Exxon Valdez Oil Spill State/Federal
Natural Resource Damage Assessment
Final Report

Detection of Sea Otters in Boat-based Surveys of Prince William Sound, Alaska

Marine Mammal Study 6-19
Final Report

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May 1995

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__Study History__: Marine Mammal Study 6 (MM6), titled *Assessment of the Magnitude, Extent and Duration of Oil Spill Impacts on Sea Otter Populations in Alaska*, was initiated in 1989 as part of the Natural Resource Damage Assessment (NRDA). The study had a broad scope, involving more than 20 scientists over a three year period. Final results are presented in a series of 19 reports that address the various project components. Earlier versions of this report were included in the November 1990 NRDA Draft Preliminary Status Report for MM6 ("Section 2 - Boat Survey Detection Probability"). A journal article regarding this project component was published in 1995 (Udevitz, M.S., J.L. Bodkin, and D.P Costa. 1995. Detection of sea otters in boat-based surveys of Prince William Sound, Alaska. Marine Mammal Science 11(1):59-71).

__Abstract__: Boat-based surveys were used to monitor the Prince William Sound sea otter population before and after the *Exxon Valdez* oil spill. Population and loss estimates could be obtained from these surveys by direct expansion from the counts in the surveyed transects under the assumption that all otters in those transects were observed. We conducted a pilot study using ground-based observers in conjunction with the August 1990 survey of marine mammals and birds to investigate the validity of this assumption. The proportion of otters detected by boat crews was estimated by comparing boat and ground-based observations on 22 segments of shoreline transects. Sixteen percent of the otters observed by ground crews were not detected by boat crews because the otters left the transect segments as the boat approached. Fourteen percent of the otters observed by ground crews were not detected by boat crews even though they remained in the transect segments until the boat arrived. Overall, we estimated that only 70% of the otters in surveyed shoreline transects were detected by the boat crews. These results suggest that unadjusted expansions of boat survey transect counts will underestimate sea otter population size and that loss estimates based on comparisons of unadjusted population estimates will be biased. Boat-based surveys should include methodology to allow estimation of the probability of detecting sea otters under the conditions specific to each survey.

__Key Words__: *Enhydra lutris*, *Exxon Valdez*, oil spill, sea otter.

__Citation__: Udevitz, M. S., J. L. Bodkin, and D.P. Costa. 1995. Detection of sea otters in boat-based surveys of Prince William Sound, Alaska, *Exxon Valdez* Oil Spill State/Federal Natural Resource Damage Assessment Final Report (Marine Mammal Study 6-19), U.S. Fish and Wildlife Service, Anchorage, Alaska.

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EXECUTIVE SUMMARY

Boat-based surveys were used to monitor the Prince William Sound sea otter population before and after the *Exxon Valdez* oil spill. Population and loss estimates could be obtained from these surveys by direct expansion from the counts in the surveyed transects under the assumption that all otters in those transects were observed. We conducted a pilot study using ground-based observers in conjunction with the August 1990 survey of marine mammals and birds to investigate the validity of this assumption. The proportion of otters detected by boat crews was estimated by comparing boat and ground-based observations on 22 segments of shoreline transects. Sixteen percent of the otters observed by ground crews were not detected by boat crews because the otters left the transect segments as the boat approached. Fourteen percent of the otters observed by ground crews were not detected by boat crews even though they remained in the transect segments until the boat arrived. Overall, we estimated that only 70% of the otters in surveyed shoreline transects were detected by the boat crews. These results suggest that unadjusted expansions of boat survey transect counts will underestimate sea otter population size and that loss estimates based on comparisons of unadjusted population estimates will be biased. Boat-based surveys should include methodology to allow estimation of the probability of detecting sea otters under the conditions specific to each survey.

INTRODUCTION

Skiffs, dories, and other small, open boats have been commonly used in surveys of sea otters, either as the primary survey platforms or as supplementary platforms in primarily shore-based or aerial surveys (Lensink 1960, Kenyon 1969, Drummer et al. 1990, Estes 1990, Riedman and Estes 1990). The U.S. Fish and Wildlife Service (now the National Biological Survey) began conducting a series of boat-based surveys of marine mammals and birds in Prince William Sound, Alaska following the *Exxon Valdez* oil spill in 1989 (Burn 1990, Garrott et al. 1993). These surveys used strip transect methods (Eberhardt 1978) to count sea otters and other species in a sample of 200 m wide transects and were designed to be comparable to a previous boat-based survey of the Sound conducted in 1984-85 (Irons et al. 1988). Objectives of these surveys included estimating the number of sea otters lost as a result of the spill and monitoring subsequent changes in the size of the Prince William Sound sea otter population.

