RU-038

Final. Report

Contract # 03-5 -022-76
Research Unit # 38
Reporting Period May 13, 1975 to
January 31, 1977

A Census of Seabirds on the Pribilof Islands

Joseph J. Hickey, P.I.
F. Lance Craighead, Research Assistant
Department of Wildlife Ecology
Russell Laboratories
University of Wisconsin
Madison, Wis. 53706

February 1, 1977

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ABSTRACT

A census of seabirds nesting on the Pribilof Islands, principal St. George Island, was undertaken in the summers of 1975 and 1976. Ledge-nesting species were estimated from cliff photographs by means of a stratified sampling technique, the counts being adjusted with correction factors for variation in daily and hourly ledge attendance for counts of thick-billed murres.

Crevice-nesting species on cliffs of St. George were estimated by using species-proportion figures based on counts of 63 reference ledges. Quadrat and flight counts were usedto estimate the least auklets at a large inland colony. Census work on Walrus Island was omitted due to the absence of nesting birds on the former, where sealions have taken over the flatrocks, and Otter Island where the small number of birds did not encourage an investment of the manpower we had available. Order-of-magnitude estimates for St. Paul were obtained by using St. George overall densities.

It was concluded that the numbers breeding on St. George in 1976 involved 1.5 million thick-billed murres; 250,000 least auklets exclusive of beach-boulder nesters that could not be satisfactorily censused; 220,000 red-legged kittiwakes; 190,000 common murres; 150,000 parakeet auklets; 72,000 black-legged kittiwakes; 70,000 fulmars; 28,000 horned puffins; 28,000 crested auklets; 6,000 tufted puffins; and 5,000 red-faced cormorants. The least auklet numbers were probably down from those witnessed by previous ornithologists. The red-legged kittiwakes here appear to have their main stronghold in the North Pacific. Exploitation of St. George's seabirds by local Aleut people in 1975-76 was trivial. An important threat to the reproductive success of the ledge-nesting

birds will occur if St. George is ever used as a sea- or airport petroleum development. The total population, on the order of 2.5 million nesting birds on this 19.9-by-8-km island, would appear to make it the largest seabird colony in the Northern Hemisphere.

The total. number of seabirds nesting on St. Paul was on the order of a quarter of a million. The total on Otter Island was reported to be very small, numbering in the low thousands.

ACKNOWLEDGMENTS

The investigators wish to acknowledge the considerable help of the following people:

Ronald C. Sguibb, University of Wisconsin
John R. Cary, University of-Wisconsin
David N. Nettleship, Canadian Wildlife Service
George L. and Molly W. Hunt, University of California--Irvine
Douglas B. Schwartz, University of California--Irvine
Sherman D. Causey, University of California--Irvine
Zoe Eppley, University of California-Irvine
Barbara Msyer, University of California--Irvine
Roger L. Gentry, National Marine Fisheries Service
James H. Johnson, National Marine Fisheries Service
James G. Bartonek, U.S. Fish and Wildlife Service
Calvin Lensink, U.S. Fish and Wildlife Service
The National. Marine Fisheries Service officials on St. George Island
And the Aleut community of St. George, particularly
Andronik Kashevarof Jr., and
Greg MacGlashan.

INTRODUCTION

General. Nature and Scope of Study

No systematic census or population estimates of the seabirds of the Pribilofs has ever been attempted, although for almost a century ornithologists have reported their numbers as in the "millions." The project reported here will provide enumerational data on what supposedly is the largest aggregate of colonial birds anywhere in North America, as a baseline on which to estimate any subsequent effects and environmental impact of petroleum exploration and development on the birdlife of this part of the Bering Sea.

Estimating large numbers of colonial seabirds is a problem with several unique difficulties. The most obvious of these being (1) the number of birds present on the cliff is in a constant state of flux due to arriving and departing birds. The pattern of this fluctuation varies among species with the hour of the day and the date during the breeding season. (2) Several species nest underground, and their numbers have to be estimated indirectly, i.e., by counts of birds present on the surface or by flight counts of arrivals and/or departures. (3) Large numbers of nonbreeding birds of some species are present in the colonies.

We have attempted to account for these difficulties on a species by species basis, the amount of effort expended on any given species being roughly commensurate with its importance, numerically, in the Pribilof ecosystem. In this regard, we have calculated the numbers and productivity of thick-billed murres (1,500,000) with more consideration than those of tufted puffins (6,000).

Abbreviations of' species names in our report are given in Table 1.

TABLE 1. ABBREVIATIONS USED IN TABLES AND GRAPHS IN THIS REPORT

ABBREVIATION	SPECIES	SPECIES CODE[a/]
Tables		
BI	Black-1 egged kittiwake incubating	8810060301
BK	Black-legged kittiwake	8810060301
BN	Black-legged kittiwake nest	8810060301
CA	Crested auklet	8810070801
CM	Common murre	8810070101
CN	Red-faced cormorant nest	8804010104
DF	Dark-phase fulmar	88030202010002
F	Fulmar	8803020201
HP	Horned puffin	8810071001
LA	Least auklet	8810070802
LF	Light phase fulmar	88030202010001
PA	Parakeet auklet	8810070701
RC	Red-faced cormorant	8804010104
RI	Red-legged kittiwake incubating	8810060302
RK	Red-legged kittiwake	8810060302
RN	Red-legged kittiwake nest	8810060302
TM[b/]	't'hick-billed murre	8810070102
TP	Tufted puffin	8810071101
UK	Unidentified kittiwake	8810063000
UM	Unidentified murre	8810070100
Graphs and Tables		
MC	Murie Cove	
PP	Pinnacle Point	
RFc	Rosy Finch Cove	

a/ as used in magnetic tape supplied to NOAA with this report.

b/ % TM = percentage of maximum number of thick-billed murres present on cliff at this time.

Max TM = maximum number of thick-billed murres present on cliff during the day.

Specific Objectives

The primary task of this study is to define a major biological population which is subject to potential impact by petroleum exploration and development in the Bering Sea. The particular objectives of the project are twofold:

(a) to obtain close estimates, for as many species as is practical within the time framework of this study, of the breeding seabirds on the Pribilof Islands, and

(b) to explore the possibilities of obtaining refined estimates of those additional nesting populations that do not readily lend themselves to conventional census techniques.

Relevance to Problems of Petroleum Development

Seabirds, because of their large numbers and high visibility, are valuable indicators of the health of a marine ecosystem. Because of their importance in the ecosystem, and their high vulnerability to oil, their numbers are a natural index to the effect of oil on the biology of the area. Birds will be among the first species to be affected by oil pollution, and the techniques to monitor their numbers are now being developed. A repeatable census technique or techniques for colonial seabirds is essential to understanding the effects of oil and gas development on the outer continental shelf.

STUDY AREA

The study area comprises the islands St. Paul, St. George, Otter, and Walrus. With the exception of Walrus Id., a low, flat rock, the islands are surrounded by cliffs of varying heights. Bird colonies

are found on all cliff areas around the islands, among talus slopes at the bases of the cliffs (and in one case inland), and among beach boulders. The largest areas for nesting, and the greatest avian populations, occur on the cliffs of St. George. St. Paul is considerably less populated, and Otter has the fewest nesting birds of the three islands. Although large populations of nesting murres were reported in the past on Walrus, there are none nesting there presently due to the establishment of a rookery there by Stellar's sea lions (Hunt pers. comm.).

In 1975 and 1.976 we concentrated our census work on St. George, St. Paul was intensely surveyed over a 5-day period in 1976. Otter and Walrus, being difficult to approach and less significant in terms of total bird numbers, were not visited.

St, George is composed primarily of basaltic lava and is older than St. Paul (Hopkins 1975). St. George is encircled by 48,700 meters of cliff. Of these cliffs, 33,5oO meters are over 61 meters high (200 ft.), 14,400 are over 122 meters high (400 ft.), 5,300 are over 183 meters high (600 ft.), and 4,200 are over 244 meters high (800 ft). The highest cliffs are 308 m high (1,012 ft.) (Table 2), We estimated total cliff area at 3,537,550 m^2 (Table 3) not including low cliffs less than 5m high.

St. Paul is lower and more weathered than St. George. Much of the island is composed of sand and sand dunes, and beaches are more prevalent. The cliffs of St. Paul are mainly restricted to the West and South sides of the island. There are 11,400 meters of cliff, 2,450 of which are over 61 meters high. The highest cliffs are 116 meters (379 ft.) (Table 2). We estimated total cliff area at 454,975 m^2 (Table 3) not including low

TABLE 2. PRIBILOF CLIFFS DIVIDED INTO 61-M. STRATA

St. George Cliffs Divided Into 61-meter Strata

Lengths estimated from photographs

Strata	Length in Meters
Stratum 1 0 to 61 m in height	
All cliffs over 7'.62 m high	48,700
Stratum 2 61 m to 122 m in height	
Ledge 48 to N Sealion Point	1,800
Shag Rock Cove	400
Black Cliffs-Umanagula-Red Bluffs	13,200
Rush Pt.-Staraya Artel (minus Needle Point Gap)	18,100
Total	33,500
Stratum 3 122 m to I-83 m in height	
Rush Pt. N-Suskarlogh Pt.	5,900
Needle Rock environs	1,500
High Bluffs	6,200
First Bluff	800
Total	14,400
Stratum 4 183 m to 244 m in height	
High Bluffs	5,300
Stratum 5 244 m and above	
High Bluffs	4,200

St. Paul Cliffs Divided Into 61-meter Strata

Lengths estimated from maps

Strata	Length in Meters
Stratum 1 0 to 61 m in height	
All cliffs over 7.62 m high	11,400
Stratum 2 61 m to 116 m in height	
Einahnuhto Bluffs	2,450

TABLE 3

ESTIMATES OF TOTAL CLIFF AREA

St. George

	Cliff Area	% of Total
Stratum 1 48,700 m x 34 m	1,625,200 m^2	46%
Stratum 2 33,500 m x 30.5 m	1,021,750 m^2	29%
Stratum 3 14,400 m x 30.5 m	439,200 m^2	12%
Stratum 4 5,300 m x 61 m	323,300 m^2	9%
Stratum 5 4,200111x 30.5 m	128,100 m^2	4%
Total	3,537,550 m^2	

St. Paul

Stratum 1 11,400 m x 34 m	387,600 m^2	85%
Stratum 2 2,450 m x 27.5 m	67,375 m^2	15%
Total	454,975 m^2	

cliffs less than 5 m high.

The weather on the Pribilofs during the breeding season is changeable and patchy from hour to hour across the islands. Fog and wind predominate, and rain is frequent. In 1975 there was almost constant rain and fog early in the season (June). In 1976 the weather was fine and clear generally until late July when the rain began and continued through August. The lee side of an island was generally clearer. The only weather pattern we found to be ubiquitous was a steady rain with no wind. This occurs in a thick fog.

SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

The seabirds nesting on the Pribilofs consist of six species that nest on cliff ledges:

thick-billed murre (Uris lomvia)
common murre (U. aalge)
black-legged kittiwake (Rissa tridactyla)
red-legged kittiwake (R. brevirostris)
fulmar (Fulmarus glacialis), and
red-faced cormorant (Phalacrocorax urile);

and five species that nest underground:

parakeet auklet (Cyclorrhynchus psittacula)
crested auklet (Aethia cristatella)
least auklet (A. pusilla)
horned puffin (Fratercula corniculata), and
tufted puffin (Lunda cirrhata).

Ledge-nesting species.—The conventional method of counting cliff-nesting birds on islands has been to photograph the birds from aircraft (Nettleship 1975). There has been some conjecture as to how to interpret these data, since under various conditions a pair may be represented by more, or less, than two birds. In censusing murres, the Canadian Wildlife Service tries to photograph murres before the nonbreeders arrive (late June or early

July in eastern Canada) and at the same date and hour each year. (Nettleship, pers. comm.). In this approach, the Canadians assume each bird equals one pair. The bias in this assumption may be cancelled out in year-to-year comparisons, but the potential bias remains real in single-year data.

To understand this potential. bias and to be able to correct for it, we undertook daily ledge-attendance counts of major species at given study ledges as often as possible throughout the season. These counts were made at various parts of the island from first light (about 0400 local time) until dark (about 2230) in 197'6. A complete count of the ledge was made every 30 minutes. Locations of these ledges are given in Table 4 and Fig. 1. Ledges 53, 57 and 21, 22, 23 were used.

In 1976, during the latter half of incubation of thick-billed murres (the predominant species), two complete sets of photos of the St. George cliffs were taken; one set on i' and 15 July, the other on 29 July. Sections of the higher cliffs were photographed again on 5 and 6 August. This phase of the project was dependent on perfect weather. Even on clear days, portions of the higher cliffs usually were clouded. Photos were taken on Tri-X 220 film using a Pentax 607 camera with 105-mm lens and W filter. We were unable to use slower film because of general overcast conditions and deep shadows on the North-facing cliffs. A 13-ft . inflatable Avon boat with 25-HP Evinrude engine was used as a photographic platform.

In order to determine the relative proportions of the various species on ledges, we arbitrarily divided the cliff areas into five different strata. Stratum 1 includes all cliff areas 0 - 61m high; stratum 2, 61-122 m high; stratum 3, 122-183 m high, stratum 4, 183-244 m high; and

St. George Id. Study Areas

REFERENCE LEDGES NORTH	COORDINATES
ROSY FINCH COVE MAIN LEDGES LEDGE 57 ST GEORGE	563609N1693524W
ROSY FINCH COVE LOITERING LEDGE LEDGE 57 ST GEORGE	563610N1693524W
ROSY FINCH COVE BK LEDGE LEDGE 57 ST GEORGE	563609N169352[illegible]
FIRST BLUFF AREA A LEDGE 1 ST GEORGE	563614N1693710W
FIRST BLUFF AREA B LEDGE 1 ST GEORGE	563614N1693711W
FIRST BLUFF WEST CM LEDGE LEDGE 2 ST GEORGE	563621N1693743W
FIRST BLUFF WEST AS A REFERENCE LEDGE	563620N1693743W
EAST GAP PUFFERY LEDGE 39	563612N1693751W
WEST GAP LEDGE 600 LEDGE 40 ST GEORGE	563610N1693848W
LEDGE 41 ST GEORGE	563611N1693909W
LEDGE 42 ST GEORGE	563610N1693950W
EAST FACE OF PROMONTORY LEDGE 43 ST GEORGE	563612N1694003W
WEST FACE OF PROMONTORY LEDGE 44 ST GEORGE	563612N1694004W
LEDGE 54 ST GEORGE HIGH BLUFFS WEST	563612N1694024W
LEDGE 55 ST GEORGE	563613N1694033W

BEACH SECTIONS NORTH		
VILLAGE CLIFFS	563612N1693242W	563608N1693248W
VILLAGE TO NORTH HAULING GROUND	563608N1693248W	563606N169332[illegible]
VILLAGE EAST	563612N1693151W	563525N1693115[illegible]
VILLAGE WEST CLIFFS	563612N1693601W	563606N1693500W

INTERIOR LEAST AUKLET COLONY	
ULAKATA RIDGE COLONY - RANDOM QUADRATS LEDGE 56	563530N1693245W
ULAKATA COLONY - 175 M. PERMANENT QUADRAT	563518N1693224W
ULAKATA COLONY - 450 M. PERMANENT QUADRAT	563516N1693236W
ULAKATA COLONY - 750 M. PERMANENT QUADRAT	563514N1693248W
LA FLIGHT OVER AIRSTRIP	563606N1693300W

REFERENCE LEDGES EAST	
PINNACLE POINT LEDGE 53 ST GEORGE	563552N1692802W
TOLSTOI NORTH LEDGE 45 ST GEORGE	563545N1692741[illegible]
TOLSTOI SOUTH LEDGE 46 ST GEORGE	563540N1692740[illegible]
LEDGE 47 ST GEORGE	563536N1692745W
LEDGE 48 ST GEORGE	563530N1692754W
LEDGE 49 ST GEORGE	563524N1692809W
LEDGE 50 ST GEORGE	563522N1692812[illegible]
LEDGE 51 ST GEORGE	563517N1692819W
LEDGE 52 ST GEORGE	563513N1692830W

ST. GEORGE ID. STUDY AREAS {CONTINUED)

REFERENCE LEDGES		COORDINATES
SOUTHWEST		
MURIE COVE UPPER LEDGE	LEDGE 22 ST GEORGE	563250 N1693913W
MURIE COVE LOWER LEDGE	LEDGE 21 ST GEORGE	563250N1693914W
MURIE COVE FULMAR LEDGE	LEDGE 23 ST GEORGE	563251N1693915W
LEDGE 30 ST GEORGE		563222N1693806W
LEDGE 31 ST GEORGE		563218 N1693751W
LEDGE 32 ST GEORGE		563218N1693749W
LEDGE 33 ST GEORGE	MARVIN GARDENS	563217N1693714W
LEDGE 34 ST GEORGE	UMANANGULA WATERFALL SOUTH	563215N1693706W
LEDGE 35 ST GEORGE		563210N1693621W
LEDGE 36 ST GEORGE		563203N1693455W
LEDGE 37 ST GEORGE		563159N1693434W
LEDGE 38 ST GEORGE		563158N1693412W
LEDGE 24 ST GEORGE	FLYING BUTTRESS CAPE	563236N1693848W
LEDGE 25 ST GEORGE		563232N1693833W
LEDGE 26 ST GEORGE		563231N1693832W
LEDGE 27 ST GEORGE		563225N1693817W
LEDGE 28 ST GEORGE		563223N1693813W
LEDGE 29 ST GEORGE		563222N1693811W

BEACH SECTION

WEST

ZAPADNI BEACH CLIFFS 563420N1693958W563448N1694042W

REFERENCE LEDGES

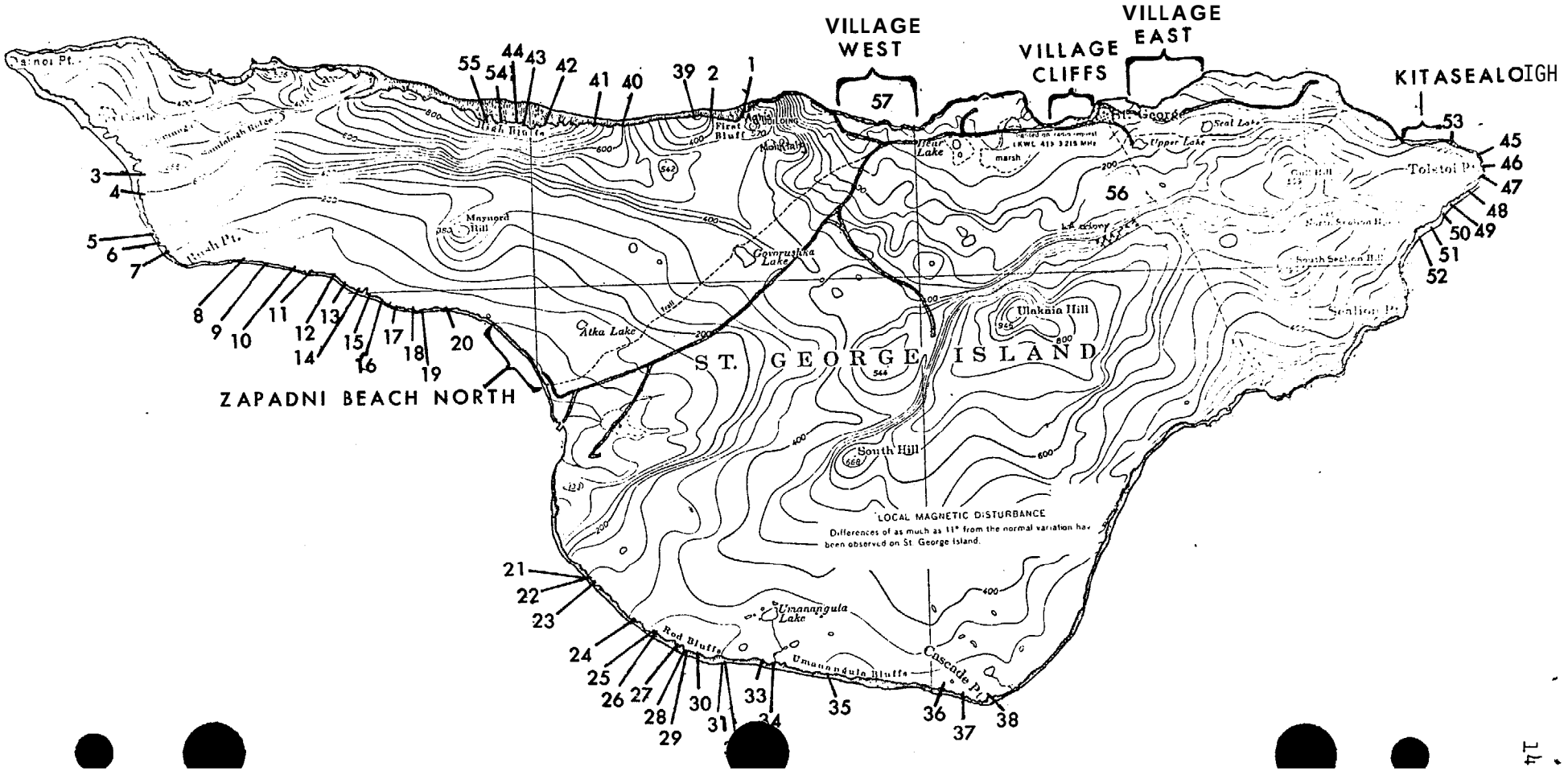
WEST.

LEDGE 20 ST GEORGE	563452N1694112W
LEDGE 19 ST GEORGE	563452N1694124W
LEDGE 18 ST GEORGE	563452N1694133W
LEDGE 17 ST GEORGE	563454N1694143W
LEDGE 16 ST GEORGE	563457N1694200W
LEDGE 15 ST GEORGE	563458N1694207W
LEDGE 14 ST GEORGE	563502N1694216W
LEDGE 13 ST GEORGE	563504N1694228W
LEDGE 12 ST GEORGE	563507N1694233W
LEDGE 11 ST GEORGE	563510N1694248W
LEDGE 10 ST GEORGE	563510N1694300W
LEDGE 9 ST GEORGE	563512N1694318W
LEDGE 8 ST GEORGE	563514N1694340W
LEDGE 7 ST GEORGE	563520N1694448W
LEDGE 6 ST GEORGE	563524N1694453W
LEDGE 5 ST GEORGE	563526N1694455W
LEDGE 4 ST GEORGE	563546N1694508W
LEDGE 3 ST GEORGE	543552NI69451OW

FIG. 1

St. George Id. Study Areas

The small x marks at 56 denote the least auklet quadrat locations studied on Ulakaia Ridge.



stratum 5, 244-308 m high. Only strata 1 and 2 occur on St. Paul. We then established reference ledges in the various strata and permanently recorded them with photographs and/or numbered metal tags; 63 such areas were set up on St. George and 35 on St. Paul (Fig. 2). Because of limited vantage points with views of the cliffs, random locations are an impossibility. We therefore tried to set up reference ledges at every vantage point we encountered where there was a section of nesting cliff that could be defined. Definitions were made by taking polaroid photos in the field which were then marked with permanent ink. These were later transferred to high-quality photos taken at the same time with the Pentax 607 or a 35-mm camera. We placed numbered metal tags at the spot where the observer stood. Coordinates for St. Paul study areas are given in Table 5.

These reference ledges are valuable for providing future indices of population change. A set of photos of these ledges accompanies the data tape. One reference ledge consists of an observation point where least auklet flights can be counted, and one is a vantage point for the entire inland least auklet colony where fixed and random quadrat counts were made.

