Exxon Valdez Oil Spill
Restoration Project Annual Report

Marine Bird and Sea Otter Population Abundance of Prince William Sound, Alaska: Trends following the *T/V Exxon Valdez* Oil Spill, 1989-2000

Restoration Project 00159
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

Shawn W. Stephensen[1], David B. Irons[1], Steven J. Kendall[1], Brian K. Lance[2], and Lyman L. McDonald[3]

[1] U.S. Fish and Wildlife Service, Migratory Bird Management, 1011 East Tudor Road, Anchorage, Alaska 99503

[2] P.O. Box 19486, Thorne Bay, Alaska 99919

[3] West Inc., 2003 Central Ave., Cheyenne, Wyoming 82001

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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 (L. Haddock et al., USFWS, unpubl. data) 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) documented 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 Projects 93045 (Agler et al. 1994), 94159 (Agler et al. 1995), 96159 (Agler and Kendall 1997), 98159 (Lance et al. 1999), and 00159 were initiated to continue monitoring marine bird and sea otter population abundance to assess recovery of injured species.

ABSTRACT: We conducted small boat surveys to estimate marine bird and sea otter (*Enhydra lutris*) populations in Prince William Sound, Alaska during March and July 2000, using methods developed in 1989-91 (Klosiewski and Laing 1994). During 2000, we recorded 62 bird and 11 mammal species. We estimated 210,945 $\pm$ 52,471 marine birds were in the Sound during March 2000. We estimated 37,468 $\pm$ 8,197 marine birds were in the oiled zone and 173,477 $\pm$ 51,826 birds were in the unoiled zone during March. During July 2000, an estimated 204,349 $\pm$ 35,071 marine birds were in Prince William Sound. We estimated 80,388 $\pm$ 26,215 marine birds were in the oiled zone and 123,960 $\pm$ 23,297 birds were in the unoiled zone. We estimated 4,668 $\pm$ 1,179 sea otters were in Prince William Sound in March and 5,093 $\pm$ 1,689 in July. In the oiled zone, the population estimate was 837 $\pm$ 383 otters in March and 1,404 $\pm$ 877 otters in July. In the unoiled zone, the population was estimated as 3,831 $\pm$ 1,115 otters in March and 3,689 $\pm$ 1,443 otters in July.

Our data suggest that most taxa for which injury was previously demonstrated were not recovering. Few species were recovering or showing continuing and increasing effects of the oil spill. During winter, two taxa ("scoters," and "goldeneyes") showed trends consistent with continuing and increasing oil spill effects, three taxa (Harlequin Ducks, Bald Eagles, and Northwestern Crows) showed trends consistent with a recovering population, while nine taxa ("grebes," "cormorants," Buffleheads, "mergansers," Mew Gulls, Glaucous-winged Gulls, "murres," Pigeon Guillemots, and "murrelets") did not exhibit any trend, suggesting populations of these taxa were not recovering. The results for "loons" were conflicting, populations in the oiled area were increasing, but not as fast as the unoiled area. During summer one taxa ("mergansers") showed trends consistent with continuing and increasing oil spill effects, three taxa (Bald Eagles, Black Oystercatchers, and Northwestern Crows) showed trends consistent with a recovering population, and eleven taxa ("loons," "cormorants," Harlequin Ducks, "scoters," Mew Gulls, Glaucous-winged Gulls, Black-legged Kittiwakes, "terns," "murres," Pigeon Guillemots, and "murrelets") showed the populations were not recovering. March and July densities of sea otters in oiled and unoiled areas show no trends, suggesting no recovery.

For Prince William Sound as a whole, we examined population trends from 1989-2000, using regression analyses. In March, we found significant positive trends for "loons," "scoters," "goldeneyes," Buffleheads, Bald Eagles, Black-legged Kittiwakes, and Northwestern Crows. "Grebes" were the only taxon exhibiting significant negative trends in overall abundance in March. In July, significant positive trends in overall abundance were found for Harlequin Ducks, Bald Eagles, Black Oystercatchers, and Northwestern Crows, and significant negative trends were found for Black-legged Kittiwakes, "terns," Pigeon Guillemots, and "murrelets". Within Prince William Sound as a whole, we found that the sea otter population had no significant trend in either March or July.

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

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

The waters and shorelines of Prince William Sound provide important feeding, resting, and breeding sites for many marine birds and mammals. In 1989, the *T/V Exxon Valdez* grounded on Bligh Reef in the northeastern corner of Prince William Sound and spilled 40 million liters of crude oil into the surrounding waters. Over 30,000 marine birds and 900 sea otter carcasses were recovered following the spill. Of these, 3,400 birds and approximately 500 sea otters were recovered in Prince William Sound. Direct mortality to marine birds in Prince William Sound and the Gulf of Alaska was estimated at approximately 250,000 birds. Mortality of sea otters was estimated as 350-4,950 otters.

The U. S. Fish and Wildlife Service conducted boat surveys in Prince William Sound in 1972-73, 1984-85, 1989-91, 1993, 1994, 1996, 1998, and 2000 to determine the population abundance of marine birds and sea otters. Data from the 1989-91 surveys were used to assess natural resource damage from the *Exxon Valdez* oil spill. The data indicated that populations of sea otters and several marine bird species declined in the oil spill area. One study demonstrated a 35% decline in sea otter density along the shoreline of the oiled zone.

A number of species were suggested for consideration on the injured species list, but not all were included. At present, the designated injured species list includes "loons," "grebes," "cormorants," Harlequin Ducks, "scoters," "goldeneyes," Bufflehead, "mergansers," Bald Eagles, Black Oystercatchers, Mew Gulls, Glaucous-winged Gulls, Black-legged Kittiwakes, "terns," "murres," Pigeon Guillemots, "murrelets," Northwestern Crows, and sea otters.

Additional species or species groups may be showing continuing affects from the *Exxon Valdez* oil spill that were never previously detected. In March 1993, 1994, 1996, and 1998 the "goldeneye" population showed significantly different trends between the oiled and unoiled zones. In July 1996 and 1998, "scoters" and Black-legged Kittiwakes showed significantly different trends between the oiled and unoiled zones. All populations increased at a slower rate in the oiled zone than in the unoiled zone. These trends are consistent with an oil spill effect.

This study was designed to monitor marine bird and sea otter populations of Prince William Sound following the *T/V Exxon Valdez* oil spill to determine recovery of species impacted by the oil spill. To do this, we estimated abundances of marine bird and sea otter populations in Prince William Sound in March and July 2000 and compared these estimates with the 1989-91, 1993, 1994, 1996, and 1998 estimates to ascertain trends in marine bird and sea otter population abundance in Prince William Sound.

Two criteria were employed to examine post-spill trends of marine bird and sea otter populations. First, we examined population trends of injured taxa only in the oiled area of Prince William Sound using regression models. Second, we examined population trends of injured taxa in the oiled area relative to the unoiled area using homogeneity of slopes tests. We considered a population recovering if there was a positive trend using either criteria.

We considered a population not recovering if there was no trend using both criteria or a negative trend in the oiled area. A significant negative trend in the oiled area relative to the unoiled area was considered a continuing and increasing effect.

Most taxa that were previously determined as injured were not recovering. Few species were recovering and some were showing continuing and increasing effects of the oil spill. During winter, two taxa ("scoters," and "goldeneyes") showed trends consistent with continuing and increasing oil spill effects, three taxa (Harlequin Ducks, Bald Eagles, and Northwestern Crows) showed trends consistent with a recovering population, while nine taxa ("grebes," "cormorants," Buffleheads, "mergansers," Mew Gulls, Glaucous-winged Gulls, "murres," Pigeon Guillemots, and "murrelets") did not exhibit any trend, suggesting populations of these taxa were not recovering. The results for "loons" were conflicting, populations in the oiled area were increasing, but not as fast as the unoiled area. During summer, one taxa ("mergansers") showed trends consistent with continuing and increasing oil spill effects, three taxa (Bald Eagles, Black Oystercatchers, and Northwestern Crows) showed trends consistent with a recovering population, and eleven taxa ("loons," "cormorants," Harlequin Ducks, "scoters," Mew Gulls, Glaucous-winged Gulls, Black-legged Kittiwakes, "terns," "murres," Pigeon Guillemots, and "murrelets") showed the populations were not recovering.

We show evidence of slow recovery, lack of recovery, and divergent population trends in many taxa which utilize shoreline and near shore habitats where oil is likely to persist. These potential lingering spill effects and natural variability appear to be acting in concert in delaying recovery of many Prince William Sound marine bird populations.

INTRODUCTION

The waters and shores of Prince William Sound (PWS) provide important feeding, resting, and breeding habitat for many marine birds and mammals (Isleib and Kessel 1973, Hogan and Murk 1982). The terminus of the Trans-Alaska oil pipeline is in Valdez in northern PWS, and since 1977 thousands of oil tankers have traveled through PWS in route to refineries in the lower 48 states. Due to concern over the effects of a potential oil spill on marine birds, the U.S. Fish and Wildlife Service conducted marine bird surveys in PWS in 1972-73 (L. Haddock et al., unpubl. data) and again in 1984-85 (Irons et al. 1988a).

On 24 March 1989, the *T/V Exxon Valdez* grounded on Bligh Reef in northeastern PWS, spilling ~ 40 million liters of crude oil into the surrounding waters. In the following weeks, wind and currents moved the oil to the southwest where a large percentage was deposited on shorelines and intertidal areas of western and southwestern PWS. Approximately 25% of the oil drifted out of PWS, traveling ~ 750 km to the southwest, contaminating areas of the Kenai Peninsula, Barren Islands, Alaska Peninsula, and Kodiak Island archipelago (Spies et al. 1996). Immediate effects of oil contamination on marine birds were pronounced. Over 30,000 marine bird carcasses were recovered in the spill area, of which, ~ 3,400 were recovered in PWS (Piatt et al. 1990a). Carcasses comprised mainly diving birds: murres, sea ducks, cormorants, murrelets, pigeon guillemots, loons, and grebes (Piatt et al. 1990a). Direct mortality of marine birds in PWS and the Gulf of Alaska was estimated at about 250,000 birds (Piatt and Ford 1996). At the time, the *Exxon Valdez* oil spill (EVOS) was the largest oil spill in North America with unprecedented toll on marine birds, eliciting much concern about the short and long-term effects on marine bird populations in PWS.

In 1989, surveys were initiated by the U.S. Fish and Wildlife Service to determine the population abundance of marine birds in PWS and to assess natural resource damage in the aftermath of the oil spill. Surveys conducted by the U.S. Fish and Wildlife Service were continued in March (1990, 1991, 1993, 1994, 1996, 1998, and 2000) and July (1989, 1990, 1991, 1993, 1996, 1998, and 2000) (Klosiewski and Laing 1994, Agler et al. 1994, 1995, Agler and Kendall 1997, Lance et al. 1999, Stephensen et al. 2001). These surveys were designed to monitor marine bird populations of PWS following the *T/V Exxon Valdez* oil spill to determine population trends; recovery, no change, or increasing effects, for those species injured by the oil spill (*Exxon Valdez* Oil Spill Restoration Plan 1996).

Previous studies on the effects of the oil spill (Murphy et al. 1997, Irons et al. 2000) found that summer densities of several species of marine birds were lower than expected (relative to densities in 1984-1985) in the oiled area of PWS after the spill, relative to densities in the unoiled area. Irons et al. (2000) found that diving species were effected more than non-diving species. Klosiewski and Laing (1994) compared population estimates, both winter and summer, and found that numbers of several species of marine birds were lower (relative to numbers in 1972-73) in the oiled area of PWS after the spill compared to populations in the unoiled area. Day et al. (1997) evaluated impacts to and recovery of marine birds by looking at use of oil-affected habitats in PWS, using post-spill data collected throughout the year over a three-year period (1989-1991), also finding oil spill effects on several species of marine birds. Using guild analysis (Wiens et al. 1996) found that the most consistent impacts of oiling were on species which feed on or close to shore, breed on the beach, or are winter or year-round residents. Thus, it is clear from these studies that the EVOS had significant impacts on marine bird populations in PWS, however, it was not certain to what degree these taxa have recovered at the population level eleven years after the spill.

Many of the species showing oil spill effects during summer have much larger winter populations in PWS (Agler and Kendall 1997). During late winter, when the oil spill occurred, most avifauna of PWS consisted of winter residents; principally: sea ducks, gulls, cormorants, grebes, loons, and alcids. Thus, most of the 3,400 bird carcasses retrieved after the oil spill probably belonged to winter populations (Klosiewski and Laing 1994). Further, one might predict that continuing impacts or recovery of those species would be more apparent in winter populations.

We used the results of post-spill studies focused on detecting oil spill effects (Klosiewski and Laing 1994, Wiens et al. 1996, Day et al. 1997, Murphy et al. 1997, Irons et. al. 2000) to determine which marine bird populations in PWS were impacted by the spill. In this study, we evaluate the trends of impacted marine bird populations of PWS to test the following hypothesis regarding recovery at the population level.

Our null hypothesis, H_o, was that populations did not change, that is, populations were not recovering. Our first alternative hypothesis, H_a1, was that populations were recovering. Recovery was measured by two methods; a significantly increasing population trend in the oiled area, or a significantly increasing population trend in the oiled area relative to the unoiled area 1989-2000. If either of these criteria were met we considered that as evidence of a recovering population. Our second alternative hypothesis, H_a2, was that oil spill effects were continuing to increase, that is, species increased (decreased) at significantly slower (faster) rate in the oiled area relative to the unoiled area.

OBJECTIVES

The purpose of this study was to obtain estimates of the summer and winter populations of marine birds and sea otters in Prince William Sound to determine whether species whose populations declined after the *T/V 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 and July 2000;

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 support restoration studies on forage fish, 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 estuarine embayment (~ 10,000 km^2) of the northern Gulf of Alaska (Fig. 1). The coastline of PWS is rugged; surrounded by the Chugach and Kenai Mountains (up to 4km elevation), with numerous tidewater glaciers, deep fiords, and islands. The climate is maritime, with moderate temperatures, high humidity, frequent fog and overcast, and high precipitation (Isleib and Kessel 1973). A low pressure trough, the Aleutian Low, is located over the area from October through March producing frequent and intense storms with high winds (Isleib and Kessel 1973). Water circulation is dominated by the Alaska Coastal Current (ACC) which mixes with a high volume of fresh water input from precipitation, rivers, and glaciers. Westerly and southwesterly currents predominate with a branch of the ACC entering through Hinchinbrook Entrance, transiting PWS from east to west before exiting through Montague Strait (Niebauer et al. 1994). Strong tidal currents that range as high as 6 meters cause rapid mixing of waters at the entrances to bays, fiords and inlets. During the winter, ice forms at the heads of protected bays and fiords that receive substantial freshwater runoff (Isleib and Kessel 1973). The study area included all waters within PWS and all land within 100 m of the shore, with the exception of Orca Inlet, near Cordova, Alaska and the southern sides of Montague, Hinchinbrook, and Hawkins Islands (Fig. 1).

Survey Methods

We divided PWS into three strata: shoreline, coastal-pelagic (nearshore), and pelagic (offshore, Fig. 1). The shoreline stratum consisted of all waters within 200 m of land. Based on habitat, the shoreline stratum was divided into 742 transects with a total area of approximately 820.74 km^2 (Irons et al.1988a). 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 ~6 km. Shoreline transects were located by geographic features, such as points of land, to facilitate orientation in the field and to separate the shoreline by habitat type. Surveys were conducted in late winter (March) and mid-summer (July).

In 1989, 187 (25%) of the total 742 shoreline transects were randomly selected for the surveys. An additional 25 shoreline transects from western PWS were randomly selected and added in July 1990 to increase the precision of estimates from the oiled zone (Fig. 1). The number of shoreline transects was reduced to 99 (13% of the total 742 transects) during March surveys to accommodate potential weather delays. Sample sizes within individual surveys sometimes varied slightly, because a few transects could not always be surveyed due to environmental conditions (e.g., ice).

To sample the coastal-pelagic and pelagic waters of PWS, the study area was divided into 5-min latitude-longitude blocks. Blocks were classified as nearshore if they included >1.8 km of shoreline. Blocks that included $\leq$1.8 km of shoreline were classified in the pelagic stratum. If coastal-pelagic or pelagic blocks intersected the 200 m shoreline buffer, they were truncated to avoid overlap with the shoreline stratum. Blocks were randomly chosen and two transects were surveyed within each block. If a block was too small to contain both transects, it was combined with an adjacent block. 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. During the July surveys, 22% (45) of the coastal-pelagic blocks (*n* = 207) and 29% (25) of those within the pelagic stratum (*n* = 86) were sampled. We surveyed two north-south transects, each 200 m wide, located 1-min longitude inside the east and west boundaries of each coastal-pelagic and pelagic block. Global Positioning Systems (GPS) and nautical compasses were used to navigate transect lines.

