

POPULATION AND TROPHICS STUDIES OF SEABIRDS
IN THE NORTHERN BERING AND EASTERN CHUKCHI SEAS,
1983

by

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TABLE OF CONTENTS

	<u>Page</u>
ACKNOWLEDGEMENTS	244
I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT.	247
A. Objectives.	247
B. Conclusions.	247
C. Implications With Respect to OCS Oil and Gas Development.	248
II. INTRODUCTION	248
A. General Nature and Scope of Study.	248
B. Specific Objectives	248
C. Relevance to Problems of Oil Development	248
III. CURRENT STATE OF KNOWLEDGE	248
IV. STUDY AREAS	249
v. SOURCES , METHODS, AND RATIONALE OF DATA COLLECTION	249
VI. RESULTS.	252
A. Murres.	252
1. Census.	252
St. Matthew Island	252
Cape Lisburne	255
2. Phenology and Reproductive Success	255
St. Matthew Island	255
Cape Lisburne.	257
3. Food Habits.	257
St. Matthew Island	257
Cape Lisburne.	262

TABLE OF CONTENTS (continued)

	<u>Page</u>
B. Black-legged Kittiwakes.	262
1. Census.	262
2. Phenology, Reproductive Success, and Chick Growth Rates	262
St. Matthew Island	262
Cape Lisburne.	268
3. Food Habits.	268
St. Matthew Island	268
Cape Lisburne.	268
c. Auklets.	268
1. Census.	268
2. Phenology and Chick Growth Rates	270
3. Food Habits.	270
D. Food Web Dynamics.	275
E. Characteristics of Prey Populations.	275
VII & VIII. DISCUSSION AND CONCLUSIONS	279
A. Bering Sea	279
B. Chukchi Sea.	285
IX. NEEDS FOR FUTURE STUDY.	288
x. LITERATURE CITED	289
APPENDIX.	293

1. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

A. Objectives

The objectives of this study were to monitor population numbers, reproductive success and food habits of key seabird species in the Bering and Chukchi seas. The work was undertaken in order to understand the relationships of seabird populations to the physical and biological processes controlling regional marine communities,

B. Conclusions

Black-legged kittiwakes (Rissa tridactyla) suffered a third consecutive year of reproductive failure in the SE Bering. Few, if any, chicks were produced on the Pribilof Is. or on St. Matthew I. The starvation of young shortly after hatching indicated that food availability was low, as it apparently has been in recent years. Common murre (Uris aalge) and thick-billed murre (U. lomvia) on St. Matthew I. had better success than kittiwakes and apparently had a better reproductive season in 1983 than in 1982. Although the census results are somewhat equivocal, murre numbers on St. Matthew I. apparently were higher in 1983 than in 1982 and similar to numbers in 1977.

Invertebrates were important to murre and kittiwakes on St. Matthew I, particularly during June, while walleye pollock (Theragra chalcogramma) was the dominant prey during July and August. The biomass of pollock in diets of both kittiwakes and murre was higher in 1983 than in 1982, suggesting that food availability improved between the two years.

Least auklets (Aethiapusilla) on St. Matthew I. during the breeding season depend on Calanus marshalliae, the dominant large copepod in the middle shelf domain. Feeding occurs near the island where local oceanographic features may concentrate prey. Declines in the number of copepods fed to auklet chicks and declines in chick growth rates between 1982-83 contrast with the general improvement in availability of pollock and in the apparent effect of the improvement on the biology of piscivorous murre and kittiwakes, suggesting multispecies interactions among members of copepod-based food webs in the SE Bering Sea.

Murre and kittiwake numbers at Cape Lisburne showed no change from previous years and reproductive success was good. Arctic cod (Boreogadus saida) were extremely abundant in Ledyard Bay in 1983, accounting for the majority of the carbon flux between lower trophic levels and the seabirds throughout the summer. In spite of the super-abundance of cod, however, the growth rates and survival of kittiwake chicks were lower than in years when sand lance (Ammodytes hexapterus) were available, indicating the pivotal role of sand lance in the economy of kittiwakes in the E Chukchi Sea.

Measurements of water temperature, phytoplankton abundance and zooplankton abundance in Ledyard Bay throughout the summer revealed a close correspondence between changes in all three in late summer and the appearance of sand lance in seabird diets. The results indicate an association between sand lance and numbers of their principal prey and support the hypothesis that hydrographic conditions in spring and early summer on the Bering-Chukchi shelf determine the availability of sand lance to seabirds by affecting the development of prey populations,

C. Implications with Respect to OCS Oil and Gas Development

Information of the kind we have gathered on the biology of seabirds, particularly on the magnitude of fluctuations in population food web and environmental parameters, will help us to detect future changes in seabird populations and to distinguish between those that are natural and those that result from human activity in the marine environment.

II. INTRODUCTION

A. General Nature and Scope of Study

This study has attempted to monitor seabird populations, including their numbers, reproductive success and food habits. Also, we have attempted to elucidate the relationship of seabirds to marine food webs and oceanography. We have focused our attention on murre, kittiwake and auklet, "key" species in the sense that they are among the most easily studied, the most numerous, and the most sensitive indicators of environmental change.

B. Specific (objectives

1. Census murre, kittiwake and auklet at breeding colonies on St. Matthew I. and at Cape Lisburne.
2. Establish permanent census plots for auklets on St. Matthew I.
- 3* Determine the breeding phenologies and reproductive success of murre, kittiwake and auklet.
4. Determine growth rates of kittiwake and auklet chicks.
5. Determine the food habits of murre, kittiwake and auklet.
6. Determine seasonal changes in water temperature and phytoplankton and zooplankton stocks in Ledyard Bay.

C. Relevance to Problems of Oil Development

Accidental oil discharges in the vicinity of seabird congregations elsewhere in the world have caused the deaths of large numbers of birds. Uncertainties associated with oil development in Alaskan waters and the possibility of spills near colonies of important biological significance are causes for concern. In the event of an accident or other negative impact of development, it will be necessary to document the extent of the effect on seabirds and other marine organisms. Our studies are designed to provide baseline information on seabird populations in the Bering and Chukchi seas with which the possible effects of oil development can be assessed.

III. CURRENT STATE OF KNOWLEDGE

Field work on St. Matthew I. in 1983 enlarged upon our studies there in 1982 and those of DeGange and Sowl (1978) in 1977. Results of previous work on the island are presented in Springer et al. (in press a). Our work at Cape Lisburne extended the long-term studies conducted there and at Cape Thompson each year since 1976. A summary account of the work between 1976 and 1981 is

presented in Springer et al. (in press b). Additional information on seabird trophic relationships and regional physical processes in the Bering and Chukchi seas is presented in Springer et al. (1984) and in Springer and Roseneau (in press).

IV. STUDY AREAS

The locations of Cape Lisburne and St. Matthew I. are shown in Fig. 1. Detailed information on these sites is presented in our previous annual reports.

We conducted the auklet studies in two of the major auklet colonies on St. Matthew I. (Fig. 2.). "Pterodactyl Colony" is located on north and west facing talus slopes between about 15-150 m above sea level and has large areas of slump block and boulder rubble at the bottom leading into the sea. These lower areas were covered with lichens and generally contained lower auklet densities than higher in the talus. The second colony, "Arch Colony", is located on northwest-facing talus slopes about 30-200 m above sea level. Large areas of this colony also were covered with lichens as well as a thin layer of soil supporting sphagnum mosses and mat-cushion tundra.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Transportation to and from St. Matthew I. was provided by ARCO Alaska in cooperation with the Alaska Office of NOAA/OMPA. Transportation from the island was provided also by the U.S. Fish and Wildlife Service.

Two people arrived on the island on 8 June after sailing on the work-vessel Bhief Trader, chartered by ARCO, from Dutch Harbor to an exploration support barge anchored near the island. They were lightered ashore from the tug Marine Constructor, also chartered by ARCO. Two additional people arrived on 13 July after a similar trip aboard the Bhief Traveler. Departing the island, two people were lightered to the barge on the tug on 4 August and were then flown to Nome aboard an ARCO-chartered twin engine helicopter on 7 August. The other two people left the island on 11 August, sailing to Homer on the Western Pacific, chartered by the USFWS.

Field work at Cape Lisburne was carried out by two or three people between 16 June - 28 August. Transportation to Cape Lisburne is via commercial air carrier.

Murres and Kittiwakes at both sites were censused on plots established during earlier work. Additional monitoring plots were established at St. Matthew I. The methods for taking the censuses, as well as for determining breeding phenology, chick growth rates and food habits were the same as those used in all other years (see Springer et al. 1984, in press b) with the following additions. The equations used for estimating the sizes of pollock were:

$$\text{Otoliths} > 10.0 \text{ mm } Y = (3,175 X^1 - 9.770)$$

$$\text{Otoliths} \leq 10.0 \text{ mm } Y = (2.246 X) - 0.510$$

where Y = fish length in cm

X = otolith length in mm; from Frost and Lowry (1981),

$$\text{and, } W = 0.0075 L^{2.977}$$

where W = fish weight in g

L = fish length in cm; from Pereyra et al. (1976) in Smith (1979).

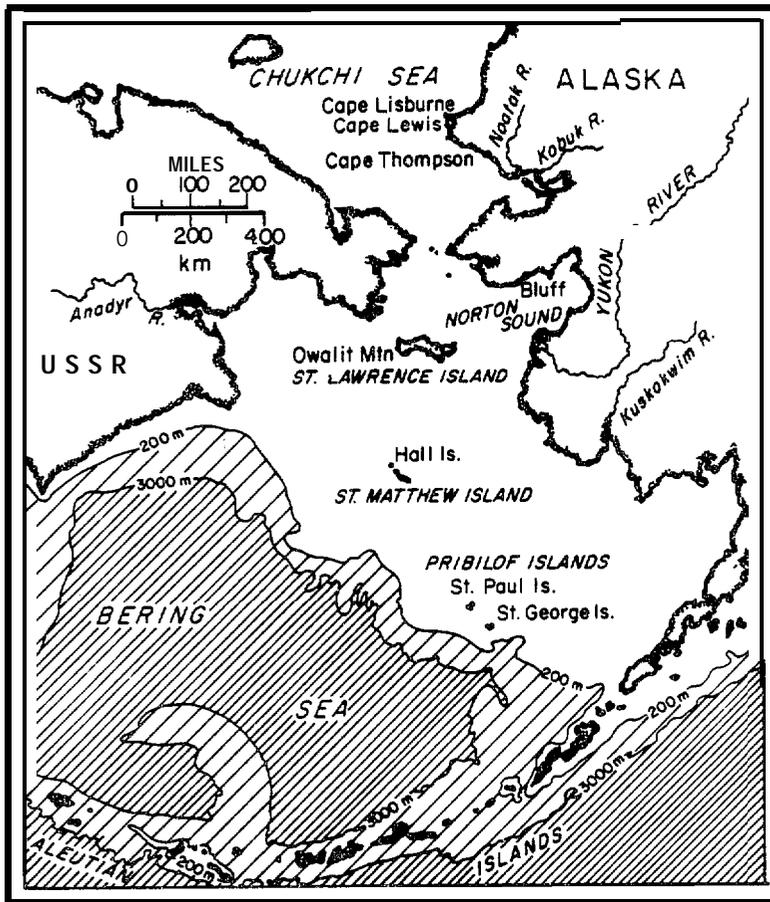


Fig. 1. Map of the study area in the Bering and Chukchi seas.

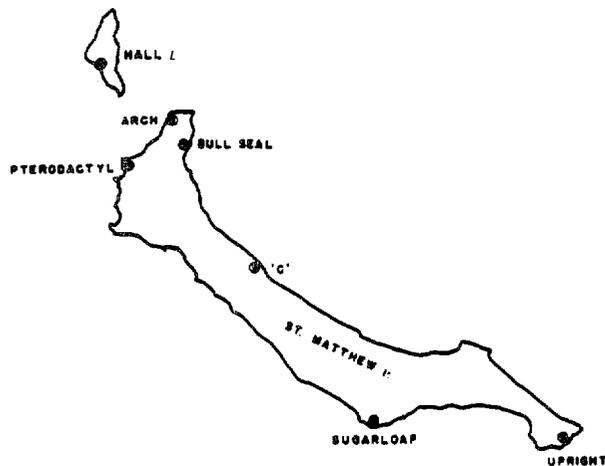


Fig. 2. Approximate location of the largest auklet breeding colonies on St. Matthew I. and Hall I.

Young-of-year pollock were all assigned a weight of 0.59, the approximate midpoint of weights of young-of-year pollock determined by T. Nishyama (unpubl. data). The length-weight estimates for capelin were taken from K. Pahlke (unpubl. data) and are as follows:

fish length < 80 mm, weight estimate = 5 g
80 mm < fish length < 115 mm, weight estimate = 10 g
fish length > 115 mm, weight estimate = 20 g.

The auklet census plots were chosen on the basis of visibility and representativeness with regard to auklet density. The plots were placed variously in areas of high, medium and low density and in transition zones between areas of different density. Counting positions were located in most cases such that more than one plot could be censused from each position. All positions were at least 40 m away from the plots to minimize disturbance of birds during the counts. Photographs were taken to document the locations of all plots.

Two methods were employed to establish indices of auklet numbers on the census plots, the "net movement" method described by Byrd et al. (1983) and a modification of the "surface average" method described by Bedard (1969a).

Bedard (1969a) counted the number of birds in 14.2 x 14.2 m plots every half hour between 0500 and 0800 hours during the last few days preceding egg-laying. The censuses were taken on three successive days and the second, third and fourth-highest counts were averaged. For our surface average counts we established 11 census plots in Pterodactyl Colony and 6 plots in Arch colony. The plots were 10x10 m in surface area. We counted the number of each species of auklet on each plot once every 15 minutes during the entire morning and early-afternoon activity period, generally between the hours of 0500-1500 in early June. Hours of peak activity became later as the season progressed, so we adjusted our census period to correspond to that change. Counts were made during three phonological periods: pre-laying (arrival of birds on the plots until 17 June), incubation (18 June - 16 July), and chick feeding (17 July - sea-going). We averaged the five highest counts from each day counts were made. Additional counts were made of the proportions of immature auklets and of adults carrying food.

Two water sampling stations at Cape Lisburne were occupied at intervals of about three days or less except when ice or weather conditions prevented boat travel. The stations were approximately 2 km offshore; one station was directly north of the Cape Lisburne Air Force Station and the other was directly west of Kay Creek on the west side of the cape. The bottom depth of each was approximately 14 m. One liter water samples for the determination of chlorophyll-a were taken in replicate from the depths of 1, 5 and 15 m. The samples were filtered through glass fiber filters within 30 minutes of collection, buffered with magnesium carbonate and frozen in air-tight, dark containers over calcium carbonate within 20 minutes of filtration according to the method of Strickland and Parsons (1972). The samples remained frozen until they were extracted in 90% acetone and read with a Turner Designs fluorimeter in the laboratory (Strickland and Parsons 1972).

