B3

Study Title: 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.

Study ID Number: Bird Study Number 3

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EXECUTIVE SUMMARY

The 1989 oil spill in Prince William Sound prompted resurvey of seabird colonies in Prince William Sound and other areas westward along the spill trajectory. Most of these colonies had been censused at least two and up to six different years out of the last 17 years prior to the oil spill. Murres and kittiwakes on one nearby colony site, Middleton Island, have been censused 14 of the last 18 years. Cliff-nesting species such as the black-legged kittiwake (Rissa tridactyla) and common and thick-billed murres (Uria aalge and lomvia) were the primary emphasis of the 1989-90 censuses. Timing of egg laying and productivity (numbers of fledging chicks) were also noted for these species. In 1990 and 1991 the major effort was placed on replicate counts of murres in those areas that showed the most drastic changes relative to historical data. Semidi Islands and Middleton Island monitoring continued as our main control sites for murres.

The preliminary evidence in 1989 suggested that kittiwakes and some other species when checked, cormorants (Phalacrocorax spp.) and parakeet auklets (Cyclorrhynchus psittacula), showed no significant changes in numbers of adults regardless of oil spill proximity. Numbers of murres, however, appeared to decline in 1989 from historical counts or estimates at the Alaska Peninsula sites (50-60 percent), the Barren Islands (60-70 percent), and the Triplet Islands near Kodiak Island (35 percent). No significant changes in murre numbers were noted in 1989 at the control areas, the Semidi Islands and Middleton Island. The dramatic decreases in murres seen in 1989 persisted in 1990 and 1991 (Triplets not censused in 1990 or 1991). The murre numbers on plots censused on the Semidi Islands eight years between 1977 and 1991 never varied more than 26 percent of the maximum seen and any decrease one year was recovered in subsequent years. A similar pattern was observed for murre numbers on Middleton Island. Since murres never laid eggs at the Chiswell Islands in 1989, it was not possible to do a comparable census that year; however, counts made in 1990 and 1991 either showed little change from or a rapid recovery to numbers seen there in 1976 or 1986.

Breeding success of murres during 1989-1991 was relatively good at the Semidi Islands (0.58 and 0.43 chicks in 1989; 0.54 and 0.42 chicks in 1990; 0.52 and 0.47 chicks in 1991 fledged per breeding pair for common and thick-billed murres respectively). Murres at all sites associated with oil had either low or no success in producing chicks with either very late egg laying (30-45 days delay) or none at all in the three post-spill years. These latter murre colonies lost a large degree of their synchrony of egg laying in the first two years, one of the key strategies that common murres use to accomplish successful reproduction. Breeding success of kittiwakes in 1989-91 was low at most sites. Future monitoring in the next few years will help evaluate the ongoing effects and the rate of recovery that occurs on these colonies.

OBJECTIVES

A. Determine whether the numbers of selected species of breeding colonial seabirds within the oiled area have decreased compared to numbers previously censused at these sites. Non-oiled nesting colonies will be surveyed as controls.

B. Compare reproductive chronology and productivity for murres (Uria aalge and lomvia) and kittiwakes (Rissa tridactyla) at colony sites within the oiled area with those found at nearby colonies in the Gulf of Alaska not affected directly by the oil spill.

The second objective was not listed in the study plans distributed for 1989 and 1990, although various reviewers have questioned its absence since no study appeared to be collecting this data on murres while similar data were collected for other species like kittiwakes and pigeon guillemots (Cepphus columba). Our initial thrust in 1989 was the effort to document changes or losses of adult seabirds. However, our field crews were often able to gather data on reproduction, especially at land-based plots, at the same time with little additional cost. They were directed to do this since numbers and productivity are the two basic components of the seabird monitoring strategy used by the U. S. Fish and Wildlife Service. It turns out that effects observed in differences of phenology and productivity are equally as striking as the change in numbers. It seemed desirable to formalize what we were doing by stating it in the objectives and methods stated in the 1991 study plan as well as modifying the title of this study to better reflect the full extent of work being done on murres. We added the last clause, "With Emphasis on Changes in Numbers and Reproduction of Murres", to the project title in last year's report.

INTRODUCTION

There are approximately 320 seabird colonies, not including the Semidi Islands, that occur within the area affected by the oil spill. They contained about 1,121,500 breeding seabirds of which 319,130 were murres (U.S. Fish and Wildlife, Catalog of Alaskan Seabird Colonies--Computer Archives 1986). The Semidi Islands contain an additional 1,133,00 murres of both species (USFWS computer archives 1986). Diving seabirds are known to be easily impacted by oil spills (King and Sanger, 1979). In addition, these species are long-lived with low reproductive rates, thus making any mortality of adults a critical factor in these species' ability to recover from loss. This study looked at changes in numbers of adults at the breeding colonies selected, compared productivity and phenology measured from land-based plots in the Semidi Islands with that recorded similarly at the Puale Bay colony the same years, and estimated productivity and phenology at the other colonies where land-based plots were not as feasible.

The 1989 studies revealed that murre numbers appeared to be quite different from those expected. In addition, an aberration in breeding behavior was observed on murre colonies in oiled areas. Egg laying was very late and asynchronous, thus essentially opening up the murre colony to predation and total loss of reproduction. It is believed that very few, if any at all, chicks were hatched and fewer still were fledged. This had the potential to be quite damaging to murre populations if it continued in subsequent years in terms of both total injury and the recovery time needed.

After the 1989 field season we were instructed by the management team to direct our 1990 efforts more towards murre populations at those sites that showed significant changes in numbers or effects on breeding behavior. Therefore assessment of injury during 1990-91 to murre populations was conducted primarily in the following geographic locations: 1)Chiswell Islands, 2)Barren Islands, 3)Puale Bay area (Alaska Peninsula), and 4)Semidi Islands (Figure 1). Although Middleton Island studies were not funded by our particular investigation, an ongoing study at that location provided numbers of murres present on those colonies for comparison with affected areas during 1989-91. Ugaiushak Island (located off the Alaska Peninsula between Nakalilok and Yantarni Bays; 56° 48', 156° 51') was visited for the first time during the 1990 season in hopes of finding another unoiled control area closer to the Alaska Peninsula. Ugaiushak Island murre colonies were carefully censused in 1976. However, there was some evidence of oiling around the beaches and the breeding phenology of the murres was disrupted similar to that of the other oiled areas of the project. We have also found reports of oil in the Aniakchak portion of the peninsula nearby. Hence, it appears that Ugaiushak murre colonies will not serve as another control, but they can indicate how murre numbers are changing (or not) along the Alaska Peninsula since the oil spill.

STUDY METHODOLOGY

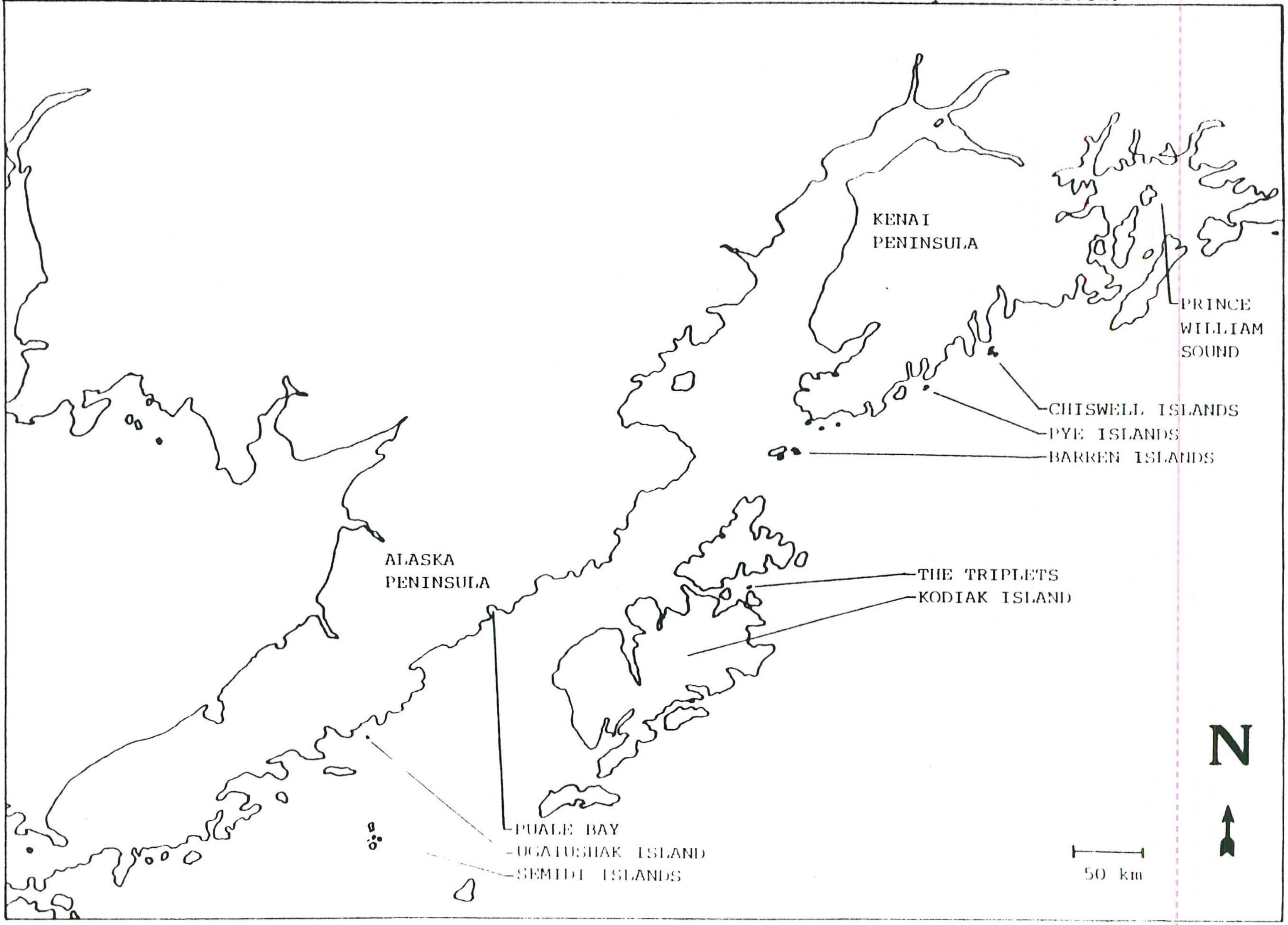
A. Sampling Methods

1. Population Counts

This study primarily looked at changes in numbers of breeding adult murres at the previously mentioned sites. In some areas there was a secondary emphasis on counts of other selected species such as black-legged kittiwakes, cormorants (Phalacrocorax spp.), and parakeet auklets (Cyclorrhynchus psittacula) if weather, logistics, timing, and geography allowed. Total coverage of large colonies like the Semidi and Barren Islands was not feasible. Hence plots and sometimes total counts of subcolonies were selected to provide an index to change.

Consequently, two survey strategies were used: 1)counts of adult seabirds on plots from land-based observation points; 2)counts from

Figure 1. Map of southcentral Alaska and Alaska Peninsula coastline with study areas labeled.



boats where land-based observations were not possible. In this latter case, boat counts provided the only comparison with prior data. When boat surveys of entire large islands were made, cliffs were subdivided into definable segments for data recording. Some of these segments were selected as plots for replicate counts on five to seven different days as a goal. These plots were set up for the first time at Puale Bay, Nord Island and East Amatuli Light in the Barren Islands. However, total counts of small islands (Chiswell Islands), certain subcolonies (Nord Island), and entire colonies (Puale Bay area) were still necessary for comparison with the data collected previously at these sites. The smaller colonies associated with islands in the Chiswells were counted at least five times each while the other larger total counts were replicated one to two times. Aerial photography was not applicable because murres colonies were highly asynchronous in egg laying and would not stay on the colony. The application of these two strategies in 1990-91 took the following form at the four primary sites:

1) The Chiswell Islands murre surveys were total counts conducted from boat for each smaller island. These counts separated out murres that were on the water from those on the cliffs which prior counts did not. Kittiwake nests and birds were counted at selected plots that had been set up in previous years.

2) The Barren Islands murre surveys were a combination of total counts of certain subcolonies like Nord Island and the more frequent replicate counts of smaller sample plots. Sample plots were subjectively chosen on the basis of accessibility and visibility. A few land-based plots were established for murres that could be visited and counted occasionally when sea condtions permitted. Time lapse cameras were used on some of these. Kittiwakes were censused only by plots.

3) The Alaska Peninsula murre colonies required a combination of new land-based plots and total counts from boats for historical comparison since some portions of the colonies were visible from land, but others required boat counts.

4) Land-based plots were continued at the Semidi Islands because these colonies are too large for total coverage, and land plots are feasible and have been used for eight of the last fifteen years. Sample plots were previously selected on the basis of accessibility.

Colonies were recensused using the standard Service methodology for land-based or boat-based counts of seabirds (Byrd 1989; Hatch and Hatch 1988 and 1989; Irons et al. 1987; Nishimoto and Rice 1987). The replicate counts of colonies or plots are conducted between 1000 and 1800 hours after eggs are laid and before chicks fledged. These replicate counts must occur on separate days. Some plots were counted simultaneously while photographs (using 6x7 cm format cameras) were taken which would help establish correction factors of photo interpretation if judged desirable at some future date. Survey units were subcolonies or plots for cliff nesters and islands for other species.

For best results during boat censuses, seas must be less than three feet and rain should not be more than a light drizzle. At least three and sometimes five observers including skiff operator made the counts by binoculars from an anchored boat, the largest one suitable for the particular situation and ideally no smaller than a 25 foot boat. Each observer counts each section of the cliff at least two times and all counts are compared to see if sections of the plot were missed and needed more replicate counts. This is determined when the counts fall within 10 percent of each other.

2. Phenology and Productivity

Nesting phenology and reproductive performance on land-based plots were determined by viewing nests at regular intervals of approximately three days. Nest sites were numbered on plot photographs and drawings and then were checked throughout the field season. Attendance of adults, nest starts, and the presence or absence of eggs or chicks were recorded for kittiwakes and fulmars while the presence of egg or chick was the prime observation on murres. For murres, it was frequently not possible to see the contents of a site because the birds remained motionless for long periods of time. We used distinctive behavior (e.g. wings held over the back so that tips did not cross, tail down, back slightly humped) to indicate that a murre was incubating an egg. Because it is possible to misinterpret such posture, we used the convention that a site had to have a bird in "incubating posture" on at least three consecutive checks to consider the site as having an egg. Wing mantling was used to indicate that a murre had a chick. However, only one sighting of wing mantling was necessary to consider a murre to have a chick or to be in a "brooding posture". The conventions of murre monitoring (Mendenhall 1991) as used by the Alaska Maritime National Wildlife Refuge were used to resolve any questions of interpretation.

At the locations where murre colonies could only be observed from boats, phenology was determined by anecdotal evidence (predators picking up eggs) or indirectly by the change in degree of murre attendance at the cliffs since murre attendance is highly variable before egg laying and becomes more consistent after that. Some portions of the rugged islands were climbed occasionally whenever sea conditions permitted a landing and portions of murre colonies were scanned for eggs or chicks. Productivity was evaluated by observing number of chicks present on plots or subcolonies near fledging times and comparing this with mean number of adults seen on that plot.

B. Data Analysis

The standard procedures and assumptions used by the U. S. Fish and Wildlife Service on colonies in the Alaska Maritime National Wildlife Refuge are described by Garton 1988 and Byrd 1989. We will not reiterate all of these, but we mention several key assumptions: 1)Plots, by necessity, are not random and selection is based on accessibility; hence this study makes the assumption that plots are representative. 2)Plot counts are indices and even counts of entire colonies are also considered a form of indices, but this study assumes that changes in these indices represent the changes occurring in the colony. 3)Counts of things are very unlikely to be normally distributed and are more likely to be skewed and clumped. This type of data requires either very large sample sizes, or the use of a non-parametric test, or the data needs to be transformed logarithmically and then tested by the appropriate parametric test. This transformation normalizes the data and is required for valid application of parametric statistical tests on small sample sizes (Fowler and Cohen 1986, D. Robson pers. comm.).

The standard Service procedures compare trends over time using numerous replicate counts where all plots are censused each count day and these counts are replicated on successive days. The average of daily counts on the Semidi Islands was used to calculate a confidence interval for the estimate as was done on the Semidi Islands data in the past (Hatch and Hatch 1988; Hatch and Hatch 1989). Within year replication is useful to test for annual variation, but annual variation is anticipated even without the influence of a factor such as an oil spill. Hence the important question is whether the 1989 response is outside the anticipated annual variation in colony numbers that would be expected from past historical data without oiling effects.

For 1989 data a one-tailed t-test was performed on logarithmically transformed data in an outlier test to test the hypothesis that the 89 index value is a single random sample from the same population as that which is sampled by the historical yearly index values. Since the Semidis were considered a control area, its population counts were tested using a two-tailed t-test to test for population trends in either direction. It was not possible to test pre-oiling data with post-oiling data for the Barren Island colonies because of limited historical data sets. However, ratios of change could be calculated for Barren Island subcolonies (Nord Island and East Amatuli Light) between 1979 and 1989 and for the control area, the Semidi Island plots, between 1979 and 1989. These ratios of change were then tested by Dr. Robson with a t-test on logarithmically transformed data.

For 1990 data, a slightly different approach than 1989 was used for comparison since there were two years of post-oil spill data. Data from all sites were treated by Dr. Bowden with the SAS t-test procedure which automatically treated the data with two different types of t-tests depending upon the data. The data was transformed by natural logarithms. Since we did not have more than one pre-oil spill count for the Barrens, Robson provided an analysis of variance for the comparison of ratios of change over a span of years in murre numbers for the Barren and Semidi Islands (1979 and 1989-90). This is following up on the ratio test used last year and provided a two-degree of freedom t-test (t=square root of F).

The 1991 data will be tested in a similar fashion at most sites as in 1990. The Barren Islands data will be tested as advice is received from expert statisticians.

