Exxon Valdez Oil Spill
Restoration Project Final Report

Winter Marine Bird and Sea Otter Abundance of Prince William Sound, Alaska: Trends following the *T/V Exxon Valdez* Oil Spill from 1990-94

Restoration Project 94159
Final Report

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Marine Bird and Sea Otter Abundance of Prince William Sound, Alaska: Trends Following the *T/V Exxon Valdez* Oil Spill

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STUDY HISTORY: The U. S. Fish and Wildlife Service, Migratory Bird Management conducted boat surveys in Prince William Sound prior to the *Exxon Valdez* oil spill in 1972-73 (Dwyer et al. 1976) and 1984-85 (Irons et al. 1988a,b). After the oil spill, Natural Resource Damage Assessment Bird Study Number 2 (Burn 1994, Klosiewski and Laing 1994) was initiated to document damage from the oil spill on the marine bird and sea otter populations of Prince William Sound. Data from these surveys indicated that populations of sea otters (Burn 1994) and several marine bird species (Klosiewski and Laing 1994) declined in the oil spill area. Thus, restoration project 93045 (Agler et al. 1994) and 94159 were initiated to continue monitoring marine birds and sea otter population abundance to assess recovery of injured species. Both restoration project 93045 and this study continue the original *Exxon Valdez* oil spill damage assessment study (Bird Study Number 2) conducted by S. Klosiewski and K. Laing, Migratory Bird Management, U. S. Fish and Wildlife Service in 1989-91 (Klosiewski and Laing 1994). These studies used Klosiewski and Laing's (1994) sampling design and data, and we are grateful for the statistical advice and insight they provided.

ABSTRACT: We conducted small boat surveys to determine population abundance of marine birds and sea otters (*Enhydra lutris*) in Prince William Sound, Alaska during March 1994. We observed 45 bird and 8 mammal species in Prince William Sound, and we estimated that 320,470 $\pm$ 63,640 marine birds were present. Of these, 86,045 $\pm$ 27,031 birds were in the oiled zone, and 234,425 $\pm$ 56,507 birds were in the unoiled zone. Densities were 35.7 birds/km^2 for the whole Sound, 24.1 birds/km^2 in the oiled zone, and 43.4 birds/km^2 in the unoiled zone. We examined trends in the March population estimates from 1990-94 by determining whether estimates in the oiled zone changed at the same rate as those in the unoiled zone. The goldeneye (*Bucephala* spp.) and merganser (*Mergus* spp.) populations showed significantly different trends between the oiled and unoiled zones. Both populations increased faster in the unoiled zone than in the oiled zone, indicating that there may be residual effects from the *Exxon Valdez* oil spill. For Prince William Sound as a whole, we also examined the population trends from 1990-94 using regression analyses. We found significant positive trends for harlequin duck (*Histrionicus histrionicus*), goldeneye, merganser, bald eagle (*Haliaeetus leucocephalus*), black-legged kittiwake (*Rissa tridactyla*), and gull (*Larus* and *Rissa* spp.) populations. We also examined the relative abundance of marine bird species groups from 1972 to 1994. The most common species group observed was waterfowl ($\bar{x}$ = 41.7% of total), except 1993, when the relative abundance of murres was 54.9%.

During March 1994, we estimated that the sea otter population was 7,746 $\pm$ 2,073 otters. Densities were 0.9 otters/km^2 for the whole Sound, 0.3 otters/km^2 in the oiled zone, and 1.2 otters/km^2 in the unoiled zone. We found no difference in the rate of

change between the oiled and unoiled zones from 1990-94, and there was no significant trend in the total number of sea otters in Prince William Sound from 1990-94.

KEY WORDS: population estimates, marine birds, sea otters, trends, Prince William Sound.

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Introduction

The U. S. Fish and Wildlife Service conducted boat surveys in Prince William Sound during 1972-73 (L. Haddock et al., U. S. Fish and Wildl., unpubl. data), 1989-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), and 1994 to determine the population abundance of marine birds and sea otters. Results of the 1989-91 surveys indicated that populations of sea otters and several marine bird species declined in the oil spill area. The purpose of this study was to monitor the marine bird and sea otter populations of Prince William Sound to determine whether species affected by the oil spill were recovering.

Methods

Survey methodology was identical to that of surveys conducted by the U. S. Fish and Wildlife Service during 1989-91 and 1993. We divided Prince William Sound into 3 strata: shoreline, coastal-pelagic, and pelagic, and we randomly chose transects from within those strata. We used a ratio estimator to calculate population estimates and variances for each strata. To examine population trends over time, and to determine if populations injured by the spill were recovering, we post-stratified Prince William Sound into oiled and unoiled zones.

Results

During March 1994, we observed 45 bird and 8 mammal species in Prince William Sound. We estimated that 320,470 $\pm$ 63,640 marine birds were in the Sound during March 1994. Of these, 86,045 $\pm$ 27,031 birds were in the oiled zone, and 234,425 $\pm$ 56,507 birds were in the unoiled zone. Densities were 35.7 birds/km^2 for the whole Sound, 24.1 birds/km^2 in the oiled zone, and 43.4 birds/km^2 in the unoiled zone.

To determine whether there were any trends in the winter population estimates from 1990-94, we assumed that in the absence of oil spill effects estimates in the oiled zone would change at the same rate as those in the unoiled zone. The goldeneye (*Bucephala* spp.) and merganser (*Mergus* spp.) populations showed significantly different trends between the oiled and unoiled zones. Both populations increased faster in the unoiled zone than in the oiled zone.

For Prince William Sound as a whole, we also examined the population trends from 1990-94 using regression analyses. We found significant positive trends for the harlequin duck (*Histrionicus histrionicus*), goldeneye, merganser, bald eagle (*Haliaeetus leucocephalus*), black-legged kittiwake (*Rissa tridactyla*), and gull (*Larus* and *Rissa* spp.) populations.

We also examined the relative abundance of the species groups seen in Prince William Sound from 1972 to 1994. The most common species group observed during March was waterfowl ($\bar{x}$ = 41.7% of total), except in 1993, when the relative abundance of murres was highest (54.9%).

During March 1994, we estimated that the sea otter population was 7,746 $\pm$ 2,073 otters. Densities were 0.9 otters/km^2 for the whole Sound, 0.3 otters/km^2 in the oiled zone, and 1.2 otters/km^2 in the unoiled zone. We found no difference in the rate of change between the oiled and unoiled zones from 1990-94, and there was no significant trend in the total number of sea otters in Prince William Sound from 1990-94.

Discussion

When we compared the total population estimates of marine birds in Prince William Sound among years, we found no significant trend in abundance since the 1989 *Exxon Valdez* oil spill. The goldeneye and merganser populations were the only species or species groups that showed significant differences in these rates of population increase or decrease between the oiled and unoiled zones. Neither of these species groups were previously considered to be injured by the oil spill. We found that both goldeneyes and mergansers increased faster in the unoiled zone than the oiled zone, indicating that the *Exxon Valdez* oil spill might have continuing effects that are only being detected now.

When large numbers of tests are preformed it is expected that some significant trends will occur by chance. We calculated statistical tests for 86 species or species groups. With a 95% critical value, an average of 4 significant trends would occur by chance (5% of 86 = 4.3). Thus, these trends should be considered with caution. It is interesting to note that this is the second year that the population estimate for goldeneyes increased faster in the unoiled zone than in the oiled zone, so even with the high probability that a species or species group would show a significant trend just by chance, we believe that goldeneyes may still be showing affects related to the *Exxon Valdez* oil spill.

Our surveys from 1990-94 showed no trend in the population abundance of sea otters in Prince William Sound during March, but from previous studies (Irons et al. 1988a, Estes 1990), we would expect that the Prince William Sound otter population should be increasing. There are 3 possible reasons why we did not detect a positive trend: (1) there has been no increase since 1989, because the population is still suffering injury from the oil spill; (2) the population has expanded to fill its range within Prince William Sound; or (3) lack of statistical power.

INTRODUCTION

The waters and shorelines of Prince William Sound provide important feeding, resting, and breeding sites for many marine birds and sea otters (Isleib and Kessel 1973, Hogan and Murk 1982, Irons et al. 1988a,b). In 1989, the *T/V Exxon Valdez* went aground on Bligh Reef in the northeastern corner of the Sound and spilled 11 million gallons of crude oil. Over 30,000 marine bird (Piatt et al. 1990) and 900 sea otter (DeGange and Lensink 1990) carcasses were recovered following the spill. Of these, 3,400 birds (Piatt et al. 1990) and approximately 500 sea otters (DeGange and Lensink 1990) were recovered in Prince William Sound. Direct mortality of marine birds in Prince William Sound and the Gulf of Alaska was estimated as 100,000-300,000 birds (Piatt et al. 1990) and 375,000-435,000 birds (Ecological Consulting, Inc. 1991). Mortality of sea otters was estimated as 350-4,950 otters (Garrott et al. 1993).

The U. S. Fish and Wildlife Service conducted boat surveys in Prince William Sound during 1972-73 (Dwyer et al. 1976), 1984-85 (Irons et al. 1988a,b), 1989-91 (Burn 1994, Klosiewski and Laing 1994), and 1993 (Agler et al. 1994) to determine the population abundance and distribution of marine birds and sea otters. Data from the 1989-91 surveys indicated that populations of sea otters (Burn 1994) and several marine bird species (Klosiewski and Laing 1994) declined in the oil spill area. Burn (1994) demonstrated a 35% decline in sea otter density along the shoreline of the oiled zone. Klosiewski and Laing (1994) documented overall declines of some Prince William Sound marine bird populations between the early 1970's (Dwyer et al. 1976) and the years after the oil spill. Populations that declined more in the oiled zone than in the unoiled zone included cormorants (*Phalacrocorax* spp.), harlequin duck, black oystercatcher (*Haematopus bachmani*), pigeon guillemot (*Cepphus columba*), and northwestern crow (*Corvus caurinus*). Detailed studies of black oystercatcher (Andres 1994), and pigeon guillemot (Oakley and Kuletz 1993) populations in Prince William Sound corroborated the changes in abundance determined by the boat surveys (Klosiewski and Laing 1994).

The overall purpose of this study was to monitor the marine bird and sea otter populations of Prince William Sound following the *Exxon Valdez* oil spill to determine whether species affected by the oil spill were recovering. Our primary objectives included estimating abundances of marine bird and sea otter populations in Prince William Sound during March 1994, and comparing these estimates with the 1990-1991 (Klosiewski and Laing 1994) and 1993 (Agler et al. 1994) estimates to ascertain trends in marine bird and sea otter population abundance in Prince William Sound.

OBJECTIVES

The purpose of this study was to obtain population estimates of marine birds and sea otters in Prince William Sound during winter to determine whether species whose populations declined due to the *Exxon Valdez* oil spill have recovered. Our specific objectives were:

a. To determine distribution and estimate abundance, with 95% confidence limits, of marine bird and sea otter populations in Prince William Sound during March 1994;

b. To determine if marine bird species, whose populations declined more in the oiled zone than in the unoiled zone of Prince William Sound, have recovered;

c. To examine the relative abundance of the common species groups from 1972-94 to determine change over time; and,

d. To support restoration studies on harlequin duck, black oystercatcher, pigeon guillemot, marbled murrelet (*Brachyramphus marmoratus*), and other marine birds and sea otters by providing data on population changes, distribution, and habitat use of Prince William Sound populations.

METHODS

Study Area

Prince William Sound is a large embayment north of the Gulf of Alaska and east of the Kenai Peninsula (Fig. 1). It is located approximately 100 km southeast of Anchorage, Alaska. Our study area included all waters within Prince William Sound and all land within 100 m of shore. We excluded Orca Inlet, near Cordova, Alaska, and the southern sides of Montague, Hinchinbrook, and Hawkins Islands (Klosiewski and Laing 1994).

Survey Methods

We surveyed all of Prince William Sound in 13 working days over a 3-week period from 10-28 March 1994. Survey methodology was similar to that of surveys conducted by the U. S. Fish and Wildlife Service during 1972-73 by Haddock et al. (unpubl. data), 1989-91 by Klosiewski and Laing (1994), and 1993 (Agler et al. 1994). To examine population trends over time, we surveyed the same transects each year. We used three 7.7 m fiberglass boats traveling at speeds of 10-20 km/hr to conduct our surveys. Two observers surveyed a sampling window 100 m on either side, ahead of, and above the vessel (Klosiewski and Laing 1994). When surveying shoreline transects, observers also recorded sightings within a terrestrial strip extending 100 m inward. Observers sampled continuously and used binoculars to aid in species identification. Observers practiced estimating distances with a duck decoy, and this year, we added radars to the survey vessels, which allowed us to measure our distance from land on shoreline transects more accurately. We surveyed most transects when

wave height was <30 cm (1 ft.), and we did not survey when wave height was >60 cm (2 ft.).

Survey design was changed in 1990, but surveys are still comparable with the 1972-73 surveys (L. Haddock et al., U. S. Fish and Wildl. Serv., unpubl. data, Klosiewski and Laing 1994). We divided Prince William Sound into 3 strata: shoreline, coastal-pelagic, and pelagic (Klosiewski and Laing 1994). The shoreline stratum consisted of all waters within 200 m of land. Irons et al. (1988b) divided this stratum, by habitat, into 742 transects with a total area of 820.74 km^2 (Table 1; Fig. 2). We located shoreline transects by geographic features, such as points of land, to facilitate orientation in the field and to separate the shoreline by habitat (Irons et al. 1988a,b). Shoreline transects varied in size, ranging from small islands with <1 km of coastline to sections of the mainland with over 30 km of coastline. Mean transect length was 5.55 km. During winter, we attempted to survey 99 shoreline transects, but this number varied among years, due to weather conditions and ice blockage (Table 2).

To sample the coastal-pelagic and pelagic waters of Prince William Sound, we divided the study area into 5-minute latitude-longitude blocks (Fig. 2). When a block included >1.8 km of shoreline, we classified it in the coastal-pelagic stratum. We classified blocks with ≤1.8 km of shoreline in the pelagic stratum (Klosiewski and Laing 1994). When coastal-pelagic or pelagic blocks intersected the 200 m shoreline buffer, they were truncated to avoid overlap with the shoreline stratum. We surveyed 2 north-south transect lines, each 200 m wide, located 1 minute longitude inside the east and west boundaries of each coastal-pelagic and pelagic block. When a block was too small to contain both transects, we combined it with an adjacent block (Klosiewski and Laing 1994). We randomly chose the blocks, and during the March surveys, 14% (29) of the coastal-pelagic blocks (n = 207) and 29% (25) of those within the pelagic stratum (n = 86) were sampled (Table 2). We used Global Positioning Systems (GPS) and nautical compasses to navigate transect lines.

Post-stratification by Oiling

To examine population trends over time and to determine if populations injured by the spill were recovering, we post-stratified Prince William Sound into 2 zones, oiled and unoiled, based upon the pattern of oiling by the *Exxon Valdez* oil spill (Fig. 1; Klosiewski and Laing 1994).

Burn (1994), in his study of sea otter abundance after the oil spill, chose a slightly different area than Klosiewski and Laing (1994) to represent the oiled zone. Due to the uncertainty of the exact geographical extent of the surface oiling, and the fact that sea otters are mobile, Burn (1994) placed a 5 km buffer around the oiled zone to represent the area within which otters might have been affected by oil. For the purposes of this report, we chose to treat the data for all species and all years the same and used the zones delineated by Klosiewski and Laing (1994).

Statistical Analysis

Grouping of Data.--Birds that were difficult to classify by species were analyzed by species group (Table 3). For example, data for marbled, Kittlitz's (*Brachyramphus brevirostris*), and unidentified *Brachyramphus* murrelets were analyzed as murrelets.

Populations were estimated both by individual species and species groups for gulls, shorebirds, puffins, and waterfowl. We observed several species, such as Steller's jay (*Cyanocitta stelleri)* and snow bunting (*Plectrophenax nivalis*), that are not ordinarily classified as marine birds. Of these, we included only the data for bald eagle (*Haliaeetus leucocephalus*) and northwestern crow, species common along the Alaskan shoreline.

Population Estimates.--We used a ratio estimator (Cochran 1977) to estimate population abundances and variances (Klosiewski and Laing 1994). Shoreline transects were treated as a simple random sample; whereas, the coastal-pelagic and pelagic transects were analyzed as two-stage cluster samples of unequal size (Cochran 1977). To do this, we estimated the density of birds counted on the combined transects for a block and multiplied by the area of the sampled block to obtain a population estimate for each block. We then added the estimates from all blocks surveyed and divided by the sum of the areas of all blocks surveyed. We calculated the population estimate for a strata by multiplying this estimate by the area of all blocks in the strata.

We calculated population estimates for each species and for all birds in Prince William Sound by adding the estimates from the 3 strata. We calculated 95% confidence intervals for these estimates from the sum of the variances of each stratum (Klosiewski and Laing 1994).

Population Trends.--We compared population trends between the oiled and unoiled zones of Prince William Sound to examine whether species with population estimates of >500 individuals changed over time. Four years of winter data (1990, 1991, 1993, and 1994) were available for this analysis (Klosiewski and Laing 1994, Agler et al. 1994). We used the $\log_{10}$ of each population estimate after adding 0.5 to the estimate to account for the effects of log 0.

We assumed that marine bird and sea otter populations would increase at the same rate in the oiled and unoiled zones. Thus, we tested whether the populations in the oiled and unoiled zones were changing at different rates by examining the homogeneity of the slopes between the population estimates from the oiled and the unoiled zones (Freud and Littell 1981). Significantly different slopes indicated that population abundance of a species or species group in a zone was changing at a different rate than in the other zone. For species or species groups showing a significant difference in slopes, we determined the rate of change in each zone by linear regression analyses.

To examine population trends from 1990-94 for the entire Sound, we calculated linear regressions of the total population estimates of each species.

Relative Abundance of Marine Birds.--To compare the composition of species within Prince William Sound by year, we estimated the total population abundance of marine birds in the Sound for each year and calculated the percentage of birds found in each major species group (Piatt et al. 1990). We then compared these percentages or relative abundances among years and calculated interannual averages.

Species Distribution.--To map species distribution, densities were calculated from the number of sightings on transects. The density on each transect was mapped for shoreline transects. For pelagic and coastal-pelagic waters, density was calculated for each block then mapped.

RESULTS

During the March 1994 survey, 45 bird and 8 mammal species were observed in Prince William Sound.

Marine Birds

Population Estimates.--During March 1994, we estimated that 320,470 $\pm$ 62,640 marine birds were in Prince William Sound, an increase of 140,000-180,000 birds over the 1990 and 1991 estimates, but 82,290 less than the 1993 estimate (Table 4). The 1994 estimate was 26% higher than the 1972 estimate and 2% lower than the 1973 estimate (L. Haddock et al., U. S. Fish and Wildl. Serv., unpubl. data). We estimated that during March 1994, 86,045 $\pm$ 27,031 birds were in the oiled zone, and 234,425 $\pm$ 56,507 birds were in the unoiled zone (Table 4). Population estimates for individual species and species groups are listed in Appendix A. Densities were 35.7 birds/km^2 for the whole Sound, 24.1 birds/km^2 in the oiled zone, and 43.4 birds/km^2 in the unoiled zone.

Population Trends.--When we compared the population trends from 1990-94 in the oiled zone with the trends for the unoiled zone, we found no difference in the rate of change between these 2 zones (Table 5). We also found no trend in the total population abundance of marine birds in Prince William Sound (Table 6).

Goldeneyes, estimated as 52,702 $\pm$ 21,857 birds (Appendix A), and mergansers, estimated as 21,748 $\pm$ 18,472 birds (Appendix A), were the only species or species groups with populations that had significantly different rates of change between the oiled and unoiled zones (P = 0.04 and P = 0.03, respectively; Table 5 and Fig. 3). Regression analyses indicated that the goldeneye and merganser populations increased faster in the unoiled zone (F = 49.76, R^2 = 24.88, P = 0.02, Slope = 0.25; and F = 65.68, R^2 = 32.84, P = 0.01, Slope = 0.53, respectively) than in the oiled zone (F = 83.67, R^2 = 41.84, P = 0.01, Slope = 0.13; and F = 1.81, R^2 = 0.91, P = 0.31, Slope = 0.14, respectively). No species or species group increased significantly faster in the oiled zone.

Regression analyses of the overall abundance estimates of Prince William Sound from 1990-94 showed significant positive trends for 6 species or species groups; harlequin duck, goldeneyes, mergansers, bald eagle, black-legged kittiwake, and gulls (Table 6 and Fig. 3). No significant negative trends were found (Table 6).

Relative Abundance of Marine Birds.--We examined the relative abundance of each major species group found in Prince William Sound from 1972 to 1994 (Table 7). The most common species group was waterfowl ($\bar{x}$ = 41.7%), except for 1993, when the most common species group was murres (54.9%). The next most common species groups were murres

($\dot{x}$ = 16.2%), gulls ($\dot{x}$ = 14.8%), and *Brachyramphus* murrelets ($\dot{x}$ = 12.5%).

Species Distribution.--Overall, the highest densities of marine birds were observed along the shoreline (Fig. 4). Birds were found in high densities in coastal-pelagic and pelagic strata north of Knowles Head (Fig. 4).

Most loons were observed on the eastern side of Prince William Sound near Port Gravina (Fig. 5). Grebes were mostly found along shorelines and in the protected bays and fiords (Fig. 6). Cormorants were observed throughout Prince William Sound (Fig. 7), and sightings were concentrated along shorelines, mostly in the southwest portion of the Sound.

Densities of waterfowl were highest along shorelines and in the bays of the eastern half of the Sound (Fig. 8). Most mallards were found along the northern and eastern shoreline of the study area (Fig. 9). Harlequin ducks (Fig. 10), oldsquaws (Fig. 11), scoters (Fig. 12), goldeneyes (Fig. 13), buffleheads (Fig. 14), and mergansers (Fig. 15) were mostly found in low densities in shoreline and coastal-pelagic areas.

Most bald eagles were sighted on shoreline transects (Fig. 16). Highest densities were near Bainbridge Island, on the northeast corner of Montague Island, and in Port Gravina.

The highest densities of gulls were found in the heads of the inlets on the eastern side of Prince William Sound and north of Montague Island (Fig. 17). The most dense concentrations of mew gulls (*Larus canus*) were seen near Valdez and between Hinchinbrook and Hawkins Islands (Fig. 18). The highest densities of glaucous-winged gulls (*L. glaucescens*) were found near Valdez and near Hinchinbrook Entrance (Fig. 19). Black-legged kittiwakes were densest in the eastern half of the Sound (Fig. 20).

Murres were found throughout the Sound, but the highest densities were seen on transects in the eastern half of the Sound and in Hinchinbrook Entrance (Fig. 21). Pigeon guillemots were found in low numbers mostly in shoreline and coastal-pelagic areas (Fig. 22), and the highest densities of *Brachyramphus* murrelets were observed west and northwest of Naked Island (Fig. 23).

Sea Otters

Population Estimates.--In 1994, we estimated that 7,746 $\pm$ 2,073 sea otters were in Prince William Sound (Appendix B). In the oiled zone, the population estimate was 1,149 $\pm$ 383 otters, while in the unoiled zone, the population was estimated as 6,597 $\pm$ 2,037 otters. Densities were 0.9 otters/km^2 for the whole Sound, 0.3 otters/km^2 in the oiled zone, and 1.2 otters/km^2 in the unoiled zone.

Population Trends.--We found no differences in the rate of change in the abundance of otters between the oiled and unoiled zones (Table 5). There was also no significant trend in the total Prince William Sound sea otter population from 1990-94 (Table 6).

Species Distribution.--The largest densities (15+ otters/km^2) of sea otters were located on shoreline transects in the northern half of the study area (ie.--College Fiord, Valdez) and near Cordova (Fig. 24). Otters were observed on 70% of the shoreline transects, in 54% of the coastal-pelagic blocks, and in 16% of the pelagic blocks.

