Exxon Valdez Oil Spill
Restoration Project Final Report

Common Murre Restoration Monitoring in the Barren Islands, Alaska, 1994

Restoration Project 94039
Final Report

David G. Roseneau
Arthur B. Kettle
G. Vernon Byrd

U.S. Fish and Wildlife Service
Alaska Maritime National Wildlife Refuge
2355 Kachemak Bay Drive (Suite 101)
Homer, Alaska 99603-8021

October 1996

Common Murre Restoration Monitoring in the Barren Islands, Alaska, 1994

Restoration Project 94039
Final Report

Study History: Murre studies sponsored by the *Exxon Valdez* Oil Spill Trustee Council were initiated in 1989 as Department of Interior - Fish and Wildlife Service (DOI-FWS) Bird Study No. 3 (Population Surveys of Seabird Nesting Colonies in Prince William Sound, the Outside Coast of the Kenai Peninsula, Barren Islands, and other nearby Colonies, with Emphasis on Changes in Numbers and Reproduction of Murres). During the course of this 3-year-long damage assessment project, 3 progress reports were submitted to the Trustee Council (see Nysewander and Dipple 1990, 1991; Dipple and Nysewander 1992), and a final report was completed in 1993 (see Nysewander *et al.* 1993, Effects of the *T/V Exxon Valdez* Oil Spill on Murres: A Perspective from Observations at Breeding Colonies). Restoration monitoring work started in 1992, and Barren Islands murre studies were continued as part of Restoration Project No. 11 (see Dragoo *et al.* 1994, Effects of the *T/V Exxon Valdez* Oil Spill on Murres: A Perspective from Observations at Breeding Colonies Four Years after the Spill). This initial restoration monitoring effort became Restoration Project 93049 in 1993 (see Roseneau *et al.* 1995, Common Murre Restoration Monitoring in the Barren Islands, Alaska, 1993). In 1994, a similar restoration monitoring study, Project 94039, was implemented after approval of a detailed DOI-FWS study plan that emphasized collecting additional population numbers, nesting chronology, and productivity data at both Barren Islands colonies (see DOI-FWS Detailed Project Description, Monitoring Recovery of Common Murres in the Barren Islands).

Abstract: This report summarizes the results of the third year of common murre *(Uria aalge)* restoration monitoring work conducted in the northern Gulf of Alaska for the *Exxon Valdez* Oil Spill Trustee Council. Information on population numbers, nesting chronology, and productivity of murres were collected by U.S. Fish and Wildlife Service (FWS) biologists at the East Amatuli Island - Light Rock and Nord Island - Northwest Islet colonies in the Barren Islands during the 1994 nesting season. These data are presented and statistically compared with information reported in the 1989-1993 FWS murre damage assessment and restoration studies, and with data obtained during 1990-1992 University of Washington (UW) and 1991 Dames & Moore (D&M) studies. Although positive trends in population numbers were found on two FWS and three UW plots at East Amatuli Island - Light Rock over the postspill period, no trends were apparent on larger sections of habitat at this colony or at the nearby Nord Island - Northwest Islet nesting complex. Nesting chronology was similar between study sites and about one week earlier than during 1993. Productivity also did not differ between study sites. At Nord Island - Northwest Islet, productivity was similar to 1993 (0.71 fledglings per egg laid vs. 0.74 in 1993); however, at East Amatuli Island - Light Rock, it was significantly higher than in 1993 (0.73 fledglings per egg laid vs. 0.55 in 1993). In general, reproductive success in the Barren Islands was normal to high, compared with other Gulf of Alaska murres colonies.

Key Words: Bald eagle, Barren Islands, black-legged kittiwake, capelin, common murre, common raven, *Corvus corax*, East Amatuli Island, East Amatuli Light Rock, *Exxon Valdez*, forage fish, glaucous-winged gull, Gulf of Alaska, *Haliaeetus leucocephalus*, humpback whale, *Larus glaucescens*, *Mallotus villosus*, *Megaptera novaeangliae*, monitoring, nesting chronology, Nord Island, oil spill, population census, population counts, Prince William Sound, productivity, reproduction, restoration, *Rissa tridactyla*, *Uria aalge*, *Uria lomvia.*

Citation: Roseneau, D.G., A.B. Kettle, and G.V. Byrd. 1995. Common murre restoration monitoring in the Barren Islands, Alaska, 1994, *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 94039), U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge, Homer, Alaska.

Table of Contents

List of Tables

List of Figures

List of Appendices

EXECUTIVE SUMMARY

Introduction

The Barren Islands in the northern Gulf of Alaska supported one of the largest breeding concentrations of common murres *(Uria aalge)* in the path of the *Exxon Valdez* oil spill. When winds and currents swept oil through the region during April-May 1989, many murres were killed: they comprised 74% of 30,000 bird carcasses recovered by 1 August. Based on this information and a computer modeling study, estimates of total bird mortality suggested that 74,000 to 314,000 murres died during the event. Because mortality of murres appeared to be high and large populations of these birds nested in the Barren Islands, the U.S. Fish and Wildlife Service (FWS) conducted *Exxon Valdez* Oil Spill Trustee Council-sponsored murre damage assessment and restoration studies there during 1989-1991 and 1992-1993, respectively. In 1994, FWS biologists continued restoration monitoring work at the Barren Islands during 16 June - 8 September. Results from this study indicated that common murre productivity was high and similar to the 1993 Nord Island levels. Nesting chronology averaged about one week earlier, compared to the previous year's schedule. Although positive trends were found on two small sets of plots, no conclusive evidence of colony-wide population growth was found at the colonies.

Objectives

The project objective was the same as in 1993—to monitor the recovery of common murres at the Barren Islands nesting colonies.

Methods

Population Counts: Three different types of counts were made at the East Amatuli Island - Light Rock and Nord Island - Northwest Islet murre colonies: censuses of entire colonies; counts of sets of multicount plots (plots used for trend analyses that are counted at least five separate times during the census period); and counts of productivity study plots. The multicount and population census plot counts were made from boats using standard FWS protocols that took into account daily and seasonal attendance patterns of adults. Productivity plots were counted from land using standard procedures. Data were compared with information from the 1989-1992 FWS damage assessment and restoration studies; two Exxon-sponsored studies, including one by the University of Washington (UW) in 1990-1992, and one by Dames & Moore (D&M) in 1991; and more recent counts made during the 1993 restoration work. One-way analysis of variance (ANOVA) and Tukey HSD multiple pairwise comparison tests were used to check for differences among years. Counts were tested for trends with Kendall's Tau (τ) rank correlation tests.

Timing of Nesting Events: Median hatching dates were calculated for each of the productivity plots in the data sets. Plots were treated as sample units and median dates were averaged to describe the timing of nesting events at the study sites. Differences between average study site hatching dates and between these dates and 1993 results were checked with two-tailed *t*-tests. Productivity plot data were also used to calculate first and mean laying dates and mean hatching dates; these variables and incidental observations of first laying dates were compared with similar information in FWS and other studies.

Productivity: Productivity data were collected from 10 East Amatuli Island - Light Rock and eight Nord Island study plots using standard FWS protocols that included noting incubation and brooding postures of adults, and analyzed by using midpoints between pre- and post-event observations to estimate laying and hatching dates. Plots were treated as sample units and fledglings-per-egg-laid was used to measure productivity. Hatching and fledging success and periodic-visit and one-day chicks-per-adult numbers were also calculated for comparison with

similar information in FWS and other studies. Among-year differences in periodic-visit and one-day chicks-per-adult results, the only variables available from the 1991-1992 FWS studies, were checked with Tukey HSD multiple pairwise comparison and ANOVA tests, and 2-tailed *t*-tests, respectively.

Avian Predators: Incidental observations of interactions between avian predators and seabirds were recorded to provide general information on disturbance and predation at the nesting colonies.

Results

Population Counts: At East Amatuli Island - Light Rock, the whole-colony count (33,011 birds) was similar to the 1993 score (32,721 birds). Testing these counts for trends in combination with the 1991 D&M score (30,294 birds) and 1991-1992 UW estimates (35,757 and 34,783 birds, respectively) was deferred until additional year of information is available. The Light Rock count (7,750 birds) was also similar to the 1993 score (8,454 birds), and both of these estimates were higher than the reported 1990 FWS Light Rock figure (5,865 birds). Although the 1993 count was higher than the 1989 FWS estimate (6,912 birds), the 1994 score was not, and no trend was apparent in these data over the postspill period. Combining 1991-1992 UW counts (9,256 and 9,655 birds, respectively) with the 1989-1994 FWS estimates did not alter the Light Rock results; no trend was found over the postspill interval. Although the East Amatuli Island - Light Rock multicount plot BMP1-8 and BMP3-4 scores (5,599 and 1,246 birds, respectively) were similar to the 1993 estimates (5,808 and 1,375 birds, respectively), the 1993-1994 BMP3-4 counts (the only FWS data available for multiyear comparison) were significantly higher than all previous FWS estimates on these two plots; a positive trend was detected in this data set. A similar positive increase was also apparent on the three East Amatuli Island OSTR plots, when the combined 1990-1992 UW scores (550, 667, and 700 birds, respectively) and the 1993-1994 FWS counts (1,003 and 866 birds, respectively) were analyzed for trends.

At Nord Island - Northwest Islet, the results of the whole-colony censuses and multicount plot BMP1-11 counts were similar to the 1993 results. The whole-colony estimate (11,753 birds) did not differ from the 1993 score (13,422 birds), or from the 1989-1992 FWS counts (11,838, 12,277, 13,333, and 11,212 birds, respectively), and no trend was found over the postspill period. When the single 1991 D&M whole-colony score (16,592 birds) was combined with these estimates, it did not alter the conclusion that population numbers remained unchanged over this interval. The average Nord Island - Northwest Islet multicount plot BMP1-11 estimate (2,893 birds) was similar to the 1989, 1991, and 1992 FWS counts (2,431, 3,558, and 2,971 birds, respectively); however, it was lower than the 1990 and 1993 FWS scores (4,383 and 4,003 birds, respectively), and no trend was apparent over the postspill period.

Timing of Nesting Events: Murres settled on the Nord Island - Northwest Islet cliffs 10 days later than they did at East Amatuli Island - Light Rock. However, median laying and hatching dates at Nord Island - Northwest Islet and East Amatuli Island - Light Rock were similar (9 and 10 July, and 10 and 11 August, respectively). These dates averaged about one week earlier than the 1993 dates.

Productivity: Productivity was high and similar at the East Amatuli Island - Light Rock and Nord Island study sites (0.73 and 0.74 chicks fledged per egg laid, respectively). Although the Nord Island value was similar to the 1993 results (1993 value = 0.71 fledglings/egg), productivity at East Amatuli Island - Light Rock was significantly higher than it was in 1993 (1993 value = 0.55 fledglings/egg). Hatching and fledging success were also similar at the East Amatuli Island - Light Rock and Nord Island study sites (0.79 and 0.84 chicks/egg laid, and 0.93 and 0.89 fledglings/egg hatched, respectively), and at Nord Island, both variables were similar to the 1993 values (0.80 chicks/egg laid and 0.93 fledglings/egg hatched). At East Amatuli Island - Light Rock, hatching success was similar to the 1993 results (0.79 chicks/egg laid vs. 0.70 in 1993);

however, fledging success was significantly higher than it was in 1993 (0.93 fledglings/egg hatched vs. 0.79 in 1993).

Based on periodic-visit data, chicks-per-adult numbers were also similar between study sites (0.44 and 0.51 chicks/adult at East Amatuli Island - Light Rock and Nord Island, respectively). Both of these values were significantly higher than the 1993 periodic-visit results (0.35 chicks/adult at both study sites) and the reported 1992 periodic-visit number (0.29 chicks/adult at Nord Island). The one-day Nord Island chicks-per-adult value (0.40 chicks/adult) was similar to the reported 1992 single-visit number (0.32 chicks/adult); however, it was significantly higher than the 1993 one-day value (0.27 chicks/adult), and all of the 1992-1994 single-visit results were significantly higher than the reported 1991 one-day value (0.12 chicks/adult).

Avian Predators: As in 1993, bald eagles *(Haliaeetus leucocephalus)*, peregrine falcons *(Falco peregrinus pealei)*, glaucous-winged gulls *(Larus glaucescens)*, and common ravens *(Corvus corax)* frequented the colonies, and disturbance (flushing events) and predation by these avian predators followed the same patterns observed in 1993. Eagles targeted adult murres (Nord Island), whereas gulls and ravens took eggs and chicks (both colonies), particularly when eagles flushed birds from nesting ledges (peregrine falcons favored smaller prey species and rarely interacted directly with murres). Eggs laid early in the nesting season appeared to be more vulnerable to gulls and ravens than those laid after attendance stabilized. Avian predation was higher at Nord Island - Northwest Islet than at East Amatuli Island - Light Rock. Eagles continued to flush murres from the Nord Island nesting cliffs well past the time these events stopped at East Amatuli Island - Light Rock (mid-August vs. early July), and gulls and ravens continued taking advantage of these incidents to search for unprotected eggs. At Nord Island, 11 (58%) of 19 eagle-murre interactions occurred in the southeastern sector of the colony. Observations of incubating and brooding murres on nesting ledges in this area on 8 September provided additional evidence that disturbance and predation were disproportionally high in this part of the colony.

Discussion

Population Counts: Based solely on 1989-1994 FWS data, no evidence of a trend in murre numbers was found on the Light Rock section of the East Amatuli Island - Light Rock colony over the postspill interval; including the somewhat higher 1991-1992 single UW Light Rock scores in the analyses did not alter this conclusion. The combined FWS, UW, and D&M whole-colony information also supported this finding. Although positive trends were detected in the 1989-1994 FWS counts of two East Amatuli Island - Light Rock plots and the combined 1990-1994 UW-FWS estimates from three East Amatuli Island UW plots, these increases should not be interpreted as conclusive evidence of colony-wide population growth because these small plot sets may not represent the entire colony. A new set of eight monitoring plots that sample a broader range of nesting habitats was established at East Amatuli Island - Light Rock in 1993; these plots will provide a better set of data for evaluating changes in murre numbers at this colony.

At Nord Island - Northwest Islet, analyses of the 1989-1994 population census plot information, including the combined FWS and D&M whole-colony data, did not detect any trends in population numbers over the postspill interval. Analyses of multicount and productivity plot information supported this finding.

A review of the 1989-1992 FWS and UW Light Rock estimates identified several factors that may help explain the numerical differences between these two sets of data: use of different methods; the difficulty in counting the densely populated top sections of Light Rock; and the facts that the 1991-1992 UW and 1992 FWS estimates were single counts without any measure of variability, and the 1989-1990 FWS estimates only consisted of two counts each (also fewer than needed to measure variability). Because measurements of variability were not obtained during the

UW and FWS counts, the differences between these two sets of estimates (about 3,500-3,600 birds) may not be as significant as they appear to be.

Timing of Nesting Events: The similarities in average median laying and hatching dates at East Amatuli Island - Light Rock and Nord Island - Northwest Islet indicated that nesting chronologies followed the same schedule at both colonies, even though birds settled on the Nord Island - Northwest Islet cliffs 10 days later than they did at East Amatuli Island - Light Rock. In 1993, attendance also stabilized about one week later at Nord Island - Northwest Islet than at East Amatuli Island - Light Rock; in both years, the later settling dates at Nord Island appeared to be associated with harassment by bald eagles that commuted between Ushagat and Nord islands. Similar nesting schedules at East Amatuli Island - Light Rock and Nord Island - Northwest Islet are probably the normal case, because the nesting colonies are located only about 11 km apart and experience the same general environmental conditions (e.g., weather and current patterns, air and water temperatures, photoperiods).

Productivity: Productivity of murres at East Amatuli Island - Light Rock was higher in 1994 than in 1993 and similar to the 1993-1994 Nord Island results. Values from both locations in these years appeared to be similar to or higher than the 1991 fledglings-per-pair ranges reported for two UW time-lapse camera plots on Light Rock. Also, the 1994 periodic-visit results were similar to values derived from the 1991 UW Light Rock information. The 1993-1994 productivity values were higher than the values reported from other Gulf of Alaska colonies, and near the upper end of the ranges recorded at colonies in other regions of Alaska during the mid-1970's - early 1990's (e.g., southeastern and northeastern Bering seas). In both years, the periodic-visit chicks-per-adult numbers from both sets of productivity data fell within or exceeded the range reported for the Semidi Islands in 1989-1991, and these results and the one-day Nord Island values were also within or above the range recorded at Agattu Island in the southern Bering Sea during the same three-year interval. These data indicate that murres reproduced at or above average levels at the Barren Islands colonies in 1993 and 1994.

High murre productivity at the Barren Islands study sites indicated that prey availability was high during critical times of the breeding cycle. Numerous boat- and land-based observations of murres, black-legged kittiwakes *(Rissa tridactyla)*, and tufted puffins *(Fratercula cirrhata)* with fish in their bills; large feeding flocks of seabirds and feeding pods of humpback whales *(Megaptera novaeangliae)*; dense balls of small fish detected on vessel fish-finders that were larger and more numerous than those seen in 1993; and observations made by a visiting team of divers provided evidence that large schools of forage fish (primarily capelin, *Mallotus villosus*) were both abundant and available in the region during most of the 1994 nesting season.

Avian Predators: Based on 1993 and 1994 observations, at least three factors contributed to the differences in numbers of bald eagles at the Nord Island - Northwest Islet and East Amatuli Island - Light Rock colonies, and to higher levels of harassment of murres by eagles on the southeastern corner of Nord Island: the proximity of Ushagat Island, which contains most of the nesting habitat available to these raptors in the Barren Islands group; the location of the nesting cliffs directly on the shortest aerial route between Nord and Ushagat islands; and the configuration of the nesting cliffs, which allowed passing eagles to fly by and easily snatch adult murres from nesting ledges.

Conclusions

1. Based on population count analyses, positive trends were found on two small sets of plots at the East Amatuli Island - Light Rock colony over the postspill interval (1989-1994). However, no trends were detected in the whole-colony counts or on the other multicount plot sets, including those at Nord Island - Northwest Islet. Because only a small number of plots were involved in the increases, and the fact that these plots may not represent the entire colony, the

positive trends found in these data sets should not be interpreted as conclusive evidence of colony-wide population growth. A new set of monitoring plots (multicount plots BMP1-8) that sample broader range of nesting habitats was established at East Amatuli Island - Light Rock in 1993; these plots will provide a better set of data for evaluating changes in murre population numbers at this colony.

2. A review of the 1989-1992 FWS and 1991-1992 UW estimates at Light Rock suggests that different methods and the difficulties in censusing the top of the rock, coupled with the fact that the UW counts and some of the FWS estimates were single counts without any measure of variability, probably account for most of the numerical differences found between these two sets of data. Because measurements of variability were not obtained during the UW and FWS counts, the differences between the two sets of estimates (about 3,500-3,600 birds) may not be as significant as they appear to be.

3. Based on mean laying dates, 1994 nesting chronology averaged about one week earlier at the Barren Islands colonies than in 1993, and at the Nord Island - Northwest Islet colony, 1993-1994 nesting schedules averaged about 9 and 19 days earlier than in 1992, respectively. First-egg dates obtained in 1993-1994 were similar to those reported from the Barren Islands and several other northern Gulf of Alaska colonies during the mid- and late 1970's (e.g., Chisik, Ugaiushak, and Hinchinbrook islands).

4. Productivity (fledglings per egg laid) of murres was high for a second year in a row at the Barren Islands colonies, compared with ranges reported from other Gulf of Alaska nesting locations in the late 1970's - early 1980's and late 1980's - early 1990's (e.g., Ugaiushak Island, Semidi Islands). Chicks-per-adult values also fell within or exceeded ranges reported from other Alaskan colonies in the late 1980's - early 1990's (e.g., Semidi Islands in the western Gulf of Alaska, Agattu Island in the southern Bering Sea). Combined fledglings-per-egg-laid and chicks-per-adult information indicate that murres reproduced at or above average levels at the Barrens Islands colonies in 1993 and 1994.

5. The high productivity of murres at the Barren Islands colonies was probably related to the abundance and availability of forage fish during critical parts of the nesting season (e.g., the chick-rearing period), just as it appeared to be in 1993. In 1994, forage fish (primarily capelin) were available to both diving species (e.g., common murres) and surface-feeding birds (e.g., black-legged kittiwakes, a species that experienced an early, near-complete breeding failure at the Barren Islands in 1993, but produced about 0.6-0.9 chicks per nest in 1994).

6. Bald eagle-related disturbance and predation events occurred more frequently at Nord Island - Northwest Islet than at East Amatuli Island - Light Rock because nearby Ushagat Island contained most of the nesting habitat available to these raptors in the Barren Islands group. Harassment of murres by eagles was concentrated on the southeastern corner of Nord Island, because this part of the colony was located directly on the shortest aerial route between Nord and Ushagat islands, and the configuration of the cliffs allowed passing eagles to fly by and easily snatch adult murres from nesting ledges.

INTRODUCTION

The Barren Islands in the northwestern Gulf of Alaska supported one of the largest breeding concentrations of common murres *(Uria aalge)* in the path of the *Exxon Valdez* oil spill (e.g., Sowls *et al.* 1978, Piatt *et al.* 1990, FWS 1994).[1] When winds and currents swept the oil through the region during April and early May 1989, many murres were killed: they comprised 74% of 30,000 bird carcasses recovered by 1 August (Piatt *et al.* 1990).[2] Based on this information and a computer modeling study, estimates of total bird mortality suggested that 74,000-315,000 murres died after contacting the floating oil (Piatt *et al.* 1990, ECI 1991).

Because the impact of the oil spill on common murres appeared to be severe, and because large populations of these birds nested at the Barren Islands colonies, the U.S. Fish and Wildlife Service (FWS) conducted *Exxon Valdez* Oil Spill Trustee Council-sponsored murre damage assessment studies there during 1989-1991 (e.g., Nysewander and Dipple 1990, 1991; Dipple and Nysewander 1992; Nysewander *et al.* 1993). FWS biologists also monitored population numbers and productivity of common murres at these islands in 1992, as part of the first Trustee Council restoration project designed to evaluate recovery of this injured species in the spill area (Dragoo *et al.* 1994).

During 1990-1992, University of Washington (UW) personnel conducted Exxon-sponsored population and productivity studies at one of the Barren Islands colonies (East Amatuli Island - Light Rock, see Boersma *et al.* 1995). Dames & Moore (D&M) also censused both colonies for Exxon in 1991 (see Erikson 1995).

In 1993, we began intensive restoration studies that focused on monitoring common murre recovery at the Barren Islands East Amatuli Island - Light Rock and Nord Island - Northwest Islet colonies (Roseneau *et al.* 1995). Common murre productivity was high and nesting chronology was within normal limits that year, compared with values reported from other Alaskan locations; however, trends were not apparent in population numbers over the 1989-1993 postspill interval.

During 1994, we returned to East Amatuli Island - Light Rock and Nord Island - Northwest Islet to conduct another year of restoration monitoring work. We compared our results with the 1993 data and with the information from other FWS, UW, and D&M postspill studies. Productivity was higher on average, and nesting chronology was earlier, compared to 1993. Trends in population size were still not apparent at Nord Island - Northwest Islet, nor on the larger sections of East Amatuli Island - Light Rock over the 6-year postspill interval; however, positive increases in numbers were found on two small sets of plots at East Amatuli Island - Light Rock that were counted during 1989-1994 and 1990-1994, respectively.

---

[1] Prespill estimates of murres listed for the Barren Islands colonies in Sowls *et al.* (1978) and the FWS Alaska seabird colony catalog computer data base and colony status record archives are incorrect. Bailey (1975a) estimated 20,000 birds at Nord Island - Northwest Islet in 1975, not 30,000 birds, as erroneously reported in Bailey (1975b, 1976). Also, Bailey (1975a,b; 1976) estimated 61,400 murres at the East Amatuli Island - Light Rock colony in 1975, and Manuwal (1980) estimated 50,000 birds there in 1979, not 100,000 individuals, which was an error created when he listed the 50,000 bird estimate in a table reporting seabird pairs (D. Manuwal, pers. comm.). During the late 1970's, the East Amatuli Island - Light Rock colony was estimated to contain about 15% thick-billed murres *(U. Lomvia)* and 85% common murres (see Manuwal 1980). In 1993, small numbers of thick-billed murres were found on the East Amatuli Island cliffs; however, they were not observed nesting at Light Rock or Nord Island - Northwest Islet. In general, these observations suggest that the total Barren Islands population probably consists of more than 85% common murres.

[2] Seventy percent of the murre carcasses were common murres (Piatt *et al.* 1990; J.F. Piatt, pers. comm.).

