CHANGES IN COLONY SIZE AND REPRODUCTIVE SUCCESS OF SEABIRDS AT THE SEMIDI ISLANDS, ALASKA, 1977-1990

by

Donald E. Dragoo, Belinda K. Bain and Anne Perillo

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U. S. Fish and Wildlife Service
Alaska Maritime National Wildlife Refuge
202 West Pioneer Avenue
Homer, Alaska 99603

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ABSTRACT

Field work at Chowiet Island, Semidi Islands, Alaska continued in the summer of 1990 as part of the T/V Exxon Valdez oil spill damage assessment studies. Productivity and population monitoring of northern fulmars, black-legged kittiwakes and common and thick-billed murres was conducted from 15 May to 26 August. Our 1990 estimate of numbers of northern fulmars on population plots declined from the high point reached in 1989 to a level similar to those found during the period 1977 through 1980. We found significant differences between fulmar counts among years, but no trends. Northern fulmar productivity (0.26 chicks fledged/egg laid) was one of the lowest on record for Chowiet Island fulmars. We found significant differences between fulmar productivity estimates among years, but no trends. The population estimate of black-legged kittiwakes on plots was the second highest on record but was similar to those from the previous three years. We found a significant difference between kittiwake population estimates among years, but no trends. Black-legged kittiwakes produced only one fledged chick on Chowiet Island plots in 1990 (0.01 chicks fledged/nest with eggs). They laid eggs in only 54% of the nests they built. Mean clutch size was 1.47 eggs/nest where eggs were laid. We found a significant difference between productivity estimates among years, but no trends. A significant positive correlation exists between the number of kittiwake nests counted on plots and kittiwake productivity. The 1990 population estimate of murres (species combined) was the highest on record. We found a significant difference between murre estimates among years, but no trends. Productivity of common murres on our plots (0.54 chicks fledged/breeding site) was the second lowest on record for Chowiet Island. Thick-billed murre productivity (0.42) was similar to other years. The ratio of sites where an egg was laid to mean number of adults on productivity plots was 0.61 for common murres and 0.77 for thick-billed murres.

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INTRODUCTION

When the T/V Exxon Valdez ran aground on Bligh Reef in Alaska's Prince William Sound it released some eleven million gallons of crude oil, the largest such spill in American history. Oil from this spill fouled hundreds of kilometers of the Alaskan coastline and adversely impacted pelagic and nearshore water columns, benthic substrates, and intertidal and supratidal coastal habitats. While most of the oiling occurred in western Prince William Sound, oil also washed ashore in the western Gulf of Alaska, southern Kenai Peninsula, the Barren Islands, lower Cook Inlet, the Kodiak archipelago, Shelikof Strait and the Alaska Peninsula as far west as Ivanof Bay. Piatt et al. (1990) estimated that between 100,000 and 300,000 marine birds were killed as a result of the oil spill. Of the 30,000 oiled bird carcasses recovered after the spill, 74% were murres (Piatt et al. 1990).

The U. S. Fish and Wildlife Service initiated a program to assess the injury to the highly susceptible marine birds that utilize the coastal areas affected by the oil. As part of this program, monitoring of the productivity and populations of seabirds was initiated or continued at colonies in Prince William Sound, the outside coast of the Kenai Peninsula, the Barren Islands, the Alaska Peninsula and the Semidi Islands. Three hundred twenty of the 386 seabird colonies in this region occur within the area affected by the oil spill (Baggot et al. 1989).

Because many seabirds feed near the top levels of ocean food webs, they are useful as indicators of changing conditions in the marine environment (Harris and Wanless 1990). Since seabirds also tend to be numerous and conspicuous, and nest in concentrated colonies, they are relatively easier to study than other representatives of upper trophic level feeders such as whales, seals, sea lions and fishes (Harris and Wanless 1990). Diving seabirds are known to be especially susceptible to the impacts of oil fouling (King and Sanger 1979, Piatt et al. 1990). While surface feeding seabirds may not themselves be as susceptible to oiling as divers, they are still at risk if the environment they depend on is disrupted. Hatch (1987a) states that northern fulmars in Alaska breed in four genetically isolated colonies. These colonies are also widely separated from one another. Any Alaskan fulmar colony adversely impacted by an oil spill would likely take many years to recover since there is apparently very little exchange of individuals between fulmar colonies in Alaska (Hatch 1987a) and immigration of new breeders into a decimated colony would probably be minimal. In light of the above traits, cliff nesting seabirds were chosen as the subject of intense scrutiny during the summers of 1989 and 1990.

This report focuses on work done on Chowiet Island, one of the Semidi Islands, during the 1990 seabird breeding season. Chowiet Island was chosen as a monitoring site because it was near to, but outside of, the area of oiling from the T/V Exxon Valdez spill. Thus, these colonies served as controls to those that were within the oiled area (e.g., Barren Islands, Puale Bay). The results from Chowiet Island can be compared to those from oiled colonies to aid in the assessment of the damage to seabird resources from oil pollution.

The objective of this study was to determine if populations and productivity of northern fulmars (*Fulmarus glacialis*), black-legged kittiwakes (*Rissa tridactyla*) and common and thick-billed murres (*Uria aalge*, *U. lomvia*) on Chowiet Island plots had changed relative to those reported in previous studies.

STUDY AREA

The Semidi Islands are located in the western Gulf of Alaska and lie about 80 km south of the Alaska Peninsula, the nearest point of the mainland (Fig. 1). This report covers work that was conducted on Chowiet Island (56° 02'N, 156° 42'W, Orth 1971) during the summer of 1990. At 1,300 ha, Chowiet is the largest of the nine major islands in the archipelago (Hatch 1987a). The topography and habitats prevalent in the Semidi Islands have been described in other reports (ie. Leschner and Burrell 1977, Baggot et al. 1989) and articles (ie. Hatch and Hatch 1983).

The Semidi Island group is of major importance to marine birds (Baggot et al. 1989), providing breeding sites for approximately 25 percent of the total number of seabirds in the Gulf of Alaska (Hatch and Hatch 1983). These islands constitute one of only four major breeding areas for northern fulmars in the northeastern Pacific Ocean (Hatch 1987a). Hatch and Hatch (1983) estimated that 90,000 northern fulmars, more than 15,000 black-legged kittiwakes and 220,000 murres (common and thick-billed combined) were present in the late 1970's on Chowiet Island alone. On this island, common murres constitute approximately 90 percent of the combined murre total (Hatch and Hatch 1983).

METHODS

DATA COLLECTION

The field crew arrived at Chowiet Island, aboard the M/V *Tiglax*, on 15 May and departed, again aboard the M/V *Tiglax*, on 26 August 1990. Four people were present from 15 May until 7 June, when one person departed. Three people remained for the balance of the summer.

A series of population and productivity plots was established along 2 km of cliffs, ranging from 50 m to 200 m in height, on the west side of Chowiet Island in 1976, 1977, 1986 and 1989 (Hatch 1978, Baggot et al. 1989). One new plot for monitoring black-legged kittiwake productivity was established in the same area in 1990. These plots consist of discrete areas on the cliff face which have easily identifiable boundary features. Black and white or color photographic enlargements, with boundaries drawn on them in permanent ink, were used to locate plots. Appendix A lists the numbers of plots of each type for each monitored seabird species. Some plots were devoted to a single species while others contained two or more monitored species.

We collected population data by counting individual birds on plots from designated observation points, utilizing spotting scopes and/or binoculars. Counts were conducted only on days with good visibility and light to moderate winds. Fog, rain and high winds sometimes impaired our ability to obtain accurate counts.

Every plot was initially counted twice for each species on any given count day. If these two values were within 5 percent of each other a mean of them was taken and used as the count for that plot on that day (replicate). If the first two counts differed by more than 5 percent we continued counting until our counts clustered to within the 5 percent level. A mean was then taken of the counts closest in value and used as the count for that species on that plot and date. A single count of black-legged kittiwake nests (defined as a site to which vegetation was added during the current season) was conducted on 2 July 1990.

The census period differed somewhat with each species or genus (murres). We made our counts during the period in which daily variability in bird attendance on the cliffs was at its lowest (Table 1). We also restricted our counts to between the hours of 0900 and 1800 Alaska Daylight Time, the hours during which within-day variability in cliff attendance of seabirds is least. These time periods were established by Hatch (1987a), and Hatch and Hatch (1988, 1989) based on counts made at many of the same Chowiet Island plots that we used.