DISCUSSION

Marine Birds

Although the increases in our 1993 and 1994 population estimates suggest that the winter marine bird population of Prince William Sound is increasing, we found no significant trend. We hypothesized that the large increase in population abundance in 1993 was due to an unexplained influx of murres (mostly common murres, *Uria aalge*) during winter 1993 (Agler et al. 1994). Our estimate of murres from our March 1993 survey was 1,298% greater than the mean of previous estimates. The March 1993 survey of Prince William Sound was followed by a die-off of an estimated 10,000-100,000 birds (Kendall et al. 1993, Piatt and van Pelt 1993). In 1994, the relative abundance of murres dropped to 16.1%, similar to the 1991 relative abundance (14.1%), but the population estimate of murres was still 590% and 115% higher than the 1990 and 1991 estimates. Some explanations for these differences are that murres found in Prince William Sound during 1993 remained in 1994, or possibly murres returned during March 1994 due to environmental conditions in the Gulf of Alaska similar to those in 1993.

The overall purpose of this study was to monitor the recovery of marine bird populations that were shown to be injured by *Exxon Valdez* oil spill (Klosiewski and Laing 1994). The only species or species groups showing significantly different rates of population increase or decrease in the oiled and the unoiled zones of Prince William Sound were goldeneyes and mergansers (Table 5). Although not previously shown to be injured by the oil spill (Klosiewski and Laing 1994), both the goldeneye and merganser populations increased faster in the unoiled zone than the oiled zone, indicating that the *Exxon Valdez* oil spill might have residual effects that have not been detected.

Within Prince William Sound as a whole, we found that the harlequin duck, goldeneye, merganser, bald eagle, black-legged kittiwake, and gull populations showed significant upward trends. This is the second year that the goldeneye and gull populations have shown significant upward trends during March (Agler et al. 1994), but the first year that the population estimate of the gull species group has been higher than both of the 1972 and 1973 population estimates. The population estimates for harlequin duck, mergansers, and bald eagle also were higher in 1994 than in all previous years. The population estimates for black-legged kittiwake, although increasing, are still lower than the 1972 and 1973 estimates. The black-legged kittiwake is virtually absent from the Sound during winter. This species moves into the area in late March to begin breeding, so our population estimates for the black-legged kittiwake vary from year to year depending upon various environmental and human-related factors operating during this dispersal/migration period.

We are limited in our ability to determine trends in population abundance using these data. With only 4 years of data, statistical tests lack the power to detect a trend in population size, and the year to year variability among estimates increases the difficulty in detecting trends (Taylor and Gerrodette 1993, Klosiewski and Laing 1994). Klosiewski and Laing (1994) performed Monte-Carlo simulations to examine the probability of detecting declines or recovery of bird populations using regression analyses. They found that population trends can be detected with the implementation of routine monitoring. The probability of detecting

changes in populations increases with the number of years of data, though for slowly changing populations, such as seabirds, sampling frequency can be reduced with little loss of statistical power (Klosiewski and Laing 1994).

Because we examined 86 species or species groups, we had a high probability of finding at least one significant trend for some species or species group. With a 95% critical value, we could expect that up to 4 significant trends might occur by chance (5% of 86 = 4.3). Thus, significant trends we found should be considered with caution. On the other hand, this was the second year that the goldeneye species group increased more slowly in the oiled zone than in the unoiled zone (Agler et al. 1994), which increases the likelihood that these differences did not occur by chance. Until we have more years of data, we will be limited in our ability to determine recovery or continued injury of populations affected by the *Exxon Valdez* oil spill (Klosiewski and Laing 1994).

This study was unique for several reasons. We used small, fast boats to survey a large number of short, widely-distributed transects (Klosiewski and Laing 1994). Most previous shipboard studies have used a large vessel to survey long lines in pelagic areas (Gould et al. 1982, Powers 1983, Tasker et al. 1984). Our study area covered both open water and shoreline habitat. Small boats allow greater maneuverability in shallow waters, increasing our abilities to obtain a more accurate population estimate along shorelines where many breeding and non-breeding birds congregate. The speed of these small boats reduces travel time between transects, allowing us to sample a large number of transects and use a statistically rigorous sampling design to increase the precision of our estimates. Thus, we obtained population estimates with relatively small confidence intervals.

As with all sampling methods, there are biases that might affect our population estimates. We counted birds continuously along each transect, a controversial technique discussed by several authors sampling from larger vessels (Tasker et al. 1984, Haney 1985, Gaston et al. 1987, Gould and Forsell 1989, Spear et al. 1992, van Franeker 1994). To minimize the problem of bird movement across transects, we used a small survey window (100 m on each side and ahead of the boat), two-thirds of the width of the window used on larger vessels. Continuous sampling of flying birds causes an overestimate of population abundance for some species by measuring bird flux instead of density (van Franeker 1994). Recently developed methods, such as a "snapshot" counting method (Gould and Forsell 1989, van Franeker 1994) to limit the number of flying birds recorded, may reduce this problem and should be explored further.

We assumed that we counted all birds and mammals on the transects; however, it was likely that some unknown percentage of birds and mammals was missed, causing us to underestimate population abundance. For instance, we might not see a bird leave the transect because of the boat. Udevitz et al. (1995) conducted a pilot study of the sightability of sea otters from boat surveys. They found that observers on the boat surveys saw only 70% of the otters seen from land. Due to their small sample size, the authors advised against wide application of their results (Udevitz et al. 1995), so we have taken the conservative approach and not corrected our estimates for sea otters upward. For most bird species, studies of this type have not been done, so we have no correction factors available to use to increase our estimates appropriately. Both of these biases should remain constant over time, so they would not affect the trend data that we have used to determine recovery of injured species.

Sea Otters

Irons et al. (1988a) found that between 1972 and 1984, sea otter populations within Prince William Sound expanded both in numbers and distribution. Estes (1990) examined 5 northern populations of sea otters and a population from California. All but the Amchitka Island, Alaska, population were increasing at an annual rate of >5% (Estes 1990). Our surveys from 1990-94 showed no trend in the population abundance of sea otters in Prince William Sound during March. From Irons' et al. (1988a) and Estes' (1990) results, we would expect that the Prince William Sound otter population should be increasing. There are 3 possible reasons why we did not detect a positive trend: (1) there has been no increase since 1989, because the population is still suffering injury from the oil spill; (2) the population has expanded to fill all available habitat within Prince William Sound; or (3) lack of statistical power.

CONCLUSIONS

Only 2 species or species groups of marine birds (goldeneyes and mergansers) showed a significant difference in population abundance between the oiled and unoiled zones of Prince William Sound from 1990-94. Both populations increased more slowly in the oiled zone, indicating that there may be continued long-term effects from the oil spill. Populations of other species and species groups did not show any trend, but with only 4 years of data, we lack the power to detect trends in the population abundances of most species.

Within Prince William Sound as a whole, we also examined population trends from 1990-94. We found that the harlequin duck, goldeneye, merganser, bald eagle, black-legged kittiwake, and gull populations showed significant upward trends.

For sea otters, we found no difference in the rate of change between the oiled and unoiled zones from 1990-94. There was also no significant trend in the total number of sea otters in Prince William Sound from 1990-94, indicating that the wintering population of sea otters in Prince William has not recovered from the *Exxon Valdez* oil spill in 1989.

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Table 1. Area (km^2) of each stratum in the oiled and unoiled zones of Prince William Sound from small boat surveys during 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), and 1994.

	Stratum		
Zones	Shoreline	Coastal-pelagic	Pelagic
Oiled	247.72	1,645.80	1,684.00
Unoiled	572.75	2,878.39	1,952.92
Total	820.47	4,524.19	3,636.92

Table 2. Number of transects and blocks surveyed in each of the 3 strata used during small boat surveys of Prince William Sound during March from 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), and 1994.

	Shoreline	Coastal-pelagic		Pelagic	
Year	Transects	Transects	Blocks	Transects	Blocks
1990	99	57	29	50	25
1991	99	57	29	50	25
1993	98	42[a]	21	50	25
1994	97	56	28	50	25
Total[b]	742		207		86

[a] Data were not used from 13 transects due to recording errors. Two other transects were covered by ice.

[b] Total number of transects possible for shoreline stratum and/or total number of blocks for the coastal-pelagic and pelagic strata.

Table 3. Species groups used in data analyses of marine bird populations estimated by small boat surveys in Prince William Sound during March 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), and 1994.

Group /Common Name	Species Name
Loons	
Red-throated loon	*Gavia stellata*
Pacific loon	*G. pacifica*
Common loon	*G. immer*
Yellow-billed loon	*G. adamsii*
Unidentified loon	*G.* sp.
Grebes	
Horned grebe	*Podiceps auritus*
Red-necked grebe	*P. grisegena*
Unidentified grebe	*P.* sp.
Storm-petrels	
Fork-tailed storm-petrel	*Oceanodroma furcata*
Cormorants	
Double-crested cormorant	*Phalacrocorax auritus*
Pelagic cormorant	*P. pelagicus*
Red-faced cormorant	*P. urile*
Unidentified cormorant	*P.* sp.
Waterfowl	
Tundra swan	*Cygnus columbianus*
Emperor goose	*Chen canagica*
Canada goose	*B. canadensis*
Green-winged teal	*Anas crecca*
Mallard	*A. platyrhynchos*
Northern pintail	*A. acuta*
Gadwall	*A. strepera*
American wigeon	*A. americana*
Unidentified dabbling duck	*A.* sp.
Greater scaup	*Aythya marila*
Unidentified scaup	*A. marila* or *A. affinis*
Steller's eider	*Polysticta stelleri*
Unidentified eider	*Somateria* or *Polysticta* sp.
Harlequin duck	*Histrionicus histrionicus*

Table 3 (continued).

Group /Common Name	Species Name
Waterfowl (continued)	
Oldsquaw	*Clangula hyemalis*
Black scoter	*Melanitta nigra*
Surf scoter	*M. perspicillata*
White-winged scoter	*M. fusca*
Unidentified scoter	*M.* sp.
Common goldeneye	*Bucephala clangula*
Barrow's goldeneye	*B. islandica*
Unidentified goldeneye	*B. islandica* or *B. clangula*
Bufflehead	*B. albeola*
Common merganser	*Mergus merganser*
Red-breasted merganser	*M. serrator*
Unidentified merganser	*Mergus* sp.
Unidentified diving/sea duck	
Unidentified duck	
Scaup	
Greater scaup	*Aythya marila*
Unidentified scaup	*A. marila* or *A. affinis*
Scoters	
Black scoter	*Melanitta nigra*
Surf scoter	*M. perspicillata*
White-winged scoter	*M. fusca*
Unidentified scoter	*M.* sp.
Goldeneyes	
Barrow's goldeneye	*Bucephala islandica*
Common goldeneye	*B. clangula*
Unidentified goldeneye	*B. islandica* or *B. clangula*
Mergansers	
Common merganser	*Mergus merganser*
Red-breasted merganser	*M. serrator*
Unidentified merganser	*M.* sp.

Table 3 (continued).

Group /Common Name	Species Name
Shorebirds	
Black oystercatcher	*Haematopus bachmani*
Black turnstone	*Arenaria melanocephala*
Ruddy turnstone	*A. interpres*
Unidentified turnstone	*A.* sp.
Surfbird	*Aphriza virgata*
Sanderling	*Calidris alba*
Rock sandpiper	*C. ptilocnemis*
Dunlin	*C. alpina*
Unidentified small sandpiper	*C.* sp.
Unidentified shorebird	
Gulls	
Bonaparte's gull	*Larus philadelphia*
Mew gull	*L. canus*
Herring gull	*L. argentatus*
Glaucous-winged gull	*L. glaucescens*
Glaucous gull	*L. hyperboreus*
Black-legged kittiwake	*Rissa tridactyla*
Unidentified gull	*L.* or *R.* sp.
Murres	
Common murre	*Uria aalge*
Thick-billed murre	*U. lomvia*
Unidentified murre	*U.* sp.
Murrelets	
Marbled murrelet	*Brachyramphus marmoratus*
Kittlitz's murrelet	*B. brevirostris*
Unidentified *Brachyramphus* murrelet	*B.* sp.
Puffins	
Tufted puffin	*Fratercula cirrhata*
Horned puffin	*F. corniculata*

Table 4. Estimated number of marine birds (±95% CI) from small boat surveys of Prince William Sound during March 1972-73 (L. Haddock et al., U. S. Fish and Wildl. Serv., unpubl. data), 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), and 1994 listed by zones oiled by the 1989 *Exxon Valdez* oil spill.

	Total		Oiled Zone		Unoiled Zone	
Year	Estimate	CI	Estimate	CI	Estimate	CI
1972[a]	235,579	63,480				
1973[a]	328,091	59,955				
1990[b]	141,911	22,902	36,343	7,760	105,568	21,547
1991	171,433	30,868	49,649	13,422	121,784	27,797
1993	402,760	167,697	83,171	34,794	319,589	164,048
1994	320,470	62,640	86,045	27,031	234,425	56,507

[a] The *Exxon Valdez* oil spill did not occur until 1989. We did not calculate population estimates for the oiled and unoiled zones prior to the spill.

[b] Survey design was changed in 1990, but survey methods remain the same. Thus, estimates are comparable.

Table 5. Results of homogeneity of slopes tests comparing estimates of marine bird and sea otter abundances in the zone oiled by the 1989 *Exxon Valdez* oil spill with estimates of abundance in the unoiled zone of Prince William Sound. We collected data on small boat surveys during March 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), and 1994. Only species groups and individual species with population estimates of >500 birds were used. All categories have 1 degree of freedom, except ERROR, which has 4 degrees of freedom. When the *P* value for YEAR*OILING ≤0.05, the result was considered significant.

Species/Source	SS	*F*	*P*
Marine Birds			
Total marine birds			
YEAR	1.15	22.86	0.01
OILING	2.32	46.12	0.00
YEAR*OILING	0.01	0.10	0.77
ERROR	0.20		
Loons			
YEAR	0.00	0.03	0.88
OILING	8.75	106.23	0.00
YEAR*OILING	0.12	1.50	0.29
ERROR	0.33		
Grebes			
YEAR	0.00	0.08	0.79
OILING	3.04	90.23	0.00
YEAR*OILING	0.01	0.38	0.57
ERROR	0.13		
Storm-petrels			
YEAR	13.55	1.30	0.32
OILING	1.42	0.14	0.73
YEAR*OILING	5.59	0.53	0.51
ERROR	41.84		
Cormorants			
YEAR	0.10	4.61	0.10
OILING	0.16	7.13	0.06
YEAR*OILING	0.02	1.07	0.36
ERROR	0.09		

Table 5 (continued).

Species/Source	SS	*F*	*P*
Mallard			
YEAR	0.00	0.00	1.00
OILING	103.03	31.19	0.01
YEAR*OILING	0.02	0.01	0.94
ERROR	13.21		
Gadwall			
YEAR	1.01	2.00	0.23
OILING	80.66	159.52	0.00
YEAR*OILING	1.01	2.00	0.23
ERROR	2.02		
Scaup			
YEAR	4.31	1.69	0.26
OILING	48.04	18.81	0.01
YEAR*OILING	6.73	2.63	0.18
ERROR	10.21		
Harlequin duck			
YEAR	0.44	32.00	0.00
OILING	2.97	214.17	0.00
YEAR*OILING	0.03	2.03	0.23
ERROR	0.06		
Oldsquaw			
YEAR	0.22	1.04	0.37
OILING	8.42	39.43	0.00
YEAR*OILING	0.05	0.23	0.66
ERROR	0.85		
Scoters			
YEAR	0.23	7.65	0.05
OILING	3.04	100.63	0.00
YEAR*OILING	0.00	0.04	0.85
ERROR	0.12		

Table 5 (continued).

Species/Source	SS	*F*	*P*
Goldeneyes			
YEAR	0.75	99.96	0.00
OILING	6.00	803.36	0.00
YEAR*OILING	0.07	9.33	0.04
ERROR	0.03		
Bufflehead			
YEAR	1.22	4.35	0.11
OILING	13.23	47.25	0.00
YEAR*OILING	0.23	0.82	0.42
ERROR	1.12		
Mergansers			
YEAR	2.20	30.57	0.01
OILING	1.81	25.09	0.01
YEAR*OILING	0.77	10.68	0.03
ERROR	0.29		
Waterfowl			
YEAR	0.41	44.14	0.00
OILING	4.97	529.01	0.00
YEAR*OILING	0.02	2.06	0.22
ERROR	0.04		
Bald eagle			
YEAR	1.06	44.20	0.00
OILING	1.58	65.71	0.00
YEAR*OILING	0.04	1.51	0.29
ERROR	0.10		
Surfbird			
YEAR	10.50	0.73	0.44
OILING	3.66	0.26	0.64
YEAR*OILING	9.86	0.69	0.45
ERROR	57.16		

Table 5 (continued).

Species/Source	SS	*F*	*P*
Rock sandpiper			
YEAR	32.46	3.57	0.13
OILING	5.58	0.61	0.48
YEAR*OILING	5.92	0.65	0.46
ERROR	36.33		
Shorebirds			
YEAR	0.25	0.16	0.71
OILING	4.43	2.77	0.17
YEAR*OILING	0.16	0.10	0.77
ERROR	6.41		
Mew gull			
YEAR	1.97	1.86	0.24
OILING	2.89	2.72	0.17
YEAR*OILING	0.03	0.03	0.88
ERROR	4.25		
Herring gull			
YEAR	9.30	24.49	0.01
OILING	0.42	1.11	0.35
YEAR*OILING	0.94	2.47	0.19
ERROR	1.52		
Glaucous-winged gull			
YEAR	2.14	6.02	0.07
OILING	0.15	0.41	0.56
YEAR*OILING	0.01	0.03	0.87
ERROR	1.42		
Black-legged kittiwake			
YEAR	11.32	15.05	0.02
OILING	0.05	0.07	0.81
YEAR*OILING	0.00	0.00	0.99
ERROR	3.01		

Table 5 (continued).

Species/Source	SS	*F*	*P*
Gulls			
YEAR	2.48	213.77	0.00
OILING	0.61	52.89	0.00
YEAR*OILING	0.00	0.00	1.00
ERROR	0.05		
Murres			
YEAR	6.73	6.45	0.06
OILING	1.28	1.23	0.33
YEAR*OILING	0.10	0.09	0.78
ERROR	4.18		
Pigeon guillemot			
YEAR	0.03	0.09	0.78
OILING	1.44	3.79	0.12
YEAR*OILING	0.01	0.02	0.91
ERROR	1.52		
Brachyramphus murrelets			
YEAR	0.02	0.07	0.81
OILING	0.76	3.19	0.15
YEAR*OILING	0.02	0.10	0.77
ERROR	0.96		
Northwestern crow			
YEAR	0.49	0.96	0.38
OILING	5.35	10.43	0.03
YEAR*OILING	0.02	0.04	0.85
ERROR	2.05		
Marine Mammals			
Sea otters			
YEAR	0.03	0.41	0.55
OILING	2.81	34.61	0.00
YEAR*OILING	0.21	2.59	0.18
ERROR	0.32		

Table 6. Regression analyses by species and species groups of March 1990-94 population estimates to determine population trends for Prince William Sound. We collected data on small boat surveys during March 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), and 1994. We used only species and species groups with population estimates of >500 birds.

Species	R^2	F	P	Slope
Marine Birds				
Total birds	0.69	1.38	0.36	-1.26
Loons	0.20	0.41	0.59	0.07
Grebes	0.00	0.00	0.96	0.00
Storm-petrels	0.09	0.18	0.71	-0.55
Cormorants	4.96	9.92	0.09	0.07
Mallard	0.01	0.02	0.89	0.03
Gadwall	1.00	2.00	0.29	0.45
Scaup	0.03	0.05	0.84	-0.07
Harlequin duck	15.30	30.60	0.03	0.17
Oldsquaw	0.08	0.16	0.73	-0.07
Scoters	6.74	13.47	0.07	0.10
Goldeneyes	25.16	50.32	0.02	0.23
Bufflehead	0.64	1.29	0.37	0.16
Mergansers	14.86	29.72	0.03	0.41
Waterfowl	0.98	1.96	0.30	-1.67
Bald eagle	11.51	23.02	0.04	0.25
Surfbird	0.01	0.03	0.88	-0.26
Rock sandpiper	3.00	5.99	0.13	1.70
Shorebirds	0.01	0.03	0.89	-0.06
Mew gull	1.71	3.42	0.21	0.32
Herring gull	6.95	13.91	0.06	0.73
Glaucous-winged gull	1.61	3.23	0.21	0.33
Black-legged kittiwake	12.64	25.28	0.04	0.80
Gulls	226.09	452.18	0.00	0.35
Murres	1.58	3.16	0.22	0.61
Pigeon guillemot	0.02	0.03	0.88	0.04
Brachyramphus murrelets	0.00	0.01	0.93	0.01
Northwestern crow	0.78	1.57	0.34	0.12
Marine Mammals				
Sea otter	1.10	2.20	0.28	0.10

Table 7. Relative abundance (%) by year for population estimates of species groups from small boat surveys of marine birds in Prince William Sound from 1972-73 (L. Haddock et al., U. S. Fish and Wildl. Serv., unpubl. data), 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), and 1994.

Species Groups	1972	1973	1990	1991	1993[a]		1994	Mean
					w/	w/o		
Loons	1.4	0.9	0.6	1.0	0.3	0.6	0.5	0.8
Grebes	4.0	3.9	4.6	3.3	1.3	2.9	2.1	3.2
Storm-petrels	0.0	0.0	0.4	0.0	0.0	0.0	0.0	<0.1
Cormorants	4.6	8.4	6.4	5.3	3.0	6.5	3.6	5.2
Waterfowl	54.2	39.0	47.0	44.1	24.6	54.2	41.3	41.7
Scoters	22.5	18.3	9.0	9.9	4.6	10.2	6.4	11.8
Goldeneyes	6.3	7.7	13.8	13.8	8.5	18.6	16.5	11.1
Mergansers	2.5	1.4	2.4	3.5	2.3	5.1	6.8	3.2
Shorebirds	0.7	2.3	2.5	0.3	0.2	0.0	0.7	1.1
Gulls	21.3	12.9	10.8	13.1	10.4	22.9	20.4	14.8
Terns	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Murres	3.5	3.3	5.3	14.1	54.9	-	16.1	16.2
Murrelets	5.1	23.1	18.4	13.7	3.5	7.7	11.3	12.5

[a] Because murre numbers were unusually high in Prince William Sound during March 1993, we examined the relative abundance of species with murres (w/) and without (w/o).