To provide a random sample of the cliff-nesting population, we located sample points around the island on a set of contact prints of the cliff areas. Random number tables were used; 100 samples were taken in rough proportion to the amount of total cliff area represented by each stratum. Thus stratum 1, 46% of total cliff area, had 46 samples taken; 900-m^2 samples were taken using the random point as the lower left-hand corner. If part of the quadrat was above cliff level or overlapping the line delimiting two strata, the quadrat was moved up or down accordingly. If a quadrat overlapped a cliff top and a stratum line, it was extended to the right until the edge of the photograph was reached and then left. 900-m^2 was estimated using the height (from

FIG. 2

St. Paul Id. Study Areas

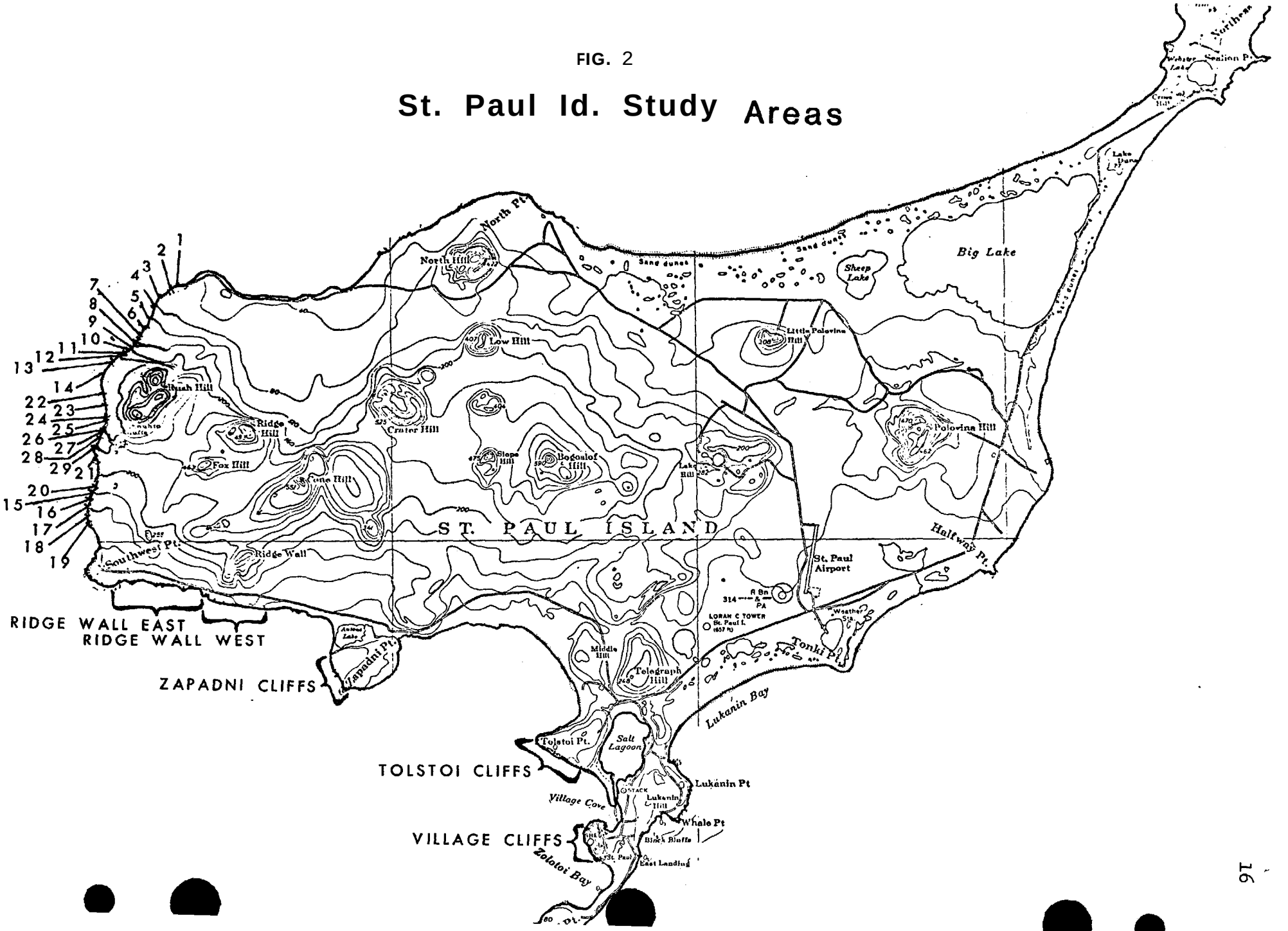


TABLE 5

St. Paul Id. Study Areas

REFERENCE LEDGES	COORDINATES
WEST	
LEDGE 1 ST PAUL	571218N1702336W
LEDGE 2 SW ST PAUL	571216N1702344W
LEDGE 3 ST PAUL	571215N1702348W
LEDGE 4 ST PAUL	571209N1702351W
LEDGE 5 NE ST PAUL	571202N1702357W
LEDGE 5 SW ST PAUL	571200N170a3581%
LEDGE 6 ST PAUL	571 158N1702400W
LEDGE 2 NE ST PAUL	571217N1702342W
LEDGE 7 ST PAUL	571155N1702403W
LEDGE 8 ST PAUL	571115N1702406W
LEDGE 9 ST PAUL	571147N1702412W
LEDGE 10 ST PAUL	571146N1702413W
LEDGE 11 ST PAUL	571143N1702422W
LEDGE 12 ST PAUL	571142N1702427W
LEDGE 13 ST PAUL	571136N1702436W
LEDGE 14 ST PAUL	571129N1702445W
LEDGE 15 ST PAUL	571027N1702451W
LEDGE 16 ST PAUL	571023NI702US4W'
LEDGE 17 ST PAUL	571018N1702457W
LEDGE 18 ST PAUL	571015N1702457W
LEDGE 19 ST PAUL	571023 NI702457N
LEDGE 20 ST PAUL	571029N1702450W
LEDGE 21 ST PAUL	571043PJI70244I3W
LEDGE 22 ST PAUL	571121N1702443W
LEDGE 23 ST PAUL	571114N1702442W
LEDGE 24 ST PAUL	571108N1702441W
LEDGE 25 ST PAUL	571106N1702441W
LEDGE 26 ST PAUL	571103N1702442W
LEDGE 27 ST PAUL	571102NI70ZU42W
LEDGE 28 ST PAUL	571057N1702445W
LEDGE 29 ST PAUL	571051N1702450W

BEACH SECTIONS	SOUTHWEST AND SOUTH
RIDGE WALL CLIFFS WEST END ST PAUL	570939N1702430W570932N1702306W
RIDGE WALL CLIFFS EAST END ST PAUL	570932N1702306W570923N1702206W
ZAPADNI CLIFFS ST PAUL	570900N1702100W570842N1702043W
TOLSTOI CLIFFS ST PAUL	570815N1701744W570800N1701654W
VILLAGE CLIFFS ST PAUL	570726N1701650W570709N1701636W

maps) of vertical cliffs as a reference. Photographic roll numbers on St. George Id. are given in Figs. 3-7, In counting birds, 11-in. by lb-in. enlargements were used.

Burro-and crevice-nesting species. --A sampling scheme for censusing talus nesters has been worked out on St. Lawrence Island by Bédard (1969) whose technique was to lay out quadrats 14.2 by 14.2 m, the observer stationing himself 40 or more meters away between 5 and 8 AM during the few days preceding laying (and coinciding with minimum daily attendance of immature birds in the colony and maximum activity of breeding birds on the surface of the slope). This involves making tallies every 30 minutes during the 3-hr. period on three successive days. This procedure further involves (1) ignoring the highest count in each series in order to correct for abnormal values resulting from disturbance and (2) averaging the 2nd-, 3rd-, and 4th-highest census figures for each quadrat.

We employed a modification of this technique in 1976 with the inland least auklet colony on Ulakaia Ridge. We set up a grid system on the hillside 1100 m by 100 m, and laid out three 10-m^2 quadrats at the 175-, 450-, and 750-m points. These were counted every 30 minutes for two all-day counts, and one count at peak attendance from 1030 to 1500 local time. We averaged the 2nd-, 3rd-, and 4th-highest figures for each quadrat.

We also used the grid system as a reference to estimate 10-m^2 areas in the telescope field, and took' four series of random 10-m^2 quadrats by locating a random point on 15X and zooming down to around 60X to count the area. These were done at times of peak attendance on the colony surface, between the 200- and 900-m grid points. Because both fixed- and random-quadrat counts required perfectly clear weather, a few false starts resulted. We had extremely good fortune with the weather, however, on the days we chose.

FIG. 3

ROLL NUMBERS OF PHOTOS TAKEN 7 JULY 1976 1315 - 1528 LOCAL TIME

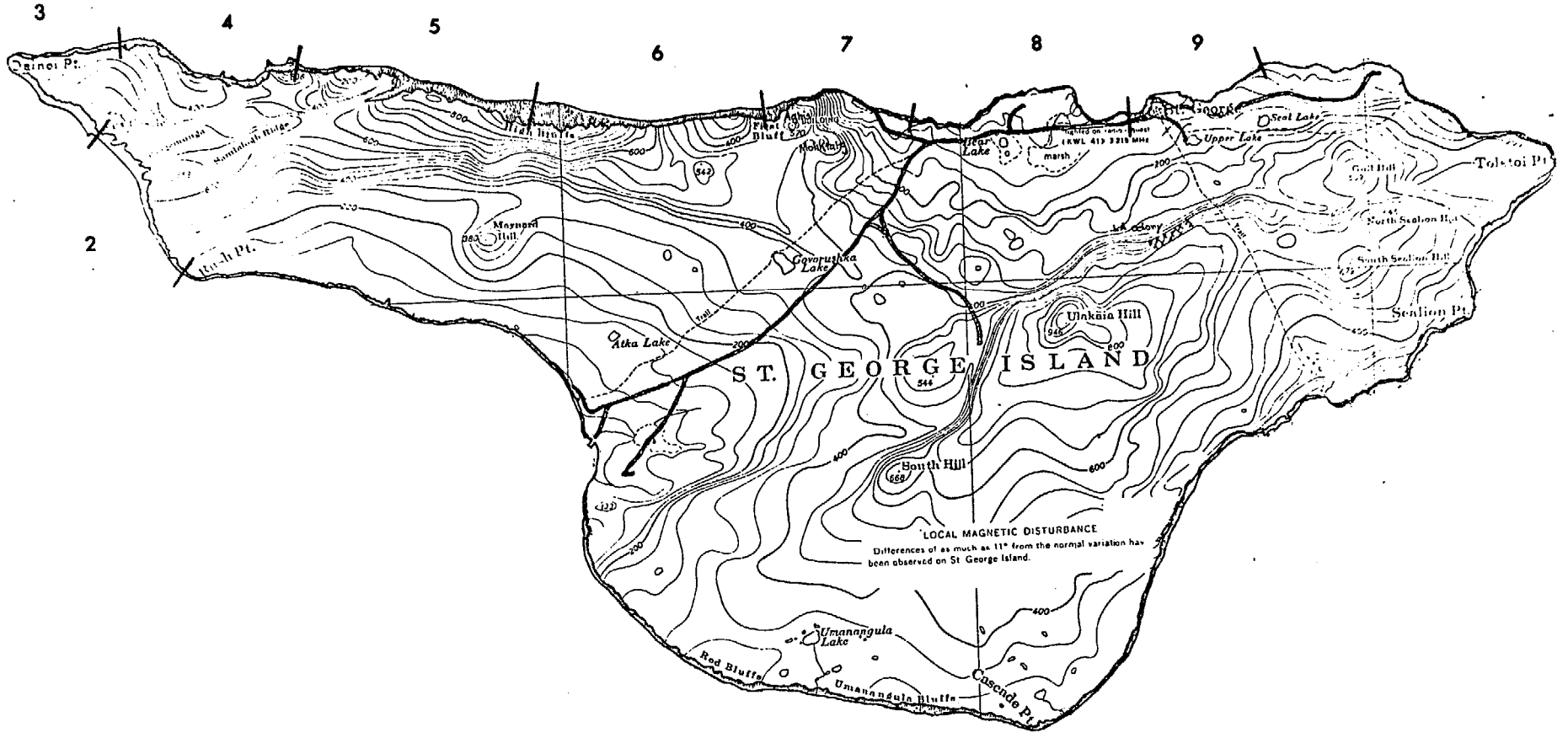


FIG. 4

ROLL NUMBERS OF PHOTOS TAKEN 15 JULY 1976 1430 - 1845 LOCAL TIME

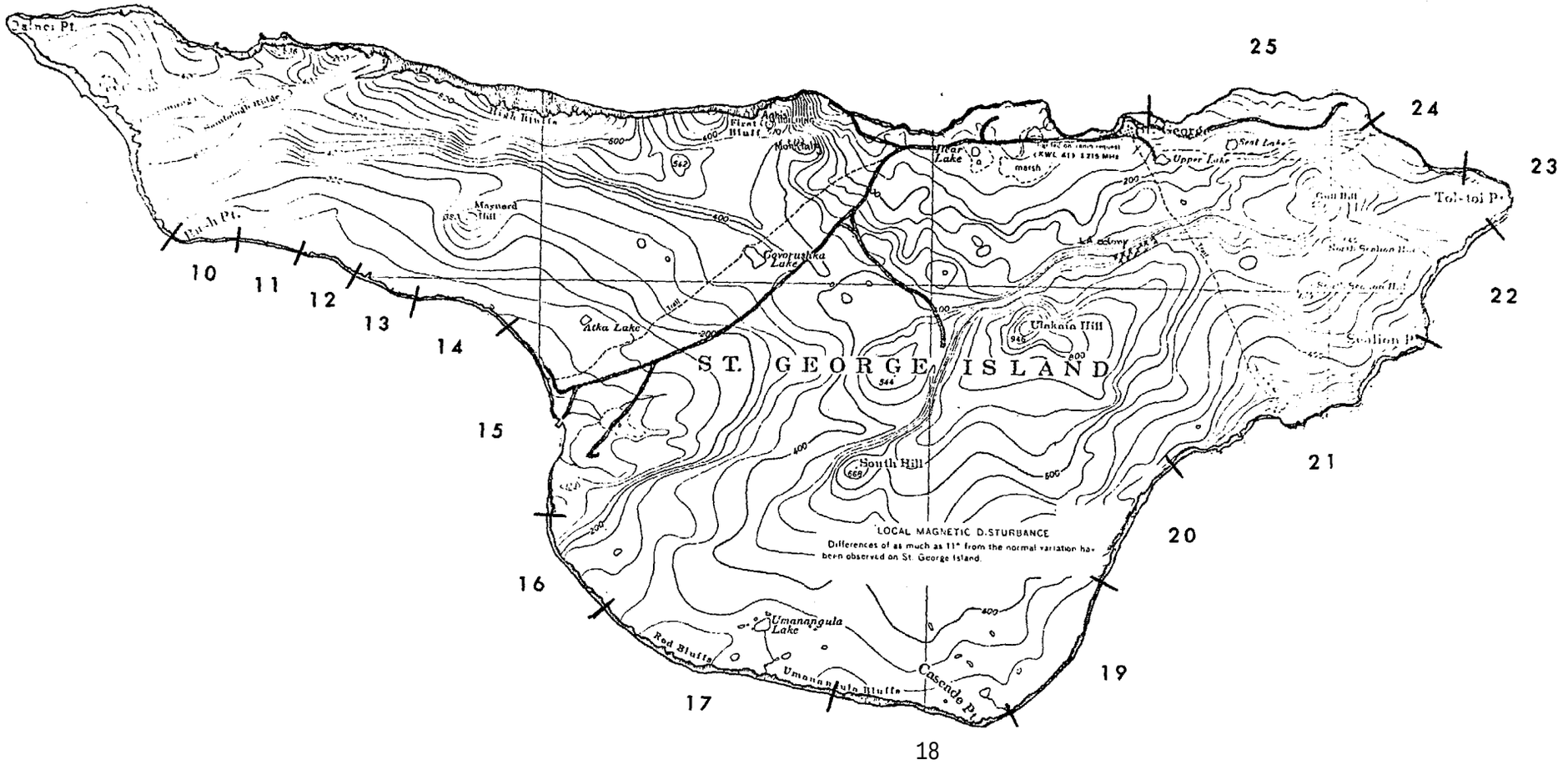


FIG. 5

ROLL NUMBERS OF PHOTOS TAKEN 29 JULY 1976 1230 - 1850" LOCAL TIME

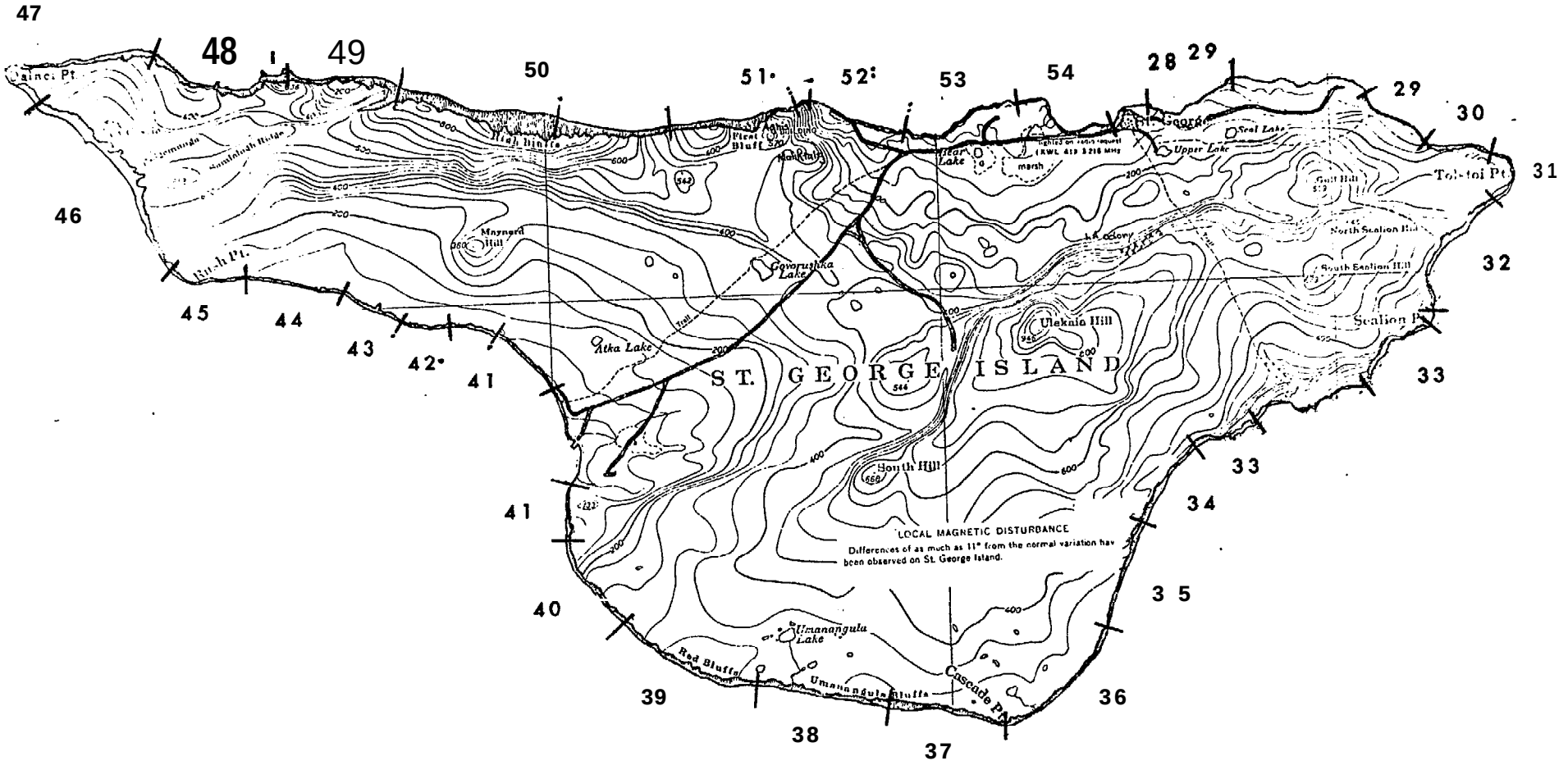


FIG. 6

ROLL NUMBERS OF PHOTOS TAKEN 5 AUG. 1976 1015 - 1100 LOCAL TIME

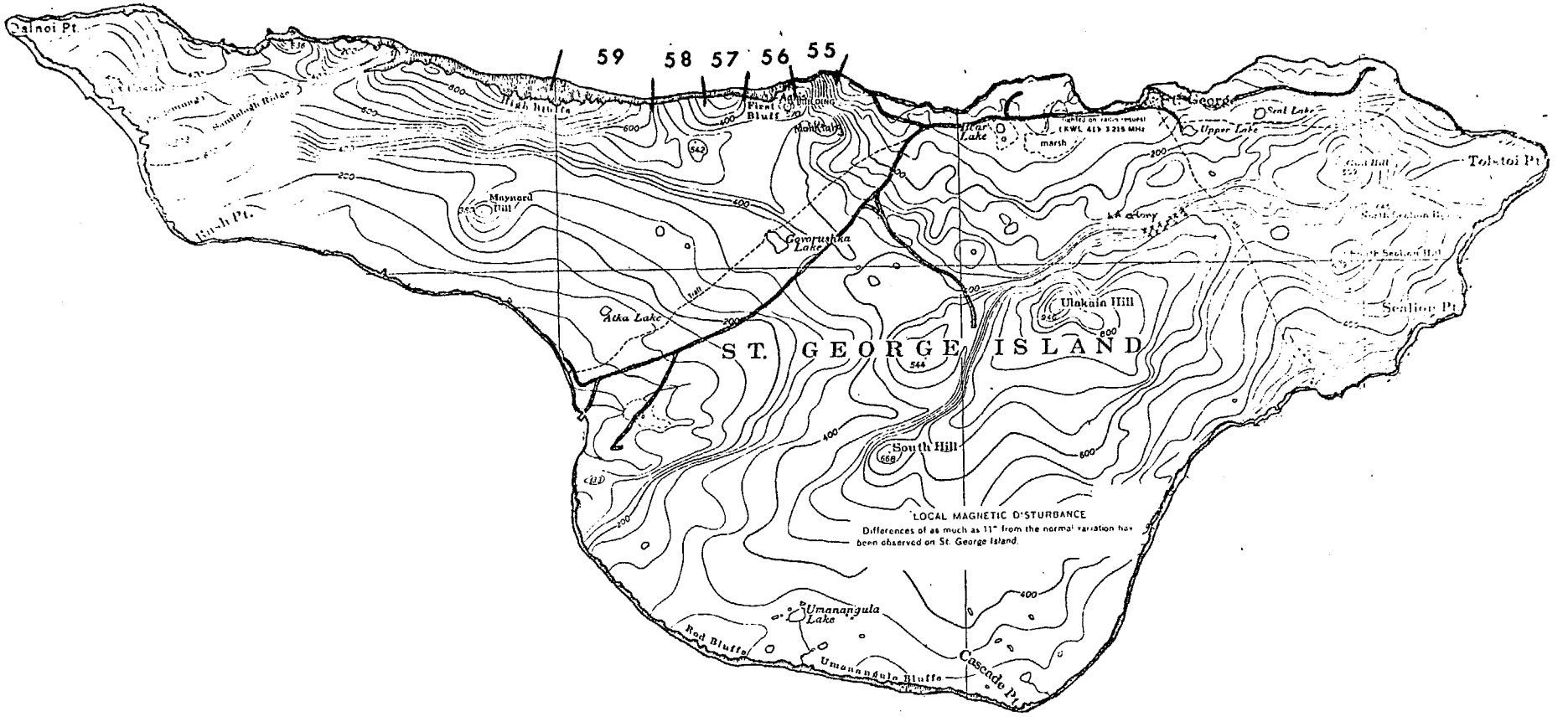
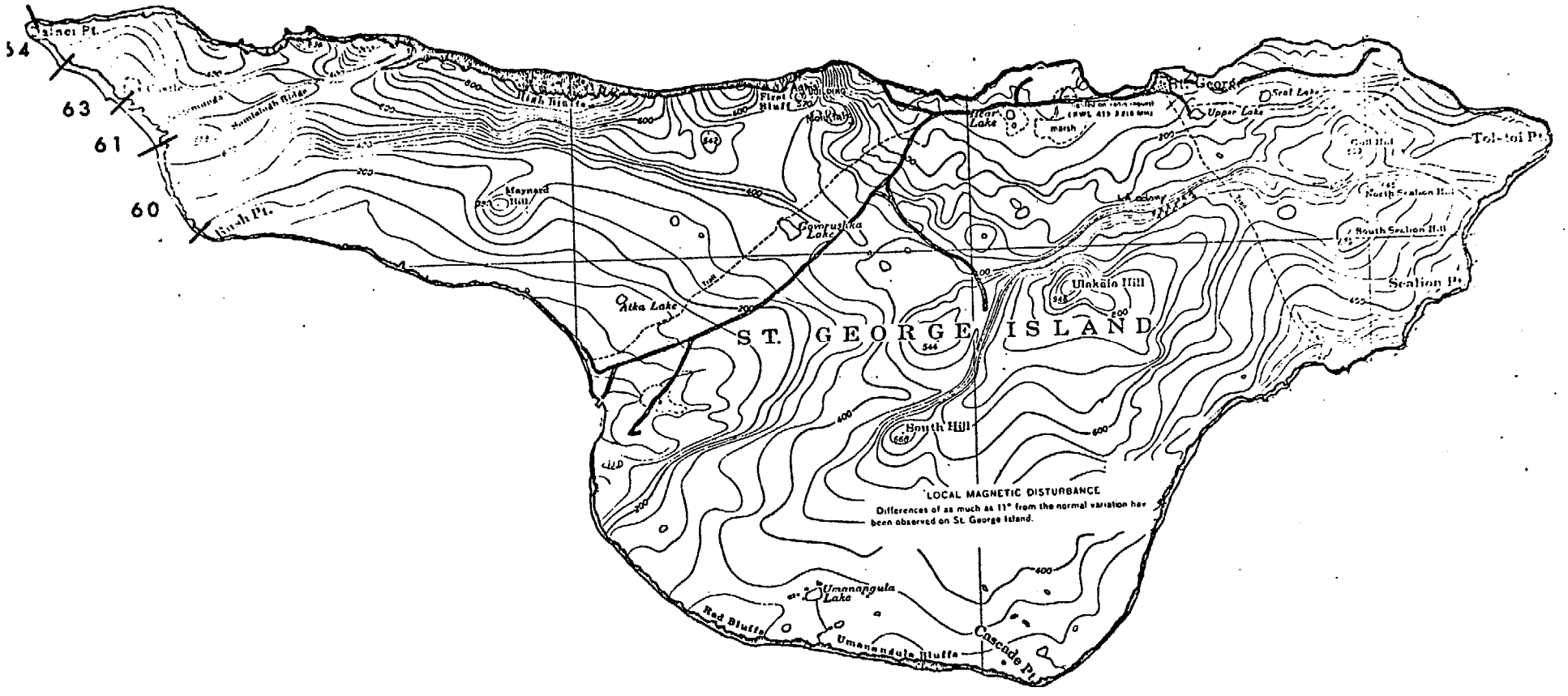


FIG. 7

ROLL NUMBERS OF PHOTOS TAKEN 6 AUG. 1976 1915 - 1950 LOCAL TIME



All the least auklets flying in to the colony can be observed as they pass over the road and airstrip west of the village. Seven 24-hour counts were made during the season by counting every other 10 minutes.