We visited productivity monitoring plots every 3 days, weather permitting. We monitored the plots from observation points located on nearby headlands. On each visit we identified any new nest starts (e.g. eggs laid by fulmars or murres, sites with new vegetation added by kittiwakes) on the plot by assigning each such site a unique number. These numbers were written on the plot photographs in permanent ink. During subsequent visits, the status (e.g. egg(s) or chick(s), or adult present but nest contents unknown) of each numbered nest site was noted. Observations were made using spotting scopes and/or binoculars. We monitored all of the kittiwake and murre productivity plots listed in Appendix A, but only three plots (P03N01, P09N02/N01 and P12N01) were monitored for fulmar productivity.

DATA ANALYSIS

Populations

Our population estimates were calculated by taking the means of the total numbers of birds counted on all plots on any given count day (replicate). These means represent our estimates of the population levels of birds on our plots, not on the island as a whole. Estimates of this type can be used to identify trends in the numbers of birds present on monitored plots (Byrd 1989). By assuming that events on our plots reflect those that occur island-wide, we can then infer that any trends we identify on plots represent changes in the island bird populations.

We performed all of the statistics using SYSTAT (Wilkinson 1988). The totals for each replicate count from every year (1976-1981, 1989 & 1990 for fulmars; 1977-1981, 1989 & 1990 for kittiwakes and murres) were entered into SYSTAT data files. Kolmogorov-Smirnov goodness of fit tests for the normal distribution showed that our population data are not normally distributed (all p's < 0.001). Therefore, a Kruskal-Wallis one-way analysis of variance (ANOVA) was conducted for each species. If a significant difference ($p < 0.10$) was found when all years were included, we proceeded to test for differences between each given pair of years. We followed the procedure outlined by Zar (1984:200-201) to accomplish this.

Black-legged kittiwake numbers declined appreciably this year after the fourth replicate count (21 June). We feel that this was probably due to a nearly complete breeding failure and is, therefore, not indicative of a true population decline. A similar trend was found in 1989 (Baggot et al. 1989) when the counts declined after the first three replicates. Only these three counts were used to calculate the mean for that year. These three counts from 1989 were also those we used for our analyses.

A Mann-Whitney test (U) was calculated to test for a difference between the mean of the first four 1990 kittiwake counts and that of the other eight counts for this year. Since this difference was significant ($U = 32$, $p = 0.007$) we used only the first four counts to obtain the estimate of kittiwake population levels on Chowiet Island plots in 1990.

Murres counted on population plots were not differentiated by species during the early years of counts (1977-1981). Because of this, the numbers of the two murre species were combined for the purposes of testing for differences among all years. In 1989 and 1990, however, counts of common and thick-billed murres were documented separately. This made it possible for us to test for differences in the counts of these individual species between these two years. A Mann-Whitney U statistic was calculated for this purpose.

We used a Spearman rank correlation coefficient (r_s) to evaluate the relationship between mean population counts and productivity of northern fulmars. We tested for correlation between mean population counts, as well as total nest counts, and productivity of black-legged kittiwakes. This was not done for murres because, until 1989, population estimates did not differentiate between the two species, whereas productivity estimates did.

Productivity

We used different techniques to calculate productivity estimates for each of the four monitored species. The productivity estimate used for northern fulmars was the number of chicks that survived to fledging per egg laid (chicks fledged/egg laid) at the sites we monitored this year. Fulmar chicks that were still alive on the last check prior to our departure were assumed to have fledged. The number of chicks living long enough to fledge for every monitored black-legged kittiwake nest on our plots where at least one egg was laid (chicks fledged/nest with eggs) was used to estimate the annual productivity of this species. Murre productivity was characterized as the number of fledged chicks for every site at which an egg was laid (chicks fledged/breeding site). In all cases, the ultimate fate of every monitored nest site present on our productivity plots was recorded.

The number of chicks fledged per breeding attempt, as defined above, was entered into a ratio estimator spreadsheet that was developed on Lotus 123 by B. Ackerman and E. O. Garton (Dept. Fish and Wildlife Resources, Univ. of Idaho, Moscow, ID). This spreadsheet calculated the productivity estimate for each species of seabird studied (Appendix B). Estimates of productivity were made by using the plots as sample units and letting the average productivity for a plot be the sample observation. This was done because of questions about whether nests that occur in clusters (e.g. plots) are independent samples for the purpose of estimating parameters (Byrd 1989).

Byrd (1989) also suggested that each plot contain at least 25 nesting pairs. In some cases, it was necessary for us to combine nests from more than one plot to achieve this. This was only done if the plots were reasonably similar with regards to elevation, aspect and geographic location. Nests from some plots could not be combined with those from others due to a lack of similarity with any other nearby plot. We let these few plots stand as they were. See Appendix B for the exact groupings of nests used in productivity calculations.

Productivity estimates for every year for which there are data (1976-1981, 1983, 1985, 1986, 1989 & 1990 for fulmars; 1977-1981, 1989 & 1990 for kittiwakes; 1979-1981, 1989 & 1990 for murres) were entered into SYSTAT data files. We tested for differences among years between the proportions of chicks that fledged. This was done by testing for significant heterogeneity among years using a contingency table and calculating the log-likelihood ratio (G).

We calculated a ratio of the number of active murre (both species) sites (site where an egg was laid) on all monitored productivity plots to the mean number of birds that occurred on the plots. This was done to facilitate an estimate of the breeding potential lost due to the T/V Exxon Valdez oil spill.

RESULTS AND DISCUSSION

NORTHERN FULMAR

Populations

A total of 11 replicate counts was made of this species on plots between 17 June and 10 July in 1990 (Table C1). Our 1990 estimate of the numbers of northern fulmars on population plots (447) declined from the high point reached in 1989 to a level similar to those found during the period 1977 through 1980 (Table 2, Fig. 2). The differences between counts among all years were highly significant (Kruskal Wallis = 60, $p \ll 0.001$).

Northern fulmar counts from 1976 were significantly lower than those from 1980, 1981 and 1989 ($p < 0.001$ for all). The two years with the highest counts (1981 and 1989) were each significantly higher than 1977 ($p < 0.001$ and $p < 0.1$ respectively) and 1979 ($p < 0.001$ and $p < 0.02$ respectively). Fulmar counts on plots in 1981 were also significantly higher than in 1978 ($p < 0.05$). There was no correlation between fulmar population indices and productivity. There was no pattern to the differences in the annual population estimates of northern fulmars.

Productivity

Northern fulmars began laying earlier in 1990 than in 1989 (Table 3). Both the date of first laying and the mean laying date were similar to those reported in the years prior to

1989. The date on which the last new fulmar egg was recorded was the earliest, by one day, of any year for which there are data. Our mean hatching date was earlier than all other years except 1976. The same is true for our projected fledging date for the chicks that were still alive when we last checked. Hatch and Hatch (1981) found that fulmar breeding phenology varied little from season to season, and seemed not to depend on external factors such as weather and food supply. This pattern continued in 1989 (Baggot et al. 1989), and again in 1990.

The 1990 estimate of northern fulmar productivity (0.26 chicks fledged/egg laid, n = 77) is one of the lowest recorded for this species on Chowiet Island (Table 2). Fifty-one percent of the eggs laid at monitored sites hatched. Likewise, 51 percent of the chicks that hatched were still alive when we left, and were assumed to have fledged. Typically, eggs or chicks that were lost merely disappeared between our visits to the plots. Only one loss was actually witnessed by an observer this year, when a glaucous-winged gull (Larus glaucescens) took a fulmar egg. Hatch (1987a) suggested that most fulmar egg losses could be attributed to this species of gull or to common ravens (Corvus corax).

Our productivity estimate must be considered maximal because we did not stay long enough to see any actual fledging of chicks. Some chick mortality may have occurred after our departure. There were highly significant differences in the productivity of fulmars among years tested ($G = 728$, $p << 0.001$). Hatch (1987a) reported that annual fulmar productivity is highly variable at colonies in both the Atlantic and Pacific. There was no pattern to these annual differences in productivity at Chowiet Island.