STUDY RESULTS AND DISCUSSION

Evidence of Injury Found

The number of murres present at colonies as well as the phenology and productivity of these murres have been found in 1990 and 1991 to continue being significantly different between the control sites and those sites associated with the oil spill. In general, the latter sites usually had significantly lower numbers present, an unusual phenology of asynchronous egg laying with eggs being laid 30-45 days late, and a very low level of productivity. This asynchronous egg laying meant that the few murres that had eggs were not able to defend against predators because all the murres without eggs would fly from the cliffs thereby opening large holes for predators to converge upon the few isolated incubating birds. These birds would in turn panic and fly when a predator approached, thereby losing the egg. What this means in losses is that the known minimum loss of 119,000 to 137,000 murres usually counted at the colonies is only part of the probable effects associated with the oil spill. The loss of productivity of murres at these same colonies 1989-90 translates into over 215,000 murre chicks that did not fledge (107,773 per year) that normally should have, if we use the level of productivity and the ratio of eggs or active breeding sites to numbers of murres observed at the Semidi Islands those same two years. At the same time, neither kittiwake numbers nor their nesting attempts have declined at these same colony sites. We will look at each site in particular from east to west and examine the murre data more specifically, also including some data on kittiwake numbers and productivity at each site as a comparison.

Middleton Island

Although this island was closest to the origin of the oil spill, the oil slick passed it by to the north and west. There was no obvious oiling of the beaches observed on Middleton Island April 5-16, 1989 (Fadely, pers. comm.). Hence this island's small murre colony serves as an additional control. The fact that the colony is small, located far out on the continental shelf edge, and associated with an exponentially growing gull colony which is colonizing earthquake uplifted areas might limit some of its usefulness as a control, but it is the second best data set for murres in the Gulf of Alaska after the Semidi Islands. A large historical database exists in the form of one-time only counts for this island (Nysewander et al. 1986). In 1987, nine Type II or replicate census plots, similar to the replicate count plots on the Semidi Islands, were established for monitoring murre attendance. The one-time only counts do not account for daily variation in colony attendance. Nevertheless, a two-tailed t-test indicated no significant difference was found between 1989-91 and previous years (Table 1). The results of statistical testing for the replicate census plots (1987-91) can be seen in Table 2. These data suggest a significant decline (16%) occurred between 1987 and 1988, with essentially no difference between murre counts in 1988 and 1989. This supports the hypothesis that, if a colony area was not oiled, there was no significant drop in murre attendance at that colony in 1989. However there was a decline on plots from 1989 to 1990. Most egg loss occurred in the first week of laying, caused by gull predation. In light of the somewhat erratic attendance behavior and probable poor nesting success seen in 1990, the decline of numbers in the whole island census and in the replicate count plots may not be actual population declines as there have been temporary downturns any one year before and a recovery the next (Fadely and Hatch, pers. comm.). This hypothesis was supported in 1991 when murre attendance returned to the 1988-89 level in the type II counts as well as the total island counts.

No attempts were made to quantify either reproductive success or breeding phenology on Middleton Island in 1989, 1990, or 1991. In 1989 murre eggs were present on June 24, eggs and chicks were present on most plots, and chicks began fledging the last week of July (Fadely, pers. comm.). This suggested that phenology was normal. In 1990 some murres were incubating by June 14 when they were first checked. Fadely left the island by August 8 and fledging success was not known, but it was suspected to be lower in 1990 than in 1989 (Fadely and Hatch, pers. comm.). Anecdotal observations in 1991 suggested that murre phenology was similarly timed as previously with an abundance of murre fledglings or "jumplings" later in the summer in the ponds below the cliffs suggesting that murres had generally better reproductive success in 1991 (Hatch and Fadely pers comm.).

Kenai Peninsula (Chiswell Islands)

1. Murres

Murre colonies along this coast have contained 28,850 breeding birds in the past, primarily located in the Chiswell Islands and the Cape Resurrection area (USFWS computer archives 1986). Murre colonies have not been censused with replicate counts during any one breeding season here in the past, but one time counts were conducted in 1976 and 1986 (Bailey 1977, Nishimoto and Rice 1987).

Table 1. Murre counts[a] for Middleton Island, Alaska, between 1974 and 1991.

Year	Plot Designation 1 & 10	2	3	4	5	6 & 7	8	9	Totals
1974	-	-	-	-	-	-	-	-	5,770[b]
1976	1,149	4,333	149	0	0	0	220	0	5,851
1978	2,798	3,370	275	0	0	0	360	0	6,803
1981	2,573	2,609	162	0	0	0	177	0	5,521
1982	2,433	3,332	235	0	0	0	161	0	6,161
1983	1,834	2,335	241	0	0	0	219	0	4,629
1984	2,505	2,973	259	0	0	0	96	0	5,832
1985	694	2,877	122	0	0	0	158	0	3,851
1986	2,693	4,584	147	0	1	0	170	0	7,595
1987	2,696	4,732	215	5	0	0	66	0	7,714
1988	2,488	5,103	230	0	0	0	78	0	7,899
1989	2,500	3,138	117	0	0	0	91	0	5,846
1990	2,480	1,771	174	0	0	0	6	0	4,431
1991	2,881	2,417	86	0	6	0	10	0	5,400

Calculated t = 1.0866; Table $t_{0.10(2),12}$ = 1.782; P = 0.32[c]

[a] These are one-time only counts

[b] This number derived by estimating number of pairs then multiplying by 2. Census not taken.

[c] The statistical testing is comparing means of 1989-91 data with that of all previous years.

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Table 2. Murre counts from Type II plots, Middleton Island, Alaska 1987-1991[a].

	1987[b]	1988	1989	1990	1991
Total Birds[c]	932.0	786.0	747.0	598.0	705.0
Standard Deviation	35.5	57.4	54.3	31.7	25.8
Standard Error	11.8	19.1	18.1	10.6	8.6
n (counts)[d]	9.0	9.0	9.0	9.0	9.0

[a] These data tested by and obtained from B. Fadely and S. Hatch, pers. comm.

[b] 1987 counts significantly different than in 1988 (t_s = 6.518; $P < 0.001$); no significant difference between murre counts in 1988 and 1989 (t_s = 1.480; $P > 0.05$); 1990 murre counts were significantly different than in 1989 (t_s = 7.271; $P < 0.001$); 1991 attendance was significantly different than in 1990 (t_s = -7.854; $P < 0.001$).

[c] Sum of mean counts on 9 census plots.

[d] Counts completed July 2-28, 1987; June 20 - July 8, 1988; June 24 - July 13, 1989; June 9-30, 1990; and June 13-17, 1991.

Both species of murres (common and thick-billed) breed in the Chiswell Islands as they do at the other sites studied, but are lumped together for convenience, both in censusing and reports on each of our study sites. In 1991 the species composition of murres was checked at four of the six islands and thick-billed murres overall composed 20 percent of the 816 murres checked, which is higher than the 10-15 percent found at the other sites. Most of the colonies in the Chiswells contained 96-100 percent common murres, but one site, Beehive "B", contained a ratio of 63 percent of thick-billed to common murres.

The murre colonies in this area in 1989 never settled down and laid eggs, with the exception of a few birds on the top of Barwell Island. Egg laying is the accepted time to census murres since their colony attendance is too variable at other times; hence it was never feasible to census murres in 1989. In 1990, the Chiswell Islands were picked as the only murre colonies to be surveyed in a replicate fashion along the Kenai coast. The phenology was delayed again in 1990 and the murres had not started laying with any sort of synchrony during our census period. Yet the colonies were small individually and when murres would fly from the cliffs they would often end up on the water nearby. The census effort completed five to seven replicate counts of each subcolony or island in 1990 and 1991, counting murres on cliffs and water. We kept the land and water counts of murres separated unlike prior surveys conducted here. The data in Table 3 is a sum of the total (land and water) murres counted for each island so as to be comparable with pre-oil spill data. The data in Table 4 summarizes the murre counts of only those murres present on the colony rocks in 1990-91, which is a more accurate reflection of the breeding activity on the colony and is more consistent with the standard monitoring procedures used with murres at the other sites in this study.

The combined counts of murres on land and water near the colony sites (Table 3) suggest that the murres either showed little change from prior levels or made a rapid recovery from any losses caused by the oil spill. However, when you examine the counts of murres found only on the colonies in 1990 and 1991 (Table 4), the counts appear to suggest that the colony was recovering in 1991 as murre numbers increased from 2,436 to 2,913. Several different factors may be in effect here:

1) one-time only counts in the past misrepresented the existing population at that time;
2) counts of murres during pre-egg laying (such as in 1990) will be much more variable and not helpful for comparisons;
3) the Chiswell Islands murre colonies were more on the edge of the oil spill, as opposed to being surrounded and washed with large tidal interchanges like the Barren Islands sites, and may have lost a much smaller percentage of their adults, thus enabling recruitment to overcome a lesser loss much as documented by Stowe (1982).

Table 3. Murre population counts on colonies and nearby waters in 1976, 1986[a], 1990 and 1991 for the Chiswell Islands, Alaska.

Island Name	Year 1976	1986	1990[b]	1991[b]
Matushka	3,040	1,135	1,206	1,057
Beehive	400	112	294	126
Beehive "B"	150	385	666	550
Chiswell	520	239	1,383	480
Chiswell "B"	280	1,297[c]	402	320
Natoa	1,640	219	420	605
Totals	6,030	3,387	4,371	3,138

Calculated $t = 0.599$; Table $t_{0.10(1),2} = 1.886$; $P > 0.25$

[a] 1976 and 1986 data from Bailey 1977 and Nishimoto and Rice, 1987.

[b] Both 1990 and 1991 counts are water and land counts combined.

[c] This count included a large raft of murres between Chiswell and Chiswell "B" that probably belonged to Chiswell Island.

Table 4. Murre population counts[a] for colony sites only for 1990 and 1991 at the Chiswell Islands.

	1990								
Island Name	6/23	6/24	6/25	6/26	6/27	6/28	6/29	6/30	MEANS
Natoa	358.0	N.C.	388.2	273.5	371.8	444.3	456.3	450.8	391.8
Matushka	N.C.	852.3	982.7	1067.8	706.0	379.5	434.5	N.C.	737.1
Chiswell	N.C.	233.5	N.C.	438.8	74.3[b]	379.8	113.5	135.8	260.3
Chiswell "B"	N.C.	82.0[b]	N.C.	254.3	157.8	304.8	525.3	407.5	329.9
Beehive	116.0	N.C.	254.6	10.0[b]	135.1	210.4	290.4	134.3	190.1
Beehive "B"	501.5	98.7[b]	260.6	0.0[b]	552.4	623.2	697.6	N.C.	527.1
								1990 Total	2,436.3

	1991						
Island Name	6/26	6/28	6/29	6/30	7/1	7/2	MEANS
Natoa	514.9	328.1	615.6	656.8	N.C.	582.5	539.6
Matushka	917.8	985.2	1162.7	1007.9	N.C.	1144.8	1043.7
Chiswell	191.4	196.3	N.C.	601.8	631.4	358.4	395.9
Chiswell "B"	453.8	349.2	243.4	271.1	N.C.	283.6	320.2
Beehive	71.3	73.0	87.3	143.5	N.C.	92.6	93.5
Beehive "B"	591.8	435.3	554.6	582.1	N.C.	439.1	520.6
						1991 Total	2,913.4

[a] These counts do not include estimates of murres on nearby waters at the time of the colony count. Daily counts are means of four to ten replicate counts done by three to five observers.

[b] These counts were not used in the mean calculation in order to obtain a more representative estimate of actual attendance.

Since counts were not possible in 1989, the picture is somewhat unclear as to what exactly has happened. Our present conclusion is that this is the one oil spill related murre colony where no decrease of murres is known. The best option will be to monitor these colonies in the future and see if the increase of murre numbers counted on colonies in 1991 continues or begins to level out. Then some conclusions will be easier to make concerning past injury and recovery rates at this colony site.

The delayed phenology and egg laying was very similar to that of the other oil spill related murre colonies in 1989-90. We were not able to return to this colony later in either of these years and hence have no estimate of productivity. The murre phenology observed in 1991 rebounded back to a more normal timing as eggs were seen late June and early July. Murres were staying more consistently on four of the five colony sites. The one exception, Chiswell Island, showed the large variability of murre attendance seen the two previous years (Table 4). Once again we were not able to return to any of these sites later in the summer and hence have no estimate of productivity for 1991.

2. Kittiwakes

The 1989 censuses in the Chiswells found no significant change compared to prior years (P=0.24) in numbers of breeding kittiwakes on the five islands that were censused (Table 5). In contrast with the murres, the kittiwakes laid eggs and had a production of chicks (0.53 chicks/nest attempt, n=675 nests on 8 islands) which was above the recent average (since 1980) for the western Gulf of Alaska (Hatch et al. in press). This contrast in reproductive performance of kittiwakes and murres in the Chiswells suggests murres may have been affected by the oil spill. Normally murres (diving birds which feed at all depths) will usually be successful whenever kittiwakes (surface feeders) are and sometimes successful when kittiwakes are not. In 1990 our surveys did not census the total number of kittiwakes again, but they did gather numbers of kittiwakes and nest attempts on the eight plots set up here in 1989 (Table 6). There was no decrease, but rather an increase in nesting effort in 1990. In 1991 the nesting effort was lower than that seen in 1990 on the same eight plots (Table 6), but it was still higher than that recorded in 1989. None of these plots were revisited later in the summer in either 1990 or 1991 and hence no estimate of production is available.

Barren Islands

1. Murres

Both species of murres (common and thick-billed) breed in the Barren Islands. Past estimates have stated that murre colony numbers contain 15 percent thick-billed murres. In total, the Barren Islands historically contained 129,500 breeding murres,

Table 5. Numbers of black-legged kittiwakes at certain colonies in or near the Chiswell Islands for 1976, 1986 and 1989.[a]

Island Name	1976	1986	1989
Barwell Island	2980	4410	2800
Twin Islands	40	22	2
Natoa Island	370	472	310
Matushka Island	1480	2062	920
Chiswell "B" Island	560	617	555
Totals	5430	7583	4587
Calculated t		-1.157	
Table $t_{0.10(1),1}$		3.078	
Calculated P		0.24	

[a] Total island counts of this species were not done in 199-91.

Table 6. Numbers of kittiwakes and nests on eight plots at the Chiswell Islands, 1989, 1990 and 1991.

Island Name/	Birds/Nests					
	1989[a]			1990		1991
Plot Label	7/3	7/4	8/3	6/23	6/24	6/23
Beehive "B"			92/52	105/61		64/47
Matushka	32/22				58/39	55/37
Beehive/ A	78/72		161/67[b]	118/78		88/66
B	37/34			36/27		28/22
C			91/47[b]	81/64		70/64
D		160/81		215/162		192/161
Chiswell/A	164/106			105/96		87/67
B	202/90			181/128		127/100
TOTAL Birds/Nests		939/499		899/655		711/564

[a] These 1989 counts were done from photos taken at those locations and probably underestimate the numbers of birds and nests.

[b] Chick counts for Beehive A were 45 and for Beehive C were 24.

primarily at Nord and East Amatuli Islands (USFWS computer archives 1986). Although various surveys and studies were conducted in the Barren Islands between 1975 and 1979 (Bailey 1976, Manuwal et al. 1980), they were either general one-time estimates or studies concentrating more on other species. Nevertheless, there were recurring observations and estimates of portions of the murre colonies over this five year period and the general consensus was that of a stable breeding population near 130,000 (Table 7).

1a. Murre Counts

In 1989 the murres did not lay eggs until late July which is a month late. When they did lay, staying on the cliffs so that they could be censused, the numbers were greatly reduced from the historical levels reported. Thirteen plots (eleven on Nord, one on E. Amatuli Light and one on E. Amatuli Main Island) were established in 1989 that contained 3,283 birds (Appendix A) at the beginning of incubation (July 26-28), but as there were no historical population plots it was necessary to also do total counts to compare with the past estimates. On Nord Island where 30,000 murres had been estimated in 1975 and 1979, we averaged 12,381 (July 26) and 11,294 (August 12) with the mean attendance being 11,838 during incubation (Table 7). On the East Amatuli "Light" colony where 20,000 murres were the usual past estimate, we averaged 7,410 (July 27) and 6,413 (August 13) with mean attendance being 6,912 (Table 7). It was highly unlikely, due to the very late egg laying, that any chicks fledged in 1989 before the fall storms.

Murre egg laying in 1990 was delayed and asynchronous again in the Barrens. Censusing occurred on July 12-20 and again on August 13-19. The thirteen plots that were established in 1989 contained 4,971 (mean throughout census period) in 1990 (Appendix B). The total count on Nord Island averaged 11,713 (August 14)and 12,842 (August 18) with mean attendance being 12,277 during incubation (Table 7). On E. Amatuli Light we averaged 5,430 (August 15) and 6,300 (August 19) with mean attendance being 5,865 during incubation (Table 7). The plot count totals contained a larger percent increase than that seen on the total counts of subcolonies when compared with those seen in 1989. This suggests that some plots may reflect better than others the changes that occur on the total colony or subcolony. One remedy was to establish more plots in future years creating a larger sample size. Since egg laying was still not synchronized very well, some of the difference in the 1989 to 1990 plot numbers could be due to the variable attendance known to occur during the pre-egg laying stage usually seen at murre colonies (Hatch and Hatch, 1989). Because of such a late phenology seen again this year, it is believed that no murre chicks were fledged. There were no eggs or chicks present on land-based plots that we examined on Nord Island August 18.

Table 7. Number of murres counted at the Barren Island colonies, Alaska: 1975, 1977-79, 1989-1991.

Island Name	1975	1977	1978	1979	1989	1990	1991
Nord Island	30,000	-	-	30,000	11,838[a]	12,277[a]	13,333[a]
Ushagat Island	0	-	-	-	-	-	-
E. Amatuli Island	61,000	-	50,000	99,500	-	-	-
(E. Amatuli Light)[b]	-	(10,000)[c]	(20,000)	(20,000)	6,912[a]	5,865[a]	5,529[d]
W. Amatuli Island	10	-	-	-	-	-	-
Sud Island	0	-	-	-	-	-	-
Sugarloaf Island	0	-	-	-	-	-	-
Carl Island	0	-	-	-	-	-	-
Totals	91,000			129,500			

[a] These numbers are the means of two different daily counts.

[b] These numbers are included in the E. Amatuli Island count (i.e. in 1979, the 20,000 is part of the 99,500).