Birds were estimated in groups of 10 or in groups of 100 when larger numbers passed. A similar all-day-count was made from the inland vantage point of birds leaving the colony.

Two large colonies of crested, parakeet, and least auklets were located in talus slopes at the base of cliffs at the Northwestern end of the island. Because landing by boat was extremely difficult and time and weather limiting, we photographed these in color with the Pentax 607 and made counts from the photos.

Approximations of the numbers of burrow- and crevice-nesters on the cliff faces were made using the species proportions we obtained from our reference ledges. Only those counts made at times of the day when auklets should have been in attendance are valid, although this greatly reduces the sample size on St. George. On St. Paul, all reference counts were made at times when auklets were in attendance.

RESULTS

In 1975 a 3-man party consisting of J. J. Hickey, F. L. Craighead, and R. C. Squibb reached St. George Island on 21 June. Fifteen reference cliffs were set up, all-day flight counts were carried out of least auklets (flying west of the village into their colony On Ulakaia Ridge) and murres (flying east to west off Staraya Artel) , and an aerial survey of the cliffs that resulted in 306 positive prints was carried out on 1 August by J. G. Bartonek of the U.S. Fish and Wildlife Service. Hickey left St. George on 14 July, Craighead on 8 August, and Squibb on 13 August. Frequent almost daily fogs were found to preclude the possibility of planning satisfactory aerial surveys of the ledge-nesting species, and plans were therefore inaugurated to photograph the cliffs from a boat in 1976.

In 1976 the field season began on St. George when Craighead arrived on 5 May. At this time the island was about 80% snow covered, with cornices and ice clinging to the North and West-facing cliffs.

The prevailing winter winds had piled drifts on the Western, lee, side of the island from Zapadni Bay NW to Dalnoi Point. In early May, both red- and black-legged kittiwakes, common murres, fulmars, cormorants, and least auklets were seen. Thick-billed murres were first seen on cliffs on 10 May (on North slopes, 17 May). Horned and tufted puffins were first seen on 18 May. Parakeet and crested auklets were not seen until 25 May, but we assume they arrived at roughly the same time as least auklets. They were seen offshore on 20 May. According to St. George Aleuts, it was an unusually late spring. The pack ice left in the last days of April, and the final thaw was about 27 May. There were still large patches of snow on the least auklet colony at Ulakaia Ridge well after egg-laying. Snowdrifts persisted throughout the summer on the Western side of the island.

Ron Squibb and John Cary arrived on 2 June, and the field work began in earnest. Three study ledges were selected on different parts of the island where the major species (thick-billed and common murres, red- and black-legged kittiwakes, and fulmars) were represented. We tried to do daily ledge-attendance counts at one of these areas every other day. A flight count of least auklets and a quadrat count were done on days after a circuit of ledges had been completed. The weather was exceptionally good during June, and we managed to do an all-day count at each of these sites every 10 days to two weeks. We divided these counts into 3 shifts with a different man taking the early shift each time. Besides giving everyone an equal chance for the easy counts, this should have dampened any effects of individual bias. In between days of attendance

counts we gridded the hillside at Ulakaia, visited reference ledges, coded and consolidated data, and otherwise waited for calm seas and a clear day to photograph the cliffs.

Cary left St. George on 16 July with the first full set of cliff photographs. On the same day, Squibb and Craighead flew to St. Paul to try to photograph the cliffs there using George Hunt's Zodiac. Unfortunately, the weather turned bad and remained bad--rough seas and fog--until 22 July when we returned to St. George. We were able to establish counts of 35 reference ledges on St. Paul which we permanently recorded as on St. George.

We continued daily ledge attendance counts and flight counts on St. George on a reduced scale with only two men, and again photographed the cliffs on a near-perfect day. The majority of St. George reference ledges were set up at this time. Craighead left on 11 August and Squibb left on 18 August.

Photographic Sample Counts

Murres, kittiwakes, and light-phase fulmars were counted from photographs with the results seen in Tables 6 and 7.

Daily Attendance

Daily attendance counts were made regularly at three sites: ledge 57 (Rosy Finch Cove), ledge 53 (Pinnacle Point) and ledges 21, 22, 23 (Murie Cove). Counts were made of birds present on a given cliff area every 30 minutes from first light until dark whenever possible. Attendance counts of shorter periods were made at ledges 1, 2, and 25. Counts were also made of least auklets on the surface of the colony in 3 fixed 100-m^2 quadrats at site 56 (Ulakaia Ridge), and of least auklets flying into and from the colony.

TABLE 6

St. George Island
1976

Numbers of Birds Counted in 900m² Random Quadrats Sampled from Photographs

Stratum 1				Stratum 2			
Sample No.	Murres	Kittiwakes	Fulmars	Sample No.	Murres	Kittiwakes	Fulmars
26	98	91	0	**23**	339	68	42
18	94	99	51	**25**	670	115	18
16	22	10	0	**19**	11	**32**	0
15	408	17	7	**11**	0	**0**	0
14	47	4	0	**6**	7[a]	18	0
13	0	0	0	5	445	238[a]	42[a]
12	26	4	5	90	113	**73**	9
10	206[a]	113[a]	55[a]	**92**	121	16	0
8	0	21	0	**85**	35	6	66
?	251	48	**2**	**28**	77	56	60
4	59[a]	5[a]	**la**	**29**	795	37	93
2	72	0	0	**32**	156	87	0
1	386[a]	la	56[a]	**33**	135	8	4
38	103	35	86	36	48	3	0
80	107	28	67	37	235	11	2
95	237	17	22	43	1,187	178	41
93	33	9	0	45	892	215	58
87	0	4	0	48	313	9	3
71	46	11	73	49	488	11	23
56	56	68	5	51	176	33	1
30	251	4	50	54	537	49	37
31	305	71	55	59	0	0	0
34	24	28	0	62	67	14	8
35	226	72	11	68	420	95	37
40	188	35	19	69	208	51	3
41	0	0	0	73	247	90	17
47	341	64	2	96	0	5	0
20	0	0	0	101	353	23	48
50	457	35	13	98	424	32	0
52	156	21	27	39	32	5	25
53	318	2	25	27	135	49	1
55	177	8	21	9	297	157	25
57	45	4	0				
58	106	18	33				
61	238	38	129				
65	144	53	58				
64	387	44	23				
66	192	44	39				
67	5	35	0				
75	68	32	26				
81	254	59	0				
82	106	16	0				
99	280	114	49				
100	396	57	14				
42	0	0	0				
102	0	0	0				

(Table continued on next page)

TABLE 6 (con' t .)

St. George Island
1976

Numbers of Birds Counted in 900m^2 Random Quadrats Sampled from Photographs (continued)

Stratum 3				Stratum 4				Stratum 5			
Sample No.	Murres	Kittiwakes	Fulmars	Sample No.	Murres	Kittiwakes	Fulmars	Sample No.	Murres	Kittiwakes	Fulmars
24	0	12	0	17	0	0	0	22	64	250	0
3	726	118	66	94	17	88	0	84	85	537	0
83	768	**21**	184	91	92	81	0	17	17	785	0
72	149	**158**	72	21	21[a]	339[a]	2[a]	78	25	466	2
76	184	49	124	74	133	220	0				
88	152	**0**	**212**	77	20	176	0				
89	221	163	**0**								
44	359	**182**	**0**								
46	91	**91**	**12**								
60	457	**130**	**8**								
63	162	18	**1**								
79	10	**33**	**0**								
70	112	**70**	**0**								
97	242	**37**	**10**								

$\frac{91{,}800\text{m}^2 \text{ sampled}}{3{,}537{,}550\text{m}^2 \text{ total area}}$ = 2.5% of total cliff area sampled

a/ The figure cited is a mean of two counts by different observers.

Table 7

St. George Island 1976

Mean Number of Birds per 900m^2 Photo Quadrat

	Stratum 1			Stratum 2			Stratum 3			Stratum 4			Stratum 5		
	Murres	Kittiwakes	Fulmars	Murres	Kittiwakes	Fulmars	Murres	Kittiwakes	Fulmars	Murres	Kittiwakes	Fulmars	Murres	Kittiwakes	Fulmars
mean	150.32	31.20	22.26	280.09	55.'?5	20.72	259.5	77.28	49.21	47.16	150.66	.3	47.75	509.5	.5 "
standard deviation	134.51	31.60	29.12	288.22	63.35	24.79	239.48	62.52	73.44	52.79	120.33	.82	32.22	220.5	1
standard error of mean	19.8	4.65	4.29	50.95	11.20	4.38	64.00	16.71	19.63	21.55	49.13	.3	16.11	110.26	.5
number of sample counts	46			32			14			6			4		
$s_{\bar{x}}$ as % of $\bar{x}$	13.17	14.90	19.27	18.19	20.08	21.14	24.66	21.62	39.89	45.70	32.61	--	33.74	21.64	--

Thick-billed Murres.--Thirteen all-day attendance counts and three shorter counts were made of thick-billed murres. Twelve all-day counts can be grouped in 4 clusters (Figs. 8-11) representing before egg-laying, egg-laying, incubation> and hatching periods. We ran correlation matrices of these curves (1) between each successive curve at a given site to demonstrate seasonal variation in ledge attendance and (2) between the three sites in a given cluster to *demonstrate* congruency of the curves or synchrony of behavior. The matrices between successive curves at a given site are shown in Table 8.

Only two ledges, 21 and 22, were used for calculating correlation coefficients at Murie Cove throughout the season. A third ledge, 23, was included in the count on 25 June and is included in the graphs.

The matrices among all three sites at a given time in the breeding season are shown in Table 9.

Common Murre.--Four all-day attendance counts and 3 counts over shorter periods were made on common murres. An example of curve produced is included (Fig. 12).

Red-legged Kittiwake.-- Five all-day counts, and 1 count over a shorter period were made of red-legged kittiwakes. An example of a curve produced is included (Fig. 13). Earlier in the breeding season these curves were flatter with less fluctuation in numbers present. During the times we photographed the cliffs, red-legged kittiwake numbers remained fairly constant at maximum levels.

Black-legged Kittiwake.--Six all-day attendance counts, and 1 count over a shorter period were made of black-legged kittiwakes. An example of a

FIG. 8

15 JUNE TO 19 JUNE, THICK-BILLED MURRE ATTENDANCE

BEFORE EGG-LAYING

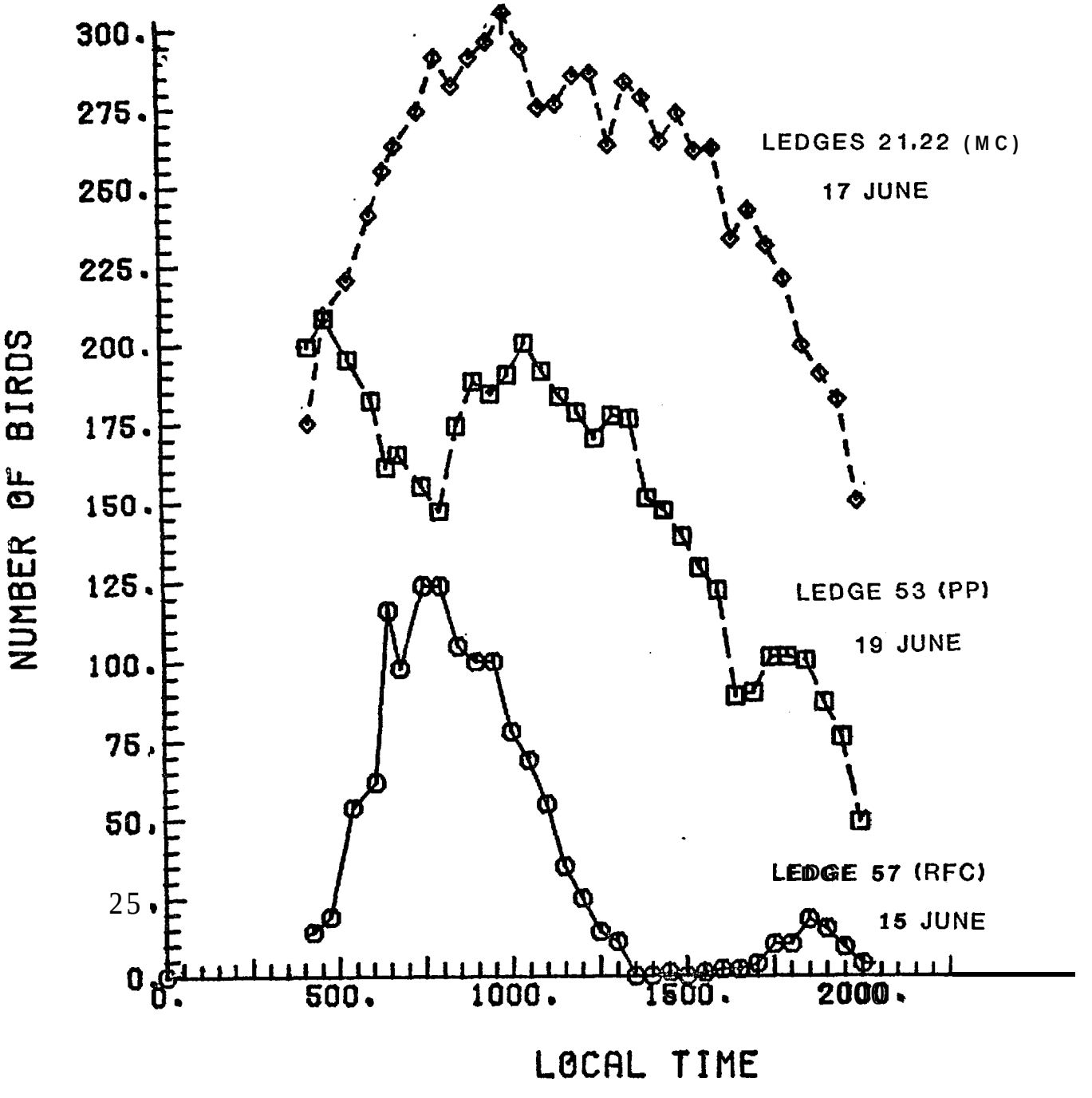


FIG. 9

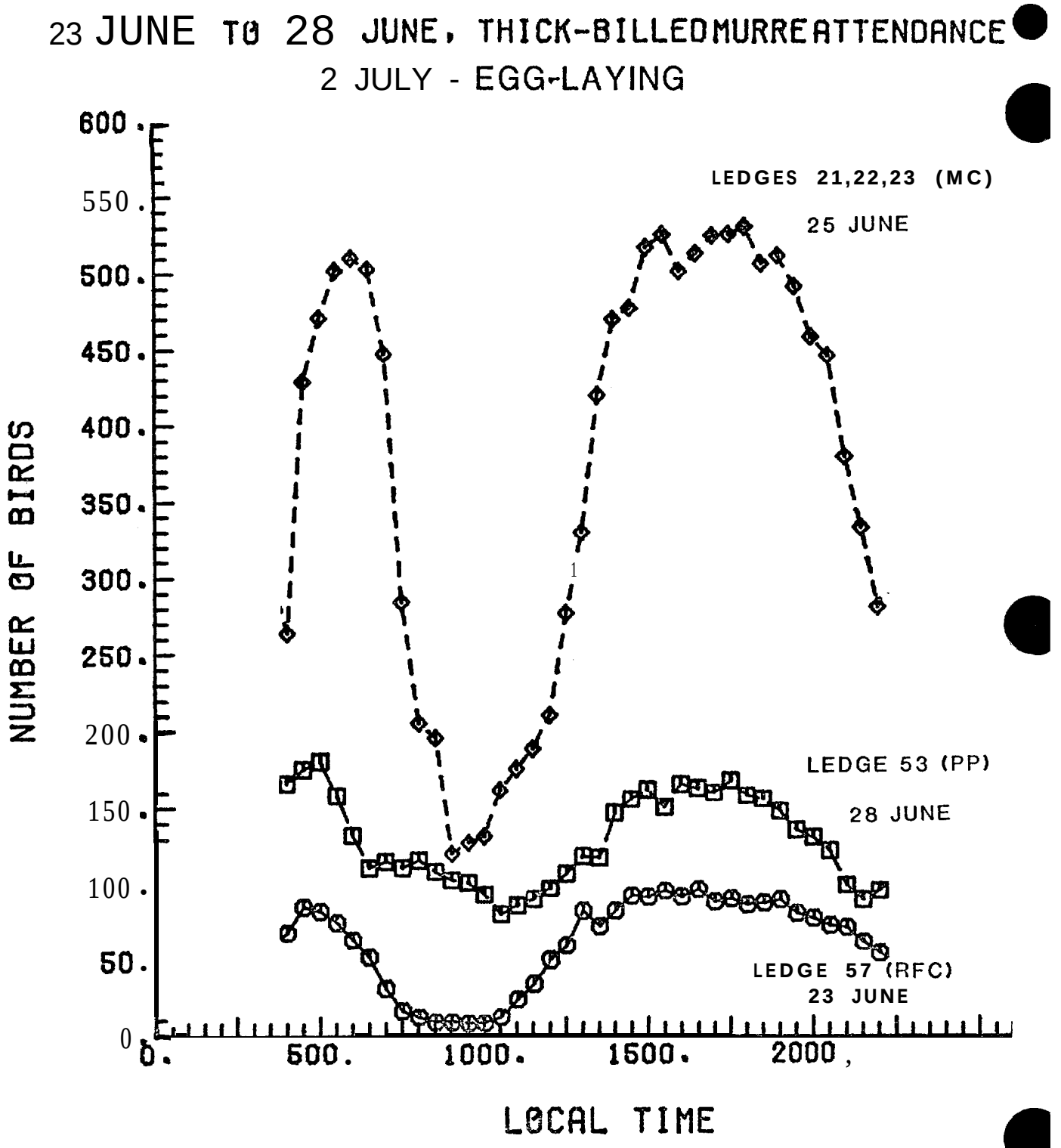

23 JUNE TO 28 JUNE, THICK-BILLED MURRE ATTENDANCE
2 JULY - EGG-LAYING
NUMBER OF BIRDS
600.
550.
500.
450.
400.
350.
300.
250.
200.
150.
100.
50.
0.
0.
500.
1000.
1500.
2000.
LOCAL TIME
LEDGES 21,22,23 (MC)
25 JUNE
LEDGE 53 (PP)
28 JUNE
LEDGE 57 (RFC)
23 JUNE

FIG. 10

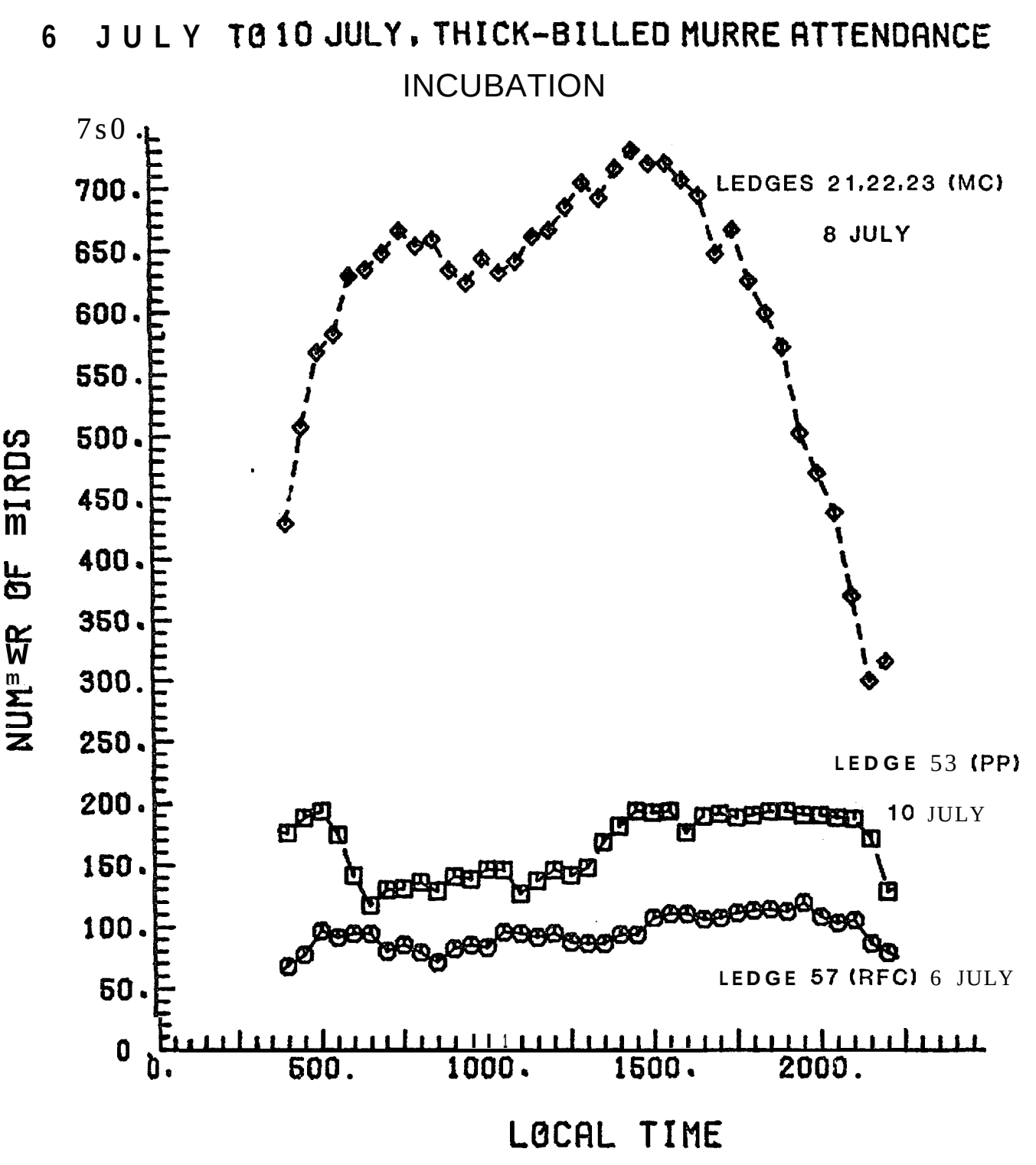

6 JULY TO 10 JULY, THICK-BILLED MURRE ATTENDANCE
INCUBATION
NUMBER OF BIRDS
750.
700.
650.
600.
550.
500.
450.
400.
350.
300.
250.
200.
150.
100.
50.
0
0.
500.
1000.
1500.
2000.
LOCAL TIME
LEDGES 21,22,23 (MC)
8 JULY
LEDGE 53 (PP)
10 JULY
LEDGE 57 (RFC) 6 JULY