BLACK-LEGGED KITTIWAKE

Populations

A total of 12 replicate counts was made of population levels of black-legged kittiwakes on plots between 14 June and 25 July in 1990 (Table C2). A nest count was conducted on 2 July. We used only the first four counts to calculate our population estimate (see methods). The estimate of black-legged kittiwakes on plots for 1990 (456) is the second highest on record (Table 4, Fig. 3) but is similar to the previous three estimates. There was a highly significant difference between the estimated population levels on plots among all years (Kruskal-Wallis = 114, $p << 0.001$).

The population estimate for kittiwakes on plots in 1977 was significantly higher than those in 1978 ($p < 0.001$), 1979 ($p < 0.001$), 1980 ($p < 0.001$) and 1981 ($p < 0.01$). Populations on plots in 1981 also differed significantly from those in 1979 ($p < 0.001$) and 1980 ($p < 0.001$). There was, however, no pattern or trend among all years to these population differences.

Hatch and Hatch (1988) found that their counts (1977-1981) of black-legged kittiwakes on plots did not change appreciably from first egg laying through the end of hatching within any one season. This was not the case in 1989 or 1990, when numbers of adults attending the cliffs declined significantly after failing to breed. This decline in attendance was especially pronounced in 1989, when the lowest replicate count (considering all 13 counts) was only 15 percent as large as the highest count (as opposed to 45 percent in 1990, considering all 12 counts). The majority of pairs in both years failed prior to the chick-rearing stage.

We found no correlation between kittiwake population levels and productivity (Table 4). However, a significant positive correlation ($r_s = 0.88$, $p < 0.01$) does exist between the number of kittiwake nests counted on plots (Fig. 4) and the productivity of this species in any given year (Table 4), suggesting that nest counts are more indicative of breeding effort within a given year than any actual change in the populations of breeders.

Productivity

Black-legged kittiwakes began laying one day earlier in 1990 than in any other year on record (Table 5). The mean laying date was similar to those in other years except 1989, when mean laying was several days later (Baggot et al. 1989). The last new kittiwake egg was laid slightly earlier in 1990 than in most other years. The mean date of hatching was similar to those in other years, whereas the one chick that fledged on our plots did so several days earlier than normal.

Kittiwakes essentially failed to produce fledged young on Chowiet Island plots in 1990 (Table 4). They laid eggs in only 131 (54%) of the 241 nests that they built. The mean clutch size was 1.47 eggs per nest where eggs were laid. Of the nests that contained an egg(s) only 13 (10%) hatched a chick(s), three of these had two chicks. Black-legged kittiwake eggs failed to hatch on four of the ten plots we monitored. Only one chick fledged out of all of the nests we monitored (0.01 chicks fledged/nest with eggs, $n = 131$). There was a highly significant difference between productivity levels among years tested ($G = 546$, $p << 0.001$). Typically, eggs or chicks that were lost simply disappeared between our visits to the plots, frequently after the adult had ceased to incubate or brood. Black-legged kittiwake reproductive output on our plots varied from year to year in such a way that no pattern was evident.

In 1989, kittiwakes at the Semidi Islands failed to hatch any chicks (Baggot et al. 1989). The mortality in that year all occurred during the egg incubation stage. Most of the mortality in 1990 occurred during that stage as well, although some loss happened during the chick stage.

Black-legged kittiwake productivity varies considerably between years and colonies in Alaska (e.g., Hatch 1987b, Dragoo et al. 1990), and years of zero productivity occasionally occur. These years of poor reproductive success seem not to be related to any discernable environmental variable but may be caused by food shortages during either the pre-laying or chick rearing periods (Hatch 1987b, Harris and Wanless 1990).

COMMON AND THICK-BILLED MURRES

Populations

A total of 10 replicate counts was made of murres on plots at Chowiet Island between 25 June and 1 August in 1990 (Table C3). The population estimate of murres on plots for 1990 (2980) was the highest on record (Table 6, Fig. 5). We found a highly significant difference between murre population levels on plots among years (Kruskal-Wallis = 98, $p << 0.001$). Murre populations on plots in 1979 and 1980 were each significantly lower than the counts obtained in 1977 ($p <0.001$ for both), 1981 ($p < 0.001$ for both), 1989 ($p < 0.001$ and $p < 0.01$, respectively) and 1990 ($p < 0.001$ for both). However, there was no pattern or trend among years to these population differences.

When the counts of the two murre species were considered separately for the last two years, we found that there was no significant difference for common murres, while thick-billed murre counts were significantly higher in 1990 ($U = 38$, $p =0.094$.

Nysewander and Dippel (1990) reported pre- and post-oil spill population data for murres. The murre populations at the Chiswell Islands apparently increased in 1990 over those estimated in 1986. Nysewander and Dippel (1990) found that murre populations in the Barren Islands had declined significantly since the oil spill. Post-oil declines in murre numbers were also documented at Puale Bay. Murre numbers were apparently down at Kodiak Island area colonies as well (Nysewander and Dippel 1990). Murre numbers at Middleton Island, another unoiled (control) site do not appear to have declined since the oil spill (Nysewander and Dippel 1990).

Productivity

The date of first egg laying for common murres in 1990 was nine days earlier than in 1989 (Table 7) but was similar to all other years. The mean laying date and the date of last egg laying were both somewhat later this year than in any other year except 1989. Mean hatching and fledging dates were both exactly the same this year as last year, and both were later than normal. The same can be said for the mean fledging dates in 1989 and 1990. Thick-billed murre phenology was similar this year to that exhibited in other years (Table 8).

Productivity of common murres that bred on our plots in 1990 (0.54 chicks fledged/breeding site, n = 213) was the second lowest ever recorded for this species on Chowiet Island (Table 6). This year was, however still a reasonably successful reproductive season for this species. Chicks were observed at 66 percent of monitored common murre breeding sites. Of those chicks that hatched, 82 percent fledged. Most mortality occurred during incubation. There was no significant heterogeneity in productivity estimates among years for which we have data. The ratio of sites where an egg was laid to the mean number of adult common murres on productivity plots was 0.61.

Our 1990 productivity estimate for thick-billed murres breeding on plots on Chowiet Island (0.42 chicks fledged/breeding site, n = 134, Table 6) was very similar to all other years except 1981, when success was significantly higher ($g = 13$, $p = 0.012$). Eggs hatched at 60 percent of the monitored thick-billed murre sites, and 69 percent of the chicks that hatched fledged in 1990. As was the case with common murres, most mortality of thick-billed murre young occurred during the egg stage. There were no patterns to the differences in productivity estimates for either species of murre. The ratio of sites where an egg was laid to the mean number of adult thick-billed murres on productivity plots was 0.77.

Nysewander and Dippel (1990) reported productivity estimates for murres at various colonies within the area contaminated by the oil spill. These authors concluded that few, if any, murre chicks fledged from the Barren Island colonies. Very few murre chicks fledged at the Puale Bay colonies in 1990 (Nysewander and Dippel 1990).

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Table 1. Population census period for fulmars, kittiwakes, and murres on the Semidi Islands, Alaska as established by Hatch (1987a) and Hatch and Hatch (1988, 1989).

Species	Census Period
Northern Fulmar	30 days extending from 11 days after first egg to 40 days after first egg
Black-legged Kittiwake	50 days extending from first egg-laying through final hatching (plus one count of nests on or about 4 July)
Murres	43 days extending from 20 June to 1 August[a]

[a]Murres have a fixed census period because egg-laying remained relatively constant from year to year.

Table 2. Comparison of northern fulmar census parameters in 11 years with different levels of breeding success on the Semidi Islands, Alaska[a].

Parameter	1976	1977	1978	1979	1980	1981	1983	1985	1986	1989	1990	r_s[b]
	Year											
Productivity[c]	0.15	0.51	0.46	0.60	0.66	0.72	0.37	0.07	0.19	0.47	0.26	--
Mean population counts	354	424	439	414	464	507	--	--	--	549	447	0.43

[a]Data from Hatch (1987a), Baggot et al. (1989) and this study.
[b]Spearman rank correlation coefficient for paired values of annual productivity and a given census parameter.
[c]Chicks fledged/egg laid.

Table 3. Phenology of northern fulmars on the Semidi Islands, Alaska in different years[a].

