Exxon Valdez Oil Spill
Restoration Project Final Report

1993 Trial Aerial Survey of Sea Otters in Prince William Sound, Alaska

Restoration Project 93043-2

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Study History: Restoration Project 93043, *Sea Otter Population Demographics in Areas Affected by the Exxon Valdez Oil Spill*, was initiated in 1993. The aerial survey reported herein was one of three components. The other two components of Project 93043 were a population model (reported separately, *A Population Model for Sea Otters in Western Prince William Sound*, by M. Udevitz, B. Ballachey, and D. Bruden) and 1993 mortality patterns (reported separately, in NRDA MM6 Report, *Age Distributions of Sea Otters Found Dead in Prince William Sound, Alaska, Following the Exxon Valdez Oil spill*, by D. Monson and B. Ballachey).

Abstract: We developed an aerial survey method for sea otters, using a strip transect design where otters observed in a strip along one side of the aircraft are counted. Two strata are sampled, one lies close to shore and/or in shallow. The other strata lies offshore and over deeper water. We estimate the proportion of otters not seen by the observer by conducting intensive searches of units (ISU's) within strips when otters are observed. Two studies were conducted in 1993 to improve methods of estimating the abundance of sea otters in Prince William Sound. The first study found no significant differences in sea otter detection probabilities between ISU's initiated by the sighting of an otter group compared to systematically located ISU's. The second study consisted of a trial survey of all of Prince William Sound, excluding Orca Inlet. The survey area consisted of 5,017 km^2 of water between the shore line and an offshore boundary based on shoreline physiography, the 100 m depth contour or a distance of 2 km from the shore. From 5-13 August 1993, two observers surveyed 1,023 linear km of high density sea otter habitat and 355 linear km of low density habitat. Our adjusted estimate of abundance is 16,814 sea otters with a proportional standard error of 0.38.

Key Words: *Enhydra lutris*, *Exxon Valdez*, oil spill, sea otter.

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EXECUTIVE SUMMARY

We have developed an aerial survey methodology for sea otters consisting of a strip transect design where all otters observed along one side of the aircraft are counted. Two strata are sampled proportional to expected sea otter abundance. One strata lies close to shore and/or in water less than 40 m deep. The other strata lies offshore and over water greater than 40 m deep. We estimate the proportion of otters not seen by the observer by conducting intensive searches of units (ISU's) within strips when otters are observed. The strip counts within ISU areas, divided by the ISU counts, provide estimates of detection probability for strip counts. Intensive searches consist of 3 repetitive passes around the perimeter of a 400 m diameter circle defined by the inner and outer boundaries of the strip.

Survey design research and development have been ongoing for three years. Methods and results from 1991 and 1992 are summarized following the introduction to provide the background necessary to evaluate the 1993 work. Two studies were conducted in 1993 as part of the continued development of an improved method of estimating the abundance of sea otters in Prince William Sound.

The first study found no significant differences in sea otter detection probabilities between ISU's initiated by the sighting of an otter group compared to systematically located ISU's. This allows increased efficiency in design by permitting ISU's to be initiated by the presence of a group of sea otters rather than through systematic selection.

The second study consisted of a trial survey of all of Prince William Sound, excluding Orca Inlet. The survey area consisted of 5,017 km^2 of water between the shore line and an offshore boundary based on shoreline physiography, the 100 m depth contour or a distance of 2 km from the shore. From 5-13 August 1993, two observers surveyed 1,023 linear km of high density sea otter habitat and 355 linear km of low density habitat. Our adjusted estimate of abundance is 16,814 sea otters with a proportional standard error of 0.38. Significant differences in detection probabilities between observers and high variance in the low density stratum contributed to the lack of precision in our trial survey point estimate. This variance can likely be reduced through increased ISU sampling effort, redefinition of the low density stratum and observer training designed to reduce variability in detection probabilities.

INTRODUCTION

Surveys of sea otter populations in the North Pacific have been conducted over the past several decades (Ebert 1968, Kenyon 1969, Estes 1971, Pitcher 1975, Schneider 1975, Estes 1977, Estes and Jameson 1983, Jameson et al. 1986, Simon-Jackson 1986, Johnson 1987, Irons et al. 1988, Pitcher 1989, Douglas et al. 1990, Burn 1994). The primary objective has been to describe changes that may have occurred in the abundance and distribution of the species over time or to provide baselines against which future surveys may be compared. Previous methods were based on counts from the ground (Estes and Jameson 1988), small or large vessels (Jameson et al. 1982, Johnson 1987), fixed (Ebert 1968, Simon-Jackson et al. 1986) or rotary wing aircraft (Pitcher 1975, Douglas et al. 1990), or a combination of two or more platforms (Jameson et al. 1986).

Two factors have generally led to difficulty in interpreting survey data. First, with the exceptions of Estes and Jameson (1988) and Udevitz et al. (1995), methods have not been rigorously tested to determine the proportion of the animals actually observed and the effects of activity and environmental conditions on detection probabilities. Second, excepting Estes and Jameson (1988), Jameson et al. (1986), and Burn (1994), survey methodologies have not been standardized, creating difficulty in comparing estimates generated by different methods.

Counts of sea otters from the ground have been generally recognized as providing the most accurate estimates of near shore sea otter abundance (Schneider 1971). Estes and Jameson (1988) estimated the probability of sighting sea otters was 94.5% for standardized shore side counts, using two experienced observers, high-resolution 10X binoculars and 50X Questar telescopes (New Hope, PA). This was the first study to rigorously evaluate the effect of activity, group size and distance from observer on sighting probability of sea otters. Their results provide a baseline against which other methods might be evaluated. However, due to limited access and transportation along most coastlines, ground counts can not be used over the large geographic areas occupied by most sea otter populations.

Initial damages to the sea otter population resulting from the *Exxon Valdez* oil spill included lethal and sub-lethal levels of direct exposure. One method used to estimate the total immediate loss to the sea otter population in Prince William Sound (PWS) was a comparison of estimates of sea otter abundance based on boat surveys conducted before and after the spill (Garrott et al. 1993). Boat surveys were used after the spill to estimate sea otter density (Burn 1994) in order to be consistent with the method used before the spill. This consistency was necessary for assessing the immediate loss of otters, but it became widely recognized that boat survey methodology, as conducted, would not provide population estimates with accuracy necessary for management purposes, primarily due to detection bias and sea otter avoidance behavior (Burn 1990, Udevitz et al. 1994, Burn 1994).

The long term objective of this study was to develop and implement a standardized survey methodology that will provide improved accuracy and precision in estimates of sea otter abundance and that will be applicable throughout the species' range. Our objectives in this report are to: 1) provide a summary of the methods and results of the survey platform evaluation conducted in 1991 and the trial survey conducted in western PWS in 1992, 2) present results of the 1993 survey methodology research and the 1993 PWS sea otter survey, and 3) to recommend changes in survey design and methodology that could potentially increase precision and efficiency.

Summary of 1991 and 1992 Research Results

Due to otter diving behavior it is not possible to use standard line or strip transect techniques in sea otter surveys. These methods rely on the assumption that all of the animals in some region (e.g., on the line or in the strip) are seen. To obtain unbiased density estimates, we need to develop estimates of the actual probability of detecting animals with the survey protocol. Our approach is based on the assumption that the probability of detecting otters in a strip transect survey can be reliably estimated based on intensive searches over subsamples of the strips (intensive search units or ISU's). Detection probability is estimated by comparing the number of otters detected in ISU's with the strip transect protocol to the number determined to be actually present with the intensive search protocol. Strip transect counts can then be adjusted by the estimated detection probability.

Aircraft Evaluation

The first phase of this work consisted of trials conducted in April and July, 1991 to evaluate the suitability of a float-equipped Piper PA-18 Super-Cub as the platform for this type of sea otter survey. The Super-Cub has been selected repeatedly for wildlife survey work based on its slow stall speed and high degree of maneuverability (Erickson and Siniff 1964, LeResche and Rausch 1974, Gasaway et al. 1986). It seats one pilot and one passenger in tandem, an arrangement recommended by Erickson and Siniff (1964) as allowing navigation and observation to occur from the same spatial orientation in the plane.

The overall objective of the trials was to evaluate the validity of the assumption that all of the otters present in subsamples of strip transects could be detected with intensive searches. Specific trails were designed to evaluate the accuracy with which strip boundaries could be delineated by an observer in the aircraft, to provide a general idea of the detectability of sea otters as a function of distance from the aircraft, and to evaluate the effects of altitude, search pattern and search duration on the proportion of otters detected during intensive searches. Assuming that the aircraft proved suitable, the information generated by the trials was expected to provide guidance for developing a survey protocol.

1. Strip delineation

By aligning a mark on the struts with the outer margin of the floats an observer can assure consistent viewing orientation and define an inner margin of the strip (Fig. 1). By sighting, from the predetermined orientation, through marks placed further out on the struts, boundaries of strips of various widths can be identified. We used a clinometer to calibrate strut marks corresponding to strip widths extending in 50 m increments from 50 to 550 m with the aircraft at an altitude of 92 m.

We used radar and a small boat to evaluate the accuracy with which an observer, using the clinometer calibrated strut marks, could estimate perpendicular distances. The boat was placed at radar measured distances from shore while the aircraft flew along the shoreline at the specified altitude and the aerial observer estimated the distance to the boat using the strut marks. Distances were estimated to the nearest 25 m by interpolating between the strut marks. Distances estimated by the aerial observer were quite consistent but were slightly less than distances measured with radar (e.g., at a radar measured distance of 400 m the aerial observer consistently estimated a distance of about 350 m, Fig. 2).

This suggested that distance estimates based on strut marks could be sufficiently accurate if field trials were used for final calibration of the marks. Final calibration of clinometer established strut marks requires reference points, at the appropriate distances apart, on the surface that can be viewed from the aircraft at the specified altitude during level flight. For all subsequent work we used a radar equipped boat placed at measured distances off a straight shoreline to accomplish the final calibration.

2. Detection function

A series of randomly located line transects in western Prince William Sound were surveyed using standard line transect methodology (Buckland et al. 1993) in order to obtain a general idea of the pattern of detectability of sea otters from the aircraft. Transects were surveyed at a speed of 27 m/s and an altitude of 92 m. Observation was only on 1 side of the aircraft. The observer recorded the number of individuals and the perpendicular distance to each group of otters detected. Distances were recorded in 50 m distance categories based on strut marks calibrated as discussed above. A total of 135 groups of sea otters ranging in size from 1 to 6 individuals were detected (Fig. 3). The region of highest detectability appeared to be from about 150 to 300 m from the inner strip boundary. Eighty six percent of the detected groups were detected at distances less than 400 m. There was no apparent relation between group size and detectability over the rather limited range of group sizes that were observed (Fig. 4). In subsequent work, all strips were of finite width and observers made explicit efforts to focus their effort uniformly within the strip in order to increase detectability of groups at distances less than 200 m.