[c] This count is believed to be a rough estimate and was not used in analysis.

[d] This count includes 2100 murres on nearby waters, it is also a one-time only count.

In 1991 there were small segments of the murre colonies that attempted to return to earlier egg laying phenologies such as the top of East Amatuli Light and some high sections of Nord Island. Most of the remaining portions of the murre colonies displayed the same delayed egg laying seen in previous years. The murre colonies were examined during July 10-18, but most murre counts took place August 17-25 because of the delayed egg laying. Five new plots were added to the thirteen used for 5-7 replicates in 1989-90. The thirteen plots used in previous years contained 4,592 murres (mean throughout census period) in 1991 while the eighteen plots in total contained a mean of 7,354 (Appendix C). The 1991 total count on Nord Island averaged 13,404 (August 17) and 13,262 (August 22) with mean attendance being 13,333 during incubation (Table 7). The counts of the East Amatuli Light murres averaged 1,380 (July 14), 1,513 (July 15), and 3,429 (July 17) with an additional 2,100 murres sitting on water in close proximity on July 17. Egg laying was just beginning at this time at least on the island top, as documented on land and by the gradually increasing number of murres remaining on the cliffs. At this time we also discovered that the East Amatuli Light murre colony was being landed upon by the Exxon funded studies in this area. They did not coordinate these landings with our studies nor did they know of our plot locations. This all raised valid concerns of ours about undocumented levels of disturbance at this site at least on our plots. When our census crews returned in August, the total estimates of the East Amatuli Light colony were not repeated because there were not enough days with suitable sea conditions to get the total counts done on both Nord and East Amatuli Light sites.

The conclusion in 1989 was that the observed 60-70 percent decrease in numbers of murres from pre-oil spill data was significant (Robson; P=0.03). This degree of change, if extrapolated to the entire murre colony, meant a decrease of 81,250 murres from the two Barren Island sites. Statistical testing of 1990 data expanded on the ratio test used in 1989. An analysis of variance for the comparison of ratios of change in murre numbers for the Barren and Semidi Islands between 1979 and 1989-90 found a significant difference between pre- and post oil spill numbers (Table 8, P=0.01). At the same time the test found no significant difference between 1989 and 1990 murre numbers (P=0.77). No statistical treatment has been applied yet that includes the 1991 counts at this site, but the 1991 counts are quite similar to those recorded 1989-90. It is likely that the same conclusions made about changes in murre colonies in 1990 will be repeated when statistical analysis is completed.

1b. Murre Phenology and Productivity

As mentioned, a few segments of the murre colonies in the Barren Islands resumed egg laying by the second week of July in 1991, which is roughly two weeks later than pre-oil spill data recorded for this site. However, most of the murres were still three to

Table 8. Comparison of ratio of change in murre numbers for the Barren Islands and the Semidi Islands between 1979 and 1989-1990.

Island Name	1979	1989	1990	1979/ 1989x1990 ratio
Barrens				
Nord Island	30,000	11,838	12,277	2.488
E. Amatuli L	20,000	6,912	5,865	3.141
Semidis	2,308	2,822	2,890	0.796

ANALYSIS OF VARIANCE OF NATURAL LOGARITHM OF COLONY ATTENDANCE COUNTS:

Source	DF	Sum of Squares	Mean Square	F	P
Islands	2	5.11959	2.55979		
Years	2	0.74345	0.37173		
Isl X Yr	4	0.73445	0.18361		
PARTITIONED ISLAND X YEAR INTERACTION:					
(pre-spill vs. post-spill) X (Barrens vs. Semidis)					
	1	0.70162	0.70162	49.83	0.02
(89 vs. 90) X (Barrens vs. Semidis)					
	1	0.00467	0.00467	0.33	0.77
(Nord Island vs. E. Amatuli Light) X Year					
Error	2	0.02815	0.01408		

Calculated t	-7.059	
Table $t_{0.02(2),2}$	6.965	
Calculated P	0.01	(one-tailed p-value)

[a] Testing performed by Doug Robson

four weeks late in egg laying. Nevertheless, at that time the murres appeared to somewhat synchronize their incubation and attempt to still produce chicks. When land-based plots on Nord Island (North Parakeet Cove) were examined on August 24 and the time lapse camera was taken down, murres were still on the cliffs but chicks or eggs were not seen. When these same land-based plots were revisited on September 12, a few small murre chicks were beginning to be seen. On four of the plots here where 161 and 184 adults were seen on August 24 and September 12 respectively, 9 chicks were seen as well as 16 adults wing mantling what might be very small chicks. This productivity can not be quantified per egg observed as it is on our intensive reproductive study sites like the Semidi Islands or Puale Bay. But there is a method by which productivity might be estimated from the limited observations of murre numbers seen at sites like Nord Island. Carter el al. (1990) and Takekawa et al. (1990) developed and used a correction factor (K-value) to adjust raw counts of birds to obtain estimates of the total number of breeding birds at a nesting area. For common murres, their mean K-value was 1.68 with a standard deviation of 0.08 (n=4 years) and it was used to convert total counts of birds into estimates of total numbers of breeding birds as follows:

$$K(t_1) = n_s(2)/n_t(t_1)$$

where n_s = number of egg laying sites for first eggs and $n_t(t_1)$ = total number of birds present in a plot at time t_1. Solving for egg laying sites, the formula would be the following:

$$n_s = K(n_t)/2$$

The K-value observed for both species of murres combined at the control site, the Semidis, was 1.32 (347 egg sites/mean of 526 murres) in 1990 and 1.28 (341/531) in 1991 with a two year mean of 1.30. If we make the assumption that disturbed colonies like the Barrens would have had a similar K-value if not injured by an oil spill, then using this formula the highest possible range of productivity for the 9 observed chicks and 16 possible additional chicks on Nord Island falls between 0.08 and 0.22 chicks produced per egg site. This is low but certainly better than anything seen at this colony the two previous years. However, it is still unknown whether chicks this small this late in the fall will make it. It is notable that the murres appeared to be persisting in attempts to produce some chicks even though the fall gales started coming through this area on a regular basis all through September. No murre chick/male adult pairs were ever seen in the waters around or near the Barren Islands up through September 13 when our survey crew left the area. This lack of chicks/male pairs on the water contrasted with their presence on the water near the Gull Island murre colony near Homer. The Gull Island murre colony was not affected much if any by the oil spill and appeared to have a more normal egg laying chronology.

To gauge if other portions of the murre colony in the Barrens were producing similar low numbers of chicks, four more areas were climbed without flushing murres in September: 1)portion of plot D on Nord Island (Sept. 11); 2)lower ledge of left side of plot T on Nord Island (Sept. 12); and 3)part of our plot on and 4)part of the top colony on East Amatuli Light (Sept. 11). Most of the chicks seen were small, maybe 4 inches tall, with a few 6 inch tall chicks. Using the above formula, the following adults, chicks, and eggs per plot portion resulted in these production estimates:

1)Plot D: 95 adults, 2 chicks, 1 adult wing mantling counted as a chick, and 3 eggs giving an estimate of 0.05 chicks fledged per egg site.

2)Plot T: 87 adults, 4 chicks, 2 adults wing mantling counted as chicks, and 8 birds incubating eggs giving an estimate of 0.11 chicks fledged per egg site.

3)E. Amatuli Plot: 226 adults, 27 chicks, and one egg giving an estimate of 0.18 chicks fledged per egg site.

4)E. Amatuli Top: 190 adults, 33 chicks, and one egg giving an estimate of 0.27 chicks fledged per egg site.

The range of productivity estimated on the land-based plots on Nord Island (0.08-0.22) appears to include all of those observed except for the slightly higher production found on top of East Amatuli Light Rock. This higher productivity there seems reasonable given that our observations have already confirmed that the earliest egg laying occurred there also this year. Nevertheless, this is still low productivity compared to that recorded at control sites in the Gulf of Alaska like the Semidi Islands or at other sites throughout Alaska (Byrd et al. in press). Yet it is a definite improvement over the previous two years at this colony site.

2. Kittiwakes

One portion of Nord Island which comprises five plots (A-E) that we use for murre monitoring contained 700 breeding kittiwakes in 1978 (Manuwal 1980). We found 597 breeding kittiwakes and 254 nests in the same area in 1989, 1,017 kittiwakes and 610 nests in 1990, and 731 kittiwakes and 199 nests in 1991 (Table 9). If the counts include a roost area found in this same vicinity (plot F), then the yearly totals for adult kittiwakes are quite similar: 1,102 in 1989, 1,124 in 1990, and 1,043 in 1991. These counts of adults and nests suggest that the numbers of kittiwakes do not change much, but the nesting effort does from year to year.

The kittiwake colonies failed to produce any chicks on our plots nor were any seen elsewhere on the Barren Islands in 1989. In 1990 the kittiwakes increased their nesting efforts, but lost almost all their eggs and chicks (0.06 chicks fledged per nest start, n=634). In 1991 the kittiwakes made their lowest nesting effort and failed to produce any chicks on our plots and few were seen anywhere else nearby. In 1990 kittiwake chicks were observed close to fledging

Table 9. Plot counts of black-legged kittiwake adults and nests on the Barren Islands, 1989, 1990 and 1991.

Island Name/ Plot Label	1989				1990				1991	
	7/26	7/28	8/12	8/13	7/12	7/15	7/17	8/15	7/11	7/14
Nord Island										
A	9/4				10/3					0/0
B	73/74		117/48		395/211			c		175/71
C	270/93		158/45		265/191			c		171/48
D	45/14		19/12			68/36				54/19
E	200/69		143/44				279/169	c		331/61
F[a]	505/0		37/0		107/0					312[d]/0
G	74/20		57/12		115/63			c		124/17
NW Islet		152/58	52/28		181/106				64/27	
E. Amatuli Main				65/49[b]				161/0		34/59[e]

[a] Plot F is a roost area only.

[b] All nests had failed at this time on E. Amatuli Mainland plot.

[c] Chick counts for these plots on 15 August are as follows: B: 11; C: 19; E: 5; G: 4. This gives an estimate of 0.06 chicks fledged per nest attempt (n=634) in 1990. Some chicks were close to fledging, but none had yet.

[d] 370 kittiwakes were counted by one person before a gull flushed some off.

[e] Most nests had failed at this time, this is an estimate of nests by remaining vegetation.

(even two per nest) in caves and certain overhangs which suggested that food was abundant enough for reproduction and that predation was affecting success in some degree that year. Kittiwakes have a less colonial behavior than murres for protection against predators. We observed differential predation occurring on kittiwakes and murres in the Barrens in 1990-91. Peregrine falcons were seen taking kittiwakes, even right off of their nests while murres responded primarily to eagles. At any rate, these observations as well as the abundance of feeding flocks and feeding whales in the vicinity all suggested that food resources should not have been limiting in 1990.

Alaska Peninsula (Puale Bay vicinity)

1. Murres

The section of the south shore of the Alaska Peninsula between Chignik and Cook Inlet has been reported to contain 156,580 breeding murres (USFWS computer archives 1986). Most of these birds are found in the Puale Bay colonies. Murre colonies here have not been censused in any replicative manner any one year, but single counts or estimates were conducted in 1976 (Sowls et al. 1978) and 1981 (Bailey and Faust 1984) during the right stage of of murre phenology. The Puale Bay/Cape Unalishagvak murre colonies were estimated to contain 92,800 murres in 1976 and 74,500 in 1981 (Table 10). Since these were one-time counts or estimates and no data are available about the breeding chronology in those years, it is uncertain whether this difference is a decline or natural variation due to daily differences of colony attendance.

The Puale Bay colonies did not have established plots and hence required both total counts as well as smaller replicated sample plots like the Barren Island sites. In 1989 the murre colonies in Puale Bay were at least a month later than expected in laying eggs, much like the Barren Islands. Counts primarily made in August after the murres were incubating eggs resulted in a total of 37,032 murres (Table 10), suggesting that possibly a minimum of 37,468 and a maximum of 55,768 murres were gone. In 1989 plots were set up that were feasible from land-based observation points. In fact, these murre colonies are the only ones in the oil spill impacted area where land-based plots are feasible to a limited degree. Productivity was recorded on these plots, and egg shells were collected for hydrocarbon analysis.

Total counts of murres in 1990 at these same colonies resulted in similar numbers as seen in 1989 (Table 10) with 32,810 murres in attendance, showing a slight decrease from 1989 figures. Total counts of murres in 1991 at the same colonies resulted in 35,836 murres (Table 10). The post oil spill numbers are significantly lower than the pre-oil spill counts ($P < 0.005$). The 1990-91 counts were made in August again because of a late egg laying

Table 10. Counts of adult black-legged kittiwake (BLKI) and murres (COMU) at Puale Bay colonies, Alaska Peninsula: 1976, 1981, 1989, 1990 and 1991.

Colony Name	MURRES				
	1976	1981	1989	1990	1991
Cape Unalishagvak/ Cape Aklek	84,800	68,000	35,400	31,277	33,188
N. Point Puale Bay	8,000	6,500	1,632	1,533	2,647
Totals	92,800	74,500	37,032	32,810	35,836

Calculated $t = 9.131$; Table $t_{0.10(1),3} = 1.638$; $P < 0.005$

Colony Name	BLACK-LEGGED KITTIWAKES				
	1976	1981	1989	1990	1991
Cape Unalishagvak/ Cape Aklek	1,000	1,200	1,000	1,288	1,326

Calculated $t = -0.650$; Table $t_{0.10(1),3} = 1.638$; $P > 0.25$

phenology which was 30 days later (Table 11; Appendix D-G) than that seen at the Semidis.

Although some chicks were hatched on Puale Bay cliffs in 1990, very few fledged. After a large storm passed through in mid-September, many chicks were missing and those remaining were exhibiting unusual behavior, forming chick creches with 2-3 chicks per adult. This made the chicks very vulnerable to predation by gulls and ravens. In fact, many chicks were witnessed being taken by these predators. The end result was that common murres produced 0.11 chicks in 1990 which was almost as low as the 1989 production of 0.06 chicks (Table 12). Thick-billed murres did similarly, producing 0.06 chicks in 1989 and 0.04 in 1990 (Table 12). In 1991 the murres were late in their phenology, but they did not abandon their chicks as they did in 1989 and 1990 in September even though several strong storms occurred. As a result, the common murres produced 0.38 chicks while the thick-billed murres produced 0.48 chicks per egg site in 1991. The end result was the first moderate to good reproductive success seen for murres in the oil spill zone. It still is debatable whether the small murre chicks have a very high probability of survival this late in the fall when they leave the colony site, but at least they were observed leaving or "jumping" this year for the first time.

2. Kittiwakes

Kittiwakes are not abundant in this area. Counts of adult kittiwakes at the colony sites show no significant change between pre-oil spill and post oil spill counts (Table 10).

Kodiak Island Area (Triplets Islands)

The Triplet Islands near Kodiak Island were not censused in 1990-91, but the findings from 1989 are included in this report (Table 13). Murres are not abundant at colonies around Kodiak Island, especially around the northeast, north, and west sides where the oil impacted. The reported colonies contain only 1,940 murres (USFWS computer archives 1986). The Triplets Islands are the largest seabird colony in the Kodiak Island area, but most of the species there are those which were not at high risk from the timing of this spill. These colonies do contain most of the murres in the above total (85 percent common and 15 percent thick-billed murres) and oil was reported early in April to have come in the vicinity of them. Some patches of mousse were seen in July south of the Triplets by this survey team. The Triplets have not had replicative types of census work, but estimates are available for 1977: 1,197 birds (Trapp et al. 1977) and 1984: 1,300 birds (R. MacIntosh, pers. comm.).

Rich MacIntosh censused the murres and cormorants on July 23-25, 1989 resulting in murre counts of 913, 630, and 987 birds on the three consecutive days. The average daily count of 843 birds is

Table 11. Phenology of common and thick-billed murres for 1989 1990 and 1991, Puale Bay, Alaska Peninsula, Alaska[a].

Events	Years 1989	1990	1991
common murres			
Laying			
First laying date	7/15	7/06	7/20
Mean date	8/06	8/01	8/01
Last laying date	8/25	8/18	8/21
Sample size	273	396	102
Hatching			
First hatching date	8/28	8/23	8/20
Mean date	9/09	9/04	9/05
Last hatching date	9/25	9/17	9/20
Sample size	130	289	65
Fledging[b]			
Mean date	10/02	9/27	9/28
Actual Mean Date			9/22
Sample Size			42
thick-billed murres			
Laying			
First laying date	7/21	7/06	7/19
Mean date	7/31	7/26	7/30
Last laying date	8/15	8/21	8/10
Sample size	15	38	22
Hatching			
First hatching date	8/30	8/23	8/19
Mean date	9/06	8/29	8/30
Last hatching date	9/13	9/06	9/09
Sample size	2	15	15
Fledging[b]			
Mean date	9/29	9/21	9/22
Actual Mean Date			9/18
Sample Size			12

[a] Data provided by Dewhurst, pers. comm.

[b] Fledging dates were extrapolated from the hatching dates using the mean time of chick departure for common and thick-billed murres - 23 days.

Table 12. Reproductive success of common and thick-billed murres, 1989, 1990 and 1991, Puale Bay, Alaska[a].

	Years					
	1989		1990		1991	
common murres						
Total eggs laid	266		388		109	
Total Chicks	133		289		64	
Total Chicks Fledged	20		39		41	
Hatching Success[b]	0.50	(0.15)	0.74	(0.08)	0.59	(0.07)[e]
Fledging Success[c]	0.15	(0.15)	0.13	(0.04)	0.64	(0.13)
Productivity[d]	0.07	(0.08)	0.10	(0.04)	0.38	(0.09)
thick-billed murres						
Total eggs laid	20		43		21	
Total Chicks	4		15		15	
Total Chicks Fledged	1		2		10	
Hatching Success	0.20	(0.54)	0.42	(2.12)	0.71	(0.40)
Fledging Success	0.25	(2.58)	0.13	(1.03)	0.67	(0.56)
Productivity	0.05	(0.42)	0.06	(0.54)	0.48	(0.65)

[a] Data provided and tested by D. Dewhurst, pers. comm.

[b] Chicks observed/eggs laid.

[c] Chicks fledged/chicks hatched.

[d] Chicks fledged/eggs laid.