Transects were surveyed in 15-17 working days over a three-week period; winter surveys (~ 3-28 March; 1990-91, 1993, 1994, 1996, 1998, and 2000) and summer surveys (~ 2-27 July; 1989-91, 1993, 1996, 1998, and 2000). Survey methodology and transects surveyed were identical in all years. Surveys were conducted concurrently by three 8 m fiberglass boats traveling at speeds of 10-20 km/hr. Two observers counted all birds and mammals detected in a sampling window 100 m on either side, 100 m ahead, and 100 m overhead of the vessel. When surveying shoreline transects, observers also recorded birds and mammals sighted on land within 100 m of shore. Observers scanned continuously and used binoculars to aid in species identification. Most transects were surveyed when wave height was <30 cm, and no surveys were conducted when wave height was >60 cm.

To examine population trends over time and to determine if populations injured by the spill were recovering, we post-stratified PWS into oiled and unoiled areas (Fig. 1). Our methodology of post-stratification followed that of Klosiewski and Laing (1994) which considered all strata within the outer boundary of the general oiled area as oiled. The oil spill, however, contaminated some beaches, while some adjacent beaches were left untouched creating a mosaic pattern of oiling. Thus, at this coarse scale unoiled habitat was present within the oiled area. Because birds are mobile, we assumed that birds on unoiled transects surrounded by oil were likely to be affected by oil (but see Irons et al. 2000). Our post-stratification analyses assumed that bird populations in the oiled and unoiled portions of PWS, as well as PWS as a whole, were discrete. While this is likely not the case for marine birds in general (Porter and Coulson 1987), data on the movement of bird populations between the various portions of PWS (Kuletz et al. 1995, Bowman et al. 1997, Rosenberg and Petrula 1998, and Suryan, *in press*) are too limited to include in our analyses.

Some bird species were grouped by genus for analyses (Appendix 1). These species were combined to allow analyses to include data on birds that were only identified to genus (e.g., unidentified *Brachyramphus* murrelet). In general, species within a taxon group were similar in natural history attributes and vulnerability to oil (see King and Sanger 1979).

Data Analysis

Population Estimates and Densities.-- We estimated population abundances and variances using a ratio of total count to area surveyed within each stratum (Cochran 1977). 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. To obtain a population estimate for each block, we estimated the density of birds counted on the combined transects for a block and multiplied by the area of the sampled block. We then added the estimates from all blocks surveyed and divided by the sum of the areas of all blocks surveyed. Next, we calculated the population estimate for a stratum by multiplying this estimate by the area of all blocks in the stratum. Total population estimates for PWS were calculated by adding the population estimates from the three strata. We then calculated the 95% confidence intervals for these estimates from the sum of the variances of each stratum. Density estimates used in regression analyses were calculated from total population estimates.

To determine if impacted populations were showing signs of recovery or not we employed two methods of analyses. We examined the post-spill population trend of the birds in the oiled area. We also examined the post-spill population trend of the birds in the oiled area relative to the unoiled area, since there are several factors other than oil spills that cause bird populations to change. This method, which uses the unoiled area as a control, provides more convincing evidence that recovery is actually occurring.

Population Trends in the Oiled Area.-- We examined the trend in marine bird densities, for summer and winter in the oiled area to determine if the population levels were changing. Only winter resident or summer breeding species with population estimates of >500 individuals were used for analysis. An impacted taxon was considered showing evidence of recovery if log (densities) in the oiled areas of PWS were exhibiting a statistically significant increasing trend (positive slope); otherwise, the taxon was considered showing no evidence of recovery (slope not significantly different than zero or was significantly negative). This test assumed that the oil spill effect was large enough that recovery could be detected using our survey methods. It makes no assumptions regarding unoiled areas.

Population Trends in Oiled Area Relative to Unoiled Area.-- We compared trends in marine bird densities, for both winter and summer, between oiled and unoiled areas of PWS. To test whether the populations were changing at different rates we examined the homogeneity of the slopes of log (density) over time between the oiled and the unoiled areas (Freud and Littell 1981) using linear models. Significantly different slopes indicated that densities of a species or species group in the oiled area were changing at a different rate than in the unoiled area. We calculated the rate of change of density in each area with linear regression analyses.

A taxon was considered recovering if bird densities in the oiled areas of PWS were increasing at a significantly greater rate (slope of the regression line) than bird densities in the unoiled areas of PWS. A taxon was considered as showing no evidence of recovery if trends of bird densities in the oiled areas of PWS were not significantly different from trends in the unoiled areas of PWS (no difference in slopes). A taxon was considered as having continuing and increasing oil spill effects if bird densities in the oiled areas of PWS had trends (slopes) which were significantly smaller (or more negative) than trends in the unoiled area.

We made several assumptions to test for recovery using the homogeneity of slopes test. 1) We assumed that an oil spill effect on a taxon was large enough that recovery could be detected using our survey methods. Murphy et al. (1997) and Irons et al. (2000) demonstrated impacts on several marine bird taxa using similar survey methods, lending support to this assumption. 2) We assumed that in the absence of an oil spill, populations would increase or decrease at approximately the same rate in the oiled and unoiled areas of PWS. 3) We assumed oiled and unoiled bird populations were discreet. 4) We assumed that no natural, density dependent mechanisms affected bird populations ability to recover in PWS (e.g., changes in the carrying capacity of the environment between 1989-2000; see Ainley and Nur 1997). If these assumptions were not met, the homogeneity of slopes test may not detect recovery.

Substantial seasonal differences exist in the distribution and abundance of the various marine bird taxa in PWS (Isleib and Kessel 1973), thus the same suite of taxa were not always analyzed in both winter and summer. Seven years of data were available for March (1990, 1991, 1993, 1994, 1996, 1998, and 2000) and July (1989, 1990, 1991, 1993, 1996, 1998, and 2000). Our hypothesis focused on whether rates of change in density were the same between oiled and unoiled areas, rather than if absolute densities differed. Consequently, densities were $\log_{10}$ transformed to yield multiplicative models (e.g., effects and any subsequent changes in density would be proportional to the previous densities in the various portions of PWS) rather than additive models (Stewart-Oaten et al. 1986, 1992); the latter being an assumption of statistical tests on untransformed data (Sokal and Rohlf 1995). To avoid the undefined log of zero, we added a constant of 0.167 to all density estimates prior to analysis (Mosteller and Tukey 1977).

In all analyses we used a test size alpha = 0.20 to balance Type I and Type II errors. The reasons for this included: 1) variation was often high and sample sizes low (n=7 survey years); 2) monitoring studies are inherently different from experiments and the number of tests being run with a multi-species survey are many, therefore, controlling for the number of tests by lowering alpha levels (e.g. Bonferroni adjustment) might obscure trends of biological value; and 3) to make our results comparable with other studies on the effects of the EVOS on marine bird populations that used an alpha level of 0.20 (Wiens and Parker 1995, Wiens et al. 1996, Day et al. 1997, Murphy et al. 1997, Irons et al. 2000).

In assessing impacts from environmental perturbations, there has been a trend of using large alpha levels (Wiens and Parker 1995, Wiens et al. 1996, Murphy et al. 1997, and Irons et al. 2000); allowing to error on the conservative side (increased chance of a Type I error, falsely identifying an impact that did not occur) rather than commit a Type II error (failing to identify an impact that did occur). It follows that in looking for recovery of an injured population, the practice of a conservative approach to setting alpha levels may be reversed. That is, the conservation and management consequences of making a Type I error (falsely identifying recovery that did not occur) may be greater than committing a Type II error (failing to identify recovery that did occur). Thus, it is likely that in assessing possible recovery of a species, the size of the alpha level should be smaller than we used in this study. In other words, our acceptance of recovery of a taxon based on an alpha of 0.20 is generous. Further, a consequence of conducting numerous statistical tests is that some results may be indicated as statistically significant by chance alone. Therefore, in this study we look at the patterns and strengths of significant results (see Tables 1, 2, 3, 4) and interpret those patterns in light of the life history attributes of the affected taxon and results from related studies in PWS.

RESULTS

We report on eleven years of post-spill marine bird population changes during July and March in the oiled area of PWS using two methods of analyses, absolute trends in the oiled area and trends in the oiled area relative to the unoiled area. Taxa are categorized by their trend.

Taxa with Positive Absolute or Relative Population Trends in the Oiled Area

During summer, three taxa (Bald Eagles, Black Oystercatchers, and Northwestern Crows) of the 15 that were analyzed demonstrated a positive trend in the oiled area (Tables 1, 3 and Fig. 2) and the Northwestern Crows increased in the oiled area relative to the unoiled area (Tables 1, 3 and Fig. 2). During winter, four of the 15 taxa that were analyzed showed a positive trend in the oiled area. "Loons," Harlequin Ducks, Bald Eagles, and Northwestern Crows increased in the oiled area from 1989 to 2000 (Tables 1, 2 and Fig. 3).

Taxa with No Trends in the Oiled Area

Five taxa, "cormorants," "scoters," Mew Gulls, Glaucous-winged Gulls, and "murres" showed no increase or decrease in densities in the oiled area during summer and winter over the eleven year study period (Tables 1, 2, 3 and Figs. 2, 3). Two taxa, "loons," and Harlequin Ducks, showed no change in densities during summer only (Tables 1, 3 and Fig. 2) and five taxa, "goldeneyes," Buffleheads, "mergansers," Pigeon Guillemots, and "murrelets" showed no change in densities during winter only (Tables 1, 2 and Fig. 3).

Taxa with Negative Absolute or Relative Trends in the Oiled Area

During summer, five taxa, "mergansers," Black-legged Kittiwakes, "terns," Pigeon Guillemots, and "murrelets" declined in the oiled area and one taxa, "mergansers" declined in the oiled area relative to changes in the unoiled area (Tables 1, 3 and Fig. 2). During winter, one taxa, "grebes," declined in the oiled area and three taxa, "loons," "scoters," and "goldeneyes," declined in the oiled area relative to changes in the unoiled area (Tables 1, 2 and Fig. 3).

Taxa with Positive Absolute and Negative Relative Trends in the Oiled Area

"Loons" exhibited opposing results during winter. The density increased significantly in the oiled area, however, the trend in the oiled area was significantly smaller than the trend in the unoiled area (Tables 1, 2 and Fig 3).

Trends using Regression Analysis

We also examined population trends from 1989-2000 for PWS as a whole, using regression analyses. We found significant positive trends in March for "loons," "scoters," "goldeneyes," Buffleheads, Bald Eagles, Black-legged Kittiwakes, and Northwestern Crows (Table 4). "Grebes" were the only taxon exhibiting significant negative trends in overall abundance in March. In July, significant positive trends in overall abundance were found for Harlequin Ducks, Bald Eagles, Black Oystercatchers, and Northwestern Crows, and significant negative trends were found for Black-legged Kittiwakes, "terns," Pigeon Guillemots, and "murrelets," (Table 4). We found that the sea otter population had no significant trend in either March or July (Table 4).

DISCUSSION

Interpreting our data for evidence of recovering populations required use of information available from the trends in the oiled area, the trends in the oiled area relative to the unoiled area, results from related studies in PWS, as well as taxon-specific ecological attributes. We assumed that any decrease in the population caused by the oil spill was detectable by previous oil spill studies and that if populations were recovering we could measure that recovery by at least one of the two methods that we used. In this study we attempted to assess whether an injured population was recovering with the burden of proof being on the available data, marshaling the collective evidence from our results (see Tables 1), other related studies, as well as the ecological attributes of the taxa.

We were fortunate to have data from a nearby unoiled area to use as a control. We felt that the homogeneity of slopes methods which used the data in the control area would provide the most convincing evidence of recovery. To look for additional evidence of recovery we also examined the trends in the oiled area alone.

Species Trends: Recovery, Lack of Recovery, and Increasing Effects

"Loons."-- Injury to "loons" from the oil spill was documented for summer populations in PWS (Irons et al. 2000). The homogeneity of slopes test and regression on summer densities of "loons" in the oiled areas of PWS indicated no trend of recovery for this species group. In addition, the homogeneity of slopes test on winter densities indicated increasing effects for this taxa. However, regression on winter densities in oiled and unoiled areas showed a slight increasing trend, suggesting winter populations may be recovering. The loons have significantly increased in the oiled and unoiled areas, however, the magnitude of increase in the oiled area (3%) was not as great as the increase in the unoiled area (8%) of PWS.

"Grebes."-- Injury to "grebes" from the oil spill was documented for birds that winter in PWS and as of 1991 showed no evidence of recovery (Day et al. 1997). The homogeneity of slopes test and regression on winter densities of grebes in the oiled areas of PWS indicated no

trend of recovery for this species group. Of equal concern were significant declines in oiled and unoiled areas of PWS indicating PWS-wide declines in this taxon.

"Cormorants."-- Injury to "cormorants" from the oil spill was documented for non-breeding birds that spend the summer in PWS (Klosiewski and Laing 1994, Day et al. 1997, Murphy et al. 1997, Irons et al. 2000). The homogeneity of slopes test and regressions on both summer and winter densities of cormorants in the oiled areas of PWS indicated no trend of recovery for this taxon.

Harlequin Ducks.-- Injury to Harlequin Ducks from the oil spill was documented for summer populations in PWS (Klosiewski and Laing 1994, Day et al. 1997, Irons et al. 2000), but effects were not detected after 1991 (Day et al. 1997, Irons et al. 2000). In contrast, data from Harlequin Duck specific surveys (July-September; Rosenberg and Petrula 1998) demonstrated that oiled and unoiled populations became more divergent during 1995-1997, suggesting continuing oil spill effects. Our homogeneity of slopes test on summer and winter densities in oiled areas relative to unoiled areas of PWS did not show any evidence of a recovering population.

Summer and winter populations of Harlequin Ducks in PWS represent different age/sex composition and structure. Summer populations in PWS are composed primarily of non-breeders and failed breeders, whereas winter populations include adult breeders (Rosenberg and Petrula 1998). Given the oil spill occurred in March, and that winter represents the period of maximum stability in Harlequin Duck populations (Rosenberg and Petrula 1998), one might predict that continuing impacts or recovery for Harlequin Ducks would be most evident in the winter population. Some studies have shown evidence of this. Winter survival rates for adult female Harlequin Ducks were lower in oiled areas of PWS than the unoiled areas between 1995-1997 (D.

Esler unpubl. data), consistent with non-recovery. Modeling efforts using this survival data predicted a stable population in the unoiled area and a declining population in the oiled area. Further, Harlequin Ducks exhibit high winter site fidelity. While site fidelity is an adaptive strategy in predictable environments (Hohman et al. 1992), it may not facilitate the enhancement of injured populations through immigration (D. Esler unpubl. data). The homogeneity of slopes test showed no evidence of recovery for Harlequin Ducks in winter or summer, however, the regression on winter densities in the oiled areas and summer densities in unoiled areas of PWS indicated an annual increase between 1990 and 2000, consistent with our definition for a recovering population. Inconsistencies between our winter results and those of Rosenberg and Petrula (1998) may stem from the fact that our winter surveys were conducted in March, while Rosenberg and Petrula conducted surveys from July-September. There is some evidence of seasonal movements of birds between eastern (unoiled) and western PWS (oiled; Rosenberg and Petrula 1998), as well as seasonal differences in population structure, which may partially explain differences in trend results.

"Scoters."-- Injury to "scoters" from the oil spill was documented for summer populations in PWS (Klosiewski and Laing 1994). Our data on both summer and winter densities of "scoters" in the oiled areas of PWS suggested no trend of recovery for this species. Further, the homogeneity of slopes test showed winter densities in the oiled and unoiled areas of PWS were diverging, suggesting continuing and increasing effects. In addition, the regression on winter and summer densities in the unoiled areas indicate an increasing population, which also supports no recovery in the oiled areas.

Bufflehead.-- Negative impacts to Bufflehead from the oil spill were documented in PWS for winter populations (Day et al. 1997). The regression on winter densities of Bufflehead in the oiled areas of PWS indicated no recovery for this species. Also, populations in the unoiled areas were increasing (8%) and appeared to be diverging from those in the oiled areas.

"Goldeneyes."-- Negative impacts to "goldeneyes" from the oil spill were documented in PWS for summer (Irons et al. 2000) and fall populations (Day et al. 1997). The regression on winter densities of "goldeneyes" in the oiled areas of PWS suggest no trend of recovery for this species. In addition, homogeneity of slopes test showed winter densities in the oiled and unoiled areas of PWS were diverging, suggesting continuing and increasing impacts. Populations were increasing (6%) in unoiled area of PWS.