If all of the otters in the surveyed transects were observed, then unbiased estimates of the total population sizes could be obtained by direct expansions from the counts. Comparison of these population estimates would provide an unbiased estimate of the total number of sea otters gained or lost between surveys. If there was some probability of not detecting each otter, but this probability was the same for all surveys, then the counts would provide indices that were proportional to population size. An unbiased estimate of the proportional change in population size between surveys could be obtained by comparing these indices. However, neither of these assumptions about detectability is likely to be even approximately true in most marine mammal surveys (Eberhardt et al. 1979).

Several factors are known to affect the detection of sea otters. Estes and Jameson (1988) found that, under highly favorable and standardized conditions (light to calm winds and moderate seas), only about 95% of the sea otters were detected by a team of trained observers using high resolution optics from the shore and that detectability depended on otter group size and activity. Geibel and Miller (1984) noted that sea otter detectability in aerial surveys was related to wind, sea state, and solar reflection. It has been generally acknowledged that not all sea otters are detected in boat-based surveys (Kenyon 1969), but there has been little quantitative work to evaluate detection probabilities for these surveys. Drummer et al. (1990) used line transect methods (Drummer and McDonald 1987) to quantify the effects of viewing distance and group size on sea otter detectability in a boat-based survey. However, their analysis was based on the untested assumptions that all otters were detected on the line and that there was no undetected movement of otters in response to the boat.

We conducted a pilot study using ground-based observers to investigate sea otter detectability in a boat-based survey of Prince William Sound. Our objectives were to estimate the relative effects of responsive movement and other factors on detectability and to assess the feasibility of using ground-based observers to adjust the survey estimates for undetected otters.

OBJECTIVES

1. Estimate the relative effects of responsive movement and other factors on the detectability of sea otters in a boat-based survey of Prince William Sound, Alaska.

2. Assess the feasibility of using ground-based observers to adjust boat-based survey estimates for undetected sea otters.

METHODS

This study was conducted in conjunction with the shoreline portion of the August 1990 boat survey of marine mammals and birds in Prince William Sound (Burn 1990). The shoreline stratum consisted of all waters within 200 m of shore. This stratum was partitioned into 742 transects and a random sample of approximately 25% of these transects was surveyed. The survey vessels consisted of 7.6-m (25-foot) Boston Whalers that traveled along the selected transects approximately 100 m offshore. Vessel speeds were approximately 9 to 19 km/hr. An observer on each side of the vessel scanned the 100 m strip on his or her side of the vessel. Each observer also scanned approximately 100 m ahead of the vessel in an attempt to detect mammals and birds that were entering or leaving the transect or diving as the boat approached. The observer on the seaward side recorded all sightings of marine mammals and birds that were in the transect as the boat approached. A third person operated the vessel and assisted in observation. These methods were similar to those of previous surveys except that the seaward observer also recorded the location of each observed otter on large scale maps of the shoreline transects. Boat crews recorded weather (<50% cloud cover and no precipitation, >50% cloud cover and no precipitation, or some form of precipitation) and sea conditions (calm, rippled, <0.6 m wavelets, 0.6-1.2 m waves, or >1.2 m waves) for each transect surveyed. In accordance with past procedures (Irons et al. 1988, Burn 1990), surveys were not conducted on days when conditions were judged severe enough to affect detection of marine mammals or birds.

Ground crews consisting of one to three experienced otter observers were deployed by boat at vantage points along selected shoreline transects at least one hour before the survey vessel arrived. Transects were selected from those on which otters had been observed during surveys in 1989 and earlier in 1990. Vantage points were selected to provide the maximum effective viewing area for the ground crews and for accessibility. Attempts were made by the ground crew to minimize disturbance of the otters within the segment of the transect to be observed. On arriving at the vantage point, the ground crew identified geographic features marking boundaries of the viewing area in which they were confident of observing all of the otters present. These boundaries were recorded on large scale maps identical to those being used by the boat crews. The ground crew used telescopes and binoculars to locate each otter within the observation segment. The number of otters in the segment and observations concerning their behavior were recorded at 15-minute intervals until the survey boat arrived. At that time the location of each otter remaining in the segment was mapped. To avoid compromising their ability to observe otters, the ground crews did not usually attempt to conceal themselves from the boats. However, the boat crews did not have any prior knowledge of which segments or transects the ground crews would be observing.