OBJECTIVES

Our objective was the same as in 1993—to monitor the recovery of common murres at the Barren Islands nesting colonies. The objective was met by collecting population and productivity data at both colonies, testing 1989-1994 FWS information and data from other postspill studies for trends, and comparing reproductive timing and success measurements with information from other Alaskan colonies to see if these variables were within normal ranges.

METHODS

The Barren Islands are located at about 58° 55' N, 152° 10' W, between the Kodiak archipelago and the Kenai Peninsula. Study sites consisted of East Amatuli and Nord islands and two closely associated islets, East Amatuli Light Rock (Light Rock) and Northwest Islet (Figs. 1 and 2). These four areas, designated the East Amatuli Island - Light Rock and Nord Island - Northwest Islet colonies, contain all of the breeding murres in the Barren Islands group (see Roseneau *et al.* 1995).

To support our work, we reused the 1993 restoration monitoring study field camps (Fig. 1; see Roseneau *et al.* 1995). Amatuli Cove camp served as base of operations for collecting population census and productivity data at East Amatuli Island - Light Rock, and the Ushagat Lagoon camp supported similar work at the Nord Island - Northwest Islet colony (Fig. 1). Three people were stationed at each camp during 16 June - 8 September, and two additional personnel visited them intermittently in July and August to help count population plots.

Field teams used outboard-powered, 4.8 m-long, ridged-hulled inflatable boats and inflatable rafts to census the colonies and commute to productivity study sites. Light helicopters and a 23-m long vessel were hired to supply the camps and transport personnel between Homer and the study area. The vessel also provided support during population and productivity work at Nord Island when weather and tidal conditions made traveling from Ushagat Island dangerous for small boats.

Basic methods for collecting and analyzing the murre population, nesting chronology, and productivity data were the same as those used during the 1993 restoration monitoring study (see Roseneau *et al.* 1995). These methods and additional procedures pertinent to the 1994 work are described below.

Population Counts

To compare numbers of murres at the nesting colonies with data collected during previous years, we made three types of counts. We censused East Amatuli Island - Light Rock and Nord Island - Northwest Islet completely to obtain whole-colony estimates and total numbers of birds on major subdivisions of the colonies (e.g., East Amatuli Island, Light Rock). We also counted sets of plots that we named multicount plots a minimum of five times during the census period to collect data for statistical analyses of among-year differences and trends in population size. The multicount plots at the colonies, which provide the primary indices for detecting changes in numbers, contained about 10-15% of the murres on the cliffs at the respective nesting complexes. We also counted sets of productivity plots at both colonies every time we visited the study sites. The productivity plot sets contained about 500 birds each; about 4% of the murres on the cliffs at each colony. Counts on the productivity plots provided information on seasonal attendance patterns that helped define the boundaries of the census period. These counts also provided an additional set of data for population trend analyses.

To count murres at East Amatuli Island - Light Rock, we used the 64 population census plots (BCP1-64) and eight multicount plots (BMP1-8) set up during the 1993 Barren Islands restoration

work (Fig. 2a; see Roseneau *et al.* 1995). These plots included three University of Washington (UW) plots established during Exxon-sponsored studies in 1990-1991 (Oval, Swatch, and Triangle Rock; see Boersma *et al.* 1995), and two plots used during the 1989-1992 FWS postspill studies (one on East Amatuli Island and one on Light Rock; see Table A1 in Dragoo *et al.* 1994). The multicount plots, scattered throughout the colony, sampled both central and peripheral areas in general proportion to the number of birds using these habitats (see Roseneau *et al.* 1995). Plot boundaries were located using photographs in Alaska Maritime National Wildlife Refuge (AMNWR) files.

To census birds at Nord Island - Northwest Islet, we used the 28 population census plots (BCP1-28) and 11 multicount plots (BMP1-11) counted during the 1993 restoration project (Fig. 2b; see Roseneau *et al.* 1995). Twenty-six of these plots (BCP1-10 and 12-27) were established during the 1989-1991 FWS postspill studies to track changes in population size (see Nysewander *et al.* 1993, Dragoo *et al.* 1994; population census plots BCP1-10 and 24 are equivalent to multicount plots BMP1-10 and 11, respectively—see Fig. 2b). BCP11 and 28 were added in 1993 to cover areas containing small numbers of murres not reported before. Photographs in Alaska Maritime National Wildlife Refuge (AMNWR) files were used to locate plot boundaries.

Three of the four team members who counted the East Amatuli Island - Light Rock and Nord Island - Northwest Islet population census and multicount plots had previous experience counting murres at large Alaskan nesting colonies. Two of these individuals counted the East Amatuli Island - Light Rock plots on numerous occasions during 1990-1993, and one of them censused the East Amatuli Island - Light Rock and Nord Island - Northwest Islet colonies several times in 1993.

Census team members worked in pairs and counted the population census and multicount plots from boats with the aid of 7 x 42 binoculars and hand-held tally-meters. Distances between observers and birds varied, depending on the height and configuration of cliffs and other factors (e.g., presence of offshore rocks); however, these variables were kept as consistent as possible between all plot counts, including those made in 1993. In most cases, boats were either tied to bull kelp *(Nereocystis* spp.) growing 30-90 m in front of the plots or were allowed to drift slowly past them at similar distances. However, when strong tidal currents were present, observers took turns censusing birds and operating boats to maintain counting positions.

Productivity plot counts were made with 7 x 42 binoculars and 15-60 power spotting scopes from land-based observation posts. Observers were assigned specific plots at the study sites, and each observer counted his or her own plots at least once during every visit to them throughout the nesting season.

All counts of birds on the multicount and population census plots were made during the portion of the nesting season when attendance was most stable. The census period was defined as the interval between the peak of laying and first sea-going of chicks (e.g., Hatch and Hatch 1989, Byrd 1989; also see Roseneau *et al.* 1995). Start and stop dates were initially based on general observations of laying and fledging at the closely monitored productivity plots. After analyzing attendance data from these frequently visited plots, we used the results to refine the census interval. Counts made before or after numbers of birds stabilized on the cliffs were excluded from the analyses.

We used a combination of census guidelines, sun-time, and information on attendance patterns from previous Barren Islands studies to determine the best times of day for counting plots (e.g., see Boersma *et al.* 1995; Dragoo *et al.* 1994; Roseneau *et al.* 1995; FWS, unpubl. data). All counts were made during 1100-2000 hrs Alaska Daylight Time (ADT).

Birds on population census and multicount plots were counted by 10's (see Roseneau *et al.* 1995); however, observers often counted the last group of birds on a plot by 1's, if the remaining

birds obviously consisted of less than 10 individuals (this procedure was also used during the 1993 counts but not clearly described in Roseneau *et al.* 1995). The only exceptions were three small East Amatuli Island multicount plots that were counted by 1's to match methods used by Boersma *et al.* (1995). Productivity plots were also counted by 1's, because of their small size.

All of the population census and multicount plots were counted by two observers, with one exception: only one observer completed the Nord Island - Northwest Islet colony count on 27 July. During the counts, one person recorded both scores without revealing his or her own count to the other team member. The recorder compared the scores to see if they were within 15% of each other (i.e., within 7.5% of their average). If they were not and time allowed, the plot was recounted until the scores fell within this range. Productivity plots were counted by single observers because the counts were made from stable land-based observation posts that allowed numbers of birds to be determined with a high degree of precision (usually within one to two individuals).

We censused East Amatuli Island - Light Rock twice and counted Light Rock three additional times. Eight counts were obtained on the eight multicount plots (plots BMP1-8; see Fig. 2a), including BMP3-4, the only plots counted by FWS crews at the East Amatuli Island - Light Rock colony during 1989-1992 (see Roseneau *et al.* 1995).

Nord Island - Northwest Islet was censused completely four times, and we obtained five counts on the 11 multicount plots at this colony (plots BMP1-11; see Fig. 2b).

At East Amatuli Island - Light Rock, we counted the 10 productivity plots 13 times during the census period (plots LPP1-10 established in 1993; see Roseneau *et al.* 1995). Fifteen counts were obtained on the eight Nord Island productivity plots during the census period, including the five plots counted by FWS crews in 1990-1992 (LPP1-5), two of the three plots added at the study site in 1993 (LPP1-6 and 8), and one plot that was set up to compensate for the loss of one of the 1993 plots (LPP7; see Roseneau *et al.* 1995).

To analyze our population data and the previous FWS postspill information, we calculated one-day totals for Light Rock, East Amatuli Island - Light Rock multicount plots BMP1-8 and 3-4, Nord Island - Northwest Islet, and Nord Island - Northwest Islet multicount plots BMP1-11. We also calculated the average number of adults counted on the East Amatuli Island - Light Rock and Nord Island productivity plots during the census period. These results were grouped with corresponding data from previous FWS postspill studies (e.g., Nysewander and Dipple 1990, 1991; Dipple and Nysewander 1992; Nysewander *et al.* 1993, Dragoo *et al.* 1994; Roseneau *et al.* 1995) and tested for differences and trends among years, as appropriate. We used Kendall's Tau (τ) rank correlation tests to check for trends, and one-way analysis of variance (ANOVA), Tukey HSD multiple pairwise comparison, and two-tailed *t*-tests, as appropriate, to check for differences among years at the 0.1 significance level (the 0.1 significance level was used to increase the power of the tests and reduce Type II error; the 0.9 confidence interval was adequate for our purposes).[1]

We also analyzed our counts in combination with the 1990-1993 FWS scores and the 1990-1992 UW and 1991 D&M estimates (see Boersma *et al.* 1995 and Erikson 1995, respectively). At East Amatuli - Light Rock, we calculated one-day totals for parts of multicount plots BMP1, 5, and 8, because certain sections of these plots were equivalent to the UW East Amatuli Island Oval, Swatch, and Triangle Rock plots (OSTR plots) counted by Boersma *et al.* (1995) in 1990-1992. To analyze our data with the East Amatuli Island - Light Rock ("E. Amatuli Island Total"), Light Rock, and Southwestern Section ("S. Colony") totals listed by Boersma *et al.* (1995), we averaged

[1] Bonferroni multiple pairwise comparison tests were run in conjunction with the Tukey HSD tests (see Wilkinson *et al.* 1992, page 244). The Tukey test proved to be more sensitive in detecting differences among data sets.

the numbers listed as ranges in Table 1 of their publication to obtain single values, and we also calculated one-day totals for our counts of population census plots BCP38-46 (the area equivalent to Southwestern Section).[1] When D&M, UW, and FWS counts were available for specific areas, the D&M and UW counts were treated as additional counts made during the census period and combined with the FWS data (e.g., the average 1992 UW Light Rock score of 9,655 birds and the 1992 FWS count of 5,960 individuals were treated as two separate counts and averaged to obtain a new total estimate of 7,808 murres for that location that year). The resulting D&M-UW-FWS, UW-FWS, and D&M-FWS East Amatuli Island - Light Rock and Nord Island - Northwest Islet data sets were checked for trends and differences among years with Kendall's τ rank correlation tests, one-way analysis of variance (ANOVA), Tukey HSD multiple pairwise comparison tests, and two-tailed *t*-tests at the 0.1 significance level. During all of these analyses, plots were treated as sample units.

Timing of Nesting Events

We calculated median hatching dates for each productivity plot at the East Amatuli Island - Light Rock and Nord Island study sites and averaged the dates in the respective plot sets to describe the timing of nesting events at the colonies (see Roseneau *et al.* 1995). Differences between average study site hatching dates and between these dates and 1993 results were checked with two-tailed *t*-tests.

Because actual nesting events (e.g., laying and hatching of eggs, fledging of chicks) were rarely observed at the East Amatuli Island - Light Rock and Nord Island productivity plots, we defined the date that a nest site changed status (i.e., from an egg to a chick) as the midpoint between the nearest pre- and post-event observation dates. We used two methods to maintain precision during data analysis. Nest sites having data gaps of more than seven days between pre- and post-event egg-laying and hatching observation dates were excluded from the data sets. Also, at sites where the range of possible laying dates was smaller than the range of possible hatching dates, we calculated hatching dates by adding 32 days to laying dates (see Byrd 1986, Roseneau *et al.* 1995).

Although we used the averages of the median hatching dates calculated for the productivity plot sets to describe nesting chronology at the colonies, this variable was not listed in the 1989-1992 FWS Barrens Islands damage assessment and restoration reports. Instead, nesting chronology was described on the basis of first laying and mean hatching dates (e.g., Nysewander *et al.* 1993, Dragoo *et al.* 1994). We calculated these variables from the productivity plot data and also compiled our incidental observations of first laying dates from other sections of the colonies for comparison with these studies. We also calculated mean laying dates and used the mean hatching dates for comparison with information reported by other investigators (e.g., Manuwal 1978, 1980; Manuwal and Boersma 1978; Boersma *et al.* 1995).

Productivity

We used fledglings-per-egg-laid as our measure of productivity and compared these data with the 1993 results (see Roseneau *et al.* 1995). We also calculated hatching success, fledging

---

[1] Apparent ranges in values listed in Table 1 of Boersma *et al.* (1995) are the individual total scores of the two observers that made the counts (A.B. Kettle, pers. comm.). To compare these data with the FWS counts, we averaged the reported numbers to obtain one score (e.g., for 1991, we averaged 8,918 and 9,594 and obtained 9,256).

success, and numbers of chicks-per-adult for comparison with information from other studies.[1] During all of these analyses, plots were treated as sample units.

Productivity data were collected from the same East Amatuli Island - Light Rock and Nord Island plots that we used in 1993 (LPP1-10 and LPP1-8, respectively—see Fig. 2 and Roseneau *et al.* 1995) with one exception. Nord Island plot LPP7 was dropped from the series and a new plot, LPP9, was set up to allow the observation post to be moved to a safer, more permanent location (see below). The plots at East Amatuli Island - Light Rock contained about 50 nest sites each, and the Nord Island plots varied from 20 to 100 nest sites each.

To support the productivity work, we set up running-line mooring systems in Lonesome and Parakeet coves to anchor our boats during visits to the study plots (see Fig. 2 and Roseneau *et al.* 1995). We also installed several fixed climbing ropes at the study sites to ensure safe access to the observation posts.

Teams of three people checked the plots with 7 x 42 binoculars and 15-60 power spotting scopes from land-based observation posts as often as possible, weather permitting (usually every 1-3 days at East Amatuli Island and every 2-5 days at Nord Island). Viewing distances varied from about 30 to 100 m, and observers were assigned specific plots for the duration of the field season. Nest sites, defined as sites with eggs, were mapped on 20 x 25 cm photographs or sketches, and data were recorded in notebooks using previously established codes. Plot checks consisted of searching for eggs, chicks, and adults in incubation and brooding postures, and counting adults. Observations began before eggs were laid at both study sites. They ended at East Amatuli Island - Light Rock several days after sea-going had peaked, and when it was almost complete at Nord Island - Northwest Islet.

The East Amatuli Island - Light Rock productivity plots were viewed from the same observation posts used during the 1993 restoration study (see Roseneau *et al.* 1995). Plot boundaries were located with the aid of photographs in AMNWR files. Observers visited the observation posts 44 times and checked each plot for eggs and chicks at least 30 times during 25 June - 7 September.

At Nord Island, the productivity plots were viewed from a new location about 6 m northwest of the old observation post because the old site was eroding and too dangerous to reach. The new observation post provided clear views of all plots established during the 1989-1992 FWS postspill studies (LPP1-6; see Nysewander *et al.* 1993, Dragoo *et al.* 1994) and one of the two additional plots set up in June 1993 (LPP8; see Roseneau *et al.* 1995). To compensate for the loss of the 1993 plot that could not be seen clearly from the new observation post (LPP7), a new plot of comparable size was established near the southwest corner of the study site (LPP9; see Fig. 2b). Plot boundaries were identified from photographs in AMNWR files. Study team members visited the new observation point 33 times and checked each plot for eggs and chicks 22 times during 8 July - 7 September.

We used postures of incubating and brooding birds to supplement direct observations of eggs and chicks (e.g., Byrd 1989, Nysewander *et al.* 1993, Roseneau *et al.* 1995). Incubating birds sit forward with their backs humped, tails held down, and wings slightly lowered with uncrossed wing-tips. Brooding individuals extend one wing and lower it to mantle (shelter) chicks after the chicks are about 1-3 days old (Byrd 1989). Birds seen in incubation posture on three consecutive occasions were assumed to have eggs, and individuals observed wing-mantling once were assumed to be brooding chicks.

---

[1] The terms "fledglings", "fledging", and "fledged", as used in this report, refer to the sea-going of chicks. Murre chicks actually jump from nesting ledges before they are fully capable of flight and fledge several weeks later at sea.

We assumed that all chicks reaching an age of at least 15 days old before they disappeared from nest sites survived and went to sea (i.e. "fledged"— e.g., Hunt *et al.* 1981; Byrd 1986, 1989; Roseneau *et al.* 1995), unless we had specific information indicating that they had died before fledging (e.g., from storms, avian predators, falling rocks). Chick ages were obtained from hatching date calculations (see above) and direct observations of chicks. Nest sites without sufficient data to indicate whether "fledging" had occurred were excluded from the analyses.

The only productivity data collected during the 1989-1992 FWS postspill studies (e.g., Nysewander *et al.* 1993, Dragoo *et al.* 1994) were chicks-per-adult measurements. During 1992, Nord Island plots LPP1-6 were visited seven times during 2 July - 25 August to obtain this information, and boat-based counts of chicks and adults were also made at several visible nesting areas in nearby multicount plots BMP1-11 on 11 September (Dragoo *et al.* 1994). To compare our data with these periodic- and single-visit data, we used the same procedures employed in our 1993 study (see Roseneau *et al.* 1995). For periodic-visit comparisons, we divided the total number of chicks on plots LPP1-6 and LPP8-9 by the average number of adults counted on them during the census period. To make single-visit comparisons (e.g., with the one-day boat-based value), we used the reported 28 July 1992 mean laying date to help identify the day in our data set that was chronologically similar to 11 September 1992, and then divided the number of chicks on plots LPP1-6 and LPP8-9 by the mean number of adults counted on them during the census period on that day (24 August).

The same single-visit procedure was also used to compare our one-day chicks-per-adult results with the Nord Island information collected from 11 plots on 11-12 September 1991 (Nysewander *et al.* 1993). Based on the reported mean laying date of 25 July (see Dragoo *et al.* 1994), we calculated the mean number of chicks-per-adult on plots LPP1-6 and LPP8-9 for the day in the nesting cycle when chick ages were closest to ages on the 1991 observation date (24 August).

The 1992-1994 periodic-visit results were checked for differences with ANOVA and Tukey HSD multiple pairwise comparison tests. These same procedures were also used to check the 1991-1994 single-visit data (the 0.1 significance level was used in all cases to increase the power of the tests and reduce Type II error).

Avian Predators

During our work, we observed several interactions between avian predators and seabirds at the East Amatuli Island - Light Rock and Nord Island - Northwest Islet colonies. We recorded these incidental events to provide general information on disturbance and predation for comparison with similar observations made in 1993 (see Roseneau *et al.* 1995).

RESULTS

Population Counts

At the East Amatuli Island - Light Rock colony, we censused Light Rock (Appendices 1-5), East Amatuli Island (Appendices 6-7), and East Amatuli Island - Light Rock, just as we did in 1993 (see Roseneau *et al.* 1995). We also counted the eight multicount plots and 10 productivity plots that we set up at the colony in 1993 (Appendices 8 and 9, respectively; see Roseneau *et al.* 1995) and three UW plots censused during the 1990-1992 UW studies (see Boersma *et al.* 1995). Multiyear comparisons with FWS postspill data were limited to counts of Light Rock and FWS multicount plots BMP3-4 (see Appendix 10), because these were the only areas counted at the nesting complex during the 1989-1992 FWS damage assessment and restoration studies (see Nysewander *et al.* 1993, Dragoo *et al.* 1994, Roseneau *et al.* 1995).

We compared our East Amatuli Island - Light Rock whole-colony estimate of 33,011 birds with the 1993 score of 32,721 individuals (see Table 1 in this study and Roseneau *et al.* 1995) and they did not differ from one another. We deferred testing the combined 1991 D&M, 1991-1992 UW, and 1993-1994 whole-colony estimates for trends because the combined information consisted of only four data points.[1] However, given the strong similarities in the respective count totals, the presence of a trend seemed unlikely (see Fig. 3; UW estimates for East Amatuli Island - Light Rock were 35,757 and 34,783 birds in 1991 and 1992, respectively, and the 1991 D&M count of East Amatuli Island - Light Rock totaled 30,294 individuals—see Boersma *et al.* 1995 and Erikson 1995, respectively).

Our Light Rock count of 7,750 murres was similar to the 1993 estimate of 8,454 birds, and both of these scores were significantly higher than the reported 1990 FWS Light Rock count of 5,865 individuals (Tukey HSD, $P = 0.023$ and 0.006, respectively). Although the 1993 score was higher than the 1989 FWS estimate of 6,912 birds, the 1994 count was not, and no trend was found over the 6-year postspill period (Table 1, Fig. 4a).[2] Combining the respective 1991 and 1992 single UW Light Rock counts of 9,256 and 9,655 birds with the 1989-1994 FWS estimates (Fig. 4b) did not change the Light Rock results; no trend was apparent over the 6-year postspill interval (Kendall's τ).

Results of the East Amatuli Island Southwestern Section (BCP38-46) counts (Fig. 5) followed the same general pattern found in the Light Rock results. Although the 1993 and 1994 scores of 2,197 and 2,081 birds appeared to be higher than the single 1990 and 1992 UW estimates of 1,189 and 1,471 individuals, they did not appear to differ from the 1991 UW count of 2,051 murres, and no trend was found over the 5-year period (Kendall's τ).

Our East Amatuli Island - Light Rock multicount plot BMP1-8 score of 5,599 (SD = 277.0, n = 8) birds was similar to the 1993 estimate of 5,808 (SD = 398.3, n = 4) individuals (see Roseneau *et al.* 1995). The 1,245 bird score on multicount plots BMP3-4 and our 1993 count of 1,375 birds were also similar to one another; however, both scores were significantly higher than all previous FWS estimates on these two plots (Tukey HSD; for 1989, 1990, 1991, and 1992, P = 0.082 and 0.011, $P = 0.001$ and < 0.001, $P = 0.091$ and 0.017, and $P = 0.001$ and < 0.001, respectively; 1989-1992 range = 575-860 individuals—see Table 2 and Roseneau *et al.* 1995), and a positive trend was found in this 6-year data set (Kendall's τ, $P < 0.01$; see Table 2, Fig. 6a).

When we analyzed the 1990-1994 UW and FWS East Amatuli Island OSTR plot counts (Fig. 6b), we discovered that our 1994 estimate of 866 birds was significantly lower than the 1993 score of 1,003 individuals [$t_{0.10(2)}$, = -3.628, $P = 0.004$; see Roseneau *et al.* 1995]. However, the positive trend suggested by our relatively high estimates and by the increasing respective 1990-1992 UW scores of 550, 667, and 700 birds was significant (Kendall's τ, $P = 0.08$).[3]

Our counts on East Amatuli Island - Light Rock productivity plots LPP1-10 averaged 456 (SD = 30.0, n = 13) birds (Table 3). This estimate was similar to our 1993 score of 481 (SD = 36.7, n = 7) individuals (two-tailed t-test; see Roseneau *et al.* 1995).

---

[1] We did not include the 1990 UW East Amatuli Island - Light Rock total of 31,041 birds in the data set because it was an estimate derived from an incomplete count; see Table 1 in Boersma *et al.* (1995).

[2] The 1992 FWS count of 5,960 birds was not included in the Tukey HSD analysis because n = 1, and the 1991 FWS score of 5,529 murres was not included in the Kendall's τ trend analysis because it included 2,100 individuals on the water (see Nysewander and Dippel 1991, Roseneau *et al.* 1995).

[3] The only information currently available for the three OSTR plots is an average value for each plot (see Table 5 in Boersma *et al.* 1995).

The Nord Island - Northwest Islet whole-colony censuses (Appendices 11-14) and multicount plot counts (Appendix 15) were similar to the 1993 results (see Roseneau *et al.* 1995). Our whole-colony estimate of 11,753 murres did not differ from the 1993 count of 13,422 birds, or from the respective 1989-1992 FWS scores of 11,838, 12,277, 13,333, and 11,212 individuals, and no trend was apparent over the 6-year postspill period (Table 1, Fig. 8a).[1] We also analyzed the 1989-1994 whole-colony information in combination with the single 1991 D&M score of 16,592 birds (Fig. 8b; see Erikson 1995). Although the D&M estimate was about 20% higher than the average of the 1991 FWS scores of 13,404 and 13,262 individuals, it was almost identical to one of the four 1993 counts (16,484 birds; see Table 1 and Roseneau *et al.* 1995), and its inclusion in the analyses did not alter our conclusion that population size had not changed at the colony over the postspill interval.