Zooplankton were collected in a 0.5 m, 0.250 mm mesh net towed vertically from the bottom to the surface. The samples were preserved in 5% formalin and

identified by K. Coyle at the Institute of Marine Science, University of Alaska. Fresh sand lance regurgitated by Kittiwake chicks were preserved in 5% formalin and the contents of their stomachs also were analysed by K. Coyle.

We have extended the notation for observers used in our earlier reports. As used in this report, the notations are: C - A. Springer, E - D. Roseneau, N - D. McGuire, O - G. van Vliet, P - P. Martin, Q - B. Cooper, R - S. Cooper.

VI. RESULTS

A. Murres

1. Census

The results of the murre censuses on St. Matthew I. and Cape Lisburne are detailed in Appendix Tables 1 and 2, respectively. Included in Appendix Table 1 are the diurnal compensation counts of murres from St. Matthew I.

St. Matthew I.

Results of the murre census on 15 plots on St. Matthew I. that contained murres and that were censused in all three years of study [1977 - DeGange and Sowls (1978), 1982 - Springer et al. (in press a)] are summarized in Table 1. Friedman's and Multiple Comparisons tests of significance indicated that the uncompensated scores in 1982 were significantly lower than those in 1977 and 1983, which were equivalent ($.01 < P < .025$).

Interpretation of the scores compensated for diurnal activity patterns are less straight-forward. DeGange and Sowls (1978) noted the counting times for only 8 of the plots and did not make any diurnal activity counts in 1977. We counted a particular plot at several different times of the day in 1982, but all counts were not on the same day. Therefore, daily (day-to-day), as well as diurnal, changes in attendance were incorporated into the activity pattern we used to compensate the 1982 scores. In 1983 we made repeated counts of a plot at different times of the day on the same day. A strong correlation over the daily cycle existed between the 1982 and 1983 curves (Fig. 3), however, the magnitude of the hourly changes differed considerably; in 1982 there was a larger proportional change between the morning low and the evening peak numbers, perhaps reflecting the overall effect of daily changes in attendance.

The 1982 census scores for all 15 plots compensated by using both the 1982 and 1983 diurnal activity curves, and the 1983 scores compensated by using the 1983 curve are summarized in Table 1. Table 2 summarizes the uncompensated and compensated scores for 8 plots where the counting times were recorded in 1977; the 1977 and 1982 scores have been compensated using both the 1982 and 1983 diurnal curves. When the scores from all three years are compensated using the 1983 curve, the same pattern as in the uncompensated scores is obtained, i.e., numbers in 1977 and 1983 are equivalent, while the number in 1982 is about 40% lower. However, when the 1982 curve is used to compensate the 1977 and 1982 scores, as done in our previous report, the numbers in 1982 and 1983 are equivalent and are about 45% lower than the number in 1977.

Table 3 summarizes the results of repeated counts of 3 subplots at St. Matthew I. in 1982 and 1983. The sum of the 1983 counts averaged 84% higher than the sum of the 1982 counts. Table 4 lists the results of repeated counts in 1982 and 1983 of a subplot containing only thick-billed murres. The mean of the

Table 1. Numbers of murre on Plots D-1, 2 and 4-9; E-1, 3, and 6-8; and F-1, 3, 4 and 6 at St. Matthew Island. Data for 1977 are from DeGange and SOWLS (1978).

Year	Uncompensated Scores	Compensated Scores
1977	42,882	- -
1982 ^A	24,634	49,120
1982 ^B	- -	30,782
1983	37,094	50,436

^A Scores compensated using 1982 diurnal counts.

^B Scores compensated using 1983 diurnal counts.

Table 2. Numbers of murre on Plots E-3 and 6-8; and F-1, 3, 4 and 6 at St. Matthew Island. Data for 1977 are from DeGange and SOWLS (1978).

Year	Uncompensated Scores	Compensated Scores
1977 ^A	20,975	54,450
1977 ^B	--	29,559
1982 ^A	15,270	27,450
1982 ^B	--	18,858
1983	22,5(52)	30,444

^A Scores compensated using 1982 diurnal counts,

^B Scores compensated using 1983 diurnal counts.

Table 3. Uncompensated numbers of murre on three subplots at St. Matthew Island where replicate counts were made in 1982 and 1983.

Subplot	1982			1983		
	n	x	s	n	x	s
9a	2	1,502	194	2	4,157	730
9b	5	1,621	833	6	1,985	690
9d	2	2,232	1,057	3	3,086	333
Total :		5,355			9,842	

Table 4. Counts of common murre (COMU) and thick-billed murre (TBMU) on two subplots in plot E-1 on St. Matthew Island, 1982 - 1983A.

Year	Date	Subplot	Time ^B	COMU	TBMU
1982	25 Jul	1	1521	0	124
		2	1732	0	187
	1 Aug	i	1530	0	139
			1930	0	133
	9 Aug	1	1520	0	83
1983	16 Jul	1	1905	0	154
	20 Jul	1	1241	0	163
	28 Jul	1	1611	0	161
	5 Aug	2	1630	13	134

^AAll counts were made by Observer E.

^BBering Daylight Time.

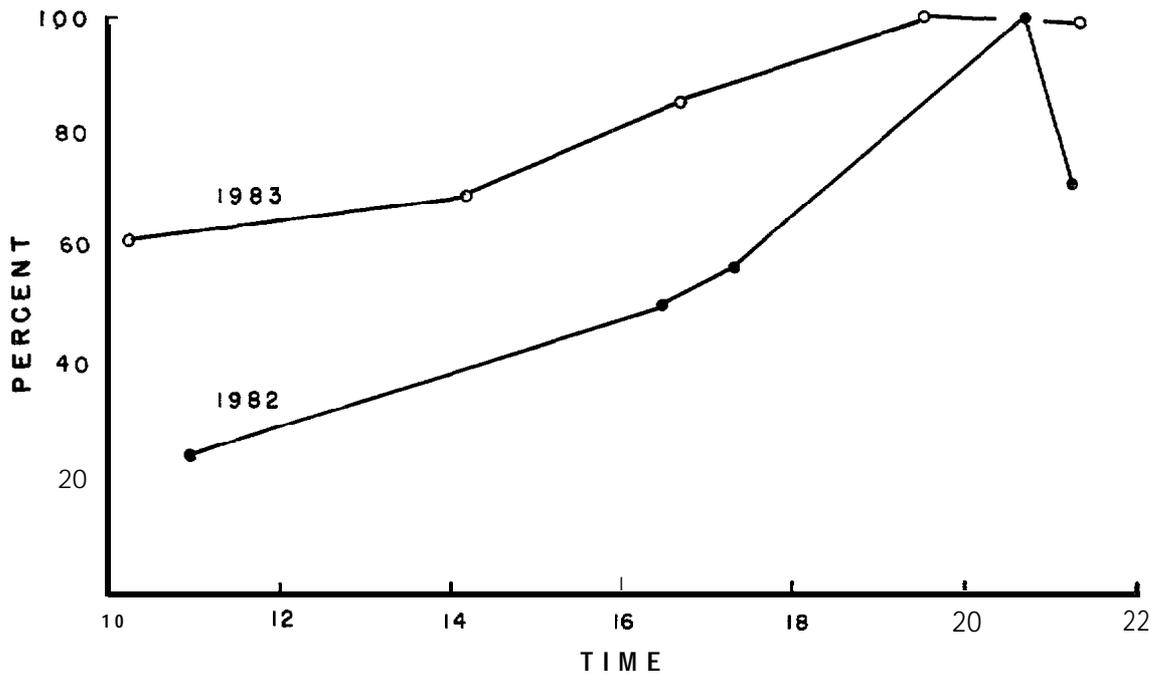


Fig. 3. Diurnal activity patterns of murrees on St. Matthew I. in 1982 and 1983.

counts in 1983, 159, is 33% higher than the mean of the counts. in 1982, 120.

Common and thick-billed murrees were differentiated during single counts of 7 subplots on St. Matthew I. (Table 5) and of 13 subplots on Hall I. (Appendix Table 3). Six of the subplots on St. Matthew I. were counted similarly by DeGange and Sows in 1977. A comparison of the proportions of the two species in 1977 and 1983 shows no consistent difference in relative numbers of the two species between years. Three additional areas were established in 1983 where repeated counts of all species were made (Appendix Tables 4-6).

Cape Lisburne

A summary of the murre censuses at Cape Lisburne is presented in Table 6, including the results from 1984 (Springer and Byrd, unpubl. data). Compensation in all years was done using the diurnal curve obtained in 1977. The results are remarkably consistent with other years, suggesting that there has been no long-term change in numbers since 1974.

2. Phenology and Reproductive Success

St. Matthew I.

Two plots were located where nesting thick-billed murrees could be easily viewed. Our counts of the numbers of eggs, chicks and adults on those plots are listed in Tables 7 and 8. We were unable to find similar plots where sufficient numbers of common murrees were visible for meaningful information. The counts of the thick-billed murre egg plots will provide a basis for comparing productivity in future years.

Table 5. Ratios of common murre (COMU) and thick-billed murre (TBMU) at St. Matthew Island, 1977 and 1983. Data for 1977 data are from DeGange and Sowls 1978; A. Sowls, unpubl. data.

Location	Time ¹	Date	COMU	TBMU	COMU/TBMU
Glory of Russia Cape					
(1st Cove - left)	ND ²	12 Jul 1977	59	203	0.3
	1303	21 Jul 1983	44	339	0.1
(1st Cove - right)	ND	12 Jul 1977	19	95	0.2
	1415	21 Jul 1983	300	466	0.6
(2nd Cove - left) ³	1700	19 Jul 1977	0	276	0
	1440	21 Jul 1983	22	137	0.2
(2nd Cove - right)	ND	1977	ND	ND	ND
	1440	21 Jul 1983	49	236	0.2
(Share-side of D-8)	1730	19 Jul 1977	194	0	0
	1338	21 Jul 1983	235	0	0
<Sea-side of D-8)	ND	1977	ND	ND	ND
	1338	21 Jul 1983	270	52	5.2
Bull Seal Point					
(Northwest side)	1130	9 Jul 1977	125	57	2.2
	1040	1 Aug 1983	197	47	4.2
(Southeast side)	1100	8 Jul 1977	26	39	0.7
	ND	1983	ND	ND	ND
Cape Upright					
(Plot No. 1)	ND	15 Jul 1977	6	274	<0.1
	ND	1983	ND	ND	ND
(Plot No. 2)	ND	15 Jul 1977	13	37	0.4
	ND	1983	ND	ND	ND
Totals (1977 plots recounted in 1983):		1977	272	631	0.4
		1983	798	989	0.8
Totals (all plots counted each year):		1977	442	981	0.5
		1983	1,117	1,277	0.9

¹ Bering Daylight Time.

² ND = no data.

³ The "2nd Cove" total reported by DeGange and Sowls (1978) is a count of the cove's north side (see DeGange and Sowls 1978, Figure 6).

Table 6. Summary of murre census results at Cape Lisburne.

Year	Uncompensated Scores		Compensated Scores	
	Sample A ¹	Sample B ²	Sample A	Sample B
1976	9,925	14,100	NA	NA
1977	10,106	15,501	14,779	22,138
1978	9,524	NA	14,094	NA
1979	10,390	16,123	17,342	26,050
1981	10,108	14,236	11,968	17,735
1983	9,401	16,395	15,110	25,151
1984	11,228	16,283	22,148	30,622

¹ Plots 11, 12, 25, 26, 30, and 32.

² Plots 11, 12, 25, 26, 30, 32, 65, 66, 70 and 72.

Common murre laid earlier than thick-billed murre as they did in 1982. Common murre began carrying fish, particularly capelin, to the colonies about 15 July and many were carrying fish by 26 July. The first common murre chick was seen on 19 July and the smallest chicks seen on 9 August were about 8-10 days old. These hatching dates are about 2-3 weeks earlier than in 1982 (see Springer et al. in press a) and are comparable to hatching dates on the Pribilof Is. during 1975-79 (Hunt et al. 1981a). Sea-going of common murre was first seen on 1 August, but few chicks left the cliffs before about 10-14 August. Thick-billed murre were first seen carrying fish on 27 July and many were carrying fish by 9 August. The first thick-billed murre chicks were seen on 7 August and were less than about five days old. On 9 August the estimated ages of 18 thick-billed murre chicks were: 1-2 days old, 6; 2-4 days old, 4; 4-6 days old, 8; } 6 days old, 0.

Cape Lisburne

The first murre chick was seen on 2 August, a date somewhat later than average (Table 9). Murre eggs and chicks were abundant on the ledges indicating that reproductive success was good.

3* Food Habits

St. Matthew I.

Food habits of murre at St. Matthew I. in 1982 and 1983 are summarized in Tables 10 and 11, respectively. Pollock and a taxon we have tentatively identified as belonging to the family Pleuronectidae were both important contributors

Table 7. Counts of adult thick-billed murre, eggs and chicks on eggplot 1 at Arch Colony, St. Matthew Island, 1983.

	27 Jun	4 Jul	13 Jul	22 Jul	1 Aug
Number of adults (time ¹)	72 (1500)	37 (0600) 31 (1500)	24 (0845) 28 (1135) 47 (1335)	66 (0900) 48 (1230) 49 (1530)	ND ²
Number of eggs	12	3	ND	ND	2
Number of chicks	0	0	ND	ND	3
Number of adults sitting on eggs or chicks	0	6	ND	ND	0
Number of eggs laid since last visit	12	0	ND	ND	0
Number of eggs or chicks lost since last visit	0	3	ND	ND	7

¹Bering Daylight Time.

² ND = no data.

Table 8. Counts of adult thick-billed murre, eggs and chicks on eggplots 1-3 at North Camp Colony, St. Matthew Island, 1983.

	27 Jun	3 Jul	22 Jul	1 Aug
Number of adults (time ¹)	116 (1615)	9% (1750)	116 (0900) 89 (1530)	63 (ND ²)
Number of eggs	21	24	ND	10
Number of chicks	0	0	ND	10
Number of adults sitting on eggs or chicks	0	0	ND	2
Number of eggs laid since last visit	21	5	ND	6
Number of eggs or chicks lost since last visit	0	2	ND	7

¹Bering Daylight Time.

² ND = no data.

Table 9. Approximate date of first hatching of murre chicks at Cape Lisburne.

Year	First Hatching
1976	6 Aug
1977	1 Aug
1978	21 Jul
1979	22 Jul
1980	1 Aug
1981	26 Jul
1983	2 Aug

Table 10. Occurrence of major taxa in diets of thick-billed murre (TBMU), common murre (COMU), and black-legged Kittiwakes (BLKI) on St. Matthew Island, 15 July - 8 August 1982.