	Years							
	1976	1977	1978	1979	1980	1981	1989[b]	1990
Laying								
First laying date	5/29	6/02	5/26	6/02	5/27	5/31	6/06	5/31
Mean date	6/06	6/11	6/07	6/11	6/08	6/10	6/15	6/06
Last laying date	6/23	6/22	6/20	6/24	7/02	6/25	7/05	6/19
Sample size	208	386	397	400	389	395	31	68
Hatching[c]								
Mean date	*7/24	*7/29	*7/25	*7/29	*7/26	*7/28	7/30	7/24
Sample size	--	--	--	--	--	--	26	29
Fledging[d]								
Mean date	9/15	9/20	9/16	9/20	9/17	9/19	9/21	9/15
Sample size	--	--	--	--	--	--	--	16

[a]Data from Hatch and Hatch (in press), Baggot et al. (1989), and this study.
[b]We were unable to determine the phenology for the majority of the eggs that were laid and the chicks that were hatched due to the difficulty in monitoring northern fulmars. The given dates and figures for the laying and hatching phenology represent, respectfully, only 17% and 23% of the total sample size - the given sample size being only a fraction of the total sample size.
[c]*Asterisks denote data that was extrapolated from the laying dates using the mean incubation period for northern fulmars.
[d]Extrapolated from the hatching dates using the mean time of chick departure for northern fulmars (53 days). Chick departure data from Hatch and Hatch (1979) and Mougin (1967; cited in Hatch 1987a).

Table 4. Comparison of black-legged kittiwake census parameters in 7 years with different levels of breeding success on the Semidi Islands, Alaska[a].

	Year							
Parameter	1977	1978	1979	1980	1981	1989	1990	r_s[b]
Productivity (chicks fledged/nest w/eggs)	0.70	0	0.51	0.34	1.15	0	0.01	--
Total nests[c]	--	256	305	381	411	219	279	0.88
Mean of population counts during census period[d]	485	406	383	377	438	436	456	0.27

[a]Data from Hatch and Hatch (1988), Baggot et al. (1989) and this study.
[b]Spearman rank correlation coefficient for paired values of annual productivity and a given census parameter.
[c]Total nests include all structures to which vegetation was added in the current year. Dates of nest counts are as follows: 3 July 1977, 27 June 1978, 8 July 1979, 3 July 1980, 4 July 1981, 5 July 1989, and 2 July 1990.
[d]Includes only the first 3 replicate counts during the census period for 1989 and only the first 4 replicate counts during the census period for 1990.

Table 5. Phenology of black-legged kittiwakes on the Semidi Islands, Alaska in different years[a].

	Years							
	1976	1977	1978	1979	1980	1981	1989	1990
Laying[b]								
First laying date	6/10	6/09	6/05	6/17	6/05	6/05	6/27	6/04
Mean date	6/20	6/19	6/15	6/24	6/14	6/14	7/01	6/17
Last laying date	6/30	6/30	6/27	7/09	7/03	7/05	7/07	6/29
Sample size	41	54	46	99	129	126	32	98
Hatching[c]								
Mean date	*7/16	*7/15	*7/11	*7/20	*7/10	*7/10	--	7/13
Sample size	--	--	--	--	--	--	--	15
Fledging[d]								
Mean date	*8/27	*8/26	*8/22	*8/31	*8/21	*8/21	--	8/15
Sample size	--	--	--	--	--	--	--	1

[a]Data from Hatch and Hatch (in press), Baggot et al. (1989), and this study.
[b]Date of the first egg laid in multiple-egg clutches. Data does not include relaid eggs.
[c]*Asterisks denote data that was extrapolated from the laying dates using the mean incubation period for black-legged kittiwakes.
[d]*Asterisks denote data that was extrapolated from the hatching dates using the mean time of chick departure for black-legged kittiwakes (42 days). Chick departure from Swartz (1966) and Coulson and White (1958).

Table 6. Comparison of COMU and TBMU census parameters in 7 years with different levels of breeding success on the Semidi Islands, Alaska[a].

Parameter	Year 1977	1978	1979	1980	1981	1989	1990
Productivity of COMU (chicks fledged/breeding site[b])	--	--	0.48	0.64	0.59	0.58	0.54
Productivity of TBMU (chicks fledged/breeding site)	--	--	0.48	0.46	0.63	0.43	0.42
Mean of COMU population counts during census period	--	--	--	--	--	2705	2835
Mean of TBMU population counts during census period	--	--	--	--	--	118	145
Mean of COMU and TBMU population counts during census period	2816	2635	2308	2451	2856	2823	2980

[a]Data from Hatch and Hatch (in press), Baggot et al. (1989) and this study. COMU = common murre TBMU = thick-billed murre
[b]Breeding site = a site where an egg was laid.

Table 7. Phenology of common murres on the Semidi Islands, Alaska in different years[a].

	Years				
	1979	1980	1981	1989	1990
Laying[b]					
First laying date	6/07	6/07	6/05	6/15	6/06
Mean date	6/18	6/16	6/16	6/25	6/21
Last laying date	7/11	6/29	7/05	8/06	7/21
Sample size	69	83	83	144	214
Hatching[c]					
Mean date	*7/20	*7/18	*7/18	7/25	7/25
Sample size	--	--	--	113	145
Fledging[d]					
Mean date	*8/12	*8/10	*8/10	8/14	8/14
Sample size	--	--	--	65	97

[a]Data from Hatch and Hatch (in press), Baggot et al. (1989), and this study.
[b]Data does not include relaid eggs.
[c]*Asterisks denote data that was extrapolated from the laying dates using the mean incubation period for common murres.
[d]*Asterisks denote data that was extrapolated from the hatching dates using the mean time of chick departure for common murres (23 days). Chick departure data from Hatch and Hatch (in press) and Harris and Birkhead (1985).

Table 8. Phenology of thick-billed murres on the Semidi Islands, Alaska in different years[a].

	Years					
	1978	1979	1980	1981	1989	1990
Laying[b]						
First laying date	6/09	6/07	6/07	6/05	6/09	6/09
Mean date	6/17	6/17	6/17	6/15	6/23	6/19
Last laying date	6/29	7/11	7/01	7/03	7/17	7/13
Sample size	43	107	105	108	95	121
Hatching[c]						
Mean date	*7/19	*7/19	*7/19	*7/17	7/23	7/21
Sample size	--	--	--	--	85	73
Fledging[d]						
Mean date	*8/11	*8/11	*8/11	*8/09	8/12	8/12
Sample size	--	--	--	--	47	46

[a]Data from Hatch and Hatch (in press), Baggot et al. (1989), and this study.
[b]Data does not include relaid eggs.
[c]*Asterisks denote data that was extrapolated from the laying dates using the mean incubation period for thick-billed murres.
[d]*Asterisks denote data that was extrapolated from the hatching dates using the mean time of chick departure for thick-billed murres (23 days). Chick departure data from Hatch and Hatch (in press) and Gaston and Nettleship (1981).