Our Nord Island - Northwest Islet BMP1-11 multicount plot estimate of 2,893 murres was similar to the respective 1989, 1991, and 1992 FWS counts of 2,431, 3,558, and 2,971 birds (Table 2, Fig. 9). However, it was significantly lower than the respective 1990 and 1993 scores of 4,383 and 4,003 individuals (Tukey HSD; $P = 0.007$ and 0.023, respectively), and no trend was apparent over the postspill period (Kendall's τ).

When the 1990-1994 counts on the five Nord Island FWS productivity plots (Appendix 9) were compared, they appeared to follow the same general among-years pattern found on multicount plots BMP1-11, with one exception: our 1993 and 1994 estimates of 398 and 408 birds on LPP1-5 did not differ from one another (Table 3, see Figs. 7b and 9). These two counts and the similar 1990 score of 412 murres were significantly higher than the 1992 count of 264 individuals (Tukey HSD; $P < 0.001$, < 0.001, and < 0.001 respectively), and no trend was present over the 5-year interval (Table 3).[2]

Timing of Nesting Events

We estimated that about 23,000-24,000 murres were present on waters near the East Amatuli Island - Light Rock colony when we had an opportunity to check it by helicopter on 4 June. Large rafts containing many thousands of individuals were also seen near the cliffs during 16-23 June. On 24 June, attendance stabilized on the nesting cliffs, and the first egg was laid on the productivity plots on 28 June (Table 4, Fig. 10). Median laying and hatching dates were 10 July and 11 August, respectively, and sea-going of chicks had peaked when we visited the plots for the last time on 7 September.

Only about 3,000-5,000 murres were rafting near the Nord Island - Northwest Islet colony when we passed by in a helicopter on 4 June. Similar small rafts of 3,000-4,000 birds also frequented the area during 16-26 June, but cliff attendance was sporadic and limited to late afternoon and evening hours. On 28 June, murre numbers increased markedly at the colony; at least 15,000 birds were present on the water below the cliffs on that day, and many of them began visiting the nesting ledges for longer periods of time. The first evidence of laying was discovered on 23 June, when we found the fresh remains of four recently eaten eggs on a rock in Parakeet Cove (Table 4, Fig. 2b). The remains of eight more eggs taken by avian predators (probably glaucous-winged gulls, *Larus glaucescens*) were found at the same location on 26 June, but laying did not begin on the productivity plots until 28 June, and attendance at nesting ledges remained unstable until 3 July (Table 4, Fig. 11). Median laying and hatching dates were 9 July and 10 August, respectively, and sea-going of chicks was essentially complete when we checked the plots for the last time on 8 September.

---

[1] The 1992 FWS count of 11,212 birds was not included in the Tukey HSD analysis because n = 1 (see Roseneau *et al.* 1995).

[2] The 1991 FWS count of 301 birds was not included in the Tukey HSD analysis because n = 1.

Attendance stabilized at Nord Island - Northwest Islet 10 days after it did on the East Amatuli Island - Light Rock cliffs, but laying began on both sets of productivity plots on the same day (28 June; see Table 4). Median laying and hatching dates were only one day later at East Amatuli Island - Light Rock, compared to Nord Island (10 July and 11 August vs. 9 July and 10 August) and this difference was not significant. However, these dates averaged about one week earlier (range = 5-9 days) than the 1993 dates from these study sites (15 July and 16 August, and 18 July and 19 August, respectively; see Roseneau *et al.* 1995); this difference was significant [laying $t_{0.10(2)}$, = 5.187 and 9.737, $P < 0.001$ and < 0.001, respectively; hatching $t_{0.10(2)}$, = 4.706 and 9.113, $P < 0.001$ and < 0.001, respectively].[1]

Productivity

Productivity (fledglings-per-egg-laid) was similar at East Amatuli Island - Light Rock and Nord Island - Northwest Islet (0.73 vs. 0.74 fledglings/egg, respectively; see Table 5). The Nord Island results were also similar to our 1993 value (0.71 fledglings/egg; see Roseneau *et al.* 1995); however, productivity at East Amatuli Island - Light Rock was significantly higher than it was in 1993 [1993 value = 0.55 fledglings/egg, see Roseneau *et al.* 1995; $t_{0.10(2)}$, = -2.961, $P = 0.008$].

Hatching and fledging success were also similar at the East Amatuli Island - Light Rock and Nord Island study sites (0.79 and 0.84 chicks/egg laid, and 0.93 and 0.89 fledglings/egg hatched, respectively; see Table 5), and at Nord Island, both variables were similar to the 1993 values (0.80 chicks/egg laid and 0.93 fledglings/egg hatched; see Roseneau *et al.* 1995). At East Amatuli Island - Light Rock, hatching success was also similar to the 1993 results (0.79 chicks/egg laid vs. 0.70 in 1993); however, fledging success was significantly higher than in 1993 [0.93 fledglings/egg hatched vs. 0.79 in 1993; $t_{0.10(2)}$, = -3.100, $P = 0.006$, respectively; see Roseneau *et al.* 1995].

Based on our periodic-visit data, chicks-per-adult results were similar at the East Amatuli Island - Light Rock and Nord Island study sites (0.44 and 0.51 chicks/adult, respectively; see Table 5). However, both of these numbers were significantly higher than the 1993 periodic-visit values [0.35 chicks/adult at both colonies, see Roseneau *et al.* 1995; $t_{0.10(2)}$, = -2.217 and -2.759, $P = 0.040$ and 0.015, respectively], and they were also higher than the reported 1992 Nord Island periodic-visit number [0.29 chicks/adult, SD = 0.11, $n = 6$—see Dragoo *et al.* 1994; $t_{0.10(2)}$, = 4.246 and 4.544 $P = 0.001$ and 0.001, respectively].

The one-day chicks-per-adult number that we calculated from the Nord Island data (0.40 chicks/adult, SD = 0.107, $n = 8$) was higher than our 1993 single-visit value (0.27 chicks/adult, SD = 0.15, $n = 8$—see Roseneau *et al.* 1995; Tukey HSD, $P = 0.092$). However, it was similar to the 1992 FWS one-day number (0.32 chicks/adult, SD = 0.09, $n = 11$; see Dragoo *et al.* 1994—Dragoo *et al.* 1994 reported 0.34 chicks/adult, but using plots as the sample unit, the number becomes 0.32 chicks/adult), and all of the 1992-1994 values were significantly higher than the 1991 FWS single-visit number (0.12 chicks/adult, SD = 0.04, $n = 6$, see Nysewander *et al.* 1993; Tukey HSD, $P < 0.001$, = 0.087, and = 0.008, respectively). The 1989-1990 FWS one-day chicks-per-adult values (0.1 and 0.1 chicks/adult, respectively; see Nysewander *et al.* 1993, Dragoo *et al.* 1994), which were much lower than the 1991-1994 numbers, were not included in our analyses, because they were single numbers without any measure of variability and the methods used to collect them were not described (see Roseneau *et al.* 1995).

Avian Predators

Disturbance (flushing events) and predation by avian predators at the East Amatuli Island - Light Rock and Nord Island - Northwest Islet murre colonies followed the same patterns observed

---

[1] Subscripts indicate the *t*-test was a two-tailed test conducted at the 0.1 significance level.

in 1993 (see Roseneau *et al.* 1995). Bald eagles *(Haliaeetus leucocephalus)* were present at both nesting locations when we arrived in mid-June, but they were more numerous at Nord Island - Northwest Islet than at East Amatuli Island - Light Rock. At East Amatuli Island - Light Rock, only a few eagles and five eagle-induced flushing events were observed from 28 June until 7 July, when they appeared to stop. In contrast, these birds-of-prey were seen 28 times during 23 June - 31 August at Nord Island - Northwest Islet, where they interacted with murres, black-legged kittiwakes *(Rissa tridactyla)*, and tufted puffins *(Fratercula cirrhata)* at least 25 times during 26 June - 16 August (total observation time was about equal at the colonies).

At Nord Island - Northwest Islet, 11 (58%) of 19 eagle-murre interactions occurred at the southeastern corner of Nord Island in the relatively small BCP/BMP4-9 section of the colony (see Fig. 2b), and adult eagles were responsible for eight (75%) of these events. The remaining interactions between eagles and murres were scattered along the upper reaches of BCP/BMP1-2, BCP13-15, and BCP21-22, and at Northwest Islet (BCP24/BMP11 and BCP25). During typical eagle-induced disturbance events, 200-300 murres left the cliffs; however, on at least three occasions (28 June, 31 July, and 16 August), 1,000-3,000 birds flushed from the BCP/BMP4-9 area. During at least two incidents (3 July and 16 August), eagles from Ushagat Island flew directly to plots BCP/BMP5-6, snatched adult murres from nesting ledges, and flew back to the eastern end of Ushagat Island. Adult eagles were also observed flying between Nord and Ushagat islands on several other occasions, but the birds were too far away to see if they were carrying prey. One commuting bird was a member of a pair that attempted to nest near Table Mountain, opposite Nord Island. The failed nest was checked on 28 August. It contained shell fragments from one broken unhatched egg, and the remains of two adult common murres, two adult kittiwakes, and one sooty shearwater *(Puffinus griseus)* were found on the ground below it.

Other evidence supported our observations that disturbance and predation by eagles were disproportionally high in the BCP/BMP4-9 section of the Nord Island - Northwest Islet colony. On 8 September, when only a few dozen murres were still present on the nesting ledges in other areas of the colony, an estimated 500-600 incubating and brooding birds were still occupying several of the BCP/BMP4-9 nesting ledges in scattered groups ranging from about 10 to 50 individuals. The presence of these late-season breeders indicated that they had lost and relayed eggs during the nesting cycle (most eggs were probably lost to common ravens, *Corvus corax*, and glaucous-winged gulls during eagle-induced flushing events—see below).

Subadult eagles were never observed attempting to take adult murres and kittiwakes, or murre chicks. However, they were seen hunting and taking some kittiwake nestlings. At Nord Island, two subadults snatched at least three kittiwake chicks from nests during 27-31 July, and the same individuals tried to take chicks from kittiwake nests on several additional occasions in early August.

Peregrine falcons *(Falco peregrinus)*, glaucous-winged gulls, and common ravens, were also present at both colonies throughout the breeding season, as in 1993 (see Roseneau *et al.* 1995). At Nord Island, peregrines fledged three young from the 1993 nest site, and at least one pair of falcons also apparently nested high above the East Amatuli Island productivity plots. Although kittiwakes often flushed when peregrines flew by the nesting cliffs, murres essentially ignored them, probably because the falcons favored smaller prey species. The Nord Island pair and their three fledged young preyed primarily on parakeet auklets *(Cyclorrhynchus psittacula)* and kittiwakes (particularly chicks). During 3 July - 2 September, members of the family group were observed hunting and taking these species nine times, and the remains of 1 fork-tailed storm petrel *(Oceanodroma furcata)*, 6 kittiwakes (two adults and four chicks), and 16 auklets were found below the eyrie on 3 September.

Disturbance and predation events involving glaucous-winged gulls and common ravens occurred at both colonies, and both of these predators took murre eggs and murre and kittiwake

chicks from nesting ledges. Predation by gulls appeared to occur primarily during eagle and raven disturbance events (see Roseneau *et al.* 1995). Ravens also took advantage of eagle-related episodes, but they also operated independently from them, both individually and as family groups. One of the most dramatic eagle-related events occurred at East Amatuli Island on 30 June, when an eagle flew by the cliffs opposite Light Rock. The passing eagle flushed several thousand murres and kittiwakes from the nesting ledges, and a passing raven quickly snatched one murre egg and a gull grabbed another. Over the next several minutes, one or more ravens returned repeatedly and took a total of 20-30 more eggs from the area. At Nord Island, a family group of five ravens (two adults and three young) worked the nesting cliffs all summer. These birds took numerous murre eggs from BCP/BMP5-9, and cached and ate them atop a grassy knoll above BCP/BMP4. Based on the remains of shells seen from below, a minimum of several dozen eggs were lost to these roving predators from this section of the colony. Ravens also physically pulled adult murres off of ledges and took chicks on at least two occasions at East Amatuli Island- Light Rock.

At East Amatuli Island, ravens and gulls took two murre chicks from one of the productivity plots on 1 September. No eggs or chicks were lost to avian predators at the Nord Island study plots.

DISCUSSION

Population Counts

Based solely on 1989-1994 FWS data, no evidence of a trend in murre numbers was found on the Light Rock section of the East Amatuli Island - Light Rock colony over the 6-year interval (see Table 1, Fig. 4a); including the somewhat higher 1991-1992 single UW Light Rock scores in the analyses (Fig. 4b) did not alter this conclusion. The combined FWS, UW, and D&M whole-colony information (see Fig. 3) supported this finding. Positive trends were detected in the 1989-1994 FWS counts of East Amatuli Island - Light Rock multicount plots BMP3-4 (see Table 2, Fig. 6a) and the 1990-1994 counts of the three East Amatuli Island UW OSTR plots (see Fig. 6b). However, each of these small plot sets contained less than 4% of the average number of birds at the colony (about 33,000 individuals; see Table 1 and Fig. 3). Also, one plot in each of the plot sets contained a roosting area where fly-offs caused bird numbers to vary on them by as much as 15% and 40%, respectively, in addition to the normal daily variation in numbers that occurred on them. Because of the small number of plots involved (two in one case; three in the other) and the fact that the plots may not represent the whole colony, we believe that the increases on these plot sets should not be interpreted as conclusive evidence of colony-wide population growth. A new set of eight monitoring plots (multicount plots BMP1-8) that sample a broader range of nesting habitats containing about 15% of the birds at the East Amatuli Island - Light Rock colony was established in 1993; these plots will provide a better set of data for evaluating changes in murre numbers at this nesting complex.

As at East Amatuli Island - Light Rock, analyses of the 1989-1994 Nord Island - Northwest Islet whole-colony counts, including the combined FWS and D&M data, did not detect any trends in population numbers over the 6-year postspill interval. Analyses of the multicount and productivity plot information supported this finding.

Boersma *et al.* (1995) commented on the numerical differences between the FWS and UW Light Rock postspill estimates. We reviewed the available information on these counts and identified at least three factors that may help explain these differences. Some differences between the two sets of estimates are probably attributable to differences in methods. Prior to 1993, FWS teams used a 7.6 m Boston Whaler to count Light Rock (FWS unpubl. field notes). In contrast, UW personnel counted it from small inflatable rafts (see Boersma *et al.* 1995) that were able to operate closer to the cliffs and provide a different perspective of the birds. However, more importantly, we discovered that the 1992 FWS count was made during the early morning hours of

the day (during about 0800-0920 hrs on 26 August; D.E. Dragoo, unpubl. field notes), while the UW estimate was made during the afternoon and evening hours (Boersma *et al.* 1995). Boersma *et al.* (1995) correctly pointed out that morning counts of murres tend to be lower than afternoon or evening estimates. As a result, the 1992 FWS count almost certainly underestimated numbers of birds on Light Rock.

The difficulty in counting the densely populated sections of nesting habitat on top of Light Rock is almost certainly another factor that helped widened the numerical differences between the pre-1993 FWS and UW postspill estimates. These areas are difficult to count accurately even under the best of conditions (calm seas, high tide levels, good light), and it is not unusual for observer estimates to vary considerably. For example, when we counted plot BCP61 on top of the rock on 1 and 2 August 1993, the average scores of the two observers were about 30-50% apart (1,135 vs. 2,480 birds and 1,675 vs. 2,440 individuals, respectively; see Appendices 3 and 4 in Roseneau *et al.* 1995). Based on our own experience with problems of estimating birds on this part of the rock, we believe that this factor may have been responsible for part of the differences found between the published pre-1993 FWS and UW postspill counts.

Although the use of different methods and the difficulty of counting the top of Light Rock probably contributed to the numerical differences between the pre-1993 FWS and UW Light Rock postspill estimates, these factors may not completely explain them. However, another aspect of these counts may. The 1991-1992 UW and 1992 FWS estimates were single counts without any measure of variability, and the 1989-1990 FWS estimates consisted of only two counts each. During 1993-1994, we counted Light Rock four and five times, respectively (see Roseneau *et al.* 1995; this study). Our counts ranged between 7,761 and 9,414 birds in 1993, and between 6,749 and 8,450 individuals in 1994. The single 1991 and 1992 UW counts of 9,256 and 9,655 birds were almost identical to our highest 1993 score of 9,414 individuals, and the lowest FWS estimate of 5,865 murres in 1990 and the 5,960 bird count in 1992 were only about 12-13% below our lowest 1994 score (7,213 individuals on 28 July; see Appendix 1). Also, Boersma *et al.* (1995) commented that in 1992, productivity appeared to be low at Light Rock and attendance was unstable throughout July and August. If this was the case, then those conditions would have almost certainly increased the chances of finding wide variation between the 1992 UW and FWS counts that year. Based on this information, we believe that the numerical differences between the reported FWS and UW Light Rock counts (about 3,500-3,600 birds) may not be as significant as they appear to be, because some of the counts may have been made on days when numbers were high, and some may have been made on days when attendance was low. Having counted Light Rock a total of nine times during 1993-1994, we have confidence that our respective annual estimates of 8,454 and 7,842 birds are solid indicators of current murre numbers on Light Rock.

Timing of Nesting Events

The one-day difference in average median laying and hatching dates at East Amatuli Island - Light Rock and Nord Island - Northwest Islet indicated that nesting chronologies followed the same schedule at both colonies, even though birds settled on the Nord Island - Northwest Islet cliffs 10 days later than they did at East Amatuli Island - Light Rock. In 1993, attendance also stabilized about one week later at Nord Island - Northwest Islet than at East Amatuli Island - Light Rock, and there was only a 3-day difference in laying and hatching dates that year (see Roseneau *et al.* 1995). In 1994, just as in 1993, later settling dates at Nord Island - Northwest Islet appeared to be associated with harassment by bald eagles that regularly commuted between Nord Island and nesting and roosting areas on Ushagat Island (see Roseneau *et al.* 1995). Similar nesting schedules at East Amatuli Island - Light Rock and Nord Island - Northwest Islet are probably the normal case, because the nesting colonies are located only about 11 km apart and experience the same general environmental conditions (e.g., weather and current patterns, air and water temperatures, photoperiods).

Based on mean laying dates, nesting chronology at Nord Island appeared to be nine days earlier in 1993 and 19 days earlier in 1994 than reported for 1992 (28 July; see Table 6 in Dragoo *et al.* 1994). This was also apparently the general case on at least one side of Light Rock in 1991, because Boersma *et al.* (1995) reported a mean fledging date of 19 September from a camera plot set up in this type of habitat (assuming 32 days for incubation and a 21-day nestling period without mortality, the mean laying and hatching dates would have been 28 July and 29 August, respectively). In contrast, the 8 September 1991 mean fledging date reported by Boersma *et al.* (1995) for a camera plot on top of Light Rock suggests nesting events were earlier in this area than on the sides of the rock, and also earlier than the reported 1991 FWS Nord Island date (25 July, see Table 6 in Dragoo *et al.* 1994; again, assuming 32 days for incubation and a 21-day nestling period without mortality, the mean laying and hatching dates based on the Boersma *et al.* 8 September date would have been 17 July and 18 August, respectively). Earlier laying dates on top of Light Rock, compared to ledge habitats on its sides, are supported by our 1993 observations (see Roseneau *et al.* 1995).

The East Amatuli Island - Light Rock first-egg date (28 June) was obtained from the productivity plots. We suspect that at least a few eggs were probably laid in other parts of this colony a few days earlier, based on the first incidental egg date obtained at Nord Island - northwest Islet (23 June). The Nord Island incidental egg date (23 June) was about one week earlier than the 1993 incidental date (30 June), and one day earlier than the incidental 1993 East Amatuli Island - Light Rock egg date (24 June). Both the Nord Island incidental and productivity plot first-laying dates (23 and 28 June, respectively), and the East Amatuli Island - Light Rock productivity plot first-egg date (also 28 June) were earlier than the first-laying dates reported in the 1989-1991 FWS Barren Islands studies (<26 July, 17 July, and <10 July, respectively; see Nysewander *et al.* 1993 and Dragoo *et al.* 1994) and nearer to the 1992 FWS date (2 July, see Dragoo *et al.* 1994). The 1993-1994 dates also fell within the range of first dates derived from the 1977-1979 Light Rock data (about 20-30 June; e.g., Manuwal 1980; also see Table A7 in Dragoo *et al.* 1994), and were similar to the 1977-1978 Hinchinbrook and Chisik island first-laying dates (Hinchinbrook = 21 and 29 June, respectively; Chisik = 29 June in 1978). The Nord Island incidental first-egg date also closely matched the reported 1974 and 1977 Ugaiushak Island first-laying dates (25 and 24 June, respectively; see Table A7 in Dragoo *et al.* 1994).

Productivity

Productivity (fledglings-per-egg-laid) of murres at East Amatuli Island - Light Rock was higher in 1994 than in 1993 (0.73 vs. 0.55 fledglings/egg, respectively), and similar to the 1993-1994 Nord Island results (0.71 and 0.74 fledglings/egg, respectively). Productivity values from both years also appeared to be similar to or higher than the 1991 fledglings-per-pair ranges reported by Boersma *et al.* (1995) for two time-lapse camera plots on Light Rock (camera 1 = 0.50-0.72 and camera 2 = 0.47-0.59 fledglings/pair, average of midpoints = 0.57 fledglings/pair). Although the variable used by Boersma *et al.* (1995) was not directly comparable to our fledglings-per-egg-laid calculations, their reported ranges probably bracketed our results. In general, the UW values were probably similar to our 1993 East Amatuli Island - Light Rock productivity plot results and somewhat lower than our 1993-1994 Nord Island and 1994 East Amatuli Island - Light Rock values.

Our 1993-1994 productivity estimates were higher than the values reported from other Gulf of Alaska colonies (numbers varied from about 0.30 fledglings/egg at Ugaiushak Island in 1977 to 0.46-0.64 and 0.52-0.58 fledglings/egg at the Semidi Islands in 1979-1980 and 1989-1991, respectively—see Wehle 1978; Hatch and Hatch 1990; Dragoo *et al.* 1991a,b; Dragoo *et al.* 1994). They were also near the upper end of the ranges recorded at nesting colonies in other regions of Alaska during the mid-1970's - early 1990's (e.g., in the southeastern and northeastern Bering seas—0.30-0.76 fledglings/egg at the Pribilof Islands during 1976-1987, and 0.51-0.73 fledglings/egg at Bluff in 1987-1990; see Byrd 1989 and Murphy 1993, respectively). These data

show that murres reproduced at or above average levels at the Barren Islands colonies in 1993 and 1994.

Chicks-per-adult calculations provided additional evidence that murre productivity was within normal limits at the Barren Islands colonies in 1993 and 1994. The 1993-1994 periodic-visit values from both sets of productivity plots (0.35 chicks/adult at both study sites in 1993, and 0.44 and 0.51 chicks/adult at East Amatuli Island - Light Rock and Nord Island in 1994, respectively; see Table 5 in this study and Roseneau *et al.* 1995) fell within or exceeded the range reported for the Semidi Islands in 1989-1991 (0.32-0.40; see Baggot *et al.* 1989, and Dragoo *et al.* 1991a,b). Also, the 1993-1994 periodic-visit results and our one-day Nord Island study site values (0.27 and 0.40 chicks/adult in 1993 and 1994, respectively; see Roseneau *et al.* 1995) were within or above the range recorded at Agattu Island in the southern Bering Sea during the same three-year interval (e.g., 0.21-0.48; see Williams and Byrd 1992). Our 1994 periodic-visit chicks-per-adult numbers were also comparable to the values we derived from the 1991 UW Light Rock information (camera 1 = 0.51 and camera 2 = 0.44 chicks seen per mean number of adults, average = 0.48; see Table 4 in Boersma *et al.* 1995).

As in 1993, the high productivity of common murres at the East Amatuli Island - Light Rock and Nord Island - Northwest Islet colonies indicated that prey availability was high for this diving species during critical periods of the 1994 breeding cycle (see Roseneau *et al.* 1995). Although we did not collect quantitative information on murre diets or the prey base, we were able to obtain some incidental observations that forage fish (primarily capelin, *Mallotus villosus*) were both available and abundant in surface waters near the nesting colonies (see Appendix 16).

The presence of large forage fish schools in surface waters also apparently influenced the productivity of at least one surface-feeding seabird species. In 1993, a year when schools of forage fish were present but apparently remained below 50 m, black-legged kittiwakes experienced an early and near-complete breeding failure (see Roseneau *et al.* 1995). In contrast, during the 1994 nesting season when forage fish were observed at and near the surface, these birds fledged at least 0.6 chicks per nest at East Amatuli Island (n = 4 plots containing about 25 nests each observed every few days during July - mid-August), and about 0.9 chicks per nest at Nord Island (n = 5 plots containing a total of 464 complete and partial nests viewed once on 7 August, just before the first nestlings fledged; empty partial nests were included in the calculations because they were conservatively treated as failed nesting attempts).