FIG. 1 1

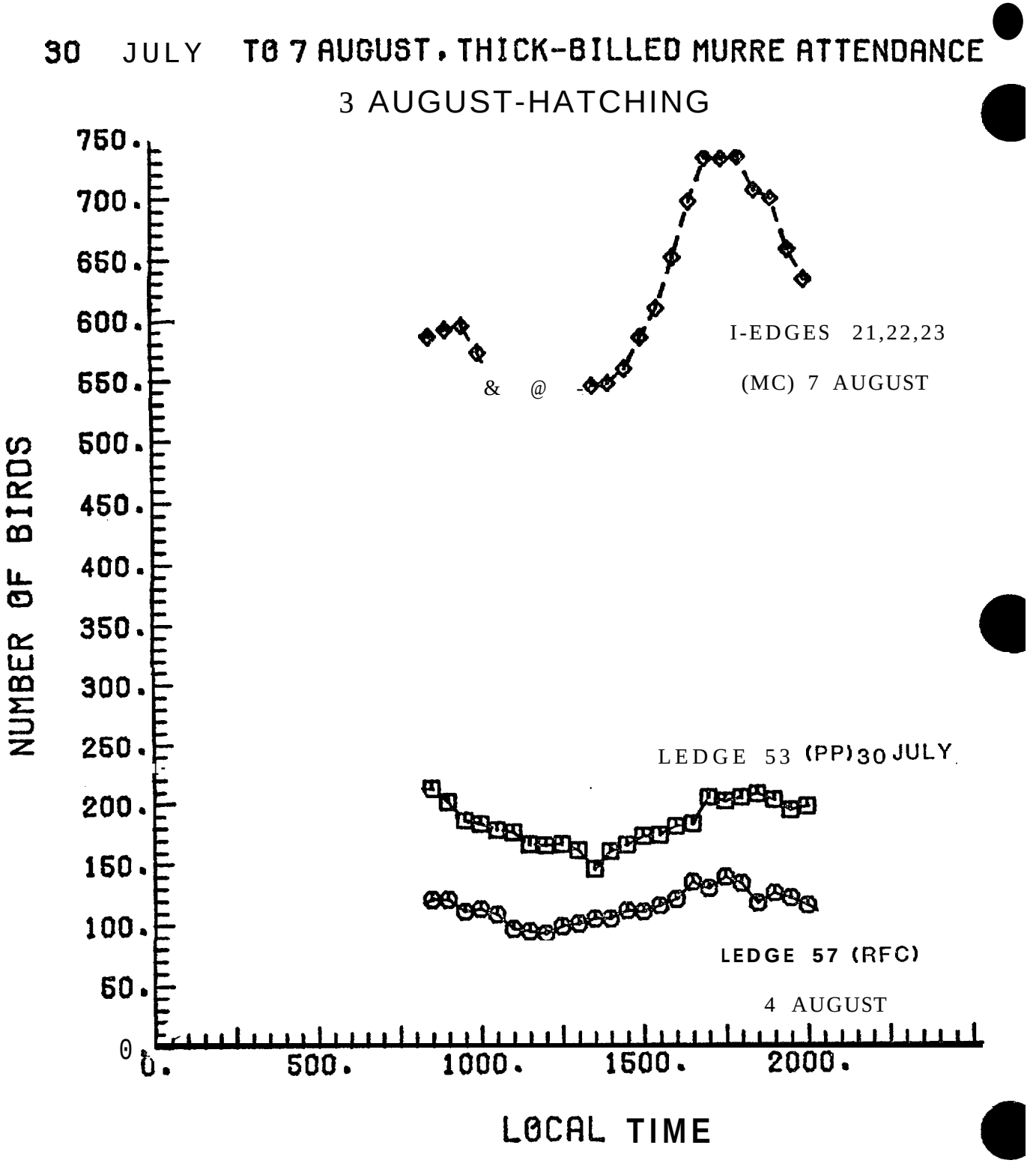

30 JULY TO 7 AUGUST. THICK-BILLED MURRE ATTENDANCE
3 AUGUST-HATCHING
NUMBER OF BIRDS
750.
700.
650.
600.
550.
500.
450.
400.
350.
300.
250.
200.
150.
100.
50.
0.
0.
500.
1000.
1500.
2000.
LOCAL TIME
I-EDGES 21,22,23
& @
(MC) 7 AUGUST
LEDGE 53 (PP) 30 JULY
LEDGE 57 (RFC)
4 AUGUST

TABLE 8. SEASONAL VARIATION CORRELATIONS
Thick-billed Murres

	Ledge 57--Rosy Finch Cove (RFC)			
Site Date	1 RFC 615	2 RFC 623	3 RFC 706	4 RFC 804
1. RFC 615	1.000			
2. RFC 623	- .937	1.000		
3. REC 706	-.662	.732	1 .000	
4. RFC 804	-.093	.349	.498	1.000

No. of observations - 24

	Ledge 56--Pinnacle Point (PP)			
Site Date	1 PP 619	2 PP 628	3 PP 710	4 PP 730
1. PP 619	1.000			
2. PP 628	-.769	1 .000		
3. PP 710	-.843	.898	1.000	
4. PP 730	-.487	.246	.189	1.000

NO. of observations - 24

	Ledges 21,22--Murie Cove (MC)			
Site Date	1 MC 617	2 MC 625	3 MC 708	4 MC 807
1. MC 617	1.000			
2. MC 625	-.693	1.000		
3. MC 708	.805	- .211	1.000	
4. MC 807	-.563	.539	-.407	1.000

No. of observations - 24

TABLE 9. ISLAND-WIDE SYNCHRONY CORRELATIONS
Thick-billed Murres

15 to 19 June (Number of observations—32)

	1 RFC	2 MC	3 PP
1. RFC	1.000		
2. MC	.397	1.000	
3. PP	-.120	.440	1.000

23 to 28 June (Number of observations—32)

	1 RFC	2 MC	3 PP
1. RFC	1.000		
2. MC	.863	1.000	
3. PP	.765	.752	1.000

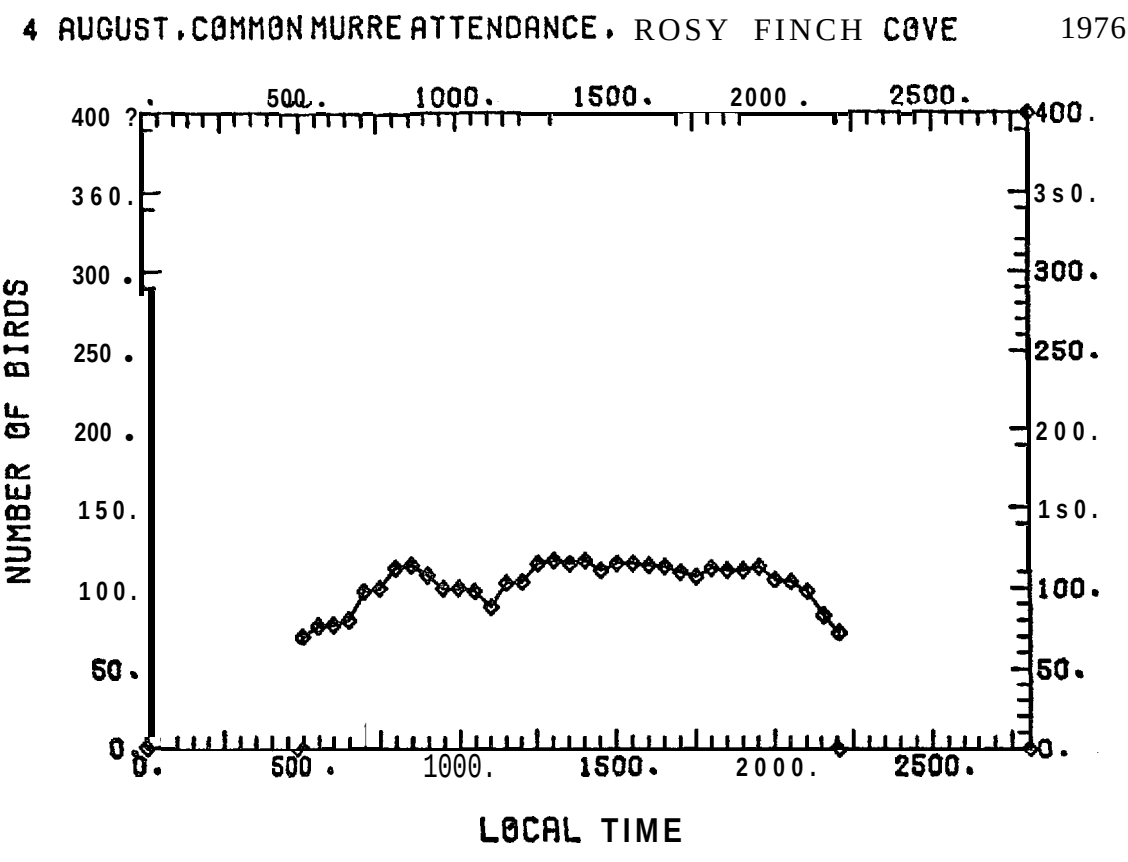
6 to 10 July (Number of observations-37)

	RFC	MC	PP
1. RFc	1.000		
2. MC	.097	1.000	
3. PP	.640	-.132	1.000

30 July to 7 August (Number of observations—37)

	1 RFC	2 MC	3 PP
1. RFc	1.000		
2. MC	.889	1.000	
3. PP	.736	.738	1.000

FIG. 12



curve produced is included (Fig. 14). During the times we photographed the cliffs, black-legged kittiwake numbers remained fairly constant at maximum levels.

Fulmar --- Seven all-day attendance counts and two counts over shorter periods were made for fulmars. An example of a curve produced is included (Fig. 15). Earlier in the breeding season these curves were flatter. During the times we photographed the cliffs, fulmar numbers remained fairly constant at maximum levels.

Red-faced Cormorant.--Five all-day attendance counts were made for red-faced cormorants. An example of a curve produced is included (Fig. 16).

FIG. 13

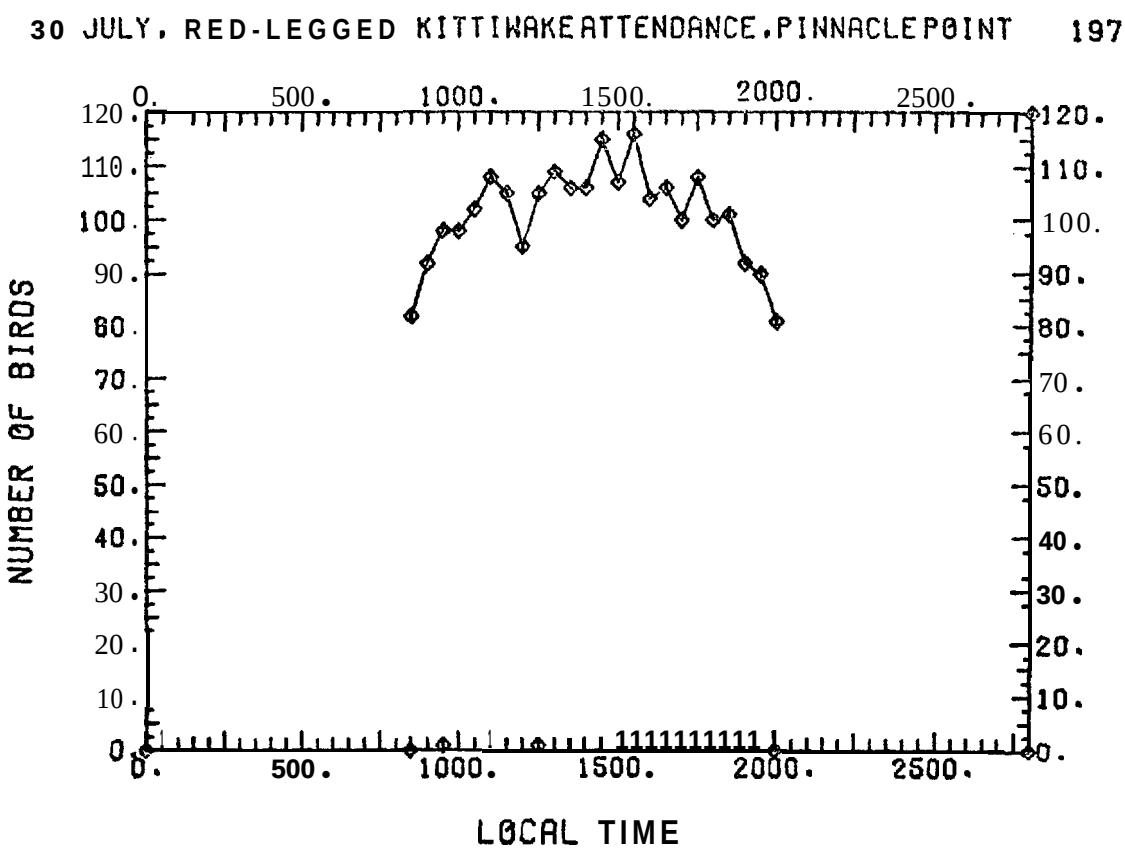

30 JULY, RED-LEGGED KITTIWAKE ATTENDANCE, PINNACLE POINT 1976
NUMBER OF BIRDS
LOCAL TIME
0.
500.
1000.
1500.
2000.
2500.
120.
110.
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.

FIG. 14

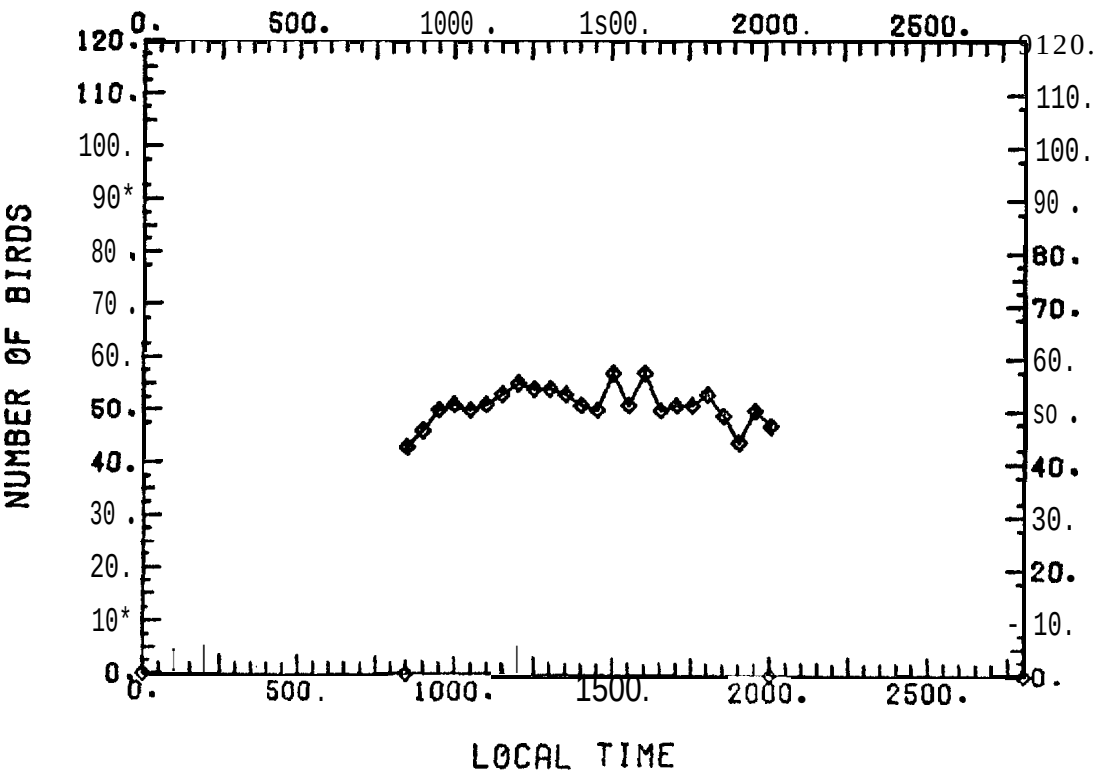

30 JULY, BLACK-LEGGED KITTIWAKE ATTENDANCE, PINNACLE POINT 1976
NUMBER OF BIRDS
LOCAL TIME
0.
500.
1000.
1500.
2000.
2500.
120.
110.
100.
90.
80.
70.
60.
50.
40.
30.
20.
10.

FIG. 15

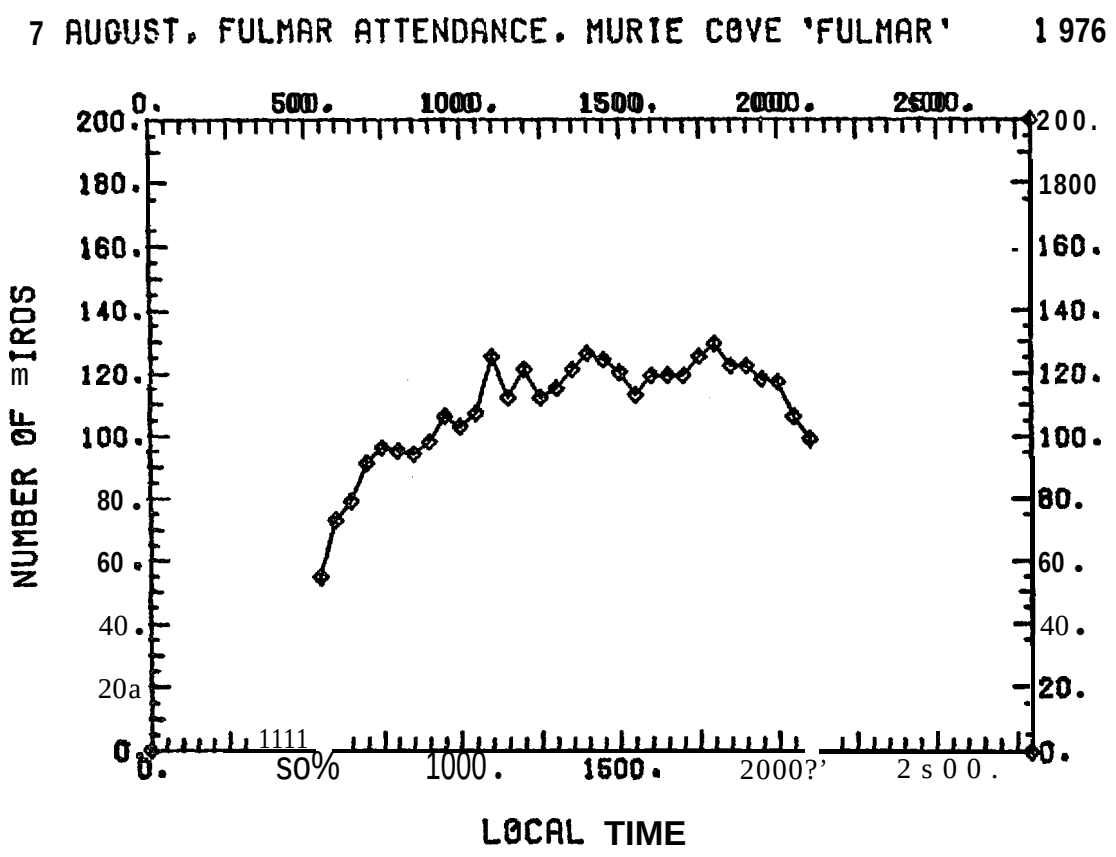
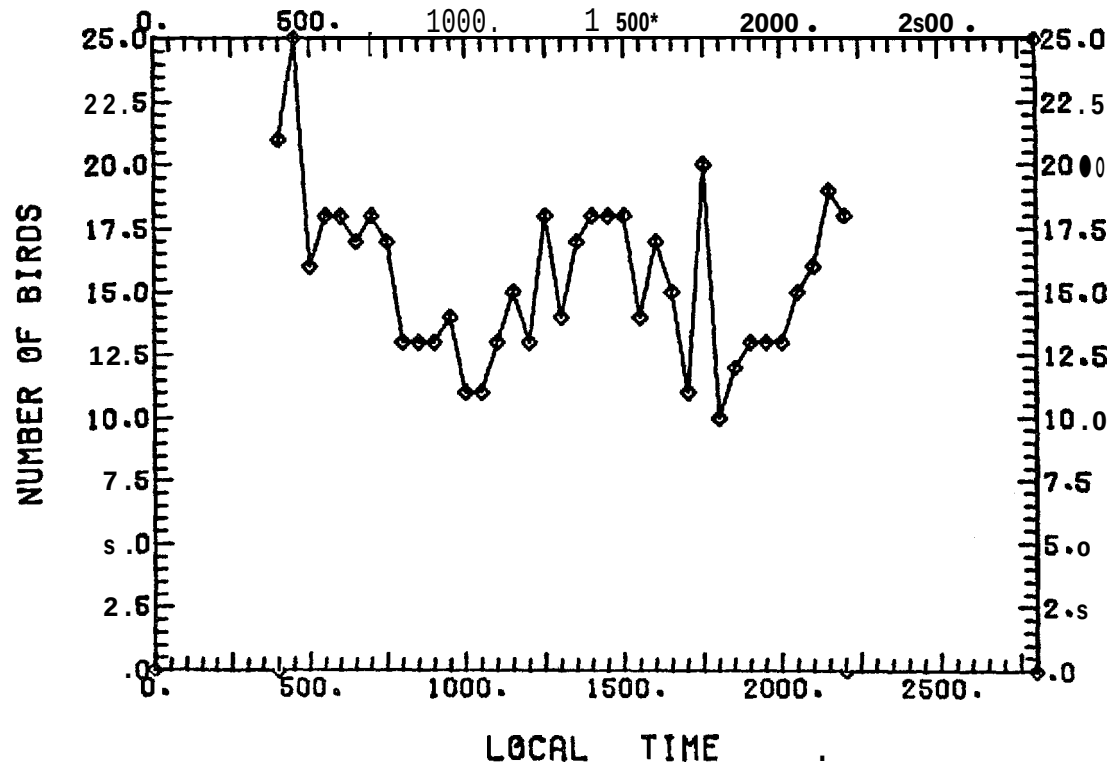

7 AUGUST, FULMAR ATTENDANCE, MURIE COVE 'FULMAR' 1976
NUMBER OF BIRDS
LOCAL TIME
0.
500.
1000.
1500.
2000.
2500.
200.
180.
160.
140.
120.
100.
80.
60.
40.
20.
1800

FIG. 16


2 8 JUNE, RED-FACED CORMORANT ATTENDANCE, PINNACLE POINT 1976
NUMBER OF BIRDS
LOCAL TIME
0.
500.
1000.
1500.
2000.
2500.
25.0
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5

Parakeet Auklet.--Nine all-day attendance counts and one count over a shorter period of time were made of parakeet auklets. An example of a curve produced is included (Fig. 17).

Crested Auklet.--One attendance count for part of a day was made of crested auklets. This curve is included (Fig. 18).

Least Auklet.--Seven 24-hr. flight counts were made throughout the season of least auklets flying inland to the Ulakaia Ridge Colony. One count of birds flying seaward was made. Examples of these curves are included (Figs. 19-22). Three all-day fixed quadrat counts and two counts over a shorter time were made on the surface of the Ulakaia colony. Four counts of random quadrats on the colony surface were made.

Horned Puffin.--Three all-day attendance counts and one count over a shorter period were made of horned puffins. The curve produced by the shorter period count is included (Fig. 23).

Tufted Puffin.--One count during part of a day was made of tufted puffins. The curve produced is included (Fig. 24).