"Mergansers."-- Negative impacts to "mergansers" from the oil spill were documented in PWS for summer populations (Day et al. 1997, Irons et al. 2000). Regressions on the winter densities of "mergansers" in the oiled areas of PWS suggest no trend of recovery for this species. Further, summer densities in the oiled and unoiled areas of PWS were diverging and the densities in the oiled area were declining, suggesting continuing and increasing effects.

Bald Eagles.-- Negative impacts to Bald Eagles from the oil spill were documented in PWS in 1989 (Bernatowicz et al. 1996, Day et al. 1997), however, by 1990 there was evidence of recovery (White et al. 1993, Bernatowicz et al. 1996, Day et al. 1997). In 1989, a decline in nesting success was observed in western PWS (oiled) relative to eastern PWS (unoiled), but this difference disappeared in 1990 (Bernatowicz et al. 1996) and by 1995 the PWS population had returned to pre-spill levels (Bowman et al. 1997). Our regressions on winter data indicated an annual increase in eagle densities for both the oiled (6%) and unoiled (6%) portions of PWS between 1989 and 2000, consistent with a recovering population. Regressions of summer densities showed Bald Eagles were increasing (5%) in the oiled and unoiled areas of PWS, suggesting summer populations of this species may be recovering. However, the homogeneity of slopes test showed winter and summer populations were not recovering. Bowman et al. (1997), however, found accurate comparisons of population changes between oiled and unoiled areas difficult to make because of the high mobility of eagles; differences reflecting local shifts in distribution related to food supplies. In the case of Bald Eagles, assumptions of the homogeneity of slopes test may not be valid, lending strength to individual regression analyses. We therefore conclude that Bald Eagles are recovering.

Our regression results are consistent with Bald Eagle specific surveys (Bowman et al. 1997) which document increases in PWS populations since 1982, and again since 1991. It is difficult to explain the sustained increase in PWS eagle numbers (similar increasing trends are documented for the Kodiak Archipelago, southeastern Alaska, and the Kodiak National Wildlife Refuge; Bowman et al. 1997) but it is possible that PWS-wide populations are rebounding from an earlier perturbation. Jacobson and Hodges (unpubl. MS) suggested that observed increases in southeast Alaska Bald Eagle populations between 1967 and 1997 were due to recovery from the effects of extensive bounty hunting earlier this century.

Mew Gull.-- Injury to Mew gulls from the oil spill was documented for summer populations in PWS (Klosiewski and Laing 1994, Day et al. 1997). The homogeneity of slopes test and regressions on both summer and winter densities of Mew Gulls in oiled areas of PWS indicated no trend of recovery for this species.

Glaucous-winged Gull.-- Injury to Glaucous-winged Gulls from the oil spill was documented for both winter and summer populations in PWS, though effects had disappeared by 1990 (Day et al. 1997). The homogeneity of slopes test and regressions on both summer and winter densities of Glaucous-winged Gulls in oiled areas of PWS indicated no trend of recovery for this species.

Black-legged Kittiwakes.-- Negative impacts to kittiwakes from the oil spill were documented in PWS for summer populations (Irons et al. 2000), however, these decreases were attributed to local shifts in foraging distributions related to temporally abundant food resources (eg. forage fish schools) rather than declines in populations. Regression on summer densities of kittiwakes in the oiled areas of PWS showed a significant negative trend (-8%), suggesting a decline in population for this species. The homogeneity of slopes test showed summer densities in the oiled and unoiled areas of PWS were not diverging, suggesting no recovery. Kittiwake productivity was lower than expected in the oiled area following the spill in 1989, while productivity in the unoiled area was the high. Productivity declined even more in the oiled area and declined in the unoiled area through 1994 (Irons 1996). Poor productivity in oiled areas of PWS may have translated to low recruitment and may partially explain the negative trend in summer densities.

"Terns."-- Negative impacts to "terns" from the oil spill were documented in PWS for summer populations (Klosiewski and Laing 1994). The homogeneity of slopes test, as well as regression on summer densities of "terns" in the oiled areas of PWS suggested no trend of recovery for this species. In fact, summer densities of birds in oiled areas showed significant negative trends (-5%), suggesting a decline in population. Further, of equal concern were

significant declines in unoiled areas (-8%) indicating PWS-wide declines in this taxon. Our data are consistent with recent surveys of tern colonies in PWS (summer 1999 and 2000), which revealed significant declines compared with pre-spill surveys, including the complete disappearance of colonies (USFWS unpubl. data).

Black Oystercatcher.-- Injury to Black Oystercatchers was documented for summer populations in 1989 and 1990 (Klosiewski and Laing 1994, Day et al. 1997, Murphy et al. 1997, Irons et al. 2000) but effects had largely dissipated after 1991 (Murphy et al. 1997, Irons et al. 2000). Effects were primarily due to breeding disruption during 1989 and 1990 by disturbance associated with cleanup and bioremediation activities (Sharp et al. 1996, Andres 1997). Studies conducted between 1992-93 (Andres 1999) found that effects from persistent shoreline oil on breeding success of oystercatchers were negligible. More recently, Murphy and Mabee (1998) showed that oystercatchers had fully re-occupied territories and were nesting at oiled sites in PWS, concluding that oiling did not affect breeding biology and success of oystercatchers in 1998. Regression analysis on summer densities of oystercatchers showed significant increasing trends in oiled (1%) and unoiled (2%) areas, suggesting recovery for this taxon. Murphy and Mabee (1998) did find significantly lower breeding success in oiled areas of PWS, attributing predation as the driving mechanism. Predation on eggs and young can be high (Murphy and Mabee 1998, Andres 1999) and a dominant force in shaping oystercatcher populations, perhaps swamping out any oil effects on breeding success.

"Murres."-- Injury to "murres" from the oil spill was documented for non-breeding birds that spend the summer in PWS (Klosiewski and Laing 1994, Day et al. 1997, Irons et al. 2000) as well as winter populations (Day et al. 1997). The homogeneity of slopes test, as well as

regressions on both summer and winter densities of "murres" in the oiled areas indicated no trend of recovery for this species group. "Murres" are a common winter resident in PWS. However, numbers are highly variable, with peak winter numbers associated with anomalous oceanographic conditions (eg. El Niño) in the Gulf of Alaska (Piatt and Van Pelt 1997).

Pigeon Guillemots.-- Injury to Pigeon Guillemots from the oil spill was documented for both winter (Klosiewski and Laing 1994) and summer populations in PWS (Murphy et al. 1997, Irons et al. 2000). Guillemot populations have declined throughout PWS since 1972 and the estimated number of birds in the oiled areas of PWS during March 1990 was 33% less than expected relative to unoiled areas (Klosiewski and Laing 1994). In addition, population counts at Naked Island, PWS showed the population declined in the three years following the spill, and declines at colonies located along oiled shorelines were greater than unoiled sites (Oakley and Kuletz 1996). Homogeneity of slopes test and regressions on both summer and winter densities of Pigeon Guillemots in the oiled areas indicated no trend of recovery for this species. In fact, summer densities of birds in oiled areas showed significant negative trends (- 2%), suggesting a population decline.

The oil spill did not have any detected effects on the abundance of shallow sub-tidal fishes (eg. gunnels, rockfishes, sculpins, blennies, etc.; Laur and Haldorson 1996), principal prey of guillemots (Golet et al., *in press*). Chick growth and reproductive success in guillemots, however, is correlated with the percentage of high-lipid schooling fish (eg. sandlance) in the diet (Golet et al., *in press*). The percent of high-lipid schooling fishes in chick diet at Naked Island, PWS was significantly greater pre-spill (1979-81) than post-spill (1989-90 and 1994-98; Golet et al. 1999). Whether this relative shift in diets is the result of the oil spill or the regime shift remains unclear.

"Murrelets."-- A minimum of 8,400 "murrelets" (both Marbled and Kittlitz's murrelet) were killed directly by exposure to oil, representing about 7% of the population in the spill zone (Kuletz 1996). Oil spill effects were detected for Marbled Murrelets in 1989, but disappeared by 1990 (Day et al. 1997, Kuletz 1996). There is evidence that cleanup and other spill-related activities disrupted nearshore murrelet distributions (Kuletz 1996), which may partially explain the oil spill effect during the summer following the spill. Our homogeneity of slopes test, as well as regression on winter densities of murrelets in the oiled and unoiled areas of PWS indicated no trend of recovery for this taxon. In addition, summer densities of birds had significant negative trends in oiled (-5%) and unoiled (-7%) areas.

Different trends are noted as winter and summer densities are compared in the oiled and unoiled areas of PWS. While "murrelets" winter in PWS, numbers are only 20-30% of summer populations. Winter data may track earlier phenology of "murrelet" arrival in PWS between 1990-1998, due to changes in oceanography and associated schooling fish distribution in the Gulf of Alaska (Anderson and Piatt, *in press*) and PWS. Spear and Ainley (1999) related annual variation in densities of Sooty Shearwaters (*Puffinus griseus*) to large-scale oceanic warming; resulting in a distributional shift in feeding location during the nonbreeding period. Since March marks the beginning of movement of murrelets into PWS, which peaks in April (Kuletz et al. 1995), a temporal shift in winter distribution is plausible, particularly in light of four El Niños that have occurred since 1990 (Trenberth 1997). As with other alcids which visit colonies throughout the year (eg. Black Guillemot [*Cepphus grylle*], Greenwood 1987; Common Murre, Harris and Wanless 1990), these winter populations of "murrelets" may be comprised primarily of experienced breeding adults (see Naslund 1993) as opposed to a mix of breeders and non-breeders in summer. Thus, it is plausible that summer and winter survey data represent discrete populations, which may explain the different trends observed.

Northwestern Crows.-- Injury to Northwestern Crows from the oil spill was documented for both winter (Day et al. 1997) and summer populations in PWS (Klosiewski and Laing 1994). The homogeneity of slopes test and regression on summer densities of Northwestern Crows in the oiled and unoiled areas of PWS suggested recovery for this species. Similarly, regression on winter densities in oiled and unoiled areas showed a slight increasing trend (5%), suggesting winter populations of this species may also be recovering.

Mechanism of Continuing Injury or Lack of Recovery

Shoreline habitats in the oiled portions of PWS were impacted to various degrees by oiling. Natural weathering and flushing by high wave energy reduced the amount of oil in some areas of PWS. However, as of 1993 some beaches in protected, low-energy areas still contained substantial amounts of oil in a toxic state in sediments and mussel beds (Babcock et al. 1996). Further, *Exxon Valdez* oil, in a relatively unweathered state in sediments, was the source of the contamination of mussel beds. Contaminated sediments were acting as a reservoir, affecting chronic exposure of nearby mussels and other intertidal organisms (Harris et al. 1996). In addition, cleaning operations killed marine life which survived oiling and damaged intertidal habitats by altering shoreline sediment structure, which could ultimately affect repopulation of shorelines by sediment-dwelling invertebrates (e.g., clams, mussels; Mearns 1996). It follows that organisms, such as marine birds, which utilize these habitats may exhibit slow rates of recovery or continuing and increasing effects. Our trend data are consistent with this idea. Several of the species showing increasing oil spill effects or no evidence of recovery (eg. Harlequin Ducks, "goldeneyes," "mergansers," Mew Gulls, Glaucous-winged Gulls, Black-legged Kittiwakes, and Pigeon Guillemots [summer], "scoters," and "murrelets" [winter] use nearshore habitats. However, this trend is confounded by other species which also use nearshore habitats, yet did show some evidence of recovery (eg. Harlequin Ducks [winter], Bald Eagles, Black Oystercatchers, and Northwestern Crows [summer]). Thus, for both winter and summer populations, our results show taxa which utilize the nearshore environment in each status category. This suggests that for some of the species effected by the EVOS, factors other than use of nearshore habitat are contributing to observed trends.

The Nearshore Vertebrate Predator Project (Ballachey et al. 1999) assessed exposure of marine birds in PWS to oil using expression of cytochrome P4501A, an enzyme induced by exposure to polynuclear aromatic hydocarbons or halogenated aromatic hydrocarbons. Higher levels of P4501A induction were found in oiled areas than unoiled areas for several species (Harlequin Ducks, Barrow's Goldeneye). These results are consistent with our trends showing increasing effects (winter) for "goldeneyes" and slow recovery in Harlequin Ducks (winter), and no recovery in summer. The P4501A data are clear evidence of greater contaminant exposure to organisms in oiled areas of PWS relative to unoiled areas (Ballachey et al. 1999). It is not known, however, what amount of oil is necessary to induce P4501A at the levels detected or the health consequences (e.g., survival, reproduction) of that much oil.

Cumulative Impacts: Regime Shifts, Oil Spills, and Recovery

Using trend data alone to assess impacts and recovery from a perturbation such as the EVOS are confounded by the effects of natural temporal and geographic variation inherent in wildlife populations (Piatt et al. 1990b, Spies 1996, Wiens and Parker 1995). Population dynamics of marine birds may be carried out at large temporal and spatial scales (Wiens et al. 1996, Piatt and Anderson 1996) and against a backdrop of high natural variation in the marine environment (Piatt and Anderson 1996, Hayward 1997, Francis et al. 1998). Movement of birds between and within wintering and breeding grounds (Stowe 1982), juvenile dispersal (Harris 1983), and large pools of non-breeding individuals (Porter and Coulson 1987, Klomp and Furness 1992), may serve to mask local population changes, effectively buffering local effects over a broader region. Some studies of the EVOS (Day et al. 1997, Wiens et al. 1996) suggested that marine bird populations have a good deal of resiliency to severe but short-term perturbations, including the EVOS. This view is supported by the occurrence of large natural die-offs and reproductive failure of marine birds associated with reduced food supply and storms (Harris and Wanless 1984, Piatt and Van Pelt 1997). Interestingly, effects of these large die-offs on local populations are often difficult to detect or are small and transitory at the scale of most monitoring programs (Dunnet 1982, Stowe 1982, Harris and Wanless 1984, Piatt et al. 1990b, Wooller et al. 1992). Further, it is widely believed that marine bird populations are limited by resources with a 5-20% natural annual adult mortality rate (Piatt et al. 1990b). Under stable conditions this mortality would be compensatory (e.g., balanced by recruitment of adults into the breeding population).

This raises the question of the ability of marine birds to respond to long-term, chronic perturbations. In particular, if perturbations act in concert to have an additive effect on populations already stressed by other factors (eg. food shortages, winter storms, introduced predators, gill nets, disease, and long term oceanographic changes). In this study, we assumed that in the absence of an oil spill, marine bird populations in the oiled and unoiled portions of PWS, all things being equal, would exhibit similar trends; and as such, should have been affected to a similar degree by natural perturbations such as those at the scale of the North Pacific regime shift (Hayward 1997, Francis et al. 1998). Agler et al. (1999) compared surveys of marine birds in PWS in July 1972 with post-spill surveys in July 1989-1991, and 1993, and found that populations of several species of marine birds that feed on fish ("loons," "cormorants," "mergansers," Glaucous-winged Gulls, Black-legged Kittiwakes, Arctic Terns, Pigeon Guillemots, and "murrelets") had declined, while most those species feeding on benthic invertebrates ("goldeneyes," Harlequin Ducks, and Black Oystercatchers) did not decline. Similarly, many of the marine bird taxa showing declines in PWS declined on the Kenai Peninsula prior to the oil spill. Agler et al. (1999) suggested declines in piscivorous marine birds were at least partially due to changes in the relative abundance of certain forage fish species that occurred during the climatic regime shift in the north Pacific Ocean in the mid 1970's (Hayward 1997, Francis et al. 1998, Anderson and Piatt, *in press*). Of the 14 taxa showing declines in PWS between 1972 and 1989-1993 (Agler et al. 1999), eight ("loons," "cormorants," "scoters," "mergansers," Black-legged Kittiwakes, "terns," Pigeon Guillemots, and "murrelets") were shown to have been negatively affected by the oil spill (Klosiewski and Laing 1994, Day et al. 1997, Wiens et al. 1996, Murphy et al. 1997, Irons et al. 2000). Of these eight species, none showed evidence of recovery based on our trend data for summer densities and only one ("loons") showed evidence of recovery based on winter densities. Thus, it appears that these taxa may be responding to the cumulative impacts of the regime shift (lowered prey availability and quality) and the oil spill, slowing recovery at the population level.