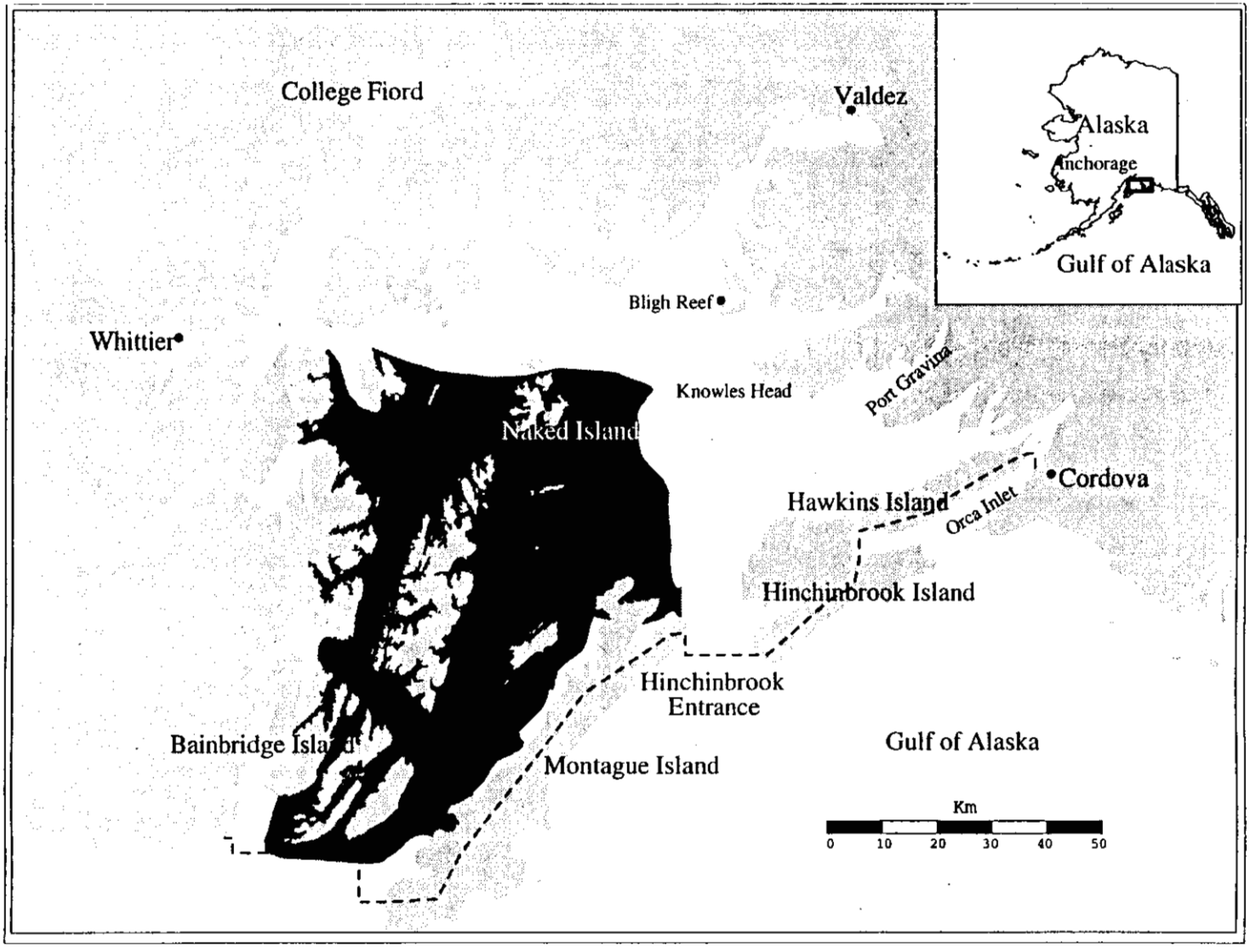

Figure 1. Map of Prince William Sound. Zone oiled by the *Exxon Valdez* oil spill in March 1989 is designated by the dark shading. The southern boundary of the study area is delineated by the dashed line.

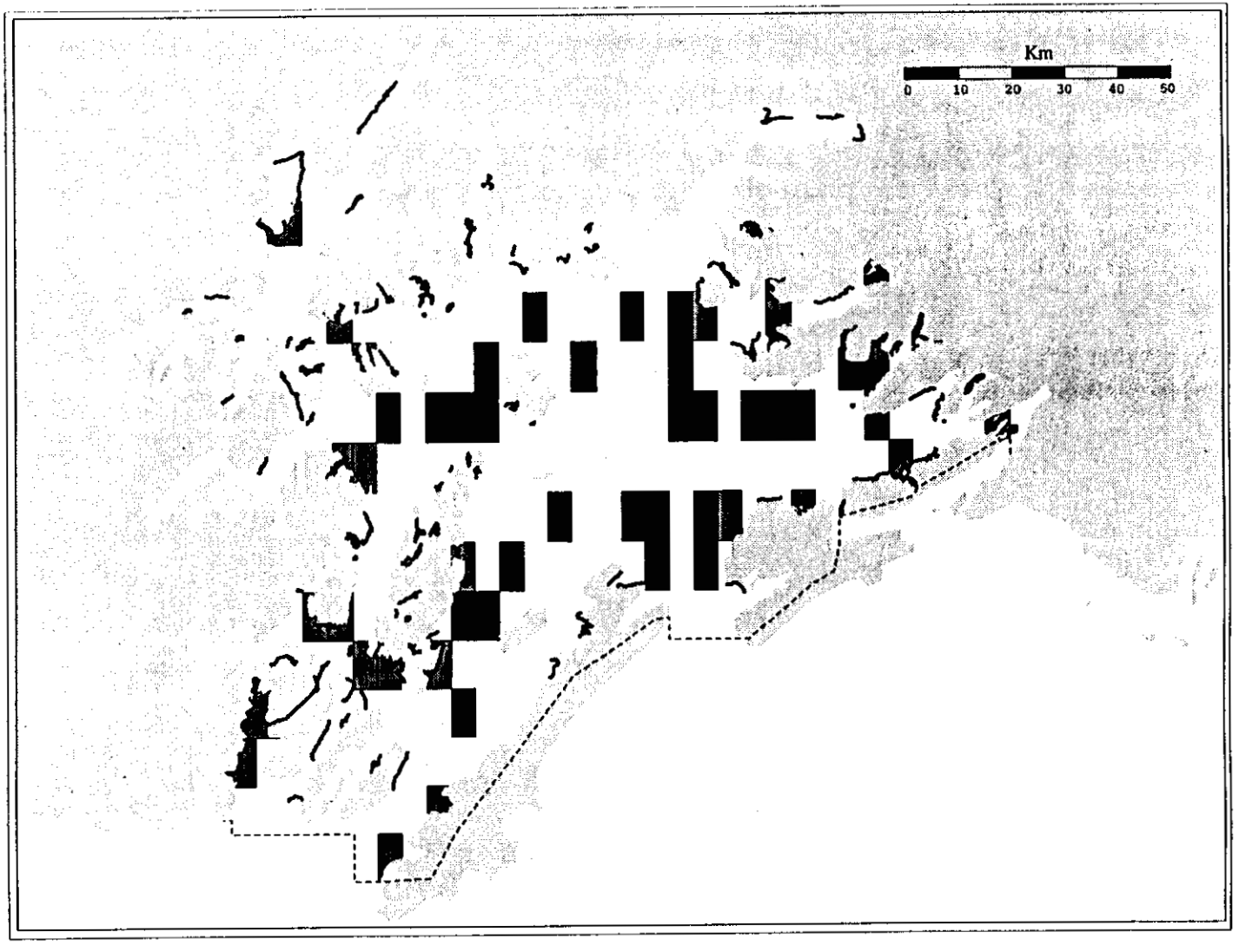

Figure 2. Transects and blocks surveyed during a small boat survey of Prince William Sound, March 1994. Transects were classified into 3 strata; the shoreline stratum (dark lines), the coastal-pelagic stratum (lighter shaded blocks), and the pelagic stratum (darker shaded blocks). We surveyed 2 200 m wide north-south transect lines in each offshore block.

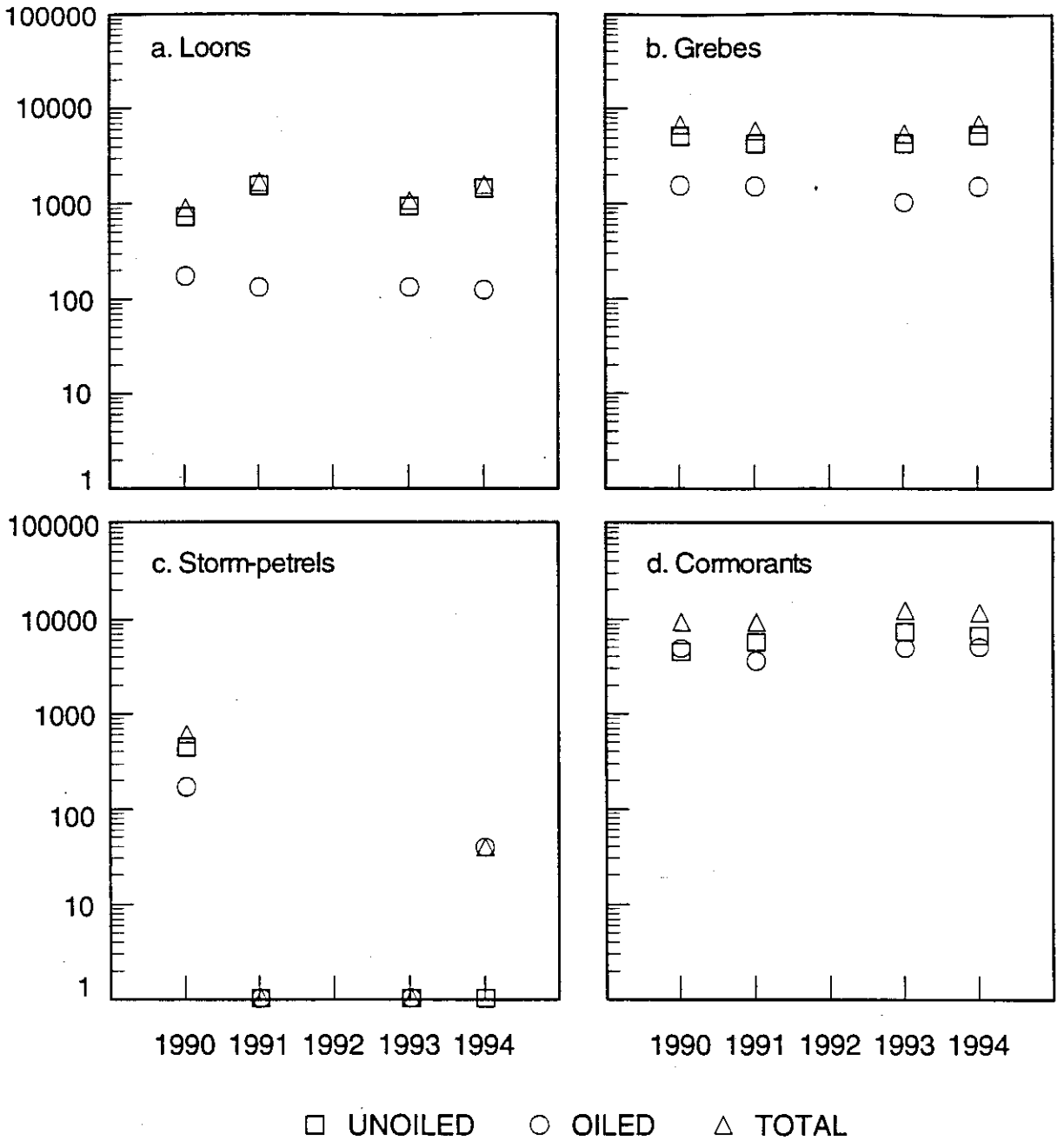

Figure 3. Population estimates (log 10) of species and species groups with population estimates of >500 birds in the unoiled (squares) and oiled (triangles) zones and the entire area of Prince William Sound (circles) from March 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), and 1994. Graph scales are logarithmic from 1-100,000 birds, except for the graphs of the gull and murre species groups, which are 1-1,000,000 birds.

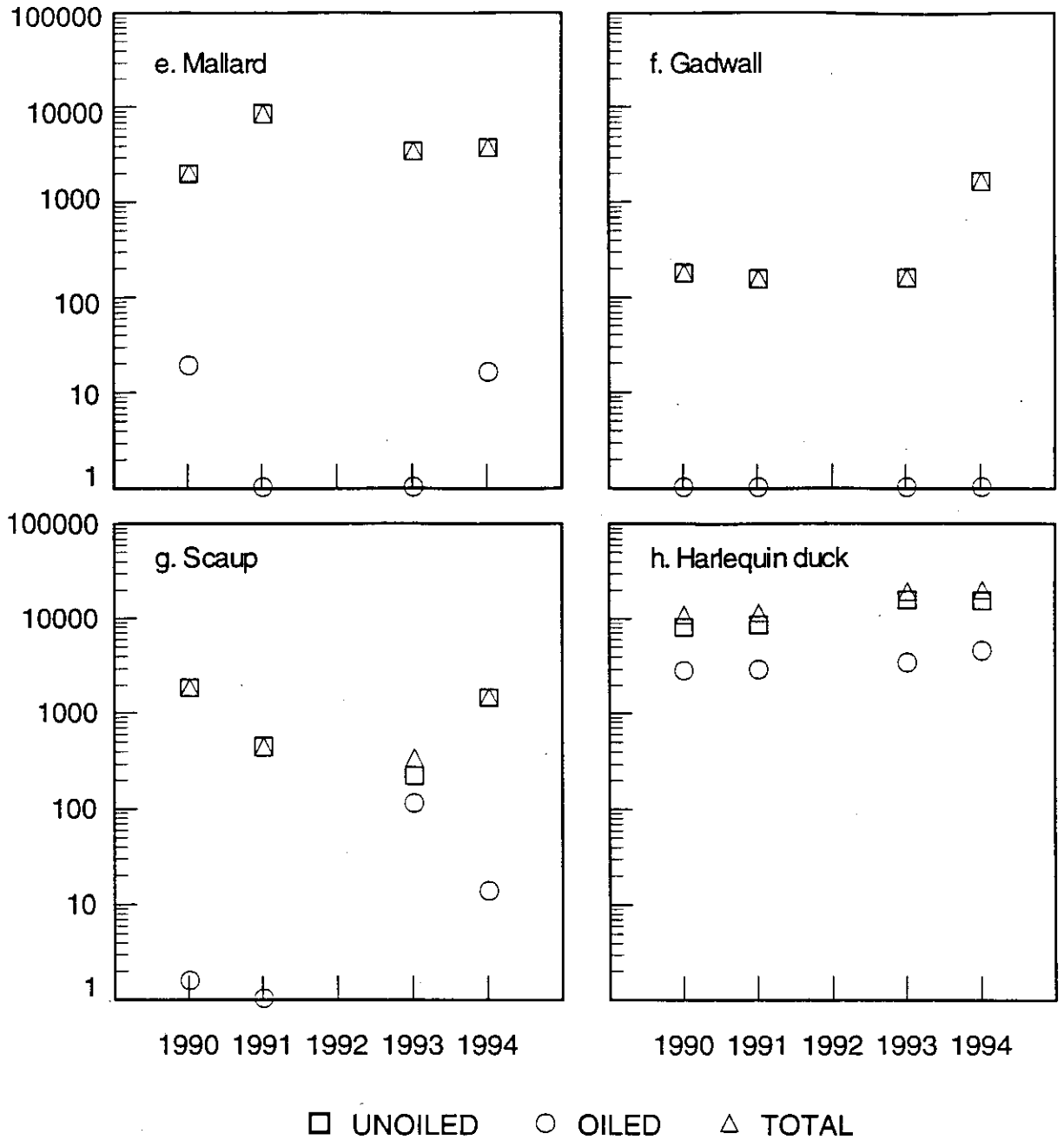

Figure 3 (continued).

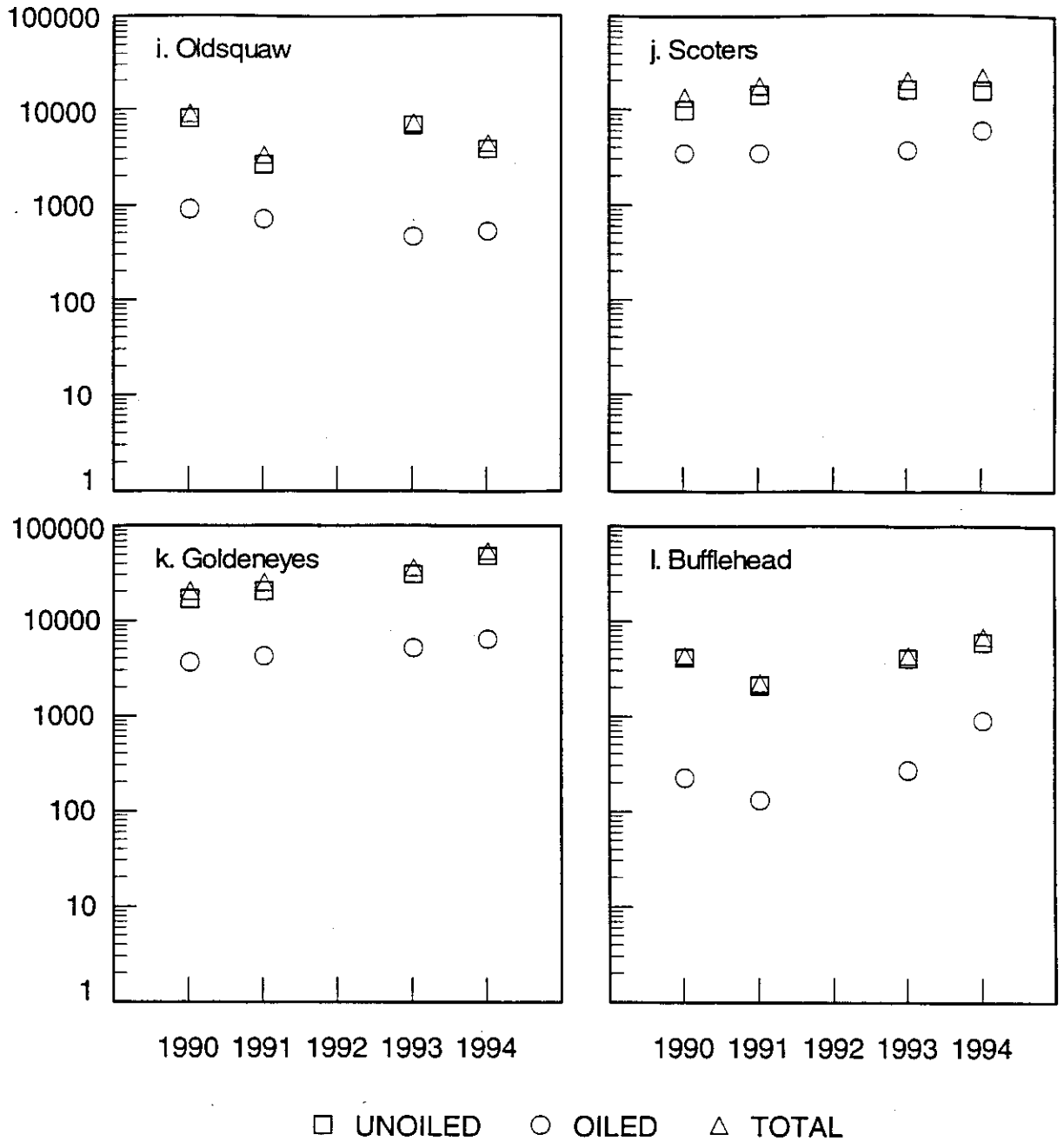

Figure 3 (continued).

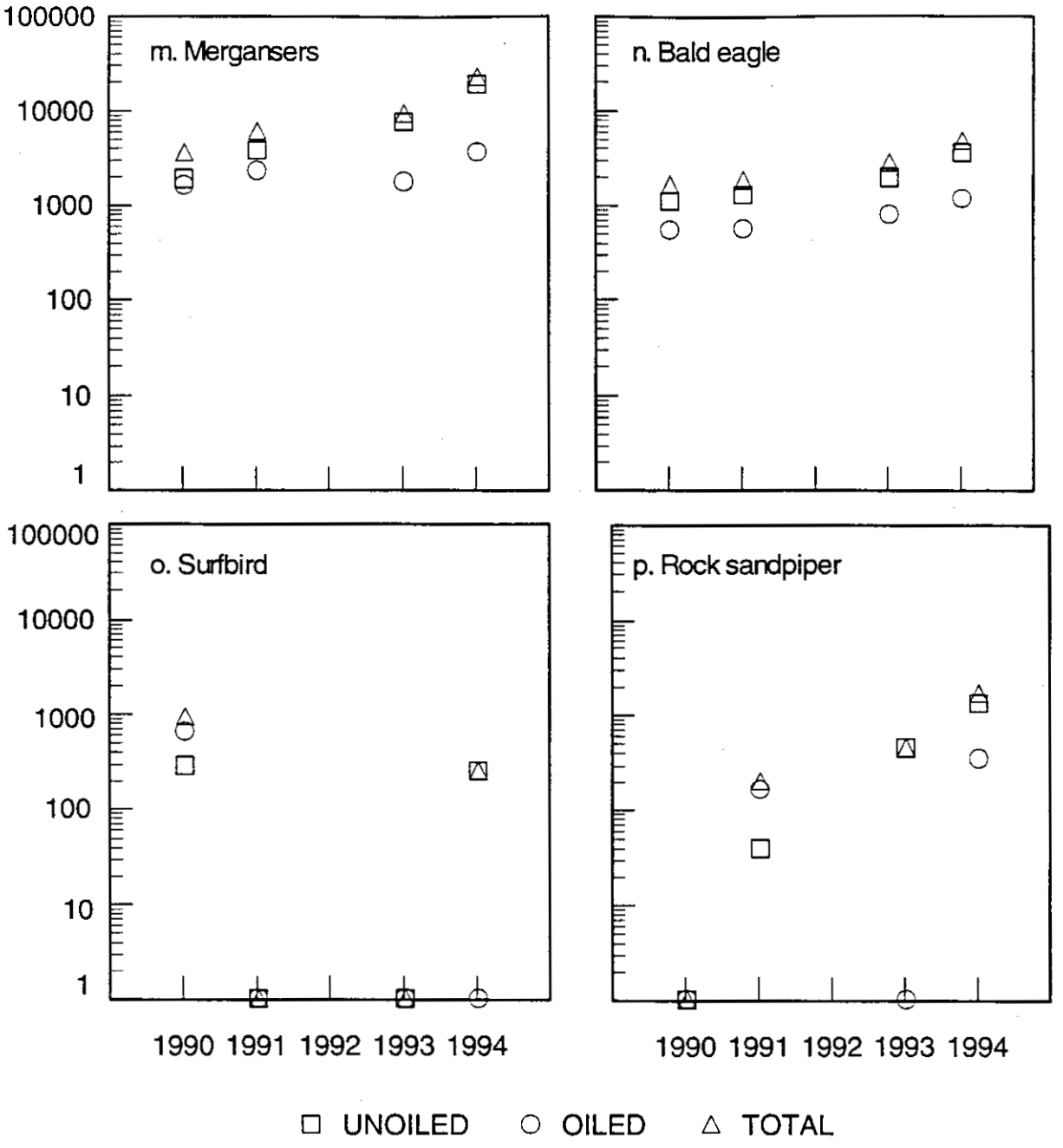

Figure 3 (continued).