FIG. 17

4 AUGUST, PARAKEET AUKLET ATTENDANCE, ROSY FINCH COVE 1976

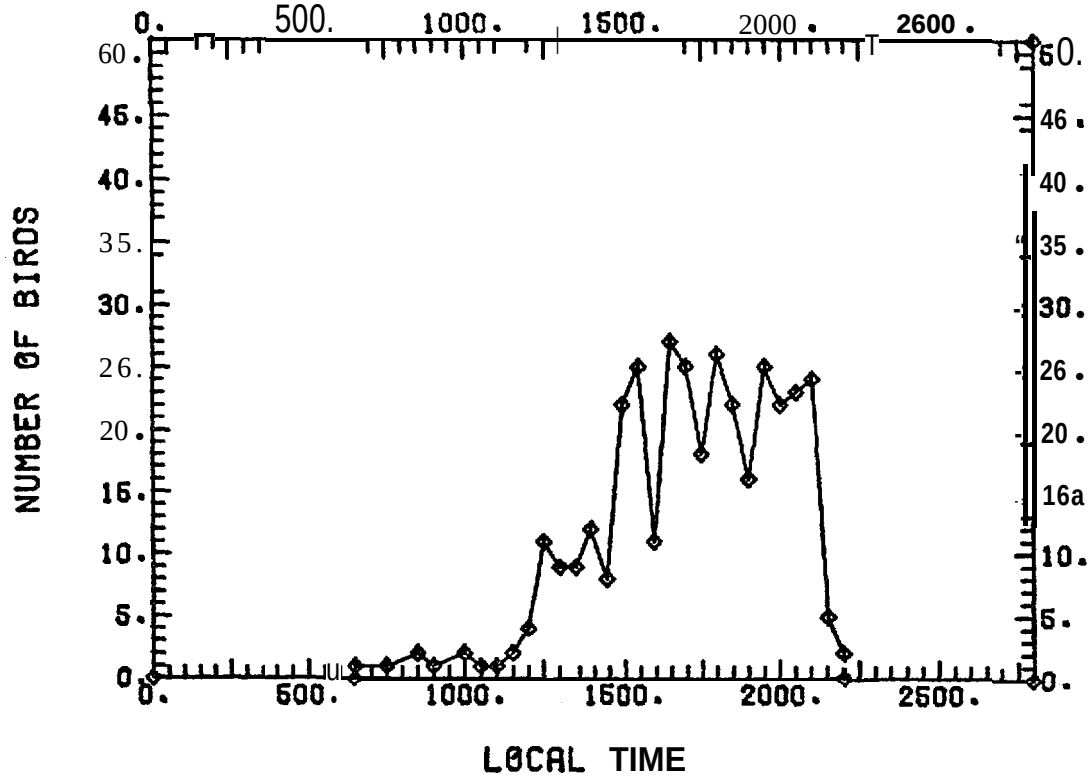


FIG. 18

23 JULY, CRESTED AUKLET ATTENDANCE, LEDGE 2 1976

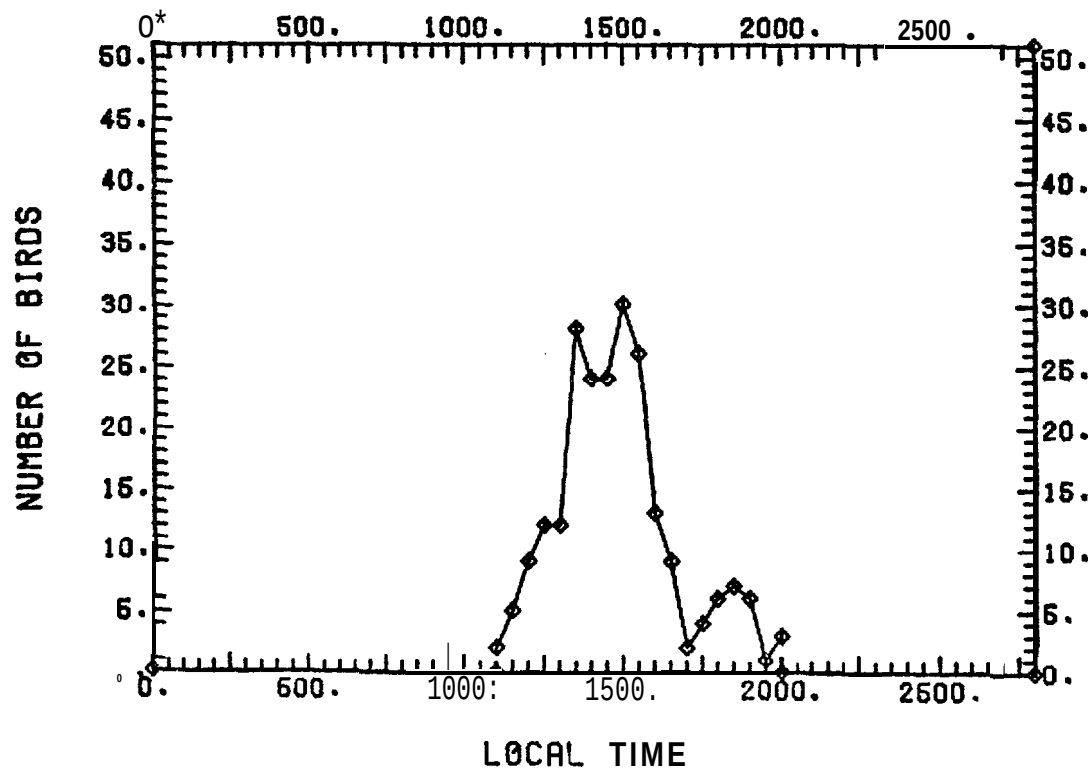


FIG. 19

1976

13 JUNE, LEAST AUKLET FLIGHT COUNT FROM SEA TO COLONY

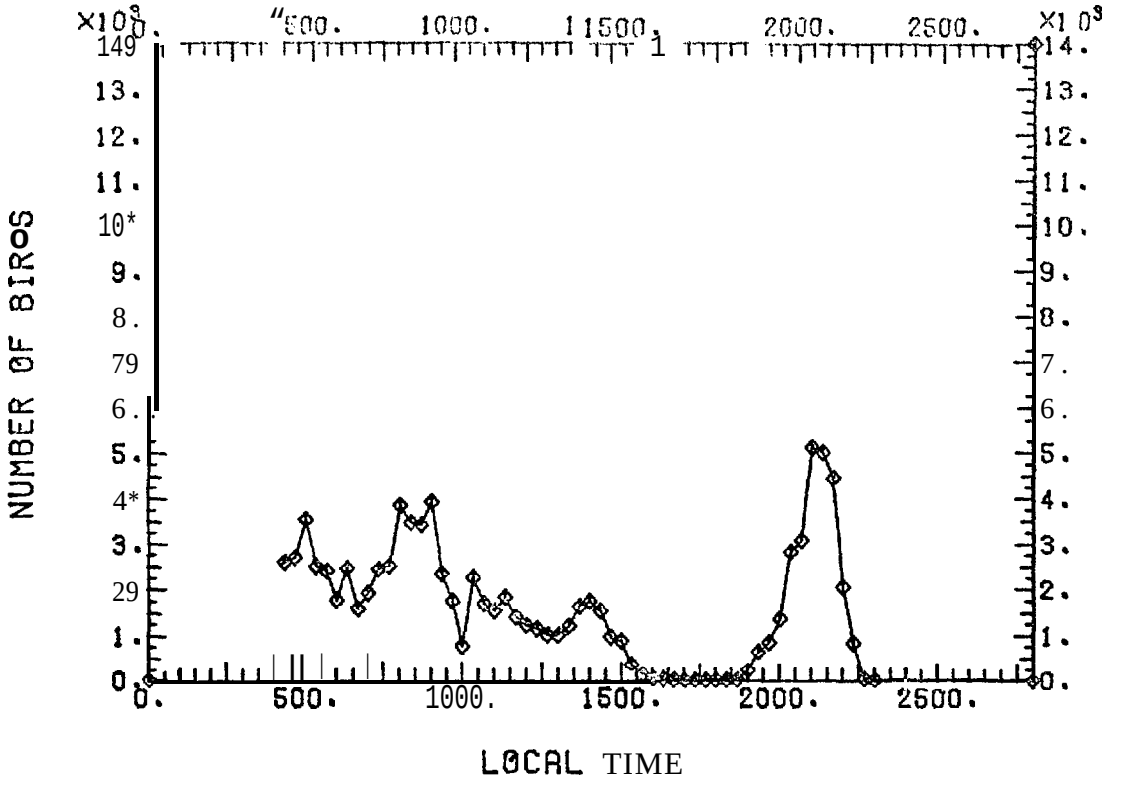


FIG. 20

1 JULY(LATE PM 1, 2 JULY. LEAST AUKLET FLIGHT COUNT FROM SEA

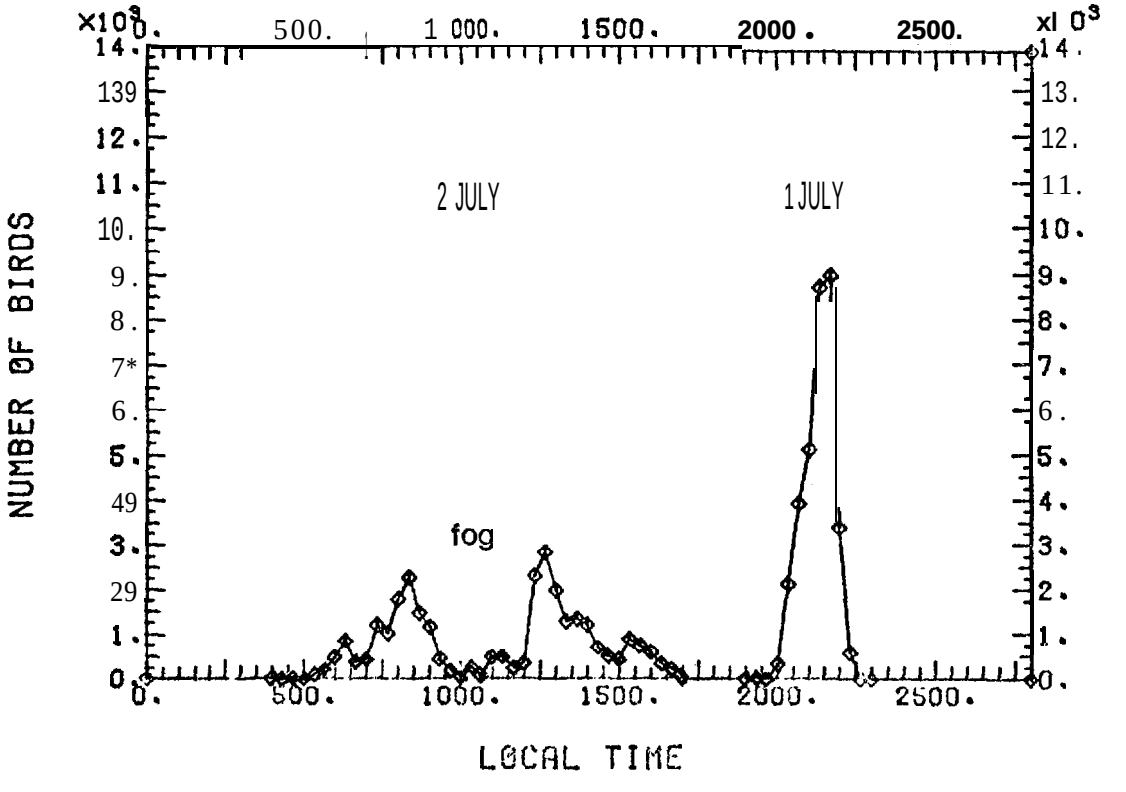


FIG. 21

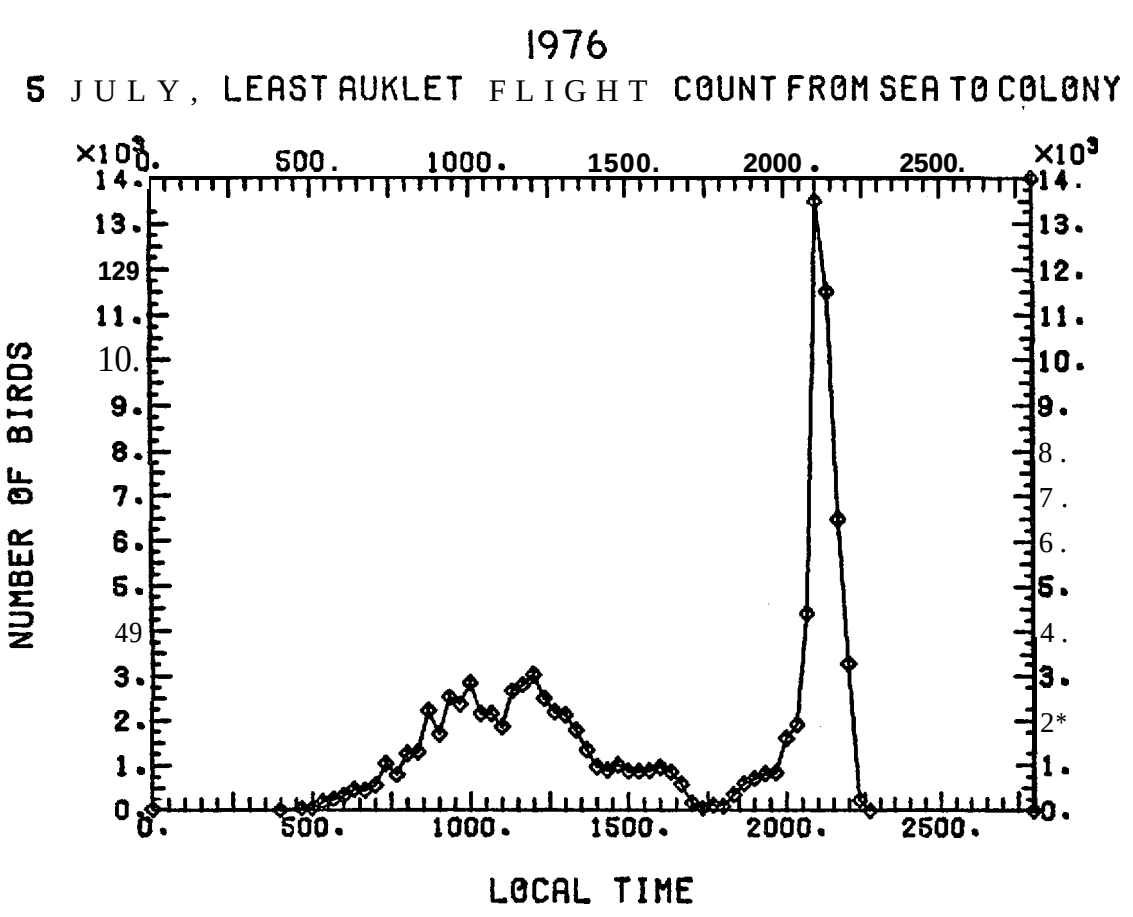

1976
5 JULY, LEAST AUKLET FLIGHT COUNT FROM SEA TO COLONY
NUMBER OF BIRDS
LOCAL TIME

FIG. 22

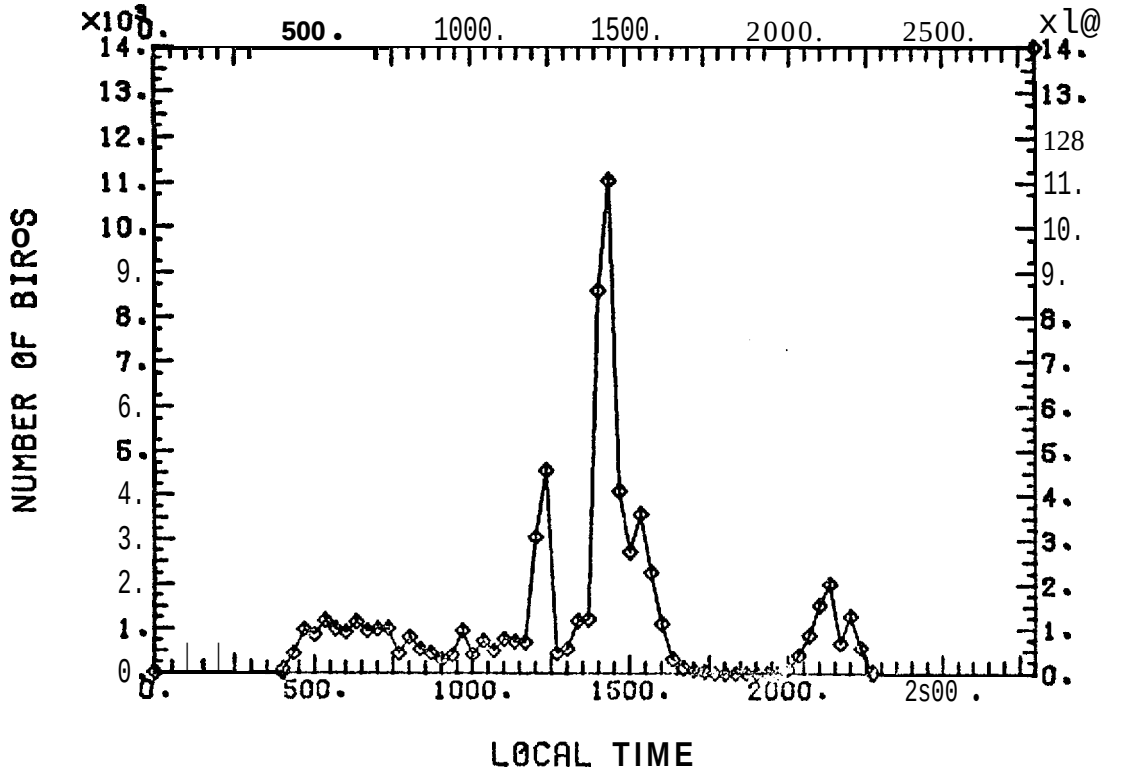

1 JULY, LEAST AUKLET FLIGHT COUNT FROM COLONY TO SEA
NUMBER OF BIROS
LOCAL TIME

FIG. 23

23 JULY, HORNED PUFFIN ATTENDANCE, LEDGE 25 1976

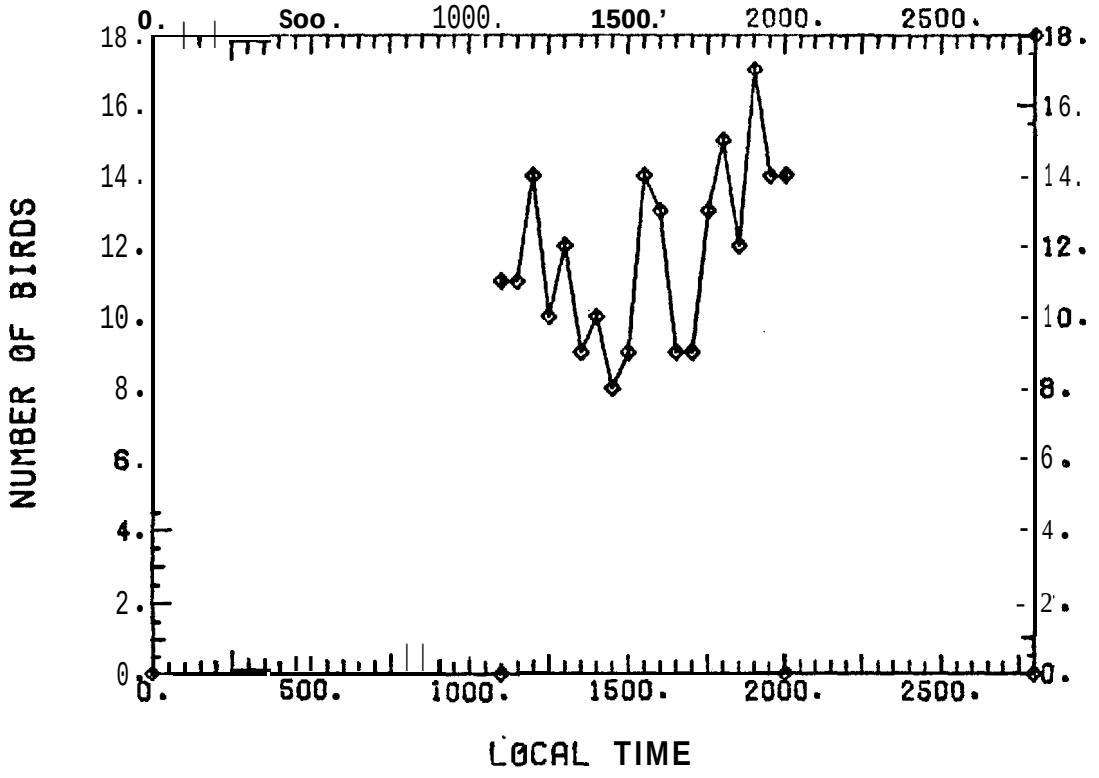
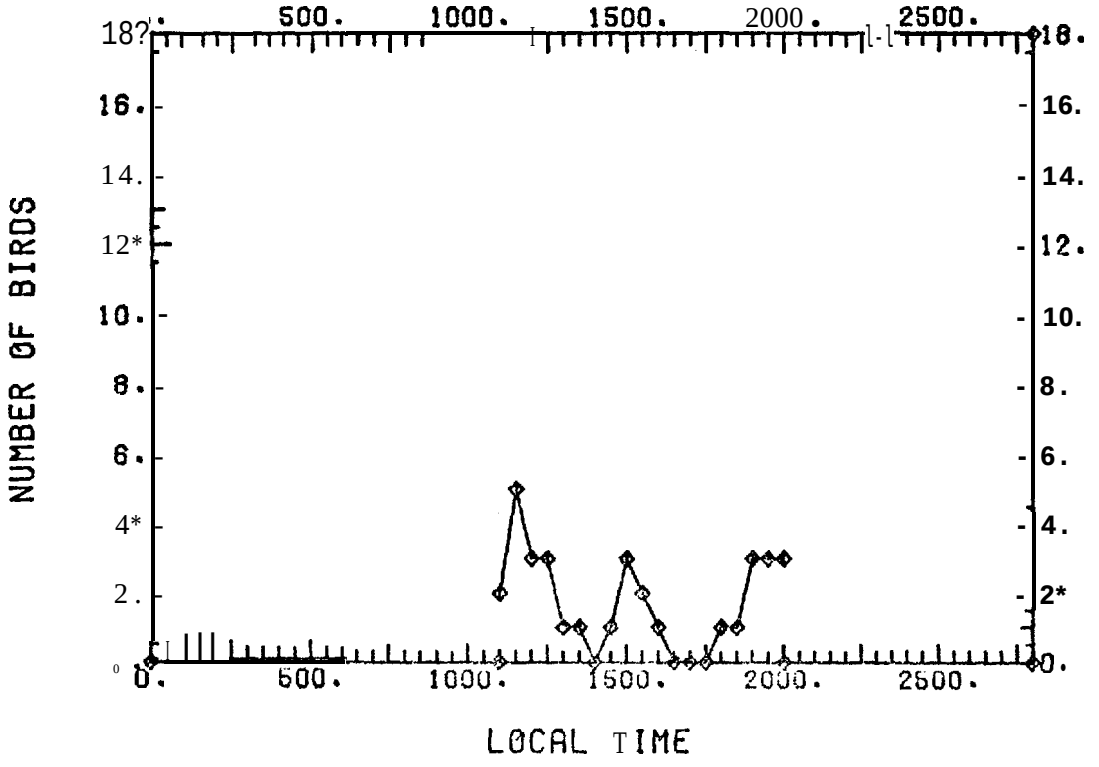


FIG. 24

23 JULY, TUFTED PUFFIN ATTENDANCE, LEDGE 25 1976



Reference-Ledge Counts

We carried out 89 ledge counts of 42,766 birds on St. George (Table 10) and two partial. ledge counts that concentrated on cormorants only. Below 800 ft. the commonest species was the thick-billed murre; above 800 ft, the red-legged kittiwake. We found it impractical to census ledges of known equal size. Counts between 1200 and 1590 hr (Table 10) are referred to later in this report as Partial Reference Counts.

On St. Paul, we counted 23,123 birds on 40 ledges (Table 11).

The proportions of species in each stratum were calculated from the reference ledge counts on St. George and St. Paul. For St. George, one set of figures was derived by using all reference counts (Table 12), and another set was derived by using only counts made from 1200 to 1500 hours (Table 13) . On St. Paul all counts were made from 1200 to 1500 hours resuiting in one set of species-proportion figures (Table 14).

Quadrat Counts and Flight Estimates

The least auklet population on Ulakaia Ridge was estimated by using three methods: counts of fixed quadrats located in the center of the colony (Table 15) , counts of randomized telescope quadrats (Table 16), and by flight-count data (Table 17). The area of the colony was estimated, and the number of birds on the surface of the colony was calculated (Table 18).

Productivity Counts

Productivity was estimated for murres (Table 19) and for fulmars (Table 20) at various sites on St. George Island. Murre ledges were visited, and the birds were flushed. Fulmar ledges were observed all day to note the number of chicks and eggs present.