[e] Data expressed as means with 90% confidence bounds in parenthesis.

Table 13. Number of murres at The Triplets colony, Kodiak Archipelago: 1977, 1984 and 1989.

Year	Count
1977	1197
1984	1300
1989	
(7/23)	913
(7/24)	630
(7/25)	987
Calculated t	-5.742
Table $t_{0.10(1),1}$	3.078
Calculated P	0.06

a 35 percent decrease from the numbers seen on this site earlier and the change tested by outlier t-test on the transformed data has a probability of 0.06 (Table 13). These are not sizeable populations nor are these changes of the magnitude seen elsewhere, but they do appear to indicate that changes may have well occurred elsewhere in lesser degrees for these species wherever oil was present (Nysewander, 1990).

Ugaiushak Island

Ugaiushak Island cliffs (figure in Appendix H) were last censused carefully in 1976 (Wehle, 1978) and the murre population was estimated to range between 8,500 and 10,000 at that time. We visited Ugaiushak for the first time after the oil spill, on August 5-6, 1990 and again on August 5, 1991. There was some official confusion initially about the degree of oiling that occurred here. We found some evidence of oiling along the north beaches of the island and it was later discovered through maps distributed concerning the spill's extent that oil must have in fact reached or passed near the island since oil showed up on the beaches of Aniakchak National Park nearby to the west. Although oil passed Ugaiushak Island, the island's shoreline did not appear to be strongly affected.

We counted 5,033 murres on the cliffs plus 840 in the water in the immediate vicinity of the cliffs in 1990 while the 1991 count recorded 5,113 murres on the cliffs with 540 on the water close to the cliffs (Table 14). There seemed to be very few incubating birds here in 1990 and the degree of incubation or presence of eggs (only three) was not much better in 1991. We climbed on the island the same day both years to count at one of the land-based census areas used as a plot by Wehle (named Murre Cove). Wehle reported 3,200 murres in this cove from the land-based observation point in 1976 whereas 1,687 murres were counted in 1990 and 1,105 in 1991 by our count from the cliff top vantage point. We returned the next day in 1990 to see how murre numbers would vary on this same plot. Only 15 murres were present at the far back end of the cove with the rest on the water. An eagle nest was very close and two eagles were seen flying frequently in the vicinity. They was presumed to be the reason for the abandonment of the cliff. Only four eggs were counted on the whole cliff face in the cove in 1990 and one egg was seen being taken by a glaucous-winged gull. Murre numbers appear to have changed since 1976 (P = ?), but the decrease (40 percent) is smaller than that seen at the Barren Islands or Puale Bay and more like the change seen at the Triplets. Since there is only one pre-oil spill count at this site and that thirteen years before the spill, it makes it difficult to evaluate if the change here necessarily relates to the oil spill. The murres here have clearly not produced many chicks the last two years. The two total island counts in 1990 and 1991 are remarkably similar and this suggests that any previous decrease has been stabilized for the time being.

Table 14. Murre population counts for Ugaiushak Island, Alaska, June-July 1976, August 5, 1990 and August 5, 1991.

Location[a]	Map Location #	1976	1990	1991
Main Talus (exposed)	1	586	313	541
Murre Point	2	1,737	1,644	1,742
Secluded Bay	3	856	238	337
Kittiwake Cove	4	298	233	458
Kittiwake Bluffs	5	939	313	296
Square Bay	6	585	549	609
Murre Cove[b]	7	3,200	1,687	1,105
Hole-in-the-wall	8	139	56	25
	Totals[c]	8,340	5,032	5,113

[a] Localized place names (see Appendix F).

[b] Murre Cove was the only location counted from a land observation point in 1976. We duplicated this count from the the same land-based observation point in 1990 and 1991. The count from the water was 787 in 1990 and 673 in 1991 and will not duplicate the 1976 count.

[c] There were an estimated 840 murres on the water around the cliffs while censusing was occurring in 1990 and 540 in 1991.

Semidi Islands (primary control site)

1. Control Site Qualifications

The Exxon Valdez oil spill (EVOS) never reached the Semidi Islands, to anyone's knowledge, either as slick, mousse, or other noticeable forms. As a result, the Semidi Islands murre populations make an excellent control site for the following reasons:

1) They are right on the edge of the spill, but the currents and winds carried it either along the Alaska Peninsula or back onto and around Kodiak Island.
2) They contain the closest unaffected large murre colonies most comparable with sites like the Barren Island murre colonies which took the heaviest murre loss.
3) They are positioned on the continental shelf in a similar fashion as the Barrens, are both adjacent to a deep trough with upwelling features and currents, have exhibited similar sea water temperatures in their adjacent waters, and are in the same oceanographic regime as the Barren Islands, if not that of Prince William Sound.
4) The food web is comparable, as feeding studies of diving alcids and the food they bring to their young have demonstrated (U.S.F.W.S research center, Alaska; Hatch pers. comm.).
5) The baseline database on pre-oil spill murre populations and their reproduction at the Semidi Islands is one of the state's top three sites for this species. Data has been gathered on murres and other species at this site for eight of the last fourteen years .

There is no direct comparison available of productivity and prey base between the Barren Islands, the Semidi Islands, the Chiswells, and Puale Bay. Hence the biological synthesis team associated with the damage assessment effort directed some of its staff to review and annotate relevant literature and interview oceanographic experts on the Gulf of Alaska. They wanted to answer the question whether the Semidis were a valid control site for the EVOS affected colonies. The available data speaks to the question in general terms and these were summarized in a letter dated November 7, 1991 to Dr. R. Spies from B. Sharp:

1) The similarities between sites throughout the Gulf of Alaska, in terms of both species composition and biomass, are greater than the differences. The striking similarity between sites in the Gulf of Alaska is due to the mixing of populations, nutrients, etc. by the Alaska Coastal Current.
2) Interannual variation seems small, usually less than an order of magnitude.
3) The preponderance of data seem to indicate that the Semidis are no more productive than other areas in the Gulf of Alaska.

2. Murres

The nine islands comprising the Semidi Islands contain at least 1,133,300 murres of both species (USFWS computer archives 1986). Murre numbers have been censused on plots at the Semidis eight years between 1977 and 1990 (Hatch and Hatch 1989). These 10 plots have contained yearly totals that averaged between 2,308 and 3,117 murres (Table 15 and figure in Appendix O). The murre numbers on these plots have never varied more than 26 percent of the maximum seen through out this 14 year period and any decrease one year was recovered in subsequent years.

The changes seen in 1989 at other murre colonies examined in the Gulf of Alaska and the persistent decreases seen again in 1990-91 were not seen at the Semidi Islands. The mean total of murres on the plots for 1990 was 2,980, up from the 1989 mean of 2,823, but this was still within the normal variance expected. However, in 1991 the mean total of murres on the plots rose to the highest level ever observed, 3,117 (Table 15). Breeding success has been consistently good here (Table 16) as 0.52 and 0.47 young were fledged per breeding pair of common murres and thick-billed murres in 1991 (0.54 and 0.42 in 1990; 0.58 and 0.43 in 1989) unlike almost all other murre colonies checked in oil spill area (Puale Bay being the exception in 1991). This good production is especially important in light of the fact that kittiwakes had no production of chicks in 1989-91 at the Semidis illustrating that failure by surface feeders does not imply a similar result for diving birds. Murres laid eggs here closer to expected times and the asynchronous egg laying seen at the oiled colonies 1989-90 was not observed here at all (Tables 17 and 18; Appendices I-N).

In addition, the ratio of active breeding sites or eggs to numbers of birds observed on the productivity plots on the Semidi Islands was 0.61 for common murres (213/352) and 0.77 for thick-billed murres (134/174) in 1990 and 0.58 for common murres (208/359) and 0.77 for thick-billed murres (133/172) in 1991. These ratios give us a way to determine a K-value for undisturbed Gulf of Alaska murre colonies. It would appear that the 1.68 correction factor used in California differs from that seen in the Semidis (1.32 for both species of murres in 1990; 1.28 in 1991; 2 year mean of 1.30).

2. Kittiwakes and Fulmars

Population counts were done and productivity was measured for black-legged kittiwakes and northern fulmars as well (Baggot et al. 1989 and Dragoo et al. 1990). The seven population plots for kittiwakes contained yearly totals that averaged between 268 and 485 breeding birds (Table 15 and Appendix P). The numbers of kittiwakes on these plots has varied by 22 percent or less from the maximum seen over the last 12 years until 1991 when the kittiwake numbers and nesting effort decreased to almost half of what it was in 1990.

Table 15. Population data of black-legged kittiwakes and murres in the Semidi Islands based on the adjusted[a] total for the years 1977-1981, 1989, 1990 and 1991.

Kittiwakes	1977	1978	1979	1980	1981	1989	1989[b]	1990	1990[b]	1991
Adjusted totals	22802	8522	18367	16582	21447	2831	1309	4254	1822	2682
Mean	485.1	405.8	382.6	376.9	437.7	217.8	436.3	354.5	455.5	268.2
n	47	21	48	44	49	13	3	12	4	10
SE	5.8	15.8	5.6	6.0	4.7	40.9	3.9	25.1	18.4	24.7

Calculated $t = 0.718$; Table $t_{0.10(2),6} = 1.943$; $(P = 0.50)$

Murres[c]	1977	1978	1979	1980	1981	1989	1990	1991
Adjusted totals	121080	18446	96932	98045	119955	36691	29795	31168
Mean	2815.8	2635.1	2307.9	2451.1	2856.1	2823.0	2979.5	3116.8
n	43	7	42	40	42	13	10	10
SE	38.5	117.8	31.6	37.0	50.5	78.4	67.2	39.2

Calculated $t = -2.2556$; Table $t_{0.10(2),6} = 1.943$; $(P = 0.069)$

[a] The adjusted totals reflect the adjustment made if one or two plots could not be counted on a given day. The adjustment was arrived at by computing the average contribution of each plot to the daily totals for each calendar month.

[b] A second set of values for the years 1989 and 1990 is included in which only the first three and four replicate counts, respectively, are used. Both years were ones of failed reproduction in the Semidis and as a result the kittiwakes abandoned their nests. It was felt that the first replicate counts represented the most valid data.

[c] Calculation based on the total number of common and thick-billed murres found on all ten murre plots.

Table 16. Comparison of common (COMU) and thick-billed (TBMU) murre census parameters in 8 years with different levels of breeding success on the Semidi Islands, Alaska[a].

	Year							
Parameter	1977	1978	1979	1980	1981	1989	1990	1991
Productivity of COMU (chicks fledged/breeding site[b])	--	--	0.48	0.64	0.59	0.58	0.54	0.52
Productivity of TBMU (chicks fledged/breeding site)	--	--	0.48	0.46	0.63	0.43	0.42	0.47
Mean of COMU population counts during census period	--	--	--	--	--	2705	2835	2976
Mean of TBMU population counts during census period	--	--	--	--	--	118	145	141
Mean of COMU+TBMU population counts during census period	2816	2635	2308	2451	2856	2823	2980	3117

[a]Data from Hatch and Hatch (1990), Baggot et al. (1989), Dragoo et al. (1991), and this study. COMU = common murre TBMU = thick-billed murre

[b]Breeding site = a site where an egg was laid.

Table 17. Phenology of common murres on the Semidi Islands, Alaska in different years[a].

	Year					
Events	1979	1980	1981	1989	1990	1991
Laying[b]						
First laying date	6/07	6/07	6/05	6/15	6/06	6/10
Mean date	6/18	6/16	6/16	6/25	6/21	6/24
Sample size	69	83	83	144	214	205
Hatching[c]						
Mean date	*7/20	*7/18	*7/18	7/25	7/25	7/25
Sample size	--	--	--	113	145	121
Fledging[d]						
Mean date	*8/12	*8/10	*8/10	8/14	8/14	8/18
Sample size	--	--	--	65	97	106

[a]Data from Hatch and Hatch (1990), Baggot et al. (1989), Dragoo et al. (1991), and this study.

[b]Data do not include relaid eggs.

[c]*Asterisks denote data that were extrapolated from the laying dates using the mean incubation period for common murres.

[d]*Asterisks denote data that were 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 18. Phenology of thick-billed murres on the Semidi Islands, Alaska in different years[a].

	Year						
	1978	1979	1980	1981	1989	1990	1991
Laying[b]							
First laying date	6/09	6/07	6/07	6/05	6/09	6/09	6/10
Mean date	6/17	6/17	6/17	6/15	6/23	6/19	6/19
Sample size	43	107	105	108	95	121	132
Hatching[c]							
Mean date	*7/19	*7/19	*7/19	*7/17	7/23	7/21	7/23
Sample size	--	--	--	--	85	73	84
Fledging[d]							
Mean date	*8/11	*8/11	*8/11	*8/09	8/12	8/12	8/15
Sample size	--	--	--	--	47	46	60

[a]Data from Hatch and Hatch (1990), Baggot et al. (1989), Dragoo et al. (1991), and this study.

[b]Data do not include relaid eggs.

[c]*Asterisks denote data that were extrapolated from the laying dates using the mean incubation period for thick-billed murres.

[d]*Asterisks denote data that were 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).

Kittiwakes totally failed in 1989 to fledge any chicks on the 192 nests monitored, and in 1990 they fledged only 0.004 chicks per nest start on the 241 nests monitored (Table 19). Fulmars fledged 0.46 chicks per nest start in 1989 and 0.26 in 1990. The productivities of murres and fulmars at the Semidis suggest that the widespread breeding failure of kittiwakes lately does not necessarily have any correlation with the failure of murres to lay eggs.

Evidence that Injury Was Caused by Oil Spill

Evidence From Sources Other Than Bird Study # 3

The most direct evidences of injury to murres were the dead oiled carcasses that were picked up. More than 30,000 dead and oiled birds were retrieved from polluted areas by August 1, 1989. Murres comprised 74 percent and other alcids another 7 percent of the carcasses identified (Piatt et al. 1989). Most birds (88 percent) were killed outside of Prince William Sound and that is where the largest murre populations reside. Murres constituted 84-90 percent of the birds picked up on Middleton Island, the Barren Islands, Kodiak, or the Alaska Peninsula.

Aerial surveys (April 6) by U. S. Fish and Wildlife Service personnel indicated that, just prior to oil contamination, at least 123,600 birds (79 percent murres, 20 percent gulls) occurred near the Barren Islands (Butler 1989, Piatt et al. 1989). Historical surveys have documented that 130,000 murres bred during the summer at the Barren Islands and that they arrived at colonies in March and April (Manuwal 1980). Ship-based (May 2) and aerial (April 29) surveys conducted near the Barren Islands after oil pollution did not locate the large numbers of murres seen April 6 just before oil swept through the islands (Piatt et al. 1989).

Evidence Gathered Through Bird Study #3

Colony censuses done during the breeding season of 1989 documented a 60-70 percent decrease in murre numbers at the Barren Island colonies (81,250 birds missing), a 50-60 percent decrease in the numbers of murres at the Puale Bay area of the Alaska Peninsula (at least 37,468 birds missing and possibly up to 55,768 missing), and a 35 percent reduction of murres (457 birds missing) at the Triplet Islands. These dramatic decreases in numbers of murres were persistent in 1990 and 1991 as well. In contrast, the murre plots on the Semidi Islands (10 plots with a total of 2980 birds in 1990 and 3,117 in 1991) have not significantly decreased over the last 14 years and have never varied by more than 26 percent of the maximum seen any one of the eight years that plots were observed. Most of the other colonies have been censused twice or more in the last 17 years before oiling. Such a large decrease of murres on colony sites in such a short time frame as seen in 1989 is observed upon occasion because of natural causes, but it is more

Table 19. Reproductive success of northern fulmars, black-legged kittiwakes, common murres, and thick-billed murres for 1989 and 1990 in the Semidi Islands.

	Northern Fulmar		Black-legged Kittiwake		Common Murre		Thick-billed Murre	
	89	90	89	90	89	90	89	90
Total # of plots	8	3	9	7[a]	16	7[a]	17	4[a]
Total nest starts	183	77	192	241	180	213	129	134
Total chicks fledged	85	20	0	1	104	115	55	56
Productivity (chicks fledged per nest start)	0.46	0.26	0.00	0.004	0.58	0.54	0.43	0.42
90% Confidence Bound	0.11	0.25	0.00	0.008	0.10	0.07	0.11	0.07

[a] Nests from some plots were combined in order to increase the sample of nest starts within a given plot.

frequently involved with man-made causes such as gill-net mortality or oil spills (Hudson 1985, Takekawa et al. 1990). More gradual changes in numbers at colonies usually occur when natural, climatic, or oceanographic changes are involved (Hudson 1985). Large changes of numbers of murres caused by natural factors usually rebound within a year or two at Alaska sites (Mendenhall 1991, Byrd in press). The persistence of the murre decreases seen over three years at the colony sites in the oil spill is not paralleled by any observations of such a dramatic change naturally occurring that persists so consistently.

Lastly, the asynchronous late egg laying and total loss of productivity suggested something has changed radically recently. However, there is no evidence that link the changes in murre numbers and productivity just described with any other phenomena than that of the oil spill. This form of indirect evidence is a lack of data for any consistent relationship between the changes in murre numbers and food availability, ocean water temperatures, or historical population trends. In the case of food supply, murres outside the spill reproduced well and inside they did not while kittiwakes sometimes succeeded in reproductive success within the oil spill area. There does not appear to be any historical trend for murre declines at all sites since Chiswell, Middleton, and Semidi murre numbers have stayed the same or increased. Likewise, an examination of ocean temperatures at the Chiswell, Barren, and Semidi Islands finds no difference in water temperatures. Even in the years (1983-84 and 1990) where El Nino or warming waters occurred in the Gulf of Alaska (Appendix Q), this did not appear to affect the above three sites as pockets of upwelling and cooler waters persisted there. The only known situation in the northeastern Pacific Ocean that appears to resemble the changes in murre numbers and reproduction we have witnessed is the decline of the common murre in the central California coast 1980-86 (Takekawa et al. 1990). These declines were attributed to high murre mortality in nearshore gill-net fisheries, compounded by mortality from oil spills and the 1982-83 El Nino (dramatic warming of the ocean). These declines in murres on colonies also resulted in a similar disruption of egg laying and productivity as seen in Alaska (H. Carter, pers. comm.).