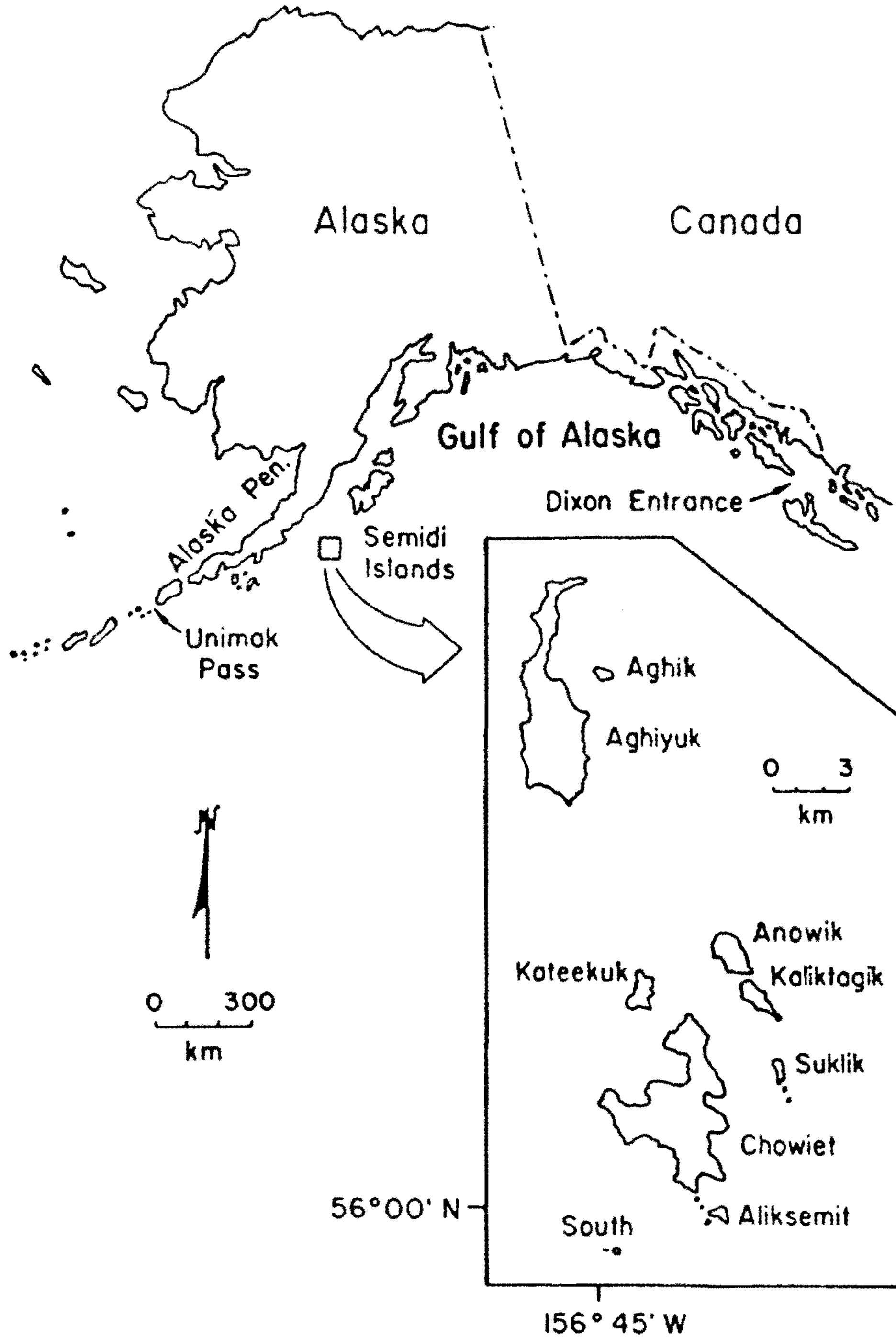

Figure 1. Location of the Semidi Islands in the western Gulf of Alaska.

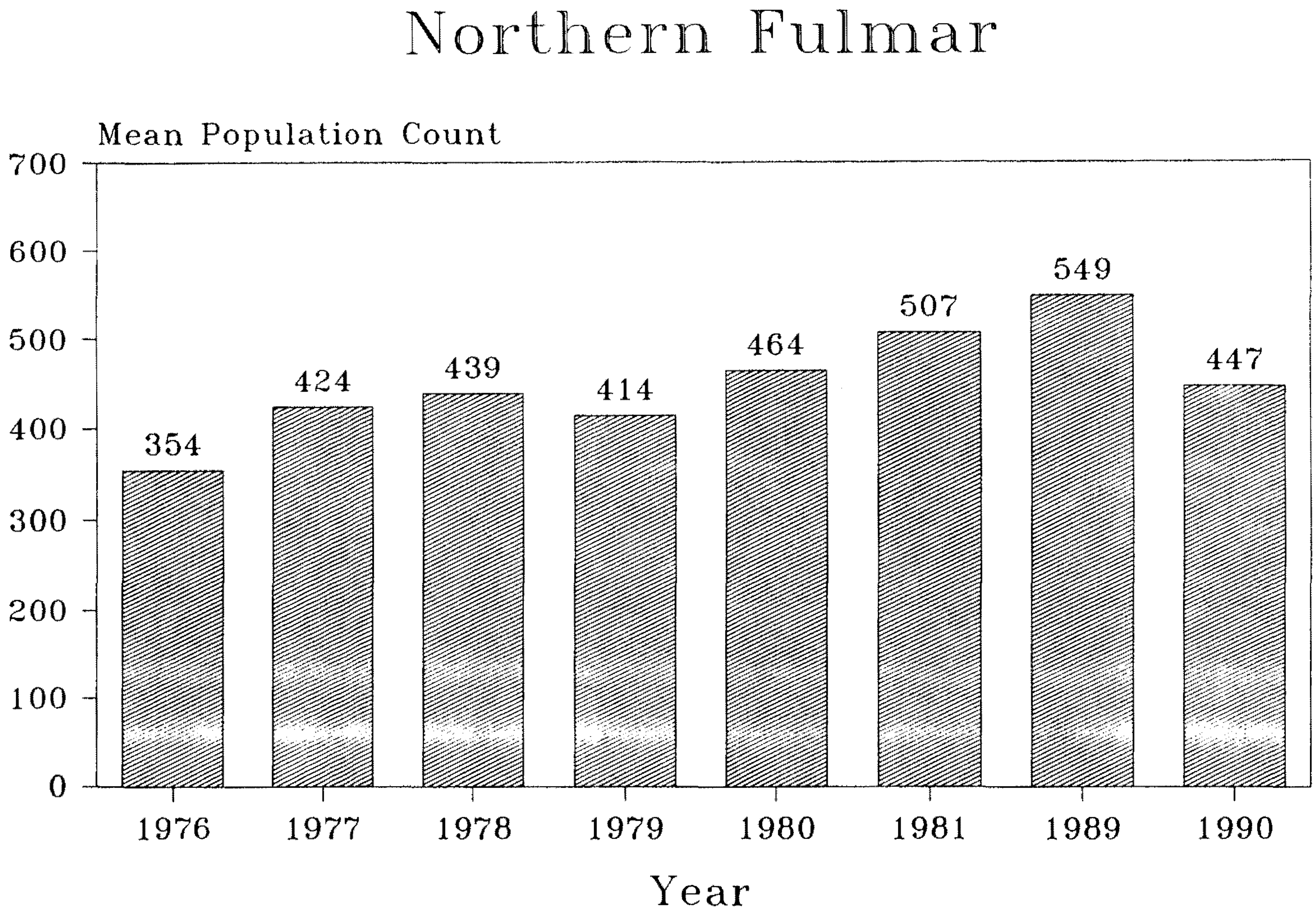

Figure 2. Northern fulmar mean population counts on plots during census period at the Semidi Islands, Alaska.