3. Intensive searches

Two series of trials were conducted to determine the proportion of the sea otters that could be detected by intensive searches. Both sets of trials used ground based observers to quantify the proportion of animals detected from the air. The first series of trials was conducted in April 1991 to assess the effect of altitude (altitude evaluation) on sea otter detectability. The second series of trials was conducted in July 1991 to assess the effect of search pattern (pattern evaluation) on sea otter detectability.

Trials were conducted on areas of ocean (survey units) that did not contain canopy forming kelp, were large enough to contain a full search pattern, allowed unrestricted observation from an adjacent vantage point, and contained 1 or more otters immediately prior to arrival of the aircraft. Survey units were selected by ground crews based on previous reconnaissance and observation of the area immediately before ground crew deployment. All survey units for the altitude evaluation were located in Eastern Prince William Sound. Survey units for the pattern evaluation were distributed throughout Prince William Sound, though most were in the west.

Ground crews approached each selected survey unit by skiff after a thorough study of the area from offshore, taking care to minimize disturbance to sea otters. Following deployment at the vantage point, the ground crew defined the boundaries of the unit, established an orientation for the aerial search pattern and determined the position and activity of each otter within the unit. The ground crew then contacted the aircraft by VHF radio to begin the trial. Ground observations followed methods established by Estes and Jameson (1988). Immediately prior to arrival of the aircraft, the ground crew recorded the location, group size, number of dependent pups and activity of each otter or group of otters.

Activity categories included swimming (changing location), resting (stationary on water surface) and diving (stationary and temporarily submerging). The ground crew also recorded the location and behavior of all otters observed outside the boundaries of the unit, observations regarding changes in sea otter activity associated with the approach of the aircraft, and the time the aircraft entered and departed the unit. Following the departure of the aircraft, the ground crew was transported by boat to the next survey unit.

Altitude evaluation trials were conducted at 46 m, 92 m and 137 m above sea level. Trials were conducted in sets of 3, with one trial at each altitude, in random order, within each set. All altitude evaluation trials were conducted using a 750 m circle intensive search pattern. In this pattern, the aircraft was piloted along the circumference of a 750 m diameter circle while the aerial observer viewed the circumscribed area. The aircraft pilot was unable to assist in visual observation due to the technical aspect of the survey procedures. Aircraft speed was maintained as close as possible to 27 m/sec (60 mph). The pilot used a stopwatch, airspeed and minute of turn to define the 750 m diameter circle (128 seconds to complete, 32 seconds through each quadrant). The location and orientation of the circle was indicated by markers positioned at the vantage point by the ground crew. The aerial observer recorded the time, location, group size, number of pups and activity of each new sea otter or group of sea otters observed. Circling was continued until 5 minutes had elapsed without any new otters being observed.

Pattern evaluation trials were conducted using 3 different intensive search patterns in conjunction with a strip count. The same aircraft, but different pilots, were used for the altitude and pattern evaluations. All pattern evaluation trials were conducted at an altitude of 92 m above sea level and at a speed of 27 m/s. Each trial began with a strip count in which the plane flew along one edge of a strip transect while the aerial observer recorded the location, group size, number of pups and activity of each sea otter or group of sea otters observed in the strip. Width of the strip was determined by the aerial observer using distance indicators marked on the wing struts and was either 400 m or 750 m, depending on the subsequent search pattern. The length of the strip was either 400 m, 750 m or 800 m, depending on the subsequent search pattern. Immediately following the strip count, the plane began one of three search patterns over the strip that had just been counted. The aircraft was piloted along the circumference of either a 400 m diameter circle, a 750 m diameter circle, or a 400 m x 800 m oval while the aerial observer viewed the circumscribed area. Selection of the search pattern was made by the ground crew according to the distribution of sea otters and the physiography of the coastline, while attempting to obtain an equal number of trials for each pattern. Ground crews indicated the location and orientation of each strip, circle and oval with markers at the vantage point. The pilot used techniques analogous to those developed for the 750 m circle to maintain each of the other 2 search patterns. The aerial observer recorded the circle or oval number, location, group size, number of pups and activity of each new sea otter or group of sea otters observed during the search. Intensive search patterns were continued until 5 minutes had elapsed without any new otters being observed.

At the end of each day, ground and aerial crews compared the mapped locations of all observed otters (for both altitude and pattern evaluations). For the otters present in trial i, $i=1, \cdots, r$, when the aircraft arrived, the number observed by both crews (b_i), the number observed only by the ground crew (g_i), and the number observed only by the aerial observer (a_i) in the observation circle or strip were determined. The number of otters in the circle or strip before any response to the approaching aircraft was determined based on ground crew observations prior to the arrival of the aircraft.

Sea otter detection probabilities (detectabilities) for the aerial observer were estimated as

$$\hat{P}_d = \frac{\sum_{i=1}^{r} b_i}{\sum_{i=1}^{r} (b_i + g_i)} , \tag{1}$$

where r is the number of trials. Detectabilities were also estimated separately for each trial as

$$\hat{P}_{di} = \frac{b_i}{b_i + g_i} . \tag{2}$$

Kruskal-Wallis tests were used to evaluate differences in detection probabilities among altitudes and patterns. Fisher's exact test for contingency tables was used to evaluate the effect of altitude and pattern on the proportion of trials in which all otters were detected and the proportion of trials in which otters exhibited disturbance behavior. All statistical tests were conducted at the 0.05 significance level.

We conducted a total of 98 trials, with observations of 329 groups of sea otters (741 individuals), in our evaluation of altitude and search pattern. Intensive searches resulted in detectability estimates greater than or equal to 0.90 for all altitudes and patterns investigated (Tables 1 and 2). All otters were detected in over half of the samples (Tables 1 and 2). The type of avoidance behavior observed in boat surveys (Udevitz et al. 1995), in which otters leave the search area before the survey platform arrives, was not observed in response to the aircraft. However, on some occasions it was apparent that otters were disturbed and began diving, swimming out of the area, or swimming erratically within the search area in response to the aircraft after it arrived. However, due to the approach speed of the aircraft, otters were unable to leave the survey area prior to the aircraft arrival.

We could not detect any differences in detection probability between trials conducted at 46, 92, or 137 m altitude (P = 0.72, Table 1). We would expect detectability to decrease substantially at altitudes much greater than those we considered. In general, safety is expected to increase with altitude (for altitudes up to at least 164 m). We considered forty-six meters as the minimum altitude safe enough for conducting this type of survey work. However, at the 46 meter altitude, disturbance to sea otters within the survey area occurred on 0.23 of our trials, compared to 0.08 at 92 and 137 meters altitude (difference not significant, P = 0.84, Table 1). We selected an altitude of 92 m for conducting subsequent work because it provides an added margin of safety above 46 meters, and minimized disturbance without appreciably decreasing detectability.

We also found no differences among the 3 intensive search patterns evaluated (P = 0.64, Table 2). However, with the 400 m circle, the entire ISU remained within the observer's view at all times, making it easier to keep track of which otters and groups had already been detected. With both of the other two patterns, the portion of the ISU furthest from the plane was always out of view (although all portions of the ISU were eventially seen each time the plane circled around). Detection probability estimates for initial strip counts ranged from 0.52 to 0.72 (Fig. 5). Detection probabilities increased sharply with the first 3 circles or ovals after the strip count (range 0.88 - 0.93) and continued to increase slightly for the next 3 to 4 circles or ovals (Fig. 5). No new otters were ever detected after the 7th circle or oval. In the absence of strong differences in detection probabilities, selection of a search pattern could be based on the probability of encountering otters in each search. We hypothesize that this probability decreases with decreasing the size of the search pattern, thus increasing the number of ISU's necessary to obtain a detection probability estimate with a given level of precision. However, because of decreasing detection probabilities with distance from observer (Fig. 3), and the need to keep track of otters within ISU's, the 400 m diameter ISU and the corresponding 400 m strip width were selected for further evaluation.

The data suggest that the most efficient search intensity consisted of 3 circles or ovals after an initial strip count (Fig. 5). Even with intensive searches, however, not all of the otters were detected. Population size estimates based on correction factors derived from these types of intensive counts can be expected to be negatively biased on the order of 0.05-0.10. This amount of bias represents a substantial improvement over some previously used methods, such as uncorrected boat and aircraft surveys.

Trial Survey

In 1992 we designed and implemented a trial survey in western Prince William Sound, using the results of our 1991 studies as a foundation. The design consisted of a series of parallel strip transects, 400 m wide and 1.2 km apart, overlaying the study area (Fig. 6). Electrical tape on wing struts indicated the viewing angle and the 400 m strip width when the aircraft wings were level at 92 m and the inside boundary was in-line with the outside edge of the airplane floats (Fig. 1). Each transect was identified by its intersection with the shoreline and an offshore boundary based on shoreline physiography (bays and inlets < 6 km wide were included in the study area regardless of depth), and the 100 m depth contour or a distance of 2 km from the shore, whichever was greater. The criteria we used to define the sample area was based on maximum known sea otter dive depths (approx. 100 m) and the otter's requirement for frequent access to foraging habitat. A GPS in the aircraft was used to locate the endpoints and navigate along each transect. Endpoint coordinates were downloaded from an external source via a memory card to the aircraft GPS. The study area contained 2,404 km^2, between shore and the seaward boundary. Transects were flown at an airspeed of 27 m/s and an altitude of 92 m. The observer searched the 400 m region between the float and the strut marks, scanning as far forward as conditions allowed. The location and size of each otter group were recorded on a transect map. A group was defined as 1 or more otters spaced less than 3 otter lengths apart. Groups of more than 30 otters were circled until a complete count was made. A camera with a 70-210 mm telephoto lens was available to photograph any groups too large and concentrated to count accurately. The number of pups (determined by size, coloration and association with a larger animal), in a group was noted behind a slash (e.g., 6/4 = 6 adults and 4 pups). Activity was recorded for each group as either diving or non-diving. If any individual(s) in a group were diving, the whole group was classified as diving. Diving otters included any individuals that swam below the surface and out of view, whether traveling or foraging. Non-diving otters were animals seen resting, interacting, swimming (but not diving), or hauled-out on land. Observation conditions were noted for each transect (wind, seas, swell, cloud cover, and glare). The pilot did not assist in sighting sea otters. A list of equipment used in the survey and a protocol for methods and survey design is provided in Appendix 1. Strip transect data forms and ISU data forms with keys to data collection are provided in Appendices 2 and 3, respectively.

