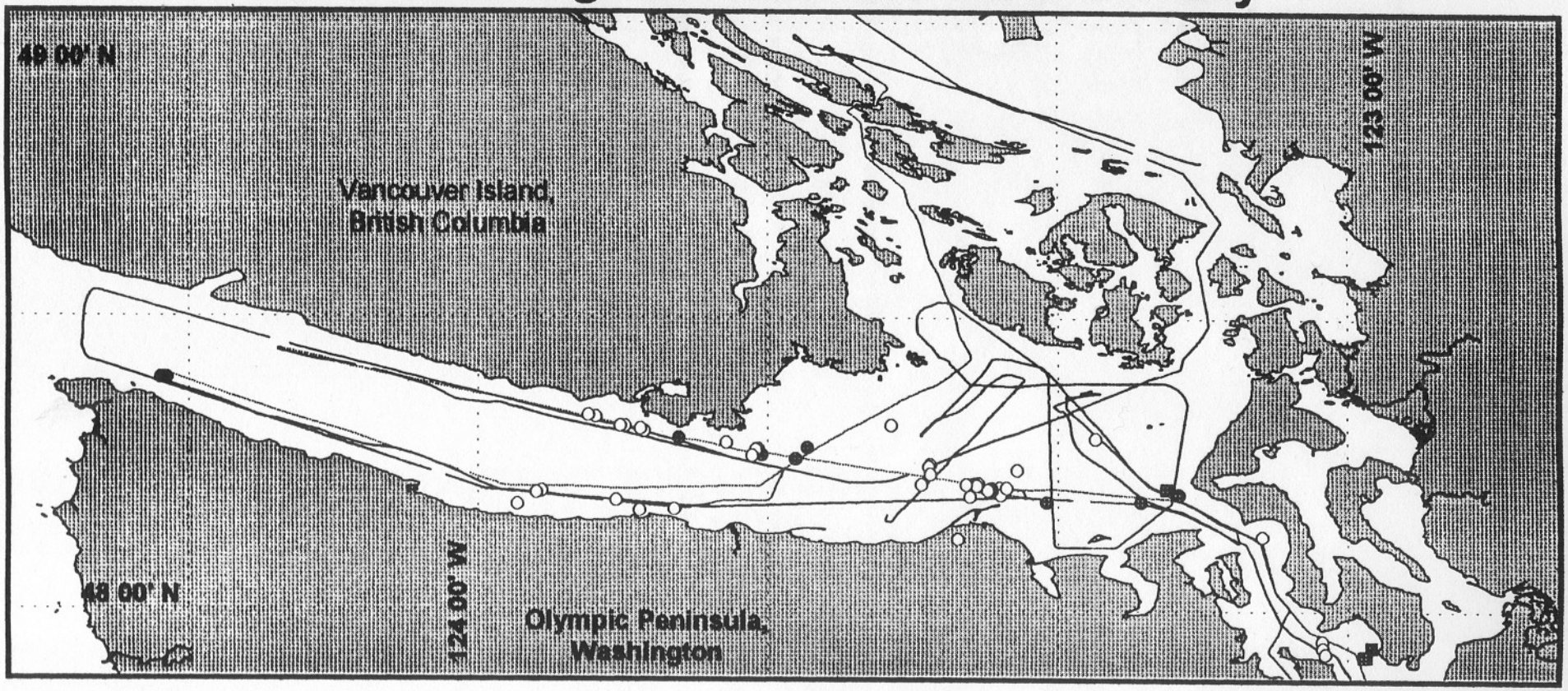
N
W E
S

Sightings

- □ CA sea lion
- ▲ Steller sea lion
- ★ N. elephant seal
- ○ harbor seal
- ···· One-minute positionsof the John P. Tully