Avian Predators

Based on our incidental observations, avian predation was similar in both type and intensity to what we observed in 1993 (see Roseneau *et al.* 1995). Adult bald eagles targeted adult murres, and subadult eagles took kittiwake chicks at Nord Island. Glaucous-winged gulls and common ravens preyed on murre eggs and murre and kittiwake chicks at both colonies, particularly when passing eagles flushed adult birds from nesting ledges. Peregrine falcons, although present at both locations, had little impact on murres, because the falcons were few in number and favored smaller prey species (e.g., parakeet auklets, kittiwakes). Murre eggs laid early in the season when many birds were still intermittently visiting nesting sites appeared to be more vulnerable to passing gulls and ravens than those laid after attendance stabilized at the nesting ledges.

Several observations supported our tentative 1993 conclusions that avian predation tended to be higher at Nord Island - Northwest Islet than at East Amatuli Island - Light Rock, and that a relatively substantial population of bald eagles nesting on nearby Ushagat Island was responsible for this difference (Roseneau *et al.* 1995). Adult eagles from Ushagat Island appeared to visit the southeastern corner of Nord Island on a regular basis to prey on adult murres until at least mid-August, and two to three subadult birds also hunted kittiwake chicks along the eastern side of the colony at least as late as early August. The visiting eagles flushed murres and kittiwakes from the

nesting cliffs well past the date eagle-induced flushing events appeared to stop at East Amatuli Island - Light Rock (7 July), and resident gulls and ravens continued to exploit these opportunities to take unprotected eggs and chicks well into August. The higher incidence of harassment by eagles in the southeastern sector of the Nord Island - Northwest Islet colony was almost certainly related to three factors: the proximity of Ushagat Island, which contained most of the nesting habitat for these raptors in the Barren Islands group; the location of the nesting cliffs directly on the shortest aerial route between Nord and Ushagat islands; and the configuration of the cliffs, which allowed passing eagles to fly by and easily snatch adult murres from nesting ledges.

During 1993, eagles occupied at least four of six known territories on Ushagat Island, and 10 different adults and 3 to 4 subadults were seen on one day (3 August; see Roseneau *et al.* 1995). In 1994, pairs were present at seven territories (14 adults) and one additional adult and at least four subadults (one three-year-old, one two-year-old, and two one-year-old birds) were identified during the nesting season. In comparison, eagles did not nest on East Amatuli Island during either year, and we saw only eight different birds there in 1993, and three to four in 1994. The marked difference in numbers of eagles seen at the Nord Island - Northwest Islet and East Amatuli Island - Light Rock colonies clearly resulted from differences in the types and amounts of nesting habitat available to the birds within the Barren Islands group (see Roseneau *et al.* 1995).

CONCLUSIONS

1. Based on population count analyses, positive trends were found on two small sets of plots at the East Amatuli Island - Light Rock colony over the postspill interval (1989-1994). However, no trends were detected in the whole-colony counts or on the other multicount plot sets, including those at Nord Island - Northwest Islet. Because only a small number of plots were involved in the increases, and the fact that these plots may not represent the entire colony, the positive trends found in these data sets should not be interpreted as conclusive evidence of colony-wide population growth. A new set of monitoring plots (multicount plots BMP1-8) that sample broader range of nesting habitats was established at East Amatuli Island - Light Rock in 1993; these plots will provide a better set of data for evaluating changes in murre population numbers at this colony.

2. A review of the 1989-1992 FWS and 1991-1992 UW estimates at Light Rock suggests that different methods and the difficulties in censusing the top of the rock, coupled with the fact that the UW counts and some of the FWS estimates were single counts without any measure of variability, probably account for most of the numerical differences found between these two sets of data. Because measurements of variability were not obtained during the UW and FWS counts, the differences between the two sets of estimates (about 3,500-3,600 birds) may not be as significant as they appear to be.

3. Based on mean laying dates, 1994 nesting chronology averaged about one week earlier at the Barren Islands colonies than in 1993, and at the Nord Island - Northwest Islet colony, 1993-1994 nesting schedules averaged about 9 and 19 days earlier than in 1992, respectively. First-egg dates obtained in 1993-1994 were similar to those reported from the Barren Islands and several other northern Gulf of Alaska colonies during the mid- and late 1970's (e.g., Chisik, Ugaiushak, and Hinchinbrook islands).

4. Productivity (fledglings per egg laid) of murres was high for a second year in a row at the Barren Islands colonies, compared with ranges reported from other Gulf of Alaska nesting locations in the late 1970's - early 1980's and late 1980's - early 1990's (e.g., Ugaiushak Island, Semidi Islands). Chicks-per-adult values also fell within or exceeded ranges reported from other Alaskan colonies in the late 1980's - early 1990's (e.g., Semidi Islands in the western Gulf of Alaska, Agattu Island in the southern Bering Sea). Combined fledglings-per-

egg-laid and chicks-per-adult information indicate that murres reproduced at or above average levels at the Barrens Islands colonies in 1993 and 1994.

5. The high productivity of murres at the Barren Islands colonies was probably related to the abundance and availability of forage fish during critical parts of the nesting season (e.g., the chick-rearing period), just as it appeared to be in 1993. In 1994, forage fish (primarily capelin) were available to both diving species (e.g., common murres) and surface-feeding birds (e.g., black-legged kittiwakes, a species that experienced an early, near-complete breeding failure at the Barren Islands in 1993, but produced about 0.6-0.9 chicks per nest in 1994).

6. Bald eagle-related disturbance and predation events occurred more frequently at Nord Island - Northwest Islet than at East Amatuli Island - Light Rock because nearby Ushagat Island contained most of the nesting habitat available to these raptors in the Barren Islands group. Harassment of murres by eagles was concentrated on the southeastern corner of Nord Island, because this part of the colony was located directly on the shortest aerial route between Nord and Ushagat islands, and the configuration of the cliffs allowed passing eagles to fly by and easily snatch adult murres from nesting ledges.

RECOMMENDATIONS

1. The East Amatuli - Light Rock and Nord Island - Northwest Islet murre colonies, including all multicount plot sets, should be recensused in 1997, when some birds belonging to the strong 1993-1994 cohorts should begin returning to natal areas to prospect for nesting sites. Monitoring population numbers at these locations in 1997 should improve the chances of finding positive trends. If convincing evidence of population growth is not found during the 1997 nesting season, the colonies should monitored at three-year intervals until it is. *Note: In the case of common murres (as with many other alcid species having delayed maturity), immature birds begin returning to their natal colonies several years before first attempting to breed (e.g., Hudson 1985; also see Birkhead and Hudson 1977). Three-year-old birds begin visiting the nesting cliffs during the early incubation period and four-year-old individuals are often present before laying begins (early enough to be detected during population counts). The percentages of birds belonging to these age-classes that return to colonies appear to average about 14% and 19%, respectively (these may be underestimates, because they are based on banded birds, and murres are prone to losing bands at sea).*

2. Productivity was high and within normal ranges in 1993-1994 (based on both fledglings-per-egg-laid and chicks-per-adult values). We recommend monitoring productivity again in 1995 to see if it remains within normal limits (five consecutive years of productivity within normal bounds is the preferred restoration objective for this variable and monitoring it in 1995 can provide additional data toward this goal).

3. We recommend starting research to explore relationships between murre productivity levels and abundance and availability of important forage fish species at the Barren Islands colonies (e.g., capelin, sand lance) and integrating this work with any proposed local and regional ecosystem studies (e.g., Minerals Management Service-sponsored studies that may begin in lower Cook Inlet during 1995).

4. We recommend starting research to explore relationships between timing of murre nesting events and physical environmental parameters (e.g., water temperatures, which can influence distribution and availability of forage fishes) and integrating this work with any proposed local or regional ecosystem studies (e.g., Minerals Management Service-sponsored studies that may begin in lower Cook Inlet during 1995).

ACKNOWLEDGMENTS

We would like to thank Margaret A. Blanding, Peter F. Chance, Kurt F. Johnson, Warren J. Platts, Mary F. Portner, Jessica E. Wachtel, and Andrea L. Roberto for helping to make the 1994 Barrens Islands murre restoration project a success. Jessica, Andrea, and Warren were stationed at the Ushagat Island field camp and worked at Nord Island. Margaret and Kurt helped collect data at East Amatuli Island. Mary and Peter provided valuable assistance during the population counts. Their boating and climbing skills and constant dedication to the work allowed us to safely collect the population, chronology, and productivity data in spite of sometimes hostile weather and sea conditions. Special thanks also go to Captain John Rogers of the M/V *Kittiwake II*, and Captain Michael Parks and First Mate Lydia Rabottini of the M/V *Waters* for their assistance in helping mobilize and demobilize the field camps, and for their safe and timely support during the population counts and late-season productivity work. Don Fell, Howard Reed, and other Maritime Helicopter pilots also deserve special mention for providing safe, efficient transportation during the field season. Trina Fellows and Carol Hagglund, Alaska Maritime NWR, monitored our radio calls on a daily basis and cheerfully helped us with many logistical needs. Joel A. Cooper also provided valuable logistical assistance to the project.

LITERATURE CITED

Baggot, C.M., B.K. Bain, and D.R. Nysewander. 1989. Changes in colony size and reproductive success of seabirds at the Semidi Islands, Alaska, 1977-1989. Unpubl. rept., U. S. Fish Wildl. Serv., Homer, AK. 34 pp.

Bailey, E.P. 1975a. Barren Islands Survey Notes, 1974-1975. Unpubl. field notes, 1974-1975. U.S. Fish Wildl. Serv., Homer, AK.

_____. 1975b. Breeding bird distribution and abundance in the Barren Islands Alaska. Unpubl. rept., 1975. U.S. Fish Wildl. Serv., Homer, AK.

_____. 1976. Breeding bird distribution and abundance in the Barren Islands Alaska. Murrelet 57:2-12.

Birkhead, T.R. and P.J. Hudson. 1977. Populations parameters for the common guillemot *Uria aalge*. Ornis Scandinavica 8:145-154.

Boersma, P.D., J.K. Parrish, and A.B. Kettle. 1995. Common murre abundance, phenology, and productivity on the Barren Islands, Alaska: The *Exxon Valdez* oil spill and long-term environmental change. Pp. 820-853 *in Exxon Valdez* Oil Spill: Fate and effects in Alaskan waters, ASTM STP 1219, P.G. Wells, J.N. Butler, and J.S. Hughes (eds.), Amer. Soc. for Testing and Materials, Philadelphia, PA.

Byrd, G.V. 1986. Results of seabird monitoring in the Pribilof Islands in 1986. Unpubl. U.S. Fish Wildl. Serv., Homer, AK. 74 pp.

_____ 1989. Seabirds in the Pribilof Islands, Alaska: Trends and monitoring methods. M.S. thesis, Univ. of Idaho.

Dipple, C. and D. Nysewander. 1992. Marine bird and mammal censuses in the Barren Islands, 1989 and 1990, with specific emphasis on species potentially impacted by the 1989 *Exxon Valdez* , including supplemental appendices for 1991 murre data. Unpubl. rept., U. S. Fish Wildl. Serv., Homer, AK. 71 pp.

Dragoo, D.E., B.K. Bain, and A. Perillo. 1991a. Changes in colony size and reproductive success of seabirds at the Semidi Islands, Alaska, 1977-1990. Unpubl. rept., U. S. Fish Wildl. Serv., Homer, AK. 38 pp.

_____, _____, M.J. Melendez, and C.M. Minch. 1991b. Changes in colony size and reproductive success of seabirds at the Semidi Islands, Alaska, 1976-1991. Unpubl. rept., U. S. Fish Wildl. Serv., Homer, AK. 43 pp.

_____, G.V. Byrd, D.G. Roseneau, D.A. Dewhurst, J.A. Cooper, and J.H. McCarthy. 1994. Effects of the *T/V Exxon Valdez* oil spill on murres: A perspective from observations at breeding colonies four years after the spill. Final rept., Restoration Proj. No. 11, U.S. Fish Wildl. Serv., Homer, AK.

ECI (Ecological Consulting, Inc.). 1991. Assessment of direct seabird mortality in Prince William Sound and the western Gulf of Alaska resulting from the *Exxon Valdez* oil spill. Unpubl. rept., Ecol. Consulting, Inc., Portland, OR. 153 pp.

Erikson, D.E. 1995. Surveys of murre colony attendance in the northern Gulf of Alaska following the *Exxon Valdez* oil spill. Pp. 780-819 *in Exxon Valdez* oil spill: Fate and effects in Alaskan waters, ASTM STP 1219, P.G. Wells, J.N. Butler, and J.S. Hughes (eds.), Amer. Soc. for Testing and Materials, Philadelphia, PA.

FWS (Fish and Wildlife Service). 1994. Alaska seabird colony catalog computer data base and colony status record archives. U.S. Fish Wildl. Serv., Migratory Bird Manage., Anchorage, AK.

Hatch, S.A. and M.A. Hatch. 1989. Attendance patterns of common and thick-billed murres at breeding sites: Implications for monitoring. J. Wildl. Manage. 53:483-493.

_____ and _____. 1990. Breeding seasons of oceanic birds in a subarctic colony. J. Can. Zool. 68:1,664-1,679.

Hudson, P.J. 1985. Population parameters for the Atlantic alcidae. Chap. 5, pp. 233-261 *in* The Atlantic alcidae. D.N. Nettleship and T.R. Birkhead (eds.). Academic Press. 574 pp.

Hunt, G.L., Z. Eppley, B. Burgeson, and R. Squibb. 1981. Reproductive ecology, food, and foraging areas of seabirds nesting on the Pribilof Islands, 1975-1979. Pp. 1-258 *in* Environ. Assess. Alaska Contin. Shelf, Final Repts. Princ. Invest., Vol. 12. NOAA Environ. Res. Lab, Boulder, CO.

Manuwal, D. A. 1978. Dynamics of marine bird populations on the Barren Islands, Alaska. Unpubl. Environ. Assess. Alaska Contin. Shelf, Annual Repts. Princ. Invest. Minerals Manage. Serv., Anchorage, AK. 97 pp.

_____. 1980. Breeding biology of seabirds on the Barren Islands, Alaska. Unpubl. rept., U.S. Fish Wildl. Serv., Off. Biol. Serv., Anchorage, AK. 195 pp.

_____ and D. Boersma. 1978. Dynamics of marine bird populations on the Barren Islands, Alaska. Pp. 575-679 *in* Environ. Assess. Alaska Contin. Shelf, Annual Repts. Princ. Invest., Vol. 3. NOAA Environ. Res. Lab, Boulder, CO.

Murphy, E.C. 1993. Population status of murres and kittiwakes at Bluff, Alaska in 1990. Chap. 4, pp. 60-93 *in* Monitoring of population and productivity of seabirds at Cape Peirce, Bluff, and Cape Thompson, Alaska, 1990. V. Mendenhall (ed.). Final Rept., U.S. Fish Wildl. Serv., Migratory Bird Manage. Marine and Coastal Bird Proj., Anchorage, AK. 236 pp.

Nysewander, D. and C. Dipple. 1990. Population surveys of seabird nesting colonies in Prince William Sound, the outside coast of the Kenai Peninsula, Barren Islands, and other nearby colonies, with emphasis on changes in numbers and reproduction of murres. Bird Study No. 3. Unpubl. prog. rept., U.S. Fish Wildl. Serv., Homer, AK. 48 pp.

_____ and _____. 1991. Population surveys of seabird nesting colonies in Prince William Sound, the outside coast of the Kenai Peninsula, Barren Islands, and other nearby colonies, with emphasis on changes of numbers and reproduction of murres. Bird Study No. 3. Unpubl. prog. rept., U. S. Fish Wildl. Serv., Homer, AK. 70 pp.

_____, C.H. Dipple, G.V. Byrd, and E.P. Knudtson. 1993. Effects of the *T/V Exxon Valdez* oil spill on murres: A perspective from observations at breeding colonies. Bird Study No. 3. Final rept., U.S. Fish Wildl. Serv., Homer, AK. 40 pp.

Piatt, J.F, C.J. Lensink, W. Butler, M. Kendziorek, and D.R. Nysewander. 1990. Immediate impact of the "Exxon Valdez" oil spill on marine birds. Auk 107:387-397.

Roseneau, D.G., A.B. Kettle, and G.V. Byrd. 1995. Common murre restoration monitoring in the Barren Islands, Alaska, 1993. Unpubl. final rept. by the Alaska Maritime National Wildlife Refuge, Homer, Alaska for the *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska (Restoration Project 93049). 71 pp.

Sowls, A.L., S.A. Hatch, and C.J. Lensink. 1978. Catalog of Alaskan seabird colonies. U.S. Fish Wildl. Serv., Biol. Serv. Prog. FWS/OBS 78/78, Anchorage, AK. 153 pp.

Wehle, D.H.S. 1978. Studies of marine birds at Ugaiushak Island, Alaska. Pp. 208-312 *in* Environ. Assess. Alaska Contin. Shelf, Annual Repts. Princ. Invest., Vol. 2. NOAA Environ. Res. Lab, Boulder, CO.

Wilkinson, L., M.A. Hill, J.P. Welna, and G. Birkenbeuel. 1992. SYSTAT for Windows: Statistics, Version 5 edition. SYSTAT Inc., Evanston, IL. 750 pp.

Williams, J.C. and G.V. Byrd. 1992. The status of kittiwakes and murres at Agattu and Buldir islands 1988-1991. Unpubl. rept., U. S. Fish Wildl. Serv., Adak, AK. 73 pp.

Table 1. Average FWS counts of murres at the Barren Islands, Alaska nesting colonies in 1989-1994 (numbers of counts are shown in parentheses).

	East Amatuli Island - Light Rock						Nord Island - Northwest Islet	
	East Amatuli Light Rock		East Amatuli Island		Entire Colony		Entire Colony	
Year	Number of Birds	CV(%)[a]	Number of Birds	CV(%)	Number of Birds	CV(%)	Number of Birds	CV(%)
1989[b]	6,912 (2)	10.2	ND[c]		ND		11,838 (2)	6.5
1990[b]	5,865 (2)	10.5	ND		ND		12,277 (2)	6.5
1991[b]	ND[d]		ND		ND		13,333 (2)	0.8
1992[e]	5,960 (1)		ND		ND		11,212 (1)	
1993[f]	8,454 (4)	8.4	24,775 (2)	6.5	32,721 (2)	5.7	13,422 (4)	15.5
1994[g]	7,750 (5)	7.5	25,195 (2)	3.8	33,011 (2)	0.5	11,753 (4)	10.7

Tukey HSD Multiple Comparisons Test (Significance Level = 0.1)[h]

East Amatuli Light Rock	Nord Island - Northwest Islet
1990 1989 1994 1993	1989 1990 1991 1993 1994

Kendall's Tau Rank Correlation: Count vs. Year (Significance Level = 0.1)

East Amatuli Light Rock	Nord Island - Northwest Islet
$\tau = 0.40$, n = 5	$\tau = 0.07$, n = 6

[a] CV = coefficient of variation (standard deviation divided by the mean and multiplied by 100).
[b] Data are from Nysewander and Dipple (1990, 1991); Dipple and Nysewander (1992); and Nysewander *et al.* (1993). Counts on Light Rock were 7,410 and 6,413 in 1989; 5,430 and 6,300 in 1990 Nord Island - Northwest Islet counts were 12,381 and 11,294 in 1989; 11,713 and 12,842 in 1990; and 13,404 and 13,262 in 1991.
[c] ND = no data.
[d] The previously reported 17 July 1991 single Light Rock count of 5,529 murres is not shown here because it included 3,429 birds on the cliffs and 2,100 individuals on nearby waters (see Nysewander and Dippel 1991).
[e] Data are from Dragoo *et al.* (1994). Counts were 5,960 at Light Rock and 11,212 at Nord Island - Northwest Islet in 1992.
[f] Data are from Roseneau *et al.* (1995). Counts were 9,414, 8,134, 7,761, and 8,507 at Light Rock and 12,474, 16,484, 12,817, and 11,913 at Nord Island - Northwest Islet in 1993.
[g] Data are from this study (see Appendices 1-7 and 11-14).
[h] The 1992 data were not included in the Tukey HSD analyses because only one count was made at each location (i.e., n = 1).

Table 2. Average FWS counts of murres on multicount plots at the Barren Islands, Alaska nesting colonies in 1989-1994 (numbers of counts are shown in parentheses).

Year	East Amatuli Island - Light Rock Multicount Plots BMP3-4		Nord Island - Northwest Islet Multicount Plots BMP1-11	
	Numbers of Birds	CV(%)[a]	Numbers of Birds	CV(%)
1989[b]	852 (2)	14.8	2,431 (2)	5.1
1990[b]	575 (2)	32.8	4,383 (3)	12.9
1991[b]	860 (2)	27.2	3,558 (2)	4.0
1992[c]	745 (5)	32.6	2,971 (5)	10.6
1993[d]	1,375 (8)	12.6	4,003 (5)	12.9
1994[e]	1,245 (8)	8.1	2,893 (5)	22.1

Tukey HSD Multiple Comparisons Test (Significance Level = 0.1)

East Amatuli Island - Light Rock	Nord Island - Northwest Islet
1989 1990 1991 1992 1993 1994	1990 1993 1991 1989 1992 1994

Kendall's Tau Rank Correlation: Count vs. Year (Significance Level = 0.1)

East Amatuli Island - Light Rock	Nord Island - Northwest Islet
$\tau = 0.47$, n = 6	$\tau = 0.07$, n = 6

[a] CV = coefficient of variation (standard deviation divided by the mean and multiplied by 100).

[b] Data are from Nysewander and Dipple (1990, 1991); Dipple and Nysewander (1992); and Nysewander *et al.* (1993). East Amatuli - Light Rock counts were 763 and 941 in 1989; 708 and 441 in 1990; and 1,025 and 694 in 1991. Nord Island - Northwest Islet counts were 2,519 and 2,343 in 1989; 4,991, 3,869, and 4,288 in 1990; and 3,659 and 3,457 in 1991.

[c] Data are from Dragoo *et al.* (1994). Counts were 467, 948, 926, 893, and 493 at East Amatuli - Light Rock, and 3,008, 2,637, 2,744, 3,449, and 3,016 at Nord Island - Northwest Islet in 1992.

[d] Data are from Roseneau *et al.* (1995). Counts were 1,580, 1,259, 1,540, 1,492, 1,505, 1,254, 1,263, and 1,110 at East Amatuli Island - Light Rock, and 4,589, 4,513, 3,813, 3,479, and 3,623 at Nord Island - Northwest Islet in 1993.

[e] Data are from this study (see Appendix 10).

Table 3. Average FWS counts of murres on productivity plots at the Barren Islands, Alaska nesting colonies in 1989-1994 (numbers of counts are shown in parentheses).

Year	East Amatuli Island - Light Rock Productivity Plots LPP1-10		Nord Island Productivity Plots LPP1-5	
	Numbers of Birds	CV(%)[a]	Numbers of Birds	CV(%)
1990[b]			412 (2)	2.7
1991[b]			301 (1)	0
1992[b]			264 (4)	14.7
1993[c]	481 (7)	7.6	398 (10)	4.8
1994[d]	456 (13)	6.6	408 (15)	6.3

Tukey HSD Multiple Comparisons Test (Significance Level = 0.1)[e]

Nord Island - Northwest Islet

1990 1993 1994 1992

Kendall's Tau Rank Correlation: Count vs. Year (Significance Level = 0.1)

Nord Island - Northwest Islet

$\tau = 0, n = 5$

[a] CV = coefficient of variation (standard deviation divided by the mean and multiplied by 100).
[b] Data are from unpubl. FWS field notes. Counts at Nord Island were 420 and 404 in 1990; 301 in 1991; and 306, 264, 212, and 272 in 1992.
[c] Data are from Roseneau *et al.* (1995). Counts were 397, 387, 410, 391, 382, 382, 424, 370, 422, and 417 at Nord Island and 492, 537, 430, 501, 463, 446, and 497 at East Amatuli Island - Light Rock in 1993.
[d] Data are from this study (see Appendix 9).
[e] The 1991 data were not included in the Tukey HSD analysis because only one count was made that year (i.e., n = 1).