Interpreting and Defining Recovery

Assessment of recovery from a perturbation is dependent upon the null hypothesis generated, the statistical test used and it's associated power, and how recovery is defined. Numerous analytical methods have been used in assessing impacts and recovery of marine birds in PWS following the EVOS (Klosiewski and Laing 1994, Wiens et al. 1996, Day et al. 1997; Murphy et al. 1997, Irons et al. 2000). These methods differ in their approach, at times producing seemingly different results, or more appropriately the interpretation of those results, from similar data. Currently, there is no consensus on which methodology is the most suitable for assessing recovery; a pattern consistent with most studies monitoring long-term population change in birds (Thomas 1996).

Wiens and Parker (1995) defined impact as a statistically significant correlation between injury and exposure; recovery being the disappearance of such a correlation through time. In short, the burden of proof is placed on the data to establish injury and no recovery. This definition has been used by several studies (Wiens et al. 1996, Day et al. 1997, Murphy et al. 1997, and Irons et al. 2000) to assess injury and recovery of marine birds in PWS following EVOS. The latter studies rejection of the null hypothesis (no difference) constituted an effect, and the failure to reject in subsequent years was defined as recovery. In contrast, Agler and Kendall (1997) compared the slopes of regression lines from oiled and unoiled areas, defining recovery as population abundance increasing in the oiled area relative to the unoiled area (homogeneity of slopes test). Here the rejection of the null hypothesis (no difference) is interpreted as a increasing effect if impacted populations have rates which are below those of the reference area, recovery if impacted populations have rates above those of the reference area, and not recovering if the rates of change were not significantly different. In short, the failure to reject the null constituted non-recovery status. The "burden of proof" of recovery is on the data in this case. The result of these various definitions of recovery (based on different criteria) is that data collected on the same population of birds can produce different conclusions regarding recovery status. Thus, while the proximate definition of recovery is based on objective analytical criteria, the ultimate definition is dependent on the more subjective choice of statistical model and numerical values of criteria employed. In our opinion, rigid application of these definitions of recovery accounts for much of the divergence in conclusions over the impacts and recovery of marine bird populations in PWS following the EVOS (Wiens et al. (1996), Day et al. (1997), Murphy et al. (1997), Irons et al. (2000), and this study).

CONCLUSIONS

Few other studies of marine birds have persisted for such a long period of time after a large environmental perturbation, such as the *T/V Exxon Valdez* oil spill. Thus, we had the opportunity to examine the effect of an oil spill on an area over time. Most data on the population trends of marine and coastal birds have been collected on a short-term basis or opportunistically over a large area. Long-term studies traditionally have been on a single species, usually at a colony (Wooller et al. 1992), but this survey covered a large area and collected data on several species.

Based on our assumption that with the absence of the oil spill, populations in the oiled zone would change at the same rate as those in the unoiled zone, we found for the designated injured species or species groups of marine birds and mammals that, "loons," "scoters," "goldeneyes", and "mergansers" showed trends consistent with continuing and increasing oil spill effects from the *Exxon Valdez* oil spill. The other injured species or species groups ("cormorants," Mew Gulls, Glaucous-winged Gulls, "murres," Pigeon Guillemots, and "murrelets") did not show any significant trends in either March or July, indicating that these populations have not recovered from the spill.

In summary, our study indicates that most taxa for which injury was previously demonstrated are not recovering and others continue to show potential population effects eleven years after the oil spill. We show evidence of slow recovery, lack of recovery, and divergent population trends in many taxa which utilize shoreline and nearshore habitats where oil is likely to persist. These potential lingering spill effects and natural variability appear to be acting in concert in delaying recovery of many PWS bird populations.

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Table 1. Summary of statistically significant trends in post-spill densities of injured marine birds in PWS, Alaska, after the *Exxon Valdez* oil spill[a].

Taxa	Oiled area		Oiled area relative to unoiled		Unoiled area	
	Trend in July	Trend in March	Trend in July	Trend in March	Trend in July	Trend in March
Northwestern Crows	+1****	+1*	+1***	0	+1*	+1*
Bald Eagles	+1**	+1***	0	0	+1**	+1***
Black Oystercatchers	+1*	nd	0	nd	+1**	nd
Harlequin Ducks	0	+1***	0	0	+1*	0
"Loons"	0	+1***	0	-1**	0	+1***
Buffleheads	nd[b]	0	nd	0	nd	+1**
"Murres"	0	0	0	0	0	0
"Cormorants"	0	0	0	0	0	0
Mew Gulls	0	0	0	0	0	0
Glaucous-winged Gulls	0	0	0	0	0	0
"Grebes"	nd	-1*	nd	0	nd	-1***
"Murrelets"	-1*	0	0	0	-1**	0
"Terns"	-1***	nd	0	nd	-1***	nd
Pigeon Guillemots	-1**	0	0	0	0	0
Black-legged Kittiwakes	-1****	nd	0	nd	0	nd
"Mergansers"	-1*	0	-1*	0	0	0
"Scoters"	0	0	0	-1**	+1***	+1***
"Goldeneyes"	nd	0	nd	-1*	nd	+1*

[a]Trends for the oiled and unoiled areas were determined by regression analyses and refer to an absolute change in the oiled and unoiled area. Trends in oiled area relative to the unoiled area were determined by homogeneity of slopes test and refer to change in the oiled area relative to the unoiled area (+1 = increasing density, 0 = no change, and -1 = decreasing density). An increasing trend in the oiled area, whether absolute or relative to the unoiled area, suggests recovery is occurring. No absolute or relative change in the oiled area suggests that recovery is not occurring. A negative trend in the oiled area relative to the unoiled area suggests that the impact is increasing with time.

[b]nd = no data, Birds were either not present or too rare to analyze during this season.

*$p \leq 0.20$.

**$p \leq 0.10$.

***$p \leq 0.05$.

****$p \leq 0.01$.

Table 2. Results of homogeneity of slopes test ($P \leq 0.20$) for injured species/species groups from March (1990-91, 1993, 1994, 1996, 1998, and 2000). Winter resident marine bird species/species groups with 7 year population estimate of >500 birds were used. NR = no recovery, IE = Increasing effects, and R = recovery.

Species/Species Group	Homogeneity of Slopes Test	Oiled Slope	Unoiled Slope
"loons"	*P*=0.08 (IE)	0.03 *P*=0.01 (R)	0.08 *P*=0.03
"grebes"	*P*=0.49 (NR)	-0.03 *P*=0.13 (NR)	-0.04 *P*=0.02
"cormorants"	*P*=0.61 (NR)	0.01 *P*=0.60 (NR)	-0.01 *P*=0.74
Harlequin Ducks	*P*=0.32 (NR)	0.05 *P*=0.02 (R)	0.01 *P*=0.65
"scoters"	*P*=0.09 (IE)	-0.01 *P*=0.87 (NR)	0.12 *P*=0.05
Buffleheads	*P*=0.29 (NR)	0.03 *P*=0.44 (NR)	0.08 *P*=0.08
"goldeneyes"	*P*=0.12 (IE)	-0.01 *P*=0.79 (NR)	0.06 *P*=0.12
"mergansers"	*P*=0.29 (NR)	-0.01 *P*=0.71 (NR)	0.09 *P*=0.34
Bald Eagles	*P*=0.98 (NR)	0.06 *P*=0.02 (R)	0.06 *P*=0.05
Mew Gulls	*P*=0.75 (NR)	0.03 *P*=0.78 (NR)	-0.01 *P*=0.89
Glaucous-winged Gulls	*P*=0.34 (NR)	-0.03 *P*=0.72 (NR)	0.06 *P*=0.32
"murres"	*P*=0.37 (NR)	-0.02 *P*=0.85 (NR)	0.13 *P*=0.33

Table 2 (continued).

Species/Species Group	Homogeneity of Slopes Test	Oiled Slope	Unoiled Slope
Pigeon Guillemots	*P*=0.75 (NR)	-0.02 *P*=0.47 (NR)	-0.01 *P*=0.75
"murrelets"	*P*=0.88 (NR)	0.03 *P*=0.54 (NR)	0.02 *P*=0.62
Northwestern Crows	*P*=0.99 (NR)	0.05 *P*=0.17 (R)	0.05 *P*=0.14

Table 3. Results of homogeneity of slopes test ($P \leq 0.20$) for injured species/species groups from July (1989-91, 1993, 1996, 1998, and 2000). Breeding marine bird species/species groups with 7 year average population estimates of >500 birds were used. NR = no recovery, IE = increasing effects, and R = recovery.

Species/Species Group	Homogeneity of Slopes Test	Oiled Slope	Unoiled Slope
"loons"	*P*=0.90 (NR)	-0.002 *P*=0.88 (NR)	0.001 *P*=0.95
"cormorants"	*P*=0.25 (NR)	0.04 *P*=0.22 (NR)	-0.01 *P*=0.75
Harlequin Ducks	*P*=0.51 (NR)	0.02 *P*=0.54 (NR)	0.04 *P*=0.19
"scoters"	*P*=0.48 (NR)	-0.02 *P*=0.84 (NR)	0.05 *P*=0.002
"mergansers"	*P*=0.15 (IE)	-0.01 *P*=0.14 (NR)	0.02 *P*=0.38
Bald Eagles	*P*=0.96 (NR)	0.05 *P*=0.06 (R)	0.05 *P*=0.06
Black Oystercatchers	*P*=0.29 (NR)	0.01 *P*=0.12 (R)	0.02 *P*=0.09
Mew Gulls	*P*=0.75 (NR)	0.01 *P*=0.69 (NR)	0.03 *P*=0.54
Glaucous-winged Gulls	*P*=0.99 (NR)	0.01 *P*=0.98 (NR)	0.0001 *P*=0.99
Black-legged Kittiwakes	*P*=0.39 (NR)	-0.08 *P*=0.01 (NR)	-0.04 *P*=0.27
"terns"	*P*=0.38 (NR)	-0.05 *P*=0.04 (NR)	-0.08 *P*=0.05
"murres"	*P*=0.81 (NR)	-0.04 *P*=0.68 (NR)	-0.02 *P*=0.74

Table 3 (continued).

Species/Species Group	Homogeneity of Slopes Test	Oiled Slope	Unoiled Slope
Pigeon Guillemots	*P*=0.53 (NR)	-0.02 *P*=0.09 (NR)	-0.05 *P*=0.22
"murrelets"	*P*=0.67 (NR)	-0.05 *P*=0.11 (NR)	-0.07 *P*=0.10
Northwestern Crows	*P*=0.03 (R)	0.04 *P*=0.0001 (R)	0.02 *P*=0.15

Table 4. Results of regression analyses for injured species/species groups and sea otter population trends from March and July 1989-2000 for entire Prince William Sound. Summer breeding or winter resident marine bird species/species groups with 7 year average population estimates of >500 birds were used.

	March		July	
Species/Species Group	Slope	P Value	Slope	P Value
"loons"	0.07	0.02	-0.00004	0.998
"grebes"	-0.04	0.02	nd	nd
"cormorants"	-0.003	0.89	0.01	0.55
Harlequin Ducks	0.02	0.37	0.03	0.19
"scoters"	0.10	0.04	0.03	0.43
"goldeneyes"	0.05	0.16	nd	nd
Bufflehead	0.07	0.09	nd	nd
"mergansers"	0.06	0.43	0.01	0.50
Bald Eagles	0.06	0.03	0.05	0.05
Black Oystercatchers	nd	nd	0.01	0.07
Mew Gulls	-0.002	0.98	0.02	0.55
Glaucous-winged Gulls	0.03	0.59	0.0002	0.99
Black-legged Kittiwakes	0.18	0.01	-0.06	0.07
"terns"	nd	nd	-0.07	0.02
"murres"	0.09	0.45	-0.03	0.71
Pigeon Guillemots	-0.01	0.64	-0.04	0.13
"murrelets"	0.03	0.56	-0.06	0.08
Northwestern Crows	0.05	0.09	0.02	0.01
Sea Otters	0.001	0.95	-0.01	0.74

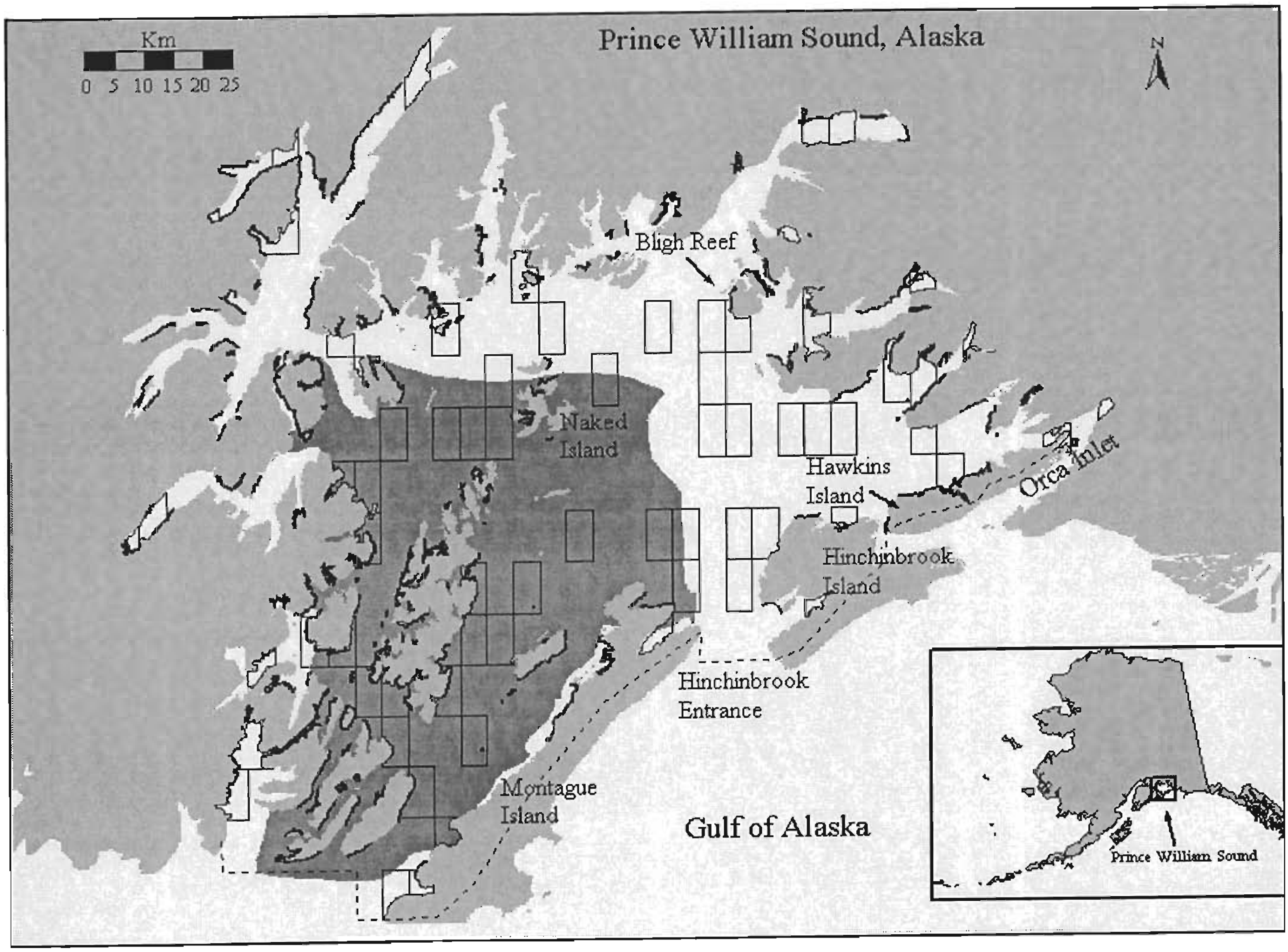

Figure 1. Map of the study area with shoreline transects and pelagic blocks surveyed in Prince William Sound during July 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), 1996 (Agler and Kendall 1997), 1998 (Lance et al. 1999) and 2000; and March 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), 1994 (Agler et al. 1995), 1996 (Agler and Kendall 1997), 1998 (Lance et al. 1999) and 2000. A subset of these transects were surveyed in July 1989 (Klosiewski and Laing 1994) and during the March surveys. The dark shading indicates the area oiled by the *T/V Exxon Valdez* oil spill in March 1989.