Figure 10

Cetaceans Sighted from the John P. Tully



20 0 20 40 60 Kilometers

N
W E
S

Sightings

- minke whale
- gray whale
- un. id. whale
- Dall's porpoise
- harbor porpoise

One-minute positionsof the John P. Tully

Figure 11

Pinnipeds Sighted from the John P. Tully

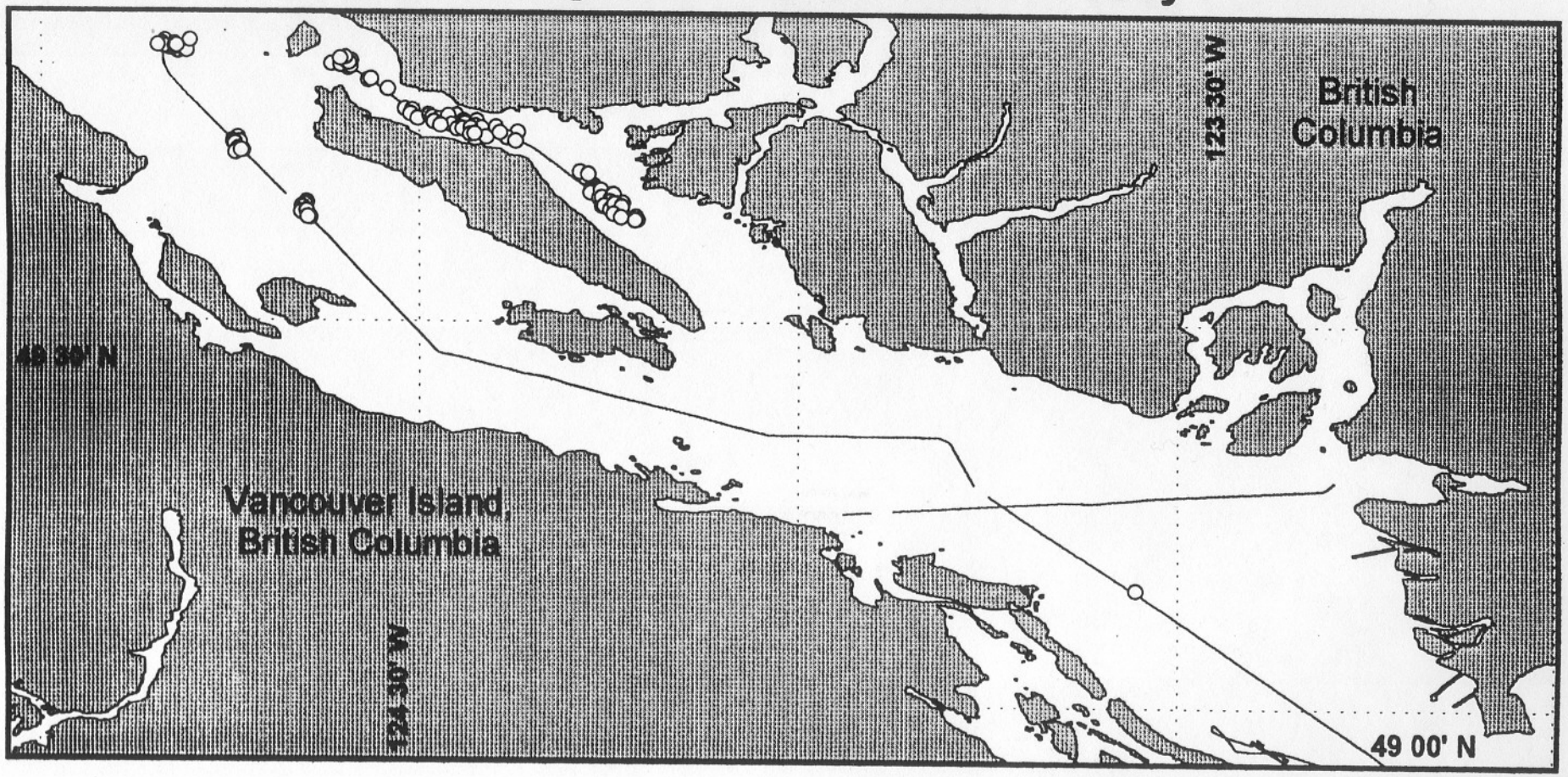
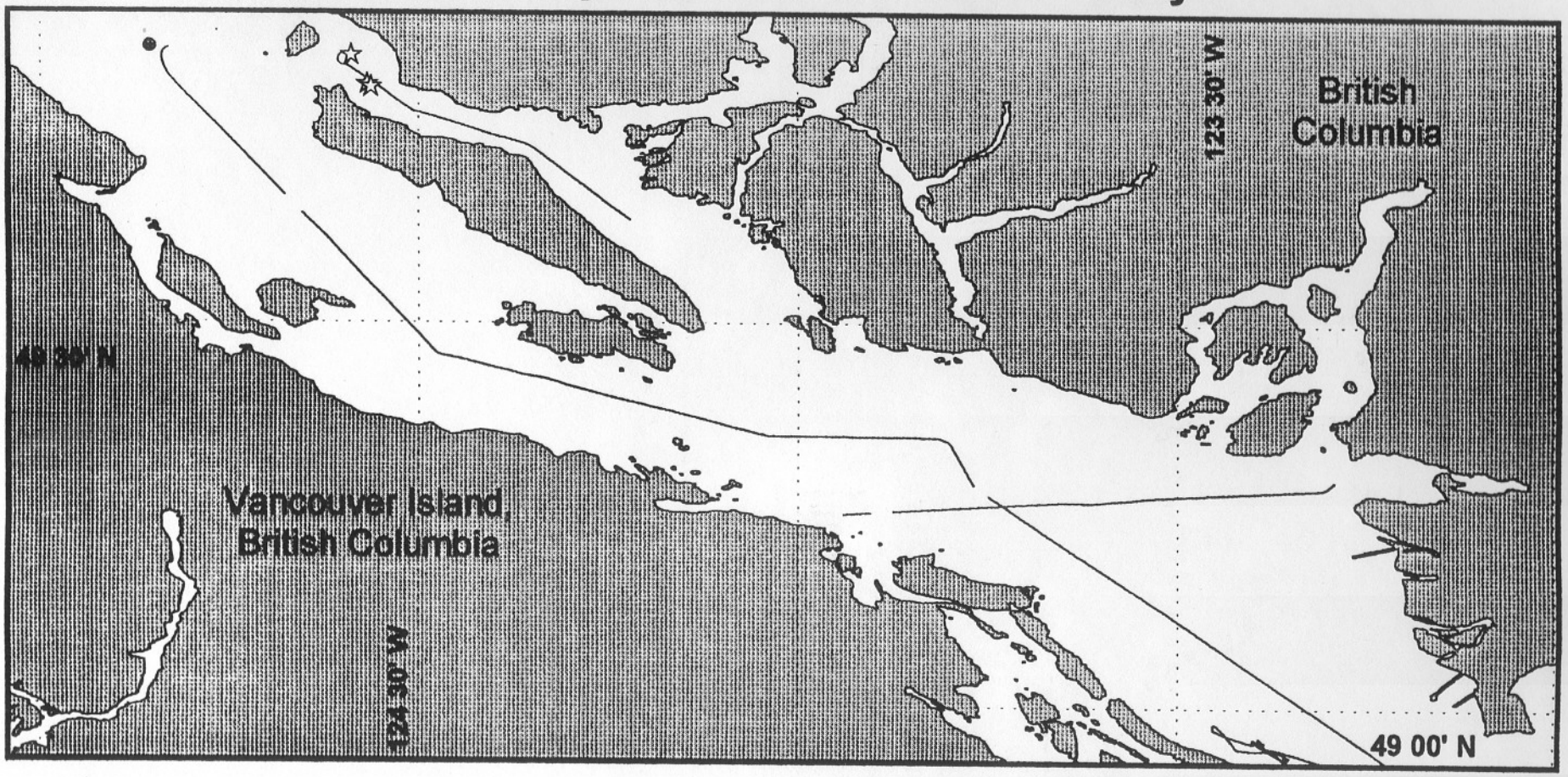