Table 4. Dates of 1994 Barren Islands, Alaska common murre nesting events calculated from productivity plot data.[1]

Nesting Event	Data Type used for Calculations	East Amatuli Island	(SD) [2]	Nord Island	(SD)
Birds settled on cliffs [3]	Rafting and cliff observations	24 Jun		3 Jul	
First egg laid	Incidental observations [4]	ND		23 Jun	
First egg laid on productivity plots	Productivity plot observations	28 Jun		28 Jun	
Average median laying date [5]	Laying and hatching data	10 Jul	(1.5)	9 Jul	(2.3)
Mean laying date	Laying and hatching data	10 Jul	(1.3)	9 Jul	(1.7)
Average median hatching date [5]	Laying and hatching data	11 Aug	(1.5)	10 Aug	(2.5)
Mean hatching date	Laying and hatching data	10 Aug	(1.4)	10 Aug	(1.6)
Mean incubation period	Hatching minus laying (n > 2)	33 days	(1.3)	28 days	(2.6)

[1] Plots are the sample units; n = 10 at East Amatuli Island (including one on East Amatuli Light Rock) and n = 8 at Nord Island (see Figs. 2a and 2b).
[2] SD = standard deviation in days among sample plots.
[3] Date numbers stabilized on cliffs.
[4] Incidental observations = nonsystematic observations obtained in other sections of the respective colonies.
[5] Average of the median dates that were calculated for each plot.

Table 5. Measurements of common murre productivity on study plots at the Barren Islands, Alaska nesting colonies in 1994.[a]

Location (Productivity Plots)	Number of Eggs Laid	Hatching Success [b]	(SD) [c]	Fledging Success [d]	(SD)	Productivity [e]	(SD)	Chicks per Adult [f]	(SD)
East Amatuli Island (LPP1-10) [g]	305 [h]	0.79	(0.08)	0.93	(0.07)	0.73	(0.08)	0.44	(0.07)
Nord Island (LPP1-8) [i]	315 [j]	0.84	(0.08)	0.89	(0.06)	0.74	(0.09)	0.51	(0.06)

[a] Productivity plots (LPP) are the sample units; n = 10 at East Amatuli Island (including one on East Amatuli Light Rock) and n = 8 at Nord Island (see Figs. 2a and 2b).

[b] Hatching success = number of chicks hatched per number of eggs laid.

[c] SD = standard deviation.

[d] Fledging success = number of chicks fledged per number of eggs hatched ("fledging" or "fledged", as used in this report, refers to sea-going of chicks—murre chicks jump from nesting ledges before they are fully feathered or capable of flight and fledge several weeks later at sea).

[e] Productivity = number of chicks fledged per eggs laid.

[f] A measurement calculated from periodic observations for comparison with data from previous years (e.g., Dragoo *et al.* 1994, Nysewander et al. 1993).

[g] LPP10 is located on the northwest side of East Amatuli Light Rock (see Fig. 2a).

[h] Three of these eggs were excluded from the productivity portion of the analysis (i.e., calculations were based on 302 eggs).

[i] LPP1-6 were established during previous FWS postspill studies (e.g., Dragoo *et al.* 1994, Nysewander *et al.* 1993).

[j] Seventeen of these eggs were excluded from the productivity portion of the analysis (i.e., calculations were based on 298 eggs).

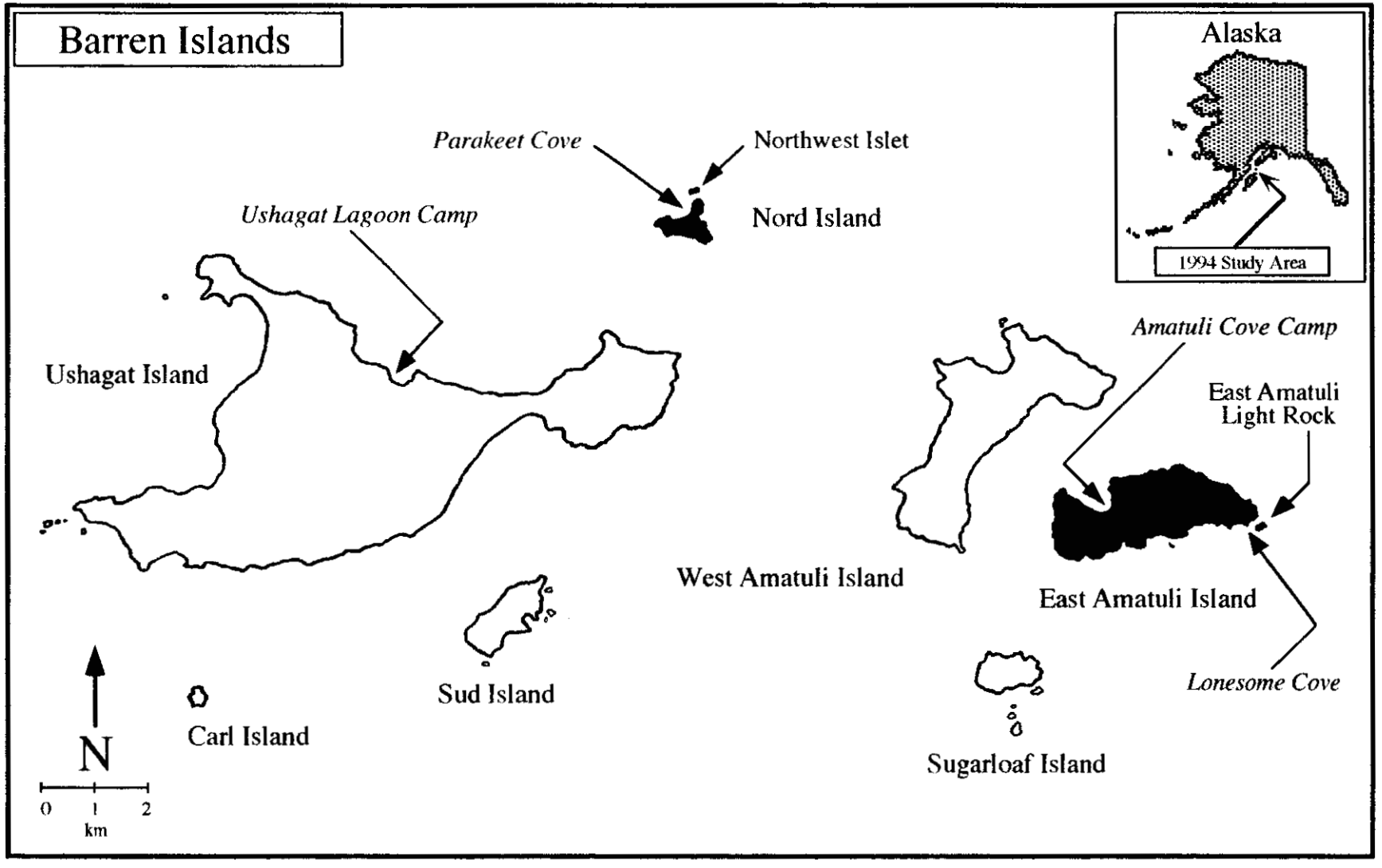

Figure 1. The East Amatuli Island - East Amatuli Light Rock and Nord Island - Northwest Islet study areas (in black) in the Barren Islands, Alaska (these locations contain all of the known murre nesting habitat in the island group).

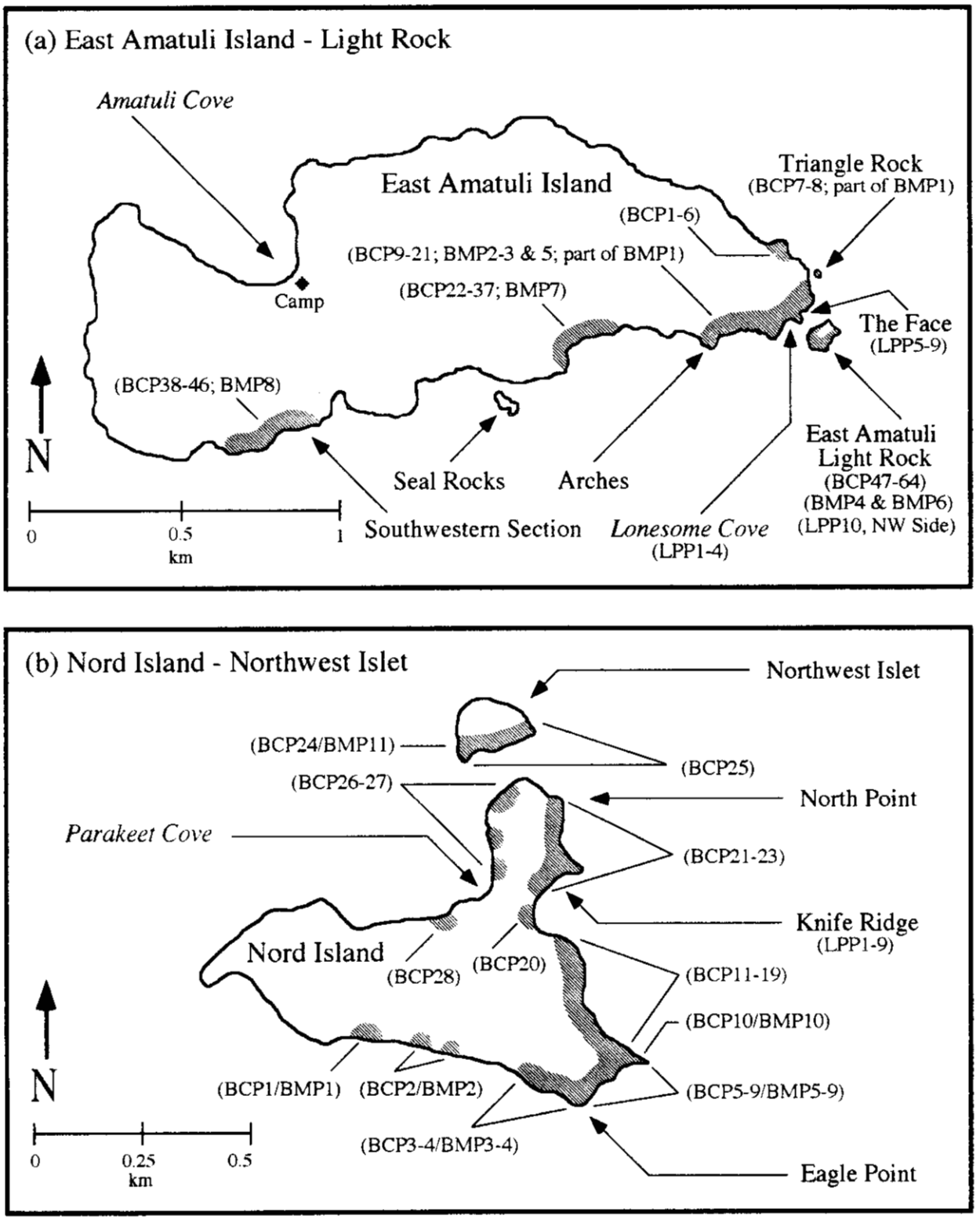

Figure 2. Murre nesting habitat (shaded areas), population census plots (BCP), multicount plots (BMP), and productivity plots (LPP) at the (a) East Amatuli Island - Light Rock and (b) Nord Island - Northwest Islet murre colonies, Barren Islands, Alaska.

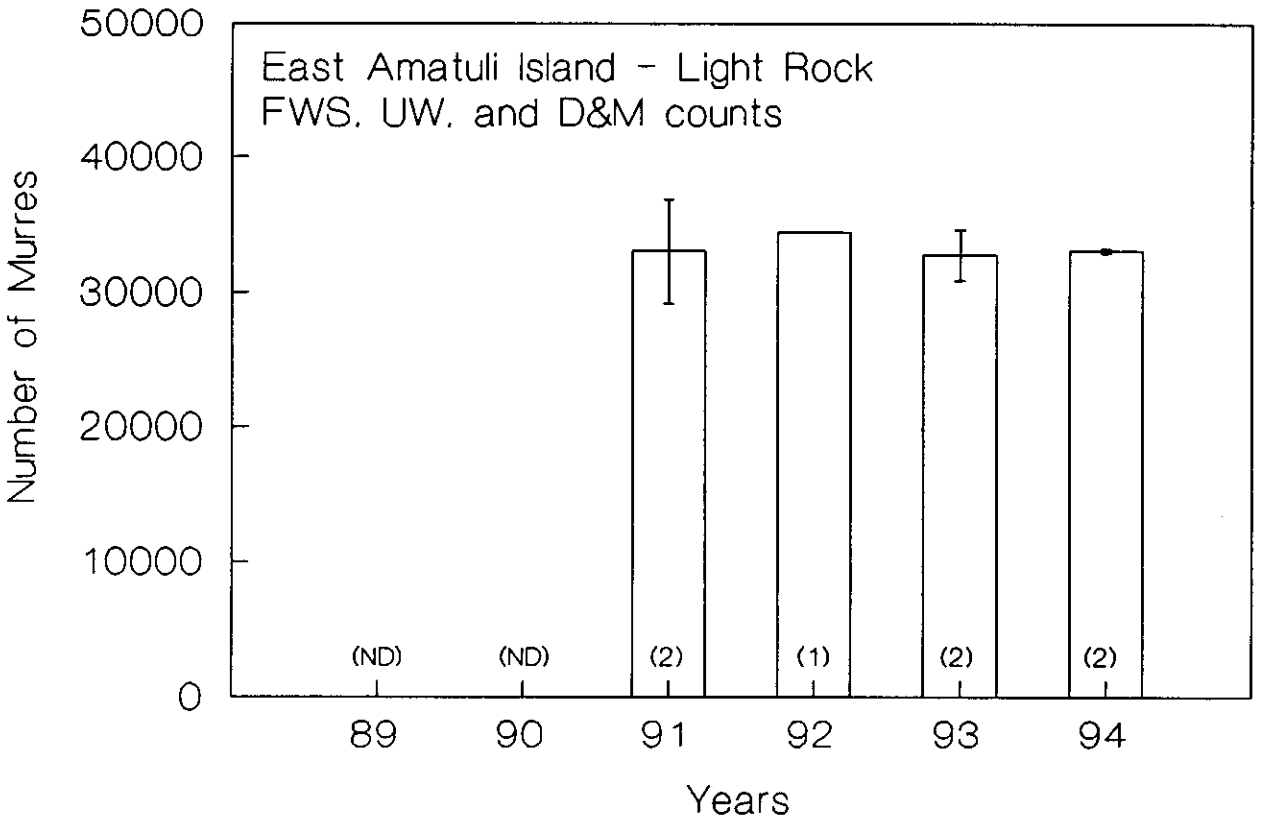

Figure 3. Average counts of murres at East Amatuli Island - Light Rock, Barren Islands, Alaska, 1989-1994. Counts were made by the Fish and Wildlife Service (FWS; 1993-1994), the University of Washington (UW; one count each year 1991-1992, see text and Boersma *et al.* 1995), and Dames & Moore (D&M; one count in 1991, see text and Erikson 1995). Number of counts shown in parentheses; error bars = standard deviation.

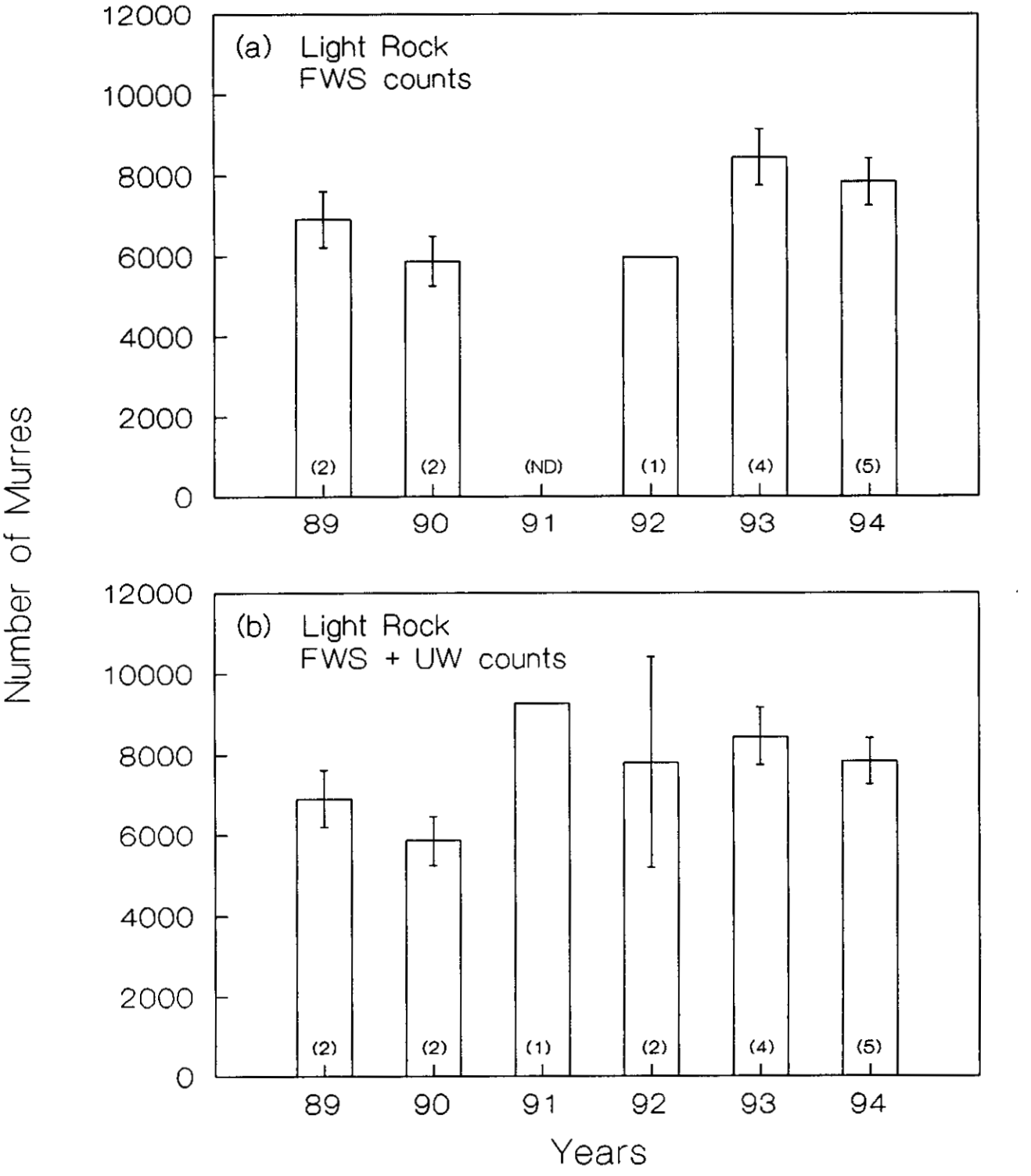

Figure 4. Average counts of murres at East Amatuli Light Rock, Barren Islands, Alaska, 1989-1994. Counts were made by (a) the Fish and Wildlife Service (FWS) and (b) the FWS and the University of Washington (UW; one UW count per year during 1990-1992, see text and Boersma *et al.* 1995). Number of counts shown in parentheses; error bars = standard deviation.

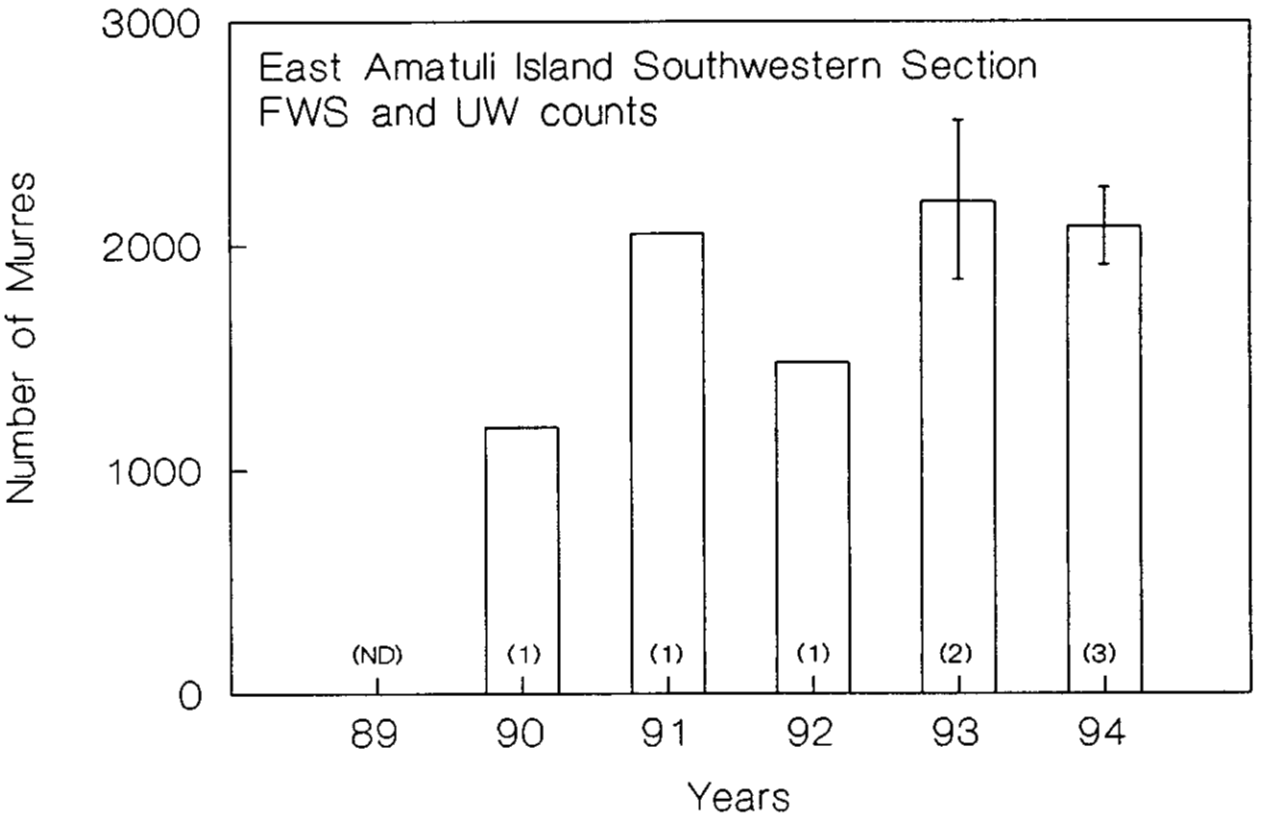

Figure 5. Average counts of murres at Southwestern Section, East Amatuli Island, Barren Islands, Alaska, 1990-1994. Counts were made by the Fish and Wildlife Service (FWS; 1993-1994) and the University of Washington (UW; 1990-1992, see text and Boersma *et al.* 1995). Number of counts shown in parentheses; error bars = standard deviation.

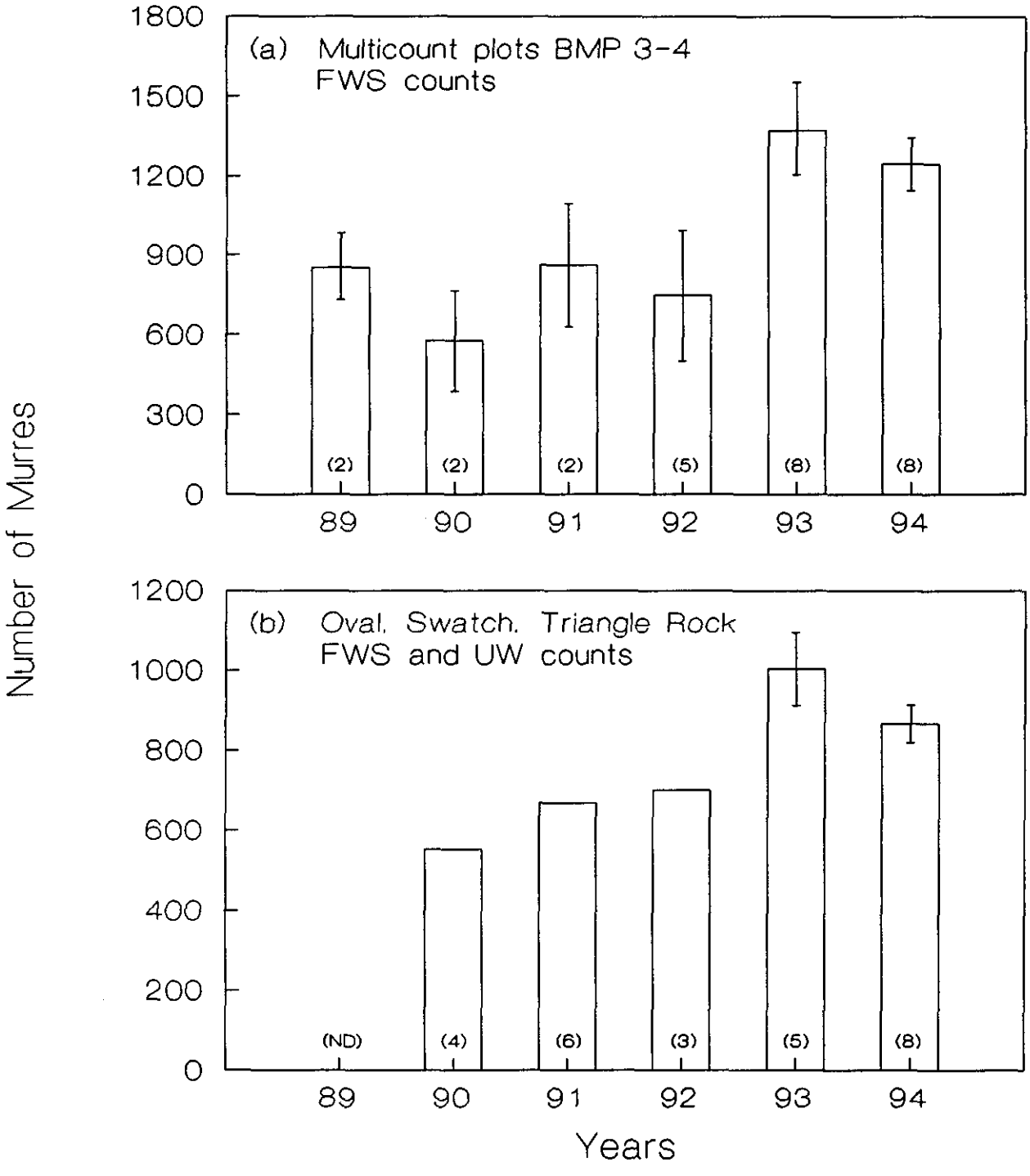

Figure 6. Average counts of murres on two small sets of multicount plots at East Amatuli Island - Light Rock, Barren Islands, Alaska, 1989-1994. Counts were made on (a) multicount plots BMP3-4 by the Fish and Wildlife Service (FWS) and (b) plots Oval, Swatch, and Triangle Rock by the FWS and the University of Washington (UW; 1990-1992 counts were made by UW, see text and Boersma *et al.* 1995; no error bars are shown for the UW counts because only averages were available). Number of counts shown in parentheses; error bars = standard deviation.