The intensive search method of estimating detectability developed here is expected to only be useful for relatively small groups of otters. We assume that groups of 30 or more otters within a 400 m strip will be detected with certainty. Thus we conceptually divide the population (as it exists during a given survey) into two portions and derive separate estimates for the portion that occurred in groups of 30 or less (small groups) and the portion that occurred in groups of more than 30 (large groups). Complete counts, aided by photography, are made of all detected large groups. These counts are expanded directly based on the proportion of the total area sampled, without any adjustment for detectability (i.e., detectability is assumed to be 1 for this portion of the population). The estimate for the portion of the population occurring in small groups is also expanded based on the portion of the total area sampled but is then adjusted based on the estimated detectability of otters in these groups. The overall estimate of the population size is obtained by summing the estimates for these two components of the population.

In general, more than 1 observer may participate in a survey and the study area may be stratified based on various habitat characteristics. A separate estimate of small group detectability is required for each observer. Each estimate should be based only on intensive searches conducted by that observer. For notational convenience, consider each portion of a stratum surveyed by a different observer to be a separate stratum. The unadjusted population size for stratum j can be estimated as:

$$\hat{Y}_{(un)j} = \frac{\sum_{i=1}^{n_j} y_{ij}}{\sum_{i=1}^{n_j} a_{ij}} A_j$$

$$var(\hat{Y}_{(un)j}) = \frac{A_j^2 \, (1-f_j) \, n_j}{\left(\sum_{i=1}^{n_j} a_{ij}\right)^2 (n_j-1)} \sum_{i=1}^{n_j} \left(y_{ij} - \frac{a_{ij} \sum_{i=1}^{n_j} y_{ij}}{\sum_{i=1}^{n_j} a_{ij}} \right)^2 \qquad \textbf{(3)}$$

where

A_j = total area of stratum j,
n_j = number of surveyed transects in stratum j,
y_{ij} = number of otters detected in strip count on transect i in stratum j, $i=1,\cdots,n_j$,
a_{ij} = area of transect i in stratum j, and
f_j = the sampling fraction, approximated by

$$f_j = \frac{1}{A_j} \sum_{i=1}^{n_j} a_{ij} \ . \tag{4}$$

The correction factor for observer k can be estimated as:

$$\hat{p}_k = \frac{\sum_{i=1}^{t_k} c_i}{\sum_{i=1}^{t_k} s_i}$$

$$var(\hat{p}_k) = \frac{t_k \sum_{i=1}^{t_k} (c_i - \hat{p}_k s_i)^2}{(t_k - 1) \left(\sum_{i=1}^{t_k} s_i \right)^2} \tag{5}$$

where

s_i = number of otters detected in strip count of ISU i, $i=1,\cdots,t_k$, and
c_i = total number of otters detected after intensive search of ISU i.

The adjusted population size for stratum j (surveyed by observer k) can then be estimated as:

$$\hat{Y}_j = \hat{p}_k \ \hat{Y}_{(un)j}$$

$$var(\hat{Y}_j) = \hat{Y}^2_{(un)j} \ var(\hat{p}_j) + \hat{p}_j^{\,2} \ var(\hat{Y}_{(un)j}) - var(\hat{p}_j) \ var(\hat{Y}_{(un)j}) \ . \tag{6}$$

For the portion of the population in large groups, population size estimates for each stratum can be obtained as in (3) with no adjustment for detectability. The overall estimates of population size and variance for each stratum can then be obtained by summing the respective estimates for otters in small and large groups. Combined estimates of population size and variance for any (or all) of the strata can be obtained by summing the respective overall stratum estimates.

In the 1992 trial survey, a single observer surveyed 1,936 linear km of transects (744.4 km^2). There was no stratification and no large groups (more than 30 individuals) were detected. Intensive search units were systematically located by time along the transects, each consisting of three concentric circles over a 400 m diameter circle within the width of the survey strip. Otters were observed in 18 of the intensive search units. Estimates based on the 1992 trial survey in western PWS are presented in Table 3. The distribution of otters encountered in the 1992 survey suggested that about 85% of the otters were in 32% of the survey area, in water depths less than 40 m (Fig. 7).

Results of the 1992 trial survey suggested that precision in the estimate of abundance could be improved by: 1)increasing our sample size of ISU's, used to estimate detection probabilities and 2) by stratifying the survey area into high and low density strata and allocating sampling effort proportional to expected densities (Fig. 7). Our research efforts in 1993 were aimed at investigating and implementing these strategies, as outlined in the following sections.

METHODS AND MATERIALS

ISU Studies - 1993

The precision of ISU detection probabilities is limited by the number of intensive search units in which otters are observed. In the trial survey of 1992, otters were observed in only a small proportion of the systematically located ISU's. Systematically located ISU's are usable for estimating detection probability only when they contain one or more otters. The objective of the July 1993 research was to investigate methods for increasing the proportion of usable ISU's. If the probability of detecting each group of otters is independent, then detection probabilities could be estimated for ISU's initiated upon detection of a group, with the estimate only based upon any additional groups that might be present in the ISU. Group initiated ISU's would be usable only if they contained additional groups. Because otter groups tend to occur in clusters, this could result in a higher proportion of usable ISU's. The July 1993 research focused on comparing detection probabilities and proportions of usable ISU's obtained from systematically located and group-initiated searches.

Systematic ISU's were located at two minute intervals along 400 m wide strip transects within high and low density strata (see PWS Trial Survey below) in eastern Prince William Sound. Group-initiated ISU's were located at each otter group separated by more than 800 meters (30 seconds) along 400 m wide strip transects, also in high and low density strata in eastern Prince William Sound. Most of the transects (and associated ISU's) were surveyed by a new observer (designated GE), but a number of the transects were surveyed by the observer who had participated in the 1991 trials (designated JB). For each group of sea otters, observers recorded the activity and number of otters observed (independents and dependents) on the strip count and the number observed during the intensive search. Size and activity of the initiating group were recorded separately when the ISU was group-initiated. Detection probabilities were estimated based on all detected otters in each systematically located ISU that contained otters. For group-initiated ISU's, detection probabilities were based on all otters except the initial group in ISU's that contained additional groups. Detection probabilities were estimated according to equation (2) for both types of ISU. Differences between detection probabilities by type of ISU, observer, and stratum were compared with Kruskal-Wallis tests at a significance level of 0.05. The overall test was followed by pairwise contrasts (Conover 1980:231) if $P \leq 0.05$. The same testing procedure was used to compare differences between the proportion of diving groups by observer and stratum. Power ($1-\beta$) of selected tests was estimated using a bootstrap technique patterned after the approach of Collins and Hamilton (1988).

PWS Trial Survey - 1993

We designed and implemented a trial survey throughout all of Prince William Sound, excluding Orca Inlet, in August of 1993, using the results of 1991, 1992, and 1993 research. The survey was conducted using the same methodology as in 1992 with the following exceptions: 1) two strata, a high and low density, were sampled proportional to expected abundances, 2) two observers conducted the survey, and 3) the sampling intensity per unit area was lower (a larger area was sampled with similar effort) in 1993.

Using the spatial distribution data obtained in the 1992 trial survey, we identified two strata. Sea otter habitat was sampled by strip transect counts in each of these strata, high density and low density, distinguished by distance from shore and/or depth contour (Fig. 9). The high density stratum extended 400 m seaward from shore or to the 40 m depth contour, whichever was further from shore. The low density stratum extended from the offshore high density boundary to an offshore boundary based on shoreline physiography, and the 100 m depth contour or a distance of 2 km from shore, whichever was greater. Bays and inlets less than 6 km wide were included in the high density stratum, regardless of depth. Parallel strip transects were spaced systematically within each stratum. Survey effort was allocated in proportion to expected otter abundance (Fig. 7), with approximately 0.20 of the high density stratum sampled (every 5th strip) and 0.05 of the low density stratum sampled (every 20th strip).

Based on the results (see below) of 1993 ISU studies, ISU's were initiated by the sighting of the first group observed within each 15 minute period of an hour (0-15, 15-30 ...) in the high density stratum and by each group sighted in the low density stratum on a strip transect. All successive ISU's were separated by a minimum distance of 800 m (30 seconds). The initiating group sighting was followed by 3 concentric circles flown over the 400 m strip. The ISU began at a point on the transect line that was perpendicular to a line from the transect to the group that initiated the ISU. The pilot used a stopwatch to time the minimum 30 second spacing between consecutive ISU's and to navigate the circumference of each circle. ISU locations were drawn on the transect map and group size and activity recorded on a separate data sheet for each ISU. For each group, we recorded the number of otters observed (independents and dependents) on the strip count and the number observed during the intensive search. Sizes of initiating groups were recorded separately. Otters that swam into an ISU post factum were not included. Population size for Prince William Sound, excluding Orca Inlet, was estimated according to equations (3) - (6).

RESULTS

ISU Studies - 1993

In July 1993, we conducted searches in 101 systematically located ISU's and 99 group initiated ISU's (Table 4). Systematically located ISU's could only be used for estimating detection probabilities if they contained at least one sea otter. Twenty-one of 101 (0.208) systematic ISU's met this criteria. Group initiated ISU's could be used for estimating detection probabilities only if they contained more than one group of sea otters. Forty-one of 99 (0.414) group initiated ISU's met this criteria. Kruskal-Wallis tests indicated that detection probabilities did not depend on the method for locating ISU's ($P = 0.27$ for GE, $P = 0.86$ for JB)., though the power of these tests were quite low ($1\text{-}\beta = 0.28$ for GE, $1\text{-}\beta = 0.16$ for JB). Differences between observer were significant for both methods ($P = 0.02$ for group-initiated, $P = 0.01$ for systematic). Differences in detection probabilities between strata were not significant for either observer ($P = 0.23$ for GE, $P = 0.63$ for JB). Differences in the proportion of diving groups were not significant for observer or strata ($P = 0.07$). Based on these data we used group-initiated ISU's in the 1993 trial survey.

PWS Trial Survey - 1993

In August 1993, we conducted a trial survey of the entire Prince William Sound, excluding Orca Inlet. The survey area consisted of 5,017 km^2 (Fig. 8) and was partitioned into two stratum (high and low) as defined above. We sampled 1,023 linear km of high stratum transects (approximately 0.20 of total) and 355 linear km of low stratum transects (approximately 0.05 of total) using two observers (Table 5). A total of 934 otters were detected in small groups in the surveyed transects. Forty ISU's with more than one group of otters were searched, resulting in correction factors of 1.23 for JB and 3.27 for GE (Table 5). In addition to the small groups, 52 otters were detected in a single large group (size > 30). This expanded to a population size estimate of 277 otters (SE = 249) occurring in large groups. Combining the adjusted stratum estimates for small groups (Table 5) and the estimate for large groups gave an estimate of 16,814 sea otters (SE = 5,741) in Prince William Sound, excluding Orca Inlet. Flight time required to complete the survey was 79.9 hours, including transit.