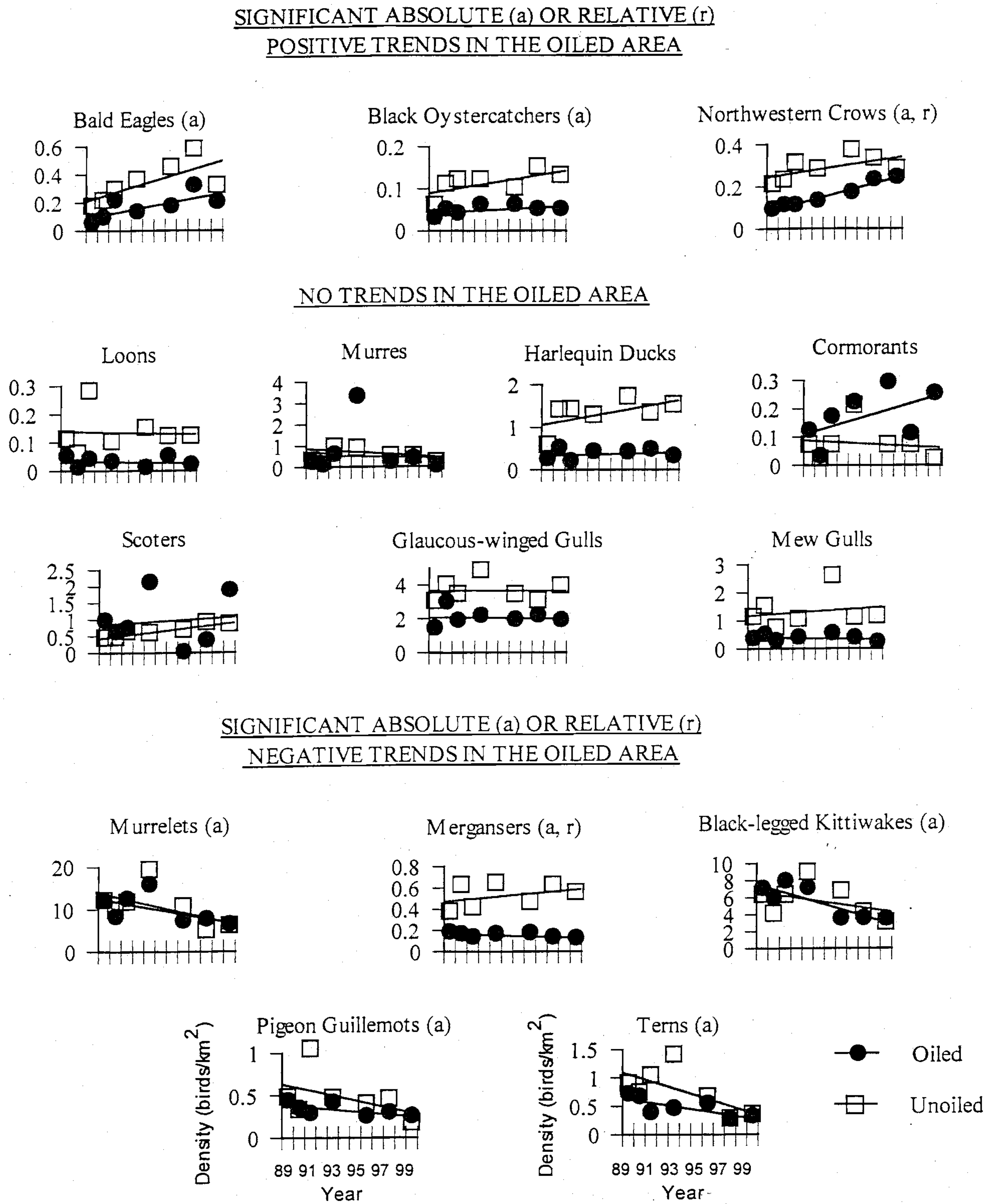

Figure 2. Changes in July densities (birds/km^2) of taxa, between 1989 and 2000, in unoiled (squares) and oiled (circles) areas of Prince William Sound, Alaska. Absolute trend (a) refers to a statistically significant trend in the oiled area; relative trend (r) refers to a statistically significant trend in the oiled area relative to the unoiled area. X axis = year, Y axis = density.

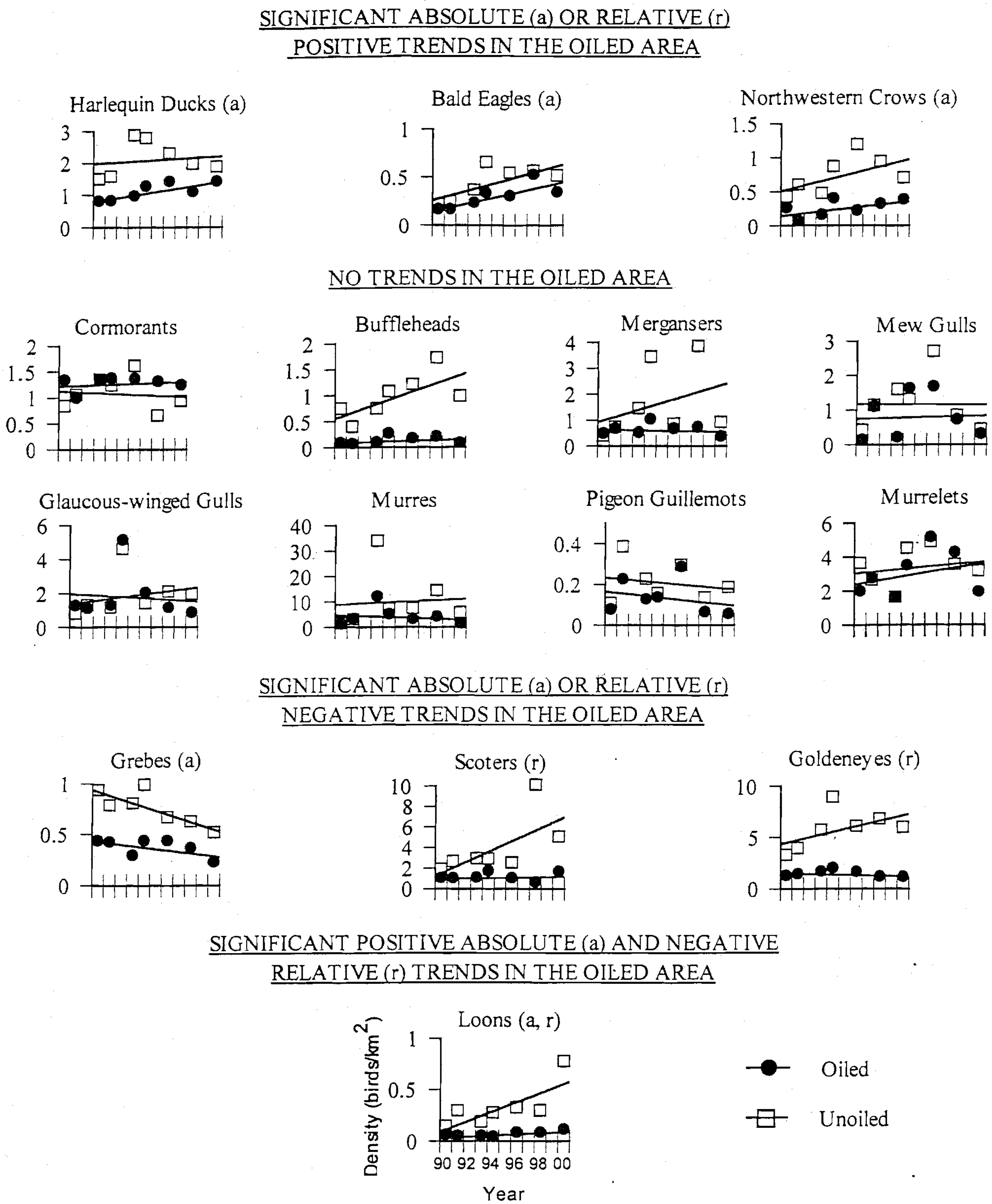

Figure 3. Changes in March densities (birds/km^2) of taxa, between 1990 and 2000, in unoiled (squares) and oiled (circles) areas of Prince William Sound, Alaska. Absolute trend (a) refers to a statistically significant trend in the oiled area; relative trend (r) refers to a statistically significant trend in the oiled area relative to the unoiled area. X axis = year, Y axis = density.

Appendix A. Common and scientific names of bird species/species groups mentioned in text.

Species/Species Group	Common Name	Scientific Name
"loons"	Red-throated Loon	*Gavia stellata*
	Pacific Loon	*Gavia pacifica*
	Common Loon	*Gavia immer*
	Yellow-billed Loon	*Gavia adamsii*
"grebes"	Horned Grebe	*Podiceps auritus*
	Red-necked Grebe	*Podiceps grisegena*
"cormorants"	Double-crested Cormorant	*Phalacrocorax auritus*
	Pelagic Cormorant	*Phalacrocorax pelagicus*
	Red-faced Cormorant	*Phalacrocorax urile*
Harlequin Duck	Harlequin Duck	*Histrionicus histrionicus*
Long-tailed Duck	Long-tailed Duck	*Clangula hyemalis*
"scoters"	Black Scoter	*Melanitta nigra*
	Surf Scoter	*Melanitta perspicillata*
	White-wing Scoter	*Melanitta fusca*
"goldeneyes"	Common Goldeneye	*Bucephala clangula*
	Barrow's Goldeneye	*Bucephala islandica*
Bufflehead	Bufflehead	*Bucephala albeola*
"mergansers"	Common Merganser	*Mergus merganser*
	Red-breasted Merganser	*Mergus serrator*
Bald Eagle	Bald Eagle	*Haliaeetus leucocephalus*
Black Oystercatcher	Black Oystercatcher	*Haematopus bachmani*
Mew Gull	Mew Gull	*Larus canus*
Glaucous-winged Gull	Glaucous-winged Gull	*Larus glaucescens*

Appendix A (continued).

Species/Species Group	Common Name	Scientific Name
Black-legged Kittiwake	Black-legged Kittiwake	*Rissa trydactyla*
"terns"	Caspian Tern	*Sterna caspia*
	Arctic Tern	*Sterna paradisaea*
	Aleutian Tern	*Sterna aleutica*
"murres"	Common Murre	*Uria aalgae*
	Thick-billed Murre	*Uria lomvia*
Pigeon Guillemot	Pigeon Guillemot	*Cepphus columba*
"murrelets"	Marbled Murrelet	*Brachyramphus marmoratus*
	Kittlitz's Murrelet	*Brachyramphus brevirostris*
Northwestern Crow	Northwestern Crow	*Corvus caurinus*

Appendix B. Overall population trends for marine birds in Prince William Sound.

Population Estimates.--In March 2000, we estimated that 210,945 ± 52,471 marine birds were in Prince William Sound (Appendix C). We estimated that during March 2000, 37,468 ± 8,197 birds were in the oiled zone, and 173,477 ± 51,826 birds were in the unoiled zone. In July 2000, we estimated that 204,349 ± 35,071 marine birds were in Prince William Sound (Appendix C). Of these, 80,388 ± 26,215 birds were estimated in the oiled zone, and 123,960 ± 23,297 birds were estimated in the unoiled zone. Population estimates for individual species and species groups are listed in Appendix C. In March, densities were 40.0 birds/km^2 for the whole Sound, 16.3 birds/km^2 in the oiled zone, and 26.0 birds/km^2 in the unoiled zone. In July, densities were 22.5 birds/km^2 for the whole Sound, 19.7 birds/km^2 in the oiled zone, and 8.2 birds/km^2 in the unoiled zone.

Overall Population Trends within Prince William Sound.-- To examine population trends from 1989-2000 for the entire Sound, we calculated linear regressions of total population estimates for each species or species group for March and July. We found a significant positive trend in the total density of marine birds in Prince William Sound for March ($P = 0.09$, slope = 0.06) but no trend for July ($P = 0.40$, slope = 0.02). In March, we found that PWS-wide densities of bufflehead, goldeneyes, bald eagles, black-legged kittiwakes, loons, scoters, and northwestern crows increased significantly, while grebes declined significantly ($P < 0.20$). In July, the overall density of bald eagles, black oystercatchers, harlequin ducks, and northwestern crows increased significantly; while the overall murrelet, pigeon guillemot, tern, and black-legged kittiwake densities in PWS decreased significantly ($P < 0.20$).

Appendix C. Overall population trends for sea otters in Prince William Sound.

Population Estimates.-- In 2000, we estimated that 4,668 ± 1,179 sea otters were in Prince William Sound in March, and 5,093 ± 1,689 otters were in Prince William Sound in July (Appendix D). In the oiled zone, the population estimate was 837 ± 383 otters in March and 1,404 ± 877 otters in July. In the unoiled zone, the population was estimated as 3,831 ± 1,115 otters in March and 3,689 ± 1,443 otters in July.

Trends from Homogeneity of Slopes Test.-- We found no significant differences in the rate of change in density of sea otters between the oiled and unoiled areas of PWS in both March and July. Also, the regression on March and July densities of sea otters in the two areas showed no \trends, suggesting no recovery.

Overall Trends within Prince William Sound.-- Within Prince William Sound as a whole, we found that the sea otter population had no significant trend in either March ($P = 0.95$, slope = 0.001) or July ($P = 0.74$, slope = -0.01).

Conclusions.-- Sea otters, a designated injured species, showed results indicative of no recovery in March and July. That is, densities in the oiled and unoiled areas of PWS do not show significant trends. Evidently, there has been no significant recovery of sea otters in the oiled zone, but populations may be stable sound-wide (non-significant trends). Sea otter populations within Prince William Sound were expanding their numbers and distribution prior to the oil spill (Irons et al. 1988a). A study of five northern populations of sea otters and a population from California found that all but the Amchitka Island, Alaska, population, were increasing at an annual rate of >5% (Estes 1990).

Appendix D. Estimated numbers of birds ($N \pm$ 95% CI) for species and species groups observed in Prince William Sound during March and July 1972-73 (Haddock et al., unpubl. data), 1989-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), 1994 (Agler et al. 1995), 1996 (Agler and Kendall 1997), 1998 (Lance et al. 1999), and 2000. No surveys were done in July 1973, July 1994, or March 1989. Species listed in phylogenetic order following American Ornithologists' Union (1983).

	March		July	
Species/Year	*N*	CI	*N*	CI
Loons				
Red-throated Loon (*Gavia stellata*)				
1972	179	161	1,255	1,125
1973	29	33		
1989			128	132
1990	8	14	3	4
1991	90	166	110	198
1993	89	126	13	17
1994	0	0		
1996	0	0	0	0
1998	12	15	58	78
2000	0	0	70	62
Pacific Loon (*Gavia pacifica*)				
1972	2,470	1,702	1,027	682
1973	1,112	1,479		
1989			0	0
1990	66	121	80	101
1991	0	0	86	75
1993	0	0	90	93
1994	206	205		
1996	242	308	322	258
1998	713	1,048	50	40
2000	203	340	13	18
Common Loon (*Gavia immer*)				
1972	97	102	133	169
1973	7	12		
1989			420	271
1990	230	249	82	47
1991	386	397	596	448
1993	67	48	244	166
1994	353	214		
1996	636	422	231	144
1998	505	246	252	220
2000	2,420	3,392	406	318

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Yellow-billed Loon (*Gavia adamsii*)				
1972	426	444	12	15
1973	143	246		
1989			4	8
1990	23	32	0	0
1991	47	69	6	6
1993	23	25	51	78
1994	140	175		
1996	90	125	0	0
1998	94	160	0	0
2000	209	380	4	8
Unidentified Loon (*Gavia* sp.)				
1972	163	139	140	222
1973	1,762	1,619		
1989			216	242
1990	549	323	204	214
1991	1,111	1,133	851	859
1993	871	644	229	165
1994	827	913		
1996	968	976	261	250
1998	431	389	498	329
2000	1,636	1,062	248	381
Total Loons (*Gavia* spp.)				
1972	3,335	1,788	2,567	1,469
1973	3,051	2,322		
1989			768	386
1990	874	453	370	245
1991	1,634	1,192	1,649	1,129
1993	1,051	659	627	255
1994	1,526	1,064		
1996	1,935	1,241	814	386
1998	1,754	1,185	859	406
2000	4,469	4,270	742	490

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Grebes				
Horned Grebe (*Podiceps auritus*)				
1972	4,847	2,247	60	113
1973	5,370	1,634		
1989			0	0
1990	3,780	1,545	0	0
1991	2,255	1,609	31	48
1993	400	326	0	0
1994	3,698	2,210		
1996	2,636	959	13	18
1998	2,353	1,044	0	0
2000	2,461	926	0	0
Red-necked Grebe (*Podiceps grisegena*)				
1972	4,459	1,695	146	223
1973	7,369	11,316		
1989			0	0
1990	2,108	1,397	20	27
1991	1,565	509	50	41
1993	681	324	31	30
1994	1,878	746		
1996	1,719	561	70	64
1998	1,396	763	106	101
2000	572	265	36	36
Unidentified Grebe (*Podiceps* sp.)				
1972	0	0	0	0
1973	5	9		
1989			0	0
1990	611	302	10	12
1991	1,775	1,375	7	11
1993	4,210	2,132	0	0
1994	1,185	538		
1996	654	257	0	0
1998	809	771	0	0
2000	401	200	0	0

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Total Grebes (*Podiceps* spp.)				
1972	9,306	3,048	206	245
1973	12,744	9,046		
1989			0	0
1990	6,499	2,053	29	38
1991	5,595	2,240	88	68
1993	5,291	2,298	31	30
1994	6,761	2,998		
1996	5,009	1,286	84	67
1998	4,558	1,530	108	101
2000	3,434	1,052	36	36
Procellariiformes				
Northern Fulmar (*Fulmarus glacialis*)				
1972	0	0	999	760
1973	0	0		
1989			0	0
1990	0	0	39	48
1991	0	0	0	0
1993	0	0	41	69
1994	0	0		
1996	0	0	1,584	948
1998	0	0	5	8
2000	0	0	113	134
Sooty Shearwater (*Puffinus griseus*)				
1972	0	0	0	0
1973	0	0		
1989			78	69
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	17,552	28,373
2000	0	0	0	0

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Unidentified Shearwater (*Puffinus* sp.)				
1972	0	0	0	0
1973	0	0		
1989			187	310
1990	0	0	34	55
1991	0	0	38,428	62,788
1993	0	0	46	64
1994	0	0		
1996	0	0	292	162
1998	0	0	0	0
2000	0	0	0	0
Total Shearwaters (*Puffinus* spp.)				
1972	0	0	0	0
1973	0	0		
1989			265	314
1990	0	0	34	55
1991	0	0	38,428	62,788
1993	0	0	46	64
1994	0	0		
1996	0	0	293	162
1998	0	0	17,552	23,373
2000	0	0	0	0
Total Fulmars and Shearwaters (*Fulmarus* and *Puffinus* spp.)				
1972	0	0	999	760
1973	0	0		
1989			265	314
1990	0	0	72	73
1991	0	0	38,428	62,788
1993	0	0	87	94
1994	0	0		
1996	0	0	1,877	958
1998	0	0	17,557	28,373
2000	0	0	113	134

Appendix D (continued).