TABLE 10

1976 Reference Ledge Counts St. George Island

Time	Location	TM	CM	BK (nests) incubating			RK (nests) incubating			PA	LA	CA	IP	TP	RC (nests)		LF (DF)		%TM	Max TM
Ledges 0	10 ft.																			
1050	19	91	16	26	24	22	0	0	0	6	0	0	0	0	2		10		76	120
*1445	9	295	0	38	25	23	7	3	2	23	2	0	3	0	1		24		81	364
1525	8	307	2	6	3	2	0	0	0	60	23	-1	9	0	2		2	2	85	361
*1330	13	105	0	0	0	0	0	0	0	9	5	0	0	0	0		15		75	140
1035	20	58	0	0	0	0	0	0	0	4	1	0	0	0	0		0		79	73
1110	45	202	8	5	4	4	1	1	1	18	1	0	8	0	2	3	16	1	76	266
1140	46	184	0	31	23	19	7	1	1	11	0	0	0	0	3	3	0		75	245
*1215	47	156	3	20	9	7	1	0	0	14	3	0	2	0	0		28		75	208
*1255	48	237	2	17	11	8	6	2	1	11	2	0	0	0	13		10		75	316
*1345	49	31	0	21	8	5	59	31	26	0	0	0	0	0	0		0		76	1/1
*1400	50	119	3	5	4	4	4	3	3	4	0	0	0	0	0		0		76	157
1510	51	96	0	50	32	16	18	5	5	19	0	4	4	2	0		10		81	119
1540	52	52	0	103	79	52	15	7	5	0	0	0	0	0	4	5	4		89	58
1030	53	188	3	49	35	25	94	50	44	2	0	0	0	0	9	7	0		79	238
1150	16	169	0	5	4	3	0	0	0	7	12	0	2	0	0		0		75	225
*1210	15	193	0	6	4	4	0	0	0	14	10	0	2	0	0		27		75	257
*1250	14	177	28	34	17	14	17	7	4	15	13	2	3	0	0		12		75	2 36
1105	18	70	0	0	0	0	0	0	0	6	8	0	3	0	1		2		76	92
1130	17	148	6	8	6	3	0	0	0	12	13	0	2	0	0		11		75	197
*1345	12	180	22	4	0	0	1	0	0	11	0	0	0	0	0		5		76	237
*1400	11	115	52	8	6	6	0	0	0	1	1	0	1	0	0		0		76	151
*1420	10	348	15	2	1	1	7	4	3	22	9	0	4	0	0		36		78	446
1620	7 bottom	95	0	12	4	3	11	5	4	10	0	2	4	2	0		18		94	101
*1200	26	155	574	3	1		1	0		4	7	0	2	0	12		2		75	207
1925	38 bottom	181	0	1	1		1	0		0	0	0	2	0	0		1		72	251
*1230	Zapadni beach	675	23	46	21	13	45	13	5	115	8	0	L5	2	18		4		75	900
1500-163	Village E	836	254	172	115	95	55	21	20	L83	44	49	6	3	15	2	66	2	87	2110
*1230-141	Village W	986	141	368	205	144	210	79	55	L97	205	14	1	0	21	8	42		76	1297
1645	6 bottom	130	22	5	0	0	6	0	0	4	0	0	0	0	2		0		98	133
1630-173	Village	730	41	358	234	165	293	50	41	L03	3	0	23	4	10	3	0		97	753
	Unmarked																			
1505	ledges R557	143	0	0	0	0	0	0	0	9	3	0	0	0	0		33	1	81	177
1510	" "	133	67	0	0	0	0	0	0	5	1	0	0	0	1		0		81	164
1530	" "	158	14	2	1	1	0	0	0	25	3	9	1	1	0		4		85	186
*1320	ledges R556	225	0	0	0	0	0	0	0	12	21	1	0	0	0		8		75	300
●1350	" "	145	0	5	2	2	0	0	0	9	2	0	0	0	0		5		76	191
*1410	ledges R556	50	1	0	0	0	0	0	0	6	7	0	0	0	2		0		76	66
●1220	" R555	40	0	0	0	0	0	0	0	16	19	0	0	0	0		0		75	53
1005	" R553	50	0	5	3	3	0	0	0	0	1	0	0	0	1		0		81	62
1015	" "	10	0	1	0	0	0	0	0	1	2	1	0	0	0		0		79	13
1030	" "	69	0	8	6	5	0	0	0	2	1	0	0	0	3		10		79	87
1535	" R558	134	7	2	0	0	0	0	0	17	0	0	0	0	6		2		85	158
41 ledges Σn		9466	1304	1426	- 8 8 8		859	282		987	430	83	97	14	L28	31	127	4		11,756
				1422	886	649	857		220											

TABLE 10

1976 Reference Ledge Counts St. George Island (continued)

Time	Location	TM	CM	BK (nests) incubating			GRK (nests) incubating			PA	LA	CA	HP	TP	RC (nests)	LF (DF)	STM	Max TM
Ledges 100-200 ft.																		
1625	24 middle	779	54	0	0	0	0	0	0	11	0	0	3	0	0	5	94	829
1620	7 top	414	21	0	0	0	2	1	1	57	4	10	32	0	0	74 1	94	440
1645	6 top	130	22	5	0	0	6	0	0	4	0	0	0	0	2	0	98	133
1520	32 lower	152	0	2	2	-	0	0		6	0	0	0	1	0	35	99	154
1730	35 lower	379	0	3	2		0	0		3	0	1	9	2	0	69	89	426
1900	37 lower	282	7	15	13		15	9		1	0	0	2	0	0	9	77	366
1925	38 middle	309	0	1	1		1	0		0	0	0	1	0	0	7	72	429
1545.	Unmarked ledges R558	25	0	1	0	0	0	0	0	5	0	0	1	0	4 4	8 1	90	26
1644	" L608	103	0	0	0	0	0	0	0	0	0	0	0	0	0	1	73	111
9 ledges Σn		2573	104	27	18		24	10		87	7	11	48	3	6 4	208 2		2914
				6	0	0	8	1	1									
Ledges 201-300 ft.																		
n % - -	5	303	0	15	11	10	6	0	0	34	0	0	4	0	1	10	98	309
* 1400	22	174	0	0	0	0	6	3	3	1	0	0	0	0	0	0	98	176
* 1400	21	104	0	0	0	0	6	3	3	0	0	0	0	0	0	0	98	106
* 1400	23	268	0	1	1	0	14	5	4	3	0	0	0	0	0	126	98	273
1617	24 lower top	142	a	1	-		0	-		3	0	0	1	0	0	1	94	151
* 1215	25	857	83	25	19		3	0		60	22	16	9	1	0	51	95	902
* 1225	27	979	10	41	24		60	31		26	57	0	6	7	7 5	99	95	1031
* 1300	28	704	93	21	19		50	31		77	26	12	11	2	0	85 2	96	733
* 1320	29	592	21	12	9	-	18	9		61	76	26	14	3	0	40	97	610
* 1345	30	640	137	20	14		16	11		56	57	38	19	4	0	45	98	653
1514	31	210	38	0	0		0	0		11	2	15	6	3	0	3	99	212
1520	32 upper	219	55	1	1		0	0	-	10	0	24	2	0	0	9	99-	221
1600	33	1202	2	18	13		475	285	-	16	0	0	2	0	0	47	98	1227
1730	35 top	303	0	24	19		3	2		0	0	0	0	0	0	39	89	340
1820	36	760	2	14	10	-	8	5		0	0	0	26	1	2 .2	72	83	916
1850	37 top	387	8	7	4	-	27	9	-	0	0	0	0	0	0	8	77	503
1925	38 top	150	0	4	3		66	53	-	1	0	0	5	0	1	8	72	208
* 1350	39	530	89	57	33	20	67	29	23	43	0	0	54	2	0	80	76	697
1700	Unmarked ledges L60	707	0	0	0		20	0	0	33	3	3	1	0	1	6	93	760
* 1444	" L61	232	37	3	3		1	0		30	8	42	2	4	0	2	81	286
20 ledges Σn		7072	583	264			847	476		465	51	76	162	7	U 7.	r28 2		10,314
				263	283		120	40	36									
				73	45	30												

(Table continued on next page)

TABLE 10

1976 Reference Ledge Counts St. George Island (continued)

Time	Location	TM	CM	BK (nests)		incubating	RK (nests)		incubating	PA	LA	CA	HP	TP	RC (nests)	LF (DF)	%TM	Max TM
Ledges 300-400 ft.																		
1605	24 top top	683	115	8	-		16	-		9	1	2	3	0	0	58	98	697
* 1445	2	466	100	3	0	0	22	13	12	6	0	0	2	0	0	4	81	575
1730	34	116	0	1	0		46	27		8	0	0	4	0	0	0	89	130
3 ledges Σn		1265	215	12			84			23	1	2	9	0	0	62	0	1402
				4	0		68	40										
				3	0	0	22	13	12									
Ledges 400-500 ft.																		
1730	4 lower	335	12	0	0	0	0	0	0	0	0	0	0	0	0	40	100	335
1820	3 far, lower	465	0	0	0	0	11	5	4	3	0	0	5	0	0	11	97	479
1300	1	320	0	19	15	12	132	73	61	8	2	0	1	0	0	2	75	427
3 ledges Σn		1120	12	19	15	12	143	78	65	11	2	0	6		0	5	3	1241
Ledges 500-600 ft.																		
1730	4 upper	88	0	2	2	2	63	30	26	0	0	0	0	0	0	14	100	88
1800	3 near	487	352	2	1	1	8	2	2	9	0	1	6	0	0	9	2	99 492
1645	40	113	0	17	9	9	169	89	77	0	0	0	0	0	0	0	98	115
3 ledges Σn		688	352	21	12	12	240	121	105	9	0	1	6	0	0	23	2	695
Ledges 600-700 ft.																		
1810	41 lower	516	19	22	17	15	132	86	74	0	0	0	0	0	0	0	99	521
1820	3 far top	764	112	-	-					33	0	0	-	-	-		97	788
2 ledges Σn		1280	131	22	17	15	132	86	74	33	0	0	0	0	0	0		1309
Ledges 700-800 ft.																		
1830	41 upper	1244	343	16	14	12	202	103	96	0	0	0	0	0	0	0	97	1282
1 ledge Σn		1244	3113	16	14	12	202	1.03	96	0	0	0	0	0	0	0		1282
Ledges 800-900 ft.																		
1600	54 lower	79	0	0	0	0	99	42	34	1	0	0	0	0	0	0	89	89
1600	54 far right	122	0	0	0	0	86	39	34	0	0	0	0	0	0	0	89	137
1650	55	425	181	19	15	12	326	157	135	4	0	0	0	5	0	26	98	434
1450	42	185	1	4	1	0	362	159	141	0	0	0	0	0	0	0	81	228
4 ledges Σn		813	182	23	16	12	873	397	344	5	0	0	0	5	0	26		888
Ledges 900-1000 ft.																		
1435	43	196	0	21	14	14	580	314	260	3	0	0	0	0	0	0	78	251
1950	44	473	0	12	9	6	521	341	277	0	0	0	0	0	0	1	90	526
1600	54 upper	21	0	0	0	0	114	39	30	2	0	0	0	0	0	0	89	24
3 ledges Σn		0	0	33	23	20	1215	69	567	5	0	0	0	0	0			801

TABLE 11

1976 Reference Ledge Counts St. Paul Island

1976 Reference Ledge Counts St. Paul Island

Time	Location	TM	CM	BK (nests)		incubating	RK (nests)		incubating	PA	LA	CA	HP	P	RC (nests)		LF (DF)
Ledges 0-1	0 ft.																
1225	1	72	15	35	32	28	9	5	5	1	0	0	0	0	14	12	0
1255	2SW	26	2	26	12	10	0	0	0	16	11	0	1	0	4		0
1310	3	79	3	47	30	24	2	1	0	14	19	0	2	0	10	7	0
1345	4	100	0	15	7	6	0	0	0	5	4	0	0	0	1		2
1430	22 bottom	54	4	0	0	0	0	0	0	4	0	0	0	0	1	1	0
1130	17	88	21	24	19	14	1	1	0	5	0	0	5	0	. .	1	0
1500-1700&																	
1000-U30	Ridge wall	2179	752	914	608	492	61	30	2 6	696	246	14	13	3	64	43	3
1030-1230	Zapadni	1952	558	720	539	462	15	9	8	322	135	12	29	5	48	19	2
		4550	1,355	1781	1247	1036			39	1063	415	26	50	18	143	82	
Ledges 0-150 ft.																	
1330-1530	Tolstoi	1087	1085	338	206	186	0	0	0	444	328	311	29	37	11	1	0
11 ledges Σn		5637	2440	2119	1453	1222	88		39	1507	1243	337	179	55	154	83	7
Ledges 100 200 ft.																	
1430	5SW	266	0	93	56	51	0	0	0	28	10	0	2	0	15	5	0
1405	5NE	120	1	14	3	8	0	0	0	5	1	0	0	0	3	2	0
1515	7 top CM	55	0	23	14	11	1	0	0	0	0	0	0	0	1		0
1515	7 ledge	87	256	24	20	19	0	0	0	7	0	0	0	0	1	1	0
1525	8	253	20	20	9	9	0	0	0	20	3	0	0	0	4	3	0
1545	9	133	104	94	72	50	5	3	2	16	0	0	5	0	1	1	2
1600	10	284	648	44	27	24	0	0	0	8	0	0	0	0	4	2	3
1100	19	181	131	52	32	28	0	0	0	11	12	0	1	0	1		2
1100	19	176	134	37	27	26	0	0	0	4	1	0	2	0	1		2
1115	18	254	192	40	22	17	3	1	1	3	0	0	0	0	8	5	0
1145	16	187	106	60	39	28	1	1	1	17	7	0	4	0	0		1
1200	15	206	11	50	36	31	2	0	0	2	0	0	5	0	7	2	4
1430	22 middle	337	2	19	12	9	2	1	0	26	3	0	5	0	0		3
1510	23 bottom	933	25	41	34	31	4	3	3	30	0	0	8	0	0		13
1220	20	37	0	15,	13	13	0	0	0	0	0	0	1	0	0		1
15 ledges Σn		3509	1630	626	416	355	18	9	7	177	33?	0	33	1	46	21	31
Ledges 200-300 ft.																	
1245	21	137	2	24	14	10	1	1	0	25	15	3	5	0	0		7
1820	22	329	7	12	6	5	1	1	1	53	2	0	4	1	0		15
1625	11	40	0	21	18	13	0	0	0	5	0	0	1	0	0		0
1345	12	193	0	78	46	37	0	0	0	3	0	0	1	0	23	10 "	0
1355	13	110	0	40	26	23	1	0	0	13	0	0	0	0	2	2	0
1405		86	0	4	3	3	0	0	0	8	0	0	0	0	1	1	0
1415	14	369	184	20	11	8	6	2	2	15	0	0	3	1	3	1	2
1430	22 top	172	0	47	43	38	0	0	0	14	0	0	3	0	0		0
1510	23 top	140	0	39	28	25	7	2	2	12	0	0	3	0	2	2	4
9 ledges Σn		1576	193	285	195	162	16	6	6	148	17	3	20	2	31	16	28
Ledges 300-400 ft.																	
1545	24	65	6	44	31	25	25	18	18	0	0	0	0	0	9	9	0
1605	25	87	0	41	27	21	3	1	1	0	0	0	0	0	0	0	0
1620	26	250	0	45	24	19	11	8	6	7	0	0	2	0	5	1	0
1645	27	13	0	25	13	11	25	2	19	0	0	0	0	0	0		0
1800	28	224	6	16	11	8	3		3	13	0	0	2	1	2	1	0

TABLE 12

Relative Proportions of Nesting Seabirds on Cliffs, St. George Id. 13 July - Aug. 5, 1976

counts made 1000-1930 hrs.

Stratum	1	1 Max*	2	2 Max*	3	3 Max*	4	4 Max*	5	5 Max*
Thick-billed Murre	0.6569	0.7000	0.7148	0.7396	1.66'?6	0.6827	0.7417	0.7469	0.3879	0.4163
Common Murre	.0768	.0672	.0518	.0504	.1344	.1283	.1393	.1366	.0470	.0449
Black-legged Kittiwake	.0793	.0693	.0191	.0174	.0148	.0141	.0112	.0110	.0145	.0138
Red-1egged Kittiwake	.0482	.0421	.0644	.0588	.1414	.1350	.0981	.0963	.5397	.5147
Parakeet Auklet	.0586	.0513	.0337	.0308	.0074	.0071	.0097	.0095	.0026	.0025
Least Auklet	,0238	.0209	.0313	.0285	.0007	.0007	0	0	0	0
Crested Auklet	.0051	.0045	.0123	.0112	.0004	.0004	0	0	0	0
Horned Puffin	.00W9	.0069	.0118	.0108	.0044	.0042	0	0	0	0
Tufted Puffin	.0009	,0008	.0119	.0017	0	0	0	0	.0013	.0012
Red-faced Cormorant	.0073	.0064	.0008	.0007	0	0	0	0	0	0
Light-phase Fulmar	.0346	.0303	.0546	.0499	.0281	.0268	0	0	.0069	.0067
Dark-phase Fulmar	.0003	.0003	.0001	.0001	.0007	.0007	0	0	0	0
Total Birds	1$,325	20,956*	14,461	15,840*	2,708	2,836*	3,403	3,470*	3,869	4,057*

Max * extrapolations based on daily attendance maxima.

TABLE 13

St. George Island
1976
Relative Proportions of Nesting Seabirds on Cliffs

Using Partial Reference Counts

Adjusted For Auklet Attendance

(only counts between 1200-1500 hrs. included)

Stratum. . . .	1	1 Max*	2	2 Max*
Thick-billed Murre	.5947	0.6584	0.6776	0.6970
Common Murre	.1213	.1022	.0696	.0657
Black-legged Kittiwake	.0810	.0682	.0224	.0211
Red-legged Kittiwake	.0503	.0423	.0321	.0303
Parakeet Auklet	.0678	.0571	.0442	.0417
Least Auklet	.0378	.0318	.0545	.0514
Crested Puffin	.0024	.0020	.0164	.0154
Horned Puffin	.0046	.0039	.0143	.0135
Tufted Puffin	.0003	.0002	.0028	.0026
Red-faced Cormorant	.0094	.0079	.0009	.0008
Light-phase Fulmar	.0306	.0258	.0650	.0613
Dark-phase Fulmar	.0000	.0000	.0002	.0002
Total Birds	7,120	8,455	8,185	8,681

Max* extrapolations based on daily attendance maxima.

TABLE 14

Relative Proportions of Nesting Seabirds on Cliffs

St. Paul Id.

17-21 July,1976

counts made 1200-1500 hrs.

all auklets present

Stratum	1	2
Thick-billed Murre	0.4602	0.6840
Common Murre	.2048	.0633
Black-legged Kittiwake	.1381	.1408
Red-legged Kittiwake	.0053	.0256
Parakeet Auklet	.0847	.0488
Least Auklet	.0644	.0053
Crested Auklet	.0169	.0009
Horned Puffin	.0107	.0074
Tufted Puffin	.0028	.0006
Red-faced Cormorant	.0101	.0145
Light-phase Fulmar	.0019	.0086
Dark-phase Fulmar	0	0
Total Birds	19,874	3,249

TABLE 15

St. George Island 1976

Counts of Fixed Quadrats Ulakaia Hill Least Auklet Colony

Date	Time	1st Highest count . Quadrat			2nd Highest count Quadrat			3rd Highest count Quadrat			4th Highest count Quadrat			Mean of 2nd, 3rd, & 4th Highest Counts Quadrat		
		175	453	750	175	453	750	175	453	750	175	453	750	175	453	750
10 June	0900	38	53	27	28	49	12	24	26	11	--	--	--	26*	37. 5*	11. 5*
11 June	0430-0600	78	130	73	68	123	63	54	119	61	53	114	50	58.3	118.6	58
12 June		83	158	86	63	153	82	63	151	82	59	146	80	61.6	150	81.3
21 June		47	100	40	42	85	34	41	79	32	39	76	27	40.6	80	31
1 July		45	118	40	44	115	39	40	111	38	36	103	35	40	1.09.6	37*3
		Average of 2nd, 3rd, & 4th highest averages												53.5	116.2	56.7
		Average of 2 counts immediately preceding laying												59.95	134.3	69.65

*4th highest count disregarded

TABLE 16

St. George Island 1976

Counts of $100m^2$ Random Telescope Quadrats

Ulakaia Hill Least Auklet Colony

Date.	Time Period	Number of counts	Mean	Standard Deviation	Standard Error of Mean
12 June	0905-1207	59	28.3051	18 .1680	2● 373
21 June	1330-1502	35	24.7428	17 .3414	2.9312
22 June	0915-1059	56	27.5	23.7869	3.1787
1 July	0942-1305	50	21.12	18.508	2.617

Grand mean of June counts = 25.6116 Least Auklets/$100m^2$

TABLE 17

St. George Island
1976

Least Auklet Estimates at Ulakaia Colony

Based on Evening Flight Counts During Incubation

1800 hrs until dark

Date	Least Auklet arriving	Least Auklet leaving
1 July	66,226	14,919
'j July	92,660	
Mean [a]	79,443	

[a] 79,443 - 14,919 = 64,524 least auklets staying overnight at the colony. This in turn yields 129,048 breeding birds.

TABLE 18

St. George Island 1976

Estimates of Area of Ulakaia Least Auklet Colony

12 June	62,500 m^2
17 June	126,562.5 m^2
Mean	94,531.25 m^2

Estimates of Least Auklets on Colony Surface

Method	
Random Quadrats	94,531.25 m^2 X .256116 birds/m^2 = 24,211 birds (Mean Density)
Fixed Quadrats	94,531.25 m^2 X .794 birds/m^2 = 75,058 birds (Peak Density)

TABLE 19

Murre Productivity St. George Island 1976

Mid-afternoon, latter half of incubation period and early hatching period

Date/Time	TM	TM Eggs	TM Chicks	CM	CM Eggs	CM Chicks	Unidentified egg	Unidentified chick
31 July 1935	32			12			20	9
31 July 1500	3	1						
31 July 1500	25	11	9					
31 July 1505	21	9	7	24		6		
31 July 1500	55			14			35	14
1 Aug* 1700	95*			113*			90*	12*
29 July 1330	38	15	2					
29 July 1330	6	4	1					
9 July 1710	21	15						
9 July 1500	165	35						
9 July 1515	36	24						
Totals	497	114	19	163	6	6	145	35
Totals**	315	114	19	24	6	6		

* Egged on June 24 and 26 by Aleuts. All replacement eggs laid by August 1.

** Excluding the data of August 1.

TABLE 20

St. George Island
1976
Fulmar Productivity

All-day observations after mean hatching date

Date/ Area	No. of Chicks seen	No. of eggs	Maximum no. possible nest sites	Maximum no. adult birds	Nests/ Chick	Nests/eggs laid	Birds/ Chick	Birds/eggs laid
7 Aug Muri e Cove	22	1	86	129	3.91	3.74	5.86	5.61
4 Aug Rosy Finch Cove	6	1	20	38	3.33	2.86	6.33	5.43
Mean					3.62	3.3	6.10	S.52

DISCUSSION

Estimates of Errors

Photographic Sample Counts.--At higher evelations and in poorer photographs it was difficult to distinguish murres and to discriminate between kittiwakes and fulmars. For this reason, the number of white birds (kittiwakes and light-phase fulmars) was calculated (Table 21, and Fig. 25) giving means with somewhat less variability. The number of photographic samples necessary to achieve a given confidence interval on the mean for counts of white birds is illustrated graphically in Fig. 26. We found similar results for murres. We sampled 2.5% of the total cliff area on St. George from 11 in. x 14 in. photograph enlargements.

TABLE 21

St. George Island 1976

Mean Number of White Birds per goon?

Photo Quadrat

	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5
mean	53.54	76.47	133.64	151	510
standard deviation	48.50	76.22	87.03	120.96	220.39
Standard error of mean	7.15	13.47	23.26	49.38	110.19
number of sample counts	46	32	14	6	4
$s_{\bar{x}}$ as % of $\bar{x}$	13.35	17.61.	17.40	32.70	21.61
C.I. on $\bar{x}$	28.6$	55%	103%	253%	701%
Stratum as a % of total area*	46%	29%	12%	9%	4%

* From Table 3.

Fig. 25

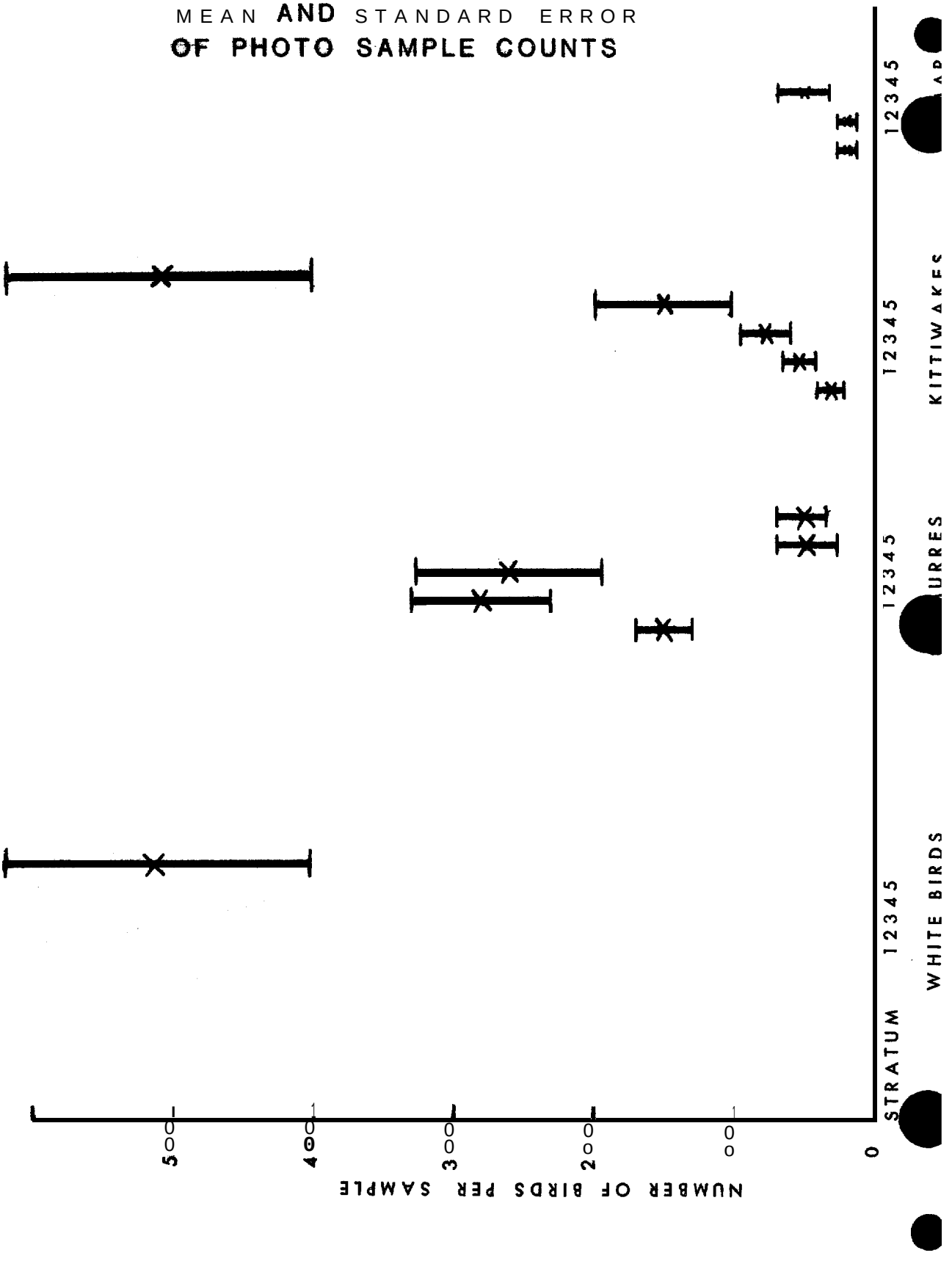

MEAN AND STANDARD ERROR
OF PHOTO SAMPLE COUNTS
NUMBER OF BIRDS PER SAMPLE
0
100
200
300
400
500
STRATUM 12345
WHITE BIRDS
12345
MURRES
12345
KITTIWAKES
12345