As soon as possible (usually at the end of the survey day), the ground and boat crews compared the mapped locations of observed otters. These comparisons were used along with ground crew observations prior to the arrival of the boat to determine for segment i, $i = 1,\cdots,n$,

t_i = the number of otters observed by the ground crew in the segment just prior to any apparent response to the approaching boat,

b_i = the number of otters remaining in the segment when the boat arrived that were observed by both crews,

g_i = the number of otters remaining in the segment when the boat arrived that were observed only by the ground crew, and

s_i = the number of otters remaining in the segment when the boat arrived that were observed only by the boat crew.

Ground crew observations of changes in otter behavior coincident with the ground crew's detection of the approaching boat were interpreted as responses of the otters to the boat. We assumed that t_i-b_i-g_i was the number of otters observed by the ground crew that left the segment due to avoidance behavior and that would have remained in the segment if they were not disturbed by the boat. It was possible for otters that left a segment before the boat's arrival to be detected by the boat crew because the crew scanned ahead of the boat. However, it was not possible to reconcile mapped locations of these otters because ground crew maps only indicated locations of otters in the segment at the time of the boat's arrival. When t_i-b_i-$g_i \geq s_i$, we assumed that s_i was the number of otters observed by the ground crew in the segment just prior to disturbance that left the segment before the boat's arrival but were observed and mapped in the segment by the boat crew.

To explicitly consider the effect of otters leaving the transect on detectability, we represented the total probability of a boat crew detecting an otter in a transect as

$$P_d = P_a P_{d|a} + P_r P_{d|r} , \tag{1}$$

where

P_a = the probability of the otter leaving the transect as the boat approached,

$P_{d|a}$ = the probability of the otter being detected, given that it left the transect as the boat approached,

$P_r = 1\text{-}P_a$ = the probability of the otter remaining in the transect until the boat arrived, and

$P_{d|r}$ = the probability of the otter being detected, given that it remained in the transect until the boat arrived.

Pollock and Kendall (1987) discussed two basic approaches for using ground-based observers to estimate detection probabilities. The first approach is based on double sampling theory (Cochran 1977:343) and requires the ground-based observers to detect all of the individuals present in a subsample of survey units. The detection probability is estimated as the ratio of the number of individuals detected by the primary observers to the number detected by the ground-based observers. The second approach has its origins in capture-recapture theory (Seber 1982:59). It requires the identification of which individuals were detected by each set of observers (e.g., by mapping the locations of detected individuals), but does not require either set of observers to detect all of the individuals in the subsample of units. The detection probability is estimated as the ratio of the number of individuals detected by both sets of observers to the number detected by the ground-based observers.

Both approaches are based on the assumption that the subsample is randomly selected from the survey units and that the detection probability is not affected by the presence of ground crews. The two approaches will produce identical estimates of the detection probability if the ground-based observers actually detect all of the individuals in subsample units (Geibel and Miller 1984).

We used a combination of these two approaches for estimating the probabilities in (1). Estimation of $P_{d|r}$ only involved counts of otters that were in the segment when the boat arrived. The locations of these otters were accurately mapped by both crews and there was little difficulty in reconciling these maps. This allowed us to relax the assumption that the ground crews detected all of the otters and use the capture-recapture approach to estimate this probability based on the assumption that the detected otters were accurately identified. All of the other probabilities in (1) depended on counts of otters that were in the segment before the boat arrived and, as discussed above, it was not possible to unambiguously determine the identities of these otters. We used the double sampling approach to estimate these probabilities based on the assumption that ground crews detected all otters present in the segments.