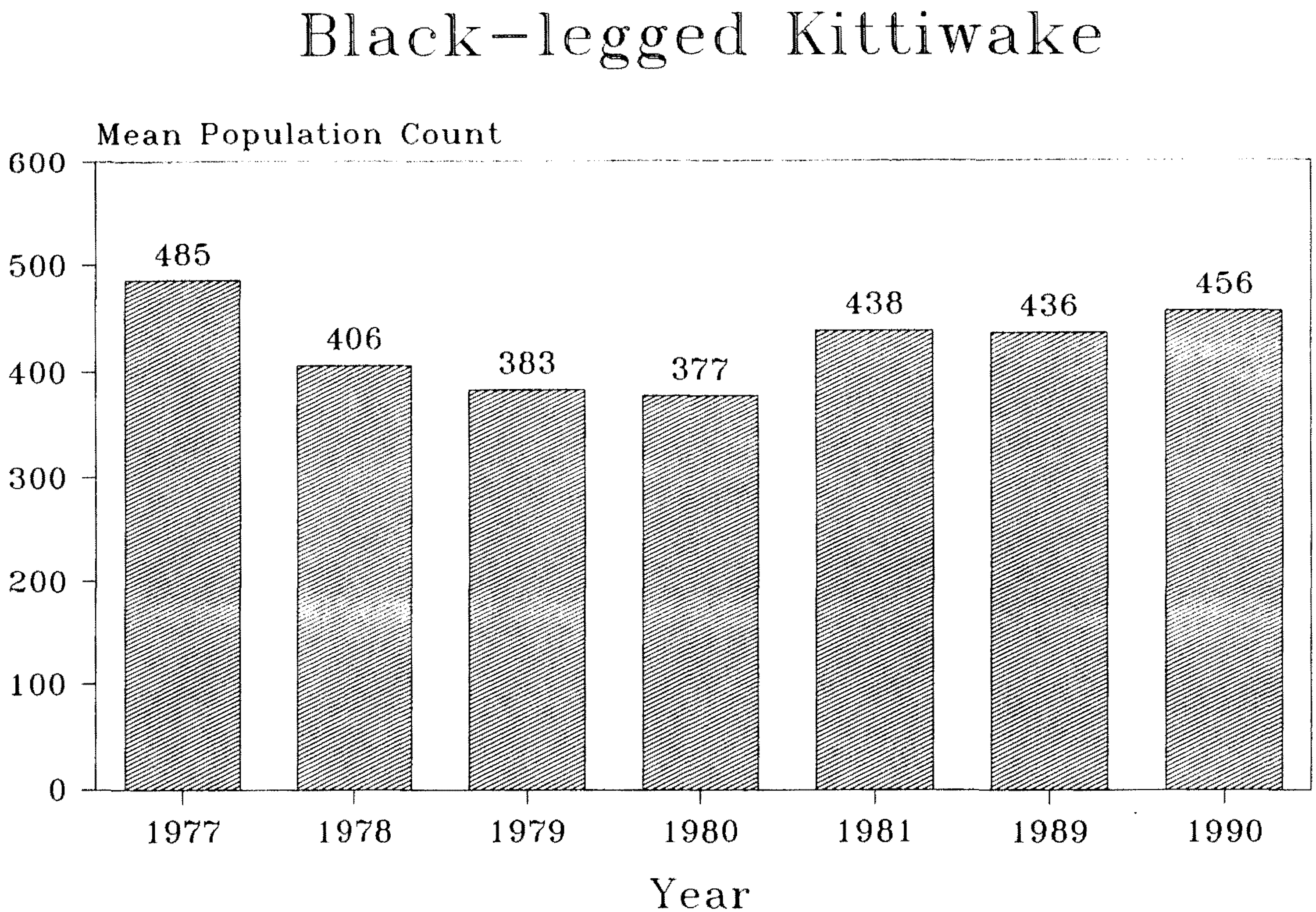

Figure 3. Black-legged kittiwake mean population counts on plots during census period at the Semidi Islands, Alaska.

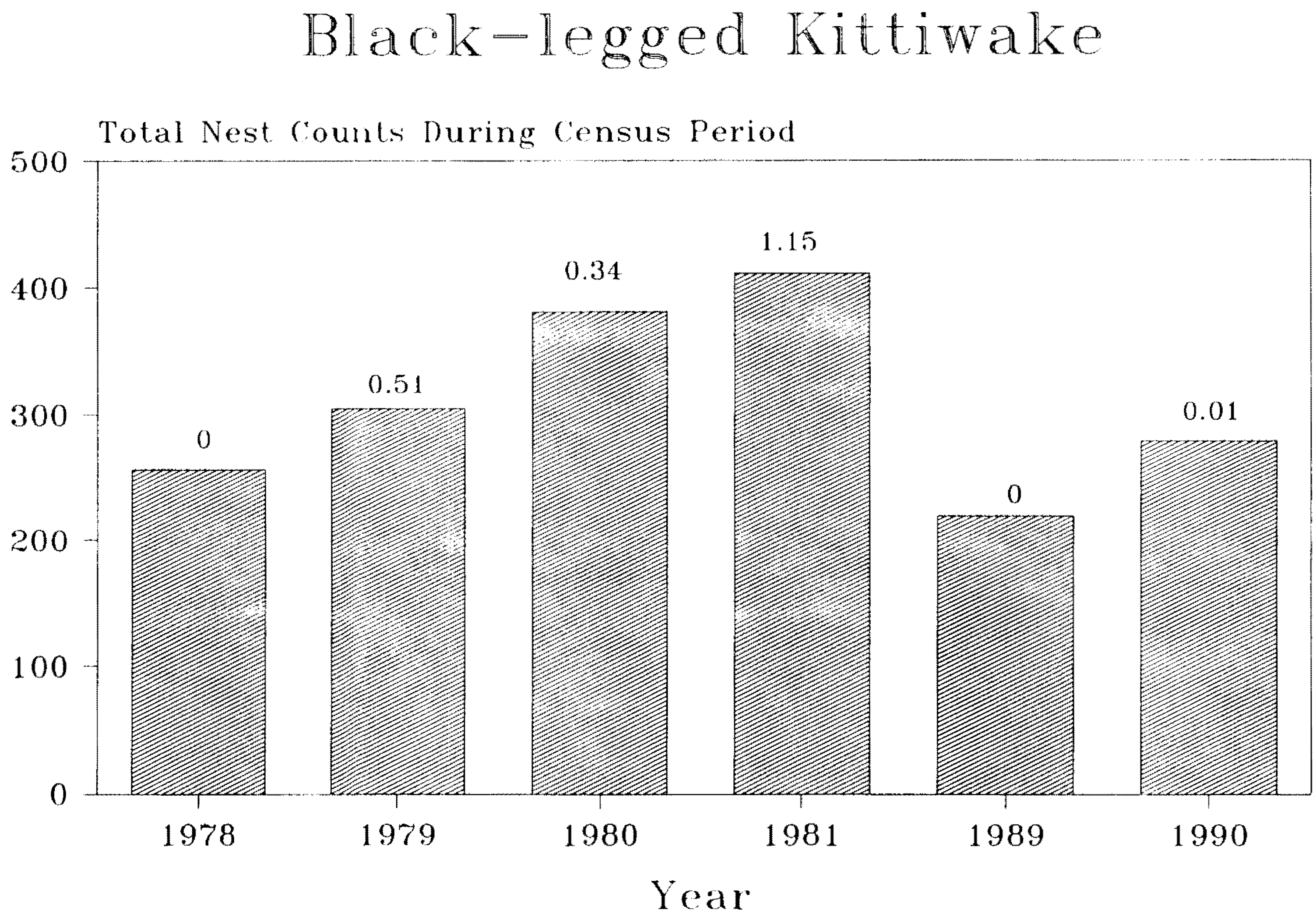

Figure 4. Counts of black-legged kittiwake nests on plots during census period at the Semidi Islands, Alaska. Numbers represent annual productivity estimates.