	TBMU		COMU		BLKI	
	n	% ^A	n	% ^A	n	% ^A
Number examined	34	(100)	42	(100)	16	(100)
Number empty	10	(30)	9	(21)	2	(13)
Frequency of invertebrates	12	35	19	45	12	75
Frequency of fishes	21	62	31	74	1	6
A. Frequency of Occurrence						
<u>Theragra chalcogramma</u>	13	54	28	85	0	0
<u>Gadus macrocephalus</u>	0	0	1	3	0	0
Cottidae	7	29	7	21	0	0
<u>Mallotus villosus</u>	0	0	2	6	0	0
Pleuronectidae ^B	6	25	20	61	1	7
Unidentified fishes	3	13	2	6	0	0
Shrimps	6	25	0	0	1	7
Crabs	1	4	2	6	2	14
<u>Parathemisto</u> spp.	3	13	5	15	1	7
Grammaridae	5	21	1	3	1	7
<u>Thysanoessa</u> spp.	0	0	2	6	2	14
Mysidae	1	2	1	1	0	0
Snails	2	8	0	0	7	50
Squids	0	0	0	0	1	7
Polychaetes	8	33	4	12	8	57
Unidentified invertebrates	0	0	7	21	1	7
B. Numbers of Individuals						
<u>Theragra chalcogramma</u>	640 ^C	68	464	71	0	0
<u>Gadus macrocephalus</u>	0	0	1	<1	0	0
Cottidae	31	3	8	1	0	0
<u>Mallotus villosus</u>	0	0	3	<1	0	0
Pleuronectidae ^B	266	28	169	26	1	100
Unidentified fishes	3	<1	4	<1	0	0
C. Estimated Wet Weight (g)						
<u>Theragra chalcogramma</u>	536	63	1,247	90	0	0
<u>Gadus macrocephalus</u>	0	0	5	<1	0	0
Cottidae	170	20	0	0	0	0
<u>Mallotus villosus</u>	0	0	35	3	0	0
Pleuronectidae ^B	133	16	85	6	0.5	100
Unidentified fishes	6	<1	8	<1	0	0

^A Values in parentheses are the frequency among the total number of birds examined. Values not in parentheses are the percent frequency, numbers, or weight, respectively, among birds containing identifiable prey remains.

^B Tentative identification.

^C One specimen contained 400 individuals, and a second specimen contained 209 individuals.

Table 11. Occurrence of major taxa in diets of thick-billed murre (TBMU), common murre (COMU), and black-legged Kittiwakes (BLK.) on St. Matthew Island, 7 June - 9 August 1983.

	TBMU		COMU		BLKI	
	n	% ^A	n	% ^A	n	% ^A
Number examined	57	(100)	79	(100)	53	(100)
Number empty	5	(9)	4	(5)	3	(6)
Frequency of invertebrates	39	75	18	24	35	70
Frequency of fishes	37	71	71	95	21	42
A. Frequency of Occurrence						
<u>Theragra chalcogramma</u>	34	65	63	84	17	36
Cottidae	2	4	2	3	0	0
<u>Mallotus villosus</u>	1	2	20	27	3	6
<u>Clupea harengus</u>	1	2	1	1	0	0
Pleuronectidae ^B	15	29	24	32	0	0
Shrimps	1	2	2	3	1	2
Crabs	1	2	0	0	0	0
<u>Parathemisto</u> spp.	6	12	2	3	3	6
Gammaridae	10	19	0	0	4	9
<u>Trixanopsis</u> spp.	2	4	7	9	1	2
Mysidae	1	2	1	1	0	0
Iso-poda	3	6	0	0	2	4
Squids	0	0	0	0	3	6
Polychaetes	8	15	1	1	12	26
Pteropoda	0	0	0	0	8	17
Unidentified crustaceans	15	29	9	12	5	11
Mollusca	0	0	0	0	3	6
B. Numbers of Individuals.						
<u>Theragra chalcogramma</u>	317	84	786	64	41	91
Cottidae	15	4	4	<1	0	0
<u>Mallotus villosus</u>	2	<1	52	4	4	9
<u>Clupea harengus</u>	1	<1	2	<1	0	0
Pleuronectidae ^B	43	11	378 ^C	31	0	0
C. Estimated Wet Weight (g)						
<u>Theragra chalcogramma</u>	1,533	90	5,773	83	388	80
Cottidae	75	4	7	<1	0	0
<u>Mallotus villosus</u>	40	2	955	14	100	20
<u>Clupea harengus</u>	30	2	60	<1	0	0
Pleuronectidae ^B	22	1	189 ^D	3	0	0

^A Values in parentheses are the frequency among the total number of birds examined. Values not in parentheses are the percent frequency numbers, or weight, respectively, among birds containing identifiable prey remains.

^B Tentative identification.

^C One specimen contained 310 individuals.

^D One specimen contained 155 individuals.

of biomass to murre diets in 1982. The importance of the flatfish in 1983, however, was much less than pollock, which dominated murre diets that year. Capelin (Mallotus villosus) were of moderate importance to croon murre in 1983.

Invertebrates were taken frequently by thick-billed murre in both years (Table 12) and probably contributed significantly to their diets, particularly during early summer. Common murre characteristically took fewer invertebrates, except in the June sample period. It was not possible to estimate the numbers or biomass of the invertebrate fraction of the stomach contents in most cases because the prey organisms were highly fragmented.

The numbers and estimated biomass of total fishes in murre diets are summarized in Tables 13-16. A greater number of fishes with a greater estimated biomass was recovered from croon murre than from thick-billed murre. For both species, the biomass of fishes was lowest in June and increased steadily throughout the summer in both years. The numbers of fishes and their estimated biomass were much higher in 1983 than in 1982.

The importance of young-of-year pollock declined dramatically between 1982-1983 (Table 17).

Cape Lisburne

Food habits of murre at Cape Lisburne in 1983 are summarized in Table 18. Cods, primarily Arctic cod with smaller numbers of saffron cod (Eleginus gracilis), dominated the diets of both species throughout the summer. The availability of cods in 1983 was unprecedented in the many prior years of study at Cape Lisburne. Other prey taxa were of little importance.

A sense of the magnitude of the contribution of cods can be seen in Table 19, which compares the numbers and estimated biomass of fishes in thick-billed murre diets between years. The average numbers of fishes/bird were not very different than in other years, although the average biomass/bird was generally much higher. This is because in other years taxa such as sculpin, sand lance and capelin contributed substantially to total numbers; however, because these taxa were generally smaller than cods, particularly Arctic cod, their contribution in terms of biomass was relatively small.

B. Black-legged Kittiwakes

1. Census

St. Matthew I.

Results of the census of black-legged Kittiwakes on St. Matthew I. are detailed in Appendix Table 7. The results of the censuses of 12 plots counted in three years of study are summarized in Table 20. The total number of birds and nests on the 12 plots increased from 1982 to 1983, but the increase in the number of nests was small. Little difference in the number of nests on those plots has been recorded in the three years that censuses have been taken.

2. Phenology, Reproductive Success and Chick Growth Rates

St. Matthew I.

On 19 July we saw one nest with two small chicks and on 24 July we found

Table 12. Frequency of occurrence (%) of invertebrates in diets of thick-billed murre (TBMU), common murre (COMU), and black-legged kittiwake (BLKI) at St. Matthew Island. Values in A include all specimens; values in B exclude empty specimens.

Year		Jun			1-20 Jul			21 Jul-10 Aug		
		TBMU	COMU	BLKI	TBMU	COMU	BLKI	TBMU	COMU	BLKI
1982	A	ND [†]	ND	ND	33	11	100	40	54	71
	B				100	17	100	50	67	100
1983	A	71	50	63	47	0	84	85	9	38
	B	89	52	68	47	0	84	85	9	43

[†] ND = no data.

Table 13. Numbers and estimated biomass of fishes in diets of common murre at St. Matthew Island. Arithmetic mean number and weight (g)/bird.

Year	Jun			1-20 Jul			21 Jul-10 Aug		
	n	\bar{x}	s	n	\bar{x}	s	n	\bar{x}	s
<u>Numbers</u>									
1982		ND ^A		9	2	3	33	20	43
1983	30	7	10	13	14	14	34	24	56
<u>Biomass</u>									
1982		ND		9	10	17	33	46	62
1983	30	54	80	13	115	73	34	130	127

^A ND = no data.

Table 14. Numbers and estimated biomass of fishes in diets of thick-billed murrelets at St. Matthew Island, Arithmetic mean number and weight (g)/bird,

Year	Jun			1-20 Jul			21 Jul-10 Aug		
	n	\bar{x}	s	n	\bar{x}	s	n	\bar{x}	s
Numbers									
1982		ND ^a		9	<1	1	25	37 ^b	119
1983	24	2	4	14	10	19	19	10	16
Biomass									
1982		ND		9	3	6	25	48 ^c	118
i 1983	24	9	21	14	39	43	19	52	59

^a ND = no data.

^b One specimen contained 480 individuals and a second specimen contained 336 individuals.

^c One specimen contained 359 g and a second specimen contained 459 g.

Table 15. Numbers and estimated biomass of fishes in diets of common murrelets at St. Matthew Island. Geometric mean number and weight (g)/bird.

Year	Jun			1-20 Jul			21 Jul-10 Aug		
	n	\bar{x}	$\pm 1s$	n	\bar{x}	$\pm 1s$	n	\bar{x}	$\pm 1s$
Numbers									
i 1982		ND		9	2	. #4	33	6	1-25
1983	30	3	.9-10	13	10	3-28	34	12	4-36
B i o m a s s									
1982		ND		9	3	.4-17	33	11	1-99
i 1983	30	16	2-110	13	63	11-365	34	73	16-327

ND = no data.

Table 16. Numbers and estimated biomass of fishes in diets of thick-billed murrelets at St. Matthew Island. Geometric mean number and weight (g)/bird.

Year	Jun			1-20 Jul			21 Jul-10 Aug		
	n	\bar{x}	$\pm 1s$	n	\bar{x}	$\pm 1s$	n	\bar{x}	$\pm 1s$
Numbers									
1982		ND		9	1	.9-1	25	3	.5-16
1983	24	2	.7-4	14	4	.5-16	19	6	2-17
Biomass									
1982		Nil		9	1	.3-4	25	3	.3-31
1983	24	1	.2-79	14	14	2-101	19	22	4-125

ND = no data,

Table 17. Relative importance (%) of young-of-year pollock among all pollock in diets of thick-billed murrelets (TBMU), common murrelets (COMU), and black-legged Kittiwakes (BLKI) at St. Matthew Island, 15 July - 8 August 1982 and 7 July - 9 August 1983.

	TBMU		COMU		BLKI	
	1982	1983	1982	1983	1982	1983
Frequency of occurrence	69	37	82	45	0	0
Number	99	68	88	21	0	0
Biomass	59	8	16	1	0	0

Table 13s Occurrence of major taxa in diets of thick-billed murre (TBMU), common murre (COMU), and black-legged Kittiwake (BLKI) at Cape Lisburne, 16 June - 28 August 1983.

	TBMU		COMU		BLKI	
	n	% ^A	n	% ^A	n	% ^A
Number examined	104	(100)	25	(100)	61	(100)
Number empty	2	(2)	0	(0)	1	(2)
Frequency of invertebrates	46	45	7	28	7	12
Frequency of fishes	101	99	25	100	40	100
A. Frequency of Occurrence						
Cods	89	87	25	100	60	100
Sculpins	44	43	7	28	3	5
Sand lance	11	11	5	20	2	3
Capelin	2	2	1	4	3	5
Other	28	27	7	28	9	15
Shrimps	11	11	0	0	0	0
Amphipods	8	8	5	20	0	0
Mysids	4	4	1	4	0	0
Euphausiids	0	0	0	0	0	0
Polychaetes	18	18	1	4	5	8
Other	29	28	1	4	3	5
B. Numbers of Individuals						
cods	1,005	73	513	73	617	92
Sculpins	216	16	32	5	2	<1
Sand lance	53	4	135	19	29	4
Capelin	7	<1	1	<1	6	<1
Other	91	7	17	2	19	3
C. Estimated Wet Weight (g)						
Cods	11,531	94	5,324	94	8,688	99
Sculpins	535	4	40	{1	2	{1
Sand lance	100	<1	270	5	58	<1
Capelin	14	<1	2	<1	11	<1
Other	120	<1	34	<1	24	{1

^A Values in parentheses represent the frequency among the total number of birds examined. Values not in parentheses represent the percent frequency, numbers, or weight, respectively, among birds containing identifiable prey remains.

Table 19. Number and estimated biomass of fishes in diets of thick-billed murre at Cape Lisburne. Arithmetic mean number and weight (g)/bird; data for 1977-80 are from Springer et al. (1984).

	<u>Jun</u>			<u>1-20 Jul</u>			<u>21 Jul - 10 Aug</u>			<u>11-31 Aug</u>		
	n	\bar{X}	s	n	\bar{X}	s	n	\bar{X}	s	n	\bar{X}	s
<u>Numbers</u>												
1977	6	5	7	22	6	8	15	7	9	9	9	12
1978		ND		17	8	14	29	20	20	10	15	13
1979		ND		17	12	14		ND		19	23	25
1980		ND			ND		32	6	8		ND	
1983	37	10	15	21	13	14	20	21	20	24	18	17
<u>Biomass</u>												
1977	6	10	13	22	19	29	15	14	18	9	23	36
1978		ND		17	23	44	29	43	70	10	53	55
1979		ND		17	54	81		ND		19	57	67
1980		ND			ND		32	54	84		ND	
1983	37	100	102	20	187	144	20	151	124	24	72	79

ND = no data.

Table 20. Black-legged Kittiwake census summary for 12 plots on St. Matthew Island that were counted in each of three years.

<u>Year</u>	<u>Birds</u>	<u>Nests</u>
1977	---	2,160
1982	2,785	2,034
1983	3,629	2,283

5 small chicks among 34 successful nests. Using the average incubation period of 28 days (Swartz 1966), the eggs from which the 5 chicks hatched were laid before 26 June. Laying dates in late June through early July are the same as in 1982 (Springer et al. in press a).

The reproductive success of Kittiwakes in 1983 was the same as in 1982 - few, if any, chicks were raised. The average clutch size was small, but was comparable to that reported for the Pribilof Is. during the late-1970's (see Hunt et al. 1981a); chick survival was very poor (Table 21). We examined an additional 28 nests on St. Matthew I. on 7 August, one of which had one egg and another of which had one chick, and 51 nests on Hall I. on 9 August, two of which had one chick each. All failures during incubation appeared to be caused by adults deserting the nests. Chicks generally died within a few days after hatching, apparently from starvation and exposure.

Cape Lisburne

The mean hatching date of Kittiwake chicks at Cape Lisburne was about 30 July, a date midway between the earliest and latest dates in past years (see Springer et al. in press b).

The clutch size of Kittiwakes (Table 22) was large compared to other years at Cape Lisburne (see Springer et al. in press b). However, most of the second chicks hatched in two-chick broods died within a few days of hatching. Starvation appeared to be the cause of death. Growth rates of the surviving chicks were relatively slow (Table 23).

3. Food Habits

St. Matthew I.

Kittiwakes at St. Matthew I. fed on pollock, capelin and a variety of invertebrates in 1983 (Table 11). They were frequently seen carrying fish, especially capelin, to the colonies during mid-July, but not after that time when the birds foraged more widely offshore. The shift coincided with the period when large schools of 'bait' fish were detected at depths of 6-24 m in nearshore waters instead of at the surface (J. Anderson, pers. obs. from July-August bathymetry surveys from the Marine Constructor. Considerably more fishes were taken in 1983 than in 1982, when only one fish was recovered from 16 Kittiwakes collected in July and August. Invertebrates were taken frequently in both years, but perhaps somewhat less so in 1983 (Table 12). "Young-of-Year pollock were not taken in either year.