Type of Potential Injury Still Being Investigated.

1. Rate of Recovery of Murre Numbers at Colony Sites

Since the murre colonies in the oil spill areas stayed at the 1989 reduced levels in 1990 and 1991, it seems reasonable to dismiss the hypothesis that murres may have abandoned the area for the 1989 season rather than die. It also appears logical to assume that many breeding adults died. Immigration from other colonies did not occur much since the murre numbers did not increase in any appreciable amount. Immigration can sometimes affect an alcid or puffin colony significantly (Harris 1983) when other breeding colonies are nearby, but it is unclear what would happen in the case of the Barren Islands as there are no nearby large colonies, unless the Semidi Islands are close enough to supply murres. It is more likely that the slight recovery of numbers at the Barrens each year reflects a return of juvenile birds that are now ready for breeding. If the loss was small enough, then recruitment could restore the colony as Stowe recorded (1982). This may have been the case at the Chiswell Islands as discussed earlier. If the percentage loss of a colony is great, then recovery rates are unknown. The disruption and decline of the central California murre colonies (Takekawa et al. 1990) led to a percentage decrease of murre numbers and reproduction at colony sites similar to what has been observed in Alaska and yet seven years after the loss in California in 1982-83, the murres have not begun to recover in any appreciable way even though the three causes of the mortality ceased some time ago. Future monitoring of numbers of murres at colonies will help establish the rate of recovery and hence how long recovery may take in Alaska.

2. Recovery of Normal Murre Breeding Phenology and Productivity

Birkhead (1977) has shown that the breeding success of common murres is density dependent. At high densities, the tightly packed murres successfully defended their eggs and chicks from predatory gulls whereas at low densities, the breeding groups were "opened up" and therefore more vulnerable to predators. The additional factor of asynchronous egg laying seen at all oiled sites verifies this observation and shows how loss of breeding colony structure complicates recovery even further. No one knows how long it will take for egg laying to become fully synchronized and restored to an earlier chronology again or for production of chicks to resume. In 1991 the first evidences of some slight type of recovery in the breeding aspects was seen at several different sites. The time taken for the population to return to initial levels can depend upon the proportion of adults killed, but this type of density-dependent breeding success can also slow down or even stop the recovery of a colony. There are various estimates of recovery times that range from 20 to 70 years for injured murre colonies. Future monitoring of murre reproductive success will help refine this estimate and warn us if the colonies are inclined to decrease rather than increase.

3. Need For Continued Studies at Control Sites

Future monitoring effort at the control sites is also important from another standpoint. The colonies where the greatest decreases of murres were noted were also those colonies which had the weaker baselines of historical data. This substantially hindered statistical analysis and future work will not overcome this limitation in that we can not increase the sample size of the pre-oil spill data. However, we know from studies on the Semidis and elsewhere that natural variance occurs from year to year, but large percentage changes in a short time frame that then persist for years have not been documented. There have been infrequent "wrecks" or die offs of murres recorded that were associated with storms or other natural factors (Bailey and Davenport 1972, Holdgate 1971, Hudson 1985), but this mortality was spread out over a number of colonies and has never been tied into any unusual decrease at any one colony between years. Hence it is important to look at the controls more, such as at the Semidi Islands, to make sure that such phenomena have not been overlooked.

STATUS OF INJURY ASSESSMENT

Objective A. Changes in Numbers

There is enough evidence from several different approaches to make preliminary conclusions that breeding numbers of murres have changed significantly in locations like the Barren Islands while they have not at a site like the Semidi Islands. Although counts during the 1976-79 studies were not replicated to account for variance, the general consensus of observations then supports the conclusion that a stable level of murres occurred in the Barren Islands. Future field seasons will not solve the lack of enough pre-oil spill historical data, but they do increase the sample size, make the observed changes even more significant statistically, and determine the rate of recovery. The decrease of murres in the Puale Bay colonies on the Alaska Peninsula appears to be a significant change. It is still unclear here if any decline associated with an oil spill is also mixed in with a natural decline that may have been in progress. Otherwise, the comments and concerns expressed about the data here would be similar to that expressed earlier about the Barren Islands. The Chiswell Island murre colony has now had two year of censusing after the oil spill. The best suggestion for monitoring the Chiswells is to monitor the rate of change in numbers and conclude that recovery is near when the rate of recovery slows down in the standard sigmoid fashion.

Objective B. Changes in Phenology and Productivity

The changes in chronology or phenology of murre breeding and the subsequent reproductive success has been very different between the control and the Chiswell Islands, Barren Islands, and Puale Bay colonies. This difference instills some confidence in the reality of the difference. However, it is open-ended as to how long these changes will continue and how recovery will be affected. The first two years it was esentially a comparison between no production at the oil spill related sites and moderate to good production at the control. The oil spill related colonies had a phenology that was 30-45 days later than that at the control. However, in 1991 synchrony of egg laying is regrouping and egg laying is not as delayed for some portions of the colonies. To know the full extent of injury to these colonies, this breeding recovery should be tracked into the future. More field observations gathered the next few years at these sites would make a much tighter case for any conclusions about total loss, recruitment, immigration, and recovery times. The Puale Bay colonies add something special to this study in that they are the only murre colonies in the oil affected areas where land-based observations of productivity are possible on a frequent basis.

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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. U.S. Dept. Interior, Fish and Wildl. Serv., Homer, Alaska, Unpubl. Rept. 34pp.

Bailey, E.P. 1976. Breeding bird distribution and abundance in the Barren Islands, Alaska. Murrelet 57:2-12.

Bailey, E.P. 1977. Distribution and abundance of marine birds and mammals along the south side of the Kenai Peninsula, Alaska. Murrelet 58(3):58-72.

Bailey, E.P. and C.H. Davenport. 1972. Dieoff of common murres on the Alaska Peninsula and Unimak Island. Condor 74:213-219.

Bailey, E.P. and N.H. Faust. 1984. Distribution and abundance of marine birds breeding between Amber and Kamishak Bays, Alaska, with notes on interactions with bears. Western Birds 15:161-174.

Birkhead, T.R. 1977. The effect of habitat and density on breeding success in the Common Guillemot, Uria aalge. Journal of Animal Ecology 46:751-764.

Butler, W. 1989. Prince William Sound and Kenai Peninsula Migratory Bird Aerial Survey Project. Unpublished data. U. S. Fish and Wildlife Service, Anchorage, Alaska.

Byrd, G.V. 1989. Seabirds in the Pribilof Islands, Alaska: trends and monitoring methods. M.S.thesis, Univ. of Idaho, Moscow, Idaho, 96pp.

Byrd, G.V., E.C. Murphy, G.W. Kaiser, A.J. Kondratyev, and Y.V. Shibaev. In press. Status and ecology of offshore fish-feeding alcids (murres and puffins) in the north Pacific Ocean. In K. Vermeer, K. Briggs, S. Fefer, and D. Siegel-Causey, eds. Status, ecology, and conservation of marine birds of the temperate North Pacific. Can. Wildl. Serv., Spec. Publ. Ottawa.

Carter, H.R., D.L. Jaques, G.J. McChesney, C.S. Strong, M.W. Parker, and J.E. Takekawa. 1990. Breeding populations of seabirds on the northern and central California coasts in 1989 and 1990. U. S. Dept. Interior, U. S. Fish and Wildl. Serv., Unpubl. rpt., 443pp.

Dragoo, D.E. and B.K. Bain. 1990. Changes in colony size, and reproductive success of seabirds at the Semidi Islands, Alaska, 1977-1990. U.S. Dept. Interior, U.S. Fish and Wildl. Serv., Homer, Alaska, Unpubl. Rept.

Fowler, J. and L. Cohen. 1986. Statistics for Ornithologists. British

Trust for Ornithology, BTO Guide No. 22, Tring, Hertfordshire. 175 pages.

Garton, E.O. 1988. A statistical evaluation of seabird monitoring programs at three sites on the Alaska Maritime National Wildlife Refuge. Univ. of Idaho, Moscow, Idaho. Unpubl. Rept. from contract with the refuge, 15pp.

Harris, M.W. 1983. Biology and survival of the immature puffin Fratercula artica. Ibis 125:56-73.

Hatch, S.A. and M.A. Hatch. 1988. Colony attendance and population monitoring of black-legged kittiwakes on the Semidi Islands, Alaska. Condor 90:613-620.

Hatch, S.A. and M.A. Hatch. 1989. Attendance patterns of common and thick-billed murres at breeding sites: implications for monitoring. J. Wildl. Mgmt. 53(2):483-493.

Hatch, S.A., G.V. Byrd, D.B. Irons, and G.L. Hunt, Jr. In press. Status and ecology of kittiwakes in the North Pacific. In K. Vermeer, K. Briggs, S. Fefer, and D. Siegel-Causey, eds. Status, ecology, and conservation of marine birds of the temperate North Pacific. Can. Wildl. Serv., Spec. Publ. Ottawa.

Holdgate, M.W. 1971. The seabird wreck in the Irish Sea autumn 1969. Publications---Natural Environment Research Council, Series C (U.K.) No. 4, 17 pp.

Hudson, P.J. 1985. Chapter 5. Population parameters for the Atlantic Alcidae. Pp. 233-261 in Nettleship, D.N. and T.R. Birkhead (ed.). 1985. The Atlantic Alcidae. Academic Press, New York. 574pp.

Irons, D.B., D.R. Nysewander, and J.L. Trapp. 1987. Changes in colony size and reproductive success of black-legged kittiwakes in Prince William Sound, Alaska, 1972-1986. U. S. Dept. Interior, Fish and Wildl. Serv., Anchorage, Alaska, Unpubl. Rept. 37pp.

King, J.G. and G.A. Sanger. 1979. Oil vulnerability index for marine oriented birds. Pp. 227-239 in J.C. Bartonek and D.N. Nettleship eds. Conservation of marine birds of northern North America. U. S. Fish and Wildl. Serv., Washington D.C. 319pp.

Mendenhall, V.M., L. Haggblom, E.C. Murphy, and B. Sharp. 1991. General Methods. Pp. 7-11 in V.M. Mendenhall ed. Monitoring of populations and productivity of seabirds at Cape Peirce, Bluff, and Cape Thompson, Alaska, 1990. U. S. Fish and Wild. Serv., Washington D.C. 149 pp.

Manuwal, D.A. 1980. Breeding biology of seabirds on the Barren Islands, Alaska. Unpublished final report summarizing 1976-79 work. U. S. Fish and Wildl. Serv., Anchorage, Alaska. 195pp.

Nettleship, D.N. 1976. Census techniques for seabirds of arctic and eastern Canada. Can. Wildl. Serv. Occ. Papers 25. 33pp.

Nishimoto, M. and B. Rice. 1987. A re-survey of seabirds and marine mammals along the south coast of the Kenai Peninsula, Alaska during the summer of 1986. U. S. Fish and Wild. Serv., Alaska Maritime National Wildl. Refuge, Homer, Alaska. Unpubl. Rept. 79 pages.

Nysewander, D.R. 1990. Population surveys of seabird nesting colonies in Prince William Sound, the outside coast of the Kenai Peninsula, Barren Islands, and other nearby colonies. U.S. Dept. Interior, U.S. Fish and Wildl Serv., Homer, Alaska, Unpubl. Rept. 35pp.

Nysewander, D.R., B. Roberts, and S. Bonfield. 1986. Reproductive ecology of seabirds at Middleton Island, Alaska, summer 1985. U. S. Dept. Interior, Fish and Wildl. Serv., Anchorage, Alaska, Unpubl. Rept. 45pp.

Piatt, J.F., C.A. Lensink, W. Butler, M. Kendziorek, and D.R. Nysewander. 1990. Immediate Impact of the "Exxon Valdez" Oil Spill on Marine Birds. The Auk 107:387-397.

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

Stowe, T.J. 1982. An oil spillage at a guillemot colony. Marine Pollution Bulletin, 13(7):237-239.

Takekawa, J.E., H.R. Carter, and T.E. Harvey. 1990. Decline of the common murre in central California, 1980-1986. Studies in Avian Biology, No. 14:149-163.

Trapp, J.L., D.J. Forsell, M.H. Dick, and E.P. Hoberg. 1977. Alaskan Seabird Colony Status Record, Area No. 034. U. S. Fish and Wildlife Service, Anchorage, Alaska.

U. S. Fish and Wildlife Service. 1986. Catalog of Alaskan seabird colonies--computer archives. U.S. Fish and Wildl. Serv., Migratory Bird Management, Anchorage, Alaska 99503.

Wehle, D.H.S. 1978. Studies of marine birds at Ugaiushak Island, Alaska. In Environmental Assessment of the Alaskan Continental Shelf, Vol 3:208-312. NOAA-BLM, Boulder, Colorado.

APPENDICIES

Appendix A. Counts* of murres on Barren Island plots for 26 and 28 July and 12 August, 1989.

Island Name/ Plot Label	1989			
	26 July	28 July	12 August	MEANS
Nord Island				
A1	154		147	150.5
A2	127		125	126.0
B	7		10	8.5
C	139		115	127.0
D	460		203	331.5
E	531		480	505.5
F (roost area)	0		0	0.0
G	74		81	77.5
H1	274		542	408.0
H2	375		250	312.5
NW Islet		219	231	225.0
I	159			159.0
			Nord sub-total	2,430.5
E. Amatuli Mainland		339	406	372.5
E. Amatuli Light		424	535	479.5
			TOTAL	3,283

* Mean of three counts.

Appendix B. Murre population plots on Nord Is. and E. Amatuli Is., Barren Islands, Alaska, 1990.

	Date								
Nord Plots	12 July	17 July	18 July	19 July	20 July	14 Aug	15 Aug	18 Aug	MEANS
A2	0	N.C.[a]	559.8	435.6	365.0	310.0	N.C.	377.0	341.2
A1	0	N.C.	0[b]	136.4	153.4	134.0	N.C.	34.3	114.5
B	0	N.C.	N.C.	N.C.	N.C.	N.C.	13.0	14.0	
C	0	141.3	185.1	248.6	176.0	230.9	169.6	102.0	156.7
D	0	839.8	977.0	1240.0	1064.1	875.0	933.0	1015.8	992.1
E	0	0	731.6	726.0	802.3	468.3	654.0	780.3	693.8
G	0	N.C.	144.3	110.2	N.C.	155.0	131.8	167.5	118.1
H1	N.C.	N.C.	N.C.	1460.0	N.C.	897.5	N.C.	977.5	1111.7
H2	N.C.	N.C.	N.C.	252.2	N.C.	380.0	N.C.	459.7	364.0
I	N.C.	N.C.	N.C.	126.5	N.C.	144.2	N.C.	133.0	134.6
NW Islet	15	N.C.	202.3	241.7	254.2	261.0	230.8	225.5	235.9[c]
								Nord Total	4,263

	Date	
E. Amatuli Plots	15 Aug	19 Aug
E. Amatuli Mainland	292.3	233.3
E. Amatuli Light	416.4	207.8

[a] N.C. indicates that no count was done.

[b] Plot A1 and A2 were lumped together on this count; all subsequent counts were separated.

[c] The 12 July count was not included in this calculation.

Appendix C. Murre population plot counts during 1991 on Nord Island and E. Amatuli Is., Barren Islands, Alaska.

Island/Plot	Date[a] 7/11	7/15	7/17	7/18	8/16	8/17	8/19	8/20	8/21	8/22	8/23	8/25	9/01	9/11	MEANS
Nord Is.															
A1	0.0[b]	--	--	0.0	--	139.0	137.1	101.0	129.2	140.0[c]	N.C.	N.C.	--	--	129.3
A2	0.0	--	--	0.0	--	291.0	295.8	190.0[d]	287.3	220.0	N.C.	N.C.	--	--	273.5
B	0.0	--	--	0.0	--	14.3	17.0	13.8	10.4	11.8	12.8	N.C.	--	--	13.4
C	0.0	--	--	0.0	159.5	152.8	191.4	167.1	163.2	126.0	176.3	N.C.	--	--	162.3
D	0.0	--	--	0.0	--	833.3	N.C.	922.6	853.2	830.0[c]	952.4	1,106.7	--	--	916.4
E	0.0	--	--	0.0	--	711.3	N.C.	717.0	614.1	514.0[c]	788.6	768.0	--	--	685.5
G	0.0	--	--	0.0	--	147.0	N.C.	N.C.	N.C.	103.3	N.C.	N.C.	--	--	125.2
H1	0.0	--	--	0.0	--	595.3	N.C.	N.C.	N.C.	825.0[c]	N.C.	N.C.	--	--	710.2
H2	0.0	--	--	0.0	--	407.0	N.C.	N.C.	N.C.	358.0[c]	N.C.	N.C.	--	--	382.5
I	0.0	--	--	0.0	--	164.7	N.C.	N.C.	147.9	129.2	165.5	N.C.	--	--	151.8
NW Islet	162.3	--	--	N.C.	194.6	204.3	185.8	188.7	185.3	200.0[c]	N.C.	N.C.	--	--	193.1
T (left)	--	--	--	0.0	--	334.0[c]	N.C.	387.2	401.4	366.0	395.9	427.3	--	--	385.3
T (right)	--	--	--	0.0	--	276.0[c]	N.C.	302.5	341.7	396.5	373.4	395.8	--	--	347.7
U	--	--	--	0.0	--	156.0	N.C.	135.0	143.8	131.0	161.4	170.7	--	--	149.7
Y	--	--	--	0.0	--	980.0[c]	N.C.	N.C.	896.4	710.0[c]	919.0	1,099.0	--	--	920.9
Z	--	--	--	0.0	--	1,023.3[c]	N.C.	N.C.	1,044.8	805.5[c]	N.C.	N.C.	--	--	957.9
											Nord Plot Total without T, U, Y & Z				3,743.2[e]
													Nord Plot Total		6,504.7
		Nord Total Island Counts				13,404.1				13,261.6					
E. Amatuli Is.															
E. Amatuli Light	--	0.0	374.3	--	--	--	528.8[c]	--	--	--	--	--	375.0[c]	511.0[f]	447.3
E. Amatuli Mainland	--	42.8	0.0	--	--	--	496.0[c]	--	--	--	--	--	318.6	389.7[f]	401.4
												E. Amatuli Plot Total			848.7

E. Amatuli Light Total Count 3,429[g]

[a] No murres were present on Nord Is. on July 10th, 12th or 13th; there were no murres present on E. Amatuli plots on July 10th, 14th or 16th.