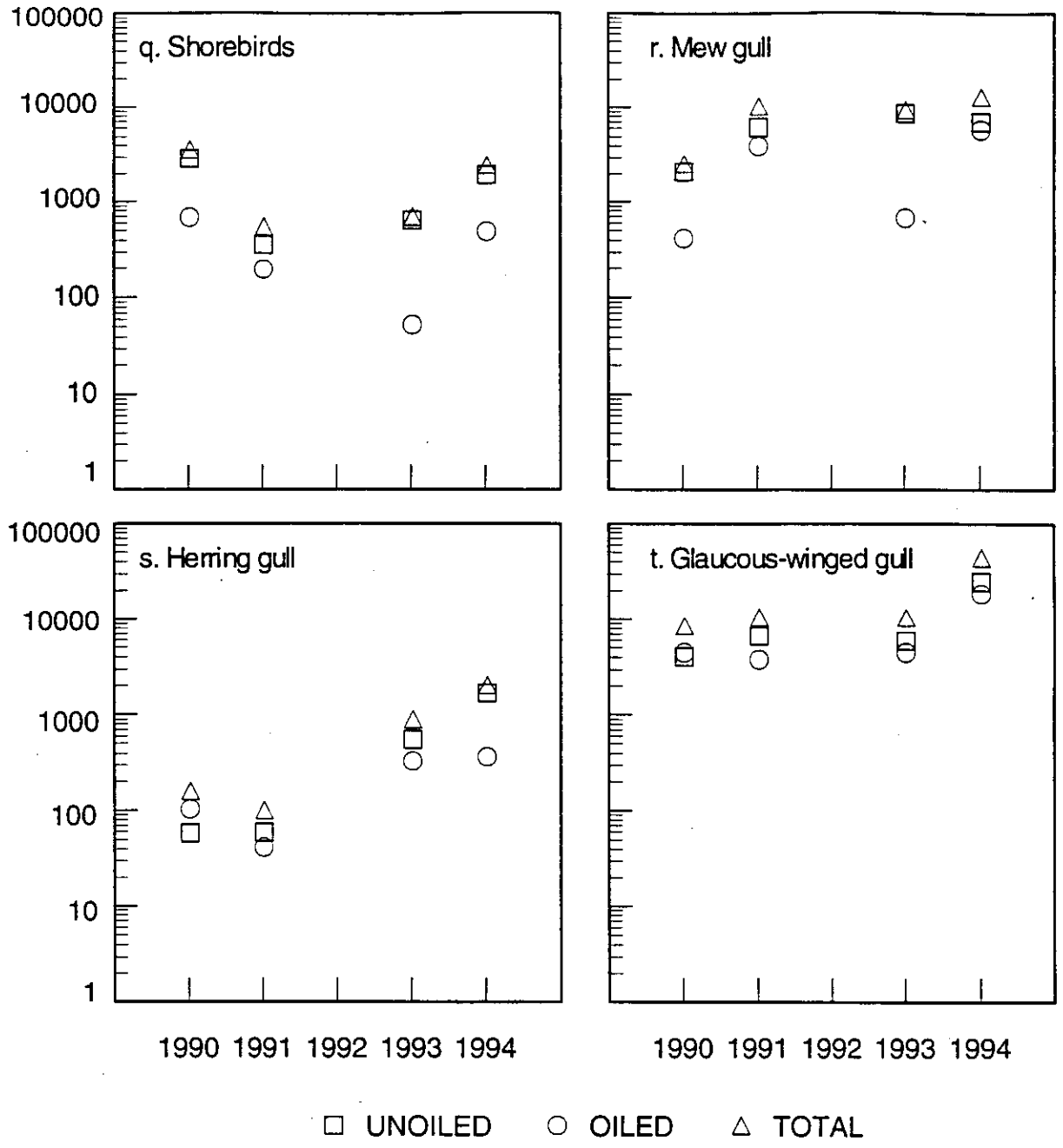

Figure 3 (continued).

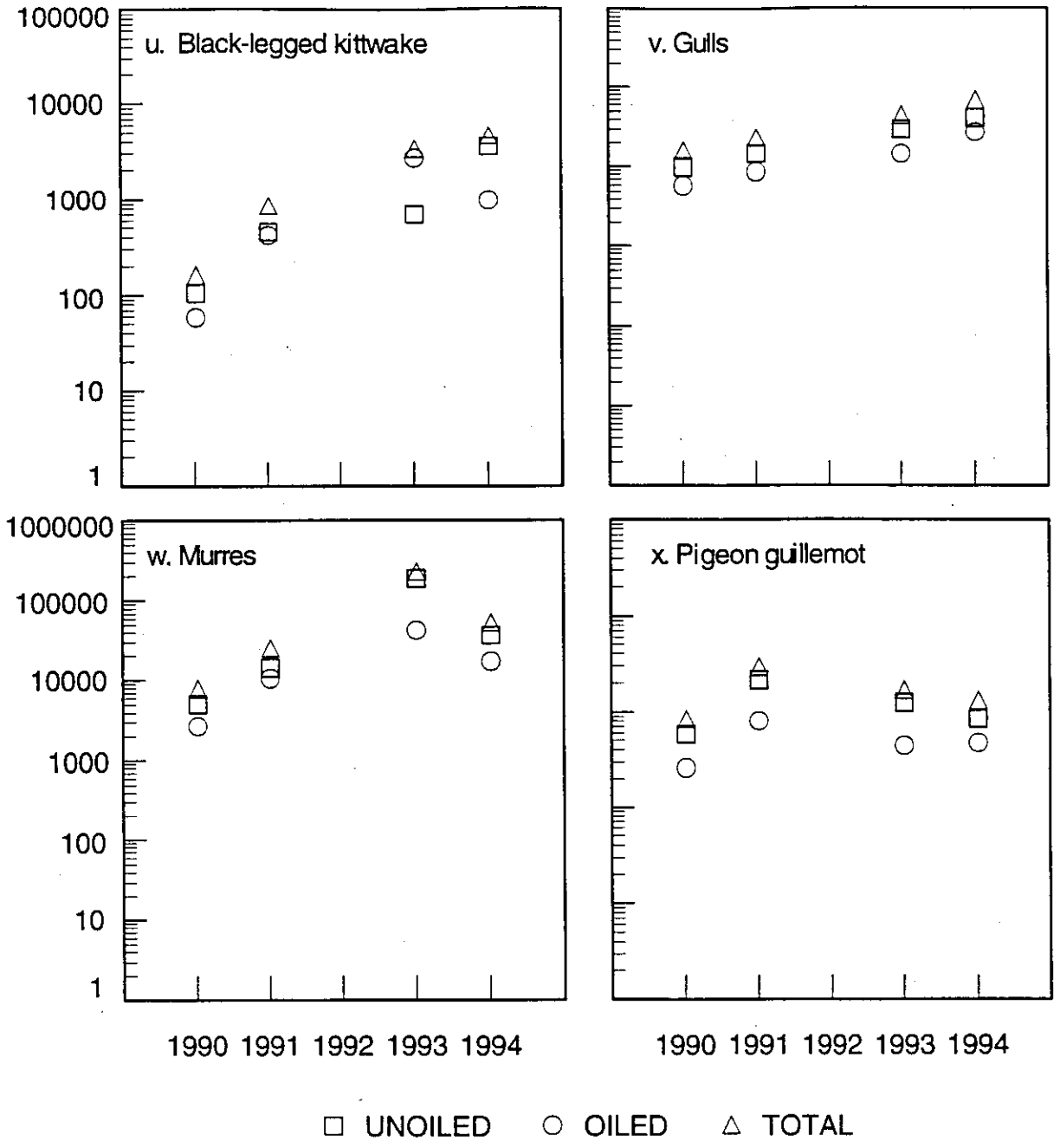

Figure 3 (continued).

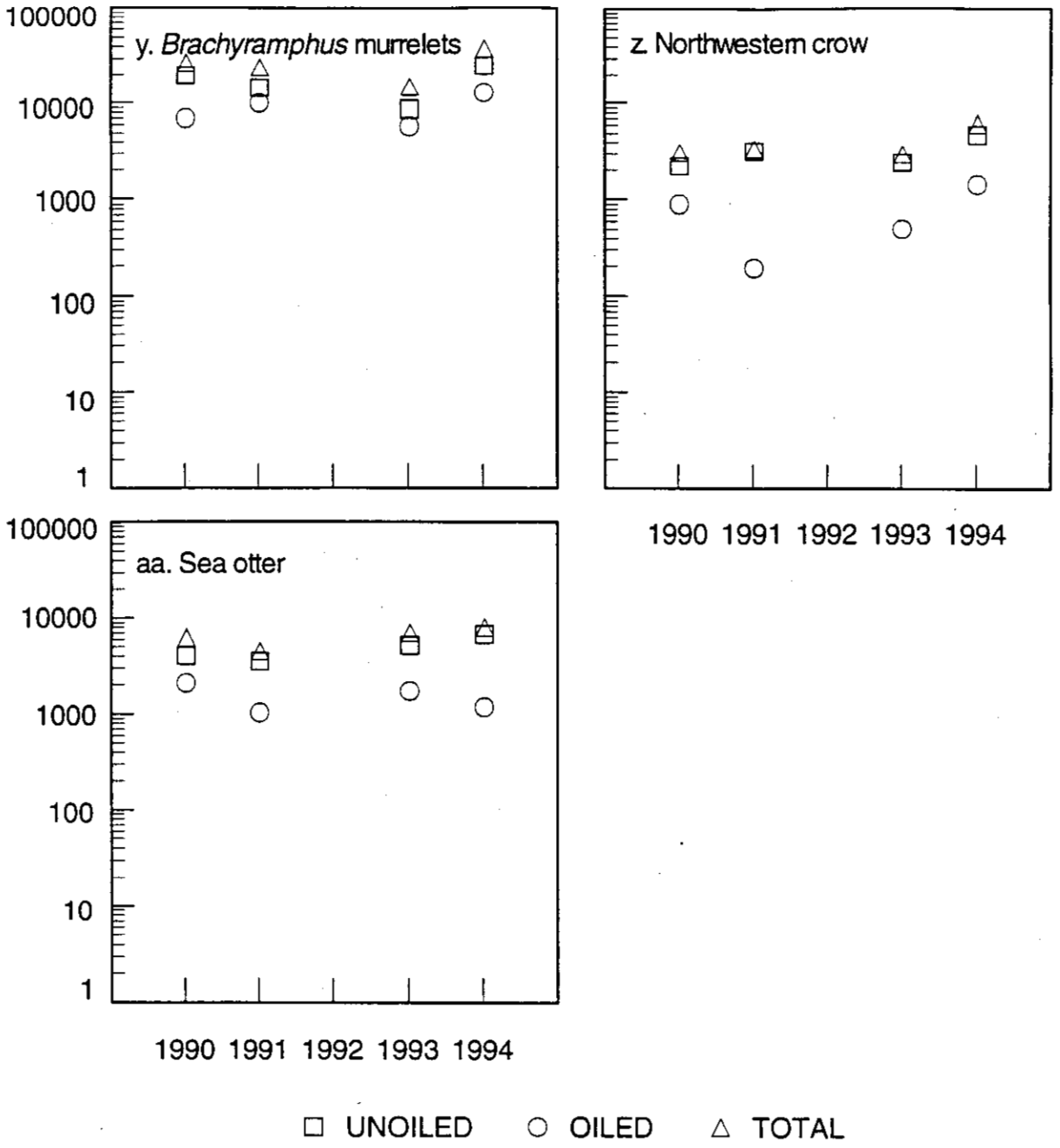

Figure 3 (continued).

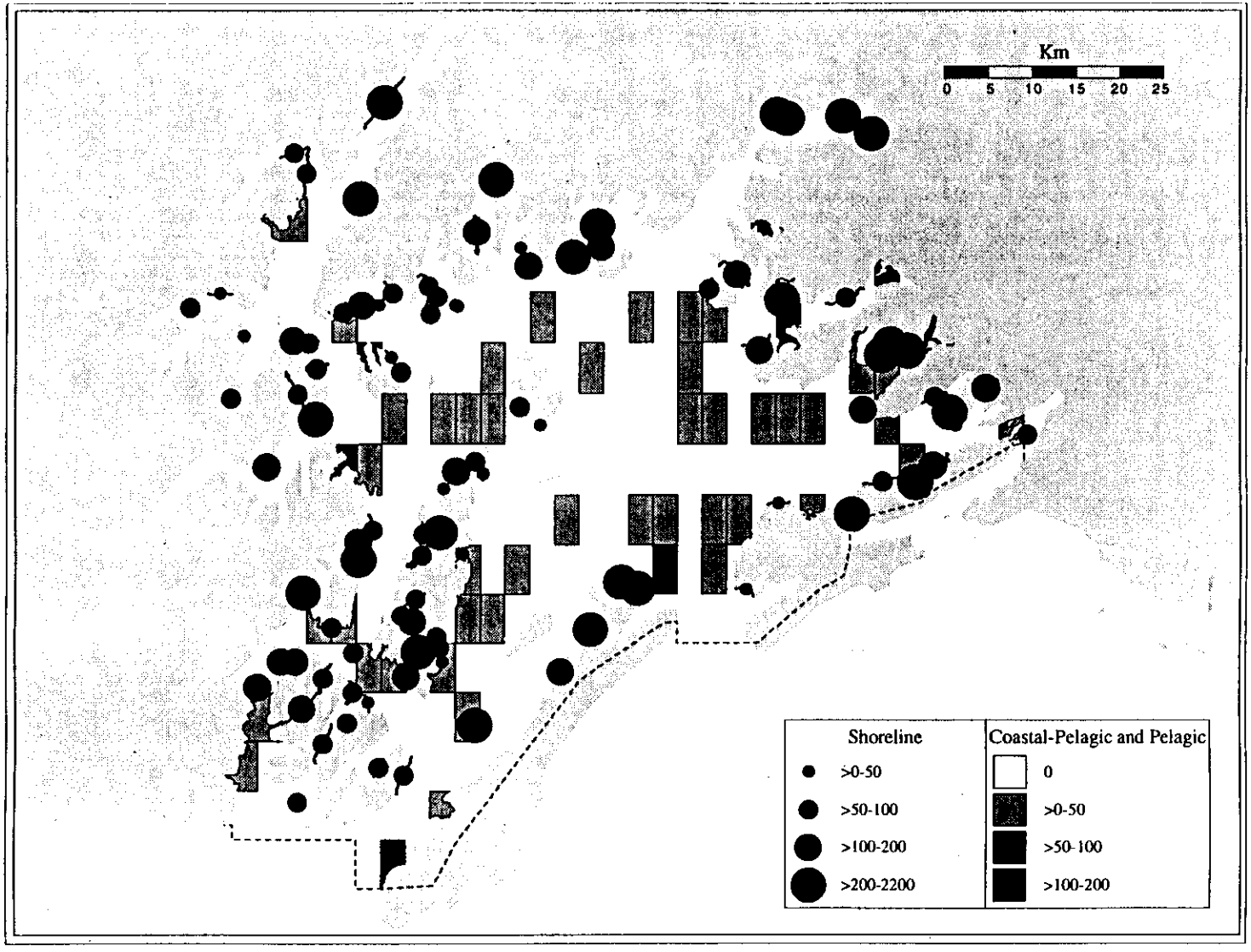

Figure 4. Estimated density (birds/km^2) of marine birds in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

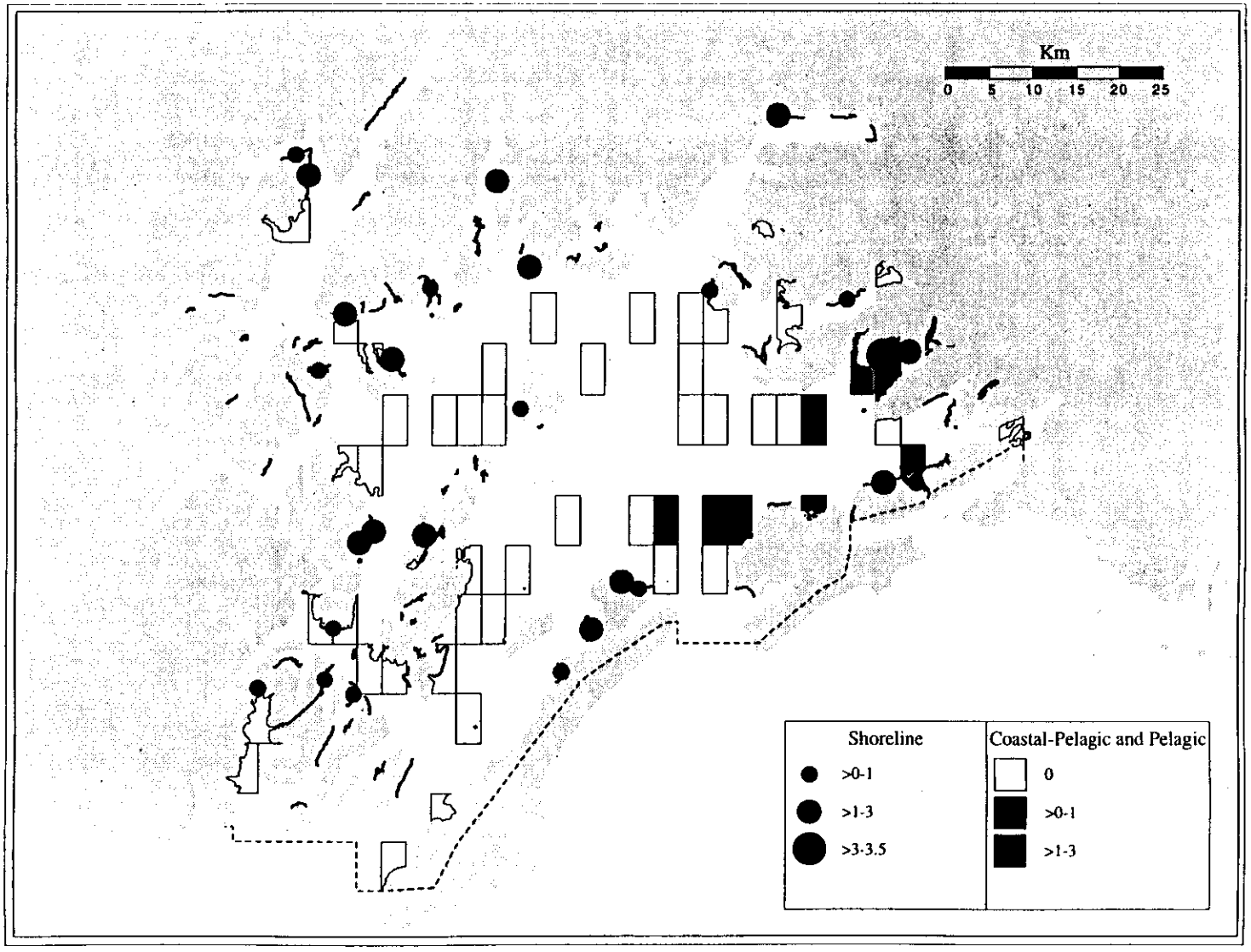

Figure 5. Estimated density (birds/km^2) of loons in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

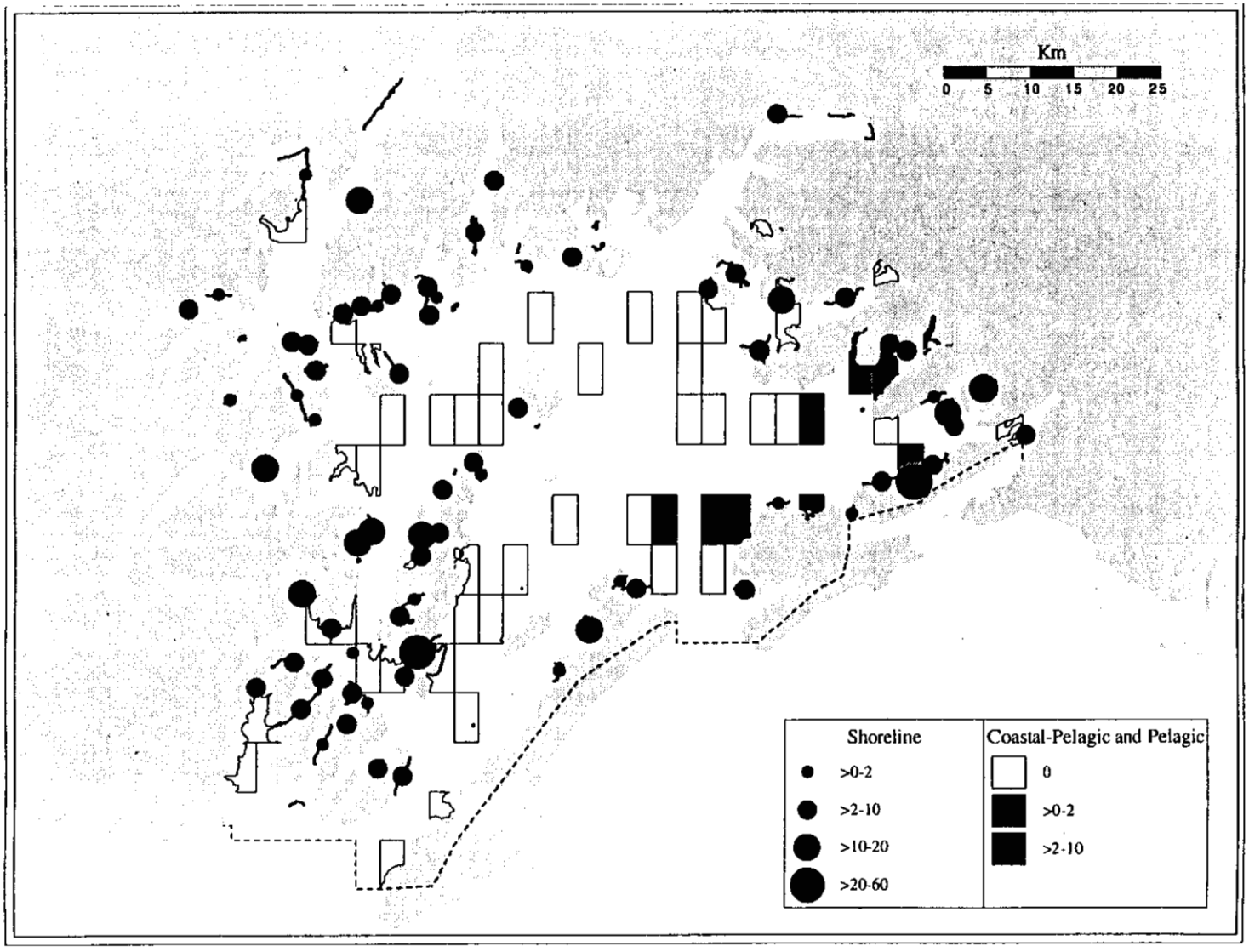

Figure 6. Estimated density (birds/km^2) of grebes in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

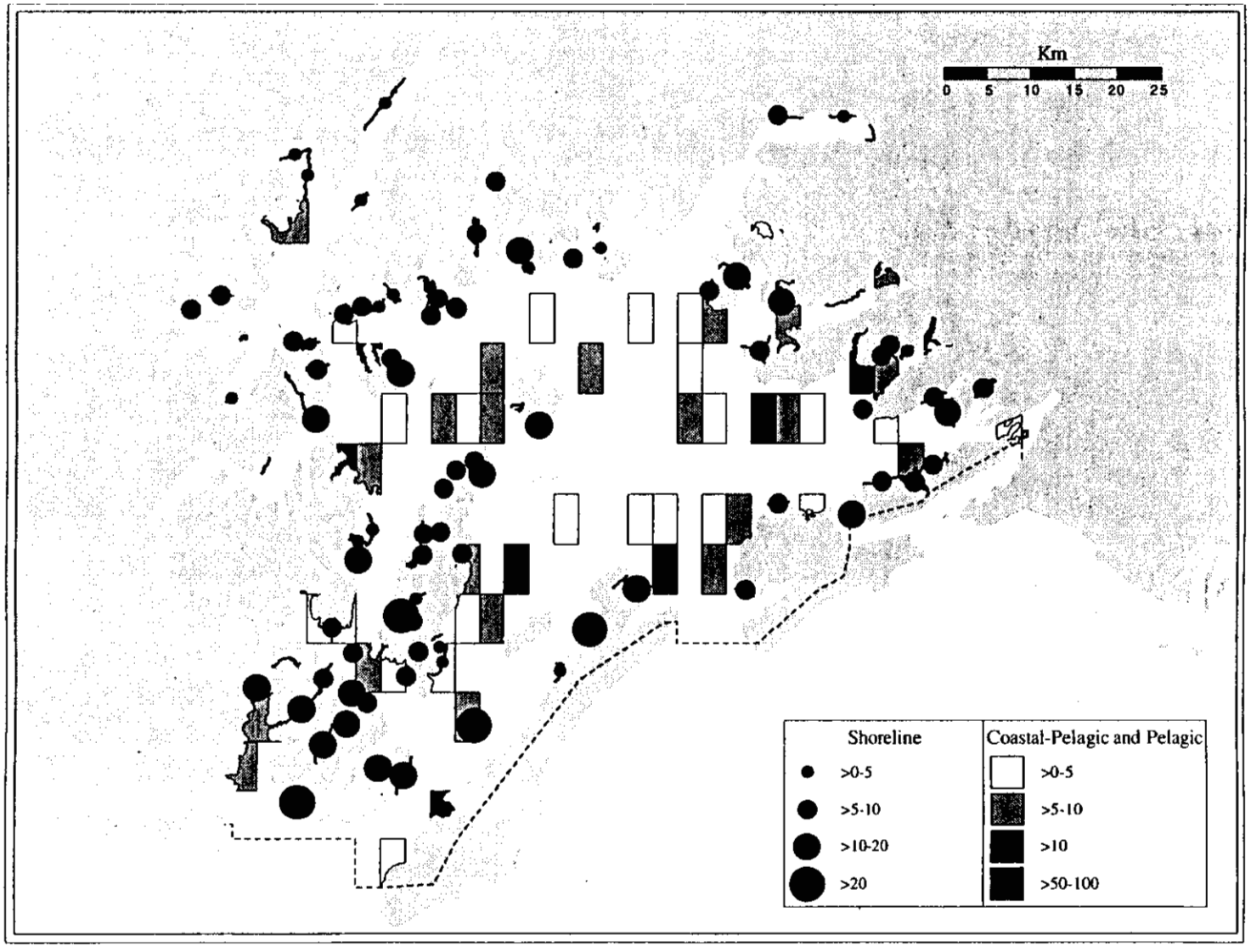

Figure 7. Estimated density (birds/km^2) of cormorants in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