Cape Lisburne

Cods, over 99% Arctic cod, were the principal food of Kittiwakes in 1983, as they were for the murrelets (Table 18). Other species of fishes and invertebrates were not important, except during August when the adults were able to obtain limited numbers of sand lance,

C. Auklets

1. Census

Least auklets, crested auklets (*Aethia cristatella*) and parakeet auklets (*Cyclorhynchus psittacula*) nest on St. Matthew I. Results of the

Table 21. Reproductive success of black-legged Kittiwakes at Tusk Colony on St. Matthew Island, 1983.

	Plot 2A	Plot 2B
No. nests	58	172
No. empty nests	29	94
No. 1-egg clutches	22	75
No. 2-egg clutches	7	3
Clutch size / nest	0.6	() .5
No. chicks fledged	0	{3

Table 22. Reproductive success of black-legged Kittiwakes at Cape Lisburne, 1983,

No. nests	103
No. empty nests	8
Clutch size / nest	1.6
No. chicks fledged	◀63

Table 23. Growth rates of black-legged Kittiwake chicks at Cape Lisburne.

Year	Grams/day \pm s (n)
1977	19 \pm 3 (18)
1978	20 \pm 7 (21)
1979	18 \pm 1 (24)
1980	18 \pm 4 (43)
1981	14 \pm 3 (30)
1983	16 \pm 3 (45)

surface average counts of auklets are detailed in Appendix Tables 8 and 9. The census was not designed to estimate the total numbers of auklets on St. Matthew I. or in the two study colonies, but was designed to provide indices of population numbers for future comparisons.

The surface average numbers of auklets on the plots in the two colonies during the three phases of the breeding cycle are summarized in Table 24. Least auklets were generally in the lowest abundance during the prelaying period. Crested auklets were most numerous during incubation. The small numbers of parakeet auklets on the plots preclude similar generalizations for this species. The presence of immature birds, plus the fact that many courtship activities take place underground (Bedard 1969a) may explain our higher numbers during the incubation and chick periods.

Comparisons of net movement and surface average counts of auklets are presented in Table 25. While some variation in the surface average counts occurred, the net movement counts were extremely variable. Thus, the surface average technique appears to be better suited for establishing an index of numbers in the St. Matthew I. colonies than does the net movement technique.

Bedard (1969a) found that immature auklets arrived on St. Lawrence I. in early June and comprised 30-35% of the total number present by 20 June. Immature least auklets were not present in the colonies on St. Matthew I. until nearly the end of June and they comprised about 20% of the total number by mid-July (Fig. 4). Immature crested auklets were not seen until 20 July and also comprised about 20% of the total number (Fig. 4).

2. Phenology and Chick Growth Rates

Upon our arrival on 8 June, auklets had formed pairs and several copulations were seen. Three female least auklets collected on 15 June each had fully developed follicles within one day of laying. The first egg was found on 21 June. On 17 July, chicks from 1-5 days old were found in 8 of 14 nests. The number of adults carrying food also began to increase about that time (Fig. 5). The first sea-going chick was seen on 7 August.

Growth rates of 22 least auklet chicks weighed during intervals of 5-18 days averaged 3.9 g/day ($s = 0.96$ g/day); growth rates of 12 chicks weighed during intervals of at least 10 days averaged 3.6 g/day ($s = 0.78$ g/day). The growth rate of 3.6 g/day was significantly lower than the average growth rate of five chicks in 1982 (4.9 g/day, $s = 0.9$ g/day) weighed during intervals of at least 10 days (Mann-Whitney $P < 0.025$).

3. Food Habits

Food habits of least auklets during the chick period in 1983 are detailed in Appendix Table 10. They are summarized and compared to food habits in 1982 in Table 26. No important differences in the composition of the prey were apparent between years; least auklets on St. Matthew I. depend on one species of copepod, Calanus marshallae, for the majority of their food during the chick period. Comparative data on auklet food habits from the Pribilofs and St. Lawrence I. are presented in Tables 27 and 28. Calanus marshallae, the species characteristic of the middle shelf domain of the SE Bering Sea (Cooney 1981; Smith and Vidal 1984), was replaced in importance on both the Pribilofs and St. Lawrence I. by C. plumchrus and C. cristatus, species characteristic of the outer shelf domain. The location of the Pribilofs relative to the outer shelf domain and of

Table 24. Surface average counts of crested auklets (CRAU), least auklets (LEAU), and parakeet auklets (PAAU) during the pre-laying (PL), incubation (IN), and chick-feeding (CF) periods on study plots at Pterodactyl and Arch colonies on St. Matthew Island, 1983.

Colony	Plot	CRAU			LEAU			PAAU		
		PL	IN	CF	PL	IN	CF	PL	IN	CF
Pterodactyl										
	1	3	2	2	57	62	102	0	<1	0
	2	2	4	2	83	141	131	{1	0	0
	3	<1	1	<1	40	51	49	{1	0	0
	4	{1	2	2	32	46	35	2	{1	<1
	5	3	4	3	59	73	62	0	<1	0
	6	8	12	9	114	126	182	0	0	0
	7	11	18	11	55	51	59	0	0	0
	8	11	25	21	42	52	58	0	0	0
	9	ND	0	0	ND	29	23	ND	0	0
	10	ND	0	0	ND	12	13	ND	0	0
	11	ND	6	6	ND	85	10K5	ND	0	0
Arch										
	1	0	<1	0	31	69	68	0	0	0
	2	4	7	6	70	96	95	2	<1	0
	3	<1	{1	0	42	44	47	0	0	0
	4	0	{1	0	52	47	51	0	{1	0
	5	ND	8	12	ND	80	80	ND	0	0
	6	ND	{1	0	ND	36	31	ND	0	0

Pre-laying period = arrival to ~17 June, incubation period = ~18 June to ~16 July, and chick-feeding period = ~17 July to fledging, ND = no data (plot added after the pre-laying period).

Table 25s Comparisons of surface average and net movement estimates of crested auklet (CRAU), least auklet (LEAU), and parakeet auklet (PAAU) numbers on study plots at Pterodactyl and Arch colonies on St. Matthew Island, 1983.

Colony	Plot	Date	CRAU	LEAU	PAAU	Method of Estimation
Pterodactyl						
	1	11 Jun	3 14	57 400	0 0	Surface average Net movement
		24 Jun	3 0	63 12	<1 0	Surface average Net movement
	2	11 Jun	2 0	129 -554	<1 0	Surface average Net movement
		24 Jun	2 -2	83 -4	0 0	Surface average Net movement
	6	13 Jun	8 4	114 226	0 0	Surface average Net movement
		24 Jun	11 -22	131 -1,252	0 0	Surface average Net movement
	8	13 Jun	11 6	42 -396	0 0	Surface average Net movement
		24 Jun	14 -34	50 -272	0 0	Surface average Net movement
Arch						
	2	16 Jun	4 0	70 16	2 0	Surface average Net movement
	3	16 Jun	<1 2	42 6	0 0	Surface average Net movement

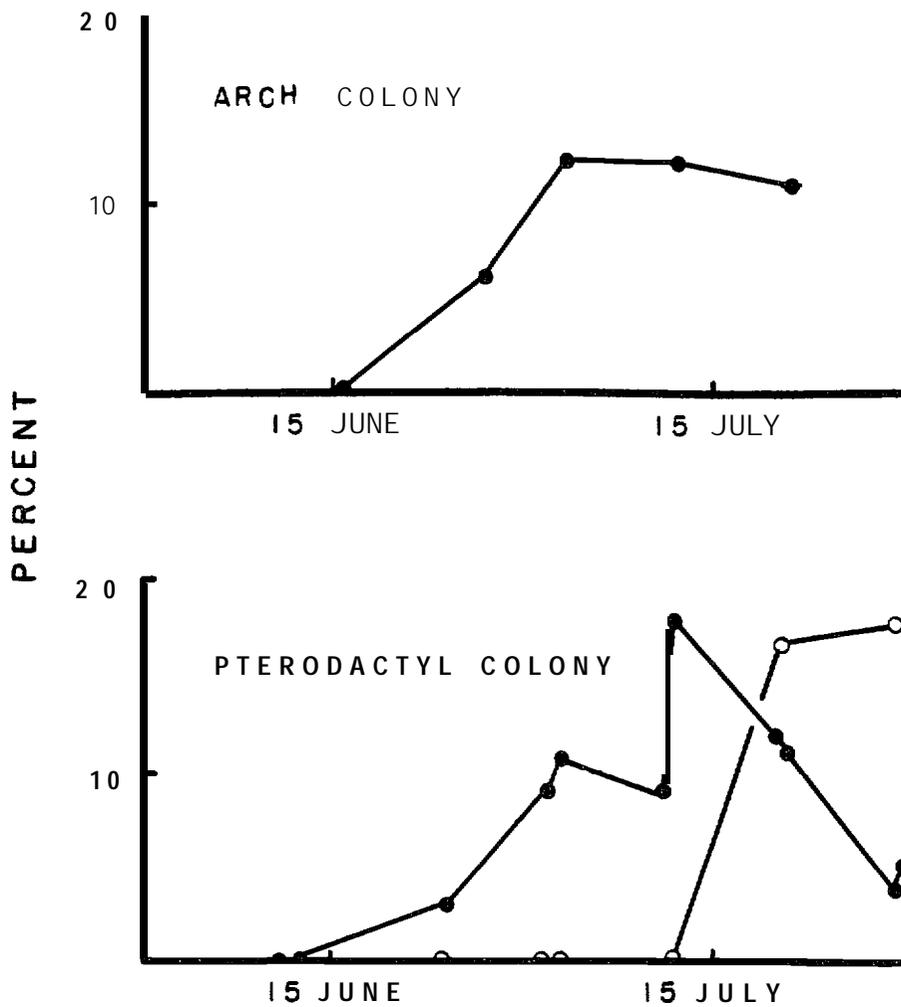


Fig. 4. Proportion of immature auklets in breeding colonies on St. Matthew I. in 1983. Solid circles are least auklets, open circles are crested auklets.

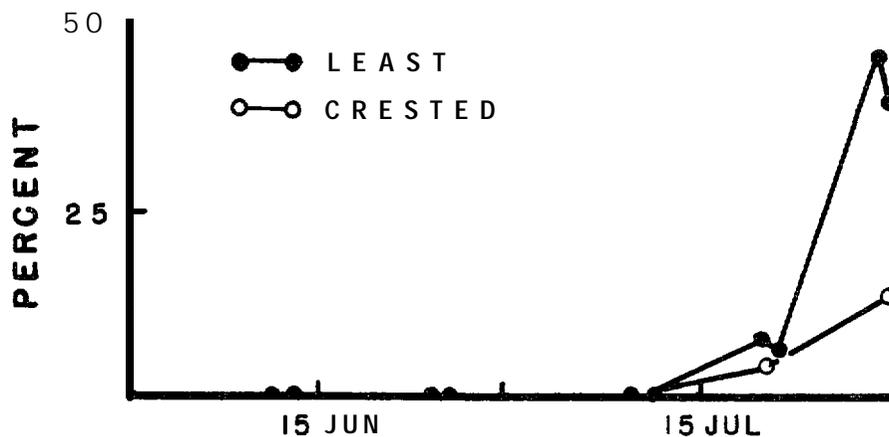


Fig. 5. Proportion of adult auklets carrying food to breeding colonies on St. Matthew I. in 1983.

Table 26. Prey of least auklets on St. Matthew I.

Taxon	1982 (n=29)		1983 (n=40)	
	Number	Volume (%)	Number	Volume (%)
<u>Calanus marshallae</u>	18,658	89	17,668	84
<u>C. plumchrus</u>	0	0	1	<0.1
Hyperiididae	150	5	59	3
Gammaridae	216	4	209	9
Decapod zoea	187	1	460	3
<u>Thysanoessa</u> spp.	10	<0.1	80	1
<u>Limacina helicina</u>	73	<0.1	8	<0.1
Other	1	<0.1	1	<0.1

Table 27. Prey of least auklets on the Pribilof Is., 1975-78. Numbers (%) are from Hunt et al. (1981a); volume (%) is according to text. N=258.

Taxon	Number (%)	Volume (%)
<u>Calanus marshallae</u>	65	30
<u>C* plumchrus</u>	11	5
<u>C. cristatus</u>	24	48
Hyperiididae	2	9
Gammaridae	2	5
Decapod zoea	0	0
<u>Thysanoessa</u> spp.	<1	2
<u>Limacina helicina</u>	0	0
Other	0	0

Table 28. Prey of least auklets on St. Lawrence I. Data for 1964-66 are from Bedard (1969); data for 1976 are from Searing (1977).

Taxon	1964-64 (n=124)		1976 (n=12)		1981 (n=24)	
	Number	Volume (%)	Number	Volume (%)	Number	Volume (%)
<u>Calanus marshallae</u>	77,908	65	344	3	3,132	26
<u>C. plumchrus</u>	0	0	9,047	90	6,205	50
<u>C. cristatus</u>	1,444	8	32	2	197	11
<u>Eucalanus bunnii</u>	169	<1	9	<1	0	0
Hyperiididae	2,102	9	57	1	32	<1
Gammaridae	533	3	9	<1	21	{1
Decapod zoea	2,808	3	47	<1	643	7
<u>Thysanoessa</u> spp.	2,325	7	2	<1	1	<1
<u>Limacina helicina</u>	6	<1	34	<1	3	{1
Other	311	i	31	<1	0	o

St. Lawrence I. relative to the Bering Slope current probably accounts for the differences between the composition of the prey of auklets on these islands and that on St. Matthew I. (Springer and Roseau in press).

Although there were no important differences in the composition of auklet prey on St. Matthew I. between 1982 and 1983, quantitative differences in prey between years may exist. Comparisons of this kind can be misleading, however, it is interesting that the difference between the average number of copepods recovered from sublingual pouches of adult least auklets in 1982 and 1983, 640 v 460, respectively, or a decline (Mann-Whitney $P < 0.001$) of about 30%, is nearly the same as the percentage decline in the growth rates of chicks between the two years. The prey in sublingual pouches is that which is fed to chicks.

Least auklets on St. Matthew I. apparently fed close to the island at most times. Hunt et al. (1981a) suggested that auklets feed generally within 30 km offshore in the Pribilof Is. Auklets nesting in the northwestern part of the island flew westward to feed during July, while those nesting in the northeastern part of the island flew northeast to feed. After 30 July, auklets in the northeast fed in large concentrations within a zone from about 5 m - 1 km of shore. We have seen similar episodes of auklets feeding nearshore on St. Lawrence I. during periods of strong upwelling (Springer and Roseau in press).

D. Food Web Dynamics

Cape Lisburne

Primary production, as measured by the integrated chlorophyll-a concentration, underwent a typical bloom in early summer as the sea ice broke up (Fig. 6). Following the bloom, phytoplankton populations remained low throughout the summer. However, beginning in early August, the chlorophyll concentration began to rise, increasing about 3-fold over the lowest levels by the end of the month. We do not know if the increase resulted from in situ production or from advection into the region from the south.