DISCUSSION

Previous researchers have recognized that some proportion of sea otters in the area surveyed are not observed, regardless of the method employed. The result is a bias in the estimate of abundance. This bias can be reduced by estimating the proportion of animals not observed, and using the reciprocal of this proportion as a correction factor. Correction factors may be affected by differences in observers and by survey conditions. Thus, any survey method should incorporate techniques for estimating a correction factor specific for the observers and conditions associated with each application of the method.

An evaluation of the PA-18 Super-Cub as a survey platform indicated that detection probabilities in strip counts were low (0.52 - 0.72), but that intensive searches over selected portions of the strip could provide correction factors to compensate for most of the detectability bias. Use of this approach in a trial survey suggested that precision could be improved by optimizing sampling effort among strata and increasing the usable sample of ISU's. Research conducted in 1993 indicated that for a given number of ISU's, the number of usable ISU's could be approximately doubled by initiating searches only when groups were detected. Detection probability estimates based on group initiated ISU's will not be more biased than estimates based on systematically located ISU's if the initiating group is not included in the estimate and if the detection of groups is independent. The assumption of independence of group detection is common in line transect theory (e.g., Burnham et al. 1980, Quang and Lanctot 1991, Buckland et al. 1993). Though the power of the tests was low, the fact that we did not find differences in estimated detection probabilities between the two methods for locating ISU's is also consistent with this assumption.

The potential for relations between size and detectability of animal groups is well known (Buckland et al. 1993) and the relation has been demonstrated for sea otters in certain cases (Estes and Jameson 1988, Drummer et al. 1990). Our line transect data did not indicate any effect of group size on detectability, but the range of observed group sizes was quite small. Other studies have found that group size effects were not evident for sea otters when there was little variation in group size or observation distances were relatively short (Udevitz et al. 1995, Drummer et al. 1990). Buckland et al. (1993) suggested that group size effects can usually be eliminated by truncating observation distances. We only apply the ISU technique for estimating detection probabilities of groups with less than 30 individuals and observation distances are truncated at 400 m. Thus, it is unlikely that there would be any strong group size effects on detectability in these surveys. In any case, if detections of groups are independent, the size of the initially detected group (or its detection probability) will not affect the estimated detection probabilities in group-initiated ISU's.

Our experience with the 1993 ISU study and trial survey indicates that differences in detectability between observers may be large. A difference in detectability between observers will not increase the bias of the adjusted population estimate as long as the correction factor for each observer is estimated separately. This can be done, as long as each observer can achieve the minimum acceptable detectability (i.e., 90%) in the intensive searches. The precision of the estimated correction factors will depend on the number of usable ISU's for each observer. The 1993 data also suggest that correction factor estimates may be more variable for less experienced observers. It may be possible to reduce this variability with additional experience or more rigorous training. In order to achieve an acceptable level of precision for the adjusted population size estimates, it will be necessary to either limit the number of observers or increase the sampling intensity so that a sufficient number of usable ISU's are obtained for each observer.

We were able to improve our allocation of sampling effort in the 1993 survey by stratifying sampling in proportion to expected densities within each stratum, but proportional standard errors for the total estimated population size were larger in the 1993 survey than in the 1992 trial survey. Several factors apparently contributed to the reduced overall precision. First, our sampling effort was slightly less in 1993 compared to 1992, while the survey area more than doubled, resulting in high variances in counts, particularly among low density transects. Also, a second observer participated in the 1993 survey. Because of inter-observer differences in detection probabilities (Table 4) we had to estimate separate correction factors for each observer. Splitting the ISU's among observers resulted in small sample sizes with high standard errors. The higher variability associated with the larger area surveyed and the large standard errors associated with estimating two correction factors led to a decrease in the precision of the population estimate between 1992 and 1993. It should be noted that the smallest sample size of ISU's (13/40) was available for estimating the detection probability of the observer with the most variation in detection probabilities (GE). If only one observer had conducted the survey so that all ISU's could be used to estimate a single correction factor, or if more of the ISU effort had been allocated to the observer with the greater variability, the precision of the overall estimate could have been substantially improved.

Future efforts to improve precision and efficiency should include a training regime to decrease variability in detection probabilities and assure that all observers detect at least 90% of the otters within ISU's. Additionally, the survey should be designed so that each observer obtains 40 usable ISU's. We did not detect differences in detectability or diving behavior (that would be expected to affect detectability) between strata. This suggests that focusing ISU's in the high density stratum where ISU's can be located most efficiently may not increase the bias of detectability estimates. Further improvements in precision may be achieved by analyzing separately the two components of detection: 1) the probability of detecting a group, and 2) the proportion of the otters detected in a group, given that the group is detected. This separation would allow the use of all ISU's in estimating the second component of the detection probability. Greater overall sampling effort would also increase precision of the population estimate.

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Table 1. Detection probabilities (estimated by comparing air to ground observations) at three altitudes in a 750 m diameter search pattern continued for 5 minutes following the last otter sighting.

	Altitude		
	46M	92M	137M
Number of trials	13	12	12
Number of groups	58	43	44
Number of otters	133	104	106
Detection probability	0.92	0.91	0.90
Detection = 1.0[a]	0.62	0.50	0.50
Disturbance [b]	0.23	0.08	0.08

[a] Proportion of samples in which all otters were detected.

[b] Proportion of samples in which disturbance by aircraft was detected by ground.

Table 2. Detection probabilities (estimated by comparing air to ground observations) for three search patterns at 92 m continued for 5 minutes following the last otter sighting.

	Search pattern		
	400M Circle	750M Circle	800M Oval
Number of trials	20	19	22
Number of groups	58	40	86
Number of otters	113	72	213
Detection probability	0.96	0.93	0.90
Detection = 1.0[a]	0.80	0.79	0.68
Disturbance [b]	0.15	0.26	0.19

[a] Proportion of samples in which all otters were detected.

[b] Proportion of samples which disturbance by aircraft was detected by ground.

Table 3. Estimates from the 1992 trial sea otter survey in western Prince William Sound, Alaska.

	Estimate	SE
Unadjusted N	1,973	391
Correction factor	1.77	0.33
Adjusted N	3,493	937

Table 4. Comparison of detection probabilities obtained from systematic and group initiated intensive search units (ISU's), by observer, stratum (high and low) and otter behavior (diving or non-diving). Sample sizes are in parentheses.

	Observer[a]	
	JB	GE
Method		
Systematic	0.95 (7)	0.68 (14)
Group Initiated	0.75 (12)	0.56 (29)
Stratum		
High	0.84 (17)	0.80 (2)
Low	0.59 (37)	0.50 (6)
Proportion of Groups Diving		
High Stratum	0.57 (17)	1.00 (2)
Low Stratum	0.30 (37)	0.57 (6)

[a] Differences between observers significant for both methods ($P < 0.05$, Kruskal-Wallis test).

Table 5. Otter counts, unadjusted population size estimates, correction factors and adjusted population size estimates for small groups in the 1993 trial sea otter survey, Prince William Sound, Alaska.

Counts and Unadjusted Estimates					
Observer	Stratum	Count[a]	Area[b]	Estimate	SE
JB	High	358	204	1,906	299
	Low	53	81	1,059	468
GE	High	444	206	2,363	339
	Low	79	61	1,578	1,293

Correction Factors			
Observer	ISU's[c]	Factor	SE
JB	27	1.23	0.12
GE	13	3.27	1.45

Adjusted Estimates			
Observer	Area[d]	Estimate	SE
JB	2,704	3,637	729
GE	2,313	12,900	5,689
Total	5,017	16,537	5,735

[a] Number of otters observed on transects.

[b] Area of surveyed transects (km^2).

[c] Number of usable ISU's.

[d] Size of study area (km^2).

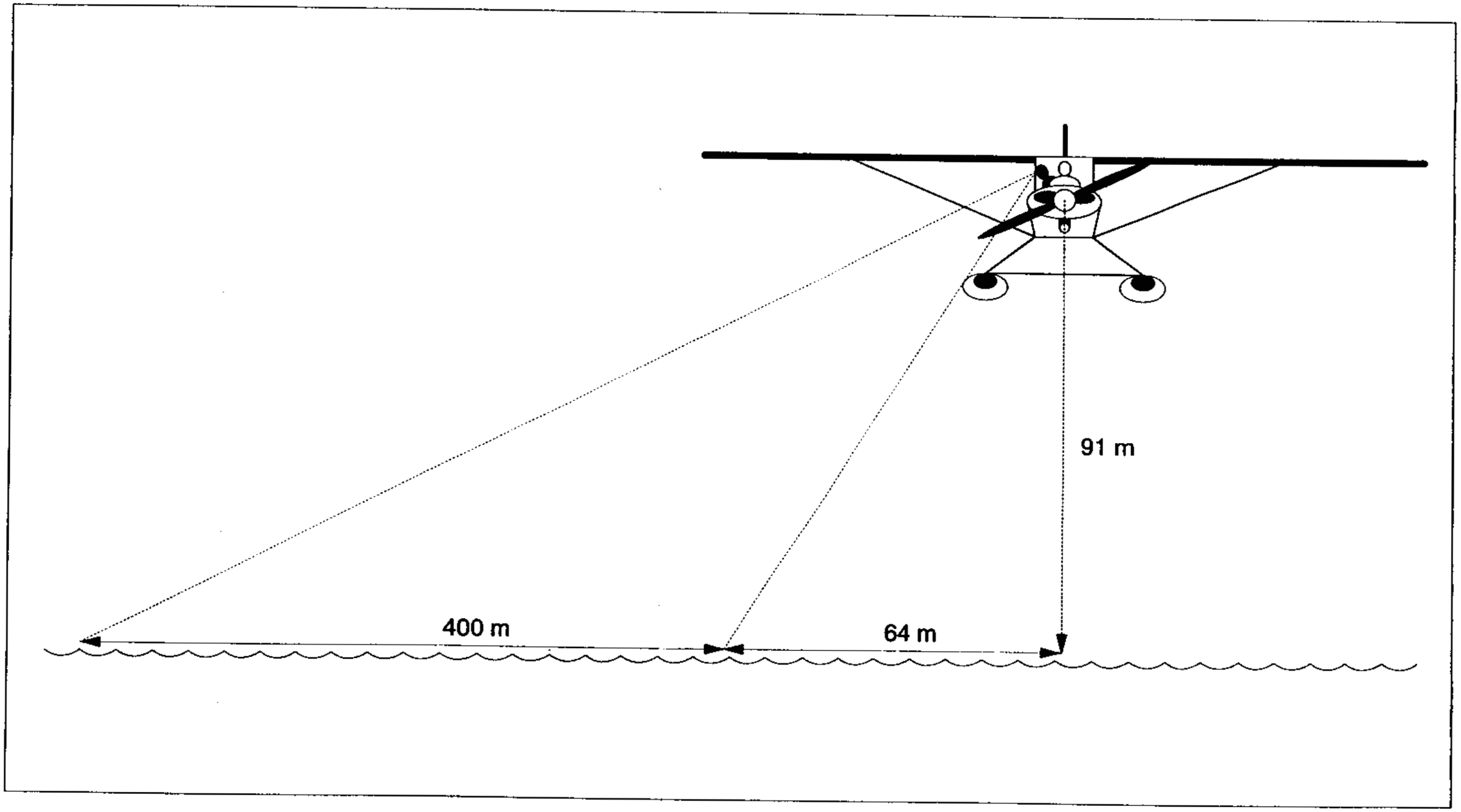

Figure 1. Illustration of delineation of 400 m wide transect from the float equipped PA-18 aircraft in sea otter survey design.