Figure 12

Cetaceans Sighted from the John P. Tully



20 0 20 40 Kilometers

N W E S

Sightings

- □ minke whale
- ■ gray whale
- △ un. id. whale
- ○ Dall's porpoise
- ● harbor porpoise
- ☆ P. white-sided dolphin

One-minute positionsof the John P. Tully

Figure 13

Preliminary Aerial Surveys: 6 March 1998

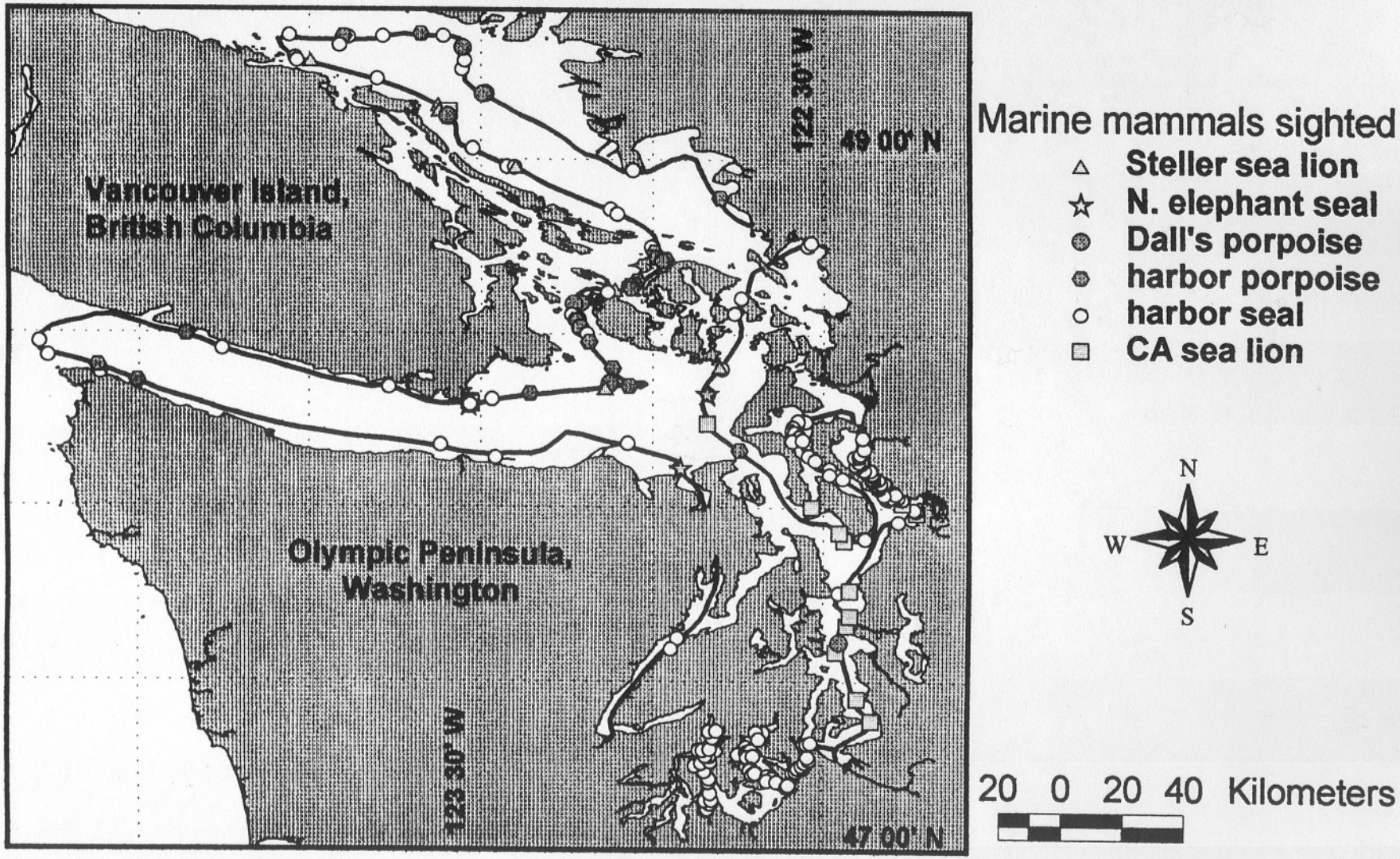


Figure 14

Aerial surveys: 11 March 1998

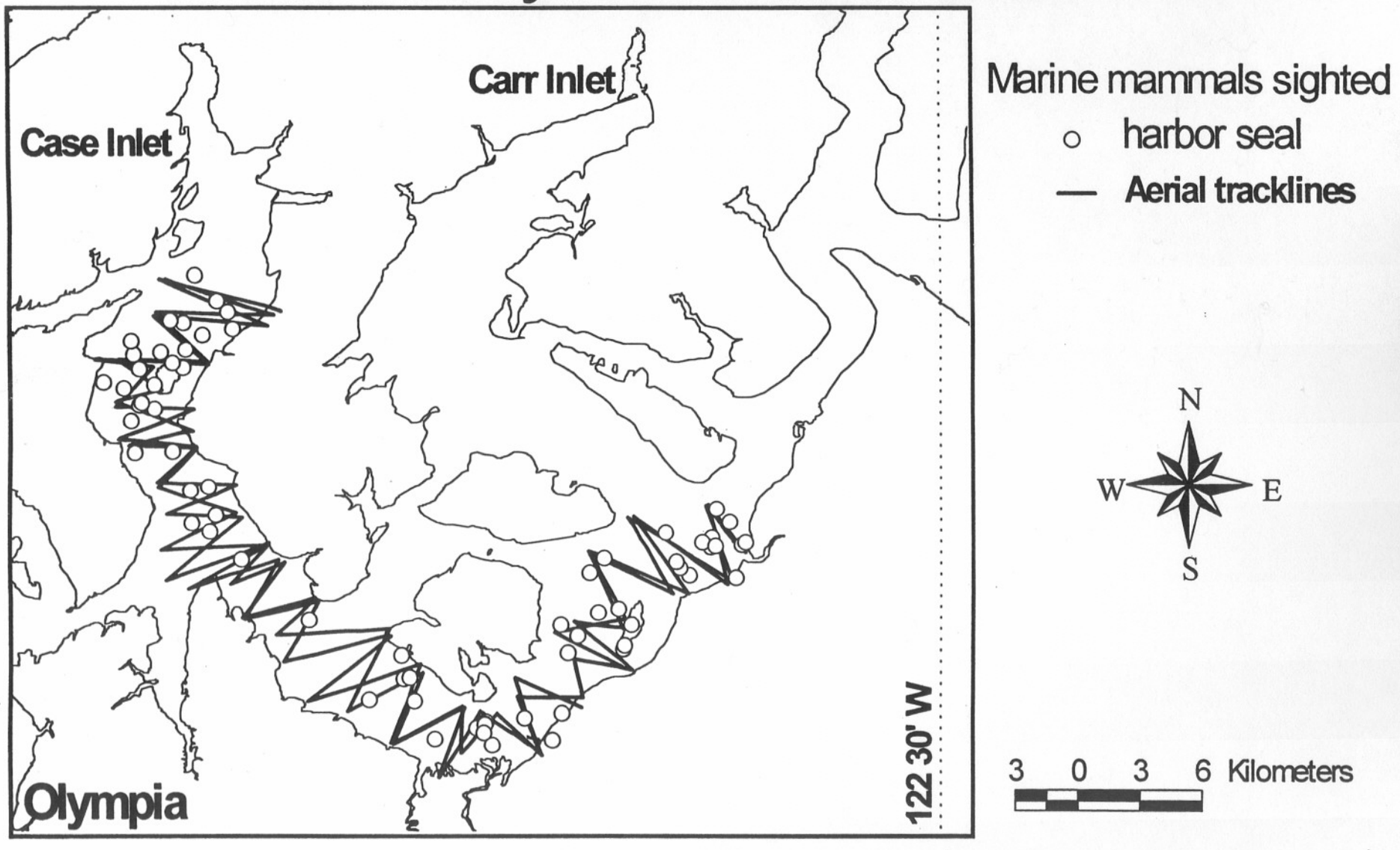
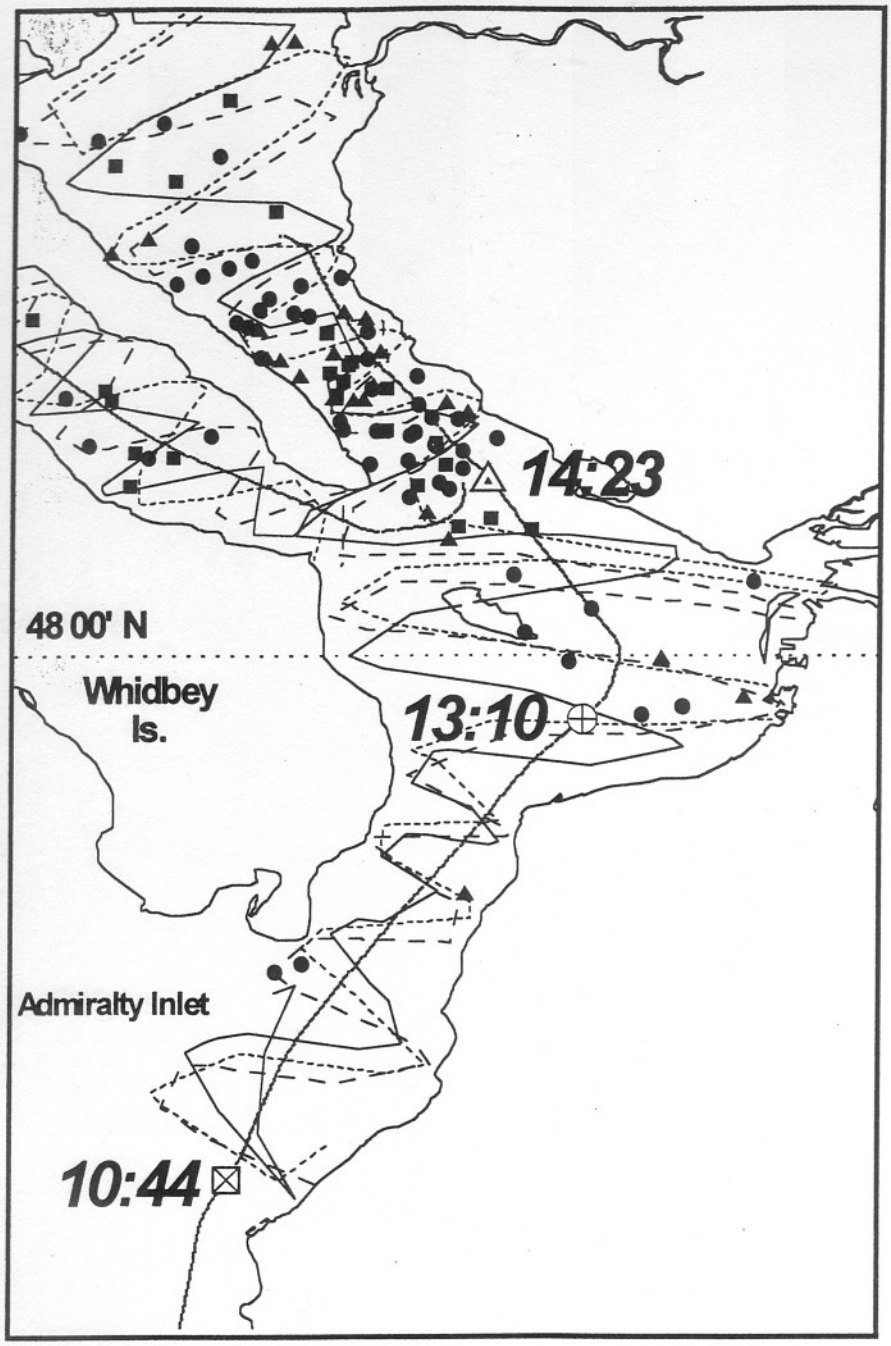