[b] Zero's were not used in mean calculation.

[c] These counts were done by 10's.

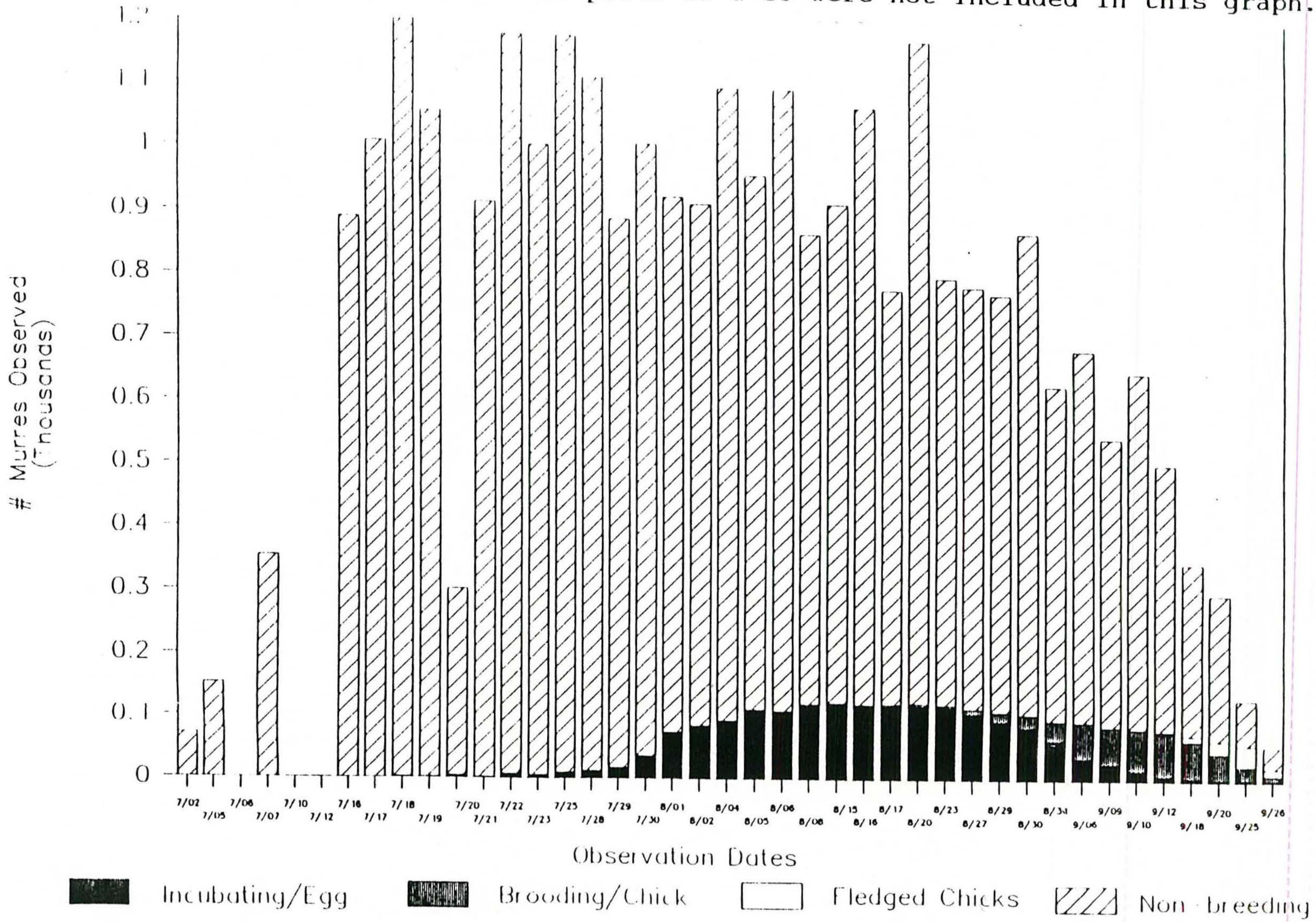
[d] Not used in mean calculation because of unfavorable lighting conditions during counting.

[e] Plots T, U, Y and Z are new monitoring plots that were added in 1991.

[f] These are single person counts.

[g] There were 2100 murres in the water surrounding E. Amatuli Light that are not included included in this count; total would be 5,529.

Appendix D. Composition of murre populations (common & thick-billed combined) observed June thru September 1991 on the 10 productivity plots at Puale Bay, Alaska Peninsula, Alaska. The Stacked bars are additive, with the top representing total counts per date. Non-breeders in plots G2 & G3 were not included in this graph.



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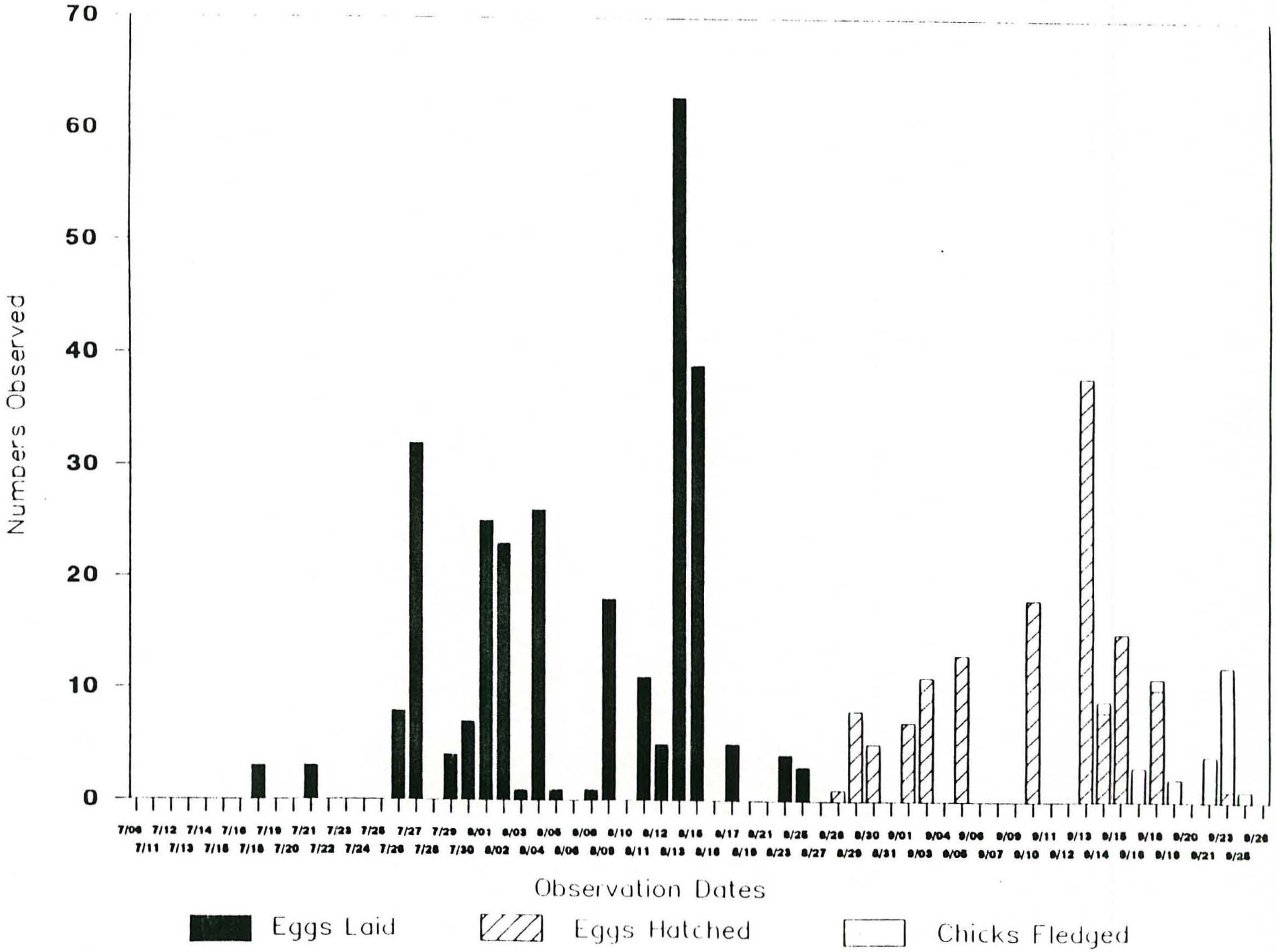
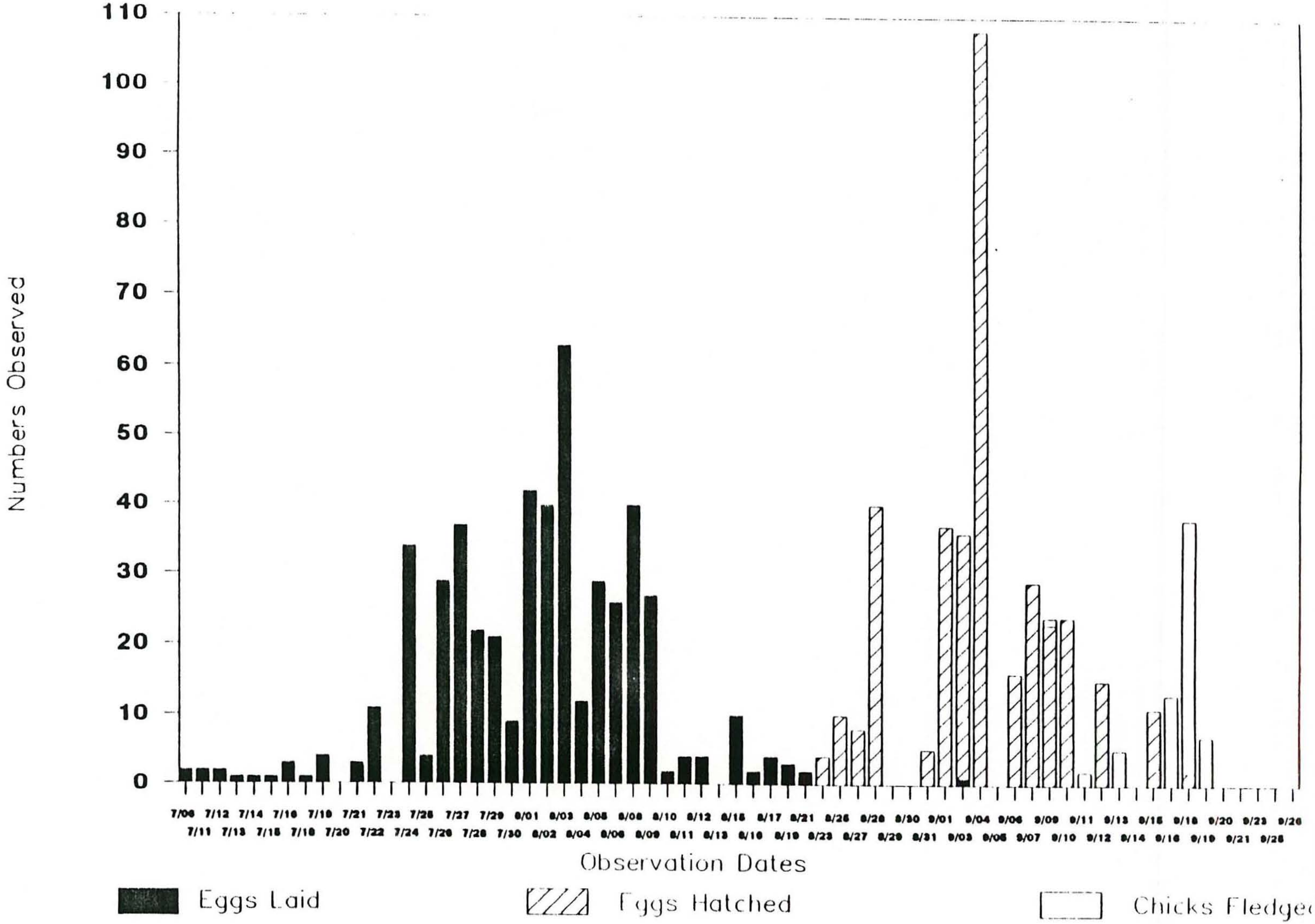
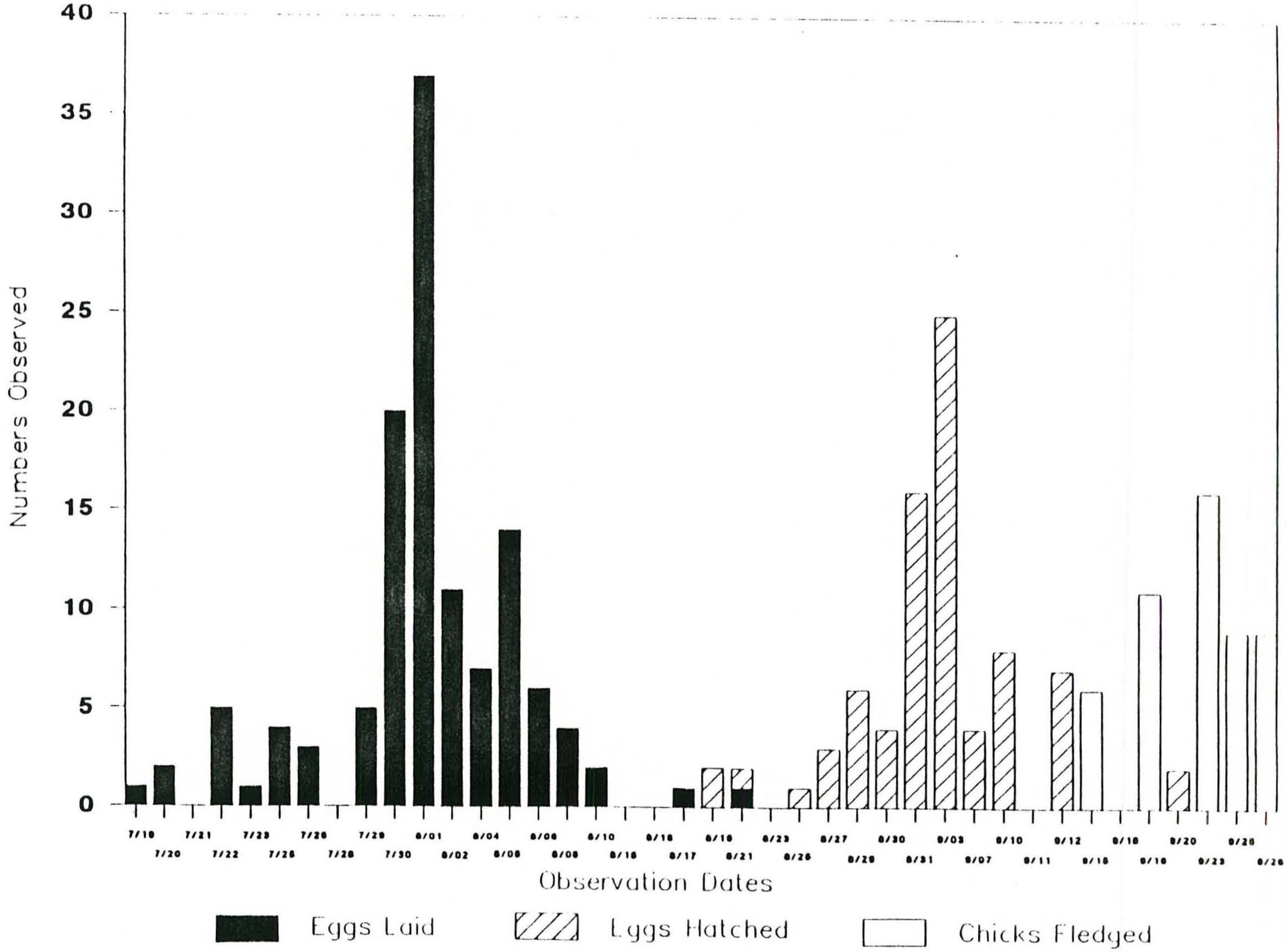
Appendix E. Chronology of murre reproductive events for Puale Bay, Alaska Peninsula, Alaska, 1989.



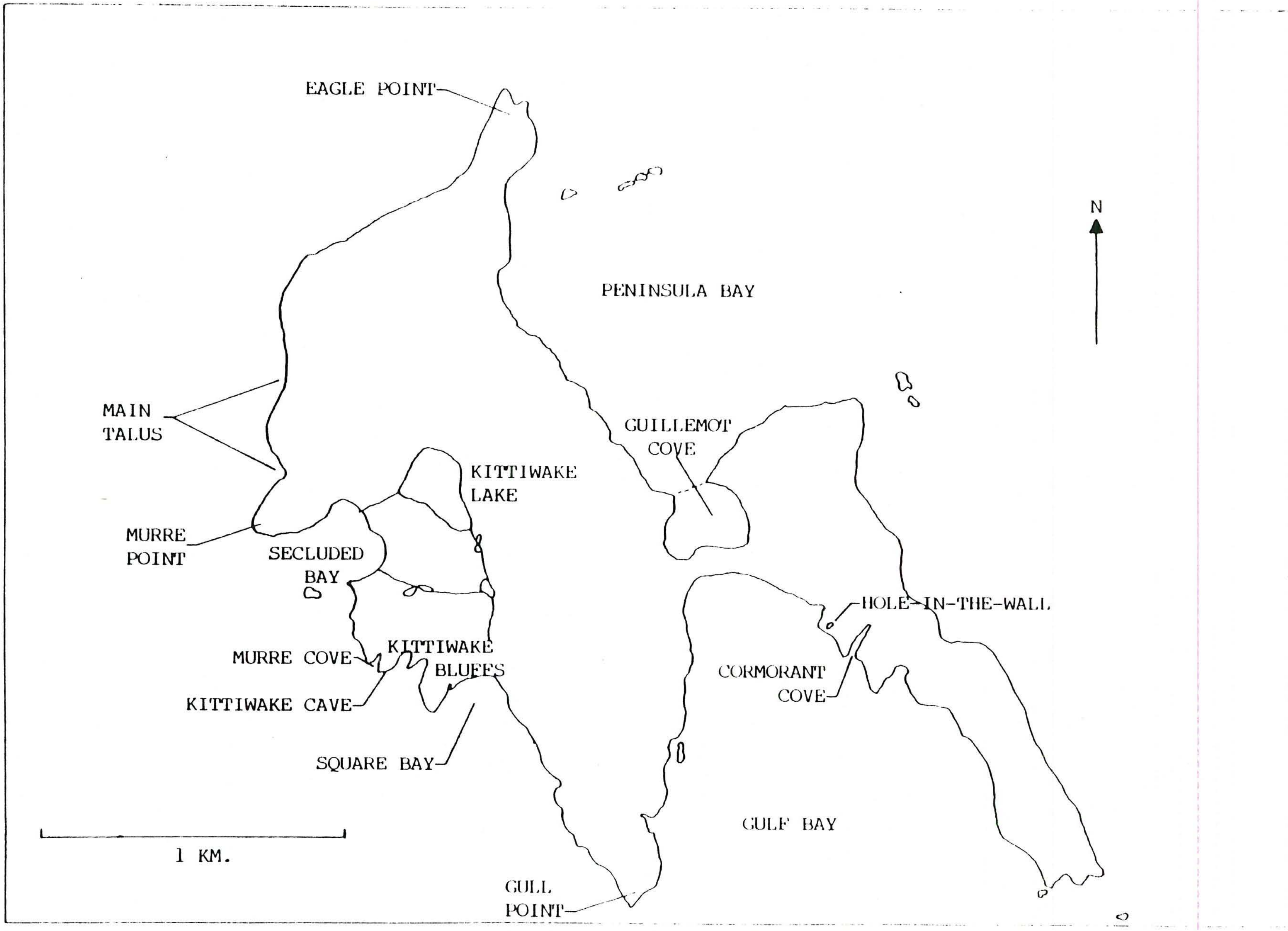
Appendix F. Chronology of murre reproductive events for Puale Bay, Alaska Peninsula, Alaska, 1990.