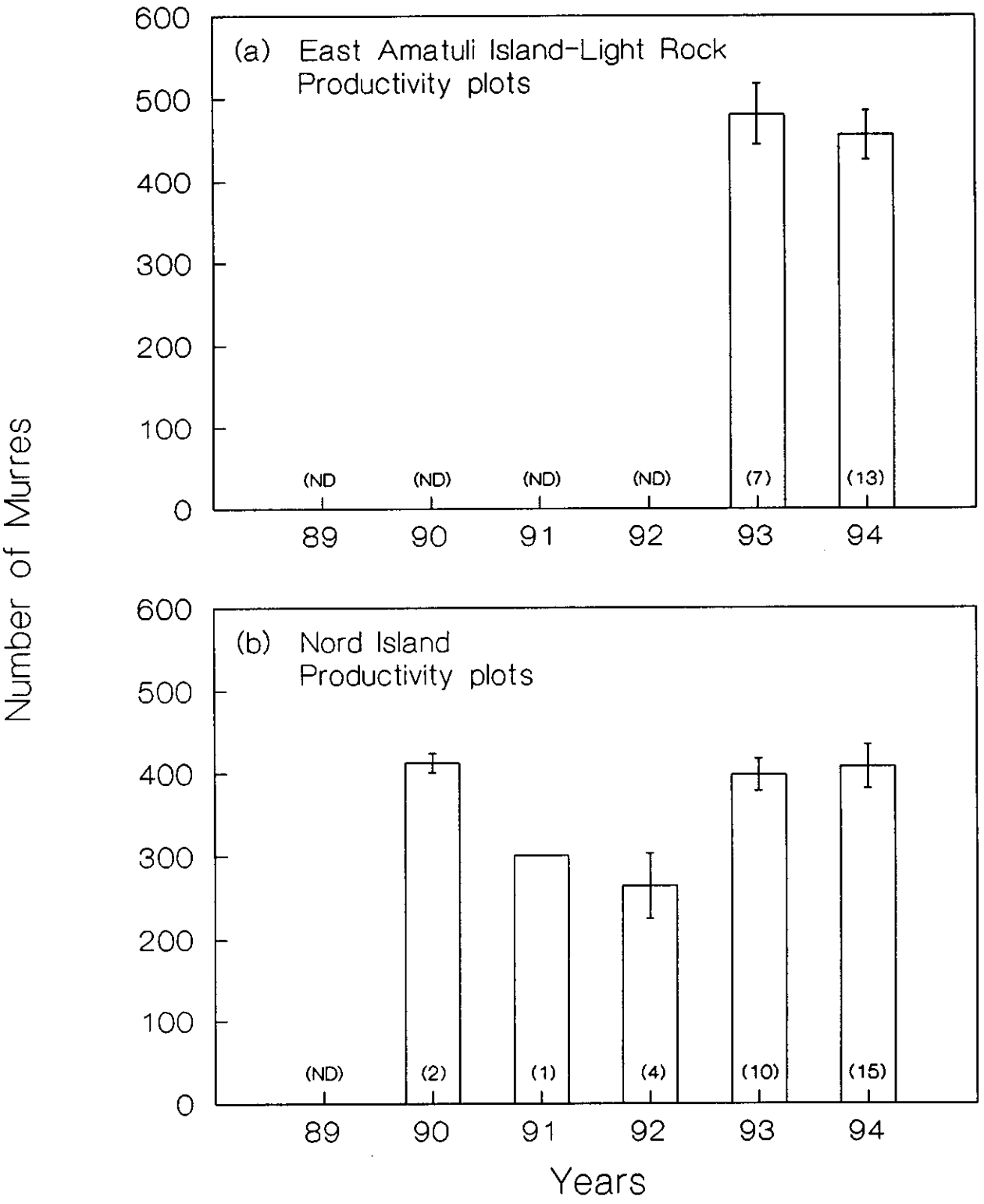

Figure 7. Average counts of murres on productivity plots (a) LPP1-10 at East Amatuli Island - Light Rock and (b) LPP1-5 at Nord Island, Barren Islands, Alaska, 1989-1994. Number of counts shown in parentheses; error bars = standard deviation.

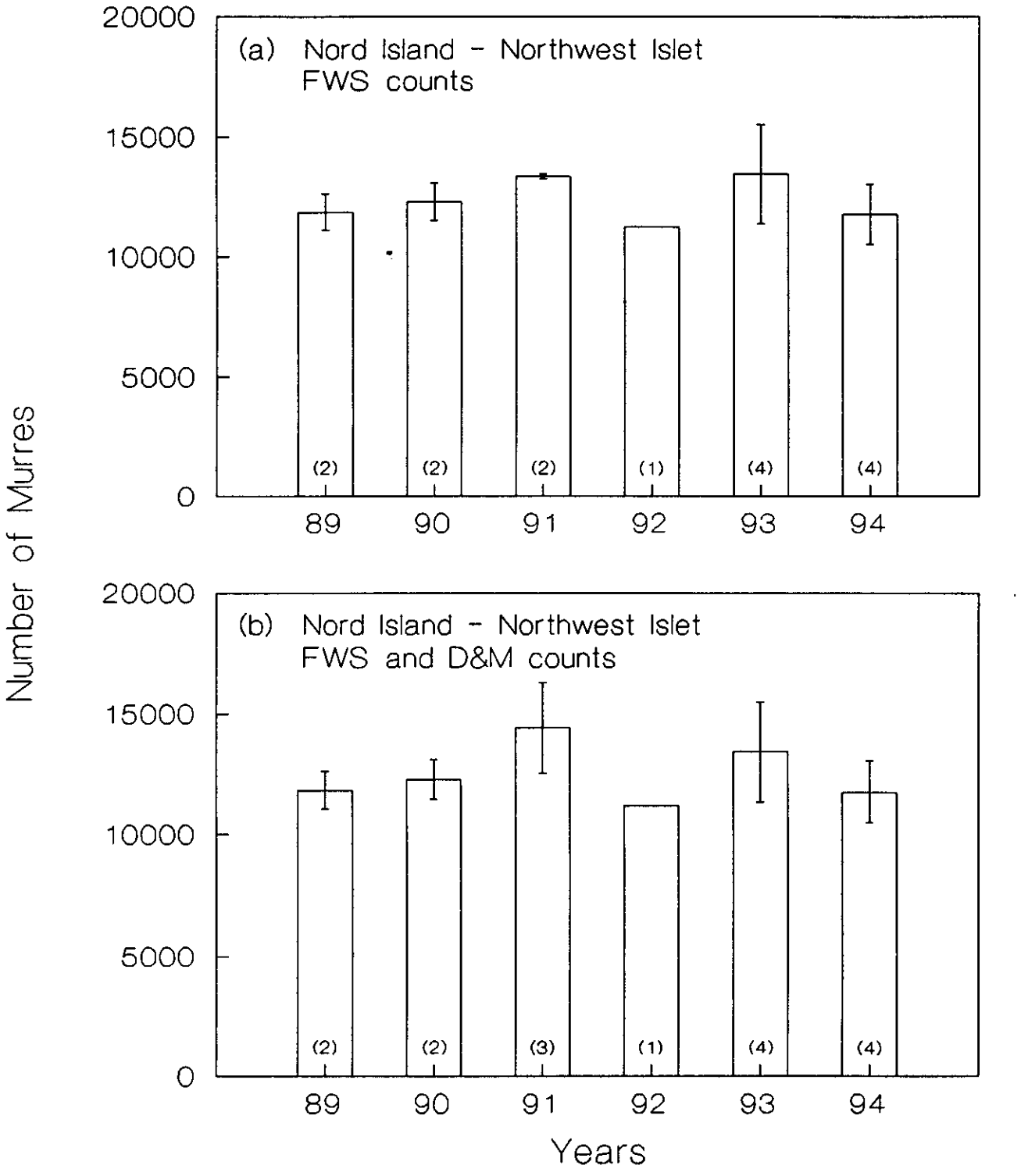

Figure 8. Average counts of murres at Nord Island - Northwest Islet, Barren Islands, Alaska, 1989-1994. Counts were made by (a) the Fish and Wildlife Service (FWS) and (b) the FWS and Dames & Moore (D&M; one D&M count in 1991, see text and Erikson 1995). Number of counts shown in parentheses; error bars = standard deviation.

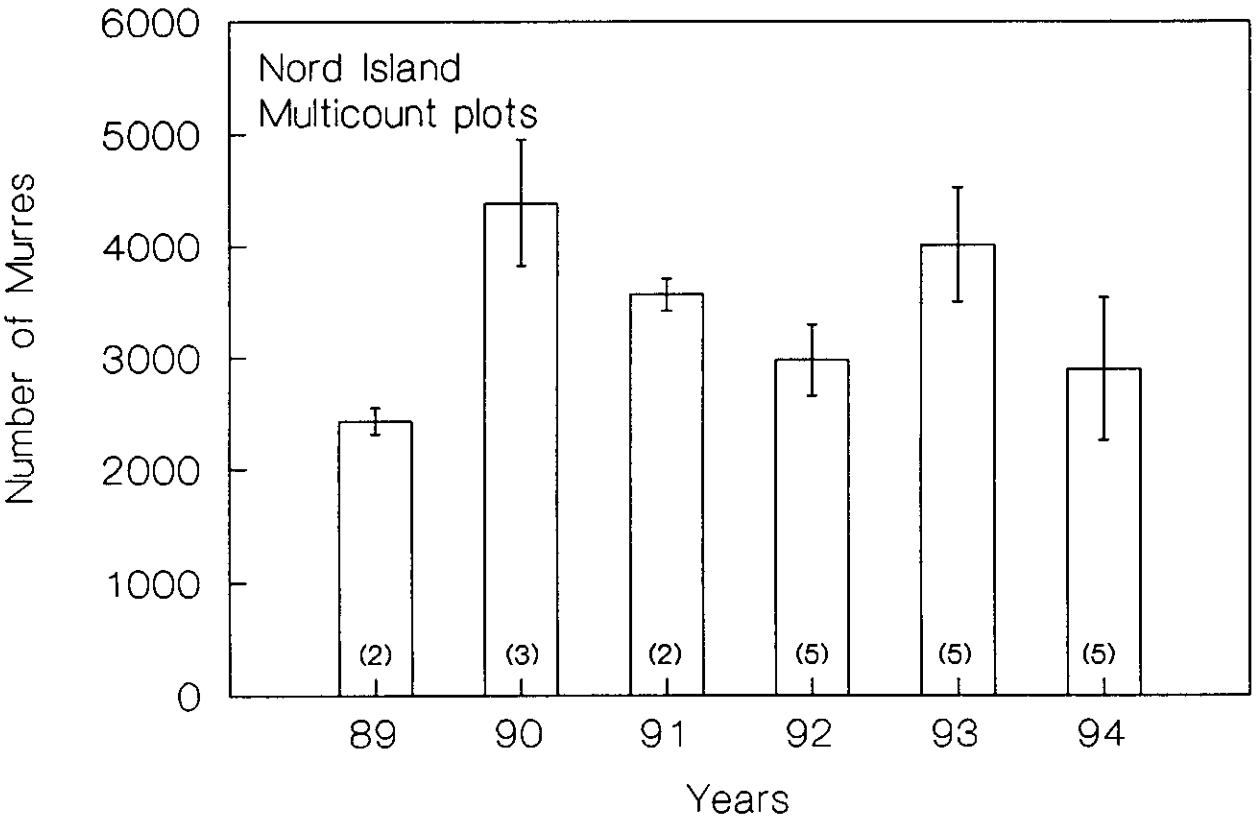

Figure 9. Average counts of murres on multicount plots BMP1-11 at Nord Island - Northwest Islet, Barren Islands, Alaska, 1989-1994. Number of counts shown in parentheses; error bars = standard deviation.

Appendix 1. Counts of murres at East Amatuli Light Rock, 28 July 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish & Wildlife Service; BCP numbers indicate the plots are boat plots counted from water, not land; ABK = Arthur B. Kettle and MAB = Margaret A. Blanding.

FWS Plot Number	Time	Observer 1 (ABK)				Observer 2 (MAB)				Observer 1 & 2 Average
		Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	
BCP47	1151	160			160	165			165	163
BCP48	1153	700			700	610			610	655
BCP49	1203	150			150	150			150	150
BCP50	1205	50			50	50	56		53	52
BCP51	1219	700			700	730			730	715
BCP52	1238	220			220	230			230	225
BCP53	1226	310			310	330			330	320
BCP54	1230	920			920	980			980	950
BCP55	1409	170			170	165			165	168
BCP56	1247	360			360	400			400	380
BCP57	[Included in BCP61]									
BCP58	1304	260	240		250	300	300		300	275
BCP59	1308	410			410	370			370	390
BCP60	1225	90			90	100			100	95
BCP61+BCP57	1343	2,000			2,000	2,100			2,100	2,050
BCP62	1351	50			50	45			45	48
BCP63	1353	40			40	50			50	45
BCP64	1142	69			69	71			71	70
TOTAL (Whole Rock)		6,659			6,649	6,846			6,849	6,749

Appendix 2. Counts of murres at East Amatuli Light Rock, 30 July 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish & Wildlife Service; BCP numbers indicate the plots are boat plots counted from water, not land; DGR = David G. Roseneau and MFP = Mary F. Portner.

FWS Plot Number	Time	Observer 1 (DGR)				Observer 2 (MFP)				Observer 1 & 2 Average
		Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	
BCP47	1355	205	210		208	197			197	202
BCP48	1415	830	850		840	870			870	855
BCP49	1410	165	170		168	160			160	164
BCP50	1403	50	55		53	50	50		50	51
BCP51	1510	760	740	750	750	780	790		785	768
BCP52	1520	230	230	210	223	210	210		210	217
BCP53	1435	420	390		405	380	400		390	398
BCP54	1500	840	800		820	790	770		780	800
BCP55	1550	300			300	290			290	295
BCP56	1530	470	490		480	510	510		510	495
BCP57	1543	190			190	190			190	190
BCP58	1617	220			220	210			210	215
BCP59	1605	480			480	480			480	480
BCP60	1623	130	130		130	120			120	125
BCP61	1640	1,960	1,850		1,905	2,050			2,050	1,978
BCP62	1630	66			66	60			60	63
BCP63	1635	45	46	46	46	45			45	45
BCP64	1350	75			75	70	70		70	73
TOTAL (Whole Rock)		7,436			7,358	7,462			7,467	7,412

Appendix 3. Counts of murres at East Amatuli Light Rock, 31 July 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish & Wildlife Service; BCP numbers indicate the plots are boat plots counted from water, not land; ABK = Arthur B Kettle and MAB = Margaret A. Blanding.

FWS Plot Number	Time	Observer 1 (ABK)				Observer 2 (MAB)				Observer 1 & 2 Average
		Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	
BCP47	1616	159			159	150			150	155
BCP48	1621	820			820	810			810	815
BCP49	1640	150			150	170			170	160
BCP50	1641	50			50	60			60	55
BCP51	1645	850			850	860			860	855
BCP52	1712	320			320	370			370	345
BCP53	1656	460			460	430			430	445
BCP54	1700	1,250			1,250	1,110			1,110	1,180
BCP55	1806	191			191	190			190	191
BCP56	1708	370			370	350			350	360
BCP57	[Included in BCP61]									
BCP58	1717	270			270	300			300	285
BCP59	1721	530			530	490			490	510
BCP60	1718	130			130	120			120	125
BCP61+57	1730	2,740	2,590		2,665	2,760	2,930		2,845	2,755
BCP62	1725	95			95	95			95	95
BCP63	1736	46			46	38			38	42
BCP64	1605	76			76	80			80	78
TOTAL (Whole Rock)		8,507			8,432	8,383			8,468	8,450

Appendix 4. Counts of murres at East Amatuli Light Rock, 5 August 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish & Wildlife Service; BCP numbers indicate the plots are boat plots counted from water, not land; ABK = Arthur B Kettle and MAB = Margaret A. Blanding.

FWS Plot Number	Time	Observer 1 (ABK)				Observer 2 (MAB)				Observer 1 & 2
		Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	Average
BCP47	1427	180			180	160			160	170
BCP48	1435	690			690	620			620	655
BCP49	1438	170			170	180			180	175
BCP50	1440	50			50	50			50	50
BCP51	1418	850			850	860			860	855
BCP52	1500	330			330	370			370	350
BCP53	1445	400			400	410			410	405
BCP54	1450	1,090			1,090	1,190			1,190	1,140
BCP55	1605	192			192	200			200	196
BCP56	1506	490			490	440			440	465
BCP57	[Included in BCP61]									
BCP58	1511	310			310	270			270	290
BCP59	1516	490			490	440			440	465
BCP60	1520	110			110	110			110	110
BCP61+57	1533	2,210	2,040	2,390	2,213	2,440	2,580	2,510	2,510	2,362
BCP62	1522	92			92	96			96	94
BCP63	1607	54			54	60			60	57
BCP64	1425	80			80	75			75	78
TOTAL (Whole Rock)		7,788			7,791	7,971			8,041	7,916

Appendix 5. Counts of murres at East Amatuli Light Rock, 16 August 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish & Wildlife Service; BCP numbers indicate the plots are boat plots counted from water, not land; ABK = Arthur B. Kettle and MAB = Margaret A. Blanding.

FWS Plot Number	Time	Observer 1 (ABK)				Observer 2 (MAB)				Observer 1 & 2 Average
		Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	
BCP47	1750	300			300	260			260	280
BCP48	1820	1,060	1,040		1,050	970			970	1,010
BCP49	1754	145			145	150			150	148
BCP50	1755	70			70	65			65	68
BCP51	1802	900			900	990			990	945
BCP52	1810	320			320	280			280	300
BCP53	1827	350	340		345	360			360	353
BCP54	1833	1,190			1,190	1,120			1,120	1,155
BCP55	1954	199			199	210			210	205
BCP56	1841	400			400	380			380	390
BCP57	[Included in BCP61]									
BCP58	1847	320			320	280			280	300
BCP59	1855	520			520	520			520	520
BCP60	1849	160			160	170			170	165
BCP61+57	1905	2,140			2,140	2,060			2,060	2,100
BCP62	1851	110			110	110			110	110
BCP63	1910	85			85	83			83	84
BCP64	1745	93			93	90			90	92
TOTAL (Whole Rock)		8,362			8,347	8,098			8,098	8,223

Appendix 6. Counts of murres at East Amatuli Island, 30 July 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish & Wildlife Service; BCP numbers indicate the plots are population census plots counted from boats, not land; DGR = David G. Roseneau; MFP = Mary F. Portner; ABK = Arthur B. Kettle; MAB = Margaret A. Blanding.

FWS Plot No.	Time	Observer 1 (DGR) Count 1	Count 2	Count 3	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Average	Observer 1 & 2 Average
BCP1	1750	0			0	0			0	0
BCP2	1750	64			64	60			60	62
BCP3	1758	15			15	15			15	15
BCP4	1800	100			100	95			95	98
BCP5	1805	65			65	63			63	64
BCP6	1810	182			182	182			182	182
BCP6.1	1900	12			12	12			12	12
		Observer 1 (ABK) Count 1	Count 2	Count 3	Average	Observer 2 (MAB) Count 1	Count 2	Count 3	Average	
BCP7	1518	138			138	140			140	139
BCP8	1510	140			140	155			155	148
BCP9	1513	360			360	370			370	365
		Observer 1 (DGR) Count 1	Count 2	Count 3	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Average	
BCP10	1905	110			110	110			110	110

Appendix 6 (Continued).

FWS Plot No.	Time	Observer 1 (ABK) Count 1	Count 2	Count 3	Average	Observer 2 (MAB) Count 1	Count 2	Count 3	Average	Observer 1 & 2 Average
BCP11	1502	207			207	210			210	209
BCP12	1507	250			250	250			250	250
		Observer 1 (DGR)				Observer 2 (MFP)				
		Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	
BCP13	1945	980			980	1,030			1,030	1,005
BCP14	1920	1,240			1,240	1,110	1,210		1,160	1,200
BCP15	1915	520			520	560			560	540
BCP16	1958	2,600			2,600	2,650			2,650	2,625
BCP17	1930	2,710	3,030		2,870	3,180			3,180	3,025
		Observer 1 (ABK)				Observer 2 (MAB)				
		Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	
BCP18	1454	400			400	370			370	385
BCP19	1450	170			170	150			150	160
BCP20	2047	3,855			3,855	4,050			4,050	3,953
BCP21	2020	920			920	1,020			1,020	970
BCP22	1446	930			930	950			950	940
BCP23	1954	1,700			1,700	1,820			1,820	1,760
BCP24	1930	750			750	705			705	728
BCP25	1820	610			610	650			650	630
BCP26	1823	70			70	80			80	75

Appendix 6 (Continued).

FWS Plot No.	Time	Observer 1 (ABK) Count 1	Count 2	Count 3	Average	Observer 2 (MAB) Count 1	Count 2	Count 3	Average	Observer 1 & 2 Average
BCP27	1800	0			0	0			0	0
BCP28	1756	430			430	400			400	415
BCP29	1754	190			190	200			200	195
BCP30	1745	570			570	500			500	535
BCP31	1735	824			824	867			867	846
BCP32	1721	85			85	86			86	86
BCP33	1640	748			748	778			778	763
BCP34	1657	198			198	218			218	208
BCP35	1712	480			480	430			430	455
BCP36	1618	110			110	100			100	105
BCP37	1617	222			222	230			230	226
BCP38	1431	94			94	91			91	93
BCP39	1429	87			87	75			75	81
BCP40	1428	108			108	100			100	104
BCP41	1427	79			79	76			76	78
BCP42	1358	380			380	370			370	375
BCP43	1607	66			66	60			60	63
BCP44	1603	1,070			1,070	980			980	1,025
BCP45	1555	220			220	230			230	225
BCP46	1550	92			92	90			90	91
TOTAL (Whole Island)		25,151			25,311	25,868			25,918	25,615

Appendix 7. Counts of murres at East Amatuli Island, 15 August 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish & Wildlife Service; BCP numbers indicate the plots are population census plots counted from boats, not land; DGR = David G. Roseneau; MFP = Mary F. Portner; ABK = Arthur B. Kettle; MAB = Margaret A. Blanding.