Figure 15

Experiment of 12 March 1988



Aerial tracklines:

Flight 1
Flight 2
Flight 3

Trackline of the Thomas G. Thompson

Position of the Thomas G. Thomson at start of flights:

Flight 1
Flight 2
Flight 3

Harbor seals sighted from the aircraft during:

Flight 1
Flight 2
Flight 3

N
W E
S

5 0 5 10 Kilometers

Figure 16

Figure 17. Initial sighting locations (daytime during air gun operations) in relation to seismic vessel locations and course

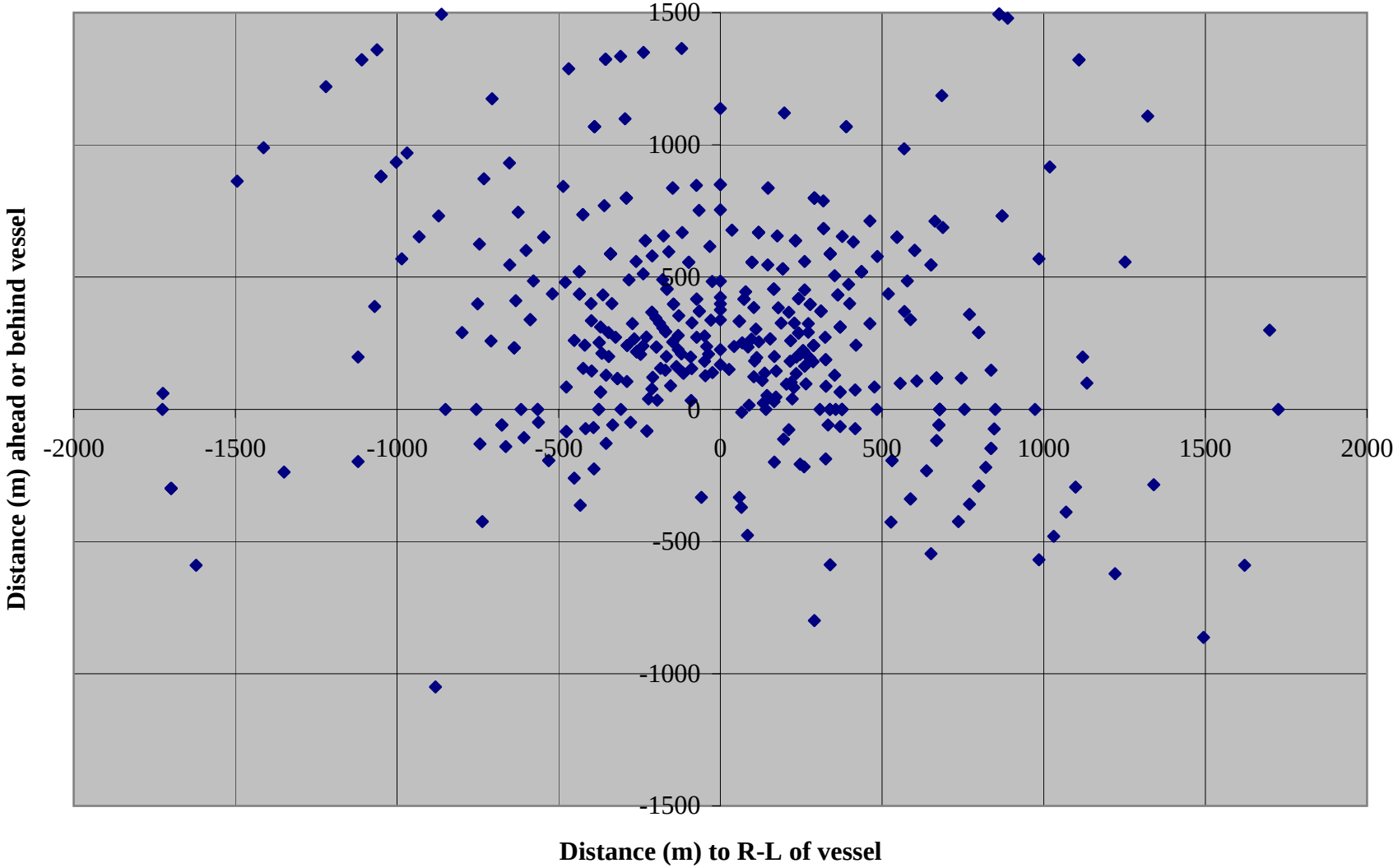


Figure 18. Initial sighitng locatiions in relation to Tully position and course

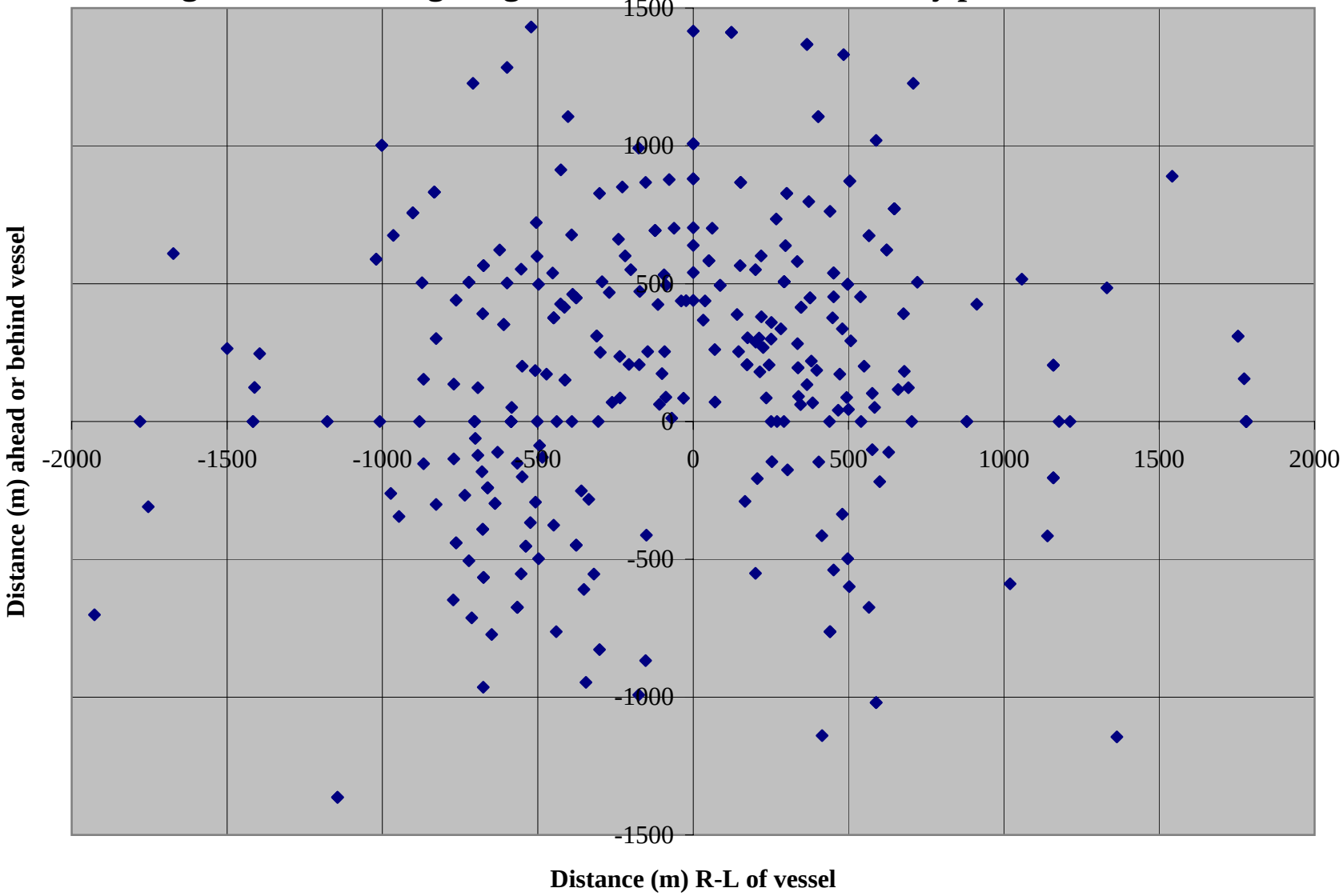


Table 1. Daily effort from the *Thompson* and *Tully* .

	Thompson			***Tully***		
Date	**Start**	**End**	**Hours**	**Start**	**End**	**Hours**
10-Mar-97	testing marine mammal methods during operations in Lake Washington					
11-Mar-98	1:15:00	23:59:59	22.75			
12-Mar-98	0:00:00	22:00:00	22.00			
13-Mar-98	6:16:00	23:59:59	17.73	7:00:00	18:00:00	11.00
14-Mar-98	0:00:00	23:59:59	24.00	7:13:00	17:55:00	10.70
15-Mar-98	0:00:00	23:59:59	24.00	6:31:00	18:15:00	11.73