Species/Year	March N	March CI	July N	July CI
Unidentified Petrel (*Pterodroma* or *Oceandroma* sp.)				
1972	0	0	0	0
1973	0	0		
1989			828	1,321
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Fork-tailed Storm-Petrel (*Oceanodroma furcata*)				
1972	0	0	17,539	10,570
1973	0	0		
1989			35,424	38,172
1990	595	705	18,426	5,319
1991	0	0	19,519	11,141
1993	0	0	13,811	8,139
1994	37	62		
1996	41	69	15,822	11,451
1998	11,506	13,024	9,459	6,898
2000	634	621	34,828	21,644
Unidentified Storm-Petrel (*Oceanodroma* sp.)				
1972	0	0	0	0
1973	0	0		
1989			155	257
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	40	50
1994	0	0		
1996	0	0	0	0
1998	0	0	281	351
2000	15	28	78	96

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Total Petrels (*Oceanodroma* and *Pterodroma* spp.)				
1972	0	0	17,539	10,570
1973	0	0		
1989			36,406	38,138
1990	595	705	18,426	5,319
1991	0	0	19,519	11,141
1993	0	0	13,851	8,144
1994	37	62		
1996	41	69	15,822	11,451
1998	11,506	13,024	9,740	6,881
2000	649	622	34,906	21,638
Cormorants				
Double-crested Cormorant (*Phalacrocorax auritus*)				
1972	0	0	0	0
1973	0	0		
1989			89	108
1990	269	233	54	51
1991	124	109	49	48
1993	1,041	1,059	254	310
1994	131	107		
1996	367	230	74	110
1998	972	1,014	27	26
2000	476	410	29	24
Pelagic Cormorant (*Phalacrocorax pelagicus*)				
1972	0	0	0	0
1973	0	0		
1989			394	289
1990	8,448	2,552	138	84
1991	5,431	2,266	512	341
1993	8,050	3,179	1,351	681
1994	10,959	2,800		
1996	590	552	263	225
1998	720	588	44	31
2000	300	328	233	295

Appendix D (continued).

Species/Year	March N	March CI	July N	July CI
Red-faced Cormorant (*Phalacrocorax urile*)				
1972	0	0	0	0
1973	0	0		
1989			22	25
1990	0	0	0	0
1991	8	14	0	0
1993	6	10	15	18
1994	0	0		
1996	34	32	11	18
1998	0	0	6	9
2000	82	143	140	228
Unidentified Pelagic or Red-faced Cormorant (*Phalacrocorax pelagicus* or *urile*)				
1996	12,056	4,005	1,067	1,508
1998	6,229	2,317	700	669
2000	7,491	2,827	580	752
Unidentified Cormorant (*Phalacrocorax* sp.)				
1972	10,792	2,744	20,045	19,401
1973	27,679	8,203		
1989			307	363
1990	352	358	34	28
1991	3,477	1,303	419	402
1993	2,775	1,611	340	228
1994	278	212		
1996	375	243	25	33
1998	87	84	14	12
2000	920	706	11	18
Total Cormorants (*Phalacrocorax* spp.)				
1972	10,792	2,744	20,045	19,401
1973	27,679	8,203		
1989			812	590
1990	9,068	2,583	225	106
1991	9,040	2,654	980	567
1993	11,872	4,079	1,959	871
1994	11,368	2,832		
1996	13,422	4,021	1,440	1,562
1998	8,007	2,699	790	693
2000	9,270	3,003	992	984

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Herons				
Great Blue Heron (*Ardea herodias*)				
1972	113	85	47	50
1973	50	41		
1989			18	16
1990	49	37	54	33
1991	30	33	36	33
1993	106	118	93	54
1994	198	205		
1996	183	155	176	103
1998	103	89	185	111
2000	150	186	65	38
Waterfowl				
Tundra Swan (*Cygnus columbianus*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	8	14	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	10	16
Trumpeter Swan (*Cygnus buccinator*)				
1972	0	0	146	260
1973	0	0		
1989			0	0
1990	0	0	3	5
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Emperor Goose (*Chen canagica*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	6	11	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Brant (*Branta bernicla*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	3	4
1993	0	0	0	0
1994	0	0		
1996	0	0	312	528
1998	0	0	0	0
2000	0	0	0	0
Canada Goose (*Branta canadensis*)				
1972	48	90	0	0
1973	138	252		
1989			164	279
1990	38	71	1,907	3,326
1991	0	0	3,101	5,284
1993	37	67	3,099	5,323
1994	0	0		
1996	15	24	1,019	1,571
1998	361	414	24	24
2000	69	76	56	59

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Blue-winged Teal (*Anas discors*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	6	10
2000	0	0	0	0
Green-winged Teal (*Anas crecca*)				
1972	148	259	106	201
1973	59	80		
1989			0	0
1990	0	0	64	86
1991	0	0	78	130
1993	0	0	0	0
1994	0	0		
1996	0	0	80	100
1998	0	0	35	59
2000	0	0	0	0
Mallard (*Anas platyrhynchos*)				
1972	7,185	8,722	291	266
1973	1,617	1,150		
1989			278	383
1990	1,954	1,382	207	246
1991	8,249	11,958	457	293
1993	3,401	2,532	30	47
1994	3,620	2,998		
1996	7,050	4,549	446	243
1998	4,495	2,269	114	108
2000	9,047	7,657	36	53

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Northern Pintail (*Anas acuta*)				
1972	348	605	177	336
1973	276	492		
1989			0	0
1990	0	0	44	72
1991	0	0	0	0
1993	8	14	0	0
1994	0	0		
1996	23	31	0	0
1998	0	0	0	0
2000	0	0	0	0
Northern Shoveler (*Anas clypeata*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	23	37
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	7	14	0	0
2000	0	0	261	264
Gadwall (*Anas strepera*)				
1972	4,407	8,025	6	11
1973	487	625		
1989			17	30
1990	174	327	27	32
1991	151	257	22	40
1993	155	292	0	0
1994	1,630	2,124		
1996	0	0	0	0
1998	22	31	76	136
2000	7	14	63	97

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
American Wigeon (*Anas americana*)				
1972	474	863	0	0
1973	0	0		
1989			0	0
1990	0	0	68	98
1991	8	14	310	341
1993	0	0	4	8
1994	0	0		
1996	0	0	84	102
1998	0	0	0	0
2000	0	0	196	318
Unidentified Dabbling Duck (*Anas* sp.)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	1,043	1,510	47	51
1991	621	720	9	16
1993	1,607	2,893	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	94	167
2000	0	0	0	0
Greater Scaup (*Aythya marila*)				
1972	0	0	0	0
1973	0	0		
1989			439	518
1990	1,187	1,478	0	0
1991	0	0	147	214
1993	0	0	82	128
1994	1,182	1,584		
1996	168	251	0	0
1998	3,201	4,845	14	24
2000	322	409	81	115

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Lesser Scaup (*Aythya affinis*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	9	16
1998	0	0	0	0
2000	0	0	0	0
Unidentified Scaup (*Aythya marila* or *affinis*)				
1972	1,626	943	29	46
1973	2,583	2,566		
1989			0	0
1990	600	753	0	0
1991	431	775	195	311
1993	328	421	0	0
1994	242	458		
1996	439	415	0	0
1998	680	877	3	5
2000	82	150	0	0
Total Scaup (*Aythya marila* and *affinis*)				
1972	1,626	943	29	46
1973	2,583	2,566		
1989			439	518
1990	1,787	1,616	0	0
1991	431	775	342	375
1993	328	421	82	128
1994	1,424	1,650		
1996	608	471	9	16
1998	3,881	4,922	17	24
2000	404	429	81	115

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Common Eider (*Somateria mollissima*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	3	5
1998	0	0	0	0
2000	0	0	0	0
Steller's Eider (*Polysticta stelleri*)				
1972	0	0	0	0
1973	13	25		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Unidentified Eider (*Somateria* or *Polysticta* sp.)				
1972	40	44	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	3	5
1998	0	0	0	0
2000	0	0	0	0

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Total Eiders (*Somateria* or *Polysticta* spp.)				
1972	40	44	0	0
1973	13	25		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	6	8
1998	0	0	0	0
2000	30	56	0	0
Harlequin Duck (*Histrionicus histrionicus*)				
1972	12,480	3,325	3,607	2,038
1973	15,831	5,528		
1989			3,923	1,318
1990	10,629	2,544	9,341	3,507
1991	11,158	2,872	8,264	3,116
1993	18,619	7,389	8,322	2,658
1994	19,204	4,573		
1996	17,151	4,041	10,619	2,991
1998	14,257	3,469	8,800	2,448
2000	14,881	3,332	9,276	2,955
Long-tailed Duck (*Clangula hyemalis*)				
1972	19,187	16,562	90	147
1973	11,377	8,314		
1989			0	0
1990	8,635	10,373	92	109
1991	3,169	1,419	47	69
1993	7,035	3,241	17	16
1994	4,109	2,714		
1996	6,852	5,722	3	5
1998	16,580	18,022	3	5
2000	1,456	890	30	48

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Black Scoter (*Melanitta nigra*)				
1972	4,119	2,575	35	36
1973	8,671	8,197		
1989			1,235	1,765
1990	2,765	1,510	42	51
1991	1,387	825	431	457
1993	1,956	1,048	276	244
1994	2,541	1.219		
1996	1,837	1,888	75	112
1998	2,772	3,252	107	150
2000	1,086	794	25	25
Surf Scoter (*Melanitta perspicillata*)				
1972	16,400	6,162	8,177	6,280
1973	27,089	17,248		
1989			528	381
1990	4,554	1,355	1,955	2,373
1991	9,313	4,709	1,069	710
1993	5,921	1,941	1,980	1,031
1994	7,451	4,894		
1996	6,492	3,074	3,024	2,124
1998	29,476	48,176	1,220	751
2000	6,518	2,858	6,017	4,266
White-winged Scoter (*Melanitta fusca*)				
1972	23,910	12,909	4,763	3,023
1973	16,782	6,523		
1989			3,024	3,003
1990	3,316	1,349	1,089	1,350
1991	5,296	2,747	3,564	3,131
1993	6,959	4,341	7,593	8,132
1994	8,165	3,822		
1996	6,203	3,691	437	366
1998	19,464	26,885	2,375	3,013
2000	24,181	37,389	5,167	6,210

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Unidentified Scoter (*Melanitta* sp.)				
1972	8,505	7,327	0	0
1973	7,647	7,493		
1989			937	1,165
1990	2,136	2,402	1,464	1,658
1991	890	998	887	662
1993	3,761	2,028	808	968
1994	2,340	2,218		
1996	1,644	1,488	67	81
1998	4,168	7,256	2,333	2,039
2000	373	488	0	0
Total Scoters (*Melanitta* spp.)				
1972	52,935	19,345	12,975	7,069
1973	60,187	22,389		
1989			5,724	3,619
1990	12,770	3,557	4,551	4,258
1991	16,886	7,067	5,950	3,821
1993	18,597	5,736	10,657	8,295
1994	20,497	6,667		
1996	16,177	5,885	6,603	2,203
1998	55,879	85,267	6,033	4,930
2000	32,158	37,513	11,210	9,183
Common Goldeneye (*Bucephala clangula*)				
1972	0	0	0	0
1973	0	0		
1989			204	194
1990	896	721	28	28
1991	148	121	135	139
1993	102	112	123	112
1994	1,842	1,748		
1996	1,770	1,088	61	51
1998	3,978	3,679	76	58
2000	1,074	522	62	58

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Barrow's Goldeneye (*Bucephala islandica*)				
1972	0	0	0	0
1973	0	0		
1989			99	105
1990	14,970	3,601	6	9
1991	20,311	6,070	50	69
1993	13,694	3,628	73	75
1994	31,649	15,931		
1996	26,443	4,321	161	160
1998	32,484	16,247	224	220
2000	28,020	8,471	124	104
Unidentified Goldeneye (*Bucephala clangula* or *islandica*)				
1972	14,802	4,741	427	381
1973	25,230	12,509		
1989			87	92
1990	3,678	1,678	203	146
1991	3,181	2,306	671	895
1993	20,274	7,866	446	475
1994	19,211	10,366		
1996	7,677	4,835	165	197
1998	2,267	1,833	60	37
2000	5,992	5,205	35	29
Total Goldeneyes (*Bucephala clangula* and *islandica*)				
1972	14,802	4,741	427	381
1973	25,230	12,509		
1989			390	254
1990	19,544	4,397	237	148
1991	23,639	6,361	856	909
1993	34,070	9,093	642	558
1994	52,702	21,857		
1996	35,891	7,355	388	265
1998	38,729	16,879	361	229
2000	35,086	10,201	221	128

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Bufflehead (*Bucephala albeola*)				
1972	8,198	4,981	0	0
1973	5,612	2,422		
1989			0	0
1990	4,122	1,666	0	0
1991	2,129	660	20	27
1993	4,125	1,856	22	28
1994	6,523	2,139		
1996	6,875	2,392	0	0
1998	9,813	4,611	3	5
2000	5,411	2,439	18	31
Common Merganser (*Mergus merganser*)				
1972	0	0	0	0
1973	0	0		
1989			2,670	1,347
1990	1,076	386	3,425	2,046
1991	4,466	2,322	2,389	894
1993	5,954	3,114	3,227	986
1994	7,460	3,641		
1996	2,721	1,358	2,886	838
1998	20,530	18,316	3,818	1,273
2000	2,798	1,750	3,071	998
Red-breasted Merganser (*Mergus serrator*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	1,477	476	106	82
1991	231	160	0	0
1993	465	408	352	237
1994	7,824	11,255		
1996	2,424	1,400	18	23
1998	2,226	2,222	69	63
2000	1,223	870	58	41

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Unidentified Merganser (*Mergus* sp.)				
1972	5,797	3,111	6,670	4,798
1973	4,473	1,634		
1989			0	0
1990	867	552	409	223
1991	1,226	1,641	299	209
1993	2,825	3,110	459	241
1994	6,464	5,530		
1996	1,364	1,244	200	125
1998	159	117	149	113
2000	1,793	1,763	279	398
Total Mergansers (*Mergus* spp.)				
1972	5,797	3,111	6,670	4,798
1973	4,473	1,634		
1989			2,670	1,347
1990	3,420	875	3,941	2,062
1991	5,924	3,336	2,688	932
1993	9,244	4,749	4,038	1,015
1994	21,748	18,472		
1996	6,510	2,471	3,104	855
1998	22,915	18,328	3,818	1,273
2000	5,814	3,244	3,408	1,139
Unidentified Diving/Sea Duck				
1972	0	0	0	0
1973	0	0		
1989			376	310
1990	2,202	2,754	98	99
1991	3,227	1,505	1,008	492
1993	1,675	895	655	432
1994	950	535		
1996	107	155	60	95
1998	29	32	0	0
2000	72	80	0	0