FWS Plot No.	Time	Observer 1 (DGR)				Observer 2 (MFP)				Observer 1 & 2 Average
		Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	
BCP1	1629	62			62	59			59	61
BCP2	1623	65			65	67			67	66
BCP3	1634	50			50	46			46	48
BCP4	1636	170			170	163			163	167
BCP5	1647	114			114	107			107	111
BCP6	1655	232			232	234			234	233
BCP6.1	1658	22			22	22			22	22
BCP7	1704	130			130	140			140	135
BCP8	1707	153			153	147			147	150
BCP9	1716	315			315	325			325	320
BCP10	1847	100			100	100			100	100
BCP11	1755	280			280	250			250	265
BCP12	1750	290	300		295	260	270		265	280
BCP13	1800	780			780	840			840	810
BCP14	1737	1,230			1,230	1,260			1,260	1,245
BCP15	1731	530			530	580	550		565	548
BCP16	1820?	2,670			2,670	2,800			2,800	2,735
BCP17	1810	2,710			2,710	2,670			2,670	2,690
BCP18	1855	370			370	360			360	365
BCP19	1850	130			130	130			130	130

Appendix 7 (Continued).

FWS Plot No.	Time	Observer 1 (ABK) Count 1	Count 2	Count 3	Average	Observer 2 (MAB) Count 1	A	Count 3	Average	Observer 1 & 2 Average
BCP20[1]	1925	2,796			2,796	2,840			2,840	2,818
		Observer 1 (DGR)				Observer 2 (MFP)				
		Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	
BCP21	1924	990	1,050		1,020	1,020			1,020	1,020
		Observer 1 (ABK)				Observer 2 (MAB)				
		Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	
BCP22	1854	840			840	820			820	830
BCP23	1831	1,750			1,750	1,850			1,850	1,800
BCP24	1825	683			683	725			725	704
BCP25	1811	840			840	850			850	845
BCP26	1820	139			139	140			140	140
BCP27	1800	0			0	0			0	0
BCP28	1759	390			390	400			400	395
BCP29	1755	220			220	250			250	235
BCP30	1751	560			560	500			500	530
BCP31	1739	800			800	840			840	820
BCP32	1731	70			70	70			70	70
BCP33	1704	889			889	800			800	845
BCP34	1718	222			222	190			190	206
BCP35	1725	540			540	490			490	515

Appendix 7 (Continued).

FWS Plot No.	Time	Observer 1 (ABK) Count 1	Count 2	Count 3	Average	Observer 2 (MAB) Count 1	Count 2	Count 3	Average	Observer 1 & 2 Average
BCP36	1659	110			110	110			110	110
BCP37	1658	227			227	260			260	244
BCP38	1650	102			102	97			97	100
BCP39	1648	79			79	73			73	76
BCP40	1647	69			69	65			65	67
BCP41	1645	62			62	62			62	62
BCP42	1639	440			440	400			400	420
BCP43	1637	55			55	50			50	53
BCP44	1633	920			920	810			810	865
BCP45	1626	150			150	160			160	155
BCP46	1623	90			90	90			90	90
TOTAL (Whole Island)		24,436			24,471	24,522			24,512	24,492

[1] BCP20 was recounted on 17 August because fog interfered with the 15 August count.

Appendix 8. Counts of murres on multicount plots at East Amatuli Island - Light Rock, 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish & Wildlife Service; BCP numbers indicate that the plots are population census plots counted from boats, not land; BMP numbers indicate that the plots are also mulitcount plots that are counted from boats at least five separate times on different days to help track population trends; ABK = Arthur B. Kettle; MAB = Margaret A. Blanding; DGR = David G. Roseneau; MFP = Mary F. Portner; numbers not ending in 0 or 5 result from averaging several counts on some subsections of the plots.

New FWS Multicount Plot Number	New FWS Boat Plot Number & Previous Plot Number/Name	Date	Time	Observer 1 (ABK)					Observer 2 (MAB)					Observer 1 & 2 Average
				Count 1	Count 2	Count 3	Count 4	Average	Count 1	Count 2	Count 3	Count 4	Average	
BMP1	BCP7-9	27 Jul	1342	623				623	620				620	622
BMP2	BCP11-12	27 Jul	1325	515				515	485				485	500
BMP3	BCP18-19	27 Jul	1252	560				560	540				540	550
BMP4	Part of BCP47-49	27 Jul	1220	530				530	590				590	560
Subtotal	*4 Plots: BMP1-4*			*2,228*				*2,228*	*2,235*				*2,235*	*2,232*
BMP5	Part of BCP20-21	27 Jul	1637	825				825	800				800	813
Subtotal	*5 Plots: BMP1-5*			*3,053*				*3,053*	*3,035*				*3,035*	*3,044*
BMP6	BCP51	27 Jul	1450	780				780	810				810	795
BMP7	BCP22	27 Jul	1515	900				900	780				780	840
BMP8	BCP38-42	27 Jul	1543	762				762	726				726	744
Subtotal	*7 Plots: BMP1-5 & 7-8*			*4,715*				*4,715*	*4,541*				*4,541*	*4,628*
TOTAL	8 Plots: BMP1-8	27 Jul		5,495				5,495	5,351				5,351	5,423

Appendix 8 (Continued).

New FWS Multicount Plot Number	New FWS Boat Plot Number & Previous Plot Number/Name	Date	Time	Observer 1 (ABK) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MAB) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP1	BCP7-9	28 Jul	1628	640				640	618				618	629
BMP2	BCP11-12	28 Jul	1620	465				465	470				470	468
BMP3	BCP18-19	28 Jul	1610	585				585	590				590	588
BMP4	Part of BCP47-49	28 Jul	1548	570				570	560				560	565
Subtotal	*4 Plots: BMP1-4*			*2,260*				*2,260*	*2,238*				*2,238*	*2,249*
BMP5	Part of BCP20-21	28 Jul	1648	755				755	790				790	773
Subtotal	*5 Plots: BMP1-5*			*3,015*				*3,015*	*3,028*				*3,028*	*3,022*
BMP6	BCP51	28 Jul	1219	700				700	730				730	715
BMP7	BCP22	28 Jul	1540	850				850	830				830	840
BMP8	BCP38-42	28 Jul	1507	629				629	648				648	639
Subtotal	*7 Plots: BMP1-5 & 7-8*			*4,494*				*4,494*	*4,506*				*4,506*	*4,500*
TOTAL	8 Plots: BMP1-8	28 Jul		5,194				5,194	5,236				5,236	5,215
BMP1	BCP7-9	30 Jul	1510	638				638	665				665	652
BMP2	BCP11-12	30 Jul	1502	457				457	460				460	459
BMP3	BCP18-19	30 Jul	1450	570				570	520				520	545
BMP4	Part of BCP47-49	30 Jul	1459	710				710	740				740	725
Subtotal	*4 Plots: BMP1-4*			*2,375*				*2,375*	*2,385*				*2,385*	*2,380*

Appendix 8 (Continued).

New FWS Multicount Plot Number	New FWS Boat Plot Number & Previous Plot Number/Name	Date	Time	Observer 1 (ABK) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MAB) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP5	Part of BCP20-21	30 Jul	1529	695				695	730				730	713
Subtotal	*5 Plots: BMP1-5*			*3,070*				*3,070*	*3,115*				*3,115*	*3,093*
				Observer 1 (DGR) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Count 4	Average	
BMP6	BCP51	30 Jul	1510	760	740	750		750	780	790			785	768
				Observer 1 (ABK) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MAB) Count 1	Count 2	Count 3	Count 4	Average	
BMP7	BCP22	30 Jul	1446	930				930	950				950	940
BMP8	BCP38-42	30 Jul	1358	748				748	712				712	730
Subtotal	*7 Plots: BMP1-5 & 7-8*			*4,748*				*4,748*	*4,777*				*4,777*	*4,763*
TOTAL	8 Plots: BMP1-8	30 Jul		5,508				5,498	5,557				5,562	5,530
BMP1	BCP7-9	31 Jul	1936	685				685	666				666	676
BMP2	BCP11-12	31 Jul	1931	515				515	500				500	508
BMP3	BCP18-19	31 Jul	1915	573				573	595				595	584
BMP4	Part of BCP47-49	31 Jul	1920	910				910	800				800	855
Subtotal	*4 Plots: BMP1-4*			*2,683*				*2,683*	*2,561*				*2,561*	*2,622*

Appendix 8 (Continued).

New FWS Multicount Plot Number	New FWS Boat Plot Number & Previous Plot Number/Name	Date	Time	Observer 1 (ABK) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MAB) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP5	Part of BCP20-21	31 Jul	1950	906				906	850				850	878
Subtotal	*5 Plots: BMP1-5*			*3,589*				*3,589*	*3,411*				*3,411*	*3,500*
BMP6	BCP51	31 Jul	1645	850				850	860				860	855
BMP7	BCP22	31 Jul	1858	980				980	890				890	935
BMP8	BCP38-42	31 Jul	1825	870				870	840				840	855
Subtotal	*7 Plots: BMP1-5 & 7-8*			*5,439*				*5,439*	*5,141*				*5,141*	*5,290*
TOTAL	8 Plots: BMP1-8	31 Jul		6,289				6,289	6,001				6,001	6,145
BMP1	BCP7-9	5 Aug	1400	604				604	655				655	630
BMP2	BCP11-12	5 Aug	1347	467				467	460				460	464
BMP3	BCP18-19	5 Aug	1340	536				536	520				520	528
BMP4	Part of BCP47-49	5 Aug	1335	750				750	710				710	730
Subtotal	*4 Plots: BMP1-4*			*2,357*				*2,357*	*2,345*				*2,345*	*2,351*
BMP5	Part of BCP20-21	5 Aug	1630	695				695	685				685	690
Subtotal	*5 Plots: BMP1-5*			*3,052*				*3,052*	*3,030*				*3,030*	*3,041*
BMP6	BCP51	5 Aug	1423	850				850	860				860	855
BMP7	BCP22	5 Aug	1323	915				915	990				990	953

Appendix 8 (Continued).

New FWS Multicount Plot Number	New FWS Boat Plot Number & Former FWS Number/Name	Date	Time	Observer 1 (ABK) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MAB) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP8	BCP38-42	5 Aug	1228	799				799	773				773	786
Subtotal	*7 Plots: BMP1-5 & 7-8*			*4,766*				*4,766*	*4,793*				*4,793*	*4,780*
TOTAL	8 Plots: BMP1-8	5 Aug		5,616				5,616	5,653				5,653	5,635
BMP1	BCP7-9	6 Aug	1937	666				666	660				660	663
BMP2	BCP11-12	6 Aug	1920	390				390	405				405	398
BMP3	BCP18-19	6 Aug	1905	522				522	570				570	546
BMP4	Part of BCP47-49	6 Aug	1900	750				750	760				760	755
Subtotal	*4 Plots: BMP1-4*			*2,328*				*2,328*	*2,395*				*2,395*	*2,362*
BMP5	Part of BCP20-21	6 Aug	1745	823				823	850				850	837
Subtotal	*5 Plots: BMP1-5*			*3,151*				*3,151*	*3,245*				*3,245*	*3,198*
BMP6	BCP51	6 Aug	1835	840				840	940				940	890
BMP7	BCP22	6 Aug	1733	850				850	800				800	825
BMP8	BCP38-42	6 Aug	1705	806				806	849				849	828
Subtotal	*7 Plots: BMP1-5 & 7-8*			*4,807*				*4,807*	*4,894*				*4,894*	*4,851*
TOTAL	8 Plots: BMP1-8	6 Aug		5,647				5,647	5,834				5,834	5,741

Appendix 8 (Continued).

New FWS Multicount Plot Number	New FWS Boat Plot Number & Former FWS Number/Name	Date	Time	Observer 1 (ABK) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MAB) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP1	BCP7-9	14 Aug	1428	682				682	714				714	698
BMP2	BCP11-12	14 Aug	1418	549				549	550				550	550
BMP3	BCP18-19	14 Aug	1355	536				536	560				560	548
BMP4	Part of BCP47-49	14 Aug	1356	630				630	650				650	640
Subtotal	*4 Plots: BMP1-4*			*2,397*				*2,397*	*2,474*				*2,474*	*2,436*
BMP5	Part of BCP20-21	14 Aug	1458	885				885	880				880	883
Subtotal	*5 Plots: BMP1-5*			*3,282*				*3,282*	*3,354*				*3,354*	*3,318*
BMP6	BCP51	14 Aug	1348	980				980	890				890	935
BMP7	BCP22	14 Aug	1325	780				780	760				760	770
BMP8	BCP38-42	14 Aug	1230	666				666	636				636	651
Subtotal	*7 Plots: BMP1-5 & 7-8*			*4,728*				*4,728*	*4,750*				*4,750*	*4,739*
TOTAL	8 Plots: BMP1-8	14 Aug		5,708				5,708	5,640				5,640	5,674
				Observer 1 (DGR) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Count 4	Average	
BMP1	BCP7-9	15 Aug	1704	598				598	612				612	605
BMP2	BCP11-12	15 Aug	1750	575				575	515				515	545
BMP3	BCP18-19	15 Aug	1850	500				500	490				490	495

Appendix 8 (Continued).

New FWS Multicount Plot Number	New FWS Boat Plot Number & Former FWS Number/Name	Date	Time	Observer 1 (ABK) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MAB) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP4	Part of BCP47-49	15 Aug	1917	720				720	780				780	750
Subtotal	*4 Plots: BMP1-4*			*2,393*				*2,393*	*2,397*				*2,397*	*2,395*
				Observer 1 (DGR) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Count 4	Average	
BMP5	Part of BCP20-21	15 Aug	1929	715				715	750				750	733
Subtotal	*5 Plots: BMP1-5*			*3,108*				*3,108*	*3,147*				*3,147*	*3,128*
BMP6	BCP51	15 Aug	1918	750	800			775	710	730			720	748
				Observer 1 (ABK) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MAB) Count 1	Count 2	Count 3	Count 4	Average	
BMP7	BCP22	15 Aug	1854	840				840	820				820	830
BMP8	BCP38-42	15 Aug	1639	752				752	697				697	725
Subtotal	*7 Plots: BMP1-5 & 7-8*			*4,700*				*4,700*	*4,664*				*4,664*	*4,682*
TOTAL	8 Plots: BMP1-8	15 Aug		5,450				5,475	5,374				5,384	5,430

Appendix 8 (Continued).

Mean of 8 counts on 4 plots (BMP1-4)	*Range = 2,232 - 2,622*	*SD = 121*	*2,378*
Mean of 8 counts on 5 plots (BMP1-5)	*Range = 3,022 - 3,500*	*SD = 166*	*3,168*
Mean of 8 counts on 7 plots (BMP1-5 & 7-8)	*Range = 4,500 - 5,290*	*SD = 232*	*4,779*
MEAN OF 8 COUNTS ON 8 PLOTS (BMP1-8)	Range = 5,215 - 6,145	SD = 277	5,599

Appendix 9. Counts of common murres on productivity plots during the census period at the Barren Islands, Alaska, 1990-1994 (1990-1992 data are from unpubl. FWS field notes and 1993 data are from Roseneau *et al.* 1995); ND = no data.

East Amatuli Island - Light Rock Productivity Plots LPP1-10		Nord Island Productivity Plots LPP1-5	
Date	Numbers of Birds	Date	Numbers of Birds
1990		1990	
ND	ND	20 Jul	420
ND	ND	15 Aug	404
Mean	ND	Mean	412
1991		1991	
ND	ND	24 Aug	301
Mean	ND	Mean	301
1992		1992	
ND	ND	6 Aug	306
ND	ND	10 Aug	264
ND	ND	22 Aug	212
ND	ND	25 Aug	272
Mean	ND	Mean	264

Appendix 9 (Continued).

East Amatuli Island - Light Rock Productivity Plots LPP1-10		Nord Island Productivity Plots LPP1-5	
Date	Numbers of Birds	Date	Numbers of Birds
1993		1993	
26 Jul	492	20 Jul	397
9 Aug	537	21 Jul	387
10 Aug	430	23 Jul	410
11 Aug	501	28 Jul	391
12 Aug	463	31 Jul	382
17 Aug	446	10 Aug	382
23 Aug	497	14 Aug	424
		16 Aug	370
Mean	481	23 Aug	422
		1 Sep	417
		Mean	398
1994		1994	
19 Jul	469	13 Jul	390
26 Jul	433	15 Jul	391
27 Jul	483	18 Jul	402
28 Jul	503	19 Jul	377
31 Jul	491	26 Jul	428
4 Aug	427	27 Jul	380

Appendix 9 (Continued).

East Amatuli Island - Light Rock Productivity Plots LPP1-10		Nord Island Productivity Plots LPP1-5	
Date	Numbers of Birds	Date	Numbers of Birds
1994		1994	
5 Aug	449	29 Jul	407
6 Aug	408	30 Jul	410
7 Aug	423	31 Jul	406
11 Aug	438	2 Aug	396
12 Aug	490	4 Aug	421
15 Aug	446	5 Aug	384
18 Aug	464	7 Aug	465
		9 Aug	407
Mean	456	16 Aug	456
		Mean	408

Appendix 10. Counts of murres on multicount plots at the Nord Island - Northwest Islet and East Amatuli Island - Light Rock colonies, Barren Islands, Alaska, 1989-1994 (1989-1992 data are from Dragoo *et al.*1994 and Nysewander *et al.*1993; 1993 data are from Roseneau *et al.*1995).[1]

	Nord Island - Northwest Islet													East Amatuli Island - Light Rock				
Date	BMP1	BMP2	BMP3	BMP4	BMP5	BMP6	BMP7	BMP8	BMP9	BMP10	BMP11	Total	(SD)[2]	Date	BMP3	BMP4	Total	(SD)[2]
1989														1989				
27 Jul	154	127	7	139	460	531	74	274	375	159	219	2,519		27 Jul	339	424	763	
13 Aug	147	125	10	115	203	480	81	542	250	159	231	2,343		13 Aug	406	535	941	
Mean	151	126	9	127	332	506	78	408	313	159	225	2,431	(124.5)	Mean	373	480	852	(125.9)
1990														1990				
19 Jul	136	436	13	249	1,240	726	110	1,460	252	127	242	4,991		ND[3]	ND	ND	ND	
14 Aug	134	310	13	231	875	468	155	898	380	144	261	3,869		15 Aug	292	416	708	
18 Aug	34	377	14	102	1,016	780	168	978	460	133	226	4,288		19 Aug	233	208	441	
Mean	101	374	13	194	1,044	658	144	1,112	364	135	243	4,383	(567.0)	Mean	263	312	575	(188.8)
1991														1991				
17 Aug	139	291	14	153	833	711	147	595	407	165	204	3,659		19 Aug	529	496	1,025	
22 Aug	140	220	12	126	830	514	103	825	358	129	200	3,457		1 Sep	375	319	694	
Mean	140	256	13	140	832	613	125	710	383	147	202	3,558	(142.8)	Mean	452	408	860	(234.1)

Appendix 10 (Continued).

	Nord Island - Northwest Islet													East Amatuli Island - Light Rock				
Date	BMP1	BMP2	BMP3	BMP4	BMP5	BMP6	BMP7	BMP8	BMP9	BMP10	BMP11	Total	(SD)	Date	BMP3	BMP4	Total	(SD)
1992														1992				
6 & 9 Aug	95	181	9	143	688	473	71	873	285	84	106	3,008		7 Aug	232	235	467	
10 Aug	63	195	0	65	618	493	76	610	242	117	158	2,637		9 Aug	440	508	948	
18 Aug	85	169	10	178	682	380	114	523	301	168	134	2,744		10 Aug	388	538	926	
24 Aug	70	321	0	163	780	541	150	760	311	165	188	3,449		18 Aug	392	501	893	
26 Aug	42	151	7	113	730	488	101	855	251	142	136	3,016		26 Aug	199	294	493	
Mean	71	203	5	132	700	475	102	724	278	135	144	2,971	(314.2)	Mean	330	415	745	(243.2)
1993														1993				
19 Jul	90	210	10	140	1,130	960	120	1,360	240	120	209	4,589		22 Jul	813	767	1,580	
3 Aug	60	175	10	141	1,090	903	90	1,208	480	103	253	4,513		26 Jul	570	689	1,259	
4 Aug	55	153	9	85	1,100	585	95	965	415	143	208	3,813		31 Jul	815	725	1,540	
9 Aug	48	150	1	113	910	443	101	1,108	370	85	150	3,479		2 Aug	735	757	1,492	
17 Aug	123	254	0	115	710	530	140	1,000	380	136	235	3,623		11 Aug	733	772	1,505	
														16 Aug	594	660	1,254	
Mean	75	188	6	119	988	684	109	1,128	377	117	211	4,003	(514.4)	17 Aug	566	697	1,263	
														2 Sep	500	610	1,110	
														Mean	666	710	1,375	(173.5)
1994														1994				
27 Jul	39	153	0	57	490	435	75	135	260	87	239	1,970		27 Jul	550	560	1,110	
28 Jul	54	111	9	50	513	513	120	579	418	96	222	2,685		28 Jul	588	565	1,153	

Appendix 10 (Continued).

Nord Island - Northwest Islet														East Amatuli Island - Light Rock				
Date	BMP1	BMP2	BMP3	BMP4	BMP5	BMP6	BMP7	BMP8	BMP9	BMP10	BMP11	Total	(SD)	Date	BMP3	BMP4	Total	(SD)
1994														1994				
14 Aug	40	155	9	90	648	630	103	605	393	90	268	3,031		30 Jul	545	725	1,270	
15 Aug	69	205	11	105	685	565	138	568	405	102	193	3,046		31 Jul	584	855	1,439	
16 Aug	78	280	9	130	797	655	124	895	439	92	219	3,718		5 Aug	528	730	1,258	
														6 Aug	546	755	1,301	
Mean	56	181	8	86	627	560	112	556	383	93	228	2,890	(636.0)	14 Aug	548	640	1,188	
														15 Aug	495	750	1,245	
														Mean	548	698	1,246	(101.1)

[1] This table contains some values that are slightly different from previously published figures (e.g., Dragoo *et al.* 1994). These revisons were made after reviewing the 1989-1992 field notes. In 1989, count dates were 27 July and 13 August, not 26 July and 12 August. Also, mean plot values have been recalculated in several cases (e.g., Nord Island, 1990), and the number 318 reported for plot BMP4 at East Amatuli Light Rock on 1 September 1991 was changed to 319. Correct dates for East Amatuli Island and Light Rock counts are also reported here. Nord Island plots BMP1-11 are equivalent to previously reported plots A1, A2, B, C, D, E, G, H1, H2, I, and NW Islet, respectively. East Amatuli Island and Light Rock plots BMP3 and BMP4 are equivalent to the "Mainland" and "Lt. Rock" plots, respectively. The 13 August 1989 total for plot BMP10 is an estimated value (Dragoo *et al.* 1994).

[2] SD = standard deviation.

[3] ND = no data.

Appendix 11. Counts of murres at Nord Island - Northwest Islet, 27 July 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish & Wildlife Service; BCP numbers indicate the plots are population census plots counted from boats, not land; DGR = David G. Roseneau and MFP = Mary F. Portner.

New FWS Plot Number	Previous FWS Plot Numbers & Names	Time	Observer 1 (DGR)				Observer 2 (MFP)				Observer 1 & 2 Average
			Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	
BCP1	A1	1335	38	38		38	39	39		39	39
BCP2	A2	1350	150			150	155			155	153
BCP3	B	1400	0			0	0			0	0
BCP4	C	1403	57	59	59	58	55			55	57
BCP5	D	1415	480			480	500			500	490
BCP6	E	1426	430	450		440	430			430	435
BCP7	G	1435	75	80	80	78	70	75		73	75
BCP8	H1	1450	140	140		140	130			130	135
BCP9	H2	1455	260	270		265	255			255	260
BCP10	I	1505	90	90	85	88	86			86	87
BCP11	(None)[1]	1540	0			0	0			0	0
BCP12	J	1510	6			6	6			6	6
BCP13	P	1825	250	240		245					245
BCP14	Q + R[2]	1842	1,510	1,575		1,543					1,543
BCP15	S [also "S-1" or "R-S"][3]	1855	520	550		535					535
BCP16	W [also "S-2"][4]	1900	150	150		150					150
BCP17	T (right)	1745	280	290		285					285
BCP18	T (left)	1740	350	340		345					345
BCP19	U	1750	120	115		118					118
BCP20	V ["V-1"+V-X"][5]	1755	65	80		73					73
BCP21	X	1800	2,570	2,710		2,640					2,640

Appendix 11 (Continued).

New FWS Plot Number	Previous FWS Plot Numbers & Names	Time	Observer 1 (DGR) Count 1	Count 2	Count 3	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Average	Observer 1 & 2 Average
BCP22	Y	1910	710	760		735					735
BCP23	Z	1925	880	940		910					910
BCP24	NW Islet Plot	1510	245	250	240	245	230	230	240	233	239
BCP25	Remainder NW Islet[6]	1610	950	950		950					950
BCP26	("Smaller NW Islet") [Subislet-2][7]	1605	243			243	257			257	250
BCP27	Parakeet Cove	1625	300			300	310			310	305
BCP28	(None) [West Parakeet][8]	1630	14			14	13			13	14
TOTAL (Whole Island)			10,883			11,074					11,071

[1] Consists of the area between BCP10 and BCP12 that was apparently not counted in previous years (i.e., 1989-1992).