16-Mar-98	0:00:00	23:59:59	24.00	8:32:00	18:15:00	9.72
17-Mar-98	0:00:00	19:00:00	19.00	6:25:00	18:12:00	11.78
18-Mar-98	12:00:00	23:59:59	12.00	14:48:00	18:15:00	3.45
19-Mar-98	0:00:00	23:59:59	24.00	6:15:00	18:15:00	12.00
20-Mar-98	0:00:00	23:59:59	24.00	6:20:00	18:00:00	11.67
21-Mar-98	0:00:00	23:59:59	24.00	6:15:00	18:15:00	12.00
22-Mar-98	0:00:00	23:59:59	24.00	6:15:00	18:15:00	12.00
23-Mar-98	0:00:00	19:50:00	19.83	6:19:00	18:15:00	11.93
Total			281.31			117.98

Table 2. Simplified safety zones employed starting 15 March that expanded the safety zone forward along the vessel's course and allowed more rapid determination of whether marine mammals were within the safety zone.

		Pinnipeds			**Odontocetes**			**Mysticetes**		
Direction	Angles off bow	Vert Ang	m from deck	m from bridge	Vert Ang	m from deck	m from bridge	Vert Ang	m from deck	m from bridge
Forward	0-60	6	112	136	3	225	273	1.4	483	586
Sides	60-120	7	96	117	3.5	193	234	1.5	451	547
Back	120-180	5	135	164	2.7	250	304	1.2	564	684

Table 3. Summary of aerial survey effort.