From the examination of stomach contents of sand lance, we found that the fish were feeding on a meroplanktonic stage of a bivalve, the cladocerans Podon spp. and Evadne spp. and the copepods Pseudocalanus spp. and Acartia clausi. The ambient concentrations of all five taxa were generally low until early August, when they increased dramatically in abundance (Fig. 7). The increases occurred at the same time as that of chlorophyll-a, postdating the seasonal rise in water temperature by about 2 weeks (Fig. 7).

A concurrent increase in the importance of sand lance in murre and Kittiwake diets occurred in early August (Fig. 8). Sand lance were not an abundant item in the birds' diets in 1983, a characteristic typical of cold years. Water temperature in mid-July was only 3°C which is in the low range of temperatures for that time of year (Table 29).

E. Characteristics of Prey Populations

The majority of pollock eaten by murre and Kittiwakes at St. Matthew I. were age class 1 according to the length of the fishes, as determined from their otoliths, and data on pollock size-at-age reported by Smith (1979). The distribution of the lengths of intact otoliths recovered from murre and Kittiwakes in 1983 (Fig. 9) indicates the sizes of length cohorts of pollock. For reference, fish lengths can be calculated by using the regression equations

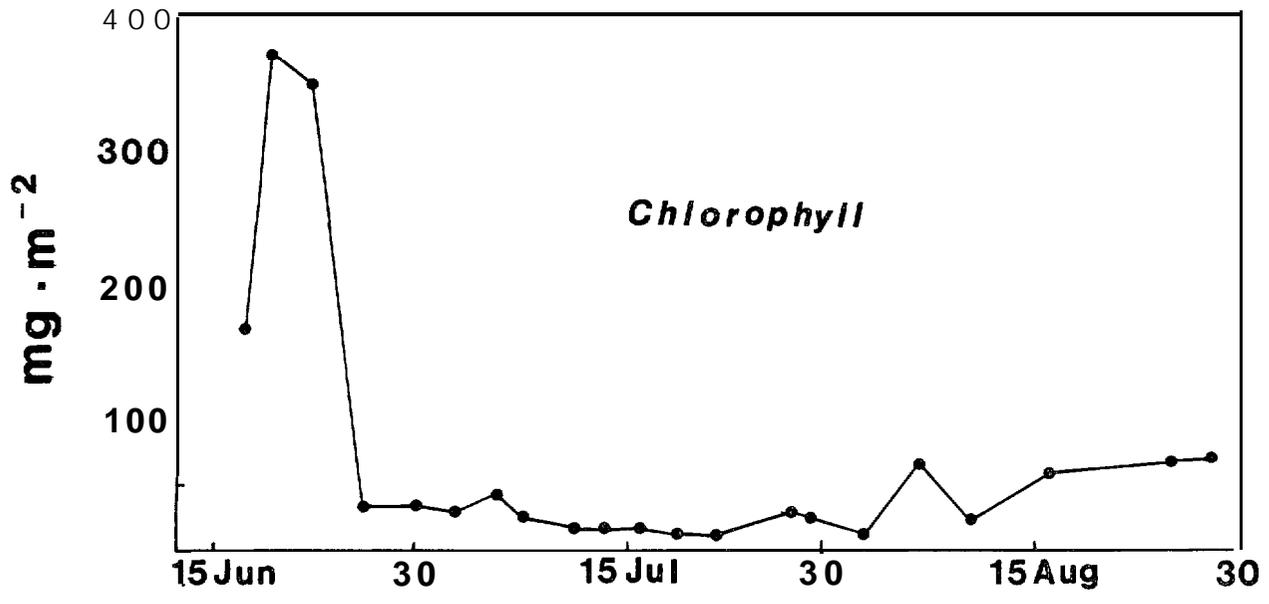


Fig. 6. Integrated chlorophyll-a at Station A, Cape Lisburne, 1983. Surface to bottom, mean depth about 15 m.

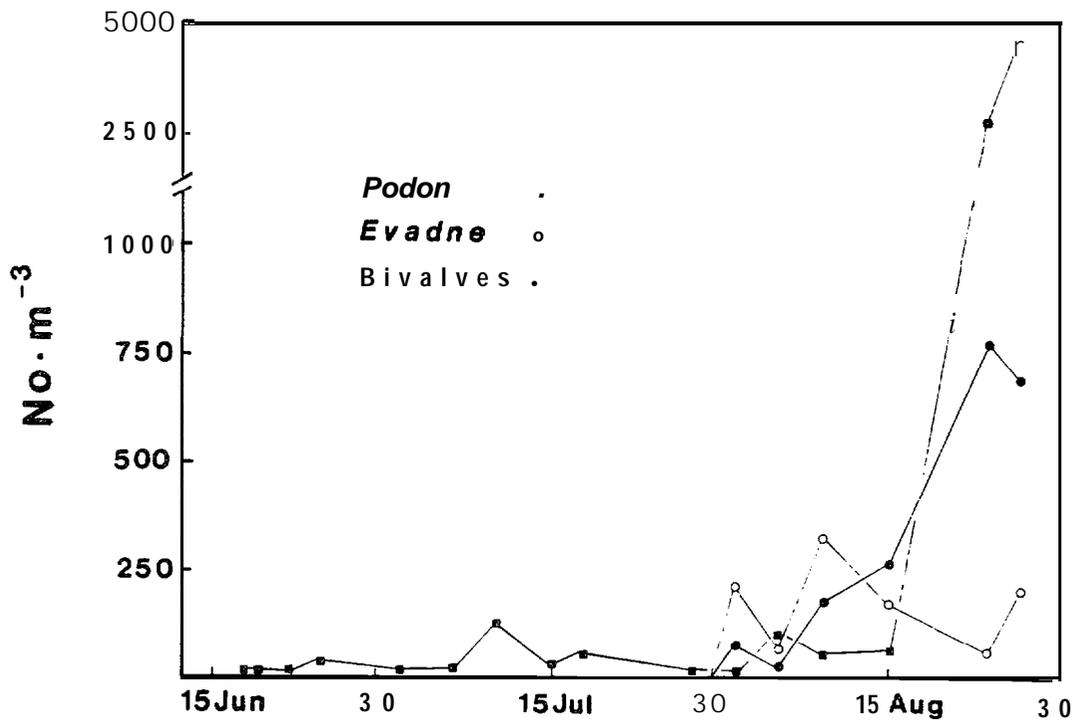
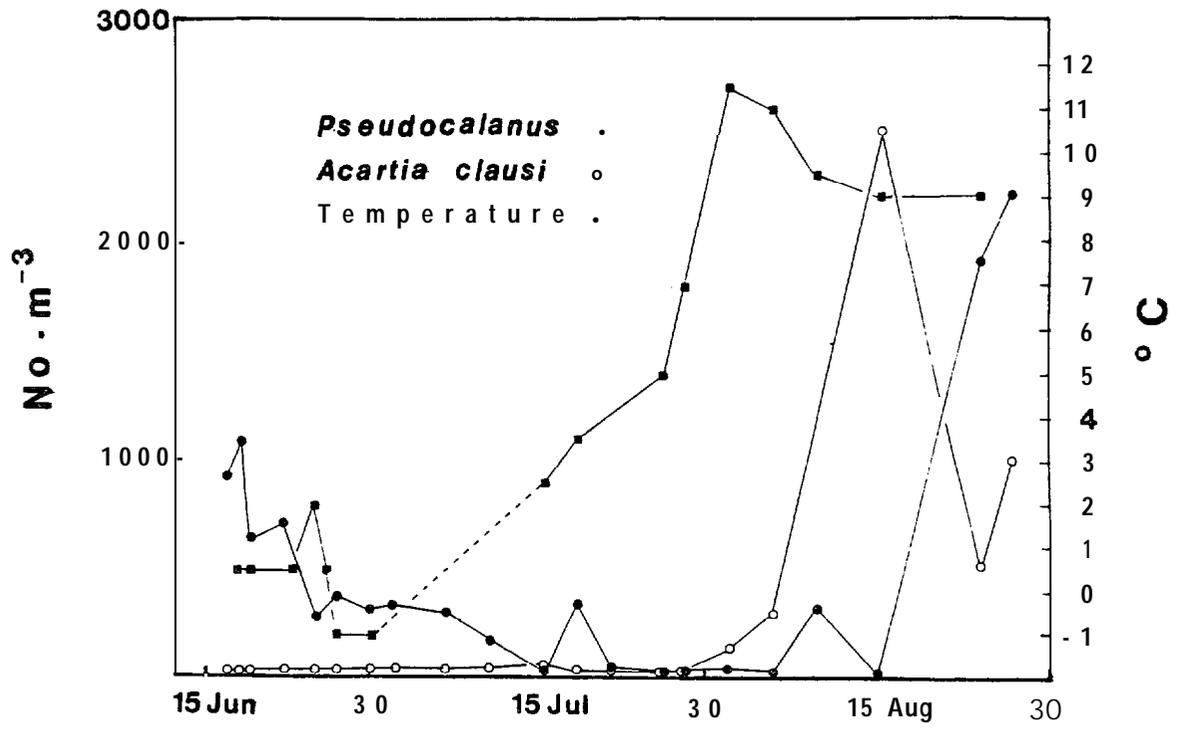


Fig. 7. Water temperature and the ambient concentrations of the five most abundant taxa in diets of sand lance near Cape Lisburne, 1983.

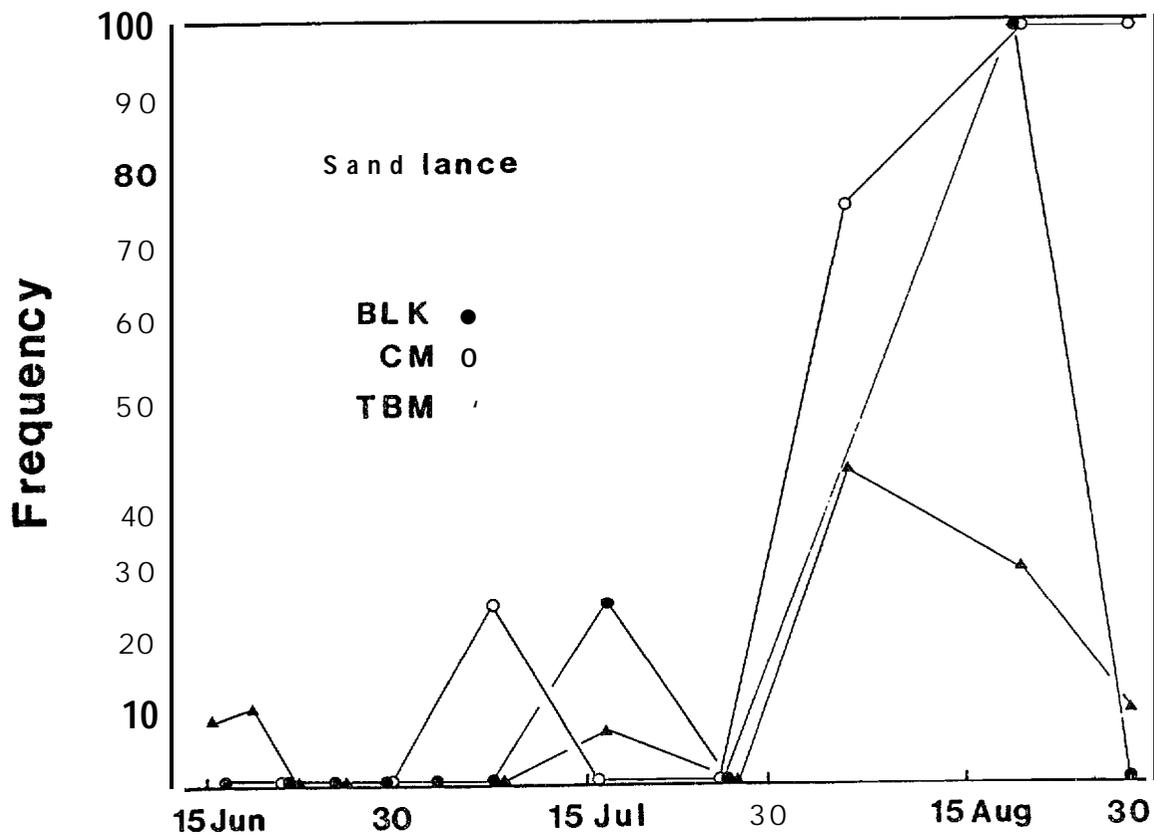


Fig. 8. Frequency of occurrence of sand lance in the diets of murre and kittiwakes at Cape Lisburne, 1983.

Table 29. Water temperature during mid-July at Cape Lisburne.

Year	Degrees C
1974	7
1975	4
1976	2
1977	6
1978	8
1979	13
1980	10
1981	11
1982	10
1983	3

reported above. There was apparently no difference between the distributions in 1982 and 1983, although the 1982 sample size was too small ($n = 32$) for meaningful comparison. The 1983 distribution does not necessarily reflect the absolute contribution of each cohort to the total numbers of pollock taken, since many of the otoliths were broken and could not be included in the above distribution. Also, the young-of-year cohort referred to in Table 17 is not shown in Fig. 9. Otoliths of that cohort were less than 14 otolith units.

The three principal size cohorts of sand lance in the 1983 sample (Fig. 10) ranged in age from 0+ - 1+. The two smallest cohorts were somewhat larger than those in 1977, but considerably smaller than those in 1980. This pattern is similar to that previously observed, when fishes tended to be larger in warmer years (Springer et al. 1984). In 1983, the size distributions of each of the three cohorts were bimodal, and the differences in size between modes of the smaller size range were proportional to those of the larger size range. This pattern suggests that individuals from two populations are represented among the otoliths, perhaps a local population and one that was advected into the region from the south. We have shown previously that sand lance taken by seabirds at Cape Thompson were larger than at Cape Lisburne, and that sand lance taken at Bluff were largest (Springer et al. 1984; in press b)

Two distinct size-age cohorts of saffron cod were taken by murre and Kittiwakes at Cape Lisburne in 1983 (Fig. 11). During the first half of the summer, larger fishes were taken, while later in the summer smaller fishes were taken. The lengths apparently represent fishes that differ in age by one year (0+ and 1+ age classes) according to Craig et al. (1981), who report length-at-age data for saffron cod in the Beaufort Sea. Advection possibly played a role also in the change in size of saffron cod during the summer. The average length of the smaller fishes was larger in 1983 than the average length of the same age class collected during the same interval in 1979 (Fig. 11). This pattern is consistent with the trend recorded in 1976-79, when saffron cod were smaller in warmer years than in colder years (Springer et al. 1984).

VII. & VIII. DISCUSSION AND CONCLUSIONS

SE Bering Sea

The breeding season of 1983 was the third consecutive year of failure for black-legged Kittiwakes on islands in the SE Bering Sea. Kittiwakes failed on the Pribilof Is. in 1981 (D. Lloyd pers. comm.), 1982 (Craighead and Oppenheim 1982) and 1983 (A. Merculieff pers. comm.) and on St. Matthew I. and Hall I. in 1982 and 1983. Our impression is that low prey availability during those years was responsible for the failures. Because pollock are the most important prey of Kittiwakes on the Pribilof Is. (Hunt et al. 1981a) and on St. Matthew I., an absence of pollock in surface waters apparently has been the direct cause.