The component probabilities in (1) were estimated separately for each segment as,

$$\hat{P}_{a,i} = \frac{t_i - b_i - g_i}{t_i}, \quad i=1,\cdots,n, \tag{2}$$

$$\hat{P}_{d|a,i} = \frac{s_i}{t_i - b_i - g_i}, \quad i=1,\cdots,n,\ s_i \le t_i - b_i - g_i,\ 0 < t_i - b_i - g_i, \tag{3}$$

$$\hat{P}_{r,i} = \frac{b_i + g_i}{t_i}, \quad i=1,\cdots,n, \tag{4}$$

and

$$\hat{P}_{d|r,i} = \frac{b_i}{b_i + g_i}, \quad i=1,\cdots,n,\ 0 < b_i + g_i. \tag{5}$$

Estimates of the total detection probabilities were obtained by substituting the component probability estimates into equation (1) to obtain

$$\hat{P}_{d,i} = \frac{b_i + s_i}{t_i}, \quad i=1,\cdots,n,\ s_i \le t_i - b_i - g_i. \tag{6}$$

In general, if interest was only in the total detection probabilities, they could be estimated directly with equation (6) and it would not be necessary to estimate the component probabilities.

The segment estimators of total detection probability and its components given in (2)-(6) are all ratios of the form y_i/x_i. Segment estimates were combined as ratio estimates (Cochran 1977),

$$\hat{R} = \frac{\sum_{i=1}^{n} y_i}{\sum_{i=1}^{n} x_i}, \tag{7}$$

to obtain overall estimates of the probabilities in (1). If the true relations between y_i and x_i for the total detection probability and its component probabilities were linear through the origin and if the individual segment estimates of these probabilities were unbiased, then the overall ratio estimates (7) will be unbiased (Cochran 1977). Variances were estimated as

$$V(\hat{R}) = \frac{n \sum_{i=1}^{n} (y_i - \hat{R}x_i)^2}{(n-1)\left(\sum_{i=1}^{n} x_i\right)^2}, \tag{8}$$

based on Cochran's (1977) equation 6.13 without the finite population correction.

RESULTS AND DISCUSSION

Ground crews were deployed on 43 segments of boat survey transects. Ground crews did not observe any otters on 18 of the segments and it was not possible to reconcile boat and ground crew observations on three of the segments because of extensive movements by the otters. All analyses were based on the remaining 22 segments.

Ground crews often observed hauled-out otters enter the water; previously resting or feeding otters begin to periscope, dive, or swim away; and groups of otters begin to scatter as the survey boat approached. On nine segments, otters were observed leaving the segment apparently in response to the approaching boat (i.e., $t_i - b_i - g_i > 0$) so that they were not available to be counted while the boat was in the segment. Estimates of P_a ranged from 0.1 to 1.0 for these nine segments (Figure 1a). Ground crews never observed otters entering transect segments as the survey boat approached.

Boat crews did not detect any of the otters that left in response to the approaching boat on seven of the nine segments with $t_i - b_i - g_i > 0$. Forward scanning boat crews apparently saw one of the otters that left before the boat arrived (i.e., $s_i > 0$ and $t_i - b_i - g_i \geq s_i$) on two segments. Estimates of $P_{d|a}$ for these two segments were 0.09 and 0.5 (Figure 1b). There were no segments where $t_i - b_i - g_i < s_i$.

Ground crews observed otters that remained until the boat arrived in 21 segments. On 11 of these segments, all of the otters observed by the ground crew in the segment at the time of the boat's arrival were also detected by the boat crew. On the remaining 10 segments, the estimates of $P_{d|r}$ ranged from 0.0 to 0.9 (Figure 1c). Behaviors that were apparently related to disturbance by the survey boat such as diving and swimming away from the boat were also observed by the ground crews while the boats were in the segments. Otters remaining in the segments may have been missed because of disturbance-related behaviors, diving behavior due to feeding and other activities not associated with the boat, and factors affecting visibility of otters on the water surface such as glare and obstructions.

Estimates of overall detection probability P_d ranged from 0.0 to 1.0, with all of the otters observed by the ground crews also detected by the boat crews on 8 out of 22 transect segments (Figure 1d). We were not able to detect any effect of weather on P_d or any of its component probabilities (Figure 2, Kruskal-Wallis test, $P > 0.4$). Boat-based surveys have been intentionally conducted within a fairly narrow range of weather and sea conditions. Nineteen of the segments observed by ground crews had sea states in the <0.6 m wavelet category. The other three segments had calm or rippled sea states in conjunction with weather conditions of >50% clouds and no precipitation. We repeated the analysis of weather effects without these three segments in order to remove the possibly confounding effect of sea state, but were still not able to detect a significant weather effect on P_d or any of its component probabilities (Kruskal-Wallis test, $P > 0.6$). Our inability to detect an effect of weather may have been due in part to small sample sizes, but may also have been due to relatively narrow range of weather conditions which were encountered in this study.