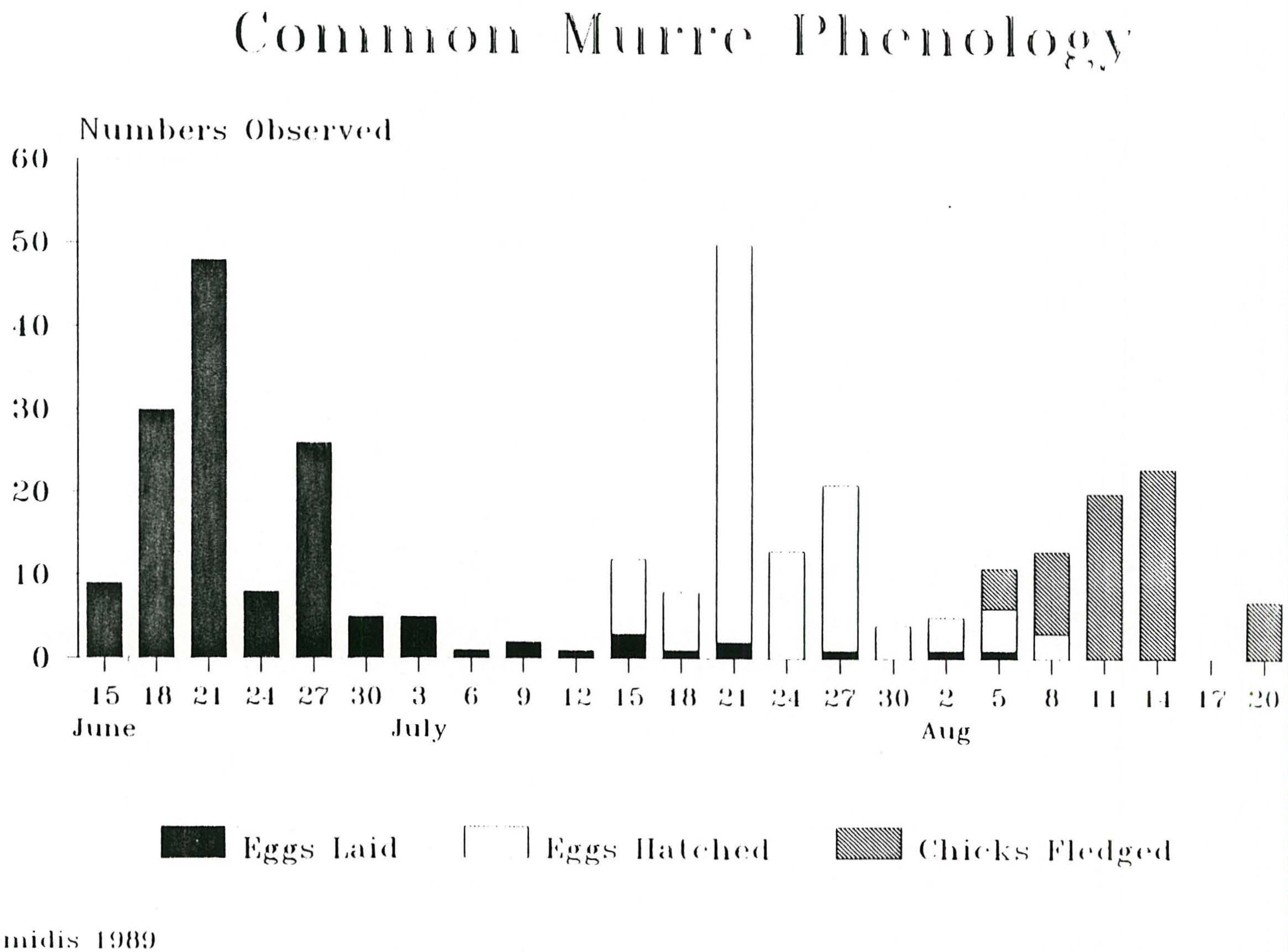
Appendix G. Chronology of murre reproductive events for Puale Bay, Alaska Peninsula, Alaska, 1991.



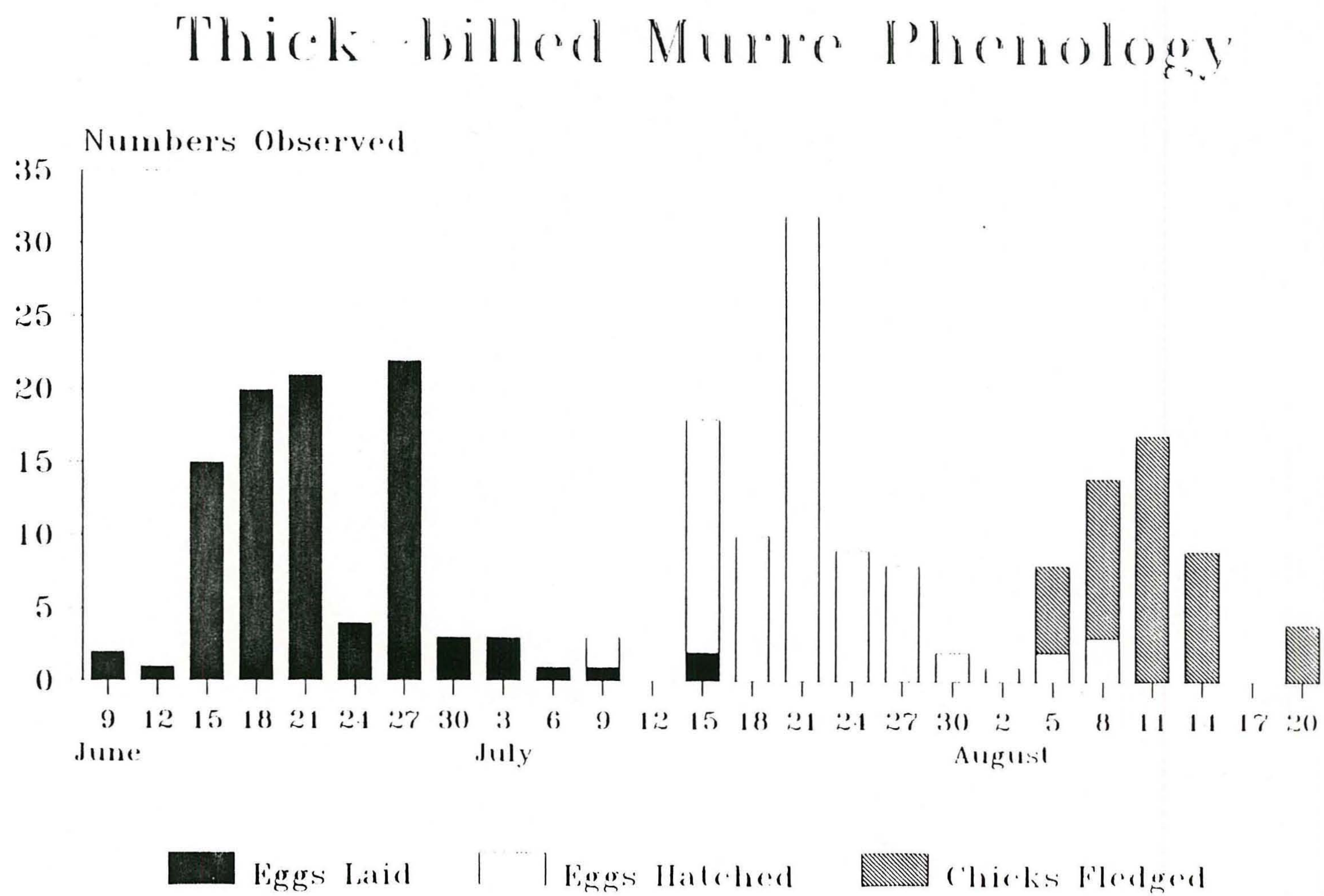
APPENDIX H. Ugaiushak Island



Appendix I. Chronology of common murre reproductive events for the Semidi Islands, Alaska, 1989.

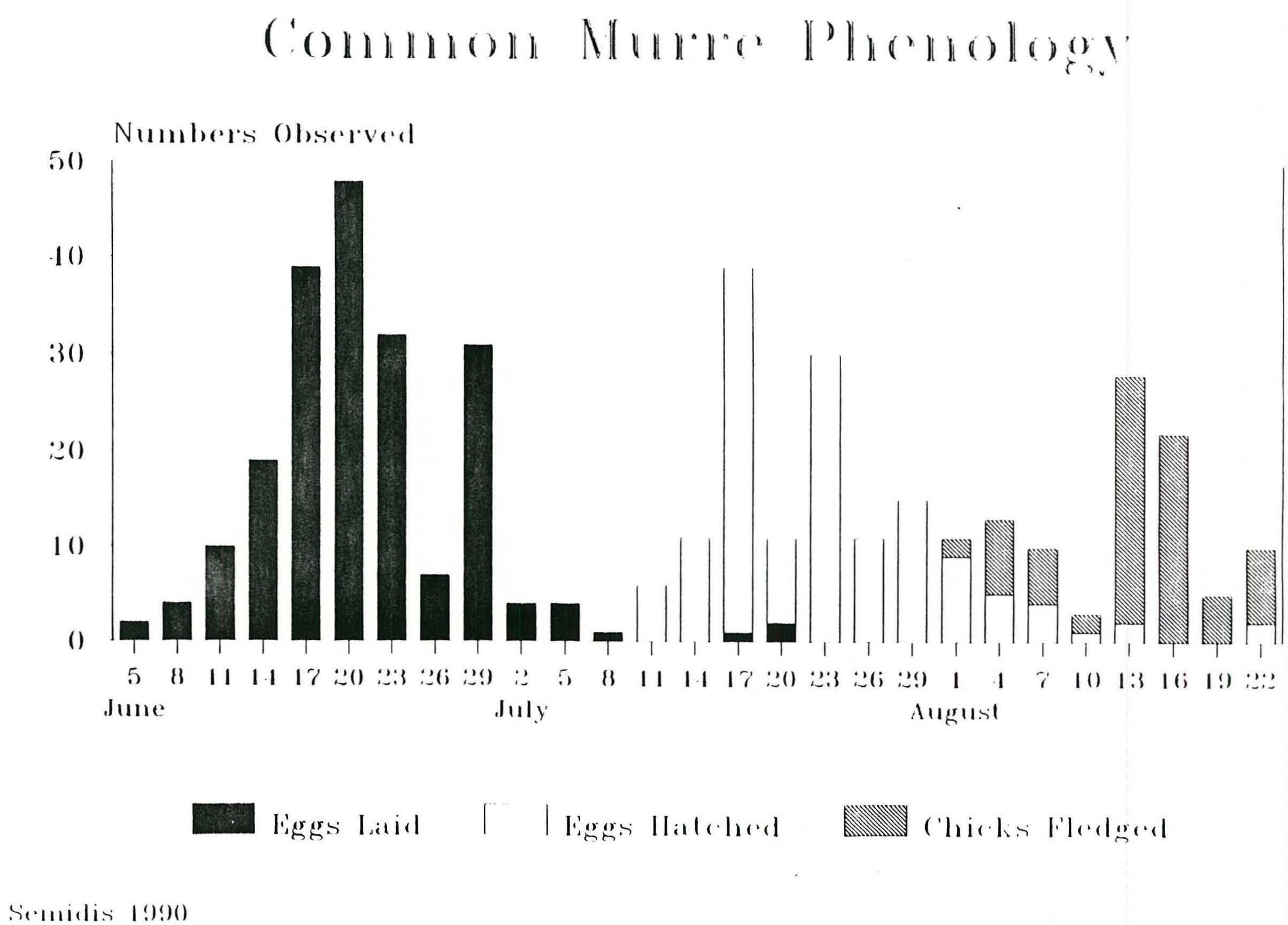


Appendix J. Chronology of thick-billed murre reproductive events for the Semidi Islands, Alaska, 1989.

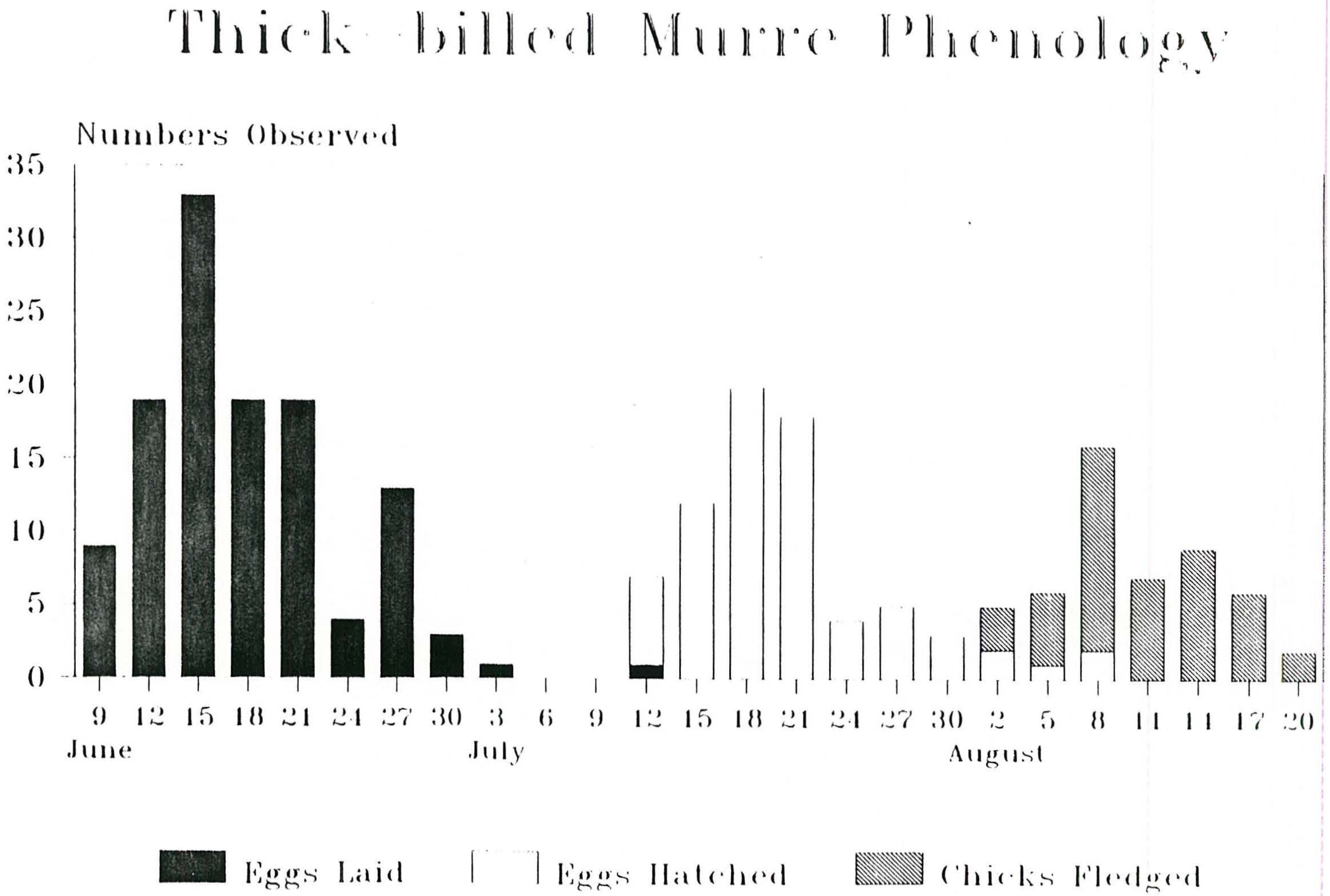


Semidis 1989

Appendix K. Chronology of common murre reproductive events for the Semidi Islands, Alaska, 1990.