Murre had a better season than they had in 1982, and they had a better season than Kittiwakes had in 1983. The uncompensated numbers of birds on the census plots on St. Matthew I. in 1983 were similar to numbers in 1977 and higher than 1982. There is little evidence of a long-term decline in the murre population on St. Matthew I. as has occurred at Cape Thompson and Bluff (see Springer et al. in press b). Similarly, murre numbers on St. Lawrence I. were lower in the particularly severe year 1976 than in 1971 and 1981 (Roseneau et al. in press). Murre numbers on the cliffs at Bluff in mid-July 1984 were only about a third as large as numbers in recent years, but are not expected to remain that low since the summer of 1984 was extremely severe oceanographically in Norton

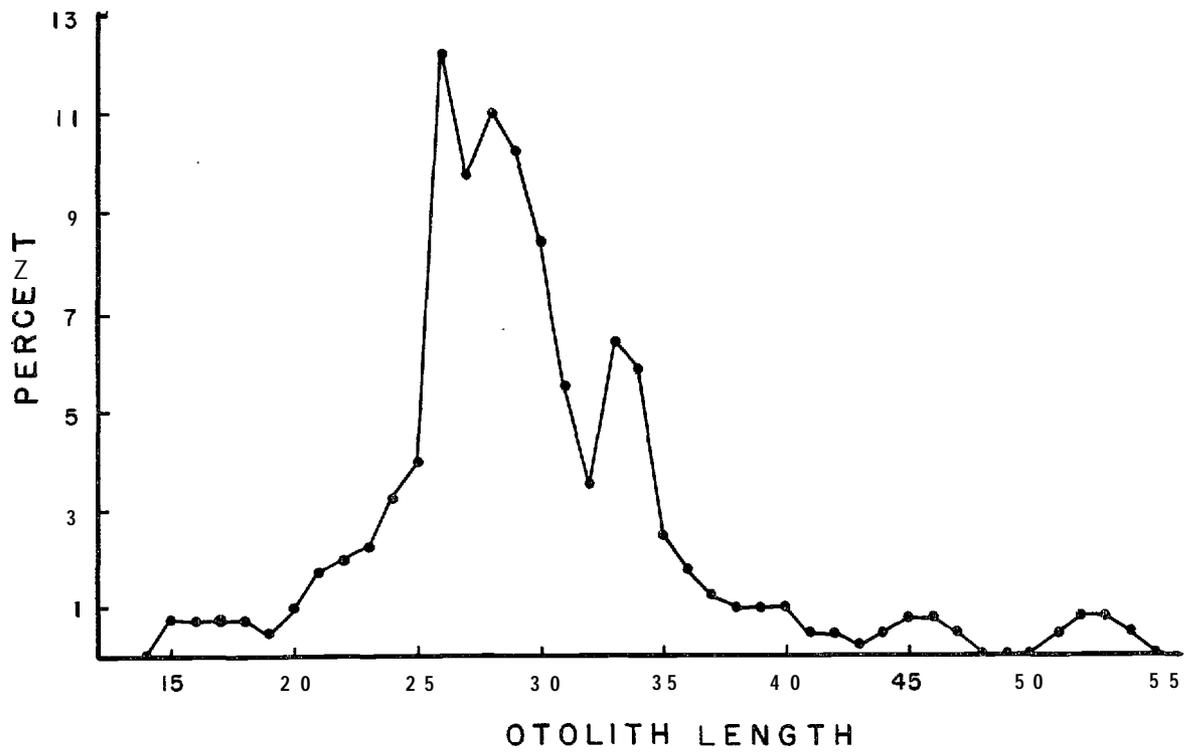


Fig. 9. Size frequency distribution of otoliths of pollock eaten by murre and kittiwake on St. Matthew I., 1983. Otolith length in units, 6.25 units/mm.

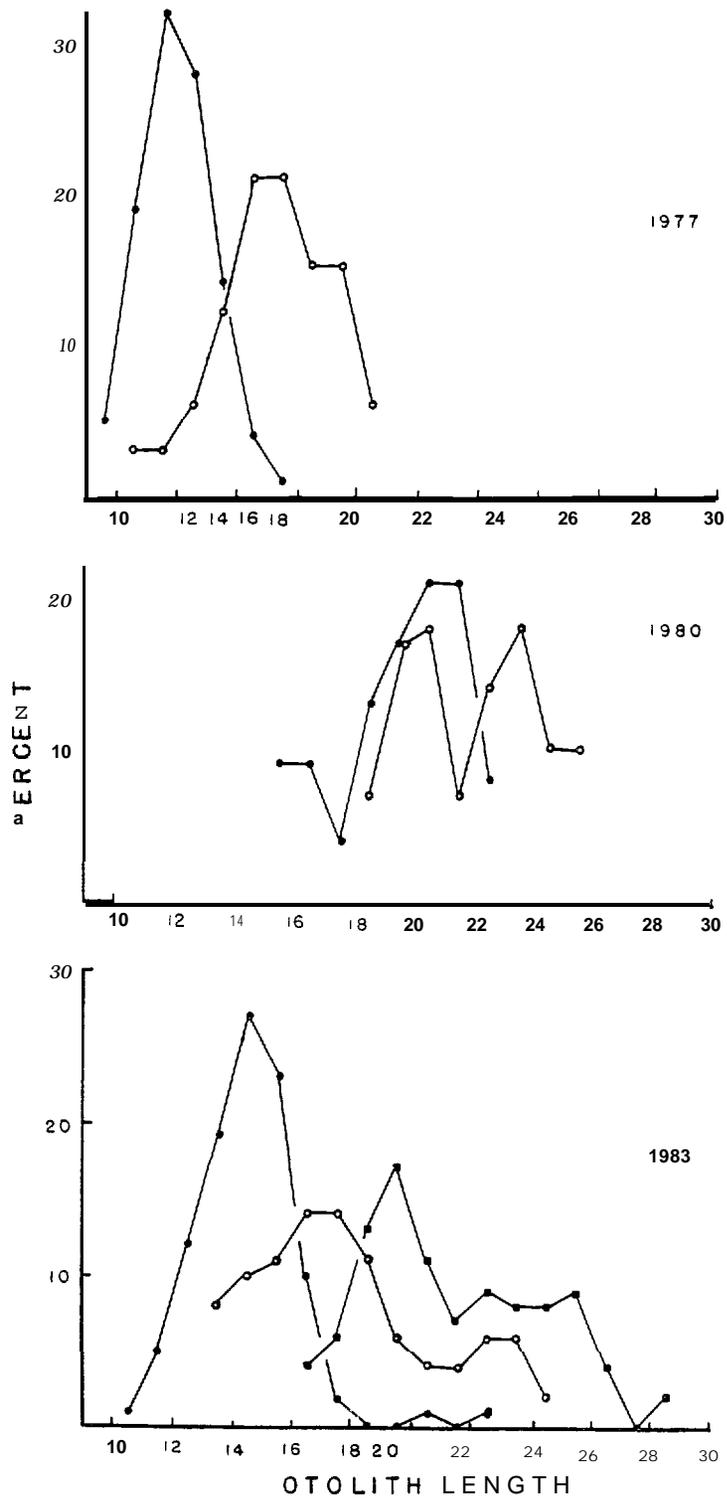


Fig. 10. Size frequency distribution of otoliths of sand lance eaten by murre and kittiwake at Cape Lisburne, 1983. Solid circles are youngest age, open circles are older age, solid squares are oldest age. Otolith lengths are in units, 12.5 units/mm.

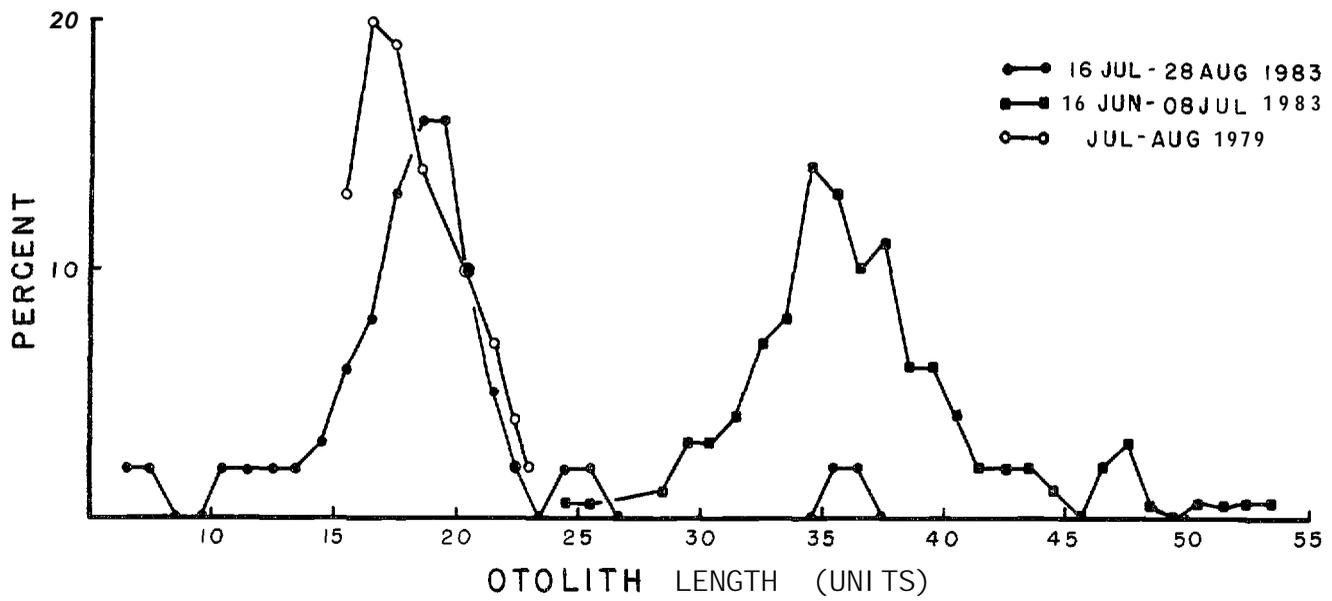


Fig. 11. Size frequency distribution of otoliths of saffron cod eaten by murre and kittiwake at Cape Lisburne, 1983. Otolith length in units, 6.25 units/mm.

Sound <Springer et al.unpubl. data>. Because pollock are the most important prey of murre in the SE Bering Sea, particularly low availability of pollock in 1982 might account for the low murre numbers that year.

The majority of pollock biomass in murre and kittiwake diets is contributed by year class 1 fish. Fishery survey data obtained by the Northwest and Alaska Fisheries Center (NAFC) indicate that the abundance of age 1 pollock in the SE Bering Sea in 1983 was about three times greater than in 1981 or 1982 (Bakkala and Traynor 1984). Our food habits data, which show a marked increase in consumption of pollock between 1952-83, are consistent with these survey data.

The NAFC data also show that the recruitment of the 1979-1981 year classes was low compared to that of the 1974 and 1978 year classes, and the abundance of age 1 pollock in 1980-1982 was low compared to 1975 and 1979. Unfortunately, comparable data are not available for the year-class years 1975-1977. Still, the information generally fits well with the pattern of reproductive success of black-legged kittiwakes on St. George I. since 1976 (Table 30). It is not inconsistent that reproductive success in 1983 remained low, since the estimated abundance of age 1 pollock in 1983, while about three times greater than the previous two years, was still only 40% of the 1979 estimate (Bakkala and Traynor 1984).

Another interesting relationship involves the auklets and the connection between the abundance of their main prey, copepods, and the abundance of pollock. We have discussed the possibility elsewhere that tight coupling in the pelagic copepod-based food web of the SE Bering Sea might lead to multispecies interactions when stocks of pollock wax and wane (Springer and Roseaneau in press). Age class 1 pollock feed on large calanoid copepods (Clarke 1978; Smith 1981; T. Nishiyama unpubl. data) that are also the major prey of least auklets. Smith and Vidal (1984) have suggested that declines in the numbers of calanoids from the outer shelf domain during spring represent losses to vertebrate consumers, including whales, birds and fishes. Thus, years in which recruitment of age 1 pollock is low, as in 1982, would be favorable for auklets, since the auklets would face less competition from the fish for prey biomass. The observations from St. Matthew I. during the past two years support such a hypothesis. In 1982, a poor pollock year, auklets apparently were able to feed their chicks more, resulting in faster chick growth, than in 1983, a much improved pollock year. In contrast, murre and kittiwakes, which depend on pollock, had better seasons in 1983 than in 1982.

On a larger scale, the distribution in the Bering Sea of pollock and copepod biomass may contribute to the geographical differences in the numbers of murre and auklets at insular breeding colonies. Copepods are apparently supplied to the northern shelf by the Bering Shelf current, which advects zooplankton from the outer shelf domain onto the northern shelf (Springer and Roseaneau in press). However, pollock are rarely found on the northern shelf, where they are replaced by Arctic and saffron cod (Frost and Lowry 1981a; Wolotira et al. 1979). Probably because of harsher environmental conditions, populations of these cods, as well as of other fishes, are small compared to the pollock population as indicated by test fishery data (Wolotira et al. 1979) and by the absence of a commercial fishery on the northern shelf. In summer, the baleen whales are represented only by the gray whale (Eschrichtius robustus), which feeds primarily on benthic amphipods (see Frost and Lowry 1981b). Thus, competitors of auklets for copepod biomass are probably few compared to those in the outer shelf domain, while at the same time copepod biomass is apparently large.

Table 30. Black-legged Kittiwake reproductive success on the Pribilof Is. and St. Matthew I. <number of chicks fledged/total nests>, and recruitment of age class 1 pollock in the eastern Bering Sea <billions of fish>. Nd = no data. Pollock data are from Bakka and Traynor(1983).

Year	Kittiwake reproductive success			
	Pollock recruitment	St. George I.	St. Paul I.	St. Matthew I.
1975	ND	ND	0.44	ND
1976	ND	0.62	0.52	ND
1977	NO	0.45	0.43	ND
197a	ND	0.22	0.36	ND
1979	8.7	0.40	0.54	ND
1980	low	0.38	ND	ND
1981	1.0	0.07	ND	ND
1982	0.9	0.01	ND	0.01
1983	3.5	0.01	ND	0.01

Pollock is the largest contributor of biomass to diets of piscivorous sea birds in the SE Bering Sea. On St. Lawrence I. piscivorous seabirds feed on a variety of fishes including Arctic cod, sand lance and capelin (Springer and Roseman unpubl. data). The ratio of the numbers of murrelets, the numerically dominant avian piscivores at Bering Sea breeding colonies, to the number of least auklets (Fig. 12) indicates a shift in the proportions of available fish and copepod biomass from predominantly fish in the south to copepods in the north. This trend is consistent with the reported distribution of pollock and with the inferred competition for copepods in the SE Bering Sea.

The persistent failures of black-legged Kittiwakes in the SE Bering Sea contrast with the pattern of average to good success punctuated by occasional failures lasting only one year at colonies in the N Bering and E Chukchi seas. The long-term nature of the Kittiwake failures at southern colonies indicates a prolonged inadequacy of pollock, and is now a cause for concern for Kittiwakes breeding at those colonies.