Date	Time		Sea state		Purpose
	start	end	min	max	
3/6/98	10:26	17:50	0	3	Scouting survey of study area
3/11/98	13:09	15:00	0	2	Grid flight in S. Puget Sound
3/12/98	10:43	15:24	0	4	Grid flight in N. Puget Sound

Table 4. Cases where air guns were shut down due to marine mammal occurrence.

Date	Stop time	Ramp-up	Comments
03/11/98	06:48:00	07:21:00	Shut-down due proximity (160 m) of California sea lion, extended due to presence of Dall's porpoise
03/11/98	09:26:00	11:23:40	Precautionary shut-down while moving up Carr Inlet to avoid any potential for trapping harbor seals
03/12/98	21:59:40	06:27:40	Precautionary shut-down during night transit of area of known gray whale presence in Saratoga Passage
03/14/98	10:07:00	10:24:20	Shut-down due to proximity (338 m) of minke whale in Strait of Juan de Fuca
03/19/98	18:00:00	18:09:34	Shut- down due to proximity (112 m) of northern sea lion

Table 5. Summary of marine mammals sightings from the aerial surveys.

	3/6/98		3/11/1998		3/12/1998		Total	
Species	Sit	Anim	Sit	Anim	Sit	Anim	Sit	Anim
Harbor seal	148	687	68	173	121	144	337	1004
California sea lion	15	101	0	0	4	166	19	267
Steller sea lion	8	15	0	0	0	0	8	15
Elephant seal	3	4	0	0	0	0	3	4
Dall's porpoise	9	15	0	0	4	5	13	20
Harbor porpoise	22	40	0	0	0	0	22	40
Total	205	862	68	173	129	315	402	1350

Table 6. Sightings (initial only) from the *Thompson* by region and day/night. Includes pinnipeds that were hauled out.

	Puget Sound		NPS & HC		U.S. SJF		Can. SJF		U.S. San Juans		Can. San Juans		Str of Georgia		All area	
	Sight	Anim	Sight	Anim	Sight	Anim	Sight	Anim	Sight	Anim	Sight	Anim	Sight	Anim	Sight	Anim
Daylight																
Harbor seal	69	161	98	111	24	24	2	2	14	216	0	0	120	138	327	652
California sea lion	23	35	13	19	5	6	0	0	3	3	0	0	18	18	62	81
Steller sea lion	1	1	1	1	0	0	0	0	3	7	0	0	1	1	6	10
Unid. seal	1	1	1	1	1	1	0	0	1	1	0	0	4	4	8	8
Dall's porpoise	8	18	6	35	4	16	3	6	0	0	0	0	1	1	22	76
Harbor porpoise	0	0	0	0	1	2	0	0	1	2	0	0	3	4	5	8
Unid. porpoise	0	0	0	0	0	0	0	0	1	3	0	0	0	0	1	3
Minke whale	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1
Gray whale	0	0	2	4	1	1	1	1	0	0	0	0	0	0	4	6
Unid. whale	0	0	0	0	1	1	0	0	0	0	0	0	1	2	2	3
Unid. marine mammal	0	0	0	0	0	0	0	0	0	0	2	3	0	0	2	3
Total	102	216	124	175	38	52	6	9	23	232	2	3	148	168	443	855
Night																
Harbor seal	16	105	8	86	6	239	3	3	1	6	0	0	0	0	34	439
California sea lion	13	21	1	1	1	2	0	0	0	0	0	0	0	0	15	24
Elephant seal	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1
Unid. seal	2	2	0	0	1	1	0	0	1	3	0	0	0	0	4	6
Total night	31	128	9	87	10	244	3	3	2	9	0	0	0	0	55	471
Total all	133	344	90	262	48	296	9	12	25	241	2	3	148	168	498	1326

Table 7. Number of sightings and animals (initial only) seen from the *Tully* by region during the day. Numbers include pinnipeds that were hauled out.

	Puget Sound		NPS & HC		U.S. SJF		Can. SJF		US San Juans		Str of Ga		All areas	
Species	Sight	Anim	Sight	Anim	Sight	Anim	Sight	Anim	Sight	Anim	Sight	Anim	Sight	Anim
Harbor seal	2	2	38	41	59	65	3	3	11	142	149	154	262	407
California sea lion	7	9	9	16	2	2	1	3	1	1	5	5	25	36
Steller sea lion	0	0	0	0	1	1	0	0	2	4	0	0	3	5
Unidentified seal	1	1	1	1	2	2	0	0	0	0	0	0	4	4
Dall's porpoise	7	15	3	6	25	40	11	18	0	0	6	7	52	86
Harbor porpoise	0	0	0	0	4	10	3	4	0	0	1	2	8	16
Pac. white-sided dolphi	0	0	0	0	0	0	0	0	0	0	1	4	1	4
Unidentified porpoise	0	0	0	0	2	2	0	0	0	0	0	0	2	2
Gray whale	0	0	2	3	1	1	0	0	0	0	0	0	3	4
Total all spp.	17	27	53	67	96	123	18	28	14	147	162	172	360	564

Table 8. Distances at which marine mammals were initially sighted during surveys from the *Thompson* and *Tully* . Includes pinnipeds hauled out.