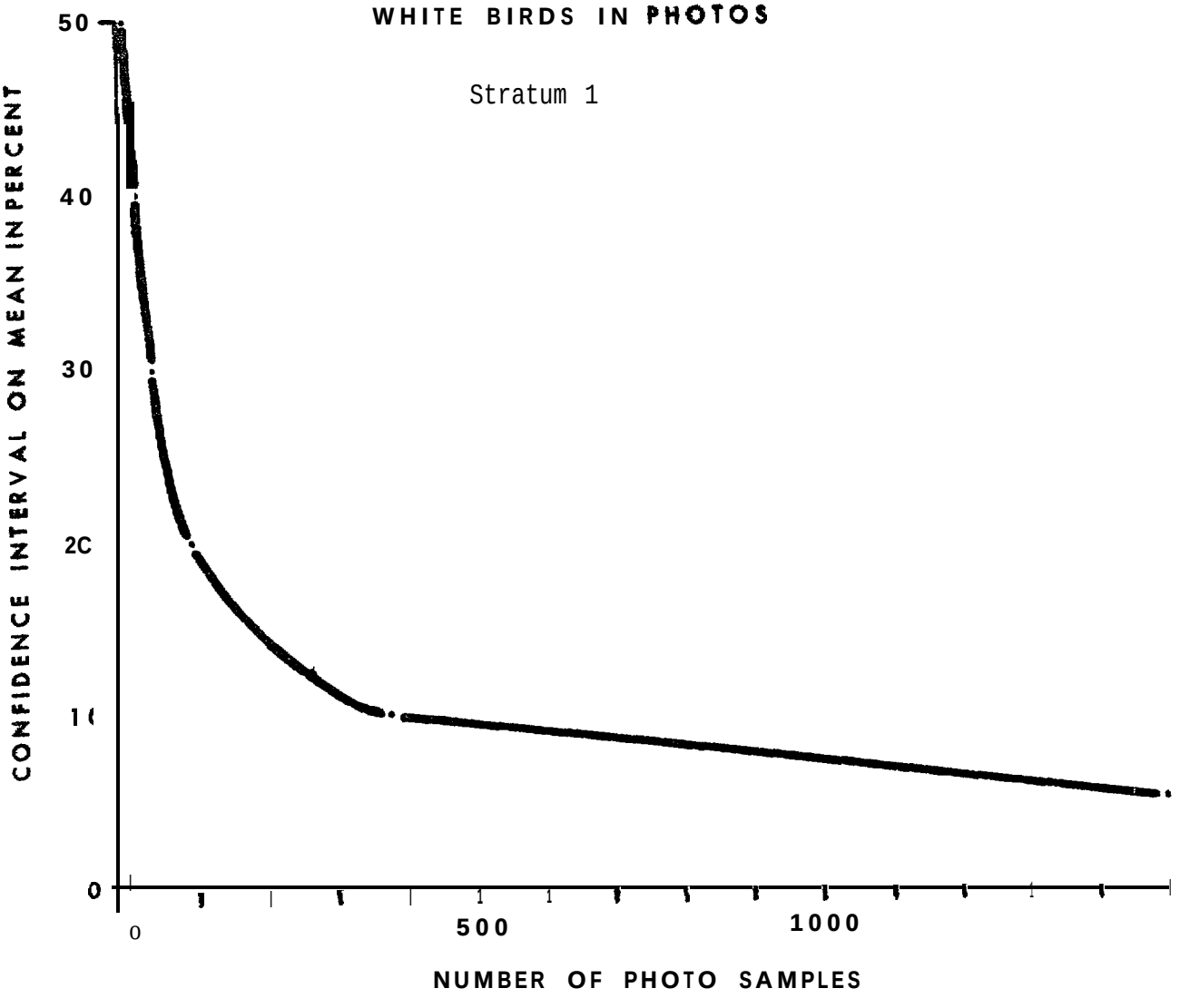
Fig. 26

PERCENT CONFIDENCE INTERVAL

AS A FUNCTION OF SAMPLES TAKEN

WHITE BIRDS IN PHOTOS

Stratum 1



The number of sample replications needed to obtain a given confidence interval on the mean was calculated using the formula

$$l = 2t_{\alpha}\,\hat{\sigma}/\sqrt{n}$$

l = confidence interval desired
n = number of samples.

Thus, for stratum 1 with 46 samples, we obtained about 29% confidence interval on the mean. For a 10% confidence interval., it would have been necessary to draw 376 samples.

We would expect standard deviation to reflect patchiness of habitat. With murres we would not expect s to change with height, and the fact that s changes with height (Fig. 25) indicates that it is a function of our method. The mean number of murres per 900-m^2 photo quadrat is best represented in the first three strata, the low numbers in the two higher strata are due mostly to the limitations of our photographic analysis. The much lower densities of murres at higher strata indicate that murres cannot be clearly counted in distant photographs.

For kittiwakes, the evidence of our reference counts and our photo counts indicate a real increase in density of kittiwakes with elevation. Likewise, with fulmars, there is evidence that density drops off sharply above stratum 3. We assumed that white birds could be seen and counted with consistent accuracy at all elevations; white fronts of murres could be distinguished from white birds at all but the highest elevations where the very narrow ledges seem to keep most murres facing inland. We used the density of white birds as an index to the numbers of other species. To do this, we determined the proportion of each species from our reference ledges on each stratum (Table 12-14) and extrapolated from the number of white birds to total number of birds present. Number of each species was calculated by taking the appropriate percentage Or the total.

Since reference-ledge counts were made throughout the day on St. George, many of these were counted at times when small alcids (PA, LA, CA, HP, TP) were not present on the cliffs. To get a better estimate of the relative proportions of these small alcids, a subsample

of reference ledges was used including only those counts made between 1200 and 1500 hours. This allows for the attendance of small alcids but substantially lowers the sample size. Only strata 1 and 2 could be treated this way.

Similarly, thick-billed murre attendance was taken into consideration. Daily attendance curves were smoothed out using a 3-point moving average, and each reference count was adjusted to account for the maximum number of murres. This generates a different set of species proportions (Tables 12-14) with a higher relative proportion of thick-billed murres. Two such 3-point moving average curves were used. One combined all curves from 30 July to 7 August (Fig. 11) for reference ledges counted late in the season. The other used the Murie Cove Ledges 21, 22, and 23 (Fig. 10) for reference ledges counted earlier (ledges 24-38).

Finally, the number of reference ledges in stratum 4 was small. This resulted in some inaccuracies. The relative proportion of red-legged kittiwakes was less than in stratum 3. Our field observations and photo analysis indicated that the density of red-legged kittiwakes increased dramatically with elevation. To arrive at closer estimates of species porportions for stratum 4, we interpolated intermediate values from strata 3and 5 (Table 14). These manipulations resulted in several population estimates for each species. We will indicate which we feel to be most accurate.

Flight counts.--Throughout the season we compared counts, two men each making an independent count and then comparing them for accuracy. Differences were on the order of five percent, but reaching up to 10 percent at peak times when several thousand birds passed within 10 minutes. Photos of flocks were taken to compare with our counts. Only

small flocks could be photographed and counted well. Differences were less than 5 percent in flocks up to two or three hundred. Larger flocks *are* spread out over a wide area and could not be photographed.

Population Estimates

Density estimates are derived based on the number of white birds counted in photo quadrats. These are presented in Tables 22-24. Three sets of population estimates are derived; one from straight photo-quadrat counts (Table 25) and two others from the density estimates based upon the number of white birds counted in photo quadrats (Tables 26, 27).

To provide an order-of-magnitude estimate of St. Paul populations, we assumed that the total density of all birds was similar for strata 1 and 2 on both St. George and St. Paul. Extrapolations of total number of birds on St. Paul are presented in Table 28. Numbers of each species are derived from this total by using the species-proportion figures in Table 14. These numbers are presented in Table 29. These figures may be high, as Stratum 2 on St. Paul is near the top of the weathered bluffs and is consequently probably more heavily vegetated and less densely populated than on St. George.

TABLE 25
St. George Island 1976
Estimates of Total Birds on Cliffs From Numbers of Murres and White Birds Seen on Random Photo Quadrats

Stratum	Number of 900m^2 areas in entire stratum	Murres/ 900m^2	White birds/ 900m^2	Total Murres	Total white birds
1	1805	150.32	53.46	271,445	96,495
2	1135	280.09	76.47	317,980	86,793
3	488	259.5	126.38	126,635	61,673
4	359.2	47.16	150.96	16,940	54,225
5	142.33	47.75	510	6,796	72,588
Total				739,796	371,774

TABLE 22

St. George Island

1976

Density Estimates Using Species Proportions From All Reference Counts Based on Number of White Birds in Sample

Density Estimates Using Species Proportions From All Reference Counts Based on Number of White Birds in Sample

Species	Stratum 1 16.21% (14.17%) White Birds		Stratum 2 13.83% (12.61%) White Birds		Stratum 3 18.43% (17.59%) White Birds		Stratum 4 10.93% (10.73%) White Birds		Stratum 5 56.11% (53.52%) White Birds	
	Birds in Sample	Birds/ 900m^2	Birds in sample	Birds/ 900m^2	Birds in sample	Birds/ 900m^2	Birds in sample	Birds/ 900m^2	Birds in sample	Birds/ 900m^2
hick-billed Murre	9,981 (12,167)	216.9 (264.5)	12,686 (14,352)	396.4 (448*5)	6,414 (6,873)	458.1 (490.9)	6,148 (6,307)	1,024.7 **(1,051)**	1,410 (1,587)	352.5 (396.7)
ommon Murre	1,167 (1,168)	25.4 (25.4)	980 (978)	30.6 (30.6)	**1,291 (1,292)**	92.2 (92.3)	1,155 (1,153)	192.5 (192.2)	171 **(171)**	42.8 (42.8)
lack-legged Kittiwake	1,205 (1,205)	26.2 (26.2)	334 (338)	10.4 (10.6)	142 (142)	10.1 (10.1)	93 (93)	**15.5 (15.5)**	53 (53)	13.3 (13.3)
ed-legged Kittiwake	732 (732)	15.9 (15.9)	1,143 (1,141)	35.7 (35.7)	**1,359** (1,359)	97.1 (97.1)	813 (813)	**135.7 (135.5)**	1,962 (1,962)	490.5 (490.'5)
arakeet Auklet	890 (892)	19.4 (19.4)	596 (598)	18.6 (18.7)	71 (72)	5.1 (5.1)	80 (80)	**13.4 (13.4)**	9 (10)	2.3 (2.4)
east Auklet	362 (363)	7.9 (7.9)	550 (553)	17.2 (17*3)	7 (7)	.5 (.5)	0 (0)	0 (0)	0 (0)	0 (0)
rested Auklet	77 (78)	1.7 (1.7)	214 (217)	6.7 (6.8)	4 (4)	.3 (.3)	0 (0)	0 (0)	0 (0)	0 (0)
orned Puffin	120 (120)	2.6 (2.6)	209 (210)	6.5 (6.5)	42 (42)	3.0 (3.0)	0 (0)	0 (0)	0 (0)	0 (0)
ufted Puffin	14 (14)	0.3 (0.3)	34 (33)	1.1 (1.0)	0 (0)	0 (0)	0 (0)	0 (0)	5 (5)	1.3 (1.3)
ed-faced *Cormorant*	111 (111)	2.4 (2.4)	14 (14)	.4 (.4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
ulmar	530 (532)	11.5 (11.5)	970 (970)	30. (30	277 (276)	19.8 (19.8)	0 (0)	0 (0)	25 (26)	6.3 (6.4)
otal Birds Extrapolated	15,194 (17,382)		17,693 (19,405)		9,609 (10,068)		8.289 (8,444)		3,635 (3,812)	

TABLE 23

St. George Island
1976

Density Estimates Using Species Proportions from-Partial Reference Counts Based on-Number of White Birds in Sample

Species	Stratum 1. White Birds in sample 16.19% (13.63%)		Stratum 2. White Birds in sample 11.95% (11.27$)	
	Birds in sample	Birds/ 900m^2	Birds in sample	Birds/ 900m^2
Thick-billed Murre	9,047 (11,897)	196.7 (258.6)	13,874 (15,134)	433.6 (472.9)
Common Murre	1,846 (1,847)	40.1	1,423 (1,424)	44.5
Black-legged Kittiwake	1,232 (1,232)	26.8	458 (457)	14.3
Red-legged Kittiwake	765 (764)	16.6	656 (657)	20.5
Parakeet Auklet	1,031 (1,032)	22.4	904 (904)	28.3
Least Auklet	575 (575)	12.5	1,114 (1,114)	34.8
Crested Auklet	37 (36)	0.8	335 (334)	10.5
Horned Puffin	70 (70)	1.5	292 (293)	9.1
Tufted Puffin	5 (4)	.11	57 (56)	1.9
Red-faced Cormorant	143 (143)	3.1	18 (17)	.6
Fulmar	466 (466)	10.1	1,333 (1,333)	41.7
Total Birds Extrapolated	15,213 (18,070)		20,476 (21,713)	

( ) parentheses indicate figures derived using maximum numbers of thick-billed murres present during the day

TABLE 24

St. George Island
1976
Density Estimates for Stratum 4 Interpolating Species Proportions From Those of Strata 3 and 5
Based on Number of White Birds in Sample
37.27% (35.60%) White Birds

Species	Relative proportion	Birds in sample	Birds/900m^2
Thick-billed Murre	0.5277 (.5495)	1282 (1398)	213.7 (233.1)
Common Murre	.0907 (.0866)	220 (220)	36.7
Black-legged Kittiwake	.0146 (.0140)	35 (36)	5.9
Red-legged Kittiwake	.3406 (.3249)	828 (827)	137.9
Parakeet Auklet	.0050 (.0048)	12 (12)	2.0
Tufted Puffin	.0007 (. 0006)	1.7 (1.7)	0.3
Fulmar	.0175 (. 0171)	43 (44)	7
Total Birds Extrapolated		2430 (2545)	

( ) parentheses include figures derived using the daily maximum of thick-billed murres

TABLE 26

St. George Island 1976

Estimates of Total Birds on Cliffs

Based on All Reference Counts

Species	Stratum 1 1805 (birds/ 900m^2)	Stratum 2 1135 (birds/ 900m^2)	Stratum 3 488 (birds/ 900m^2)	Stratum 4 359 (birds/ 900m^2)	Stratum 5 142 (birds/ 900m^2)	Total
Thick-billed Murre [a]	391,505 (477,423)	449,914 (509,048)	223,553 (239,559)	368,072 (377,519)	50,161 (56,450)	1,483,205 1,659,999)
Common Murre	45,847	34,731	44,994	69,146	6,090	209,808
Black-legged Kittiwake	47,291	11,804	4,929	5,567	1,893	71,484
Red-legged Kittiwake	28,700	28,148	47,385	48,672	69,798	222,703
Parakeet Auklet	35,017	21,111	2,489	4,777	327	63,721
Least Auklet	14,260	19,522	244	0	0	34,026
Crested Auklet	3,069	7,605	146	0	0	10,820
Horned Puffin	4,695	7,378	1,464	0	0	13,537
Tufted Puffin	542	1,249	0	0	185	1,976
Red-faced Cormorant	4,332	454	0	0	0	4,786
Fulmar	20,758	34,050	9,662	0	896	65,366
Total Percent	596,016 27.4%	615,966 28.4$	334,866 15.4%	496,234 22.8$4	129,350 6.0%	2,172,432 [b] 100.0%

a/ parentheses include maximum number of thick-billed murres present during the day. b/ (2,349,226)

TABLE 27

St. George Island
1976

Estimates of Total Birds on Cliffs Based on Partial Reference Counts for Strata 1 and 2 and Interpolated Reference Counts for Stratum 4

Species	Stratum 1 birds	Stratum 2 birds	Stratum 3[b] birds	Stratum 4 birds	Stratum 5[b] birds	Total
Thick-billed Murre [a]	355,044 (466,773)	492,136 (536,742)	**236,241 (239,559)**	76,761 (83,73o)	50,161 (56,450)	1,210,343 1,383,254)
Common Murre	72,381	50,508	**47,531**	13,183	6,090	189,693
Black-legged Kittwake	48,374	16,231	**5,222**	2,119	1 ,893	73,839
Red-legged Kittiwake	29,963	23,268	**50,020**	4?,534	69,798	222,583
Parakeet Auklet	40,432	32,121	**2,636**	718	327	76,234
Least Auklet	22,563	39,498	244	0	0	62,305
Crested Auklet	1,444	11,918	146	0	0	13,508
Horned Puffin	2,708	10,329	1,562	0	0	14 ,5?9
Tufted Puffin	199	2,157	0	108	185	2,649
Red-faced Cormorant	5,596	681	0	0	0	6,277
Fulmar	18,231	47,33a	10,199	2,514	896	79,170
Total Percent	596,935 31%	726,177 37%	353,801 18%	144,937 7%	129 ,350 7%	1;951,200[c] 100%

[a] parentheses include maximum number of thick-billed murres present during the day

[b] estima[illegible] based on all reference counts (Table 2[illegible]

[c] (2,124,1[illegible]

TABLE 28
St. Paul Estimates Based on-Total Bird Densities on St. George

Stratum	Area (1,000 m²)		Estimated Total. No. St. George[a/]		Extrapolated No. for All Species on St. Paul
	St. George	St. Paul	All Species	Per m²	
1	1,625	387.6	733,037	0.451	174,846
2	1,022	67.4	770,783	0.754	50,832
Total		455.0			225,678

a/ Based on partial reference counts involving maximum numbers of murres on cliffs (Table 27).

TABLE 29
Estimates of Species on St. Paul Directly Extrapolated From Total. Bird Densities on St. George and Not Rounded Off

Species	Stratum 1	Stratum 2	Total
Thick-billed murre	80,464	34,769	115,233
Common murre	35,808	3,218	39,026
Black-legged kittiwake	24,146	7,157	31,303
Red-legged kittiwake	927	1,301	2,228
Parakeet auklet	14,809	2,481	17,290
Least auklet	11,260	269	11,529
Crested auklet	2,955	46	3,001
Horned puffin	1,871	376	2,247
Tufted puffin	490	30	520
Red-faced cormorant	1,766	737	2,503
Light-phase fulmar	332	437	769
Dark-phase fulmar	0	0	0

Using the statistics generated from our photo-sample counts, we see that we are estimating the mean with one significant digit and may be close to two significant digits. Accuracy is worst at higher strata. If these figures are then used (i.e., white-bird counts) to extrapolate to numbers of other species, we lose control of the sampling errors involved. These extrapolations are based on counts of species on ledges of varying size so there is no way to calculate error. They are, however, based on large sample sizes on St. George Id. :18,325 birds counted in stratum 1; 14,461 in stratum 2; 2,708 in stratum 3; 3,403 in stratum 4; 3,869 in stratum 5 (Table 12). The sample size is reduced if we utilize only those counts from 1200-1500 when small alcids are present, 7,120 birds being counted in stratum 1 and 8,185 in stratum 2 (Table 13).

All things considered, we feel that we have an accuracy of one significant digit, and close to two with our extrapolated estimates. This is a considerable *improvement* over past population *estimates* by Gabrielson and Lincoln (1959) and Elliot (1884) who of course did not make serious attempts to determine numbers. This will enable us to detect a change in population of 50%. When one considers the possibly long lives of these seabirds, their reproductive strategies, and the probable year-to-year population fluctuations, a change of this magnitude may be close to a minimal amount that can be considered a real change in population size. A change on the order of 50% should be important enough to enable government officials to take action, generate interest and study, and bring a restraining order to any activities in the area that are environmentally degrading. If these techniques can demonstrate this change, they should be heeded.

The Species on St. George

Thick-billed murres. --Tuck (1960) found definite seasonal and daily variation in numbers of thick-billed murres on ledges at Cape Hay in 1957. Seasonally, the numbers of older breeding birds before egg-laying were increased by prospecting birds; after egg-laying, by inexperienced early prospectors beginning nesting; and then by late prospectors visiting the ledges after hatching. A breeding population of 80% of maximum occurred from the beginning of egg-laying until the late-nesting prospectors arrived. Daily variation in numbers changed during the season with a maximum number of birds present throughout the day early in the season (June 20 - egg-laying period).

A large daily fluctuation was found at the time of hatching (July 20) with a low in the afternoon and evening and a high in the morning hours. Four daily peaks were observed on August 18 at the time of sea-going of the young. Pennycuick (1956) at Spitzbergen and Uspenski (1956) at Novaya Zemlya found no such fluctuation. Swartz (1966) found a cycle of daily fluctuation at Cape Thompson after hatching in 1959 with one daily peak. Counts made during 8 days "seemed to indicate that curves of these diurnal patterns of cliff roosting tended to be nearly congruent."

Our data for thick-billed murres show marked seasonal and daily fluctuations in numbers. We made four groups of counts, a five-day circuit of the island visiting each of three ledge sites every other day, during the season. The three areas we chose for ledge attendance counts are on opposite sides of the island at places accessible by walks of an hour or less. If we compare the curves of attendance for Rosy Finch Cove (ledge 57), Murie Cove (Ledges 21, 22, 23) and Pinnacle Point (ledge 53) we find significant changes at each site during the season,

and an expression of breeding synchronization between the three sites at certain periods during the breeding cycle.

Correlations of ledge attendance curves at each site throughout the season (Table 8) demonstrate the obvious fact that there is seasonal variation in ledge attendance.

Correlations between the three sites at four times during the breeding season (Table 9) demonstrate that thick-billed murre populations on all sides of the island are significantly identical, i.e., that ledge attendance behavior is highly synchronized, at the times immediately before egg-laying and at hatching, though not during the before egg-laying or incubation stages. This lack of synchrony could possibly be due to weather effects. Weather data were collected at all sites, and conditions were very similar at all three sites. During the counts at time of incubation, temperatures ranged from 4°C to 10°C and winds from 0 to 22 kt, the average at each site being about 6-10 kt. Correlating the curves with weather did not seem necessary. The weather was remarkedly consistent during this time of year. Although the Rosy Finch Cove site did have slightly higher temperatures and higher winds at certain times of the day, these were not extreme conditions. It may have been enough to change attendance behavior patterns however.

Pre-incubation temperatures during counts ranged from -2*C to 8*c with winds from 0 to 15 kt.

The weather varied more during counts that were synchronous: -l″c to 10*C! with winds o-26 kt during the egg-laying counts, so it seems unlikely that attendance behavior is sensitive to perturbations of this magnitude. Therefore, these differences--highly synchronized behavior at the times of egg-laying and hatching and less precise synchronization before egg-laying and hatching and during incubation--seem to be real differences.

The incubation curves were taken immediately after egg-laying. It is probable that some birds were still laying while others had begun incubating. These two overlapping phases of breeding behavior result in asynchronous graphs. Unfortunately, a series of curves at the height of incubation was not obtained as we went to St. Paul and had to wait for a return flight. We assume that behavior is synchronized during incubation, This is perhaps an expression in overall activity of what others have found with regard to timing of breeding on a more finely focused level of observation, i.e., actual time of egg-laying and of hatching.

Our findings on seasonal. variation in general agree with those of Tuck . A continual high rate of occupancy was found early in the season before egg-laying (15-19 June). Tuck found that early in the breeding season (June 20) a maximum number of birds was present throughout the day. This was the egg-laying date, and two small peaks were observed. At this time on St. George, the birds had established a regular fluctuation, however, with two very large peaks. Two daily peaks were found at all other times up to a few weeks after hatching when the study was terminated. A low during the day was found which occurred later as the season progressed, and a low was found overnight. The fact that we found two peaks where Tuck and Swartz (although later in the *season)* found one may be due to continual daylight at those higher latitudes. The close congruence we found among study areas at the times of egg-laying aud hatching seems to break down during the period of incubation. We feel this is due to an overlapping with egg-laying behavior. Counts later in incubation should be congruent.

Activity patterns appear unaltered by the fact of native egging at the Rosy Finch Cove site on 24 and 26 June, although total numbers may have dropped for awhile as seen at our next count on 6 July. By the time

of our next circuit and our count on 4 August, numbers were back to normal and many birds had re-layed. At the time that other sites had almost completed hatching, several eggs were still being incubated on the large ledge at Rosy Finch Cove, and some eggs appeared clean and newly laid. Only two egging attempts were made at this site, however, 70 eggs total being collected on 24 and 26 June. It is customary for Aleuts to visit ledges *one* to *two* weeks after the first collection to get the newly laid eggs, but this was not done at this site this year. Possibly, our interest in the proceedings made our Aleut friends wary, and they decided to "give the birds a rest" in case our reports would be unfavorable to them. At any rate, the native impact on the total population is negligible.

Population estimations of thick-billed murres are as follows: 739,?96 murres (both CM and TM) are estimated from those seen in random black and white photo quadrats (Table 25). This does not take into account the fact that murres are very difficult to see against white backgrounds when they are facing seaward or against black backgrounds when facing landward. These counts should be close for strata 1 and 2. estimates based on white birds (Tables 26, 27") are higher. Some murres are undoubtedly counted as white birds in the two higher strata, 4 and 5.