Regression analyses indicated that the relationships between the numerator (y_i) and the denominator (x_i) in each of the probabilities were all fit well by a straight line through the origin (Table 1). All of the slope coefficients were significantly greater than 0 ($P < 0.05$) while none of the intercepts were significantly different from 0 ($P > 0.15$). Examination of the residuals did not indicate any lack of fit, but suggested that the transect segment with $t_i=39$, $b_i=22$, $s_i=1$, $g_i=6$ may have been an influential observation. This was the only segment with $t_i > 10$ or $t_i-b_i-g_i > 2$. Deleting this observation did not substantially affect the results for $P_{d|r}$ or P_d, but the slope coefficients for P_a and $P_{d|a}$ were no longer significant ($P > 0.35$).

These regression results suggest that the values of P_d and $P_{d|r}$ were relatively constant over transect segments and were not affected by the number of otters per segment. Sightability of sea otters has been found to be related to otter group size in ground-based (Estes and Jameson 1988) and boat-based (Drummer et al. 1990) surveys. Although we did not measure group size directly, the number of otters per segment is likely to be closely related to group size. The lack of relation between the number of otters per segment and detectability for the Prince William Sound boat survey may be due to the narrow survey strip, in which group size is not as important, and to the limited variability in number of otters per segment encountered on the segments observed by ground crews. Maximum sighting distances were 1,300 m for the Estes and Jameson (1988) survey and 500 m for the Drummer et al. (1990) survey in contrast to the Prince William Sound survey in which observers did not attempt to detect otters farther than 100 m from the boat. Drummer et al. (1990) did not detect a group size effect on a day when otters were more dispersed and group sizes were less variable.

Regression results for P_a and $P_{d|a}$ were too sensitive to the single point with $t_i > 10$ and $t_i-b_i-g_i > 2$ to support strong conclusions for the full range of observations. For cases with $t_i < 10$ and $t_i-b_i-g_i < 2$, P_a and $P_{d|a}$ did not appear to be constant, but there was no evidence that these probabilities were related to the number of otters per segment.

Overall, 30% of the sea otters observed by ground crews on transect segments were not detected by boat crews (Table 2). A substantial portion of the otters left the transect segments as the survey boat approached and the probability of detecting any of the otters that left before the boat arrived was low. Otters that were not detected because they left the transect segments as the survey boat approached comprised 53% of the total number of otters not detected. Otters that were not detected even though they remained in the segment until the boat arrived comprised the remaining 47% of the undetected otters.

CONCLUSIONS

It is still possible to obtain an unbiased estimate of the population size when all of the otters in the surveyed transects are not detected, if an unbiased estimate of the detection probability is available. The basic procedure is to divide the unadjusted population estimate by the estimated detection probability. This type of correction factor has been used for aerial surveys of sea otters in California (Eberhardt et al. 1979, Geibel and Miller 1984). There is no basis for assuming that our particular estimate of P_d would be unbiased for any application other than the shoreline portion of the August 1990 survey. However, in the absence other information, it has been used as a correction factor for estimating change in size of the Prince William Sound sea otter population based on boat surveys conducted before and after the spill (Garrott et al. 1993). Classical procedures for estimating the variance of the adjusted population estimate have been described by Gasaway et al. (1986) and Pollock and Kendall (1987). The variance can also be estimated with bootstrap procedures (Garrott et al. 1993).

Unbiased estimation of the detection probability using ground-based observers requires either that the ground crews detect all of the otters in the observed segments, or that there are no errors in determining which crews saw each detected otter. In general, it is unlikely that ground-based observers can detect all of the otters present in a subset of survey units. Previous estimates of sea otter detection probabilities for ground-based observers have ranged from 0.84 to 0.95 (Geibel and Miller 1984, Estes and Jameson 1988). In our study, there were a total of

$$\sum_{i=1}^{22} s_i = 2 \tag{9}$$

otters that were mapped in segments by boat crews, but not by ground crews. If we assume that these represented otters that were not detected by the ground crews (rather than otters that were detected by ground crews but left the segment as the boat approached), then the capture-recapture type estimate of the detection probability for the ground crews would be 0.98 (rather than 1.00). Ground-based detection probabilities may have been higher in our study than in previous studies because of the relatively small size of the segments. Ground-based detection probabilities may be increased by reducing the size of the survey units observed, but this will tend to decrease the precision of the boat-survey detection probability estimates unless the number of survey units observed by ground crews is correspondingly increased. If the ground-based detection probabilities were less than 1.0, then our estimates of $P_{d|a,i}$ would tend to be too high.