Unfortunately there are no systematic data on seabirds from the Pribilofs or St. Matthew I. collected before the inception of the commercial pollock fishery in the late 1960's. Preble and McAtee (1923) quoted from Palmer (1899), ". . . St. Paul Island, August 2, 1890, most nests with young, but a few had a young and an egg, or sometimes two or three eggs." Thus, we do not know if the levels of reproductive success reported for the Pribilofs during the period 1975-79 (Hunt et al. 1981a) are typical of levels in such a pelagic system. During the late 1970's, the average clutch sizes of laying pairs were about in the middle of the range of clutch sizes at northern colonies (see Springer et al. in press b). Chick growth rates were slow-moderate and mortality was relatively high.

The availability of pollock to surface-feeding seabirds, such as Kittiwakes, on islands in the SE Bering Sea may never be as high as is the availability of sand lance and capelin to coastal populations. Sand lance and capelin form dense shoals in shallow water and are easily captured by Kittiwakes. The availability of these fishes accounts for generally high chick growth rates and survival. Pollock do not form such near-surface shoals and therefore they are less available to Kittiwakes, even though the total biomass of pollock may greatly exceed that of the other forage species. Major changes in the abundance of pollock, such as in the recent years of poor recruitment of age 1 fish, are likely to have major effects on Kittiwake reproductive success. Generally lowered recruitment, which might have resulted from the reduction of adult pollock by the commercial fishery (Fig. 13), might have contributed to the low-moderate levels of Kittiwake reproductive success during the late 1970's.

E Chukchi Sea

Murre numbers at Cape Lisburne apparently have varied little between years since censuses were first taken there in 1976. This trend contrasts with those at all other colonies in the Bering and Chukchi seas where we and others have made systematic counts in two or more years during the same interval. Such numerical constancy suggests that murre food webs in Ledyard Bay are also stable compared to those elsewhere, and may be more effectively buffered in some way against disruption by seasonal and annual variations in the physical environment.

The great abundance of Arctic cod at Cape Lisburne in 1983 allowed Kittiwakes to lay large clutches of eggs, but was not sufficient to maintain all

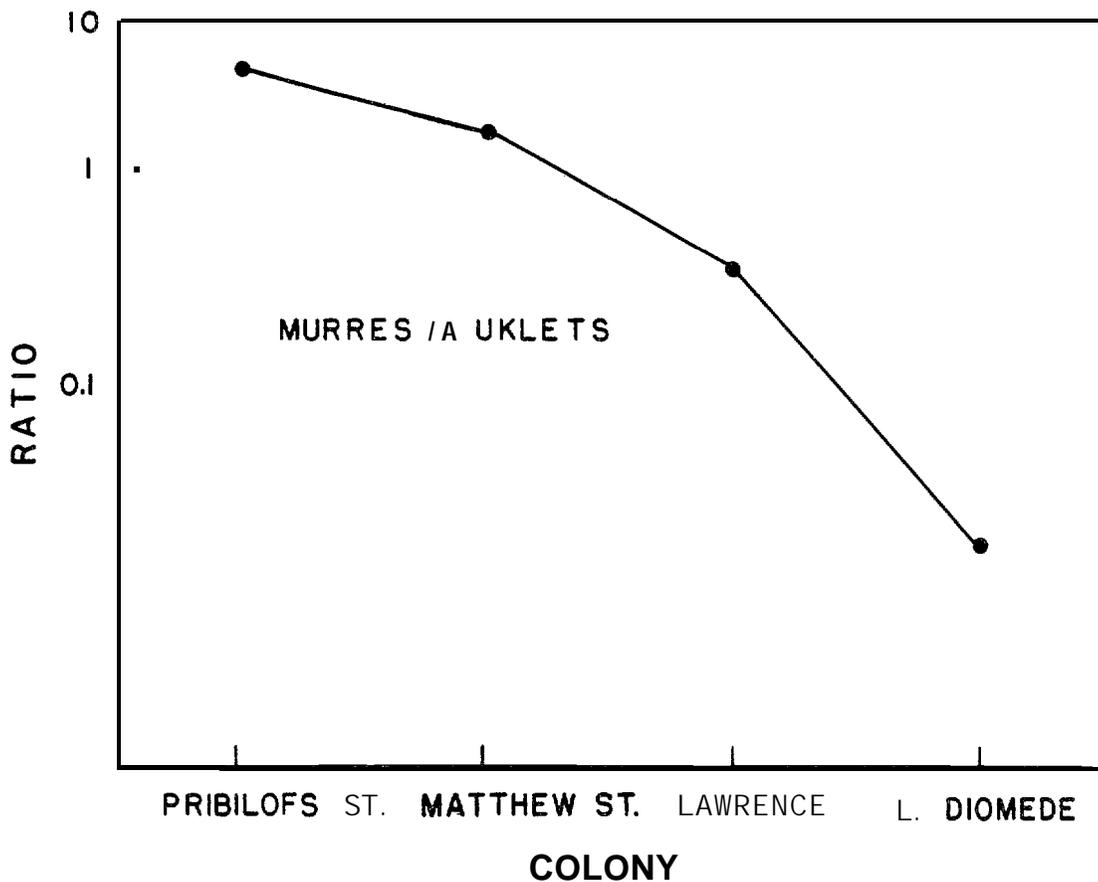


Fig. 12. Relative numbers of murre and least auklet at colonies in the eastern Bering Sea. From SOWLS et al. (1978) and Roseneau et al. (in press).

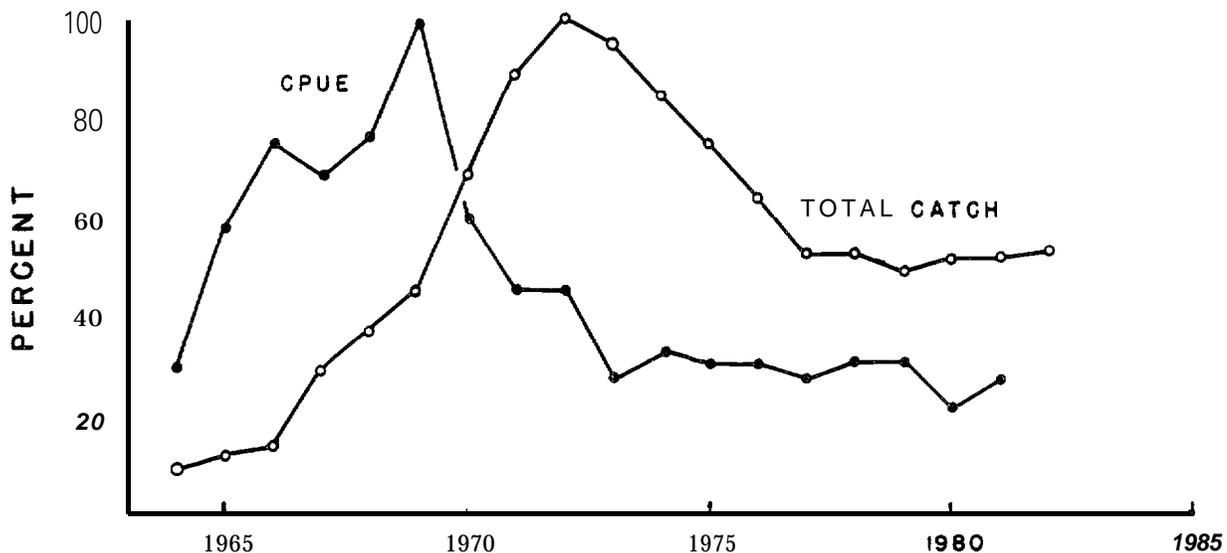


Fig. 13. Total catch and catch per unit effort (CPUE) of pollock in the eastern Bering Sea. The 100% levels of the annual catch and the CPUE were about 1.9 million tonnes and 31.5 tonnes/1000pair horsepower hour, respectively. From Bakkala and Traynor (1984).

of the chicks at the colony. Chick mortality was high - most of the second chicks to hatch in two chick broods died - and growth rates of the surviving chicks were slow compared to other years at Cape Lisburne when sand lance have been available during the chick period. Thus, sand lance appear to be a key species to Kittiwakes in terms of the overall production of young. While Arctic cod is probably always important to Kittiwakes during the egg-laying period, sand lance seem to be necessary for the birds to enjoy a highly successful breeding season.

The close correspondence between the increases in chlorophyll-a, zooplankton populations and the availability of sand lance to seabirds in Ledyard Bay suggests interactions between three trophic levels of the neritic community. We do not know if warming conditions beginning about mid-July promoted the increases in zooplankton, or if they all resulted from the advective import of associated food web organisms from the south. Neimark (1976) found a significant positive correlation between numbers of Acartia clausi and warming water temperatures in Norton Sound; in 1976, an environmentally cold year, the number of Acartia clausi began to increase rapidly beginning in the interval 16-31 JULY and peaked during the interval 1-15 August. The increase followed the rise in water temperature in Norton Sound by about two weeks, as it did in Ledyard Bay in 1983. However, the period of maximum abundance of the cladocerans was two weeks earlier than that of Acartia, while the period of maximum abundance of bivalve veligers was two weeks later. At Barrow, Redburn (1974) suggested that the abundance of Acartia and the cladocerans was a function of advection from the south, since the peak in numbers coincided with the intrusion of warmer water and the presence of other neritic copepod taxa.

Although many details remain undescribed, it seems that oceanographic conditions on the Bering-Chukchi shelf play a major role in determining annual levels of seabird reproductive success at colonies in Norton Sound, on St. Lawrence I., in the E Chukchi Sea, and probably on the Diomedes Is. Two marine "rivers" having sharply contrasting physical and chemical properties flow northward through Bering Strait during summer. In the east, Alaskan Coastal Water, a warm, low-salinity water mass normally develops in early summer following the dissipation of sea ice in Norton Sound, breakup of the Yukon River and increased insolation (Coachman et al, 1975). Annual variability in the development of this seasonal water mass is thought to have significant effects on the coastal zone food webs supporting coastal seabird populations (Springer et al. 1984). Contrasting in the west, Bering Shelf-Anadyr water consists of Bering Shelf Water and Anadyr Water, both of which originate at depth in the Bering Sea and are cold, high salinity water masses (Coachman et al, 1975). The flow of this water across the northern shelf promotes exceptionally high levels of primary production during summer (Sambrotto et al. 1984) and advects sufficient copepod biomass from the south to apparently influence the breeding distribution of least auklets in the Bering Sea (Springer and Roseman in press).

Ordinarily, the presence of the two flow regimes, Alaskan Coastal Water and Bering Shelf-Anadyr water, maintains two very different marine environments on the Bering-Chukchi shelf, in which characteristic food webs have adapted to the prevailing physical conditions. However, in some years the juxtaposition of these water masses breaks down leading to major disruptions of regional food webs. For example in 1984, anomalous circulation in the N Bering Sea, carried Bering Shelf-Anadyr water deep into Norton Sound, a situation that persisted from early summer through about mid-August (Springer et al, unpubl. data). Consequently, the normally very warm environment of the NE Bering and E Chukchi seas was unusually cold throughout the summer. In Norton Sound where the anomaly

was greatest, murre and kittiwakes experienced the worst breeding season ever recorded (Murphy and Springer unpubl. data). The normal kittiwake breeding population of about 10 thousand pairs at Bluff was reduced to 500-750 birds total. Adult kittiwakes were found dead and dying along the Unalakleet River. Five emaciated specimens we examined had eaten berries and apparently had starved to death. Murres were less severely affected, but only about a third of the normal number was at the colony during mid-July. The reproductive success of murre and kittiwakes was nil. It seems certain that the availability of fishes normally taken by murre and kittiwakes in Norton Sound, particularly sand lance and saffron cod (Springer et al. unpubl. data), was very low. The analysis of zooplankton samples collected at Bluff (Springer and Murphy in progress) may indicate whether the prey of the fishes was reduced as well.

IX. NEEDS FOR FUTURE STUDY

The persistent reproductive failures of black-legged kittiwakes on the Pribilofs and St. Matthew I. pose an important question about the stability of the pollock population in the SE Bering Sea. They also emphasize the need for the monitoring of selected seabird colonies each year, especially during periods of anomalous breeding performance such as that during the 1980's. The insight provided by long-term data is that which will be needed to adequately assess the affect of OCS oil and gas development on regional seabird populations. Thus, certain colonies should be designated for low-level surveys each year, such as those we have done in the E Chukchi and at Bluff. Colonies that would be appropriate are those on the Pribilofs, at Bluff and at Cape Lisburne, since they are in distinct environmental regimes and have long histories of nearly uninterrupted study. A schedule for visiting other colonies at regular, but less frequent intervals, should be considered for a period of 10 years.

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APPENDIX

Table 1. Murrecensus results from St. Matthew Island, 1983.

Plot	21 Jul				26 Jul				27 Jul			
	Time ^A	Ohs.	E	Obs. P \bar{x}	Time	Ohs.	E	Ohs. P \bar{x}	Time	Obs.	E	Ohs. P \bar{x}
c-1												
C-2,3												
C-4,6												
C-8					1525			28	28			
C-9					1530			81	81			
D-1 ,2	1145	1,209		1,209								
D-6	1230	390		390								
D-7	1245	2,930		2,930								
D-8	1340	557		557								
D-9a	1315	3,225		3,225					1345	2,740	2,430	2,585
D-9b	1425	2,245		2,245					1315	1,570	1,820	1,695
D-9c	1455	1,100		1,100								
D-9d	1520	2,440		2,440					1200	2,320	2,130	2,225
E-1	1400	1,190		1,190								
E-3												
E-4												
E-5												
E-6												
E-7												
E-8, F-1												
F-2												
F-3												
F-4,4												

^A Bering Daylight Time.

(Table 1, cont.)

(Plot)	29 Jul				30 Jul				1 Aug						
	Time*	Ohs,	E	Obs. P	Ohs,	E	Obs. P	\bar{x}	Time	Obs.	E	Ohs.	P	\bar{x}	(%)
(C-1)									1710	2,400				2,600	
(C-2,3)									1555	410	410			410	
(C-4,4)									1340	1,440				1,440	
(C-8)															
(C-9)															
(D-1,2)															
									1015	735	595			445	(61)
									1410	723	783			753	(69)
									1645	887	854			871	(80)
									1935	1,151	1,022			1,087	(100)
									2120	1,114	1,034			1,074	(99)
(D-6)															
(D-7)															
(D-8)															
(D-9a)															
(D-9b)	1815	2,430	2,700						2,565						
(D-9c)															
(D-9d)															
(E-1)															
(E-3)	1215		90											90	
(E-4)															
(E-5)															
(E-6)	1340	8,260	8,980											8,620	
(E-7)	1355		340			375								357	
(E-8,F-1)	1515	12,080	12,580											12,330	
(F-2)															
(F-3)	1655		740											740	
(F-4,6)	1705		448											410	
														425	

* Bering Daylight Time.

(Table 1, cont.]