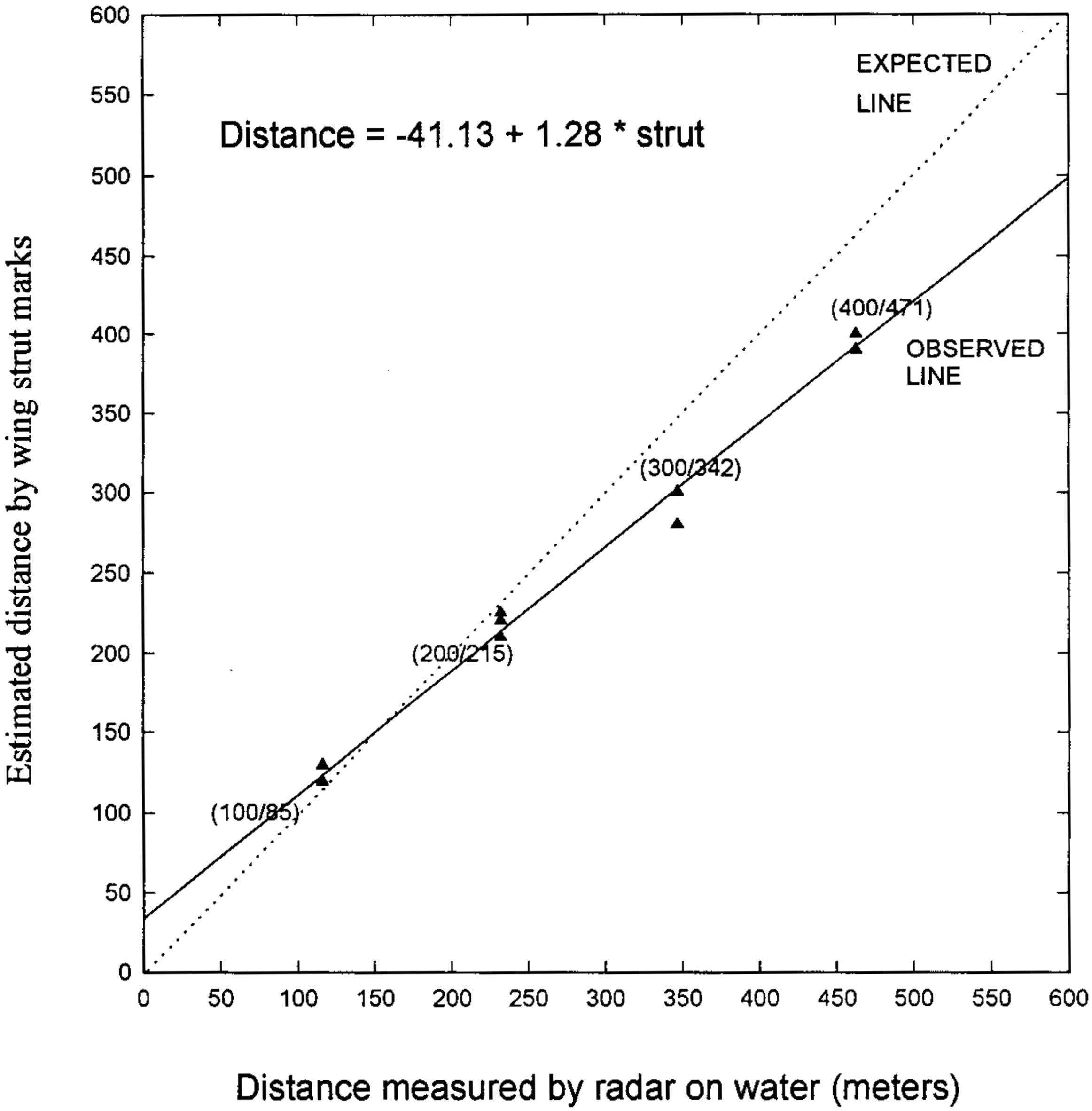

Figure 2. Estimated distances from inner strip line to radar measured distances on the water using wing strut markers and assuming no radar error. Radar measured / mean estimated distances are in parentheses.

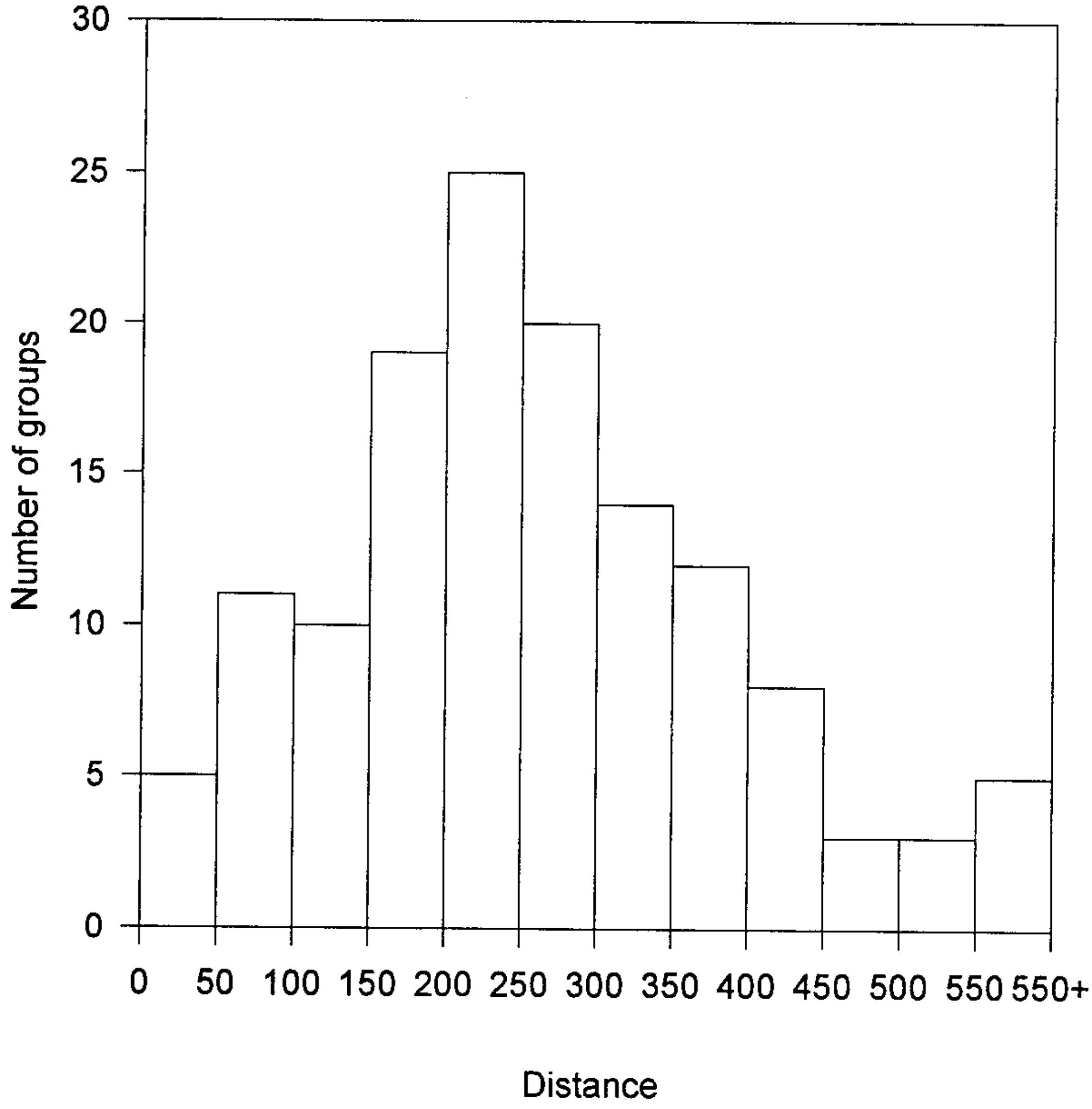

Figure 3. Number of sea otter groups observed in each distance category from the flight line with a standard line transect survey protocol.