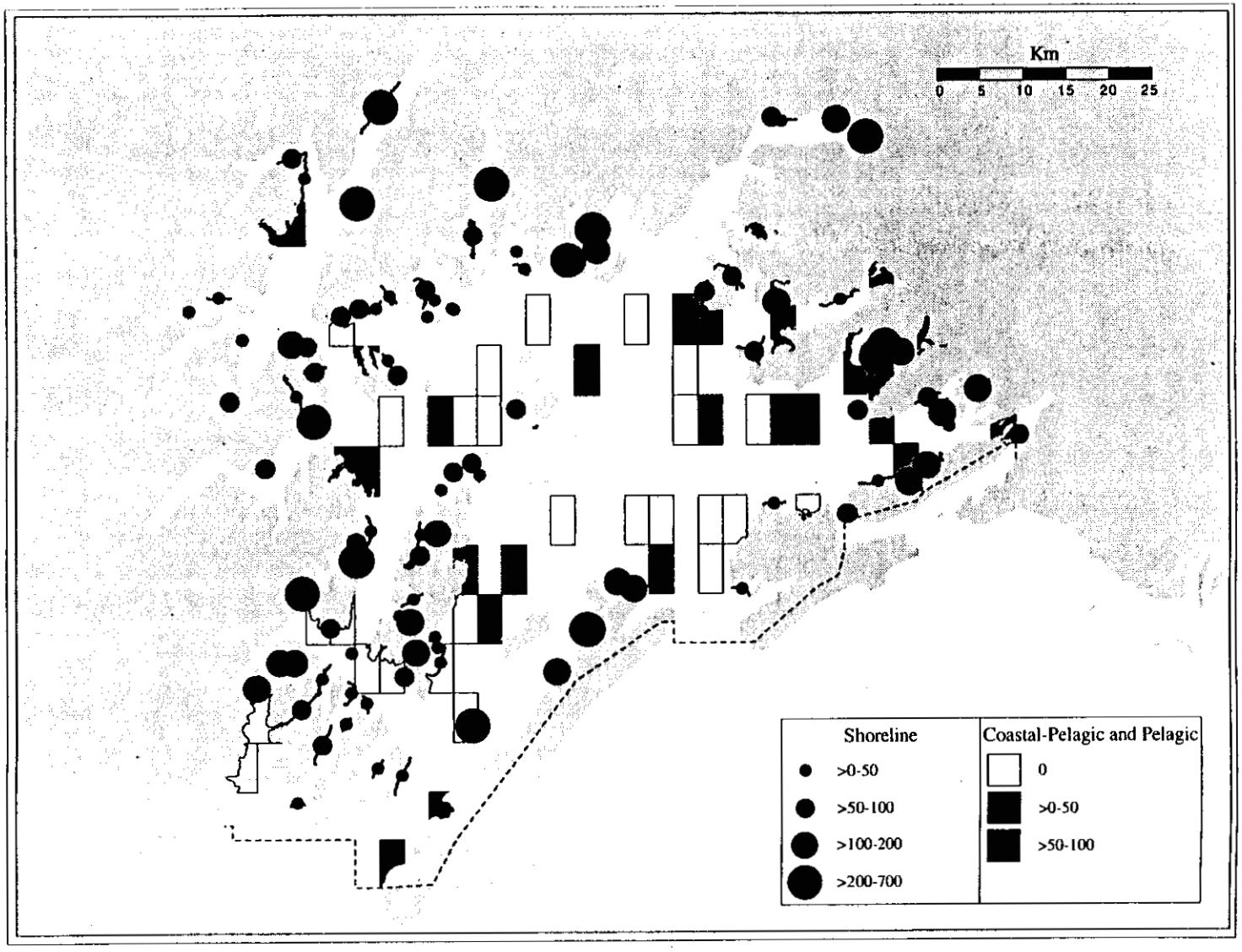

Figure 8. Estimated density (birds/km^2) of waterfowl in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

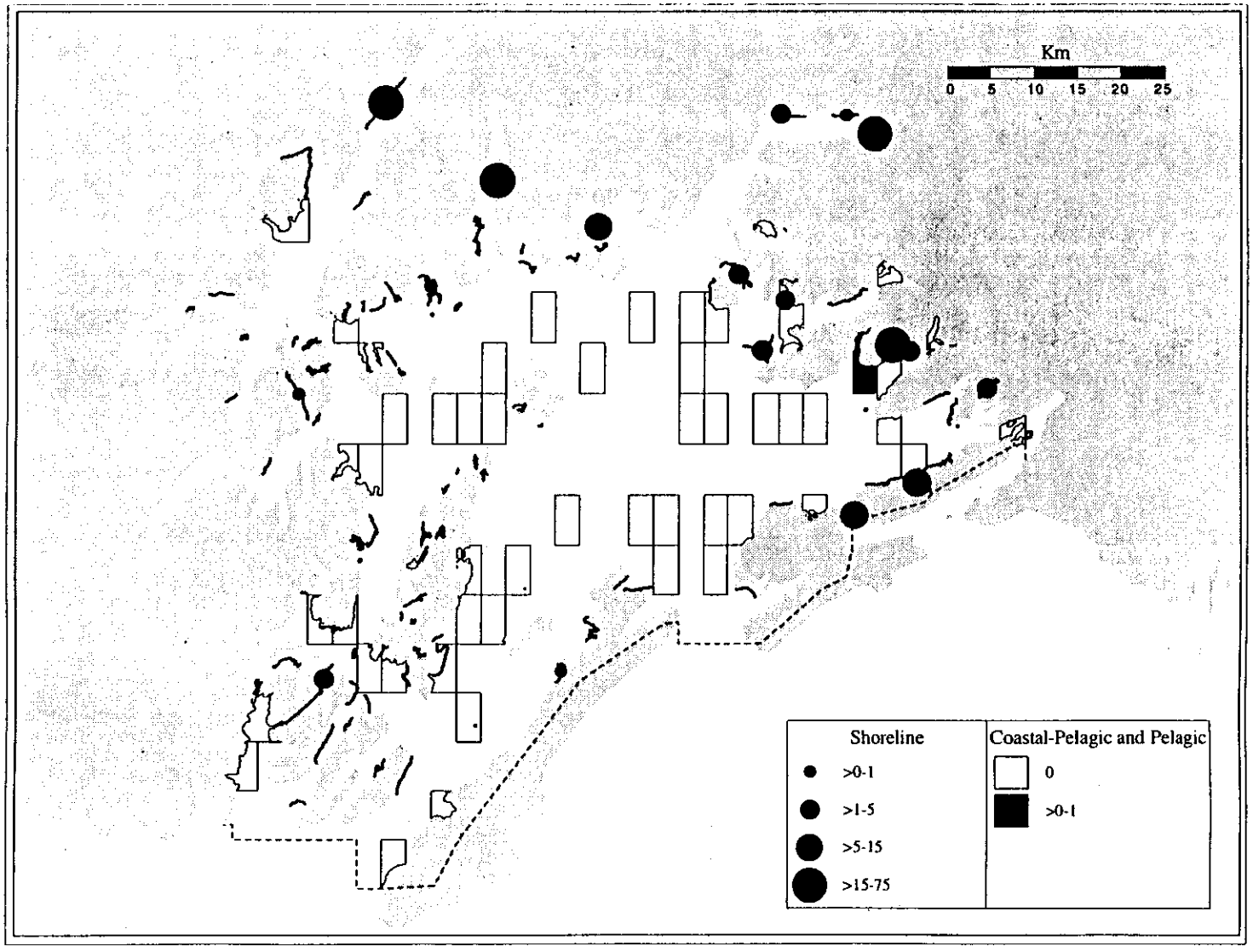

Figure 9. Estimated density (birds/km^2) of mallards in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

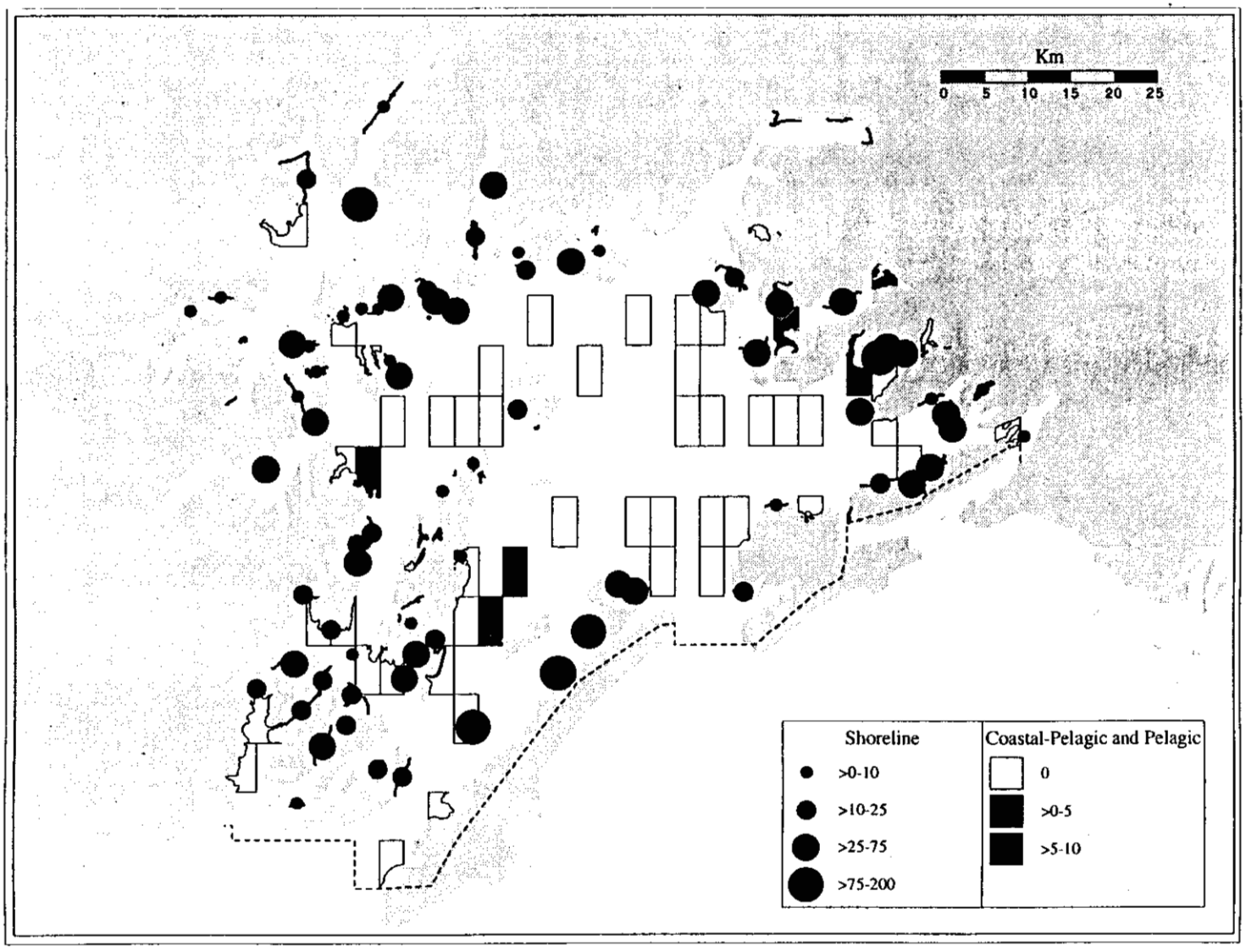

Figure 10. Estimated density (birds/km^2) of harlequin ducks in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

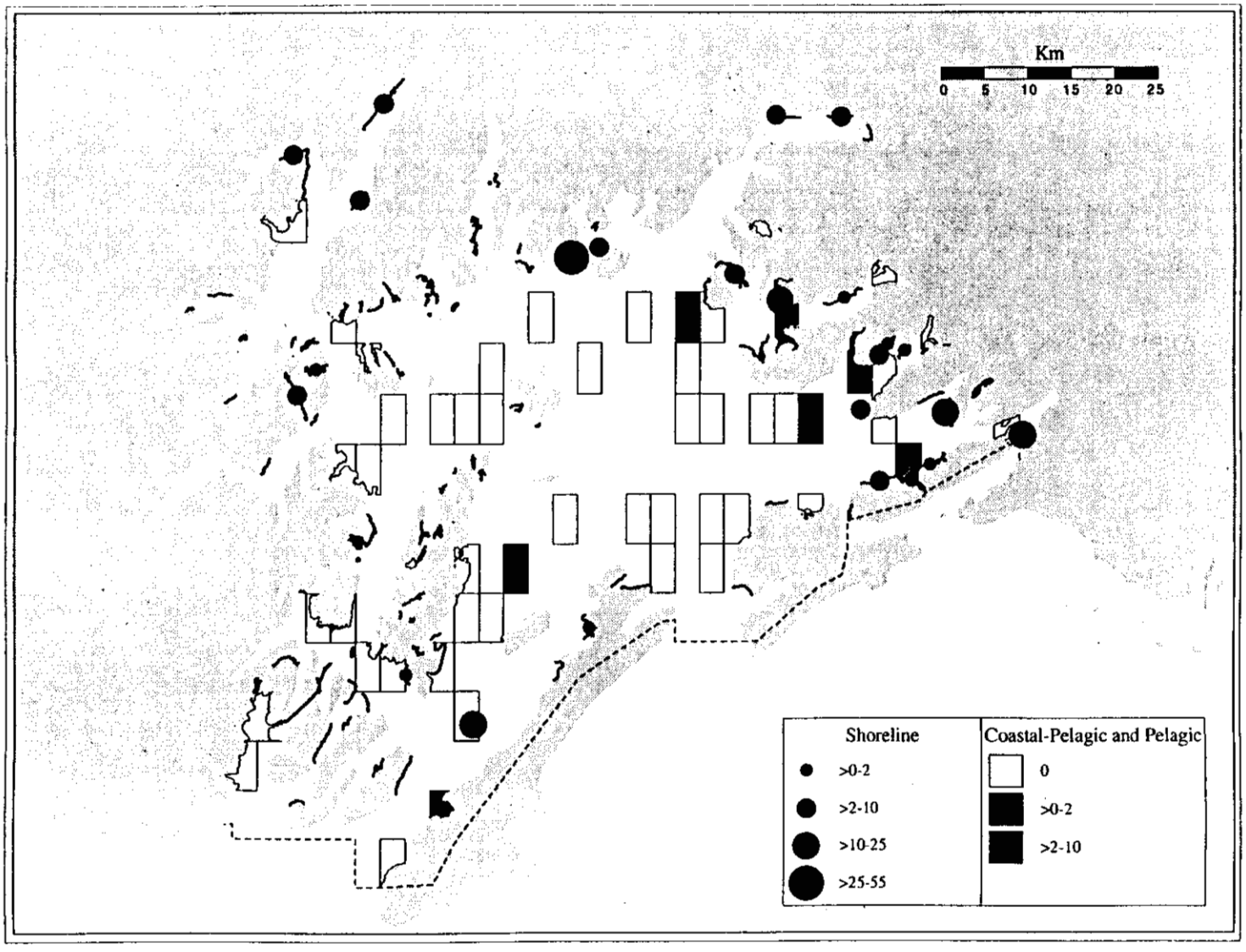

Figure 11. Estimated density (birds/km^2) of oldsquaw in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

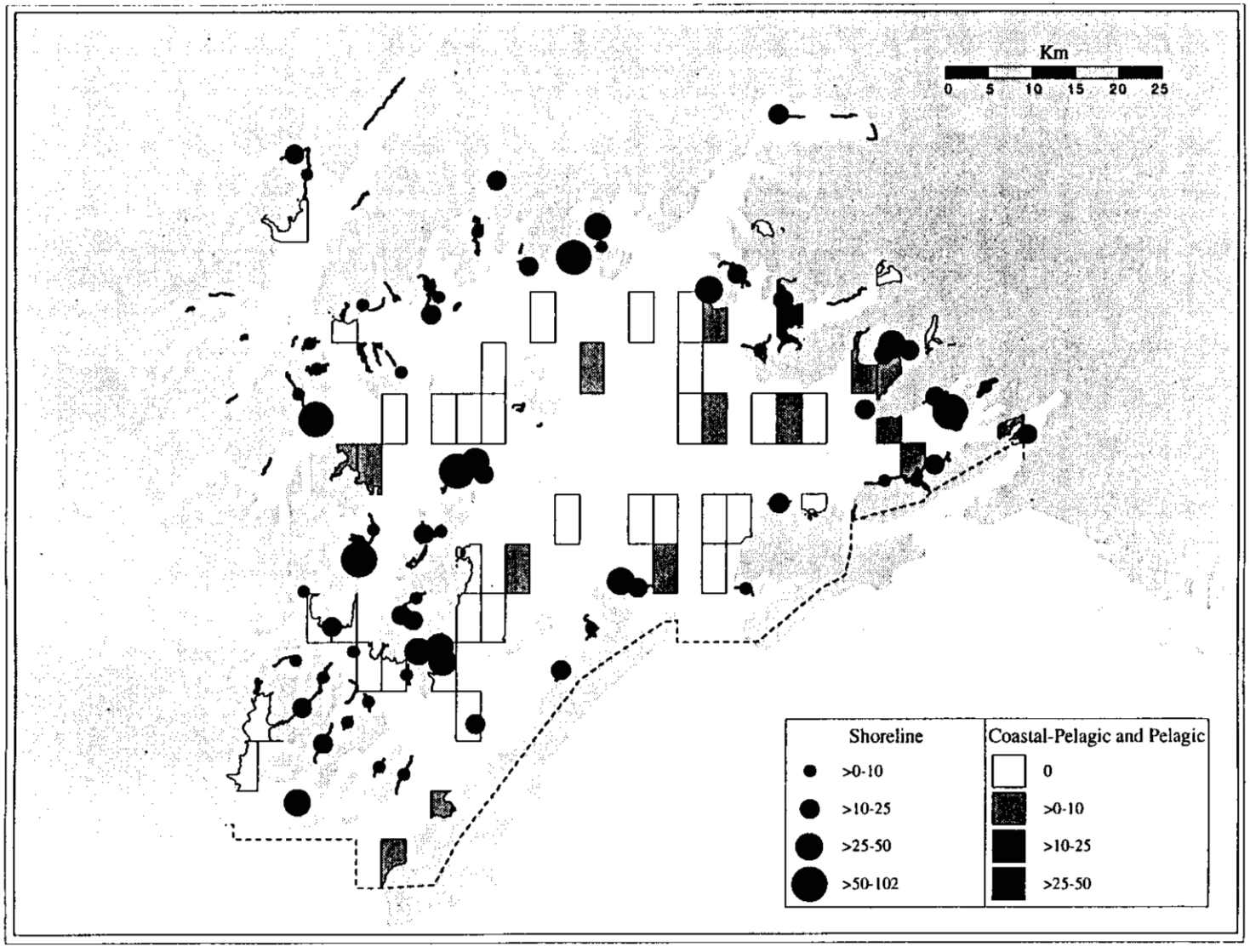

Figure 12. Estimated density (birds/km^2) of scoters in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

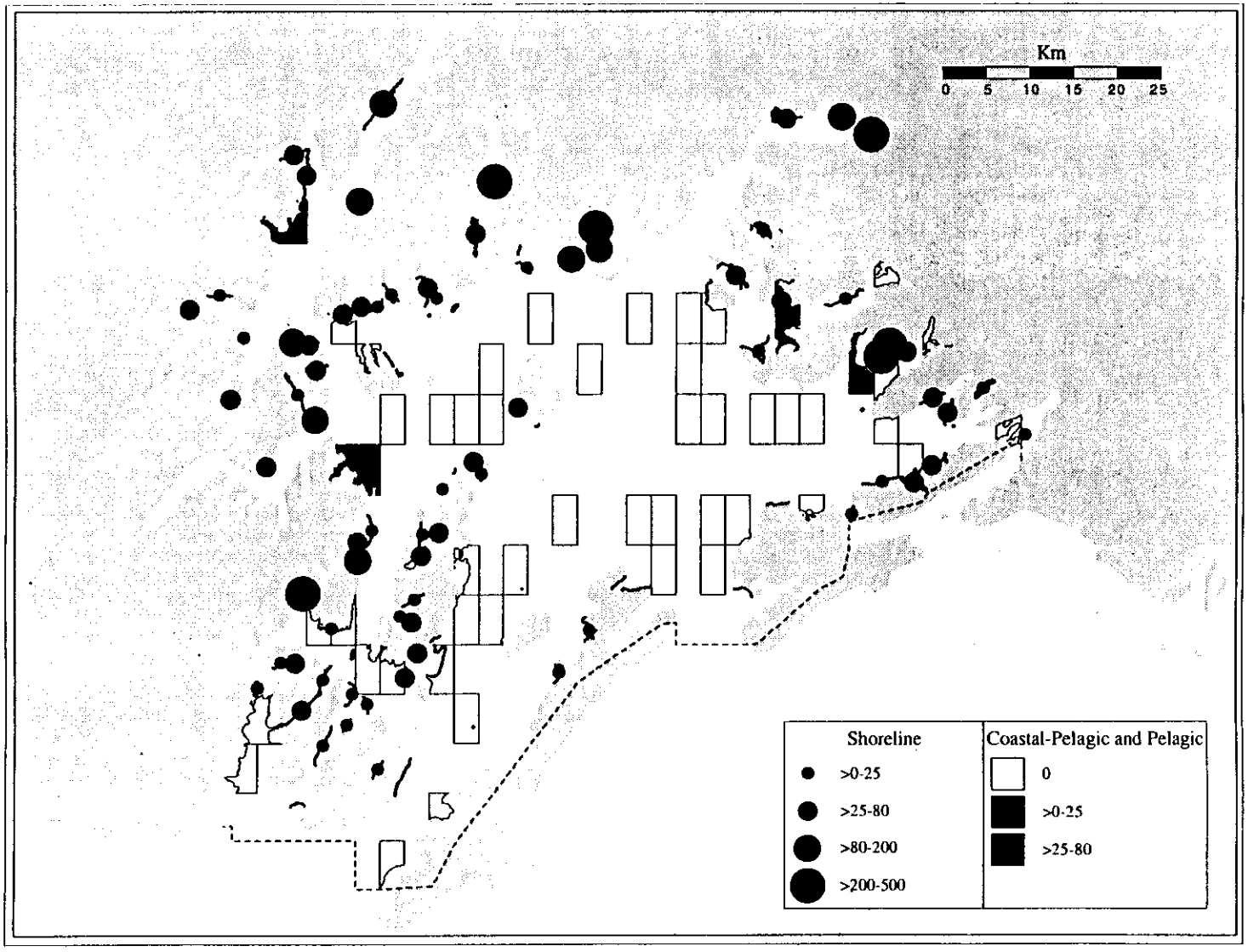

Figure 13. Estimated density (birds/km^2) of goldeneyes in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