	***Thompson* day w/o seismic**			***Thompson* day w/ seismic**			***Thompson* night w/ seismic**			***Tully* (day)**		
Species	**n**	**mean**	**SD**	**n**	**mean**	**SD**	**n**	**mean**	**SD**	**n**	**mean**	**SD**
Harbor seal	84	556	455	242	690	542	33	1,181	1,164	257	808	499
California sea lion	16	647	421	48	1,196	976	14	1,969	1,417	25	1,274	805
Steller sea lion	1	850		5	1,270	487	0			3	1,220	540
Elephant seal	0			0			1	338				
Unid. seal	0			8	1,147	1,068	3	849	833	4	816	351
Dall's porpoise	2	802	67	20	1,056	397	0			44	1,639	2,177
Harbor porpoise	1	679		3	1,105	566	0			8	1,539	661
Pacific white-sided dolphi	0			0			0			1	2,401	
Unid. porpoise	0			1	679		0			1	704	
Minke whale	1	338		0			0					
Gray whale	0			3	2,388	1,277	0			3	2,229	1,334
Unid. whale	0			2	1,431	416	0					
Unid. marine mammal	0			2	2,031	433	0					
Total	105	577	441	334	836	686	51	1,361	1,257	346	985	977

Table 9. Orientation in relation to the survey vessel for the three most commonly seen species.
Figures include resightings.

		Thompson					*Tully*				
	Distance	Percent of sightings by orientation					Percent of sightings by orientation				
Species	(m)	away	left	right	towards	n	away	left	right	towards	n
Air guns off											
Harbor seal	<500	27%	29%	38%	7%	45	18%	33%	41%	8%	51
	>500	16%	26%	37%	21%	19	6%	46%	45%	3%	192
Subtotal	all	23%	28%	38%	11%	64	8%	44%	44%	4%	243
California sea lion	<500	0%	50%	33%	17%	6	17%	17%	50%	17%	6
	>500	0%	100%	0%	0%	2	0%	33%	50%	17%	6
Subtotal	all	0%	63%	25%	13%	8	8%	25%	50%	17%	12
Dall's porpoise	<500	100%	0%	0%	0%	1	0%	20%	80%	0%	5
	>500	25%	50%	25%	0%	4	2%	59%	36%	2%	44
Subtotal	all	40%	40%	20%	0%	5	2%	55%	41%	2%	49
Total for air guns off		22%	32%	35%	10%	77	7%	45%	44%	4%	304
Air guns on											
Harbor seal	<500	19%	33%	41%	8%	106					
	>500	15%	28%	49%	8%	89					
Subtotal	all	17%	31%	45%	8%	195					
California sea lion	<500	36%	32%	27%	5%	22					
	>500	25%	50%	25%	0%	4					
Subtotal	all	35%	35%	27%	4%	26					
Dall's porpoise	<500	0%	100%	0%	0%	5					
	>500	26%	29%	41%	5%	66					
Subtotal	all	24%	34%	38%	4%	71					
Total for air guns on		20%	32%	41%	7%	292					
Total for all		21%	32%	40%	7%	369	7%	45%	44%	4%	304

Table 10. Orientation of marine mammals sighted from the *Tully* in relation to calculated position for *the Thompson* (and distance to the *Thompson*). Includes sightings and resightings during air gun operations. Figures include resightings.

	Distance		**% sightings by orientation**	
Species	**(nmi)**	**n**	**away**	**towards**
Dall's porpoise	2-10	25	**40%**	**16%**
	>10	17	**35%**	**29%**
Harbor seal	0-2	36	**22%**	**14%**
	2-10	103	**38%**	**15%**
	>10	60	**25%**	**32%**

Table 11. Photographic identification of individual gray whales in northern Puget Sound in 1998.

Date	Time	Vessel	S#	Location	Latitude	Longitude	Photog
Whale #21							
22-Mar	1051	*Tully* Launch	2	Possession Pt.	47 54.0	122 28.3	TEC
27-Mar	1620	CRC RHIB	8	off Saratoga	48 05.1	122 28.6	TEC
15-Apr	1545	DS	6	off Saratoga	48 05.9	122 29.0	NS
16-Apr	1134	CRC RHIB	1	off Clinton	47 57.7	122 20.4	JRE
16-Apr	1440	CRC RHIB	10	Possession Pt.	47 53.2	122 26.3	JAC
19-Apr	1443	CRC RHIB	2	Possession Pt.	47 53.6	122 23.0	JRE
Whale #22							
14-Mar	1155	*Tully* Launch	1	Admiralty Head	48 10.1	122 43.8	TEC
22-Mar	1051	*Tully* Launch	2	Possession Pt.	47 54.0	122 28.3	TEC
27-Mar	1620	CRC RHIB	8	off Saratoga	48 05.1	122 28.6	TEC
15-Apr	1545	DS	6	off Saratoga	48 05.9	122 29.0	NS
16-Apr	1134	CRC RHIB	1	off Clinton	47 57.7	122 20.4	JRE
16-Apr	1440	CRC RHIB	10	Possession Pt.	47 53.2	122 26.3	JAC
19-Apr	1443	CRC RHIB	2	Possession Pt.	47 53.6	122 23.0	JRE
Whale #49							
12-Mar	1455	*Thompson* Launch	1	Possession Pt.	47 54	122 23	JAC
27-Mar	1620	CRC RHIB	8	off Saratoga	48 05.1	122 28.6	TEC
15-Apr	1545	DS	6	off Saratoga	48 05.9	122 29.0	NS
16-Apr	1134	CRC RHIB	1	off Clinton	47 57.7	122 20.4	JRE
16-Apr	1440	CRC RHIB	10	Possession Pt.	47 53.2	122 26.3	JAC
Whale #56							
12-Mar	1455	*Thompson* Launch	1	Possession Pt.	47 54	122 23	JAC
Whale #A							
21-Mar	1314	*Tully* Launch	16	Useless Bay	47 58.5	122 29.6	TEC
22-Mar	1143	*Tully* Launch	3	Useless Bay	47 58.8	122 29.7	TEC
27-Mar	1018	CRC RHIB	3	Useless Bay	47 58.6	122 30.2	TEC
15-Apr	1227	DS	2	Useless Bay	47 58.4	122 30.2	HH
16-Apr	1539	CRC RHIB	13	Mutiny Bay	47 59.7	122 33.9	JAC