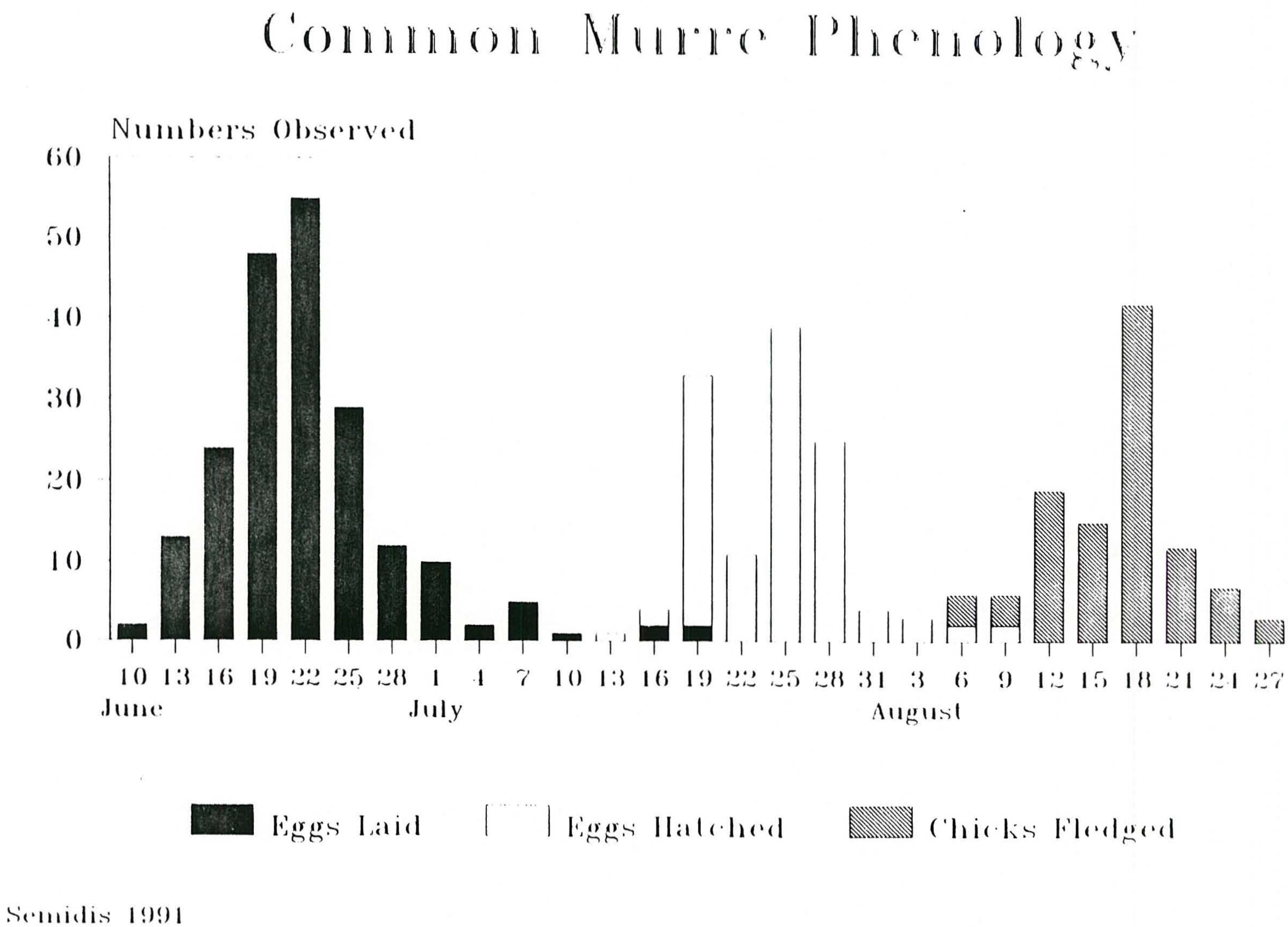


Appendix L. Chronology of thick-billed murre reproductive events for the Semidi Islands, Alaska, 1990.

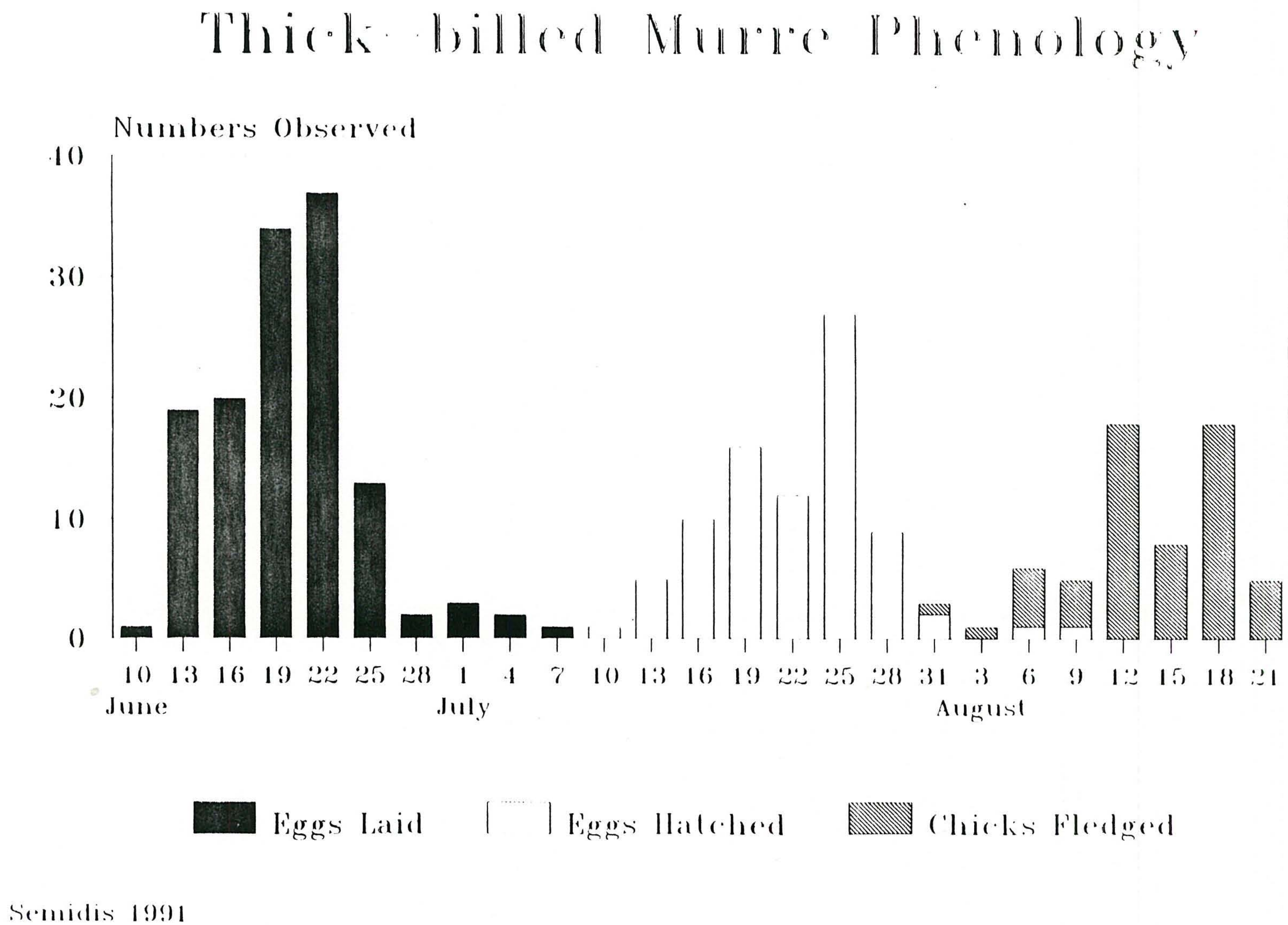


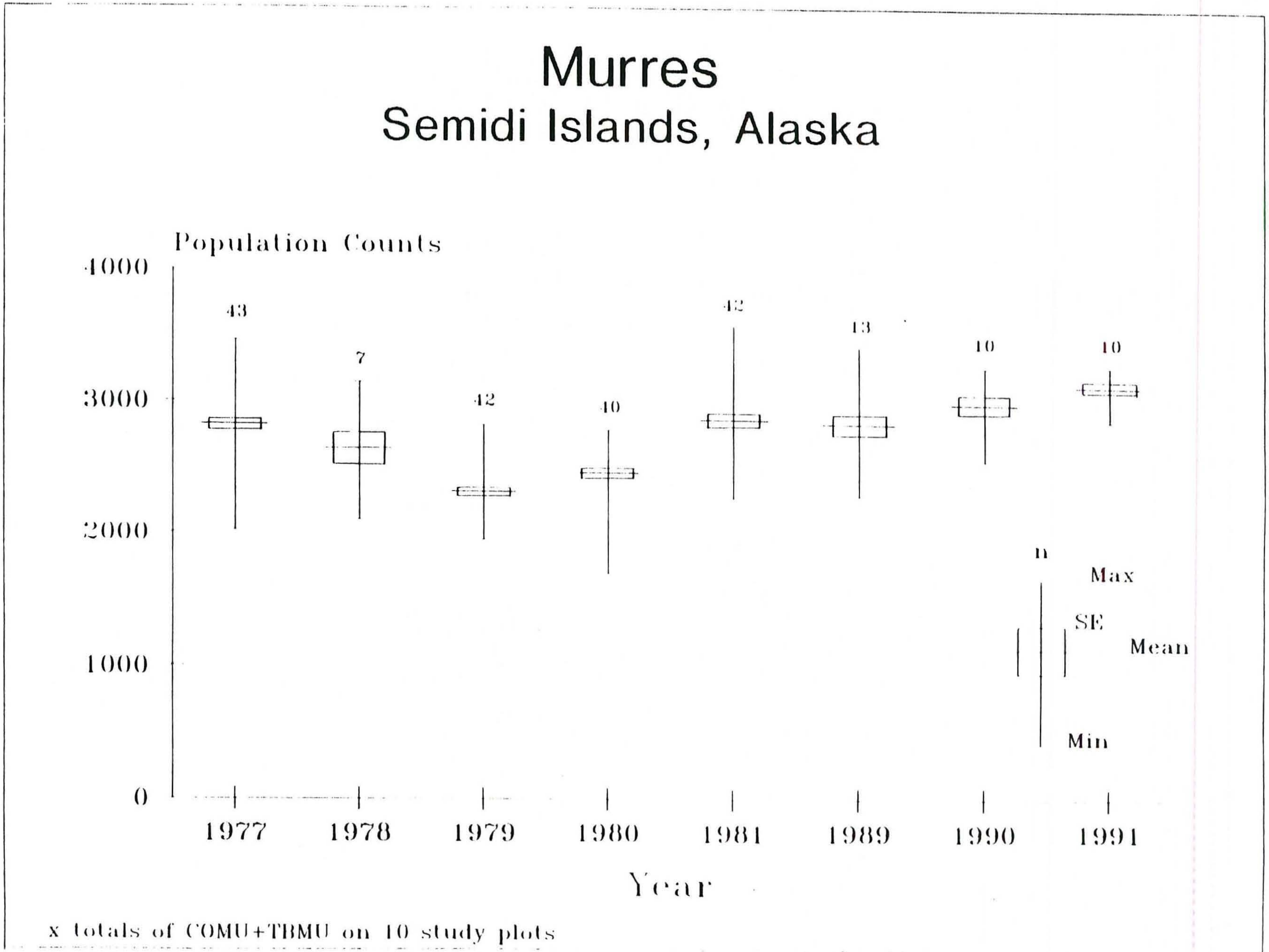
Semidis 1990

Appendix M. Chronology of common murre reproductive events for the Semidi Islands, Alaska, 1991.

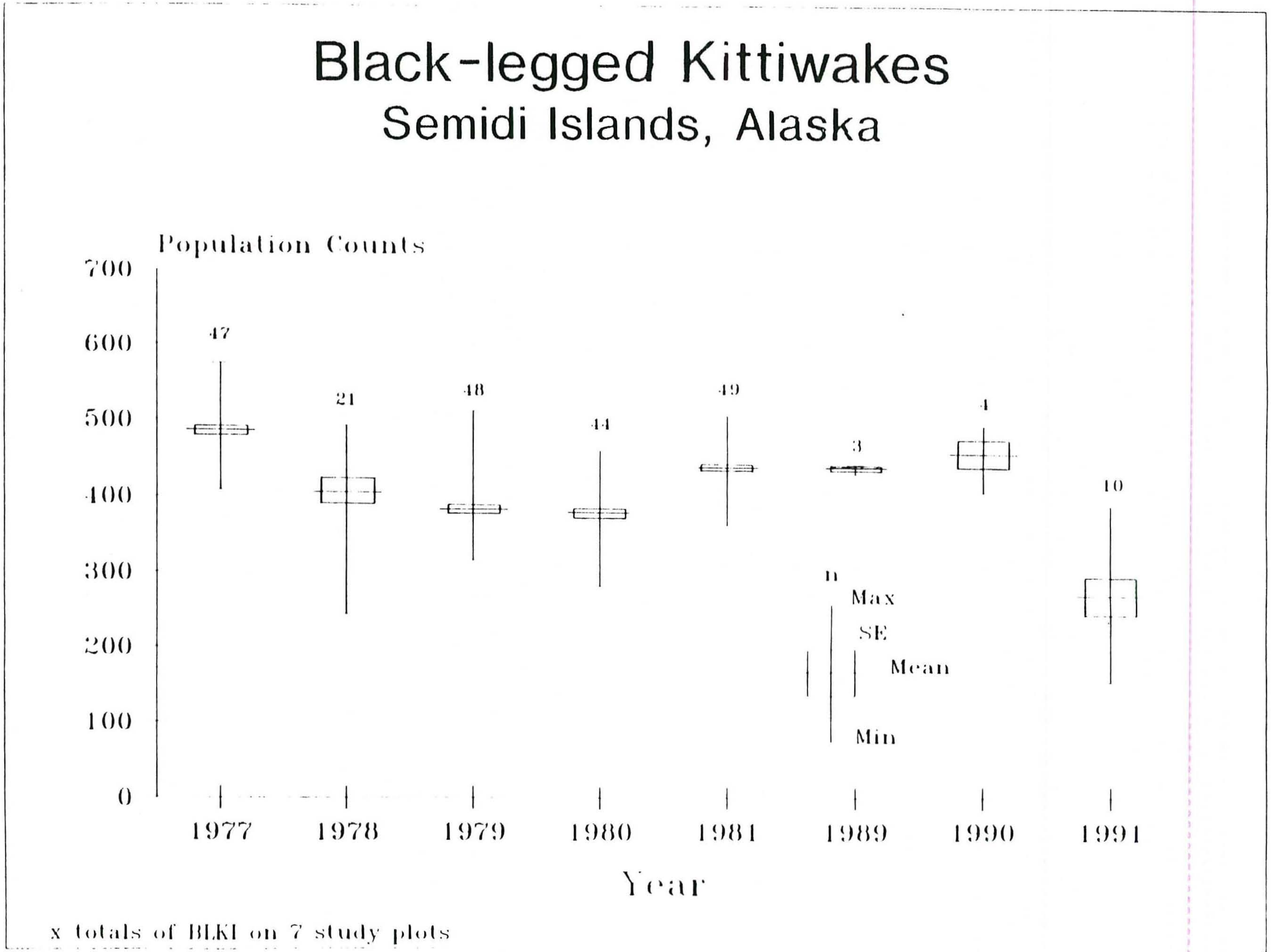


Appendix N. Chronology of thick-billed murre reproductive events for the Semidi Islands, Alaska, 1991.



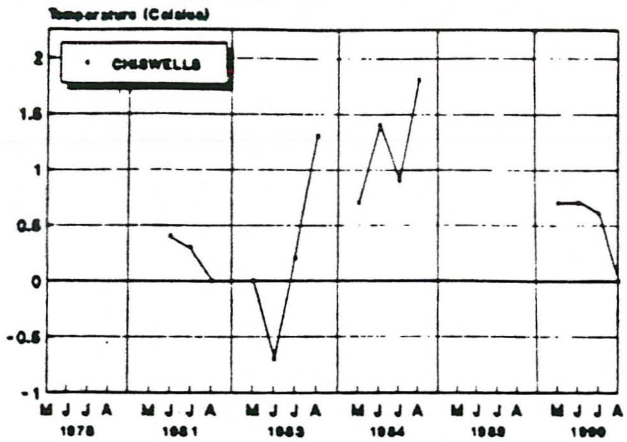


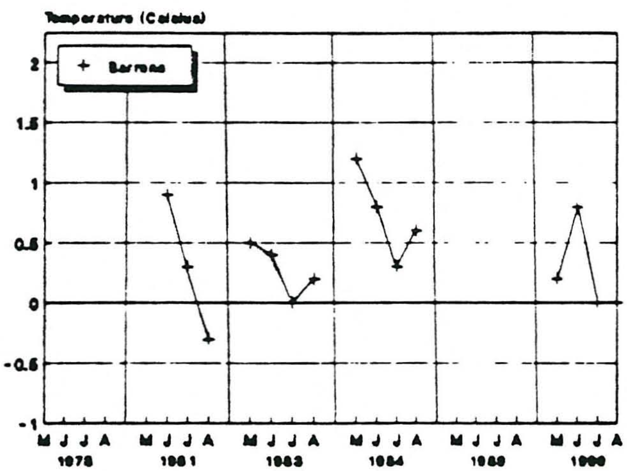
Appendix O. Murre counts on the Semidi Islands, Alaska, 1977-81, 1989-91.

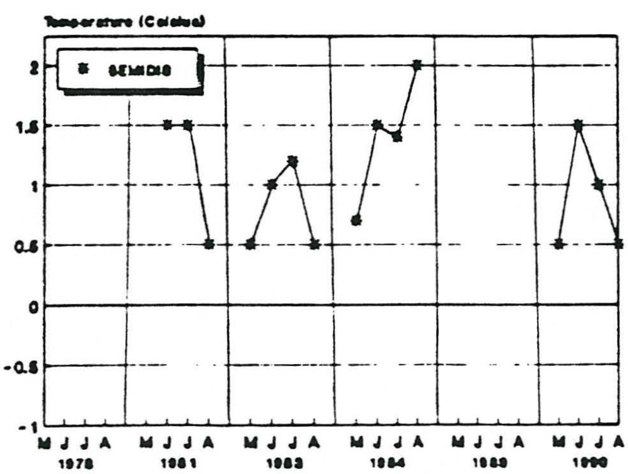


Appendix P. Black-legged kittiwake counts on the Semidi Islands, Alaska, 1977-81, 1989-91.

Appendix Q. Sea surface temperature anomalies for the Chiswell, Barrens and Semidi Islands, Alaska.*







* Missing data expected for later draft.