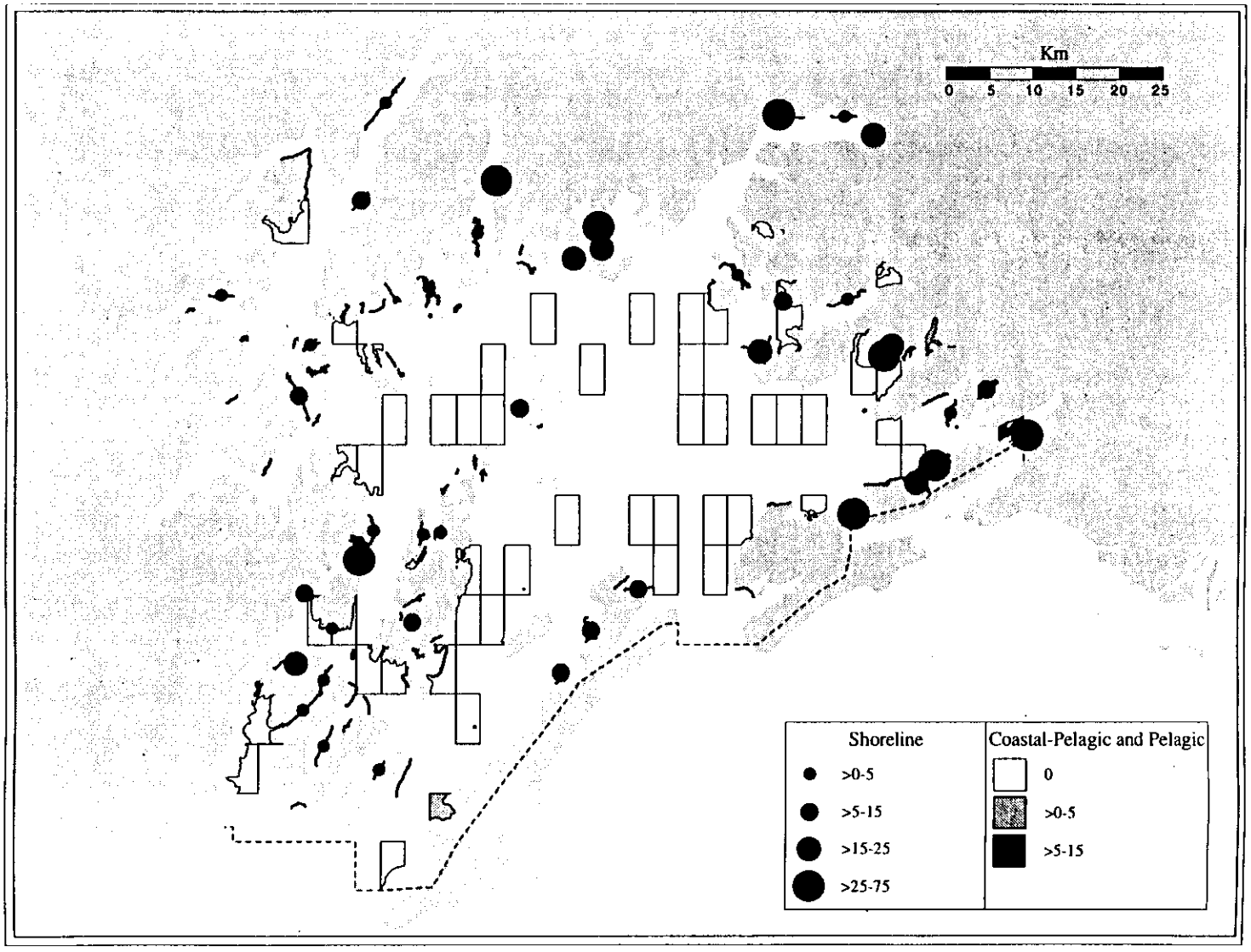

Figure 14. Estimated density (birds/km^2) of buffleheads in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

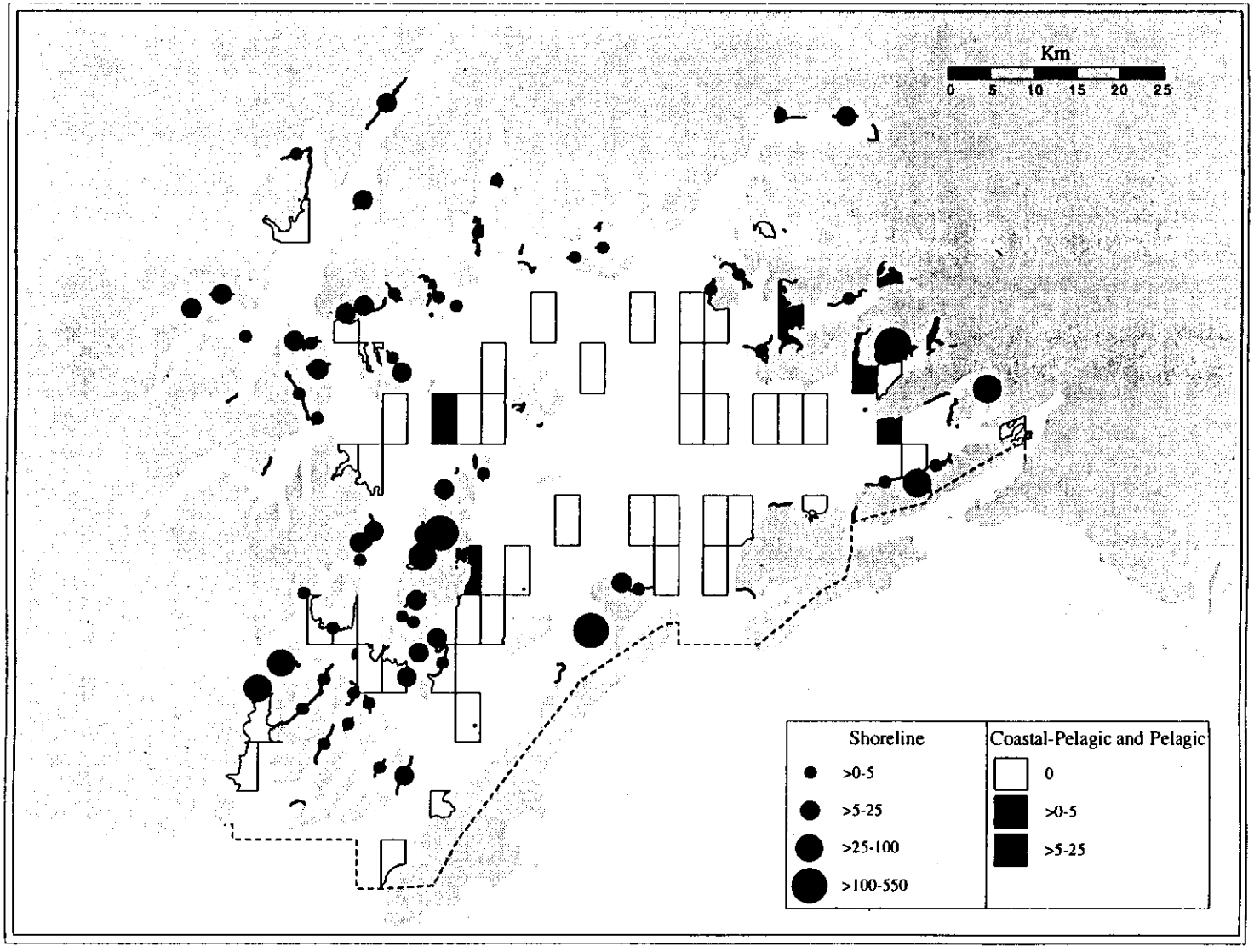

Figure 15. Estimated density (birds/km^2) of mergansers in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

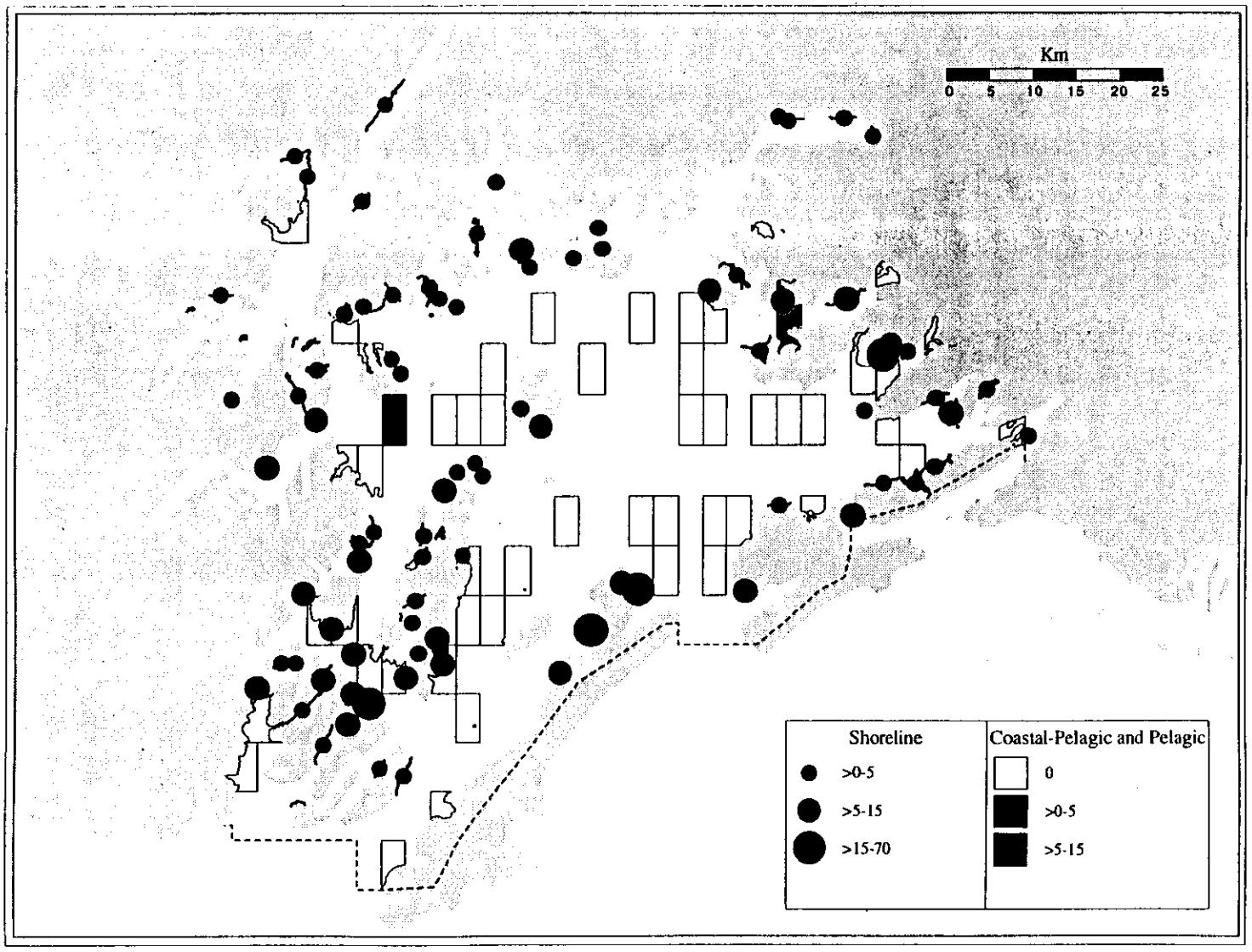

Figure 16. Estimated density (birds/km^2) of bald eagles in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

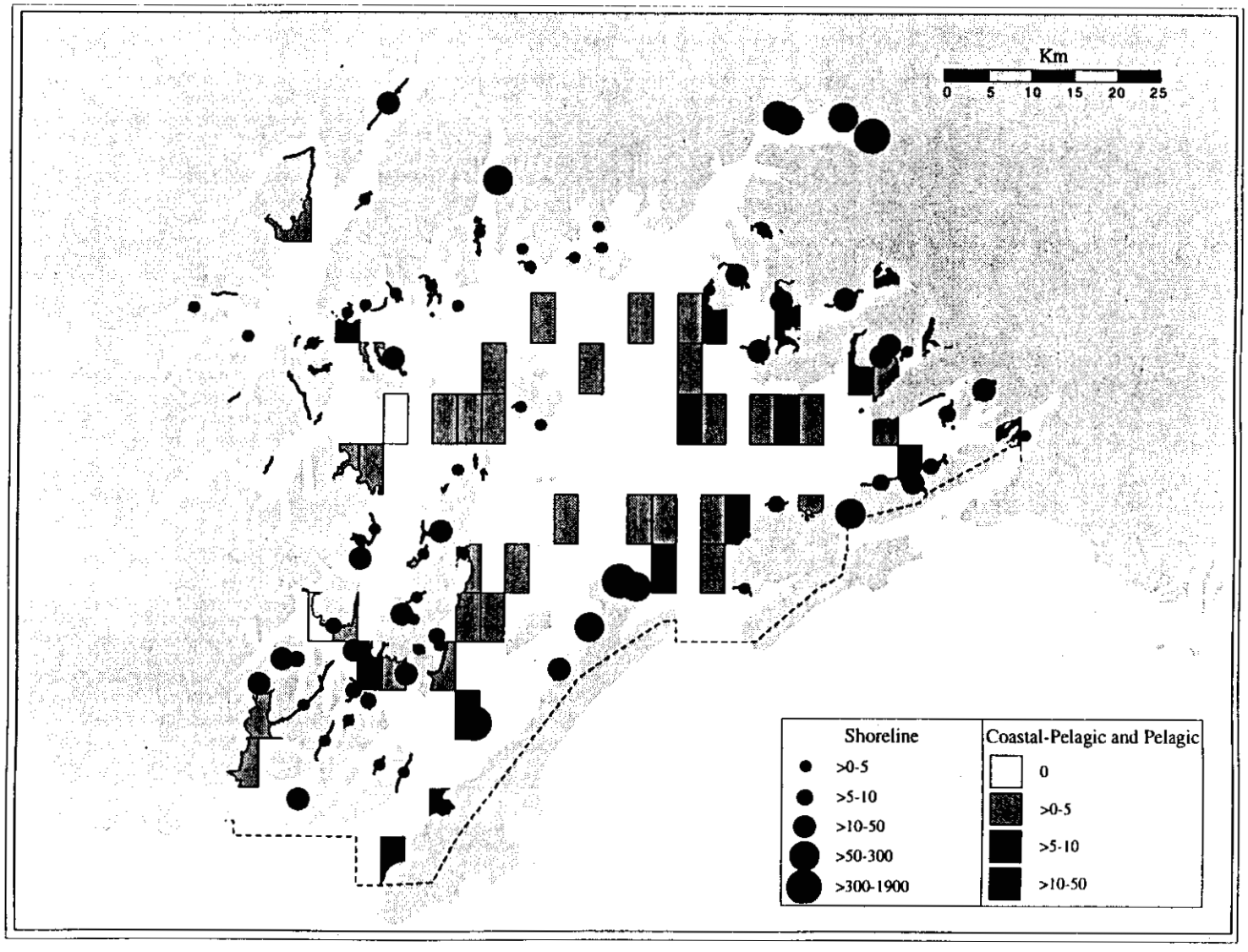

Figure 17. Estimated density (birds/km^2) of gulls in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

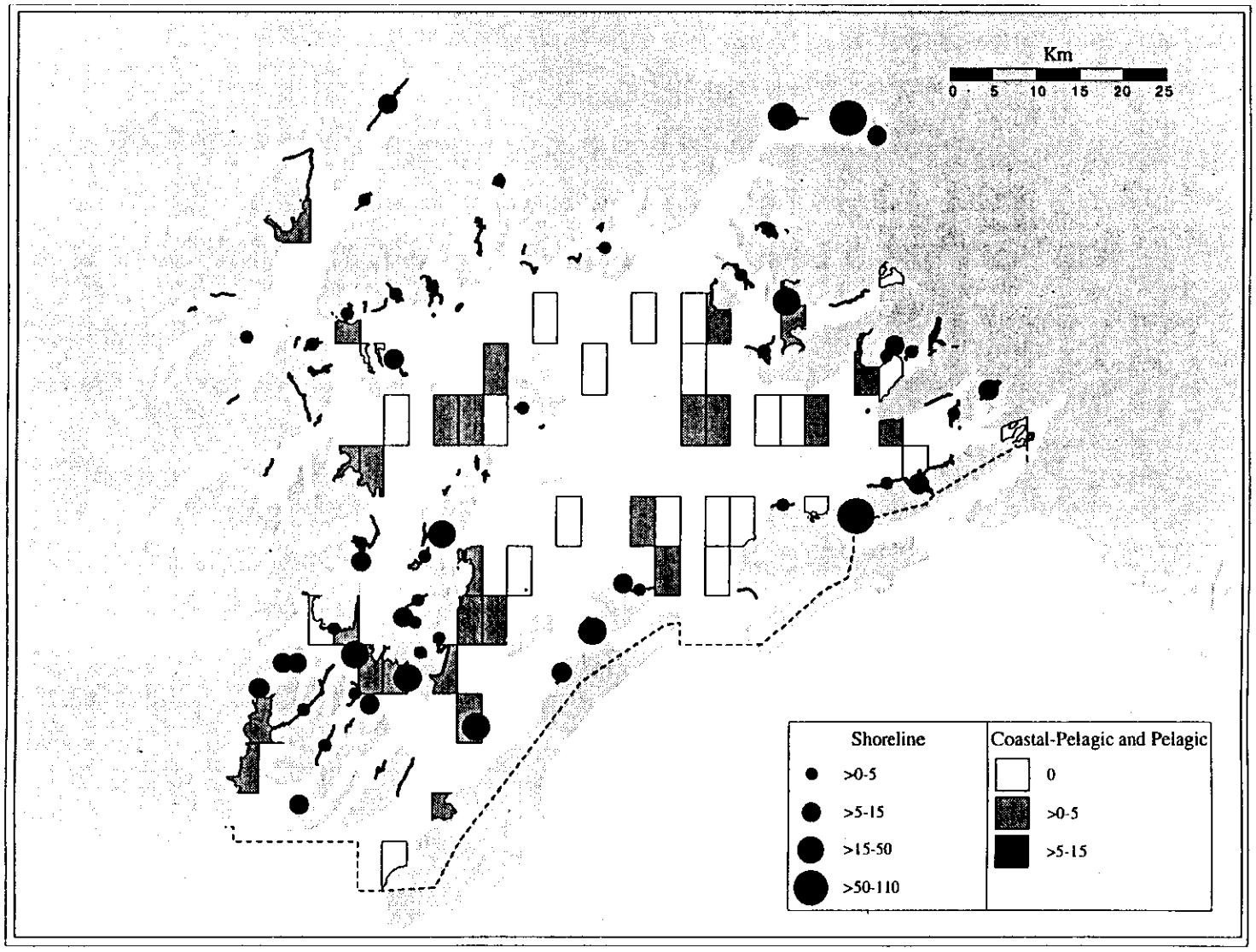

Figure 18. Estimated density (birds/km^2) of mew gulls in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

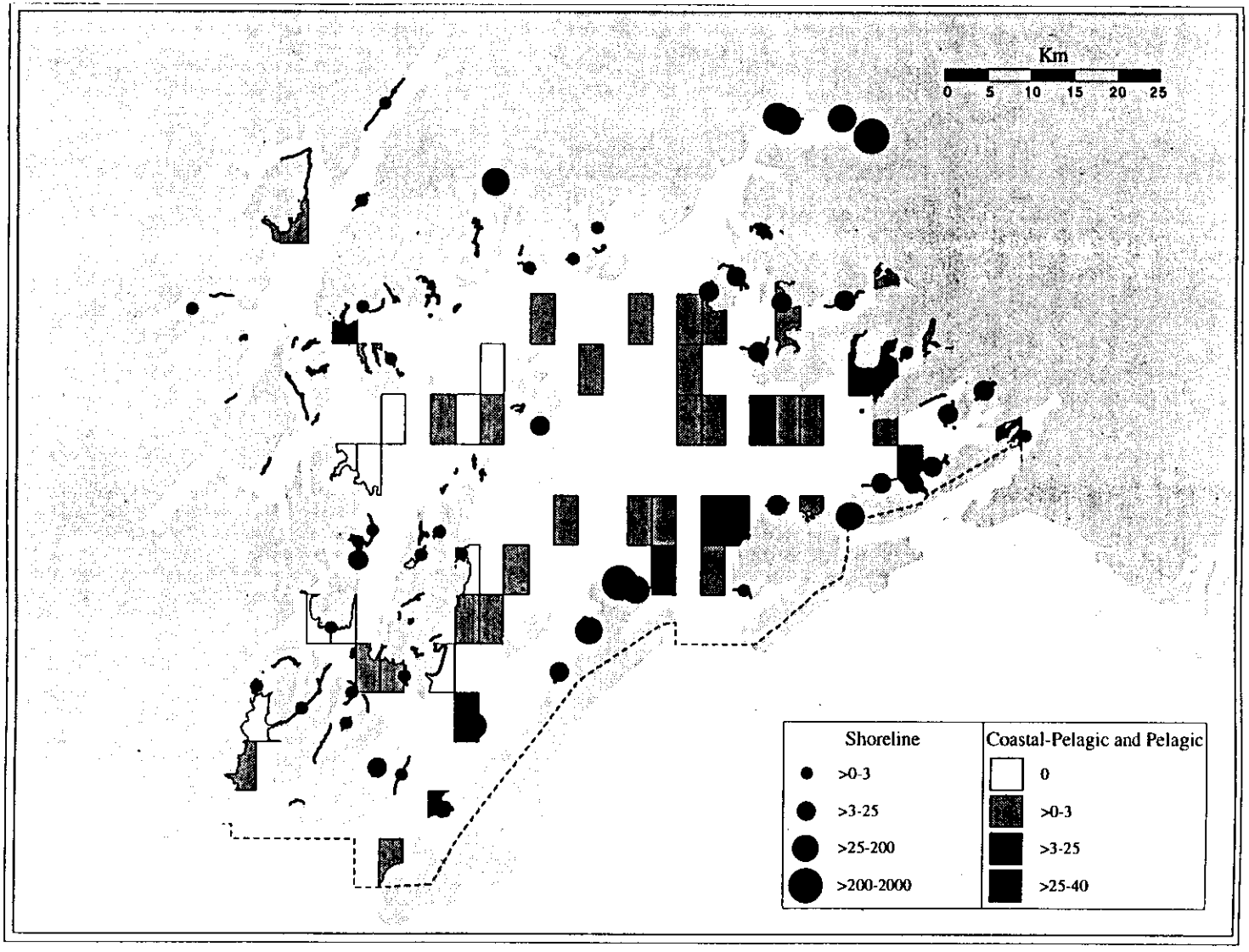

Figure 19. Estimated density (birds/km^2) of glaucous-winged gulls in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