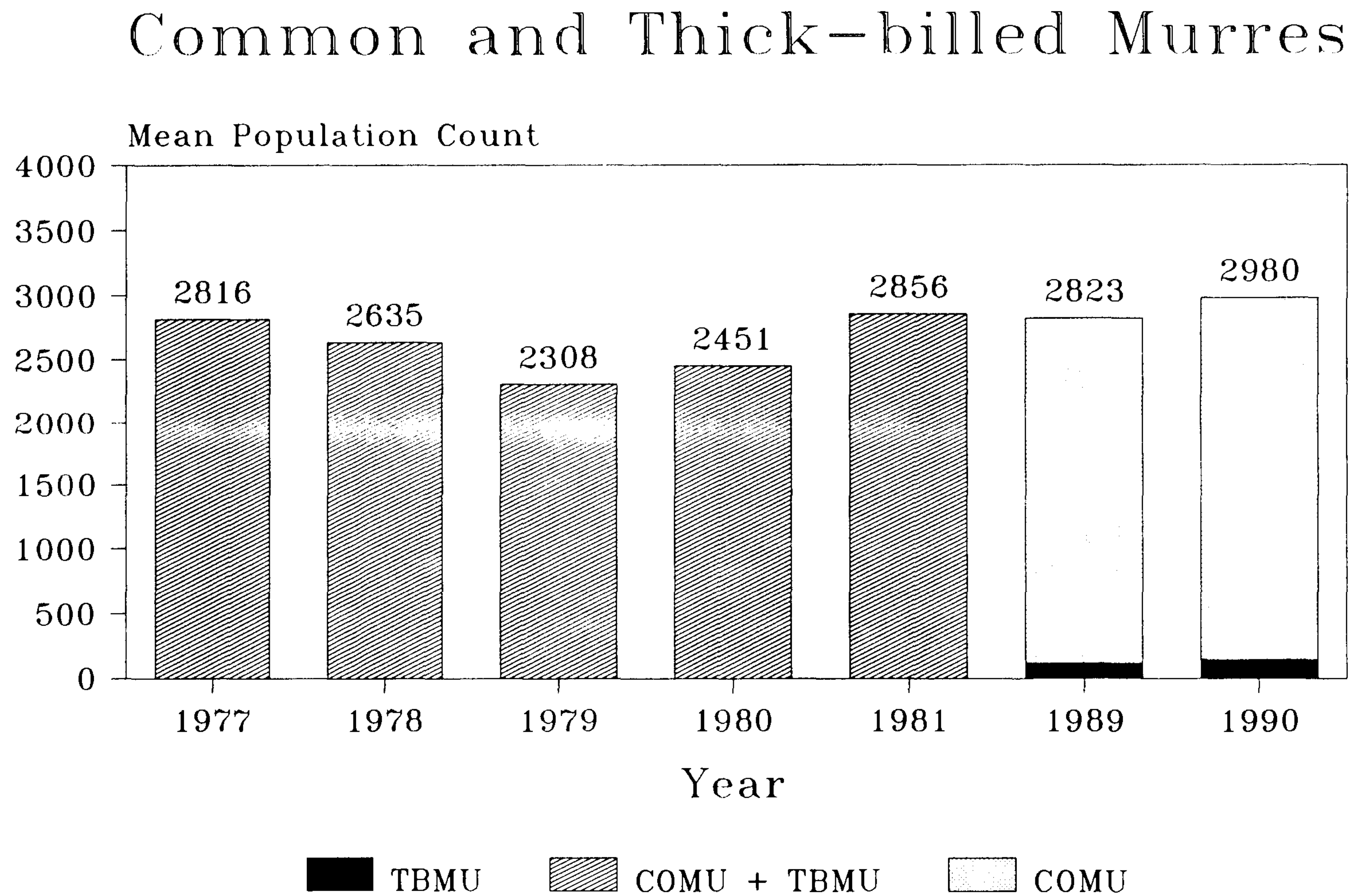

Figure 5. Common and thick-billed murre mean population counts on plots during census period at the Semidi Islands, Alaska.

Appendix A. Population (attendance) and productivity plot codes used at Chowiet Island in 1990 with reference to prior plot codes used by Hatch.

1989 Plot Code	Plot Codes used by Hatch	Comments
Northern Fulmar Population Plots		
A03N01	F1	
A04N01	F2	
A07N01	F5	
A10N01	F6A	
A10N02	F6B	
A12N01	F7	
A12N02	F8	
Black-legged Kittiwake Population Plots		
A02B01	1	
A02B02	2	
A03B01	3	
A03B02	3A	
A03B03	3	Separate section of plot 3 located on different cliff face
A06B01	4	
A06B02	5	
A09B01	6	
A09B02	7	
Murre Population Plots		
A03M01	1	
A03M02	2	
A03M03	3	
A03M04	4	
A03M05	5	
A06M01	6	
A09M01	7	
A09M02	8	
A10M01	9	
A10M02	10	

Appendix A. Population (attendance) and productivity plot codes used at Chowiet Island in 1990 with reference to prior plot codes used by Hatch (continued).

1989 Plot Code[a]	Plot Codes used by Hatch	Comments
Northern Fulmar Productivity Plots		
P03N01	Q	
P04N01	P	
P07N01	M1	
P07N02	M2	
P07N03	M3	
P09N01	L1	
P09N02	L2	
P12N01	B	
Black-legged Kittiwake Productivity Plots		
P03B01	A	
P03B02	B	
P03B03	C	
P03B04	D	
P03B05	E	
P03B06	F	
P09B01	C-1	
P10B01		Established in 1989
P10B02		Established in 1990
P11B01	E	
Murre Productivity Plots		
P03M01	A-1	
P03M02	A-2	
P03M03	A-3	
P03M04	A-4	
P03M05	A-5	
P03M06	A-6	
P03M07	A-7-1	
P03M08	A-7-2	
P03M09	A-8	
P03M10		Established in 1989
P03M11	B-1	
P03M12	B-2	
P03M13	B-3	
P03M14		Established in 1989
P03M15		Established in 1989
P09M01	D-2	
P09M02	D-3	
P09M03	D-4	
P09M04	D-5	

Appendix A. Population (attendance) and productivity plot codes used at Chowiet Island in 1990 with reference to prior plot codes used by Hatch (continued).

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[a]1989 plot codes (Baggot et al. 1989) were established in the following manner:

Plot code A03N01
Key 122344

Key explanation:

1 = A for Population (Attendance) Plot
1 = P for Productivity Plot
2 = Stake location from which plot is viewed (01-12)
3 = N for Northern Fulmar
3 = B for Black-legged Kittiwake
3 = M for murre (both Common and Thick-billed Murres)
4 = Plot number for the given species (01-15), additional plots could be added at the same location by increasing the plot number suffix

APPENDIX B

Ratio Estimation Lotus Spreadsheets
Semidi Islands, AK 1990

RATIO ESTIMATION LOTUS SPREADSHEET
Developed by Bruce Ackerman and Oz Garton, November 1987
Dept. Fish and Wildlife Resources
University of Idaho
Moscow ID 83843

Seabird Productivity - 1990
Semidi Islands - Northern Fulmar
NUMBER OF OBSERVATIONS (PLOTS) n = 3

UNIVARIATE STATISTICS

	Nest Started X	Fledged Y
TOTAL	77	20
MEAN	25.667	6.667
STAND DEV	0.577	6.429
STAND ERR	0.333	3.712
CV (%)	2.249	96.437
95% BOUND	0.667	7.424
90% BOUND	0.533	5.939

LINEAR REGRESSION COEFFICIENTS

START HERE Regression Output:	
Constant (INTERCEPT)	ERR
Std Err of Y Est	ERR
R Squared	ERR
No. of Observations	ERR
Degrees of Freedom	ERR
X Coefficient(s)	ERR (SLOPE)
Std Err of Coef.	ERR

RATIO ESTIMATION PROCEDURE

		Fledglings/ Nest Start
SUM(DEVIATION SQUARED)	Sum((Y-rX)^2) =	80.287
OVERALL RATIO	R = Sum(Y)/Sum(X) =	0.26
VARIANCE OF RATIO	Var(R) =	0.02031

			Limits Low	High
95% BOUND ON RATIO	= 4.303*Sqrt(Var(r))=	0.6133	-0.3535	0.8730
90% BOUND ON RATIO	= 2.920*Sqrt(Var(r))=	0.4162	-0.1564	0.6759

Column 1	2	3	4	5	6	7
Obs. i	Nest Started X	Fledged Y	Fledglings/ Nest Start r = Y/X	Deviation From Exp. Y-rX	Deviation Squared (Y-rX)^2	Predict Y from X Y'=RX
P03N01	26	14	0.54	7.2468	52.5154	6.7532
P09N02/N01	25	2	0.08	-4.4935	20.1916	6.4935
P12N01	26	4	0.15	-2.7532	7.5804	6.7532

RATIO ESTIMATION LOTUS SPREADSHEET
Developed by Bruce Ackerman and Oz Garton, November 1987
Dept. Fish and Wildlife Resources
University of Idaho
Moscow ID 83843

Seabird Productivity - 1990
Semidi Islands - Black-legged Kittiwake
NUMBER OF OBSERVATIONS (PLOTS) n = 7

UNIVARIATE STATISTICS	Nest w/Eggs X	Fledged Y
TOTAL	131	1
MEAN	18.714	0.143
STAND DEV	11.041	0.378
STAND ERR	4.173	0.143
CV (%)	58.998	264.575
95% BOUND	8.346	0.286
90% BOUND	6.677	0.229

LINEAR REGRESSION COEFFICIENTS

START HERE Regression Output:	
Constant (INTERCEPT)	ERR
Std Err of Y Est	ERR
R Squared	ERR
No. of Observations	ERR
Degrees of Freedom	ERR
X Coefficient(s)	ERR (SLOPE)
Std Err of Coef.	ERR

RATIO ESTIMATION PROCEDURE

		Fledglings/ Nest w/Eggs		
SUM(DEVIATION SQUARED)	Sum((Y-rX)^2) =	0.972		
OVERALL RATIO	R = Sum(Y)/Sum(X) =	0.008		
VARIANCE OF RATIO	Var(R) =	0.00007		
		Limits	Low	High
95% BOUND ON RATIO	= 2.447*Sqrt(Var(r))=	0.0199	-0.0123	0.0275
90% BOUND ON RATIO	= 1.943*Sqrt(Var(r))=	0.0158	-0.0082	0.0234

Column 1	2	3	4	5	6	7
Obs.	Nest w/Eggs	Fledged	Fledglings/ Nest w/Eggs	Deviation From Exp.	Deviation Squared	Predict Y from X
i	X	Y	r = Y/X	Y-rX	(Y-rX)^2	Y'=RX
P03B1/3/4	14	1	0.07	0.8931	0.7977	0.1069
P03B02	24	0	0.00	-0.1832	0.0336	0.1832
P03B05/B06	22	0	0.00	-0.1679	0.0282	0.1679
P09B01	9	0	0.00	-0.0687	0.0047	0.0687
P10B01	6	0	0.00	-0.0458	0.0021	0.0458
P10B02	17	0	0.00	-0.1298	0.0168	0.1298
P11B01	39	0	0.00	-0.2977	0.0886	0.2977