(Plot)	9 Aug				Rau \bar{x}	Compensated \bar{x} [®]
	Time [®]	Ohs, E	Ohs, P	\bar{x}		
(C-1)					2,600	3,132
(C-2,3)					410	518
(C-4,4)					1,440	2,309
(C-8)					28	36
(C-9)					81	105
(D-1,2)					943	1,474
(D-6)					390	582
(D-7)					2,930	4,309
(D-8)					557	785
(D-9a)					2,798	4,158
(D-9b)	1900	3,120	2,610	2,865	1,961	2,606
(D-9c)					1,100	1,467
(D-9d)	1945	2,730	2,710	2,720	2,466	3,086
(E-1)					1,190	1,526
(E-3)					90	136
(E-4)						
(E-5)						
(E-6)					8,420	12,140
(E-7)					357	502
(E-8, F- 1)					12,330	16,223
(F-2)						
(F-3)					740	925
(F-4,6)					425	518
					41,631	53,700
				Total:		53,700

[®] Bering Daylight Time,

[®] Rau x compensated using diurnal counts at Plots D-1,2 on 1 Aug (see above),

Table 2. Murre census results from Cape Lisburne, 1983.

Plot	21 Jul				6 Aug				11 Aug			
	Time ^A	Obs.	N	Obs. O \bar{x}	Time	Obs.	N	Obs. C \bar{x}	Time	Obs.	N	Obs. O \bar{x}
11	2000	1,230	1,110	1,170								
12	2045	1,250	1,740	1,500								
25	2115	820	690	755								
26	2130	1,040	810	925								
30	2220	3,140		3,140								
32	2245	1,860	1,960	1,910								
65					1430		2,470 ^B	2,740	1500	2,220 ^B		2,220
66					1430	2,140	1,870	2,005	1330	1,635		1,535
70					1500		2,130 ^B	2,130	1430	2,100 ^B	2,340 ^B	2,220
72					1640	1,010	1,190	1,100	1415	870		870
73					1650	590	630	610	1410	410		410

^A Bering Daylight Time.

^B Counts made from shore; all other counts made from raft.

(Table 2, cont.)

(Plot)	19 Aug				27 Aug ^C		28 Aug ^C		Raw \bar{x}	Compensated \bar{x}
	Time ^A	Obs.	N	Obs. O \bar{x}	Time	Obs. N	Time	Obs. N		
(11)								1,170	1,746	
(12)								1,500	1,923	
(25)								755	888	
(26)								925	1,051	
(30)								3,140	3,237	
(32)								1,910	1,949	
(45)	1850	2,000 ^B	2,612 ^B	2,304	1700	1,156	1100	2,424	4,366	
(66)								1,820	3,524	
(70)	1930	1,490 ^B	1,530 ^B	1,510	1715	1,000	1120	1,520	3,662	
(72)								985	1,888	
(73)								510	945	
								Total :	14,204	25,201

^A Bering Daylight Time,

^B Counts made from shore; all other counts made from raft.

^C These counts were made outside of the census period and are not included in the raw and compensated means.

Table 3. Ratios of common murre (COMU) and thick-billed murre (TBMU) at Hall Island, 1983.

Location ¹	Time ²	Date	COMU	TBMU	COMU/TBMU
Subplot No. 3	1321	18 Jul	398	51	7.8
Subplot No. 4	1321	18 Jul	26	325	0.1
Subplot No. 5	1350	18 Jul	<u>205</u>	<u>46</u>	<u>4.5</u>
		(Subtotal)	(629)	(422)	(1.5)
Subplot No. 6	1350	18 Jul	<u>467</u>	<u>265</u>	<u>1.8</u>
		Total (18 Jul)	<u>1,096</u>	<u>688</u>	<u>1.6</u>
Subplot No. 3	1240	9 Aug	442	44	10.1
Subplot No. 4	1220	9 Aug	52	224	0.2
Subplot No. 5	1257	9 Aug	<u>213</u>	<u>40</u>	<u>5.3</u>
		(Subtotal)	(707)	(308)	(2.3)
Eggplot No. 1	1315	9 Aug	9	102	0.1
Eggplot No. 2	1330	9 Aug	0	51	0
Eggplot No. 3	1345	9 Aug	3	23	0.1
Eggplot No. 4	1400	9 Aug	26	50	0.5
Eggplot No. 5	1430	9 Aug	11	17	0.6
Eggplot No. 6	1415	9 Aug	<u>18</u>	<u>12</u>	<u>1.5</u>
		(Subtotal)	(67)	(255)	(0.3)
		Total (9 Aug)	<u>774</u>	<u>563</u>	<u>1.4</u>

¹ All subplots and eggplots are located near the boundary separating Plots H-1 and H-2 (see DeGange and Sowlis 1978).

² Bering Daylight Time.

Table 4. Counts of seabirds on subplots 1-4 at Tusk Colony, St. Matthew Island, 1983.

Date	Subplot	Time ¹	TBMU ²	COMU ³	BLKI ⁴
17 Jun	1	1217	0	0	77
		175%	0	0	60
	2	1240	32	125	224
		1747	33	115	212
	3	1245	32	6	92
		1734	38	7	93
	4	1255	22	12	109
		1713	38	11	100
29 Jun	1	1430	0	0	70
	2	1435	17	111	331
	3	1445	17	10	105
	4	1500	13	14	117
9 Jul	1	1400	0	0	53
	2	1400	28	102	238
	3	1415	24	12	57
	4	1430	21	7	88
15 Jul	1	1700	0	0	56
	2	ND ⁵	ND	ND	ND
	3	1700	27	10	87
	4	1715	35	12	99
19 Jul	1	1625	0	0	49
	2	1640	25	163	257
	3	1655	48	13	76
	4	1715	34	13	90
28 Jul	1	1420	0	0	66
	2	1430	19	167	303
	3	1445	28	9	81
	4	1455	18	13	95
1 Aug	1	1020	0	0	53
	2	1030	18	95	154
	3	1040	19	9	28
	4	1055	0	11	54

¹ Bering Daylight Time.

² TBMU = thick-billed murre.

³ COMU = common murre.

⁴ BLKI = black-legged Kittiwake.

⁵ ND = no data.

Table 5. Counts of seabirds on subplot 1 at Arch Colony, St. Matthew Island, 1983.

Date	Time ¹	TBMU ²	COMU ³	NOFU ⁴
15 Jun	1400	136	8	10
	1700	142	4	8
	2000	142	5	12
	2200	110	5	12
16 Jun	1400	305	17	7
26 Jun	1830	120	13	8
	2030	143	13	8
27 Jun	0400	202	10	8
	1445	307	14	9
4 Jul	0600	141	12	7
	1500	142	15	12
13 Jul	0845	74	2	?
	1135	150	20	8
	1335	163	19	7
22 Jul	0900	242	18	6
	1230	169	10	6
	1530	219	15	6

¹Bering Daylight Time.

²TBMU = thick-billed murre.

³COMU = common murre.

⁴NOFU = northern fulmar.

Table 6. Counts of thick-billed murre (TBMU) on subplots 1-4 at NorthCamp Colony, St. Matthew Island, 1983.

Date	Subplot	Time ¹	TBMU
18 Jun	1	1127	36
		1241)	38
	2	1127	6
		1240	11
27 Jun	1	1615	48
	2	1630	17
	3	1645	51
	4	1700	21
3 Jul	1	1750	37
	2	1800	20
	3	1815	41
	4	1825	29
22 Jul	1	0900	44
		1530	32
	2	0915	19
		1545	15
	3	0930	53
		1600	42
	4	0943	20
		1615	17
1 Aug	1	ND ²	20
	2		12
	3		31
	4		14

¹ Bering Daylight Time.

² ND = no data.

Table 7. Black-legged Kittiwake census results from St. Matthew Island, 1983.

Plot	20-21 Jul			29-30 Jul		
	Time ¹	Birds	Nests	Time	Birds	Nests
C-1				1700	215	150
C-2				1600	0	0
C-3				1600	0	0
C-4,6				1330	375 ²	324
D-0 ²	1330	545	335			
D-1a	1110	158	75			
D-1b	1130	521	281			
D-2	1200	0	0			
D-3	1200	0	0			
D-4	1200	0	0			
D-5	1200	0	0			
D-6	1230	43	26			
D-7	1245	248	115			
D-8	1345	0	0			
D-9a	1315	717	344			
D-9b	1420	337	178			
D-9c	1450	403	161			
D-9d	1520	2	0			
E-1	1600	0	0			
E-6				1300	10	4
E-7				1350	86	59
E-8				1515	977	740
F-1				1615	1,104	1,020

¹ Bering Daylight Time.

² Plot D-0 = Tusk Colony, a concentration of murre and kittiwakes not reported by DeGange and Sowlis (1978).

Table 8. Numbers of crested auklets (CRAU), least auklets (LEAU), and parakeet auklets (PAAU) on Plots 1-6 at Pterodactyl Colony on St. Matthew Island, 1983.

Plot	Date	Observer	Surface Average			Net Movement		
			CRAU	LEAU	PAAU	CRAU	LEAU	PAAU
1	11 Jun	WR	3	57	0	+14	+400	0
	24 Jun	R	3	63	<1	0	+12	0
	3 Jul	Q	2	56	0			
	11 Jul	R	1	66	0			
	20 Jul	R	3	100	0			
	30 Jul	R	1	104	0			
2	11 Jun	Q/R	2	129	<1	.0	-554	0
	24 Jun	R	2	83	0	-2	-4	0
	2 Jul	Q	5	175	0			
	11 Jul	#	5	164	0			
	21 Jul	R	4	167	0			
	31 Jul	R	<1	96	0			
3	11 Jun	Q/R	<1	40	<1			
	24 Jun	R	0	15	0			
	2 Jul	Q	1	65	0			
	3 Jul	Q	2	67	0			
	11 Jul	Q	<1	56	0			
	21 Jul	R	2	61	0			
31 Jul	R	#	37	0				
4	11 Jun	Q/R	1	32	2			
	24 Jun	R	2	36	1			
	2 Jul	Q	4	64	2			
	11 Jul	R	2	37	0			
	21 Jul	R	4	43	1			
	31 Jul	R	{1	27	0			
5	13 Jun	R	3	59	0			
	24 Jun	Q	5	86	{1			
	2 Jul	R	6	70	{1			
	12 Jul.	R	2	64	0			
	21 Jul	Q	4	68	0			
	31 Jul	Q	2	55	0			
6	13 Jun	R	8	114	0	+4	+226	0
	24 Jun	Q	11	131	0	-22	-1,252	0
	2 Jul	R	17	136	0			
	12 Jul	R	8	111	0			
	21 Jul	Q	12	195	0			
	31 Jul	Q	5	169	0			

Table 8, cont. Numbers of crested auklets (CRAU), least auklets (LEAU), and parakeet auklets (PAAU) on Plots 7-11 at Pterodactyl Colony on St. Matthew Island, 1983.

Plot	Date	Observer	Surface Average			Net Movement		
			CRAU	LEAU	PAAU	CRAU	LEAU	PAAU
7	13 Jun	Q	11	55	0			
	25 Jun	Q	16	45	0			
	3 Jul	R	18	62	0			
	12 Jul	Q	19	48	0			
	20 Jul	Q	18	71	0			
	30 Jul	Q	4	48	0			
8	13 Jun	Q	11	42	0	+6	-396	0
	25 Jun	Q	14	50	0	-34	-272	0
	3 Jul	R	34	49	0			
	12 Jul	Q	27	58	0			
	20 Jul	Q	31	64	0			
	30 Jul	Q	10	51	0			
9	3 Jul	R	0	25	0			
	12 Jul	Q	0	33	0			
	20 Jul	Q	0	28	0			
	30 Jul	Q	0	19	0			
10	2 Jul	R	0	10	0			
	12 Jul	R	0	14	0			
	21 Jul	Q	0	19	0			
	31 Jul	Q	0	7	0			
11	3 Jul	Q	9	95	0			
	11 Jul	R	3	76	0			
	20 Jul	R	7	98	0			
	30 Jul	R	4	115	0			

Table 9. Numbers of crested auklets (CRAU), least auklets (LEAU), and parakeet auklets (PAAU) on Plots 1-6 at Arch Colony on St. Matthew Island, 1983.

Plot	Date	Observer	Surface Average			Net Movement		
			CRAU	LEAU	PAAU	CRAU	LEAU	PAAU
1	16 Jun	R	0	31	0			
	27 Jun	R	2	92	0			
	4 Jul	R	0	69	0			
	14 Jul	R	0	45	0			
	22 Jul	R	0	68	0			
2	16 Jun	R	4	70	2	0	+16	0
	27 Jun	R	8	117	1			
	4 Jul	R	9	95	0			
	14 Jul	R	5	75	<1			
	22 Jul	R	6	95	0			
3	16 Jun	Q	{1	42	0	0	+6	0
	27 Jun	Q	1	52	0			
	4 Jul	Q	<1	49	0			
	14 Jul	Q	0	30	0			
	22 Jul	Q	0	47	0			
4	16 Jun	Q	0	52	0			
	27 Jun	Q	{1	56	1			
	4 Jul	Q	0	44	1			
	14 Jul	Q	<1	41	0			
	22 Jul	Q	0	51	0			
5	4 Jul	R	13	87	0			
	14 Jul	R	3	73	0			
	22 Jul	R	12	80	0			
6	4 Jul	Q	<1	42	0			
	14 Jul	Q	0	29	0			
	22 Jul	Q	0	31	0			

Table 10. Numbers of prey taken by least auklets on St. Matthew Island during the chick period in 1983. Size categories are I, 0.0-7.0 mm; II, 7.1-15.0 mm; III, 15.1 mm and larger (from Bedard 1969). Number of samples = 40.

Taxon	Size	Number
<u>Calanus marshallae</u>	I	17,668
<u>C. plumchrus</u>	I	1
<u>Parathemisto libellula</u>	I	11
	II	43
<u>Parathemisto</u> spp.	I	4
<u>Hyperoche medusarum</u>	II	1
<u>Monoculodes</u> spp.	I	2
<u>Westwoodilla caecula</u>	I	2
<u>Atylus bruggeni</u>	I	1
	II	146
<u>Orchomene</u> spp.	I	4
<u>Jassa</u> spp.	I	1
	II	3
<u>Iscyroceras</u> spp.	?	1
<u>Pontogeneia</u> spp.	I	6
	II	20
<u>Anonyx</u> spp.	I	2
<u>Lepidepcreum</u> spp.	I	1
<u>Pontoporea affinis</u>	I	1
Stenothoidae	I	4
	II	9
Me phid p dae	?	1
Oedicerotid	II	5
<u>Thysanoessa raschii</u>	II	1
	III	2
<u>Thysanoessa</u> spp.	II	45
	III	1
<u>Euphausia d furci ia</u>	I	30
	II	1
Hippolytidae zoea	II	147
Crangonidae zoea	II	2
Pandalidae zoea	II	7
Shrimp zoea	II	12
Paguridae zoea	I	53
Lithodidae zoea	I	130
	II	15
Paralithoides zoea	I	3
Anomuran zoea	I	12
<u>Argis</u> spp.	II	79
<u>Limacina helicina</u>	I	8
Cumacean	II	1