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Unidentified Duck				
1972	0	0	0	0
1973	0	0		
1989			65	83
1990	404	401	0	0
1991	76	82	20	27
1993	408	502	4	8
1994	24	45		
1996	269	343	39	42
1998	376	693	87	97
2000	75	73	0	0
Total Waterfowl (Family Anatidae)				
1972	127,673	42,739	24,524	10,279
1973	127,885	37,920		
1989			14,046	4,615
1990	66,728	14,400	20,625	7,453
1991	75,676	21,503	23,198	8,958
1993	99,309	21,977	27,572	11,158
1994	132,480	37,289		
1996	97,528	16,758	19,772	4,351
1998	167,344	108,140	19,471	5,792
2000	104,510	41,127	24,865	9,769
Hawks, Eagles and Falcons				
Bald Eagle (*Haliaeetus leucocephalus*)				
1972	1,372	382	1,172	419
1973	1,916	525		
1989			1,120	235
1990	1,620	366	1,473	273
1991	1,811	489	2,325	356
1993	2,678	911	2,387	686
1994	4,612	2,133		
1996	3,893	832	3,046	741
1998	4,783	1,580	4,247	916
2000	3,877	689	2,414	549

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Unidentified Eagle (*Haliaeetus* or *Aquila* sp.)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	8	14	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Peregrine Falcon (*Falco peregrinus*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	6	7
1998	0	0	3	5
2000	0	0	7	9
Northern Goshawk (*Accipiter gentilis*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	7	13	0	0
2000	0	0	0	0

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Shorebirds				
Black Oystercatcher (*Haematopus bachmani*)				
1972	181	337	544	410
1973	207	355		
1989			432	126
1990	15	19	766	202
1991	8	14	773	316
1993	12	16	864	224
1994	14	19		
1996	34	37	754	192
1998	66	84	1,010	249
2000	119	215	893	284
Black-bellied Plover (*Pluvialis squatarola*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	7	11
1998	6	11	0	0
2000	0	0	0	0
Semipalmated Plover (*Charadrius semipalmatus*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	6	10
2000	0	0	0	0

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Lesser Yellowlegs (*Tringa flavipes*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	11	13
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Greater Yellowlegs (*Tringa melanoleuca*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	17	22
2000	0	0	0	0
Unidentified Yellowlegs (*Tringa flavipes* or *melanoleuca*)				
1972	0	0	6	11
1973	0	0		
1989			0	0
1990	0	0	84	91
1991	0	0	0	0
1993	0	0	4	8
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Solitary Sandpiper (*Tringa solitaria*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	3	5
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Wandering Tattler (*Heteroscelus incanus*)				
1972	0	0	408	353
1973	0	0		
1989			3	5
1990	0	0	84	73
1991	0	0	8	9
1993	0	0	0	0
1994	0	0		
1996	0	0	96	50
1998	0	0	21	32
2000	0	0	36	25
Spotted Sandpiper (*Actitus macularia*)				
1972	0	0	55	56
1973	0	0		
1989			13	13
1990	0	0	48	26
1991	0	0	21	16
1993	0	0	8	10
1994	0	0		
1996	0	0	85	41
1998	0	0	63	80
2000	0	0	66	34

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Whimbrel (*Numenius phaeopus*)				
1972	0	0	27	54
1973	0	0		
1989			108	133
1990	0	0	39	40
1991	0	0	30	35
1993	0	0	64	76
1994	0	0		
1996	0	0	60	64
1998	0	0	19	32
2000	0	0	67	94
Black Turnstone (*Arenaria melanocephala*)				
1972	0	0	0	0
1973	0	0		
1989			5,169	8,994
1990	37	59	802	763
1991	303	554	22	26
1993	0	0	69	66
1994	31	57		
1996	0	0	39	32
1998	392	488	188	202
2000	12	23	49	86
Ruddy Turnstone (*Arenaria interpres*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	31	56	0	0
1994	0	0		
1996	0	0	134	188
1998	0	0	0	0
2000	0	0	0	0

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Unidentified Turnstone (*Arenaria* sp.)				
1972	57	76	0	0
1973	66	126		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Surfbird (*Aphriza virgata*)				
1972	8	15	1,582	2,352
1973	0	0		
1989			679	798
1990	906	1,266	686	688
1991	0	0	3,880	3,385
1993	0	0	4,285	4,599
1994	250	386		
1996	706	1,175	1,642	1,246
1998	243	338	3,783	2,421
2000	641	869	803	854
Sanderling (*Calidris alba*)				
1972	0	0	0	0
1973	157	322		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0

Appendix D (continued).

Species/Year	March N	March CI	July N	July CI
Semipalmated Sandpiper (*Calidris pusilla*)				
1972	0	0	0	0
1973	0	0		
1989			9	15
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Western Sandpiper (*Calidris mauri*)				
1972	0	0	95	163
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	16	26
2000	0	0	0	0
Rock Sandpiper (*Calidris ptilocnemis*)				
1972	775	822	0	0
1973	7,188	7,976		
1989			0	0
1990	0	0	0	0
1991	197	221	0	0
1993	435	733	109	133
1994	344	341		
1996	169	198	3	5
1998	2,629	2,343	0	0
2000	6,194	6,334	0	0

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Dunlin (*Calidris alpina*)				
1972	0	0	0	0
1973	42	65		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	8	14
1998	0	0	0	0
2000	0	0	0	0
Short-billed Dowitcher (*Limnodromus griseus*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	16	27
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Long-billed Dowitcher (*Limnodromus scolopaceus*)				
1972	0	0	0	0
1973	0	0		
1989			6	10
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Unidentified Dowitcher (*Limnodromus* sp.)				
1972	0	0	12	22
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Red-necked Phalarope (*Phalaropus lobatus*)				
1972	0	0	2,178	3,561
1973	0	0		
1989			9,701	9,169
1990	0	0	2,414	1,323
1991	0	0	19,218	27,529
1993	0	0	1,938	1,739
1994	0	0		
1996	0	0	7,427	4,300
1998	0	0	2,703	1,843
2000	0	0	0	0
Unidentified Phalarope (*Phalaropus* sp.)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	163	262
1991	0	0	0	0
1993	0	0	121	205
1994	0	0		
1996	0	0	604	1,097
1998	0	0	834	1,060
2000	0	0	0	0

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Unidentified *Calidris* sp.				
1972	329	316	0	0
1973	0	0		
1989			612	862
1990	0	0	3	5
1991	0	0	41	37
1993	0	0	18	31
1994	0	0		
1996	0	0	68	112
1998	0	0	230	270
2000	0	0	0	0
Unidentified Shorebird				
1972	306	595	1,296	2,141
1973	0	0		
1989			545	453
1990	2,547	3,152	754	529
1991	31	57	143	90
1993	192	299	118	77
1994	415	633		
1996	1,142	1,500	13	24
1998	184	335	283	415
2000	0	0	6	7
Total Shorebirds (Families Haematopodidae and Scolopacidae, except *Phalaropus* sp.)				
1972	1,656	1,185	4,025	3,202
1973	7,660	7,986		
1989			7,576	9,942
1990	3,504	3,394	3,268	1,330
1991	538	660	4,919	3,435
1993	670	790	5,570	4,618
1994	2,369	2,140		
1996	2,050	1,904	2,929	1,368
1998	3,521	2,649	5,759	2,648
2000	6,966	6,387	1,921	945

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Jaegers				
Pomarine Jaeger (*Stercorarius pomarinus*)				
1972	0	0	1,011	662
1973	0	0		
1989			1,508	774
1990	0	0	699	396
1991	0	0	0	0
1993	0	0	369	263
1994	0	0		
1996	0	0	144	142
1998	0	0	41	69
2000	0	0	0	0
Parasitic Jaeger (*Stercorarius parasiticus*)				
1972	0	0	203	316
1973	0	0		
1989			505	309
1990	0	0	56	94
1991	0	0	371	247
1993	0	0	127	113
1994	0	0		
1996	0	0	341	321
1998	0	0	9	16
2000	0	0	213	187
Long-tailed Jaeger (*Stercorarius longicaudus*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	4	8
1991	0	0	63	95
1993	0	0	75	124
1994	0	0		
1996	0	0	0	0
1998	0	0	5	8
2000	0	0	0	0

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Unidentified Jaeger (*Stercorarius* sp.)				
1972	0	0	29	57
1973	0	0		
1989			1,543	954
1990	0	0	538	343
1991	0	0	115	108
1993	0	0	186	159
1994	0	0		
1996	0	0	6	9
1998	0	0	171	196
2000	0	0	0	0
Total Jaegers (*Stercorarius* spp.)				
1972	0	0	1,243	841
1973	0	0		
1989			3,556	1,305
1990	0	0	1,296	628
1991	0	0	549	276
1993	0	0	757	394
1994	0	0		
1996	0	0	491	349
1998	0	0	224	208
2000	0	0	213	187
Gulls				
Bonaparte's Gull (*Larus philadelphia*)				
1972	112	248	9,848	9,803
1973	336	997		
1989			2,469	1,843
1990	0	0	1,423	1,153
1991	94	178	823	689
1993	0	0	2,108	1,646
1994	0	0		
1996	0	0	1,620	1,343
1998	0	0	600	637
2000	0	0	2,618	4,125

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Mew Gull (*Larus canus*)				
1972	8,949	10,045	8,588	3,004
1973	3,401	1,860		
1989			5,645	1,909
1990	2,457	1,286	8,254	2,793
1991	9,785	3,339	3,278	1,096
1993	9,069	10,036	5,353	1,353
1994	12,590	3,332		
1996	20,324	11,702	14,164	5,526
1998	6,797	3,383	5,604	1,671
2000	3,124	1,724	6,770	1,880
Herring Gull (*Larus argentatus*)				
1972	198	176	0	0
1973	396	1,439		
1989			7	9
1990	154	172	125	129
1991	96	133	214	180
1993	858	548	48	38
1994	1,987	2,046		
1996	60	72	58	64
1998	676	793	53	65
2000	307	247	144	137
Glaucous-winged Gull (*Larus glaucescens*)				
1972	27,930	12,405	51,850	33,230
1973	32,215	17,002		
1989			21,255	4,876
1990	8,269	1,866	31,979	7,789
1991	10,226	3,693	25,107	5,504
1993	10,053	4,653	33,616	10,554
1994	42,480	18,750		
1996	13,936	5,442	25,095	6,547
1998	14,578	7,406	24,020	6,249
2000	12,844	4,949	27,638	7,275

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Glaucous Gull (*Larus hyperboreus*)				
1972	5	10	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	3	5
1994	0	0		
1996	0	0	3	5
1998	0	0	214	349
2000	6	12	0	0
Black-legged Kittiwake (*Rissa tridactyla*)				
1972	9,444	11,013	106,764	39,116
1973	6,102	3,214		
1989			58,642	9,569
1990	157	118	42,191	8,757
1991	843	455	61,596	9,552
1993	3,292	2,919	73,093	25,012
1994	4,451	2,187		
1996	5,279	2,129	48,227	18,882
1998	12,568	6,130	35,012	7,470
2000	6,244	3,015	28,187	7,575
Unidentified Gull (*Larus* or *Rissa* sp.)				
1972	3,607	3,226	146	244
1973	0	0		
1989			13,063	8,204
1990	4,230	4,750	4,975	2,141
1991	1,440	973	4,124	1,817
1993	18,547	11,969	2,510	2,175
1994	3,932	2,194		
1996	1,392	1,460	587	290
1998	544	398	2,137	1,796
2000	1,493	1,008	4,894	8,294

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Total Gulls (*Larus* and *Rissa* spp.)				
1972	50,247	23,401	177,196	59,393
1973	42,451	18,416		
1989			101,082	15,939
1990	15,267	5,541	88,947	15,680
1991	22,483	5,398	95,143	12,917
1993	41,818	17,235	116,730	27,834
1994	65,441	21,323		
1996	40,991	15,362	89,753	21,638
1998	35,163	11,284	67,765	13,141
2000	24,019	6,993	70,250	15,990
Terns				
Caspian Tern (*Sterna caspia*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	40	68
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	5	8
2000	0	0	41	35
Arctic Tern (*Sterna paradisaea*)				
1972	0	0	33,177	9,504
1973	0	0		
1989			7,279	2,455
1990	0	0	6,240	1,782
1991	0	0	6,224	1,384
1993	0	0	8,558	4,893
1994	0	0		
1996	0	0	4,852	1,656
1998	0	0	2,415	1,017
2000	0	0	2,903	1,280

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Aleutian Tern (*Sterna aleutica*)				
1972	0	0	6	11
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	323	483
1993	0	0	114	133
1994	0	0		
1996	0	0	320	549
1998	0	0	0	0
2000	0	0	0	0
Unidentified Tern (*Sterna* sp.)				
1972	0	0	0	0
1973	0	0		
1989			52	76
1990	0	0	49	81
1991	0	0	318	323
1993	0	0	481	409
1994	0	0		
1996	0	0	224	250
1998	0	0	0	0
2000	0	0	0	0
Total Terns (*Sterna* spp.)				
1972	0	0	33,183	9,504
1973	0	0		
1989			7,331	2,456
1990	0	0	6,289	1,783
1991	0	0	6,905	1,548
1993	0	0	9,153	4,901
1994	0	0		
1996	0	0	5,396	1,710
1998	0	0	2,420	1,017
2000	0	0	2,944	1,281

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Alcidae				
Common Murre (*Uria aalge*)				
1972	0	0	0	0
1973	0	0		
1989			268	209
1990	4,895	2,107	875	530
1991	11,735	6,637	4,533	1,494
1993	157,177	142,396	16,005	6,433
1994	47,340	18,083		
1996	44,856	19,597	2,751	2,151
1998	87,198	49,337	3,823	2,959
2000	27,317	12,552	1,061	722
Thick-billed Murre (*Uria lomvia*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	60	110
1991	0	0	0	0
1993	264	505	0	0
1994	0	0		
1996	0	0	53	93
1998	0	0	0	0
2000	98	141	0	0
Unidentified Murre (*Uria* sp.)				
1972	8,195	4,037	5,915	3,405
1973	10,681	9,144		
1989			1,914	1,436
1990	2,597	1,960	576	561
1991	12,368	6,898	2,505	1,287
1993	63,528	38,015	364	350
1994	4,387	1,860		
1996	1,223	658	475	439
1998	427	365	133	128
2000	4,108	1,808	53	92

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Total Murres (*Uria* spp.)				
1972	8,195	4,037	5,915	3,405
1973	10,681	9,144		
1989			2,183	1,503
1990	7,492	2,978	1,512	796
1991	24,103	12,076	7,038	2,061
1993	220,969	162,517	16,368	6,439
1994	51,727	18,692		
1996	46,079	19,571	3,280	2,177
1998	87,625	49,287	3,956	3,016
2000	31,523	12,578	1,114	745
Pigeon Guillemot (*Cepphus columba*)				
1972	3,695	1,294	15,567	5,134
1973	9,188	6,231		
1989			4,070	1,488
1990	812	348	2,961	762
1991	2,842	2,178	6,625	4,941
1993	1,640	916	3,947	953
1994	1,276	660		
1996	2,541	1,056	2,982	905
1998	903	714	3,466	837
2000	1,139	1,126	1,797	519
Marbled Murrelet (*Brachyramphus marmoratus*)				
1972	11,567	2,413	236,633	51,727
1973	72,675	25,410		
1989			59,284	11,825
1990	13,764	5,939	39,486	9,986
1991	7,717	4,595	42,477	9,151
1993	7,360	4,090	14,177	4,499
1994	23,260	15,542		
1996	25,801	9,032	63,455	16,043
1998	29,147	11,388	49,879	9,444
2000	17,570	10,606	52,377	14,471