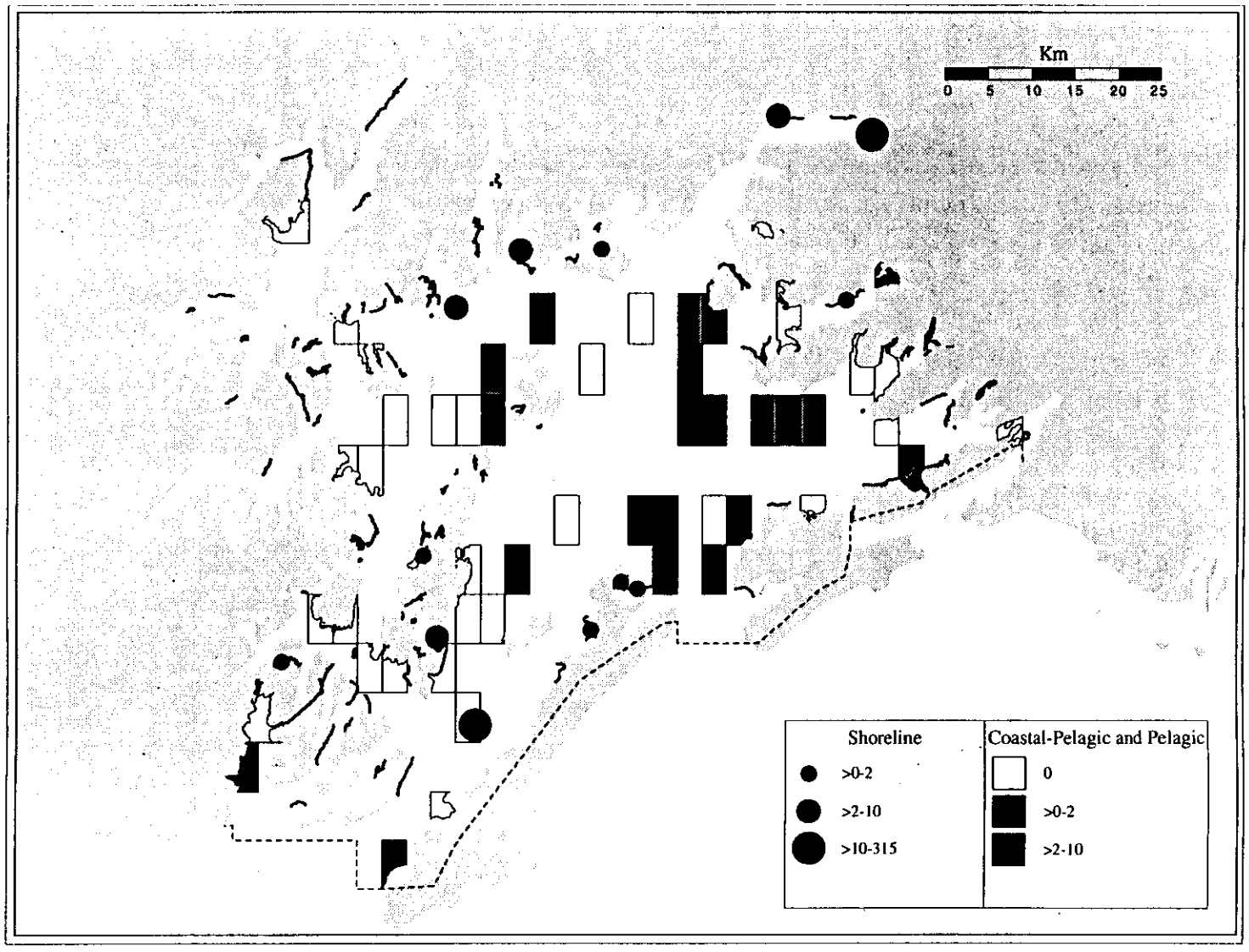

Figure 20. Estimated density (birds/km^2) of black-legged kittiwakes in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

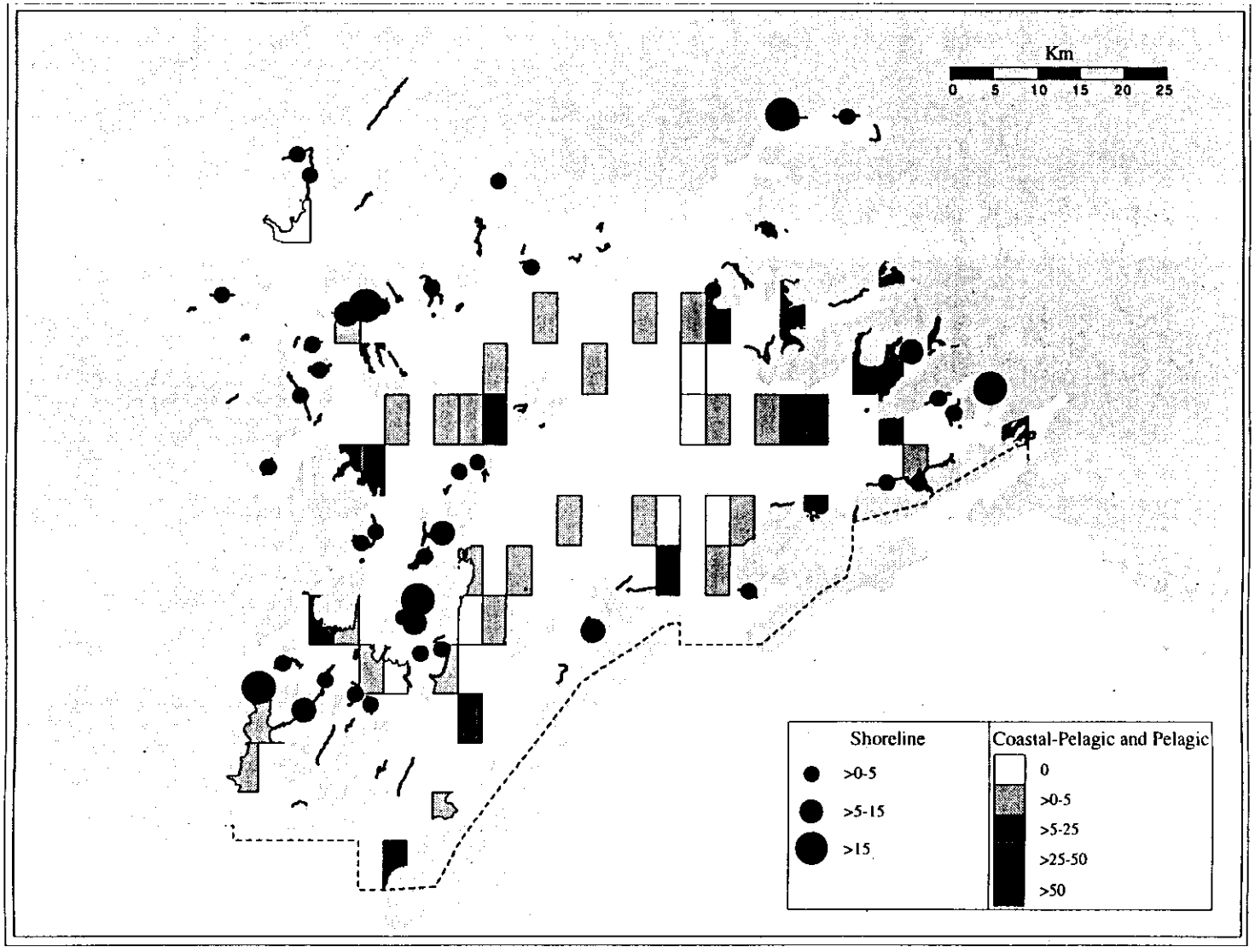

Figure 21. Estimated density (birds/km^2) of murres in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

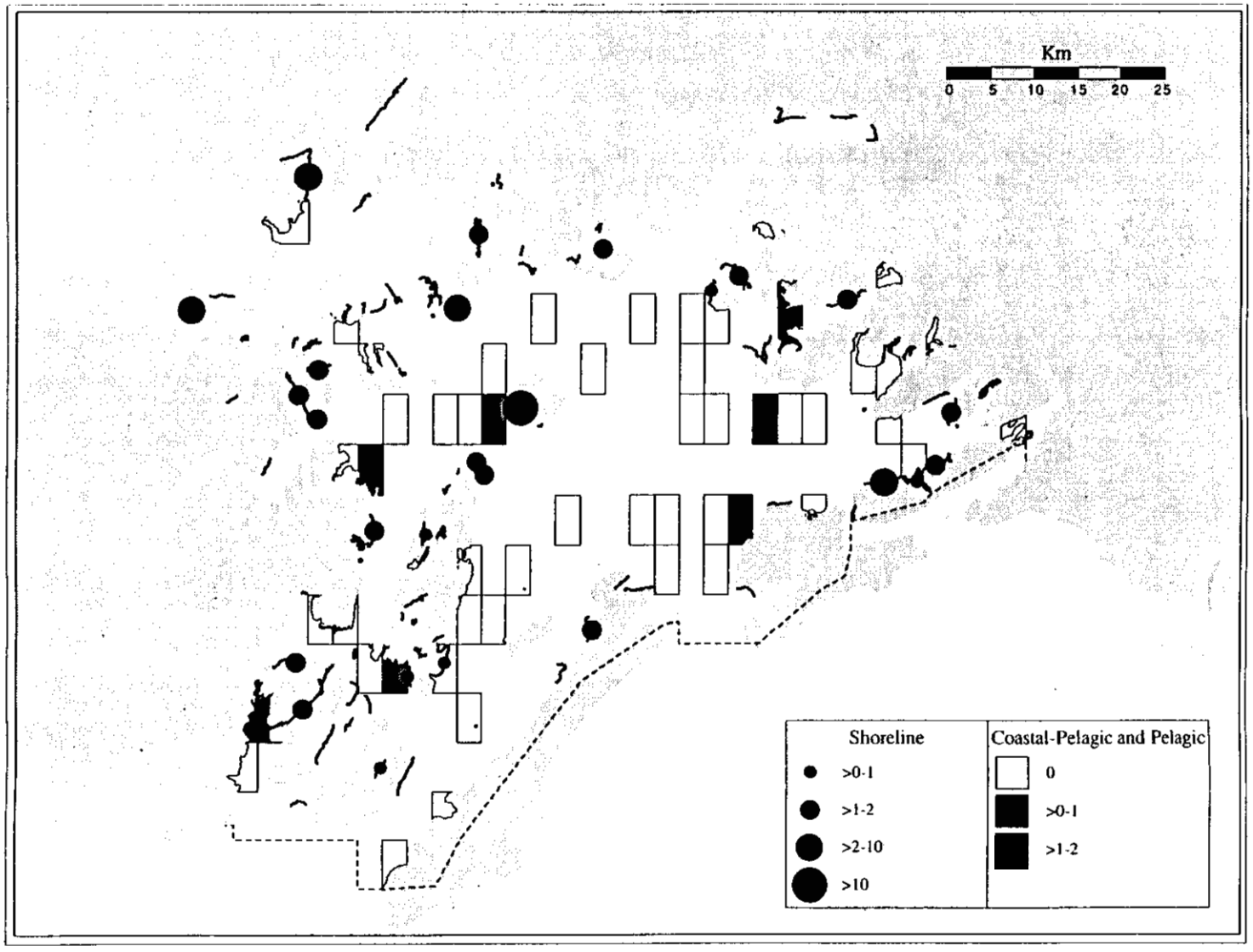

Figure 22. Estimated density (birds/km^2) of pigeon guillemots in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

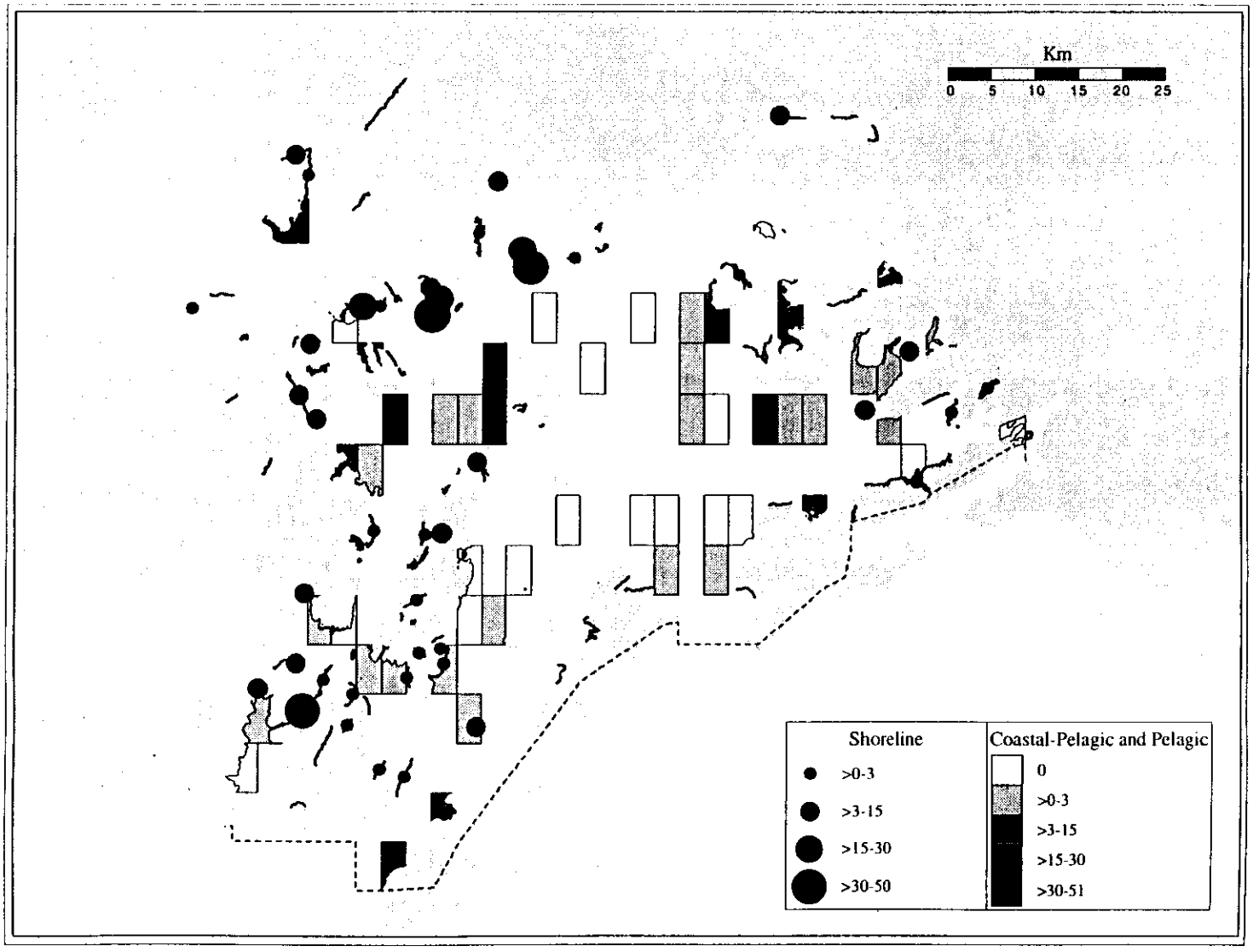

Figure 23. Estimated density (birds/km^2) of *Brachyramphus* murrelets in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

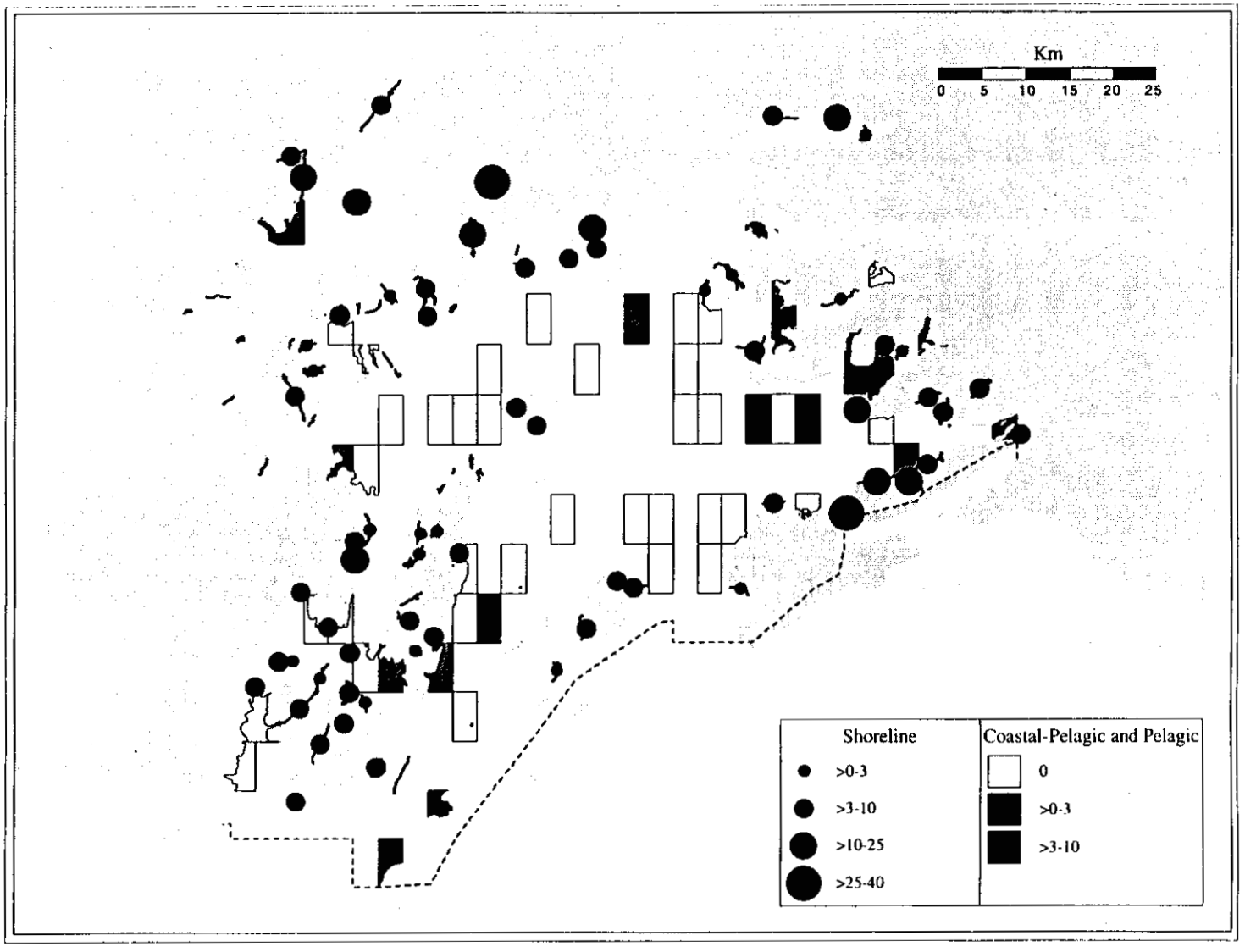

Figure 24. Estimated density (birds/km^2) of sea otters in Prince William Sound during March 1994. Densities are shown by circles for shoreline transects, and shading for coastal-pelagic and pelagic blocks. Dark lines represent shoreline transects.

Appendix A. Estimated numbers of birds ($N \pm 95\%$ CI) for species and species groups observed in Prince William Sound during March 1972-73 (L. Haddock et al., U. S. Fish and Wildl. Serv., unpubl. data), 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), and 1994. We listed species in phylogenetic order (American Ornithologists' Union 1983).

	Oiled Zone		Unoiled Zone		Total	
Species/Year	*N*	CI	*N*	CI	*N*	CI
Loons						
Red-throated loon (*Gavia stellata*)						
1972	66	108	113	127	179	161
1973	0	0	29	33	29	33
1990	0	0	8	14	8	14
1991	0	0	90	166	90	166
1993	74	123	16	29	89	126
1994	0	0	0	0	0	0
Pacific loon (*Gavia pacifica*)						
1972	11	15	2,458	1,702	2,470	1,702
1973	0	0	1,112	1,479	1,112	1,479
1990	0	0	66	121	66	121
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	18	18	188	204	206	205
Common loon (*Gavia immer*)						
1972	19	42	78	95	97	102
1973	0	0	7	12	7	12
1990	33	27	196	247	230	249
1991	25	25	362	396	386	397
1993	11	14	56	45	67	48
1994	45	35	308	212	353	214
Yellow-billed loon (*Gavia adamsii*)						
1972	19	42	78	95	97	102
1973	0	0	7	12	7	12
1990	33	27	196	247	230	249
1991	25	25	362	396	386	397
1993	11	14	56	45	67	48
1994	45	35	308	212	353	214

Appendix A (continued).

Species/Year	Oiled Zone N	Oiled Zone CI	Unoiled Zone N	Unoiled Zone CI	Total N	Total CI
Unidentified loon (*Gavia* sp.)						
1972	17	23	146	137	163	139
1973	24	26	1,738	1,618	1,762	1,619
1990	134	172	414	273	549	323
1991	96	120	1,015	1,127	1,111	1,133
1993	41	34	830	643	871	644
1994	31	44	796	912	827	913
Total loons (*Gavia* spp.)						
1972	294	393	3,041	1,759	3,335	1,788
1973	24	26	3,028	2,322	3,051	2,322
1990	168	173	707	419	874	453
1991	126	128	1,507	1,185	1,634	1,192
1993	126	128	925	647	1,051	659
1994	119	63	1,407	1,062	1,526	1,064
Grebes						
Horned grebe (*Podiceps auritus*)						
1972	1,245	527	3,602	2,182	4,847	2,247
1973	1,657	774	3,713	1,444	5,370	1,634
1990	754	432	3,026	1,483	3,780	1,545
1991	185	210	2,071	1,595	2,255	1,609
1993	23	33	377	325	400	326
1994	618	300	3,080	2,189	3,698	2,210
Red-necked grebe (*Podiceps grisegena*)						
1972	1,383	939	3,076	1,450	4,459	1,695
1973	4,775	10,922	2,595	1,406	7,369	11,316
1990	635	294	1,472	1,366	2,108	1,397
1991	688	387	877	330	1,565	509
1993	173	116	508	302	681	324
1994	477	174	1,401	725	1,878	746
Unidentified grebe (*Podiceps* sp.)						
1972	0	0	0	0	0	0
1973	5	9	0	0	5	9
1990	117	90	494	289	611	302
1991	587	1,016	1,188	926	1,775	1,375
1993	821	408	3,389	2,092	4,210	2,132
1994	403	228	781	488	1,185	538

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Total grebes (*Podiceps* spp.)						
1972	2,628	1,345	6,678	2,748	9,306	3,048
1973	6,437	11,259	6,308	2,246	12,744	9,046
1990	1,506	607	4,993	1,961	6,499	2,053
1991	1,459	1,150	4,136	1,923	5,595	2,240
1993	1,017	444	4,274	2,254	5,291	2,298
1994	1,499	456	5,262	2,964	6,761	2,998
Procellariiformes						
Fork-tailed storm-petrel (*Oceanodroma furcata*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	164	167	431	685	595	705
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	37	62	0	0	37	62
Total tubenoses (Order Procellariiformes)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	164	167	431	685	595	705
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	37	62	0	0	37	62
Cormorants						
Double-crested cormorant (*Phalacrocorax auritus*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	178	194	91	129	269	233
1991	94	104	30	34	124	109
1993	585	830	455	657	1,041	1,059
1994	36	45	95	97	131	107
Pelagic cormorant (*Phalacrocorax pelagicus*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	4,236	2,254	4,212	1,195	8,448	2,552
1991	1,966	1,187	3,466	1,930	5,431	2,266
1993	2,634	1,413	5,416	2,848	8,050	3,179
1994	4,748	1,770	6,211	2,170	10,959	2,800

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Red-faced cormorant (*Phalacrocorax urile*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	8	14	8	14
1993	5	9	1	3	6	10
1994	0	0	0	0	0	0
Unidentified cormorant (*Phalacrocorax* sp.)						
1972	4,148	1,577	6,644	2,279	10,792	2,744
1973	12,541	6,755	15,138	4,702	27,679	8,203
1990	273	349	78	77	352	358
1991	1,421	763	2,056	1,056	3,477	1,303
1993	1,501	1,277	1,273	983	2,775	1,611
1994	50	66	228	202	278	212
Total cormorants (*Phalacrocorax* spp.)						
1972	4,148	1,577	6,644	2,279	10,792	2,744
1973	12,541	6,755	15,138	4,702	27,679	8,203
1990	4,687	2,251	4,381	1,268	9,068	2,583
1991	3,481	1,518	5,559	2,177	9,040	2,654
1993	4,726	2,558	7,146	3,178	11,872	4,079
1994	4,833	1,776	6,535	2,205	11,368	2,832
Herons						
Great blue heron (*Ardea herodias*)						
1972	11	14	102	83	113	85
1973	14	19	36	35	50	41
1990	18	25	30	27	49	37
1991	0	0	30	33	30	33
1993	43	63	62	100	106	118
1994	12	16	186	204	198	205

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Waterfowl						
Tundra swan (*Cygnus columbianus*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	8	14	8	14
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Emperor goose (*Chen canagica*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	6	11	0	0	6	11
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Canada goose (*Branta canadensis*)						
1972	0	0	48	90	48	90
1973	0	0	138	252	138	252
1990	0	0	38	71	38	71
1991	0	0	0	0	0	0
1993	37	67	0	0	37	67
1994	0	0	48	91	48	91
Green-winged teal (*Anas crecca*)						
1972	0	0	148	259	148	259
1973	0	0	59	80	59	80
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Mallard (*Anas platyrhynchos*)						
1972	46	69	7,139	8,722	7,185	8,722
1973	15	23	1,602	1,149	1,617	1,150
1990	17	24	1,937	1,382	1,954	1,382
1991	0	0	8,249	11,958	8,249	11,958
1993	0	0	3,401	2,532	3,401	2,532
1994	15	23	3,605	2,998	3,620	2,998

Appendix A (continued).