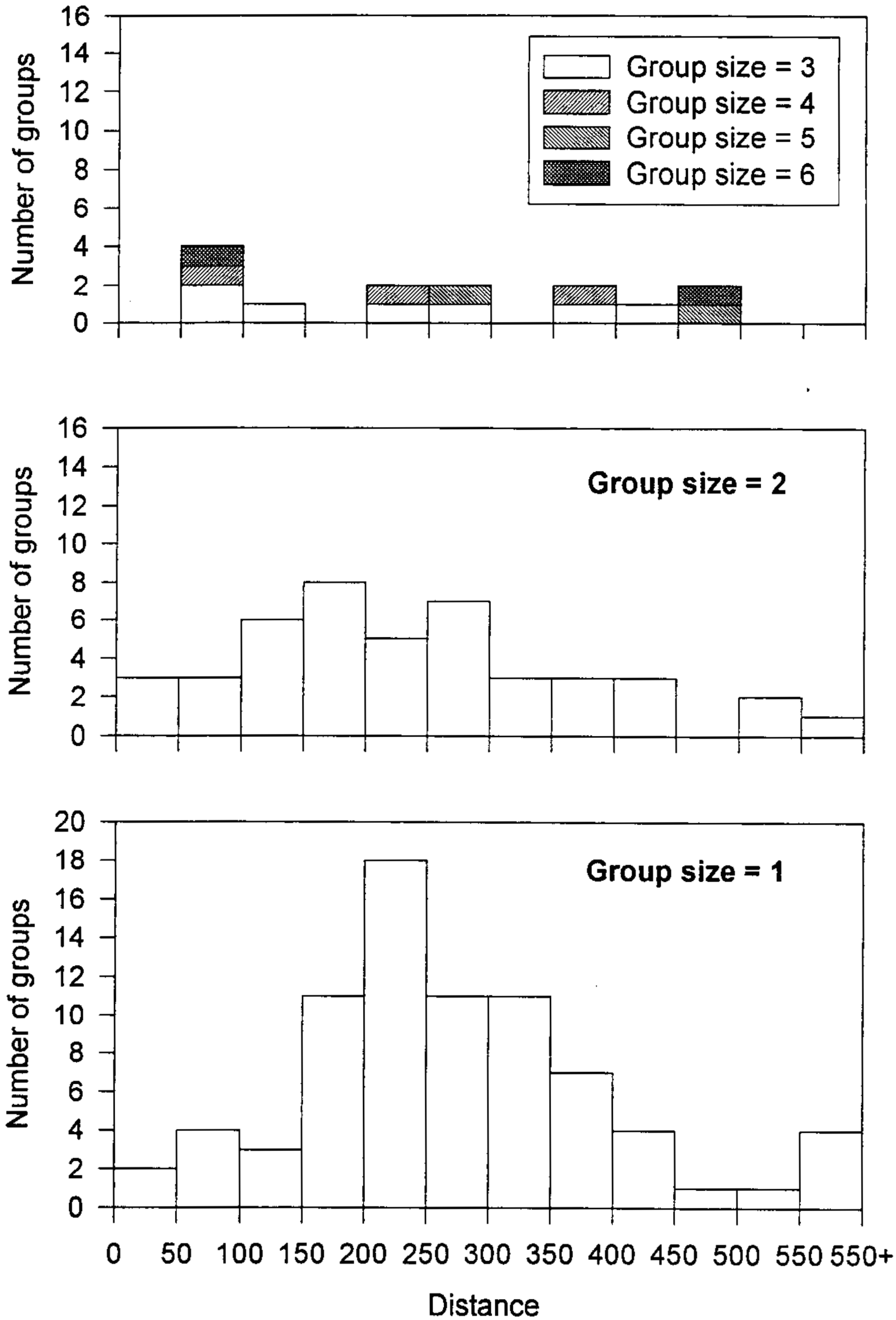

Figure 4. Number of sea otter groups of various sizes observed in each distance category from the flight line with a standard line transect survey protocol.

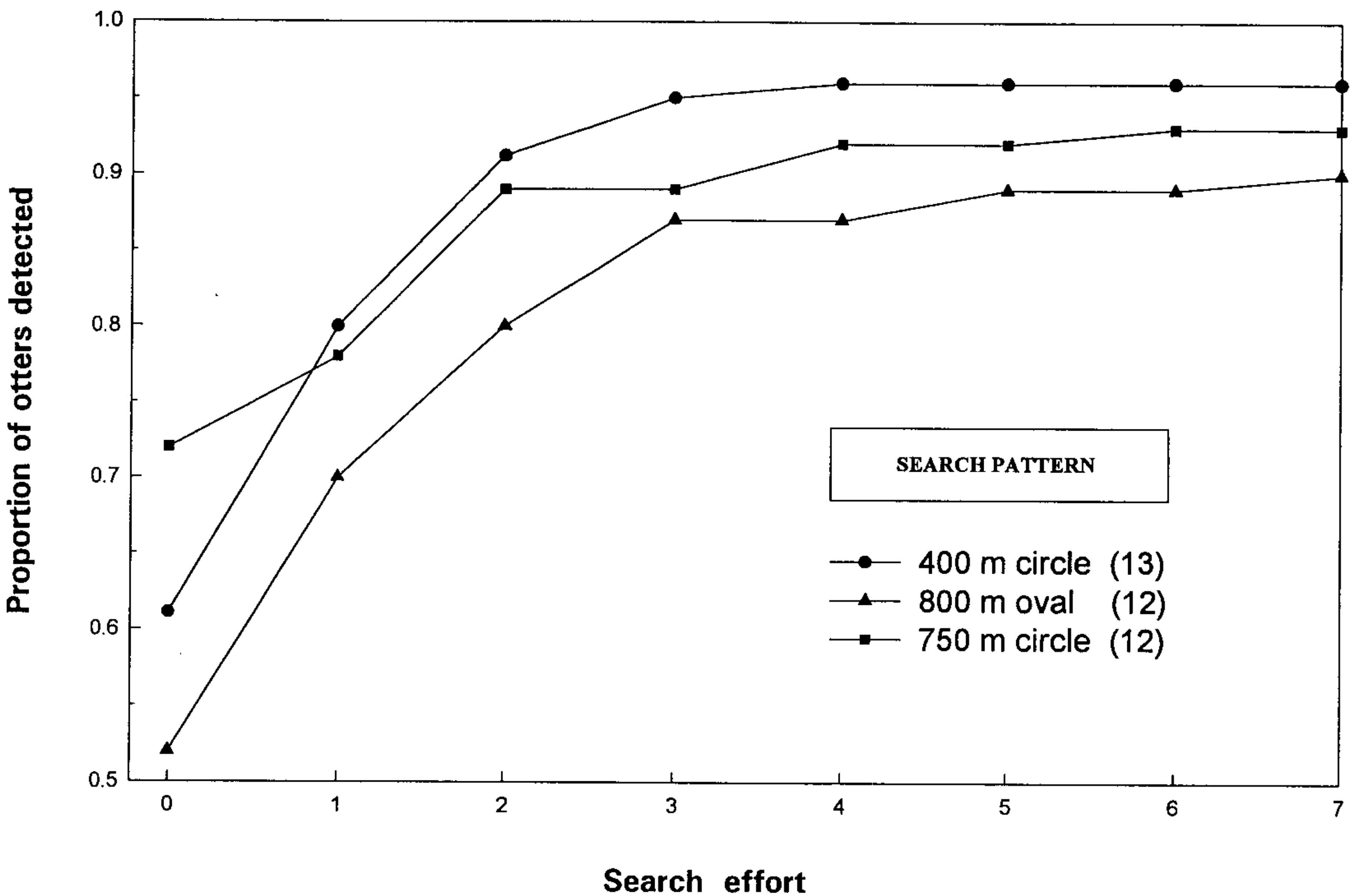

Figure 5. Mean detection probability as a function of search effort, as indicated by the number of concentric flight paths, for three different search patterns, for one observer in 1991. Sample sizes are in parentheses.

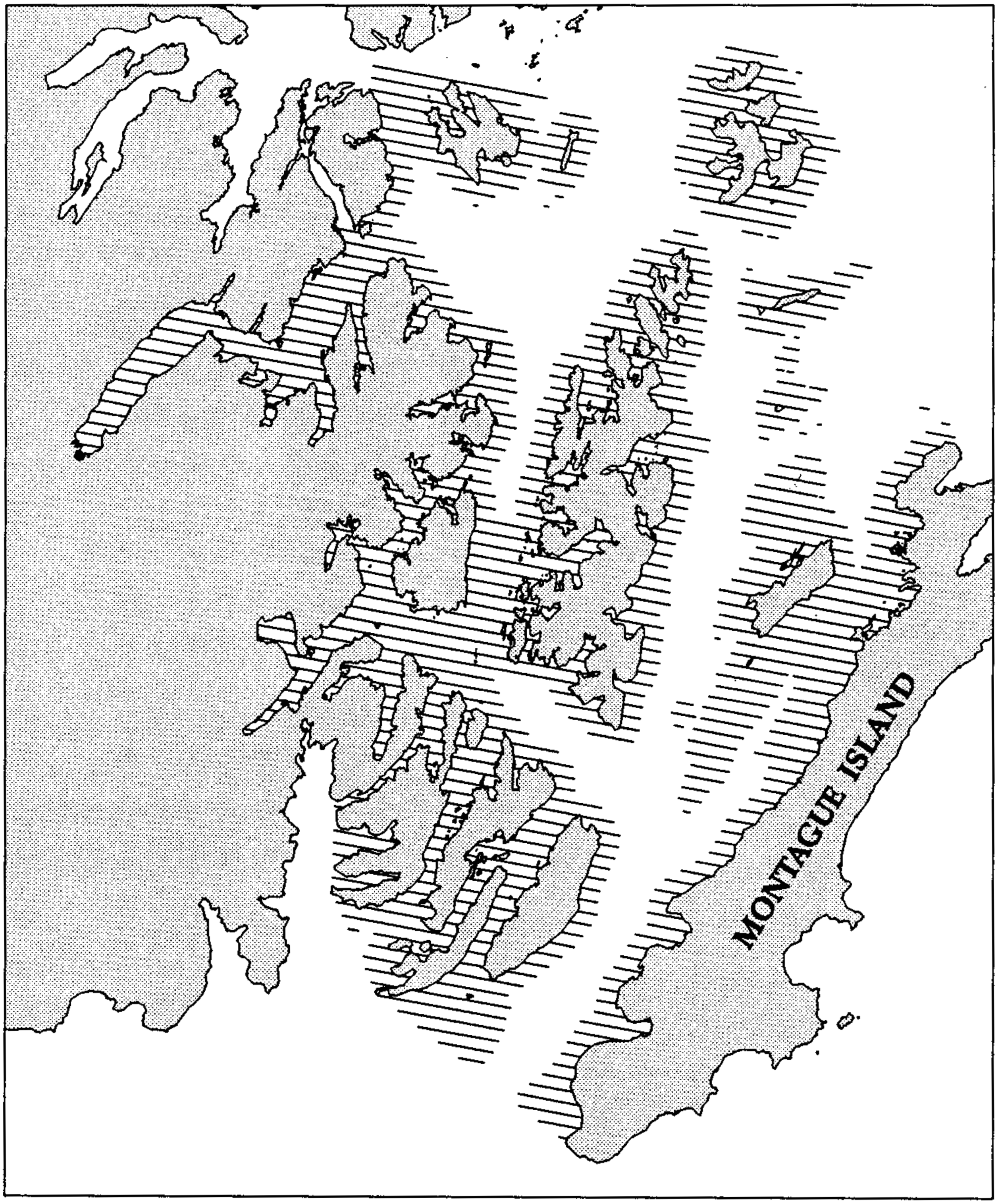

Figure 6. Survey area and location of transects surveyed in 1992 trial survey of Western Prince William Sound, Alaska.