RATIO ESTIMATION LOTUS SPREADSHEET
Developed by Bruce Ackerman and Oz Garton, November 1987
Dept. Fish and Wildlife Resources
University of Idaho
Moscow ID 83843

Seabird Productivity - 1990
Semidi Islands - Common Murre
NUMBER OF OBSERVATIONS (PLOTS) n = 7

UNIVARIATE STATISTICS

	Nest Started X	Fledged Y
TOTAL	213	115
MEAN	30.429	16.429
STAND DEV	7.871	3.952
STAND ERR	2.975	1.494
CV (%)	25.867	24.056
95% BOUND	5.950	2.988
90% BOUND	4.760	2.390

LINEAR REGRESSION COEFFICIENTS

START HERE Regression Output:

Constant (INTERCEPT)	ERR
Std Err of Y Est	ERR
R Squared	ERR
No. of Observations	ERR
Degrees of Freedom	ERR
X Coefficient(s)	ERR (SLOPE)
Std Err of Coef.	ERR

RATIO ESTIMATION PROCEDURE

		Fledglings/ Nest Start
SUM(DEVIATION SQUARED)	Sum((Y-rX)^2) =	68.480
OVERALL RATIO	R = Sum(Y)/Sum(X) =	0.54
VARIANCE OF RATIO	Var(R) =	0.00176

		Limits Low	High
95% BOUND ON RATIO = 2.447*Sqrt(Var(r))=	0.1027	0.4372	0.6426
90% BOUND ON RATIO = 1.943*Sqrt(Var(r))=	0.0815	0.4584	0.6214

Column 1	2	3	4	5	6	7
Obs.	Nest Started	Fledged	Fledglings/ Nest Start	Deviation From Exp.	Deviation Squared	Predict Y from X
i	X	Y	r = Y/X	Y-rX	(Y-rX)^2	Y'=RX
P03M01	25	15	0.60	1.5023	2.2570	13.4977
P03M03/M04	27	17	0.63	2.4225	5.8687	14.5775
P03M5/7/10	25	15	0.60	1.5023	2.2570	13.4977
P03M6/8/9	26	15	0.58	0.9624	0.9263	14.0376
P03M11-M15	45	25	0.56	0.7042	0.4959	24.2958
P09M01/M04	38	13	0.34	-7.5164	56.4967	20.5164
P09M02/M03	27	15	0.56	0.4225	0.1785	14.5775

RATIO ESTIMATION LOTUS SPREADSHEET

Developed by Bruce Ackerman and Oz Garton, November 1987
Dept. Fish and Wildlife Resources
University of Idaho
Moscow ID 83843

Seabird Productivity - 1990
Semidi Islands - Thick-billed Murre
NUMBER OF OBSERVATIONS (PLOTS) n = 4

UNIVARIATE STATISTICS

	Nest Started X	Fledged Y
TOTAL	134	56
MEAN	33.500	14.000
STAND DEV	8.426	3.162
STAND ERR	4.213	1.581
CV (%)	25.153	22.588
95% BOUND	8.426	3.162
90% BOUND	6.741	2.530

LINEAR REGRESSION COEFFICIENTS

START HERE Regression Output:

Constant (INTERCEPT)		ERR
Std Err of Y Est		ERR
R Squared		ERR
No. of Observations		ERR
Degrees of Freedom		ERR
X Coefficient(s)	ERR (SLOPE)	
Std Err of Coef.	ERR	

RATIO ESTIMATION PROCEDURE

		Fledglings/ Nest Start
SUM(DEVIATION SQUARED)	Sum((Y-rX)^2) =	20.394
OVERALL RATIO	R = Sum(Y)/Sum(X) =	0.42
VARIANCE OF RATIO	Var(R) =	0.00151

		Limits	Low	High
95% BOUND ON RATIO	= 3.182*Sqrt(Var(r))=	0.1238	0.2941	0.5417
90% BOUND ON RATIO	= 2.353*Sqrt(Var(r))=	0.0916	0.3263	0.5095

Column 1	2	3	4	5	6	7
Obs.	Nest Started	Fledged	Fledglings/ Nest Start	Deviation From Exp.	Deviation Squared	Predict Y from X
i	X	Y	r = Y/X	Y-rX	(Y-rX)^2	Y'=RX
P03M01-M10	46	17	0.37	-2.2239	4.9456	19.2239
P03M11	28	13	0.46	1.2985	1.6861	11.7015
P03M12-M15	29	10	0.34	-2.1194	4.4919	12.1194
P09M01-M04	31	16	0.52	3.0448	9.2707	12.9552

APPENDIX C

Summary of seabird population counts at plots in 1990 at Chowiet Island, Alaska.

Table C1 . Summary of northern fulmar population counts at plots in 1990 at Chowiet Island, Alaska.

Plot #	Replicate Counts 1	2	3	4	5	6	7	8	9	10	11
A03N01	127	130	79	91	118	122	91	114	120	111	92
A04N01	29	26	18	18	27	24	16	27	29	37	12
A07N01	143	144	65	75	179	116	88	197	189	219	146
A10N01	39	44	29	38	51	39	41	53	46	52	36
A10N02	32	29	20	29	36	32	21	32	38	48	27
A12N01	58	47	48	61	65	59	50	54	84	68	60
A12N02	33	30	29	52	54	36	22	31	54	55	34
	==	==	==	==	==	==	==	==	==	==	==
Total	461	450	288	364	530	428	329	508	560	590	407

Table C2 . Summary of black-legged kittiwake population counts[a] at plots in 1990 at Chowiet Island, Alaska.

	Replicate Numbers											
Plot #	1	2	3	4	5	6[b]	7	8	9	10	11	12
A02B01	36	39	31	37	33	24(20)	28	21	21	29	24	18
A02B02	114	129	107	105	93	84(61)	96	84	45	97	67	70
A03B01	50	46	37	49	35	26(32)	38	22	24	32	22	29
A03B02	36	41	29	41	31	20(27)	34	28	19	39	28	31
A03B03	9	13	3	5	7	5(7)	6	6	3	11	2	3
A06B01	50	46	42	48	29	38(34)	33	27	26	44	30	31
A06B02	43	43	37	39	38	26(25)	21	19	11	28	17	25
A09B01	43	40	39	39	32	17(24)	22	22	27	28	32	18
A09B02	89	96	81	90	67	58(49)	63	55	48	61	58	46
	==	==	==	==	==	======	==	==	==	==	==	==
Total	470	493	406	453	365	298(279)	341	284	224	369	280	271

[a]We used only the first four replicate counts in our data analysis as the later counts showed significantly lower numbers (P=0.007). We feel that the lower attendance was due, in part, to a very poor year of productivity and therefore, is not a true indicator of the population at large.

[b]The numbers within the parentheses indicate nest counts that were taken during the sixth replicate count on 2 July 1990.

Table C3. Summary of common and thick-billed murre population counts at plots in 1990 at Chowiet Island, Alaska.

	Replicate Count									
Plot #	1	2	3	4	5	6	7	8	9	10
A03M01										
COMU	146	163	161	166	157	175	203	157	154	160
A03M02										
COMU	98	90	93	115	104	104	117	117	106	120
A03M03										
COMU	73	90	83	92	83	83	88	84	96	90
A03M04										
COMU	178	185	195	246	217	200	224	245	229	235
TBMU	31	31	30	38	30	33	40	37	37	38
A03M05										
COMU	29	43	45	51	45	46	46	41	42	43
TBMU	10	11	12	14	10	12	13	10	12	11
A06M01										
COMU	219	274	253	277	287	252	265	292	307	310
TBMU	3	0	4	1	0	0	0	0	3	2
A09M01										
COMU	62	59	69	93	76	63	60	72	62	67
A09M02										
COMU	492	568	575	577	545	559	620	540	589	585
TBMU	95	110	68	86	90	99	132	90	103	101
A10M01										
COMU	758	738	712	790	773	863	902	784	863	801
A10M02										
COMU	353	525	472	507	490	510	546	556	603	580
	===	===	===	===	===	===	===	===	===	===
Total	2547	2887	2772	3053	2907	2999	3256	3025	3206	3143