Species/Year	Oiled Zone		Unoiled Zone		Total	
	N	CI	*N*	CI	*N*	CI
Northern pintail (*Anas acuta*)						
1972	0	0	348	605	348	605
1973	0	0	276	492	276	492
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	0	0	8	14	8	14
1994	0	0	0	0	0	0
Gadwall (*Anas strepera*)						
1972	0	0	4,407	8,025	4,407	8,025
1973	0	0	487	625	487	625
1990	0	0	174	327	174	327
1991	0	0	151	257	151	257
1993	0	0	155	292	155	292
1994	0	0	1,630	2,124	1,630	2,124
American wigeon (*Anas americana*)						
1972	0	0	474	863	474	863
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	7	14	8	14
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Unidentified dabbling duck (*Anas* sp.)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	1,043	1,510	1,043	1,510
1991	0	0	621	720	621	720
1993	0	0	1,607	2,893	1,607	2,893
1994	0	0	0	0	0	0
Greater scaup (*Aythya marila*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	1	1	1,186	1,478	1,187	1,478
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	12	23	1,169	1,584	1,182	1,584

Appendix A (continued).

Species/Year	Oiled Zone		Unoiled Zone		Total	
	N	CI	*N*	CI	*N*	CI
Unidentified scaup (*Aythya marila* or *affinis*)						
1972	0	0	1,626	943	1,626	943
1973	0	0	2,583	2,566	2,583	2,566
1990	0	0	600	753	600	753
1991	0	0	431	775	431	775
1993	110	197	217	372	328	421
1994	0	0	242	458	242	458
Total scaup (*Aythya marila* and *affinis*)						
1972	0	0	1,626	943	1,626	943
1973	0	0	2,583	2,566	2,583	2,566
1990	1	1	1,786	1,616	1,787	1,616
1991	0	0	431	775	431	775
1993	110	197	217	372	328	421
1994	12	23	1,411	1,650	1,424	1,650
Steller's eider (*Polysticta stelleri*)						
1972	0	0	0	0	0	0
1973	0	0	13	25	13	25
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Unidentified eider (*Somateria* or *Polysticta* sp.)						
1972	30	39	11	21	40	44
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Harlequin duck (*Histrionicus histrionicus*)						
1972	6,084	2,465	6,395	2,213	12,480	3,325
1973	5,652	3,643	10,180	4,073	15,831	5,528
1990	2,739	974	7,891	2,350	10,629	2,544
1991	2,832	989	8,327	2,696	11,158	2,872
1993	3,315	1,254	15,304	7,282	18,619	7,389
1994	4,419	1,459	14,785	4,334	19,204	4,573

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Oldsquaw (*Clangula hyemalis*)						
1972	3,446	3,183	15,741	16,253	19,187	16,562
1973	1,468	1,171	9,909	8,231	11,377	8,314
1990	856	1,086	7,780	10,316	8,635	10,373
1991	683	508	2,486	1,325	3,169	1,419
1993	435	452	6,600	3,210	7,035	3,241
1994	493	569	3,616	2,654	4,109	2,714
Black scoter (*Melanitta nigra*)						
1972	468	364	3,651	2,549	4,119	2,575
1973	4,042	10,093	4,629	2,109	8,671	8,197
1990	378	437	2,387	1,446	2,765	1,510
1991	347	538	1,040	626	1,387	825
1993	113	114	1,843	1,041	1,956	1,048
1994	1,132	965	1,410	745	2,541	1,219
Surf scoter (*Melanitta perspicillata*)						
1972	2,654	1,461	13,746	5,999	16,400	6,162
1973	1,198	934	25,890	17,222	27,089	17,248
1990	1,156	604	3,398	1,213	4,554	1,355
1991	1,527	761	7,786	4,647	9,313	4,709
1993	1,594	804	4,326	1,766	5,921	1,941
1994	1,698	758	5,753	4,835	7,451	4,894
White-winged scoter (*Melanitta fusca*)						
1972	1,888	1,330	22,022	12,844	23,910	12,909
1973	1,483	923	15,298	6,457	16,782	6,523
1990	431	229	2,885	1,329	3,316	1,349
1991	1,039	1,201	4,256	2,470	5,296	2,747
1993	908	1,054	6,051	4,211	6,959	4,341
1994	2,684	1,868	5,480	3,335	8,165	3,822
Unidentified scoter (*Melanitta* sp.)						
1972	4,827	6,785	3,678	2,738	8,505	7,327
1973	1,374	1,018	6,272	7,423	7,647	7,493
1990	1,305	2,288	831	732	2,136	2,402
1991	368	581	522	812	890	998
1993	845	501	2,916	1,965	3,761	2,028
1994	148	131	2,192	2,214	2,340	2,218

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Total scoters (*Melanitta* spp.)						
1972	9,837	6,920	43,098	18,065	52,935	19,345
1973	8,098	10,628	52,090	21,825	60,187	22,389
1990	3,270	2,367	9,500	2,654	12,770	3,557
1991	3,281	1,933	13,605	6,797	16,886	7,067
1993	3,460	1,507	15,137	5,534	18,597	5,736
1994	5,661	2,402	14,835	6,219	20,497	6,667
Common goldeneye (*Bucephala clangula*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	17	22	878	721	896	721
1991	16	28	132	117	148	121
1993	55	91	47	65	102	112
1994	121	166	1,721	1,740	1,842	1,748
Barrow's goldeneye (*Bucephala islandica*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	2,978	996	11,993	3,461	14,970	3,601
1991	3,614	1,336	16,697	5,921	20,311	6,070
1993	2,821	1,388	10,874	3,352	13,694	3,628
1994	5,018	1,744	26,631	15,835	31,649	15,931
Unidentified goldeneye (*Bucephala clangula* or *islandica*)						
1972	941	401	13,861	4,725	14,802	4,741
1973	1,504	723	23,726	12,490	25,230	12,509
1990	457	395	3,221	1,631	3,678	1,678
1991	407	329	2,774	2,282	3,181	2,306
1993	2,035	1,063	18,239	7,793	20,274	7,866
1994	985	671	18,227	10,345	19,211	10,366
Total goldeneyes (*Bucephala clangula* and *islandica*)						
1972	941	401	13,861	4,725	14,802	4,741
1973	1,504	723	23,726	12,490	25,230	12,509
1990	3,452	1,069	16,092	4,265	19,544	4,397
1991	4,037	1,340	19,603	6,219	23,639	6,361
1993	4,911	2,153	29,159	8,834	34,070	9,093
1994	6,123	1,969	46,579	21,768	52,702	21,857

Appendix A (continued).

Species/Year	Oiled Zone		Unoiled Zone		Total	
	N	CI	*N*	CI	*N*	CI
Bufflehead (*Bucephala albeola*)						
1972	521	815	7,676	4,923	8,198	4,981
1973	250	240	5,363	2,410	5,612	2,422
1990	210	174	3,912	1,657	4,122	1,666
1991	125	92	2,003	654	2,129	660
1993	254	184	3,871	1,846	4,125	1,856
1994	866	720	5,657	2,015	6,523	2,139
Common merganser (*Mergus merganser*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	635	319	441	217	1,076	386
1991	1,856	1,046	2,610	2,073	4,466	2,322
1993	1,425	913	4,529	2,977	5,954	3,114
1994	2,330	1,979	5,130	3,056	7,460	3,641
Red-breasted merganser (*Mergus serrator*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	576	249	901	405	1,477	476
1991	80	77	151	140	231	160
1993	93	132	372	386	465	408
1994	402	325	7,422	11,250	7,824	11,255
Unidentified merganser (*Mergus* sp.)						
1972	1,076	584	4,721	3,057	5,797	3,111
1973	819	529	3,654	1,582	4,473	1,634
1990	352	242	515	496	867	552
1991	291	427	936	1,585	1,226	1,641
1993	209	131	2,616	3,107	2,825	3,110
1994	765	707	5,698	5,485	6,464	5,530
Total mergansers (*Mergus* spp.)						
1972	1,076	584	4,721	3,057	5,797	3,111
1973	819	529	3,654	1,582	4,473	1,634
1990	1,563	501	1,857	717	3,420	875
1991	2,226	1,091	3,697	3,153	5,924	3,336
1993	1,727	969	7,516	4,649	9,244	4,749
1994	3,497	2,143	18,251	18,348	21,748	18,472

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Unidentified diving/sea duck						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	226	156	1,975	2,749	2,202	2,754
1991	1,110	938	2,116	1,177	3,227	1,505
1993	705	637	970	628	1,675	895
1994	263	178	687	505	950	535
Unidentified duck						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	93	188	311	355	404	401
1991	31	55	45	61	76	82
1993	62	77	346	496	408	502
1994	0	0	24	45	24	45
Total waterfowl (Family Anatidae)						
1972	21,981	8,051	105,692	41,974	127,673	42,739
1973	17,805	7,782	110,081	37,277	127,885	37,920
1990	12,431	3,647	54,296	13,931	66,728	14,400
1991	14,326	3,515	61,351	21,214	75,676	21,503
1993	15,018	3,917	84,291	21,625	99,309	21,977
1994	21,349	4,608	111,131	37,003	132,480	37,289
Hawks and Eagles						
Bald eagle (*Haliaeetus leucocephalus*)						
1972	385	191	987	334	1,372	382
1973	708	394	1,207	345	1,916	525
1990	533	148	1,087	335	1,620	366
1991	549	212	1,262	441	1,811	489
1993	771	415	1,907	811	2,678	911
1994	1,150	320	3,461	2,109	4,612	2,133
Unidentified eagle (*Haliaeetus* or *Aquila* sp.)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	8	14	8	14
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Shorebirds						
Black oystercatcher (*Haematopus bachmani*)						
1972	181	337	0	0	181	337
1973	187	354	20	26	207	355
1990	0	0	15	19	15	19
1991	0	0	8	14	8	14
1993	12	16	0	0	12	16
1994	6	12	8	15	14	19
Black turnstone (*Arenaria melanocephala*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	37	59	0	0	37	59
1991	0	0	303	554	303	554
1993	0	0	0	0	0	0
1994	31	57	0	0	31	57
Ruddy turnstone (*Arenaria interpres*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	1	1	30	56	31	56
1994	0	0	0	0	0	0
Unidentified turnstone (*Arenaria* sp.)						
1972	57	76	0	0	57	76
1973	0	0	66	126	66	126
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Surfbird (*Aphriza virgata*)						
1972	8	15	0	0	8	15
1973	0	0	0	0	0	0
1990	626	1,152	280	524	906	1,266
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	250	386	250	386

Appendix A (continued).

Species/Year	Oiled Zone		Unoiled Zone		Total	
	N	CI	*N*	CI	*N*	CI
Sanderling (*Calidris alba*)						
1972	0	0	0	0	0	0
1973	0	0	157	322	157	322
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Rock sandpiper (*Calidris ptilocnemis*)						
1972	0	0	775	822	775	822
1973	773	996	6,415	7,958	7,188	7,976
1990	0	0	0	0	0	0
1991	160	210	38	69	197	221
1993	0	0	435	733	435	733
1994	344	341	1,315	1,977	1,659	2,006
Dunlin (*Calidris alpina*)						
1972	0	0	0	0	0	0
1973	0	0	42	65	42	65
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Unidentified small sandpiper (*Calidris* sp.)						
1972	329	316	0	0	329	316
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Unidentified shorebird						
1972	306	595	0	0	306	595
1973	0	0	0	0	0	0
1990	3	5	2,544	3,152	2,547	3,152
1991	31	57	0	0	31	57
1993	37	69	155	291	192	299
1994	92	172	323	610	415	633

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Total shorebirds						
(Families Haematopodidae and Scolopacidae, except *Phalaropus* sp.)						
1972	881	858	775	822	1,656	1,185
1973	960	1,024	6,700	7,965	7,660	7,986
1990	665	1,166	2,839	3,187	3,504	3,394
1991	190	217	348	623	538	660
1993	50	71	620	787	670	790
1994	472	500	1,896	2,080	2,369	2,140
Gulls						
Bonaparte's gull (*Larus philadelphia*)						
1972	0	0	112	248	112	248
1973	336	997	0	0	336	997
1990	0	0	0	0	0	0
1991	94	178	0	0	94	178
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Mew gull (*Larus canus*)						
1972	374	495	8,576	10,033	8,949	10,045
1973	856	932	2,546	1,616	3,401	1,860
1990	406	253	2,051	1,261	2,457	1,286
1991	3,825	1,977	5,960	2,691	9,785	3,339
1993	653	357	8,416	10,029	9,069	10,036
1994	5,709	2,112	6,882	2,576	12,590	3,332
Herring gull (*Larus argentatus*)						
1972	0	0	198	176	198	176
1973	168	819	228	1,184	396	1,439
1990	98	157	56	71	154	172
1991	39	77	56	108	96	133
1993	318	256	540	484	858	548
1994	357	398	1,630	2,007	1,987	2,046

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Glaucous-winged gull (*Larus glaucescens*)						
1972	2,199	1,194	25,731	12,347	27,930	12,405
1973	13,957	14,752	18,258	8,452	32,215	17,002
1990	4,322	1,565	3,947	1,017	8,269	1,866
1991	3,659	2,023	6,567	3,089	10,226	3,693
1993	4,302	3,205	5,751	3,372	10,053	4,653
1994	18,103	16,599	24,377	8,719	42,480	18,750
Glaucous gull (*Larus hyperboreus*)						
1972	0	0	5	10	5	10
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Black-legged kittiwake (*Rissa tridactyla*)						
1972	2,165	1,831	7,279	10,888	9,444	11,013
1973	1,485	1,585	4,617	2,962	6,102	3,214
1990	56	68	101	97	157	118
1991	401	250	442	380	843	455
1993	2,610	2,888	682	429	3,292	2,919
1994	956	908	3,495	1,990	4,451	2,187
Unidentified gull (*Larus* or *Rissa* sp.)						
1972	2,410	3,162	1,197	980	3,607	3,226
1973	0	0	0	0	0	0
1990	753	589	3,476	4,714	4,230	4,750
1991	359	246	1,081	941	1,440	973
1993	5,697	7,029	12,850	9,688	18,547	11,969
1994	685	467	3,247	2,143	3,932	2,194
Total gulls (*Larus* and *Rissa* spp.)						
1972	7,148	2,239	43,098	23,296	50,247	23,401
1973	16,802	14,818	25,648	10,915	42,451	18,416
1990	5,636	2,066	9,631	5,142	15,267	5,541
1991	8,378	2,922	14,105	4,539	22,483	5,398
1993	13,580	8,826	28,238	14,804	41,818	17,235
1994	25,810	17,266	39,630	12,512	65,441	21,323

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Alcids						
Common murre (*Uria aalge*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	1,911	1,301	2,984	1,657	4,895	2,107
1991	3,655	3,336	8,080	5,739	11,735	6,637
1993	21,744	11,932	135,433	141,895	157,177	142,396
1994	15,286	11,263	32,055	14,147	47,340	18,083
Thick-billed murre (*Uria lomvia*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	264	505	0	0	264	505
1994	0	0	0	0	0	0
Unidentified murre (*Uria* sp.)						
1972	4,180	3,813	4,015	1,863	8,195	4,037
1973	6,961	8,770	3,720	2,531	10,681	9,144
1990	655	418	1,942	1,915	2,597	1,960
1991	6,533	6,053	5,835	3,309	12,368	6,898
1993	19,170	17,380	44,358	33,810	63,528	38,015
1994	1,121	684	3,265	1,729	4,387	1,860
Total murres (*Uria* spp.)						
1972	4,180	3,813	4,015	1,863	8,195	4,037
1973	6,961	8,770	3,720	2,531	10,681	9,144
1990	2,566	1,547	4,926	2,544	7,492	2,978
1991	10,188	9,149	13,915	7,882	24,103	12,076
1993	41,178	28,240	179,792	160,045	220,969	162,517
1994	16,407	11,451	35,320	14,774	51,727	18,692
Pigeon guillemot (*Cepphus columba*)						
1972	1,363	858	2,331	968	3,695	1,294
1973	3,716	8,552	5,472	3,738	9,188	6,231
1990	253	205	560	281	812	348
1991	777	383	2,064	2,144	2,842	2,178
1993	428	522	1,212	753	1,640	916
1994	455	317	821	579	1,276	660

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Marbled murrelet (*Brachyramphus marmoratus*)						
1972	5,090	1,719	6,477	1,711	11,567	2,413
1973	41,427	16,617	31,248	19,223	72,675	25,410
1990	4,451	3,028	9,313	5,109	13,764	5,939
1991	2,440	1,755	5,278	4,247	7,717	4,595
1993	3,302	3,017	4,057	2,762	7,360	4,090
1994	7,670	5,126	15,590	14,673	23,260	15,542
Kittlitz's murrelet (*Brachyramphus brevirostris*)						
1972	302	646	44	117	346	657
1973	1,180	2,544	2,038	2,693	3,219	3,827
1990	943	1,599	15	28	958	1,599
1991	119	139	347	373	466	398
1993	150	195	298	262	448	326
1994	0	0	0	0	0	0
Unidentified *Brachyramphus* murrelets sp.						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	1,452	864	9,928	6,972	11,379	7,026
1991	7,079	4,822	8,249	5,465	15,328	7,288
1993	2,131	1,708	4,045	2,785	6,176	3,267
1994	4,669	2,912	8,389	4,026	13,058	4,969
Total Brachyramphus murrelets spp.						
1972	5,392	1,766	6,520	1,722	11,913	2,454
1973	42,607	20,130	33,286	21,660	75,893	31,963
1990	6,846	3,498	19,256	9,007	26,102	9,663
1991	9,637	6,061	13,873	9,383	23,510	11,171
1993	5,583	3,685	8,400	5,092	13,983	6,286
1994	12,339	6,693	23,979	16,391	36,318	17,705
Ancient murrelet (*Synthliboramphus antiquus*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	81	145	81	145
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Cassin's auklet (*Ptychoramphus aleuticus*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	19	32	20	36	39	48
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Parakeet auklet (*Cyclorrhynchus psittacula*)						
1972	0	0	0	0	0	0
1973	3	6	3	5	5	8
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Tufted puffin (*Fratercula cirrhata*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	23	43	23	43
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Horned puffin (*Fratercula corniculata*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	81	137	81	137
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Total puffins (*Fratercula* spp.)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	104	144	104	144
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0

Appendix A (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Unidentified alcid						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	251	412	251	412
1991	333	347	288	267	621	438
1993	160	274	308	266	468	382
1994	186	174	182	173	368	245
Total alcids						
1972	10,935	4,472	12,867	3,448	23,802	5,437
1973	53,287	15,068	42,481	19,886	95,768	24,324
1990	9,665	4,400	24,993	9,757	34,658	10,703
1991	20,954	10,515	30,346	13,844	51,300	17,385
1993	47,349	29,859	189,711	160,048	237,060	162,810
1994	29,388	15,364	60,302	23,008	89,690	27,667
Passerines						
Northwestern crow (*Corvus caurinus*)						
1972	3,734	3,186	3,549	1,486	7,283	3,470
1973	1,849	1,798	7,038	5,278	8,887	5,553
1990	868	671	2,173	1,757	3,041	1,881
1991	186	160	3,139	1,599	3,325	1,607
1993	492	394	2,414	1,158	2,905	1,223
1994	1,374	573	4,616	1,929	5,990	2,012
Marine Birds						
Total marine birds						
1972	52,145	11,062	183,434	62,509	235,579	63,480
1973	110,426	30,342	217,665	48,395	328,091	56,955
1990	36,343	7,760	105,568	21,547	141,911	22,902
1991	49,649	13,422	121,784	27,797	171,433	30,868
1993	83,171	34,794	319,589	164,048	402,760	167,697
1994	86,045	27,031	234,425	56,507	320,470	62,640

Appendix B. Estimated numbers of marine mammals ($N \pm$ 95% CI) for species observed in Prince William Sound during March 1972-73 (L. Haddock et al., U. S. Fish and Wildl. Serv., unpubl. data), 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), and 1994.

	Oiled Zone		Unoiled Zone		Total	
Species/Year	*N*	CI	*N*	CI	*N*	CI
Cetaceans						
Harbor porpoise (*Phocoena phocoena*)						
1972	0	0	395	454	395	454
1973	676	1,995	142	271	818	2,074
1990	0	0	197	364	197	364
1991	155	257	0	0	155	257
1993	306	289	66	117	372	312
1994	75	124	0	0	75	124
Dall's porpoise (*Phocoena dalli*)						
1972	1,604	2,933	752	850	2,356	3,054
1973	6,438	5,561	3,029	2,533	9,467	6,110
1990	441	389	889	1,226	1,330	1,286
1991	0	0	0	0	0	0
1993	0	0	1,394	1,680	1,394	1,680
1994	451	477	494	506	944	696
Unidentified porpoise						
1972	468	614	584	618	1,052	867
1973	1,348	6,115	174	1,104	1,522	6,214
1990	0	0	41	69	41	69
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Killer whale (*Orcinus orca*)						
1972	48	141	195	323	243	352
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	0	0	16	29	16	29
1994	0	0	0	0	0	0

Appendix B (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Unidentified whale						
1972	0	0	0	0	0	0
1973	50	87	56	100	106	132
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Otters						
Sea otter (*Enhydra lutris*)						
1972	1,139	784	1,422	868	2,561	1,158
1973	1,311	829	1,668	1,815	2,979	1,997
1990	2,019	1,257	3,949	1,118	5,968	1,682
1991	1,012	498	3,401	855	4,413	989
1993	1,687	1,015	5,125	1,560	6,813	1,861
1994	1,149	383	6,597	2,037	7,746	2,073
River otter (*Lutra canadensis*)						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	37	35	37	40	75	53
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	43	47	57	56	100	73
Unidentified otter						
1972	36	44	5	10	41	45
1973	0	0	0	0	0	0
1990	6	12	0	0	6	12
1991	0	0	0	0	0	0
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Sea Lions						
Steller sea lion (*Eumetopias jubatus*)						
1972	437	569	2,081	1,494	2,518	1,599
1973	4,148	7,217	2,585	1,722	6,733	7,419
1990	6,116	10,049	145	177	6,261	10,051
1991	3,247	4,524	548	830	3,795	4,600
1993	2,424	3,514	835	1,136	3,260	3,694
1994	1,662	2,352	418	500	2,080	2,404

Appendix B (continued).

Species/Year	Oiled Zone *N*	Oiled Zone CI	Unoiled Zone *N*	Unoiled Zone CI	Total *N*	Total CI
Unidentified pinniped						
1972	0	0	0	0	0	0
1973	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	12	23	0	0	12	23
1993	0	0	0	0	0	0
1994	0	0	0	0	0	0
Seals						
Harbor seal (*Phoca vitulina*)						
1972	2,111	2,346	3,475	1,534	5,585	2,820
1973	1,908	1,533	2,330	1,328	4,239	2,016
1990	517	248	1,315	738	1,832	779
1991	240	228	671	390	911	452
1993	268	209	1,245	1,296	1,513	1,313
1994	210	131	1,224	1,160	1,434	1,167