When it is possible for each set of observers to produce comparable maps of the locations of all detected otters, it will usually be preferable to use the capture-recapture estimator that does not require all of the otters to be detected. Pollock and Kendall (1987) suggested that such mapping will only be possible for nonmoving objects such as nests, but the approach has been used to estimate detection probabilities of sea otters in ground-based (Estes and Jameson 1988) and aerial (Geibel and Miller 1984) surveys. We used the capture-recapture approach to estimate $P_{d|r}$ and found that, in most cases, the correspondence of the maps was reasonably clear. However, it did become more difficult to reconcile the maps as the amount of otter movement increased. When questions about the identity of mapped otters arose, the crews usually decided they had seen the same otter rather than two different otters. If these decisions were not always correct, our estimates of $P_{d|r,i}$ would tend to be too high. The potential for incorrect decisions was reduced by excluding from analysis the three segments where identities of the otters were most difficult to reconcile. In general, reconciliation of mapped otter identities may be more of a problem with boat-based surveys than other platform-based surveys because boats appear to induce a great deal of sea otter movement. Use of the capture-recapture approach to estimate P_d (or its other components) would require careful mapping of otter locations and movements both inside and outside of the transect segments and would be much more difficult.

Regardless of the approach used for estimating the detection probability, it is essential that the data be representative of conditions in the overall survey. In general, this will require the ground counts to be conducted concurrently with the survey and the sites for the counts to be randomly selected from the survey units. If the sites can not be randomly selected it may be sufficient that they be uniformly distributed among the survey units (Eberhardt et al. 1979). In many areas, including Prince William Sound, the lack of accessible vantage points precludes a random or even uniform distribution of ground-based observation sites.

It may be possible to introduce methodological improvements that will increase detectability of sea otters in boat-based surveys. For example, detectabilities of sea otters would likely be higher if the observers were not simultaneously responsible for counting birds and other marine mammals (Eberhardt et al. 1979). It would be advantageous to incorporate such improvements, but it is unlikely that they will increase detectability to the point where the probability of missing otters will be negligible. Each boat-based survey should include methodology to allow estimation of the probability of detecting sea otters under the conditions specific to that survey. Ground-based observer methods such as those used in our study may be appropriate in areas where nearly all of the sea otter habitat is potentially visible from ground-based vantage points. In cases where much of the survey area is not potentially observable by ground crews, it may be possible to use observers on another platform, such as an aircraft or a second boat (cf. Buckland and Turnock 1992). Alternatively, it may be possible to develop detectability models based on covariates that can be measured during each survey (Samuel et al. 1987).

ACKNOWLEDGEMENTS

We thank J. Ames, D. Crocker, A. Giles, B. Grey, K. Lyons, J. Hardwick, K. Kloecker, and D. Monson for serving on ground crews, and G. Balough, L. Barnes, D. Burn, G. Esslinger, S. Kalxdorff, K. Laing, T. Odenbaugh, J. Pohl, A. Smith, and R. Turner for serving on boat crews. We also thank B. Ballachey, D. Irons, L. Holland-Bartels, S. Klosiewski, and K. Oakley for helpful comments on earlier versions of this manuscript.

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Table 1. Linear regression of the numerator (y_i) on the denominator (x_i) for estimates of sea otter detection probability and its components in a boat-based survey of Prince William Sound, Alaska. Symbols are defined in the text.

				Coefficient (S.E.)		
Probability	y_i	x_i	n*	Intercept	Slope	R^2
P_a	t_i-b_i-g_i	t_i	22	-0.44(0.32)	0.25(0.03)	0.76
$P_{d\|a}$	s_i	t_i-b_i-g_i	9	-0.02(0.15)	0.10(0.04)	0.49
$P_{d\|r}$	b_i	b_i+g_i	21	0.09(0.22)	0.81(0.03)	0.98
P_d	b_i+s_i	t_i	22	0.43(0.37)	0.62(0.04)	0.93

* Number of transect segments.

Table 2. Ratio estimates of sea otter detection probability and its components in a boat-based survey of Prince William Sound, Alaska. Symbols are defined in the text.