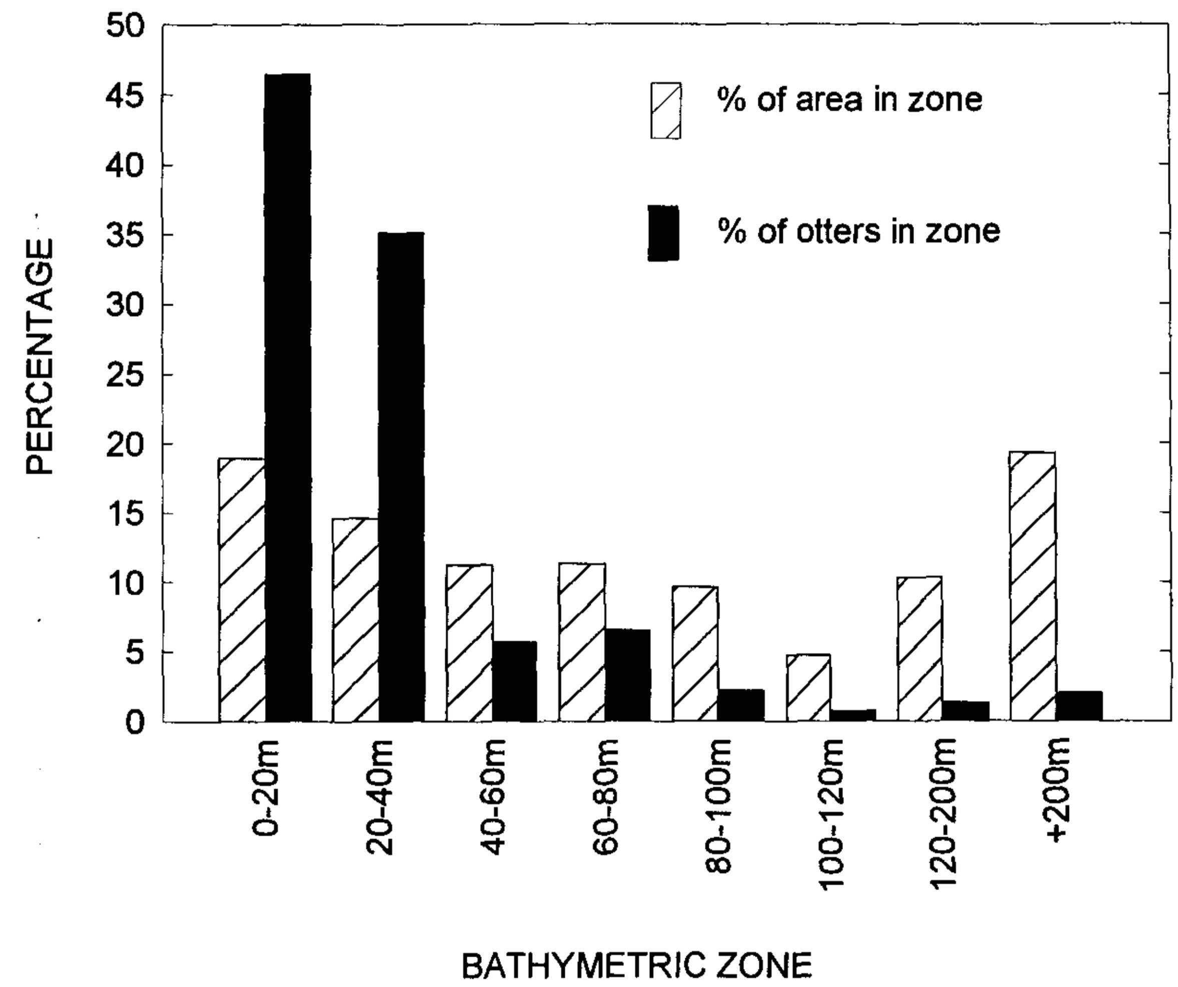

Figure 7. Percentage of otters observed in eight bathymetric zones and the percentage of total survey area represented by those zones in 1992 trial survey of Western Prince William Sound, Alaska.

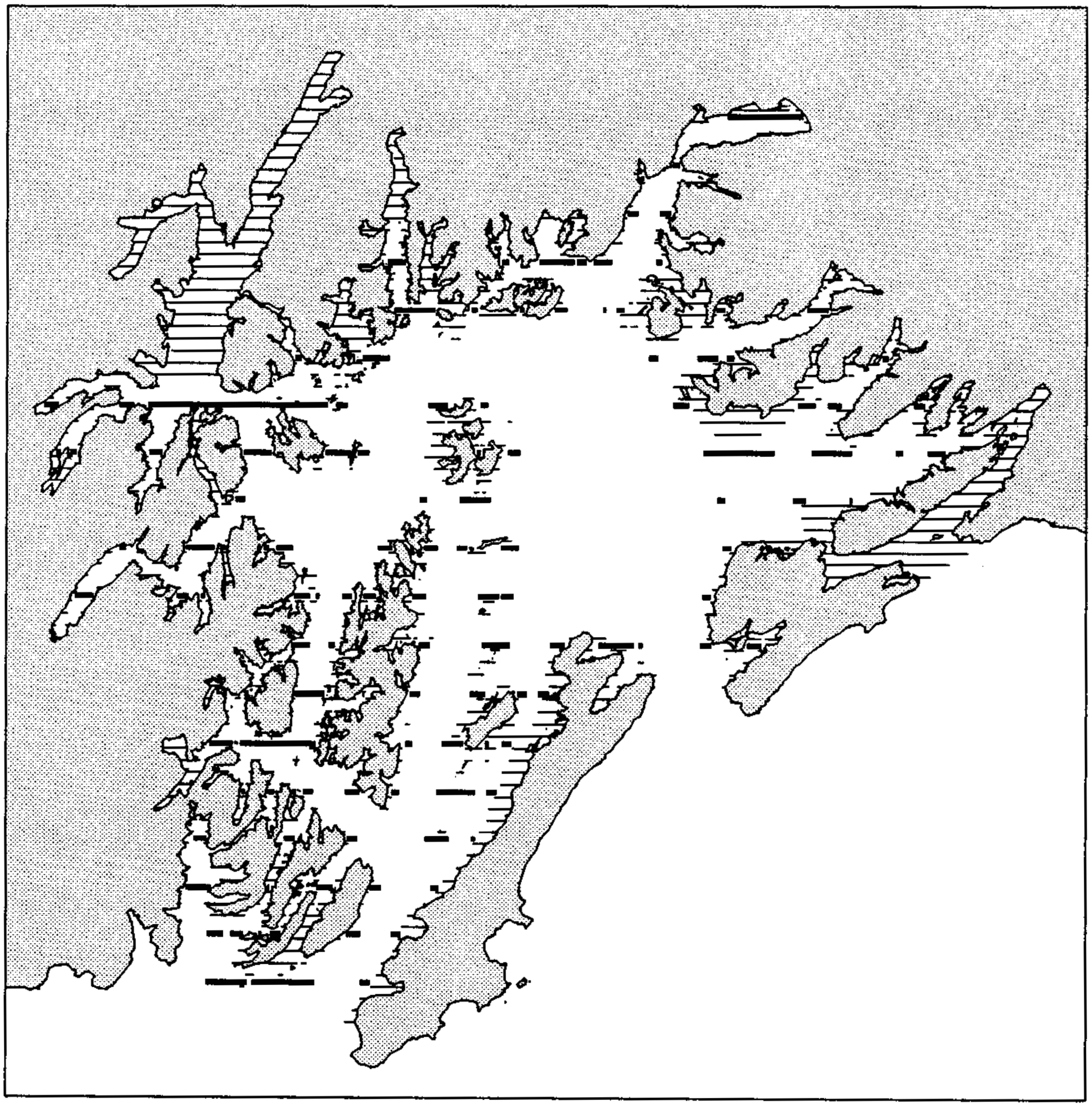

Figure 8. Survey area and location of transects surveyed in 1993 trial survey of Prince William Sound, Alaska.

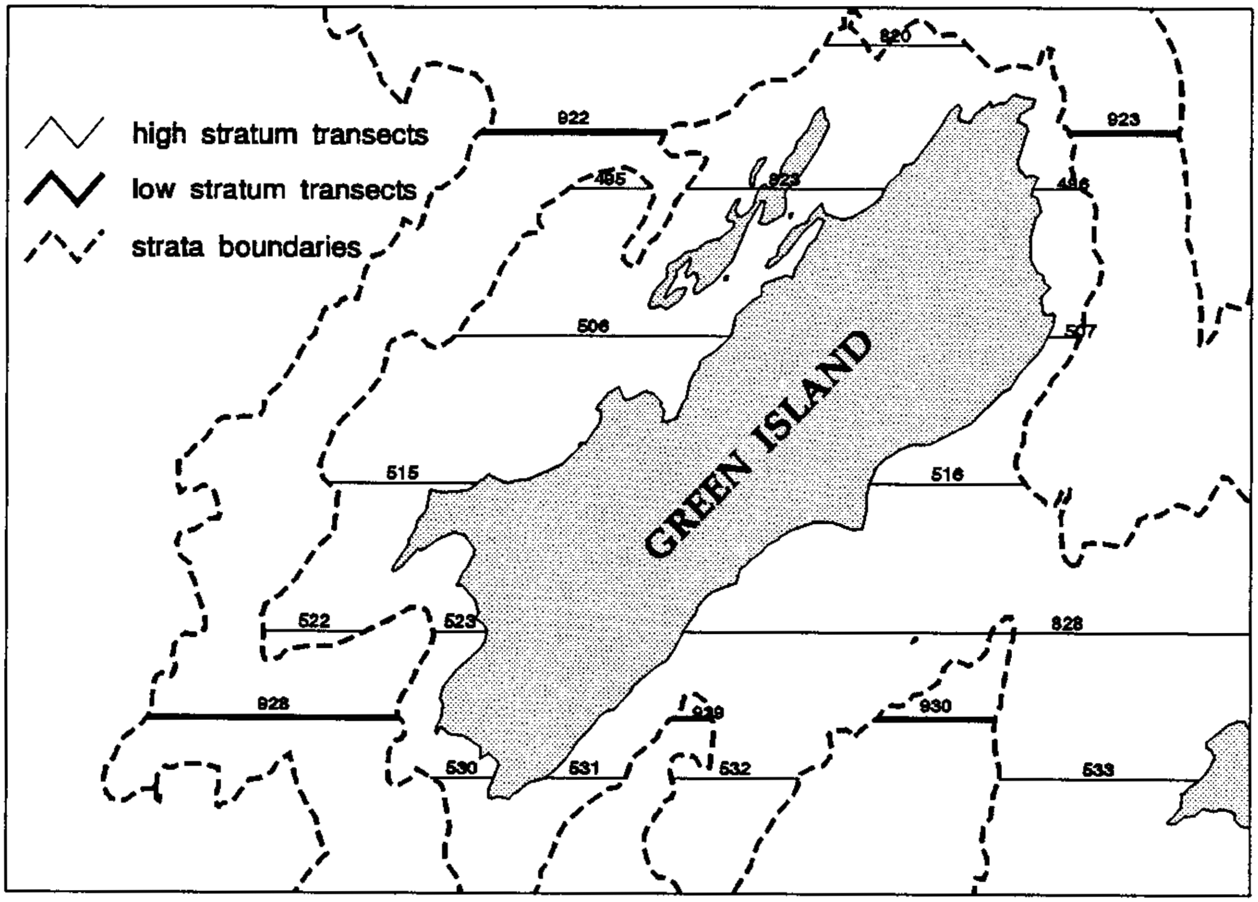

Figure 9. Example of distinction between high and low stratum transects and relative sampling intensity.