[2] Plots Q and R were combined to form BCP14 because of a boundary problem that occurred during the 19 July and 3 August 1993 counts.

[3] Plot S (BCP15) is equivalent to Plot "S-1" and it is also equivalent to Plot "R-S".

[4] Plot W (BCP16) is equivalent to Plot "S-2".

[5] Plot V was counted as "V-1" (1755 hrs: DGR = 38 birds) + "V-X" (1758 hrs: DGR = 35 birds).

[6] Includes a small islet immediately adjacent to Northwest Islet that was counted as part of "Remainder NW Islet" in 1992. In 1993, this small islet was designated "Subislet-1" and the 27 July 1994 counts were: (1555 hrs) DGR = 105 birds; MFP = 105 birds.

[7] Consists of a small islet immediately adjacent to Nord Island that was designated "Smaller NW Islet" in 1992 and redesignated "Subislet-2" in 1993.

[8] Consists of a small group of birds found on a high cliff west of Parakeet Cove that was apparently not counted prior to 1993.

Appendix 12. Counts of murres at Nord Island - Northwest Islet, 28 July 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish & Wildlife Service; BCP numbers indicate the plots are population census plots counted from boats, not land; DGR = David G. Roseneau and MFP = Mary F. Portner.

New FWS Plot Number	Previous FWS Plot Numbers & Names	Time	Observer 1 (DGR)				Observer 2 (MFP)				Observer 1 & 2 Average
			Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	
BCP1	A1	1320	54			54	53			53	54
BCP2	A2	1330	115	120		118	104			104	111
BCP3	B	1335	9			9	9			9	9
BCP4	C	1342	51	50		51	50			50	50
BCP5	D	1405	530	500		515	490	530		510	513
BCP6	E	1415	500	510		505	520			520	513
BCP7	G	1350	110	120		115	140	110		125	120
BCP8	H1	1430	585	630		608	550			550	579
BCP9	H2	1450	400	430		415	420			420	418
BCP10	I	1505	90	100		95	90	100	100	97	96
BCP11	(None)[1]	1525	0			0	0			0	0
BCP12	J	1530	170	150		160	140	140		140	150
BCP13	P	1920	180	200	200	193	180	180		180	187
BCP14	Q + R[2]	1855	1,430	1,450		1,440	1,500			1,500	1,470
BCP15	S [also "S-1" or "R-S"][3]	1845	600			600	580			580	590
BCP16	W [also "S-2"][4]	1835	110			110	120			120	115
BCP17	T (right)	1745	250	240		245	260	250		255	250
BCP18	T (left)	1740	245	255		250	250			250	250
BCP19	U	1755	130			130	120			120	125
BCP20	V ["V-1"+V-X"][5]	1758	81	86		84	79			79	81
BCP21	X	1800	1,440	1,430		1,435	1,270	1,230		1,250	1,343

Appendix 12 (Continued).

New FWS Plot Number	Previous FWS Plot Numbers & Names	Time	Observer 1 (DGR) Count 1	Count 2	Count 3	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Average	Observer 1 & 2 Average
BCP22	Y	1710	850			850	860			860	855
BCP23	Z	1725	800			800	760			760	780
BCP24	NW Islet Plot	1630	226			226	223			223	225
BCP25	Remainder NW Islet[6]	1700	998			998	957			957	978
BCP26	("Smaller NW Islet") [Subislet-2][7]	1650	276			276	275			275	276
BCP27	Parakeet Cove	1940	315			315	320			320	318
BCP28	(None) [West Parakeet][8]	1950	10			10	10			10	10
TOTAL (Whole Island)			10,555			10,605	10,330			10,317	10,461

[1] Consists of the area between BCP10 and BCP12 that was apparently not counted in previous years (i.e., 1989-1992).

[2] Plots Q and R were combined to form BCP14 because of a boundary problem that occurred during the 19 July and 3 August 1993 counts.

[3] Plot S (BCP15) is equivalent to Plot "S-1" and it is also equivalent to Plot "R-S".

[4] Plot W (BCP16) is equivalent to Plot "S-2".

[5] Plot V was counted as "V-1" (1758 hrs: DGR = 36 birds; MFP = 39 birds) + "V-X" (1824 hrs: DGR = 48 birds; MFP = 40 birds).

[6] Includes a small islet immediately adjacent to Northwest Islet that was counted as part of "Remainder NW Islet" in 1992. In 1993, this small islet was designated "Subislet-1" and the 28 July 1994 counts were: (1640 hrs) DGR = 128 birds; MFP = 132 birds.

[7] Consists of a small islet immediately adjacent to Nord Island that was designated "Smaller NW Islet" in 1992 and redesignated "Subislet-2" in 1993.

[8] Consists of a small group of birds found on a high cliff west of Parakeet Cove that was apparently not counted prior to 1993.

Appendix 13. Counts of murres at Nord Island - Northwest Islet, 31 July 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish & Wildlife Service; BCP numbers indicate the plots are population census plots counted from boats, not land; DGR = David G. Roseneau; MFP = Mary F. Portner; ALR = Andrea L. Roberto; JEW = Jessica E. Wachtel.

New FWS Plot Number	Previous FWS Plot Numbers & Names	Time	Observer 1 (ALR) Count 1	Count 2	Count 3	Average	Observer 2 (JEW) Count 1	Count 2	Count 3	Average	Observer 1 & 2 Average
BCP1	A1	1352	60	90		75	80	70		75	75
BCP2	A2	1358	150	170	170	163	160			160	162
BCP3	B	1405	7			7	5			5	6
BCP4	C	1407	130			130	130			130	130
BCP5	D	1410	710			710	780			780	745
BCP6	E	1417	530			530	490			490	510
BCP7	G	1413	70			70	70			70	70
BCP8	H1	1421	630			630	590			590	610
BCP9	H2	1425	381			381	380	400		390	386
BCP10	I	1437	110			110	115			115	113
			Observer 1 (DGR) Count 1	Count 2	Count 3	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Average	
BCP11	(None)[1]	1607	8			8	8			8	8
BCP12	J	1615	21			21	20			20	21
BCP13	P	1616	310			310	300			300	305
BCP14	Q + R[2]	1632	1,555			1,555	1,480			1,480	1,518
BCP15	S [also "S-1" or "R-S"][3]	1654	545			545	570			570	558
BCP16	W [also "S-2"][4]	1635	230			230	240			240	235
BCP17	T (right)	1518	280	280	280	280	270	280		275	278

Appendix 13 (Continued).

New FWS Plot Number	Previous FWS Plot Numbers & Names	Time	Observer 1 (DGR) Count 1	Count 2	Count 3	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Average	Observer 1 & 2 Average
BCP18	T (left)	1510	320	320		320	320			320	320
BCP19	U	1535	170			170	170			170	170
BCP20	V ["V-1"+V-X"][5]	1540	68	68		68	72			72	70
BCP21	X	1549	1,860			1,860	2,010			2,010	1,935
BCP22	Y	1457	800			800	750			750	775
BCP23	Z	1730	1,000			1,000	1,090			1,090	1,045
BCP24	NW Islet Plot	1848	254			254	269			269	262
BCP25	Remainder NW Islet[6]	1821	1,333			1,333	1,278			1,278	1,306
BCP26	("Smaller NW Islet") [Subislet-2][7]	1803	382			382	401			401	392
BCP27	Parakeet Cove	1852	280			280	285			285	283
BCP28	(None) [West Parakeet][8]	1903	13			13	13			13	13
TOTAL (Whole Island)			12,207			12,235	12,346			12,356	12,296

[1] Consists of the area between BCP10 and BCP12 that was apparently not counted in previous years (i.e., 1989-1992).

[2] Plots Q and R were combined to form BCP14 because of a boundary problem that occurred during the 19 July and 3 August 1993 counts.

[3] Plot S (BCP15) is equivalent to Plot "S-1" and it is also equivalent to Plot "R-S".

[4] Plot W (BCP16) is equivalent to Plot "S-2".

[5] Plot V was counted as "V-1" (1540 hrs: DGR = 30 birds; MFP = 32 birds) + "V-X" (1546 hrs: DGR = 38 birds; MFP = 40 birds).

[6] Includes a small islet immediately adjacent to Northwest Islet that was counted as part of "Remainder NW Islet" in 1992. In 1993, this small islet was designated "Subislet-1" and the 31 July 1994 counts were: (1815 hrs) DGR = 133 birds; MFP = 128 birds.

[7] Consists of a small islet immediately adjacent to Nord Island that was designated "Smaller NW Islet" in 1992 and redesignated "Subislet-2" in 1993.

[8] Consists of a small group of birds found on a high cliff west of Parakeet Cove that was apparently not counted prior to 1993.

Appendix 14. Counts of murres at Nord Island - Northwest Islet, 14 August 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish & Wildlife Service; BCP numbers indicate the plots are population census plots counted from boats, not land; DGR = David G. Roseneau and MFP = Mary F. Portner.

New FWS Plot Number	Previous FWS Plot Numbers & Names	Time	Observer 1 (DGR)				Observer 2 (MFP)				Observer 1 & 2 Average
			Count 1	Count 2	Count 3	Average	Count 1	Count 2	Count 3	Average	
BCP1	A1	1252	41	41	39	40	39			39	40
BCP2	A2	1318	170	170		170	140			140	155
BCP3	B	1320	9			9	9			9	9
BCP4	C	1325	90			90	90			90	90
BCP5	D	1335	660	680		670	630	620		625	648
BCP6	E	1345	620			620	640			640	630
BCP7	G	1341	90	100		95	110			110	103
BCP8	H1	1415	615			615	595			595	605
BCP9	H2	1430	400	400		400	380	390		385	393
BCP10	I	1450	95			95	85			85	90
BCP11	(None)[1]	1730	10			10	10			10	10
BCP12	J	1752	11			11	11			11	11
BCP13	P	1756	300	320		310	350			350	330
BCP14	Q + R[2]	1725	1,960			1,960	2,000			2,000	1,980
BCP15	S [also "S-1" or "R-S"][3]	1648	240			240	245			245	243
BCP16	W [also "S-2"][4]	1706	610			610	610	610		610	610
BCP17	T (right)	1636	390			390	380			380	385
BCP18	T (left)	1631	440	430		435	420	430		425	430
BCP19	U	1620	140			140	150			150	145
BCP20	V ["V-1"+V-X"][5]	1600	76			76	76			76	76
BCP21	X	1610	1,830			1,830	1,890			1,890	1,860

Appendix 14 (Continued).

New FWS Plot Number	Previous FWS Plot Numbers & Names	Time	Observer 1 (DGR) Count 1	Count 2	Count 3	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Average	Observer 1 & 2 Average
BCP22	Y	1813	1,030			1,030	1,100			1,100	1,065
BCP23	Z	1814	1,110			1,110	1,050			1,050	1,080
BCP24	NW Islet Plot	1510	267	267	267	267	277	287		282	275
BCP25	Remainder NW Islet[6]	1831	1,235			1,235	1,215			1,215	1,225
BCP26	("Smaller NW Islet") [Subislet-2][7]	1836	460			460	440			440	450
BCP27	Parakeet Cove	1850	420			420	420			420	420
BCP28	(None) [West Parakeet][8]	1900	6			6	6			6	6
TOTAL (Whole Island)			13,325			13,344	13,368			13,378	13,361

[1] Consists of the area between BCP10 and BCP12 that was apparently not counted in previous years (i.e., 1989-1992).

[2] Plots Q and R were combined to form BCP14 because of a boundary problem that occurred during the 19 July and 3 August 1993 counts.

[3] Plot S (BCP15) is equivalent to Plot "S-1" and it is also equivalent to Plot "R-S".

[4] Plot W (BCP16) is equivalent to Plot "S-2".

[5] Plot V was counted as "V-1" (1626 hrs: DGR = 35 birds; MFP = 35 birds) + "V-X" (1600 hrs; DGR = 41 birds; MFP = 41 birds).

[6] Includes a small islet immediately adjacent to Northwest Islet that was counted as part of "Remainder NW Islet" in 1992. In 1993, this small islet was designated "Subislet-1" and the 14 August 1994 counts were: (1840 hrs): DGR = 105 birds; MFP = 105 birds.

[7] Consists of a small islet immediately adjacent to Nord Island that was designated "Smaller NW Islet" in 1992 and redesignated "Subislet-2" in 1993.

[8] Consists of a small group of birds found on a high cliff west of Parakeet Cove that was apparently not counted prior to 1993.

Appendix 15. Counts of murres on multicount plots at Nord Island - Northwest Islet, 1994.

Note: All counts were made by 10's from small boats; times are Alaska Daylight Time; FWS = U.S. Fish and Wildlife Service; BCP numbers indicate the plots are population census plots counted from boats, not land; BMP numbers indicate the plots are also multicount plots that are counted from boats at least 5 separate times on different days to help track population trends; DGR = David G. Roseneau; MFP = Mary F. Portner.

New FWS Multicount Plot Number	New FWS Boat Plot Number & Previous Plot Number/Name	Date	Time	Observer 1 (DGR)					Observer 2 (MFP)					Observer 1 & 2 Average
				Count 1	Count 2	Count 3	Count 4	Average	Count 1	Count 2	Count 3	Count 4	Average	
BMP1	BCP1 (A1)	27 Jul	1335	38	38			38	39				39	39
BMP2	BCP2 (A2)	27 Jul	1350	150				150	155				155	153
BMP3	BCP3 (B)	27 Jul	1400	0				0	0				0	0
BMP4	BCP4 (C)	27 Jul	1403	57	59	59		58	55				55	57
BMP5	BCP5 (D)	27 Jul	1415	480				480	500				500	490
BMP6	BCP6 (E)	27 Jul	1426	430	450			440	430				430	435
BMP7	BCP7 (G)	27 Jul	1435	75	80	80		78	70	75			73	75
BMP8	BCP8 (H1)	27 Jul	1450	140	140			140	130				130	135
BMP9	BCP9 (H2)	27 Jul	1455	260	270			265	255				255	260
BMP10	BCP10 (I)	27 Jul	1505	90	90	85		88	86				86	87
BMP11	BCP11 (NW Islet Plot)	27 Jul	1540	245	250	240		245	230	230	240		233	239
Subtotal	*6 Plots: BMP1-4, BMP10, BMP11*			*580*				*580*	*565*				*568*	*574*
Subtotal	*8 Plots: BMP1-6, BMP10, BMP11*			*1,490*				*1,500*	*1,495*				*1,498*	*1,499*
TOTAL	11 Plots: BMP1-11			1,965				1,983	1,950				1,956	1,969

Appendix 15 (Continued).

New FWS Multicount Plot Number	New FWS Boat Plot Number & Previous Plot Number/Name	Date	Time	Observer 1 (DGR) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP1	BCP1 (A1)	28 Jul	1320	54				54	53				53	54
BMP2	BCP2 (A2)	28 Jul	1330	115	120			118	104				104	111
BMP3	BCP3 (B)	28 Jul	1335	9				9	9				9	9
BMP4	BCP4 (C)	28 Jul	1342	51	50			51	50				50	50
BMP5	BCP5 (D)	28 Jul	1405	530	500			515	490	530			510	513
BMP6	BCP6 (E)	28 Jul	1415	500	510			505	520				520	513
BMP7	BCP7 (G)	28 Jul	1350	110	120			115	140	110			125	120
BMP8	BCP8 (H1)	28 Jul	1430	585	630			608	550				550	579
BMP9	BCP9 (H2)	28 Jul	1450	400	430			415	420				420	418
BMP10	BCP10 (I)	28 Jul	1505	90	100			95	90	100	100		97	96
BMP11	BCP11 (NW Islet Plot)	28 Jul	1630	223				223	220				220	222
Subtotal	*6 Plots: BMP1-4, BMP10, BMP11*			*542*				*549*	*526*				*533*	*541*
Subtotal	*8 Plots: BMP1-6, BMP10, BMP11*			*1,572*				*1,569*	*1,536*				*1,563*	*1,566*
TOTAL	11 Plots: BMP1-11			2,667				2,707	2,646				2,658	2,682

				Observer 1 (DGR) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP1	BCP1 (A1)	14 Aug	1252	41	41	39		40	39				39	40
BMP2	BCP2 (A2)	14 Aug	1318	170	170			170	140				140	155

Appendix 15 (Continued).

New FWS Multicount Plot Number	New FWS Boat Plot Number & Previous Plot Number/Name	Date	Time	Observer 1 (DGR) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP3	BCP3 (B)	14 Aug	1320	9				9	9				9	9
BMP4	BCP4 (C)	14 Aug	1325	90				90	90				90	90
BMP5	BCP5 (D)	14 Aug	1335	660	680			670	630	620			625	648
BMP6	BCP6 (E)	14 Aug	1345	620				620	640				640	630
BMP7	BCP7 (G)	14 Aug	1415	90	100			95	110				110	103
BMP8	BCP8 (H1)	14 Aug	1415	615				615	595				595	605
BMP9	BCP9 (H2)	14 Aug	1430	400	400			400	380	390			385	393
BMP10	BCP10 (I)	14 Aug	1450	95				95	85				85	90
BMP11	BCP11 (NW Islet Plot)	14 Aug	1510	260	260	260		260	270	280			275	268
Subtotal	*6 Plots: BMP1-4, BMP10, BMP11*			*665*				*664*	*633*				*638*	*651*
Subtotal	*8 Plots: BMP1-6, BMP10, BMP11*			*1,945*				*1,954*	*1,903*				*1,903*	*1,929*
TOTAL	11 Plots: BMP1-11			3,050				3,064	2,988				2,993	3,029

				Observer 1 (DGR) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP1	BCP1 (A1)	15 Aug	1356	60	75			68	70				70	69
BMP2	BCP2 (A2)	15 Aug	1405	205	205			205	205				205	205
BMP3	BCP3 (B)	15 Aug	1208	11				11	11				11	11
BMP4	BCP4 (C)	15 Aug	1214	115	110			113	95	100	100		98	105

Appendix 15 (Continued).

New FWS Multicount Plot Number	New FWS Boat Plot Number & Previous Plot Number/Name	Date	Time	Observer 1 (DGR) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP5	BCP5 (D)	15 Aug	1219	670				670	700				700	685
BMP6	BCP6 (E)	15 Aug	1244	570				570	560				560	565
BMP7	BCP7 (G)	15 Aug	1234	140	140			140	140	130			135	138
BMP8	BCP8 (H1)	15 Aug	1248	750				750	760				760	755
BMP9	BCP9 (H2)	15 Aug	1254	390				390	420				420	405
BMP10	BCP10 (I)	15 Aug	1256	107				107	96				96	102
BMP11	BCP11 (NW Islet Plot)	15 Aug	1130	200	195			198	190	185			188	193
Subtotal	*6 Plots: BMP1-4, BMP10, BMP11*			*698*				*701*	*667*				*668*	*684*
Subtotal	*8 Plots: BMP1-6, BMP10, BMP11*			*1,938*				*1,941*	*1,927*				*1,928*	*1,934*
TOTAL	11 Plots: BMP1-11			3,218				3,221	3,247				3,243	3,232

				Observer 1 (DGR) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP1	BCP1 (A1)	16 Aug	1550	85	77			81	75				75	78
BMP2	BCP2 (A2)	16 Aug	1611	280	285	275		280	280				280	280
BMP3	BCP3 (B)	16 Aug	1622	9				9	9				9	9
BMP4	BCP4 (C)	16 Aug	1624	140	130			135	130	120			125	130
BMP5	BCP5 (D)	16 Aug	1631	780	820			800	777	810			794	797
BMP6	BCP6 (E)	16 Aug	1644	640				640	670				670	655

Appendix 15 (Continued).

New FWS Multicount Plot Number	New FWS Boat Plot Number & Previous Plot Number/Name	Date	Time	Observer 1 (DGR) Count 1	Count 2	Count 3	Count 4	Average	Observer 2 (MFP) Count 1	Count 2	Count 3	Count 4	Average	Observer 1 & 2 Average
BMP7	BCP7 (G)	16 Aug	1653	125	120			123	125				125	124
BMP8	BCP8 (H1)	16 Aug	1700	930				930	860				860	895
BMP9	BCP9 (H2)	16 Aug	1714	420	450			435	425	460			443	439
BMP10	BCP10 (I)	16 Aug	1719	94				94	90				90	92
BMP11	BCP11 (NW Islet Plot)	16 Aug	1746	220	220			220	220	210	224		218	219
Subtotal	*6 Plots: BMP1-4, BMP10, BMP11*			*828*				*819*	*804*				*797*	*808*
Subtotal	*8 Plots: BMP1-6, BMP10, BMP11*			*2,248*				*2,259*	*2,251*				*2,261*	*2,260*
TOTAL	11 Plots: BMP1-11			3,723				3,747	3,661				3,688	3,717

Mean of 5 counts on 6 plots (BMP1-4, BMP10, AND BMP11)	*Range = 541 - 808*	*SD = 105*	*652*
Mean of 5 counts on 8 plots (BMP1-6, BMP10, AND BMP11)	*Range = 1,499 - 2,260*	*SD = 310*	*1,837*
MEAN OF 5 COUNTS ON 11 PLOTS (BMP1-11)	Range = 1,969 - 3,717	SD = 653	2,926

Appendix 16. Summary of incidental observations of forage fish near the Barren Islands, Alaska, seabird colonies, 1994.

Large feeding melees typically containing several hundred to several thousand black-legged kittiwakes, tufted puffins, and sooty shearwaters *(Puffinus griseus)* and smaller numbers of murres and cormorants *(Phalacrocorax* spp.*)* were regularly seen near Nord and Ushagat islands and in the straits between Ushagat and West Amatuli islands almost every day during late June - late August. In most cases, many of the birds in these melees had small, bright silver-green fish in their bills that appeared to be either capelin *(Mallotus villosus)* or Pacific sand lance *(Ammodytes hexapterus)*. Stomachs from two 9-10 kg Pacific halibut *(Hippoglossus stenolepis)* and one large Pacific cod *(Gadus macrocephalus)* caught in and near three of these melees contained 35 capelin and two sand lance. The capelin were all males about 125-130 mm long with fully developed lateral ridges indicating that they were either spawning or post-spawning individuals.

Also during this time, many murres returning to the Nord Island nesting cliffs were carrying bright silver-green fish in their bills that also appeared to be either capelin or sand lance. Several murres were observed on the Nord Island study plots with capelin in their bills during the incubation and chick-rearing periods.

We also saw large dense schools of small forage fish on our contract vessel's fish-finder on a regular basis during late July - mid-August. Based on many observations of birds with fish in their bills, stunned fish seen near surfacing humpback whales *(Megaptera novaeangliae)*, and underwater observations made by a team of visiting SCUBA divers, most of these schooling fish were capelin. In general, the schools appeared to be larger and more numerous than the concentrations of unidentified forage fish detected in the same area in 1993 (see Roseneau *et al.* 1995); some concentrations appeared to be up to 1.0 km in circumference and at least 50 m thick. Also, in contrast to 1993 when balls of unidentified fish appeared to stay below about 50 m in depth, the capelin schools were frequently seen at and near the surface in 1994 (including at night, when hundreds of these fish and occasional small schools of sand lance and unidentified cod were seen just below the surface under our anchored vessel's lights—in comparison, only occasional schools of small cod were observed under the vessel's lights in 1993). For example, during 12-18 August, several thousand kittiwakes were observed plunging into the water near the northeastern tip of Ushagat Island on several occasions each day. Two divers attempting to video-tape several whales feeding underwater in this area reported seeing massive schools of densely packed capelin extending from just below the surface to depths of at least 15-20 m deep on these same dates (D. Zatz and P. McCollum, pers comm.).

The total biomass of forage fish (primarily capelin) in Barren Islands waters was even more impressive than in 1993, particularly around Nord Island and in the straits between West Amatuli and Ushagat islands. We estimated that at least 200 humpback whales fed on capelin schools in these areas during late June - late August. During that time, we typically saw several pods of 5-15 whales almost every day, and in one case, we were able to count 100 individuals from our contract vessel during one 10-15 minute interval on a single day (1 August) in the area between Nord, Ushagat, West Amatuli, Sud, and Sugarloaf islands (this was almost the same date that 100 whales were counted in the same location from atop Nord Island in 1993—see Roseneau *et al.* 1995). Huge flocks of seabirds also fed in association with the whales in the same area throughout July and most of August. For example, on 1 August when we encountered the largest concentration of whales, many thousands of kittiwakes and puffins and at least 500,000 shearwaters were observed plunging and diving next to the surfacing whales. Although we were not able to determine what the shearwaters were eating, about 20 kittiwakes and 30 puffins that emerged from the water near our vessel had capelin in their bills (all of these fish were large males with lateral ridges).