Probability	Estimate	Standard Error
P_a	0.18	0.05
$P_{d\|a}$	0.09	0.04
P_r	0.82	0.05
$P_{d\|r}$	0.83	0.03
P_d	0.70	0.05

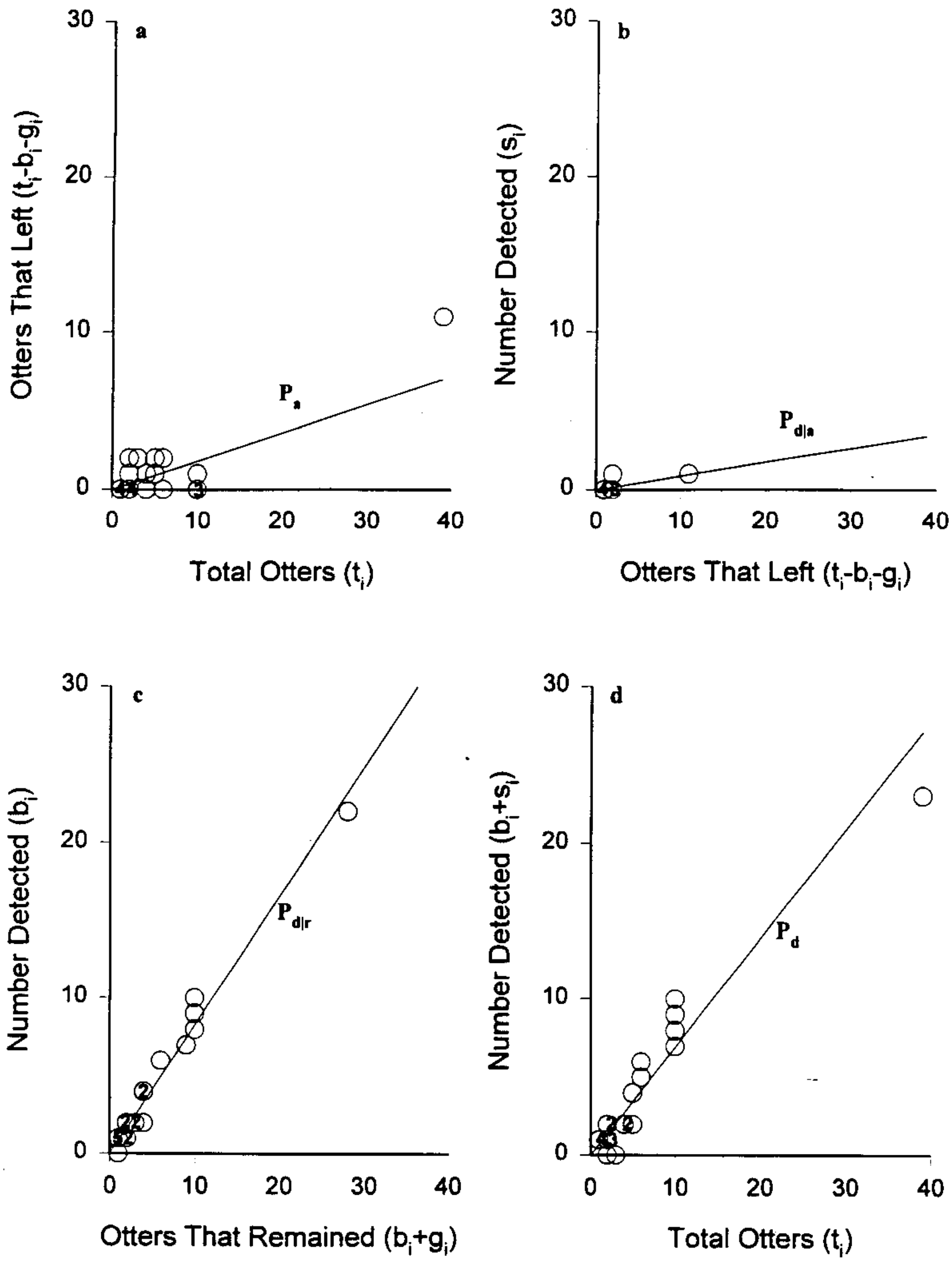

Figure 1. Scatter plots of the numbers of sea otters observed by ground crews, boat crews, or both on boat survey transect segments in Prince William Sound, Alaska. Numbers in circles indicate the number of segments represented by the circle. Circles without numbers represent one segment. Lines represent the overall ratio estimates of the probabilities.