APPENDIX 1: Sampling Protocol for Sea Otter Aerial Surveys

Overview of survey design

The survey design consists of 2 components: 1) strip transect counts, and 2) intensive search units.

1) Strip Transect Counts

Sea otter habitat is sampled in two strata, high density and low density, distinguished by distance from shore and depth contour. The high density stratum extends from shore to 400 m seaward or to the 40 m depth contour, whichever is greater. The low density stratum extends from the high density line to a line 2 km offshore or to the 100 m depth contour, whichever is greater. Bays and inlets less than 6 km wide are sampled entirely, regardless of depth. Transects are spaced systematically within each stratum. Survey effort is allocated proportional to expected otter abundance in the respective strata.

Prior to surveying a geographic area (e.g., College Fjord), the observer will determine which side of the transect lines (N, S, E, or W) has less glare. The side with less glare will be surveyed by a single observer in a fixed-wing aircraft. Transects with a 400 meter strip width are flown at an airspeed of 60 mph (27 m/s) and an altitude of 300 feet (92 m). The observer searches forward as far as conditions allow and out 400 m, indicated by marks on the aircraft struts, and records otter group size and location on a transect map. A group is defined as 1 or more otters spaced less than 3 otter lengths apart. Any group greater than 30 otters is circled until a complete count is made. A camera should be used to photograph any groups too large and concentrated to count accurately. The number of pups in a group is noted behind a slash (e.g., 6/4 = 6 adults and 4 pups). Observation conditions are noted for each transect and the pilot does not assist in sighting sea otters.

2) Intensive Search Units

Intensive search units (ISU's) are flown at intervals dependent on sampling intensity*, throughout the survey period. An ISU is initiated by the sighting of a group and is followed by 3 concentric circles flown within the 400 m strip perpendicular to the group which initiated the ISU. The pilot uses a stopwatch to time the minimum 1 minute spacing between consecutive ISU's and guide the circumference of each circle. With a circle circumference of 1,256 m and an airspeed of 60 mph (27 m/s), it takes 48 seconds to complete a circle (e.g., 12 seconds/quarter turn). With 3 circles, each ISU takes about 2.4 minutes to complete. ISU circle locations are drawn on the transect map and group size and behavior is recorded on a separate form for each ISU. For each group, record number observed on the strip count and number observed during the circle counts. Otters that swim into an ISU post factum are not included and groups greater than 30 otters cannot initiate an ISU.

Behavior is defined as "whatever the otter was doing before the plane got there" and recorded for each group as either diving (d) or nondiving (n). Diving otters include any individuals that swim below the surface and out of view, whether traveling or foraging. If any individuals(s) in a group are diving, the whole group is classified as diving. Nondiving otters are animals seen resting, interacting, swimming (but not diving), or hauled-out on land or ice.

* The targeted number of ISU's per hour should be adjusted according to sea otter density. For example, we have an area that is estimated to take 25 hours to survey and the goal is to have each observer fly 40 "usable" ISU's; an ISU must have more than one group to be considered usable. Because previous data show that only 40 to 55% of the ISU's end up being usable, surveyors should average at least 4 ISU's per hour. Considering the fact that one does now always get 4 opportunities per hour - especially at lower sea otter densities, this actually means taking something like the first 6 opportunities per hour. However, two circumstances may justify deviation from the 6 ISU's per hour plan:

1) If the survey is not progressing rapidly enough because flying ISU's is too time intensive, *reduce* the minimum number of ISU's per hour slightly.

2) If a running tally begins to show that, on average, less than 4 ISU's per hour are being flown, *increase* the targeted minimum number of ISU's per hour accordingly.

The bottom line is this: each observer needs to obtain a preset number of ISU's for adequate statistical precision in calculation of the correction factor. To arrive at this goal in an unbiased manner, observers must pace themselves so ISU's are evenly distributed throughout the survey area.

Preflight

Survey equipment:
- stopwatches (2)
- low power, wide angle binoculars (e.g., 4 x 12)
- clipboards (2)
- transect maps
- transect data forms
- ISU data forms
- list of transects waypoints
- Global Positioning System (GPS)
- memory cards with waypoints
- 35 mm camera with 70-210 mm zoom lens
- high-speed film

Airplane windows must be cleaned each day prior to surveying.

Global Positioning System (GPS) coordinates used to locate transect starting and end points, must be entered as waypoints by hand or downloaded from an esxternal source via a memory card.

Electrical tape markings on wing struts indicate the viewing angle and 400 m strip width when the aircraft wings are <u>level</u> at 300 feet (92 m) and the inside boundary is in-line with the outside edge of the airplane floats.

The following informatiion is recorded at the top of each transect data form:

Date - Recorded in the DDMMMYY format.
Observer - First initial and up to 7 letters of last name.
Start time - Military format.
Aircraft - Should always be a tandem seat fixed wing which can safely survey at 60 mph.
Pilot - First initial and up to 7 letters of last name.
Area - General area being surveyed.

Observation conditions

Factors affecting observation conditions include wind velocity, seas, swell, cloud cover, glare, and precipitation. Wind strong enough to form whitecaps creates unacceptable observation conditions. Occasionally, when there is a short fetch, the water may be calm, but the wind is too strong to allow the pilot to fly concentric circles. Swell is only a problem when it is coupled with choppy seas. Cloud cover is desirable because it inhibits extreme sun-glare. glare is a problem that can usually be moderated by observing from the side of the aircraft opposite the sun. Precipitation is usually not a problem unless it is extremely heavy.

Chop (C) and glare (G) are probably the most common and important factors effecting observation conditions. Chop is defined as any deviation from flat calm water up to whitecaps. Glare is defined as any amount of reflected light which may interfere with sightability. After each transect is surveyed, presence is noted as C, G, or C/G and modified by a quartile (e.g., if 25% of the transect had chop and 100% had glare, observation conditions would be recorded as 1C/4G). Nothing is recorded in the conditions category if seas are flat calm and with no glare.

Observer fatigue

To ensure survey integrity, landing the plane and taking a break after every 1 to 2 hours of survey time is essential for both observer and pilot. Survey quality will be compromosed unless both are given a chance to exercise their legs, eat, go to the bathroom, and give their eyes a break so they can remain alert.

Vessel activity

Areas with fishing or recreational vessel activity should still be surveyed.

Unique habitat features

Local knowledge of unique habitat features may warrant modification of survey protocol:

1. **Extensive shoaling or shallow water** (i.e., mud flats) may present the opportunity for extremely high sea otter densities with groups much too large to count with the same precision attainable in other survey areas. Photograph only otters within the strip or conduct complete counts, typically made in groups of five or ten otters at a time. Remember, groups > 30 cannot initiate an ISU.

   Example: Orca Inlet, PWS. Bring a camera, a good lens, and plenty of film. Timing is important when surveying Orca Inlet; the survey period should center around a positive high tide - plan on a morning high tide due to the high probability of afternoon winds and heavy glare. Survey the entire area from Hawkin's cutoff to Nelson Bay on the same high tide because sea otter distribution can shift dramatically with tidal ebb and flow in this region.

2. **Cliffs** - How transects near cliffs are flown depends on the pilot's capabilities and prevailing weather conditions. For transects which intersect with cliff areas, including tidewater glaciers, discuss the following options with the pilot prior to surveying.

   In some circumstances, simply increasing airspeed for turning power near cliffs may be acceptable. However, in steep/cliff-walled narrow passages and inlets, it may be deemed too dangerous to fly perpendicular to the shoreline. In this case, as with large groups of sea otters, obtain complete counts of the area when possible.

   In larger steep-walled bays, where it is too difficult or costly to obtain a complete count, first survey the entire bay shoreline 400 m out. Then survey the offshore transect sections, using the 400 m shoreline strip just surveyed as an approach. Because this is a survey design modification, these data will be analyzed separately.

   Example: Herring Bay, PWS. Several cliff areas border this area.
   Example: Barry Glacier, PWS. Winds coming off this and other tidewater glaciers may create a downdraft across the face. The pilot should be aware of such unsafe flying conditions and abort a transect if necessary.

3. **Seabird colonies** - Transects which intersect with seabird colonies shoud be shortened accordingly. These areas can be buffered for a certain distance in ARC dependant on factors such as colony size, species composition, and breeding status.

   Example: Kodiak Island. Colonies located within 500 m of a transect AND Black-legged Kittiwakes > 100 OR total murres > 100 OR total birds > 1,000 were selected from the seabird colony catalog as being important to avoid.

4. **Drifters** - During calm seas, for whatever reason - possibly a combination of ocean current patterns and geography - large numbers of sea otters can be found resting relatively far offshore, over extremely deep water, miles (up to 4 miles is not uncommon) from the nearest possible foraging area.

   Example: Port Wells, PWS. Hundreds of sea otters were found scattered throughout this area with flat calm seas on 2 consecutive survey years. As a result, Port Wells was reclassified as high density stratum.

5. **Glacial moraine** - Similar to the drifter situation, sea otters may be found over deep water on either side of this glaciel feature.

   Example: Unakwik, PWS. Like Port Wells, Upper Unakwik was reclassified as high density stratum.

Planning an aerial survey

Several key points should be considered when planning an aerial survey:

1. Unless current sea otter distribution is already well known, it is well worth the effort to do some reconnaissance. This well help define the survey area and determine the number of observers needed, spacing of ISU's, etc.

2. Plan on using 1 observer per 5,000 otters.

3. Having an experienced technical pilot is extremely important. Low level flying is, by nature, a hazardous proposition with little room for error; many biologists are killed this way. While safety is the formost consideration, a pilot must also be skilled at highly technical flying. Survey methodology not only involves low-level flying, but also require intimate familiarity with a GPS and the ability to fly in a straight line at a fixed heading with a fixed altitude, fixed speed, level wings, from and to fixed points in the sky. Consider the added challenge of flying concentric 400 meter circles, spotting other air traffic, managing fuel, dealing with wind and glare, traveling around fog banks, listening to radio traffic, looking at a survey map, and other distractions as well. Choose the best pilot available.

APPENDIX 2: Strip Transect Data Form

AERIAL SEA OTTER SURVEY DATA SUMMARY FORM

Date____________ Observer____________________ Time begin_________________

Aircraft__________ Pilot___________________ Area__________________________

Conditions (1-10)-______ Wind (kts)______ Seas (ft)______ Cloud cover (%)_________

Glare (None, Lt, Mod, Heavy)______ Remarks_______________________________

Transect Number	Conds	ID Number	Strip Count	ISU Number	Circle Count

APPENDIX 3: ISU Data Form

Transect #	Random / Nonrandom	
Group #	Strip count	Circle count
*1		
2		
3		
4		
5		

Transect #	Random / Nonrandom	
Group #	Strip count	Circle count
*1		
2		
3		
4		
5		

Transect #	Random / Nonrandom	
Group #	Strip count	Circle count
*1		
2		
3		
4		
5		