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Kittlitz's Murrelet (*Brachyramphus brevirostris*)				
1972	346	657	63,229	80,122
1973	3,219	3,827		
1989			6,436	3,151
1990	958	1,599	5,231	8,457
1991	466	398	1,184	1,121
1993	448	326	2,710	1,343
1994	0	0		
1996	181	238	1,280	1,364
1998	78	96	279	192
2000	0	0	1,033	1,339
Unidentified *Brachyramphus* Murrelet sp.				
1972	0	0	4,570	7,875
1973	0	0		
1989			41,634	8,221
1990	11,379	7,026	36,624	7,910
1991	15,328	7,288	62,816	14,012
1993	6,176	3,267	142,546	41,876
1994	13,058	4,969		
1996	18,351	6,756	17,429	5,990
1998	4,621	2,775	3,036	2,134
2000	5,874	2,108	1,077	1,017
Total *Brachyramphus* Murrelet spp.				
1972	11,913	2,454	304,432	98,430
1973	75,893	31,963		
1989			107,354	17,483
1990	26,102	9,663	81,341	17,758
1991	23,510	11,171	106,478	20,095
1993	13,983	6,286	159,433	42,059
1994	36,318	17,705		
1996	44,333	13,158	82,165	18,917
1998	33,845	12,652	53,194	10,583
2000	23,443	11,715	54,488	14,605

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Ancient Murrelet (*Synthliboramphus antiquus*)				
1972	0	0	446	347
1973	0	0		
1989			26	26
1990	0	0	265	260
1991	81	145	231	223
1993	0	0	1,874	1,281
1994	0	0		
1996	0	0	188	185
1998	0	0	0	0
2000	0	0	82	138
Cassin's Auklet (*Ptychoramphus aleuticus*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	39	48	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Parakeet Auklet (*Cyclorrhynchus psittacula*)				
1972	0	0	1,893	1,455
1973	5	8		
1989			501	665
1990	0	0	842	529
1991	0	0	7	11
1993	0	0	725	648
1994	0	0		
1996	0	0	809	419
1998	0	0	588	397
2000	0	0	462	513

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Rhinoceros Auklet (*Cerorhina monocerata*)				
1972	0	0	269	283
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Tufted Puffin (*Fratercula cirrhata*)				
1972	0	0	9,596	4,798
1973	0	0		
1989			2,282	1,128
1990	0	0	3,819	1,588
1991	23	43	5,043	2,011
1993	0	0	4,092	1,356
1994	0	0		
1996	0	0	5,049	2,126
1998	0	0	4,481	2,905
2000	0	0	4,707	3,957
Horned Puffin (*Fratercula corniculata*)				
1972	0	0	3,580	3,055
1973	0	0		
1989			1,856	1,867
1990	0	0	1,252	784
1991	81	137	1,297	818
1993	0	0	1,520	1,209
1994	0	0		
1996	0	0	499	391
1998	0	0	994	603
2000	0	0	378	405

Appendix D (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Unidentified Puffin (*Fratercula* sp.)				
1972	0	0	0	0
1973	0	0		
1989			106	134
1990	0	0	0	0
1991	0	0	38	63
1993	0	0	342	386
1994	0	0		
1996	0	0	0	0
1998	0	0	242	315
2000	0	0	0	0
Total Puffins (*Fratercula* spp.)				
1972	0	0	13,176	5,799
1973	0	0		
1989			4,244	2,217
1990	0	0	5,071	1,960
1991	104	144	6,378	2,219
1993	0	0	5,954	2,360
1994	0	0		
1996	0	0	5,548	2,305
1998	0	0	5,717	3,108
2000	0	0	5,085	3,960
Dovekie (*Alle alle*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	3	5
2000	0	0	0	0

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Unidentified Alcid				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	251	412	619	324
1991	621	438	1,584	1,050
1993	468	382	205	160
1994	368	245		
1996	0	0	468	308
1998	0	0	3	5
2000	37	62	75	125
Total Alcids				
1972	23,802	5,437	341,698	98,011
1973	95,768	24,324		
1989			118,378	18,067
1990	34,658	10,703	92,610	17,980
1991	51,300	17,385	128,340	21,867
1993	237,060	162,810	188,507	42,803
1994	89,690	27,667		
1996	92,952	23,376	95,440	19,406
1998	122,373	51,861	67,197	11,786
2000	56,143	21,143	63,102	15,117
Kingfishers				
Belted Kingfisher (*Ceryle alcyon*)				
1972	0	0	0	0
1973	9	17		
1989			21	16
1990	12	15	10	10
1991	0	0	12	12
1993	32	26	64	41
1994	81	45		
1996	48	34	121	54
1998	108	98	48	27
2000	37	55	8	9

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Passerines				
Black-billed Magpie (*Pica pica*)				
1972	141	151	12	22
1973	123	92		
1989			0	0
1990	88	80	50	33
1991	52	51	43	29
1993	101	54	29	22
1994	521	211		
1996	383	231	64	33
1998	444	174	35	32
2000	419	234	33	19
Northwestern Crow (*Corvus caurinus*)				
1972	7,283	3,470	2,074	1,029
1973	8,887	5,553		
1989			1,479	609
1990	3,041	1,881	1,638	523
1991	3,325	1,607	2,061	607
1993	2,905	1,223	1,944	603
1994	5,990	2,012		
1996	7,053	3,822	2,574	702
1998	6,057	2,474	2,608	532
2000	4,949	1,869	2,366	509
Common Raven (*Corvus corax*)				
1972	98	100	79	87
1973	52	40		
1989			121	190
1990	178	179	157	148
1991	302	278	62	80
1993	451	322	79	41
1994	108	62		
1996	252	213	45	36
1998	168	85	59	42
2000	1,409	2,484	64	88

Appendix D (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Unidentified Bird				
1972	1,025	767	0	0
1973	0	0		
1989			2,056	977
1990	1,293	1,206	871	476
1991	2,288	2,360	281	224
1993	1,182	770	204	193
1994	522	469		
1996	14	18	67	94
1998	0	0	0	0
2000	411	547	186	200
Total Marine Birds				
1972	235,579	63,480	628,696	141,858
1973	328,091	56,955		
1989			302,538	54,444
1990	141,911	22,902	237,900	32,570
1991	171,433	30,868	343,357	98,670
1993	402,760	167,697	371,327	58,189
1994	320,470	62,640		
1996	253,001	34,917	246,572	41,400
1998	358,935	143,974	201,765	46,179
2000	210,945	52,471	204,349	35,071

Appendix E. Estimated numbers of marine mammals (*N* ± 95% CI) for species observed in Prince William Sound during March and July 1972-73 (Haddock et al., unpubl. data), 1989-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), 1994 (Agler et al. 1995), 1996 (Agler and Kendall 1997), 1998 (Lance et al. 1999), and 2000. Surveys were not conducted in July 1973, July 1994, or March 1989.

	March		July	
Species/Year	*N*	CI	*N*	CI
Cetaceans				
Harbor Porpoise (*Phocoena phocoena*)				
1972	395	454	939	693
1973	818	2,074		
1989			0	0
1990	197	364	0	0
1991	155	257	112	191
1993	372	312	789	609
1994	75	124		
1996	413	439	0	0
1998	0	0	0	0
2000	41	69	3	5
Dall's Porpoise (*Phocoenoides dalli*)				
1972	2,356	3,054	5,782	2,567
1973	9,467	6,110		
1989			153	154
1990	1,330	1,286	1,012	1,009
1991	0	0	482	299
1993	1,394	1,680	435	503
1994	944	696		
1996	1,728	1,129	1,104	713
1998	2,263	1,776	2,359	1,461
2000	2,769	2,693	909	703
Unidentified Porpoise				
1972	1,052	867	1,207	963
1973	1,522	6,214		
1989			0	0
1990	41	69	39	48
1991	0	0	40	62
1993	0	0	224	249
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0

Appendix E (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Killer Whale (*Orcinus orca*)				
1972	243	352	101	187
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	36	45
1993	16	29	37	62
1994	0	0		
1996	0	0	6	9
1998	0	0	0	0
2000	82	148	0	0
Minke Whale (*Balaenoptera acutorostrata*)				
1972	0	0	7	16
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	39	48
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Humpback Whale (*Megaptera novaeangliae*)				
1972	0	0	188	281
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	225	170
1994	0	0		
1996	0	0	530	397
1998	0	0	241	233
2000	0	0	0	0

Appendix E (continued).

Species/Year	March *N*	March CI	July *N*	July CI
Unidentified Whale				
1972	0	0	125	245
1973	106	132		
1989			62	106
1990	0	0	78	96
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0
Otters				
Sea Otter (*Enhydra lutris*)				
1972	2,561	1,158	8,868	8,268
1973	2,979	1,997		
1989			8,238	2,056
1990	5,968	1,682	6,648	3,159
1991	4,413	989	6,634	1,878
1993	6,813	1,861	8,216	2,435
1994	7,746	2,073		
1996	8,139	2,207	10,776	3,988
1998	8,049	4,073	6,515	3,240
2000	4,668	1,179	5,093	1,689
River Otter (*Lutra canadensis*)				
1972	0	0	0	0
1973	0	0		
1989			9	16
1990	75	53	15	15
1991	0	0	23	24
1993	0	0	77	47
1994	100	73		
1996	60	54	135	85
1998	46	28	45	33
2000	67	53	77	43

Appendix E (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Unidentified Otter				
1972	41	45	0	0
1973	0	0		
1989			0	0
1990	6	12	3	5
1991	0	0	0	0
1993	0	0	4	8
1994	0	0		
1996	6	10	0	0
1998	0	0	0	0
2000	0	0	0	0
Sea Lions				
Steller Sea Lion (*Eumetopias jubatus*)				
1972	2,518	1,599	80	96
1973	6,733	7,419		
1989			2,358	2,366
1990	6,261	10,051	3,702	3,066
1991	3,795	4,600	2,312	2,364
1993	3,260	3,694	1,000	796
1994	2,080	2,404		
1996	1,955	1,655	953	878
1998	954	963	2,115	1,729
2000	2,249	2,058	834	796
California Sea Lion (*Zalophus californianus*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	4	8
1998	0	0	0	0
2000	0	0	0	0

Appendix E (continued).

Species/Year	March		July	
	N	CI	*N*	CI
Northern Fur Seal (*Callorhinus ursinus*)				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	0	0	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	40	68
1998	0	0	0	0
2000	0	0	0	0
Seals				
Harbor Seal (*Phoca vitulina*)				
1972	5,585	2,820	16,204	12,449
1973	4,239	2,016		
1989			2,428	870
1990	1,832	779	2,666	2,807
1991	911	452	1,583	491
1993	1,513	1,313	16,920	26,784
1994	1,434	1,67		
1996	983	418	1,195	391
1998	1,766	823	1,184	456
2000	1,572	1,259	1,201	554
Unidentified Pinniped				
1972	0	0	0	0
1973	0	0		
1989			0	0
1990	0	0	0	0
1991	12	23	0	0
1993	0	0	0	0
1994	0	0		
1996	0	0	0	0
1998	0	0	0	0
2000	0	0	0	0

Appendix F. Estimated number of marine birds (± 95% CI) from small boat surveys of Prince William Sound during winter and summer of 1972-73 (Haddock et al., unpubl. data), 1989-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), 1994 (Agler et al. 1995), 1996 (Agler and Kendall 1997), 1998 (Lance et al. 1999), and 2000.

	Winter[a]		Summer[b]	
Year	*N*	CI	*N*	CI
1972	235,579	63,480	628,696	141,858
1973	328,091	59,955	475,618	144,213
1989	nd [c]	nd [c]	302,538	54,444
1990	141,911	22,902	237,900	32,570
1991	171,433	30,868	343,357	98,670
1993	402,760	167,697	371,327	58,189
1994	320,470	62,640	nd [c]	nd [c]
1996	253,001	34,917	246,572	41,400
1998	358,935	143,974	201,765	46,179
2000	210,945	52,471	204,349	35,071

[a] All winter surveys were conducted in March, except for March 1989, when no survey was conducted.
[b] Surveys were conducted during July, except for 1973, when the Sound was surveyed in August and 1994. There was no summer survey in 1994.
[c] nd = no data

Appendix G. Estimated number of marine birds (± 95% CI) from small boat surveys of Prince William Sound during March 1990-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), 1994 (Agler et al. 1995), and 1996, and July 1989-91 (Klosiewski and Laing 1994), 1993 (Agler et al. 1994), 1996 (Agler and Kendall 1997), 1998 (Lance et al. 1999), and 2000 listed by zone oiled by the *T/V Exxon Valdez* oil spill.

	Oiled Area		Unoiled Area	
Year	*N*	CI	*N*	CI
March				
1990	36,343	7,760	105,568	21,547
1991	49,649	13,422	121,784	27,797
1993	83,171	34,794	319,589	164,048
1994	86,045	27,031	234,425	56,507
1996	64,402	17,081	188,599	30,454
1998	58,304	16,511	300,632	143,024
2000	37,468	8,197	173,477	51,826
July				
1989	102,402	20,032	200,136	50,625
1990	88,191	20,140	149,709	25,597
1991	116,115	24,129	227,242	95,674
1993	116,219	26,896	255,108	51,600
1996	74,039	25,200	172,533	32,846
1998	70,483	12,409	131,281	44,481
2000	80,388	26,215	123,960	23,297

Appendix H. Summary of non-injured marine bird species/species groups population trends in PWS, Alaska after the *Exxon Valdez* oil spill. Winter resident or summer breeding marine bird species/species groups with 7 year population estimate of >500 birds were used.

Fork-tailed Storm-Petrels, "scaups," Long-tailed Ducks, Bonaparte's Gulls, Herring Gulls, Parakeet Auklets, and "puffins" were examined by Klosiewski and Laing (1994) and Day et al. (1997), although injury from the oil spill was never documented. The homogeneity of slopes test and regression on winter densities of "scaups," Long-tailed Ducks, and Herring Gulls and summer densities of Fork-tailed Storm-Petrels, Bonaparte's Gulls, Parakeet Auklets, and "puffins" in the oiled and unoiled areas of PWS indicate no trend for these species. "Puffins" had previously suggested an increasing population trend (Lance et al. 1999). These patterns may reflect differences in foraging distributions or the fact that the largest colonies of both Horned and Tufted Puffins are at Smith, Little Smith, and Seal Islands, all within the oiled area (USFWS unpubl. data). Thus, any growth in PWS "puffin" populations would most likely occur in the oiled areas.

Below is a summary of statistically significant trends in post-spill densities of non-injured marine birds in PWS, Alaska, after the *Exxon Valdez* oil spill.[a]

Taxa	Oiled area		Oiled area relative to unoiled		Unoiled area	
	Trend in July	Trend in March	Trend in July	Trend in March	Trend in July	Trend in March
"Puffins"	0	nd[b]	0	nd	0	nd
Bonaparte's Gulls	0	nd	0	nd	0	nd
"Scaups"	nd	0	nd	0	nd	0
Herring Gulls	nd	0	nd	0	nd	0
Long-tailed Ducks	nd	0	nd	0	nd	0
Fork-tailed Storm-Petrels	0	nd	0	nd	0	nd
Parakeet Auklets	0	nd	0	nd	0	nd

[a]Trends for the oiled and unoiled areas were determined by regression analyses and refer to an absolute change in the oiled and unoiled area. Trends in oiled area relative to the unoiled area were determined by homogeneity of slopes test and refer to change in the oiled area relative to the unoiled area (+1 = increasing density, 0 = no change, and -1 = decreasing density).
[b]nd = no data, Birds were either not present or too rare to analyze during this season.

Appendix H (continued).

Results of homogeneity of slopes test ($P \leq 0.20$) for non-injured species/species groups from March (1990-91, 1993, 1994, 1996, 1998, and 2000) and July (1989-91, 1993, 1996, 1998, and 2000). NT = no trend, IT = increasing trend, and DC = decreasing trend.

March			
Species/Species Group	Homogeneity of Slopes Test	Oiled Slope	Unoiled Slope
"scaups"	P=0.84 (NT)	0.02 P=0.36 (NT)	0.01 P=0.88
Long-tailed Ducks	P=0..87 (NT)	-0.02 P=0.35 (NT)	-0.03 P=0.74
Herring Gulls	P=0.81 (NT)	-0.001 P=0.95 (NT)	0.01 P=0.82

July			
Species/Species Group	Homogeneity of Slopes Test	Oiled Slope	Unoiled Slope
Fork-tailed Storm-Petrel	P=0.40 (NT)	0.03 P=0.75 (NT)	-0.06 P=0.35
Bonaparte's Gulls	P=0.78 (NT)	-0.01 P=0.35 (NT)	-0.005 P=0.99
Parakeet Auklet	P=0.45 (NT)	0.02 P=0.52 (NT)	-0.01 P=0.72
"puffins"	P=0.29 (NT)	-0.03 P=0.47 (NT)	0.02 P=0.41