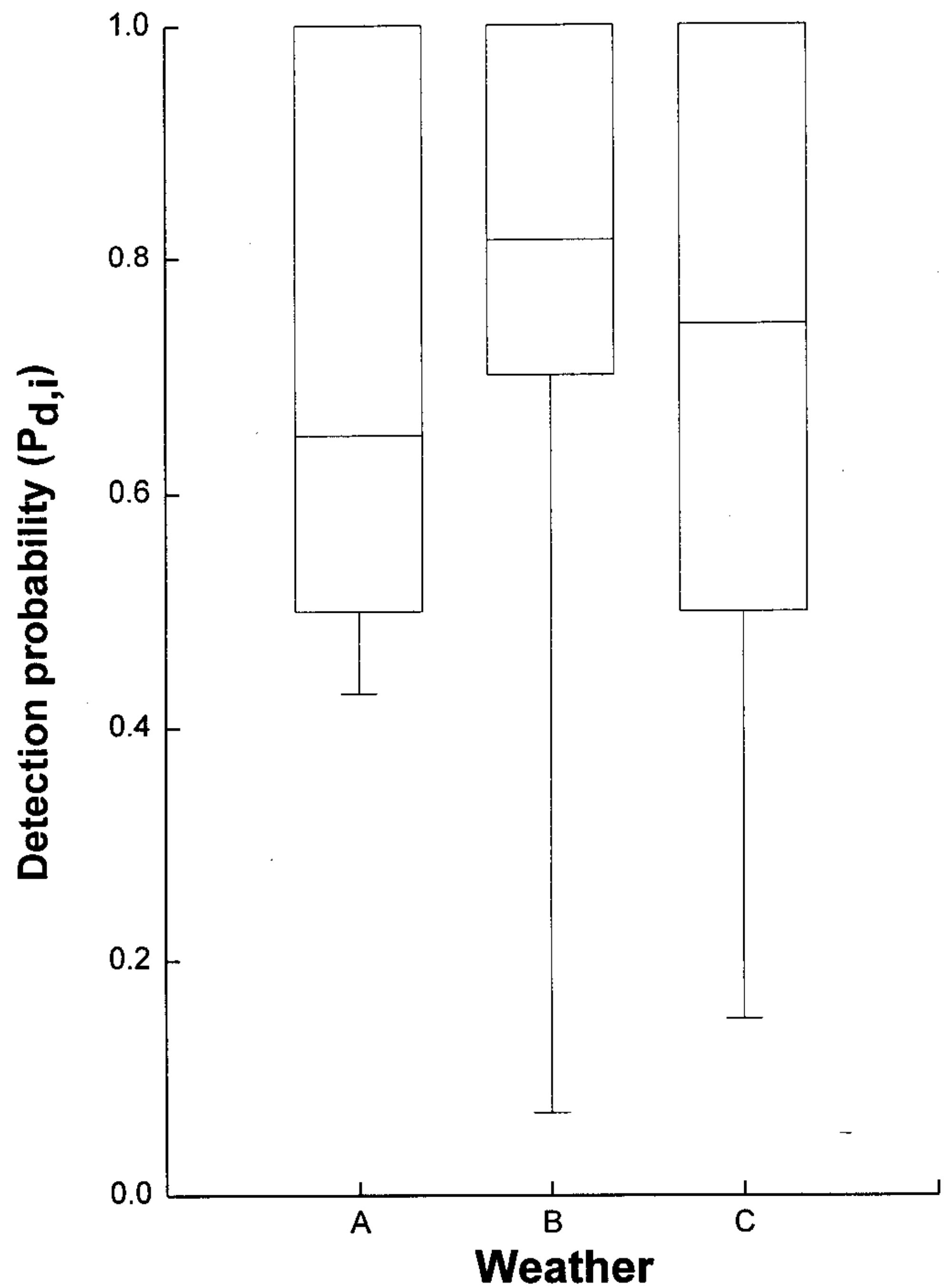

Figure 2. Box plots of sea otter detectability estimates ($P_{d,i}$) obtained under different weather conditions on boat survey transect segments. Lines within boxes indicate the medians, ends of boxes indicate the 25th and 75th percentiles, and capped bars indicate the 10th percentiles. Weather conditions are A = <50% cloud cover, no precipitation (8 segments); B = >50% cloud cover, no precipitation (6 segments); and C = precipitation (8 segments).