When one uses all Reference Counts for proportions (Table 26), the murres counted in photos represent at maximum numbers:

247,015 thick-billed murres in stratum 1
298,901 thick-billed murres *in* stratum 2
106,373 thick-billed murres in stratum 3

and when Partial Reference Counts for proportions are used (Table 27):

233,443 thick-billed murres in stratum 1
289,362 thick-billed murres in stratum 2

This is contrasted with extrapolations based on the number of white birds by using all reference counts (Table 26):

477,423 thick-billed murres in stratum 1
509,048 thick-billed murres in stratum 2
239,559 thick-billed murres in stratum 3

and by using Partial Reference Counts (Table 27):

466,773 thick-billed murres in stratum 1
536,742 thick-billed murres in stratum 2
239,559 thick-billed murres in stratum 3

Our comparisons of a few photo counts with land counts are somewhat ambiguous (Table 30), but they indicate that not all murres are counted in photos. This makes sense. We feel the extrapolated numbers for murres are closer to the actual population, especially in the higher strata. Tuck (1960 p. 1.12) found that more birds tended to face the sea as the season progressed and loitering increased. We did not try to verify this. The majority of murres in our photographs were facing landward. Except in extremely dense concentrations with lots of guano, the backgrounds of the photos are dark basaltic lava in areas where murres (particularly thick-billed murres) are nesting. In distant photos and on the higher cliff strata, fewer and fewer murres can be distinguished as shown by comparison of photo counts with known reference ledges (Table 30).

Photo counts of white birds (kittiwakes and fulmars) are probably more consistently accurate as distance from the camera increases. If we accept the number of white birds as correct and use this number to extrapolate to the total number of birds by using the species proportions derived from our reference ledges, we arrive at the following figures:

(a) 1,483,205 thick-billed murres if all reference ledge counts are used, not allowing for daily fluctuations in numbers;

(b) 1,210,343 thick-billed murres if we use only partial reference ledge counts and not allow for daily fluctuations;

(c) 1,659,999 thick-billed murres by including the maximum number present during the day--using all reference counts.

(d) 1,383,254 thick-billed murres by using partial reference counts including the maximum present during the day.

TABLE 30

St. George Island
1976
Comparison of Land Counts with Photo Counts

STRATUM 1				
Ledge 47	Photo 29 July 1300		Land 3 Aug 1215	
	M	146	TM 156	CM 3
	K	31	BK 20	RK 1
	F	45	F 28	
	HP	2	H P 2	
Ledge 53 Pinnacle Point	Photo 9 June 1030		Land 6 June 1245	
	M	37	TM 78	CM 1
	K	67	BK 16	RK 79
	RC	10	RC 17	
STRATUM 2				
Ledge 52	Photo 29 July 1330		Land 3 Aug 1540	
	M	87	TM 52	
	K	122	BK 103	RK 15
	F	4	F 4	
			RC 4	
Ledge 23 Murie Cove Fulmar	Photo 29 July 1510		Land 7 Aug 1500	
	M	293	TM 29.5	
	K	14	K 14	
	F	112	F 120	
Ledge 5	Photo 29 July 1600		Land 25 July 1700	
	M	290	TM 303	
	K	45	BK 15	RK 6
	F	29	F 10	
Ledge 33 Marvin Gardens	Photo 29 July 1450		Land 13 July 1600	
	M	799	TM 1202	CM 2
	K	484	BK 18	RK 475
	F	27	F 47	
Totals	M	1,552	M 2092	
	K	763	K 762	
	F	217	F 209	
	HP	2	HP 2	
	RC	10	RC 21	
	Total	2,544	Total 3086	

We place most confidence in the figures 1,383,254 and 1,659,999 as the total number of birds of breeding age utilizing nesting sites. This represents approximately 644,000 eggs successfully surviving until hatching.

Egg loss and replacement is a continual process that has been studied in some detail by Tuck, Swartz, and others. In addition to natural loss, there is man-caused loss by egging and by disturbance. On two occasions during 1976, aircraft passed close by (1,500 ft.) during our attendance counts, and a rough estimate of the number of birds frightened from the ledges was obtained. This is approximately 15%. At this distance, during incubation, only loitering birds were frightened, but at closer distances (observed but not quantified) aircraft noise can frighten all birds with subsequent great damage to eggs and birds. The incubating birds kick their eggs off their feet as they fly, and birds collide with one another and with falling eggs and rocks knocked from ledges.

Cliff-nesting birds on the Pribilofs are sensitive to the noise of rock falls, and a moderate rock fall can clear a nearby section of cliff in seconds. Rock falls are fairly frequent--4 were observedby us in the course of our work in 1976, 2 of them very close--and the aftermath of many others was observed on subsequent visits to sites. There has been therefore constant selection for panic behavior in birds in response to loud noise. The birds may be able to adjust to frequent loud noises resulting fr oil development, etc, but it would require several disrupted seasons, and perhaps even generations.

Common murres.--Common murres are relatively inaccessible on St. George. Small ledges are found on the Village East and Village West cliffs and on First Bluff . The only ledge easily observed was at Rosy Finch Cove. Ledge 25, which we located later in the season has a good large sample, but it is farther away from the road (1.5 - 2 hrs walk).

The Rosy Finch Cove ledge was a favorite Aleut egging spot as we discovered later. Common murres and thick-billed murres nest in about equal numbers on a large flat ledge. Since the daily ledge-attendance patterns of thick-billed murres at this site paralleled those of other sites, perhaps we can assume that neither common or thick-billed murres were upset for long by egging activity. We found less daily fluctuation in numbers among common murres than among thick-billed murres (Fig. 12) but place little reliance on it because of our limited sample. George Hunt found similar daily changes among the two species on St. Paul. Because of this uncertainty, and the fact that common murres are only 4th in total numbers, we did not attempt to adjust their numbers to allow for daily fluctuations on a ledge-by-ledge basis as for thick-billed murres.

Using the counts of murres from photos, we find the following numbers of common murres. Based on proportions from all reference ledges, the maximum number is:

24,430 common murres in stratum 1
19,079 common murres in stratum 2
11,626 common murres in stratum 3

Based on proportions from partial reference ledges:

38,002 common murres in stratum 1
28,618 common murres in stratum 2

Again, the extrapolated figures are higher (Table 26, 27). As with thick-billed murres, we feel the extrapolated figures are more accurate.

A total of 189,693 common murres is estimated by using only partial ledge-attendance counts; 200,808 are estimated by using all reference ledge counts to determine the species proportion. Spring (1971) cites evidence that common murres tend to displace thick-billed murres on the wide flat ledges. This seems to be the case in the Pribilofs. All large

flat ledges (free of sea lions as on Walrus Island) are jammed with common murres. Although thick-billed murres are found nesting with them on some of the smaller ledges, such as ledge 57, they tend to be excluded to the periphery or more uneven areas. The number of common murres on the Pribilofs seems to be limited only by nesting sites.

Red-legged kittiwakes.--Although the black-legged kittiwakes are increasing in numbers on St. Paul, this does not seem to be at the expense of the red-legged kittiwakes at this time. The data, however, are limited. Kenyon and Phillips (1969) data for red-legged kittiwakes compare with ours as follows :

area	no. of nests	
	1965	1976
Tolstoi	0	0
Zapadni	13	9
Ridge wall	33	30
Village	0	0

We find little appreciable change in 11 years.

From reference ledge counts on both islands, our averages were 1.7 birds per nest on St. Paul, and 2.0 birds per nest on St. George. At Pinnacle Point ledge St. George, a growing colony, we found an average over the entire day of 1.4 on 10 July 1976 and 1.8 on 30 July 1976. At Pinnacle Point there were 38 completed nests near time of hatching on 29 July 1975 and 56 completed nests on 30 July 1976. At First Bluff (ledge 1 St. George), red-legged kittiwakes decreased insignificantly from 43 nests in 1975 to 40 nests in 1976. Birds per nest were 1.1 at 1500 on 29 July 1975 as compared with 1.5 at 1300 on 29 July 1976.

At First Bluff (ledge 2 St. George), red-legged kittiwakes increased from 24 to 33 nests from 1975 to 1976. Birds per nest were 1.4 at 1500 on 29 July as compared with 1.7 at 1300 on 29 July 1976. There is more daily

variation in average number of birds per nest than among black-legged kittiwakes so that determining a constant number (Coulson and White 1956) seems unfeasible; 1.7 - 2.00, our island-wide totals, are the best approximate ions.

Red-legged kittiwakes are third in total numbers on St. George. Their nesting density increases with altitude in an inverse relationship with black-legged kittiwake density. In the highest stratum they constitute over 50% of all nesters, outnumbering even the thick-billed rnurres. On St. Paul, there is also an increase in density with altitude which is not directly comparable with St. George because of the lower cliffs on St. Paul. The lower overall numbers on St. Paul. may be due to a preference for the higher cliffs of St. George or competitive exclusion for nest sites at the lower strata. We estimate 222,703 red-legged kittiwakes on St. George using all reference ledges and 222,583 using partial-reference-ledge counts.

Red-legged kittiwakes on St. Paul number in the *thousands. Since* these birds are only *reported to* nest in small numbers in the Aleutians and on Copper Id. in the Commander group, the birds of St. *George represent* the bulk of the total world population of red-legged kittiwakes. The value of maintaining this population of a unique species should be carefully considered as regards oil-development activities.

Black-legged kittiwake.--Black-legged kittiwake numbers are reported by Coulson and White(1956) to average 1.2 birds per nest in the N, Atlantic, Coulson reports that the proportion of nonbreeding birds is greater in younger colonies. Our daily attendance curves show that the number of black-legged kittiwakes rises quickly in the morning and remains fairly *constant* throughout the day, dropping

just before dark. The number of birds per nest at pinnacle Point ledge averaged higher than Coulson's average at 1.5 on 10 July and 1.6 on 30 July 1976. Pinnacle Point seems to be a growing colony and therefore a young one (Coulson and White 1956). In 1975 near time of hatching on 29 July, there were 23 completed nests. In 1976 on 30 July, there were 31 completed nests.

On both islands, our island-wide averages of birds per nest were high; 1.457 on St. Paul and 1.56 on St. George based on reference ledge counts . Comparing our counts on St. Paul with Kenyon and Phillips (1965), we see that the black-legged kittiwake population has increased greatly in some areas:

area	no. of nests	
	1965 –	1976
Village	0	0
Tolstoi	249	206
Zapadni	463	539
Ridge wall (low bluffs)	221	608
Total	993	1,353

The high proportion of nonbreeding birds present may indicate that the colonies on both islands are still growing or it may be due to a regional. difference in black-legged kittiwake populations. On the East Village Cliffs of St. George we found 1.4 birds/nest in a total of 108 nests.on I.I.July 1976. There was no change in number of nests between 1975 (110) and 1976 (108). There were 1.5 birds per nest on 11 July 1975.

Black-legged kittiwakes are about sixth in total numbers on St. George. Using all reference ledges for our species proportions, we estimate 71.,484. Using only partial. reference counts, we estimate 73,839.

Fulmar.--Fulmars are early breeders, being preceeded in breeding phenology only by the red-faced *cormorant.* They also, like the cormorant, invest more relative time in incubating and caring for young than the other birds of the Pribilof community. Nonbreeding birds characteristically occupy nest sites for several years before they begin breeding.

We made 9 all-day attendance counts of fulmars at two of our study sites. The Rosy Finch Cove site has a small population (maximum 38), and the Murie Cove site has a much larger population (maximum 129). Little daily and seasonal variation was noted. The numbers rise abruptly in the early morning, stay at the same level throughout the day, and drop rapidly just before dark. Any changes in the attendance behavior of breeding birds could presumably be masked by the large proportion of "nonbreeders. Because of the inaccessibility of the ledges, we made no attempt to distinguish between individual breeding and nonbreeding birds, although we made rough estimates of productivity as the chicks grew large enough to be seen (Table 20).

We estimate 65,366 fulmars by using all reference-ledge counts as a basis for species proportions, and 79,170 by using partial-reference counts . Light-phase fulmars far outnumbered dark-phase fulmars in the ratio 153/1. George Hunt's group (pers. comm.) reported a greater proportion of dark-phase fulmars among those seen in feeding aggregations at sea around the islands.

Our productivity estimates result in calculations of about 12,000 chicks and 13,500 eggs laid (when one uses the mean of the two population estimates).

Red-faced cormorant.--Red-faced *cormorants are year-round* residents of the Pribilofs. Because they are present in relatively low numbers, followed only by tufted puffins, little time was spent studying them.

One study site at Pinnacle Point yielded data on daily attendance. We estimate 4,786 by using all reference-ledge counts, and 6,277 using partial-reference-ledge counts. They are confined to the two lower strata of cliffs and were not seen even loitering any higher than this.

Auklets.-- Parakeet auklets are fifth in numbers on the cliffs of St. George with least auklets second and crested auklets ninth. Least auklets are about fifth in total numbers when the inland colony at Ulakaia Hill is not included.

No satisfactory method was found to estimate the numbers of least auklets nesting among beach boulders around the perimeter of the island, but these additional birds should place them second in overall numbers. All three auklets were found nesting together in two large talus slopes on the Northwest end of the island where they were counted in our photographs. All three are diurnal (Seal-y 1973, Bédard 1969), the congeneric least and crested auklets typically showing two peaks of attendance per day, and the parakeet only one.

Parakeet auklets.--Parakeet auklets were the most numerous crevice nesters on cliffs. They appeared to nest along borders between the solid rock of murre ledges and areas of vegetation. We have several good ledge. attendance counts (Fig. 14). Most show a single afternoon peak, but one on 7 Aug. at Murie Cove clearly shows two peaks. Hunt's counts from St. Paul show one peak. Parakeet auklets fed in large flocks with crested auklets and lesser numbers of least auklets within a kilometer of shore. We did not go farther from shore than this. The principal aggregations were always encountered during the day at the Northeast and Northwest points of the island. We estimate 63,721 parakeet auklets by using all reference ledges and 76,234 using partial. reference counts. Parakeet

auklets were found on all cliff areas of the island but were relatively scarce in the higher strata; 3,349 were counted on the surface of the two talus slopes. These numbers probably represent only one bird of each breeding pair.

Crested auklet.--Crested auklets prefer loose boulder rubble of a certain size for nesting (Bédard 1969). We found them in two large talus slopes (which we nicknamed Meditterranian and Baltic Avenue) on the Northwest side of St. George, and scattered along the cliffs in crevices and small piles of loose, fractured rock on ledges. Only one good attendance count was made of a single peak from 1100 to 2000 at ledge 25 St. George. Counts made by George Hunt's team on St. Paul on 19 and 26 July show only one peak from 0400 to 2200.

Crested auklets were seldom seen close to areas of human activities, but on the water they did not seem anY more wary than the other auklets. We estimate 10,820 on the basis of all reference ledge counts, and 13,508 using partial. reference counts. In addition, 760 were counted on the surface of the two large talus slopes. None were seen above stratum 3. These numbers probably represent only one bird of each breeding pair since both birds seldom loiter together during incubation,

Least auklets.--Least auklets or "choochkis" are the most amenable of the auklets to study because of the large inland colony on Ulakaia Hill. The effective nesting area extended for about 1,300 meters along the slope, and was 100-200 meters wide. We estimated the area at about 94,531 m^2 (Table 18). The slope is approximately 30 degrees. Least auklets arrived before any of the hillside was free of snow, and engaged in courtship activities above the nesting holes for increasingly longer periods during the day as the season progressed.

The birds fly inland along a slight ridge between the village and the airstrip in a corridor that varies with weather conditions. On clear days, all the auklets flying inland can be clearly seen and counted. Birds flying out to sea disperse in smaller flocks over a wider area, but can be counted on a good day from our observation point in front of the colony hillside.

Seven 24-hour inland-flight counts were made throughout the season (Figs. 19-21). OneSeaward count was made on a very clear day for comparison (Fig. 22). At the time of the counts made just before egg-laying, we examined the colony at mid-day when no birds were present on the surface, and found no evidence of any birds underground either. Thus the entire population seems to visit the colony at least twice a day at this time of year--once in the morning and once in the evening. The morning peak is much broader and consists of some birds making repeated trips. Birds were seen 'flying back out to sea and feeding. in small flocks offshore at this time. Birds from these flocks would then join the main flight inland which proceeds Westward along the North coast to the bay just West of the village. In this bay the joiners would mingle with the larger flock and fly inland across the airstrip. Fewer birds fly out during the evening peak, and these birds were never seen to land near shore, or to join incoming flocks. The birds leaving in the evening drop low to the water and fly rapidly out of sight to the North.

We feel that the evening peak is largely composed on one bird of each breeding pair which, after egg-laying, spends the night ashore. If we subtract the birds that return to sea in the evening from this peak, we should have an accurate estimate of the number of breeding pairs.

This number can be compared to the figures derived from our colony quadrat counts; 108 counts of each of the three fixed quadrats were made

during 5 dsys prior to and during egg-laying. The average of the 2nd, 3rd, and 4th-highest count for each day (Bédard 1969) gives a figure of 79.4 birds/100 m^2. In addition, 150 counts of randomly placed telescope quadrats give a mean density of 24.49 birds/100 m^2.

The fixed quadrat counts show a pattern of daily attendance at the colony surface that can be compared with the flight counts. They were located in high-density areas in the center of the colony. The random telescope quadrats give a mean density at the surface for the entire colony.

Eggs were found on the beaches on 12 June 1976 although none were found on the colony hillside at this time.

We estimate 34,o26 on the cliffs using all reference-ledge counts, and 62,305 using partial-reference counts allowing for auklet attendance. These probably represent only *one* bird of each breeding pair. In addition we estimate a total of 129,048 breeding birds in the Ulakaia colony using flight-count data, and 1,609 birds on the two large talus slopes in the Northwest. None were seen above stratum 3.

If the flight counts are an accurate estimate, the random telescope counts represent about 1/4 of the total birds seen on the colony surface, and the fixed, central quadrats about 3/4 of the total.

Horned puffin.--Horned puffins are present in about the same numbers as the crested auklets. Daily attendance data was obtained at Murie Cove Nmar Ledge and at Ledge 25. Samples are not *large* enough to show any definite trend except for a possible afternoon peak. They *are* present in the afternoon and evening. We estimate 13,537 by using all reference-ledge counts for species proportions, and 14,599 by using partial-reference counts allowing for auklet attendance. These numbers probably

represent only one bird of each breeding pair since both birds are seldom seen loitering during incubation.

Tufted puffins.--Tufted puffins are the scarcest breeding seabirds on the Pribilofs (with the exception of the glacous-winged gull). This is near the northern limit of their breeding range. Very few attendance data were collected, although these birds also seem to be present on cliffs in the afternoon and evening. We estimate 1,976 puffins by using all reference ledge counts, and 2,649 when partial counts are used to allow for auklet attendance. Again, these numbers probably represent one bird of each breeding pair, since both birds seldom loiter together on the cliff during incubation.

CONCLUS1OIYS

The resulting numbers indicate that St. George Island has over 2 million birds and is one of the larger seabird colonies in the world and apparently the largest in the Northern Hemisphere. Krasovski (1937) estimated the murre population at Bezymyannaya Bay at 1,644,503 in two colonies (bazaars). To our knowledge, no other close estimates of colonies of this size have been made.

The major threats to these seabird populations posed by petroleum exploration will be disturbance of the ledge-nesting species by people or aircraft if St. George is ever used as a local or regional base of operations for petroleum drilling.

Considering all alternative estimates, we place the numbers of each species on St. George in 1976 at close to 2.5 million birds (Table 31).

If one may be permitted to extrapolate from these figures to St. Paul, the breeding birds on that island number about a quarter of a million (Table 32).

TABLE 31

Breeding Seabirds on St. George Id., 1976

Thick-billed murre	1,500,000
Least auklet	250,000[a/]
Red-legged kittiwake	220,000
Common murre	190,000
Parakeet auklet	150,000
Black-1egged kittiwake	72,000
Nmar	70,000
Horned puffin	28,000
Crested auklet	28,000
Red-faced cormorant	5,000
Tufted puffin	6,000
Total	2,519,000

[a/] Exclusive of beach-boulder nesters.

TABLE 32

Crude Estimates of the Number of Breeding Seabirds on St. Paul Island, 1976

Thick-billed murre	110,000
Common murre	39,000
Parakeet auklet	34,000
Black-legged kittiwake	31,000
Least auklet	23,000[a/]
Crested auklet	6,000
Horned puffin	4,400
Red-faced cormorant	2,500
Red-legged kittiwake	2,200
Tufted puffin	1,000
Fulmar	700
Total	253,800

[a/] Exclusive of beach-boulder nesters.

Perhaps the most feasible method of monitoring the Pribilof seabird populations in the future is by recounting our 63 reference ledges on St. George and the 35 on St. Paul. Photos of these sites accompany the data sets we have submitted to NOAA; additional sets are at (a) the Department of Wildlife Ecology, University of Wisconsin--Madison; (b) the Environmental Research Institute, Moose, Wyoming (Lance Craighead); and (c) with Dr. George Hunt, Department of Population and Environments Biology, University of California Irvine. Any significant change in the populations on these reference ledges should reflect changes in the entire population.

One special reference site is the least auklet flight count that streams over the airstrip into the Ulakaia Hill colony. Evidence indicates that this population has declined steadily since the visit of Gabrielson in 1940. During a short visit to St. George, this flight could be counted during one day if no other ornithological work was possible. Such a count would give an index to the least auklet population although not to populations of other species.

Finally, in regard to the Aleut impact on local bird populations, we offer the opinion that in 19'75-76 Aleuts had a negligible effect on all species on the Pribilofs. The birds primarily affected by hunting were the thick-billed murre and the red-legged kittiwake. Our friends on St. George estimated that a family ate around 800 birds in 1975 when ammunition was plentiful and around 300 birds in 1976 when it was expensive. About 20 such large families live on St. George.

Most hunting is done in May by wing shooting along the low cliffs and beaches. There is some crippling loss when this takes place. Birds are also shot on the water occasionally, from an outboard powered

skiff. This is considerably more efficient, and we have seen 80 birds collected in about 2 hours. Wing shooting harvests mostly kittiwakes, while shooting from a boat harvests mostly murres. All birds shot are utilized.

Egg collecting as mentioned before is also negligible and affects only birds on the low, accessible cliffs or near cliff tops in what is probably marginal habitat.

Whatever disposition is made of the bird cliffs (wildlife refuge or sanctuary are possibilities), the Aleuts should *certainly* retain their traditional hunting and fowling rights; they will not damage the populations. The threat to cliff-nesting species, especially murres, from too-close aircraft is much greater.

BIBLIOGRAPHY

Ashmole, N. P., 1971. Sea bird ecology and the marine environment, p. 223-286. In D.S. Farner and J. R. King [cd.] Avian Biology. Vol. 1. Academic Press, New York. 586 p.

Bédard, J., 1969. The nesting of the crested, least, and parakeet auklets on St. Lawrence Island, Alaska. Condor 71:386-398.

Belopol'skii, L. O., 1961. Ecology of sea colony birds of the Barents Sea. Israel Prog. Sci. Transl., Jerusalem. 346 p.

Coulson, J. C., and E. White, 1956. A study of colonies of the kittiwake Rissa tridactyla (L.), Ibis 98:93-79.

————, 1958a. The effect of age on the breeding biology of the kittiwake Rissa tridactyla, Ibis 100:40-51.

————, 1958b. Observations on the breeding of the kittiwake, Bird Study 5:74-83.

———, 1960. The effect of *age* and density of breeding birds on the time of breeding of the kittiwake Rissa tridactyla. Ibis 102:71-86.

Elliot, H. W., 1884. Report on the seal islands of Alaska. Census Office, U.S. Dept. Interior. 188 p.

Gabrielson, I. N., and F. C. Lincoln, 1959. Birds of Alaska. StackPole co., Harrisburg, Penn. and Wildl. Mgmt. Inst., Wash., D.C. 922 p.

Hopkins, D. M., 1967. Quarternary marine transgressions in Alaska, In Hopkins, D. M., [cd.], The Bering Land Bridge. Stanford Univ. Press, p. 47-90.

———, 1975. Fault history of the Pribilof Island and its relevance to bottom stability in the St. George Basin. Annual Report-Research Unit #209, OCERP.

Kenyon, K.W., and R. E. Phillips, 1965. Birds from the Pribilof Islands and vicinity. The Auk 82:624-635.

Krasovski, S. K., 1937. Studies on the biology of the thick-billed murre (in Russian), Trudy Arkticheskogo Instituta Biologiya, 77:32-92 [original not seen; quoted from Tuck (1961) and Swartz (1966)].

Nettleship, D. N., 1976. Census techniques for seabirds of arctic and eastern Canada. Canadian Wildlife Service, Occasional Paper NO. 25. 31 p.

Pennycuick, C. J., 1956. Observations on a colony of Brunnich's guillemots (Uris lomvia) in Spitsbergen. Ibis 98:80-99.

Preble, E. A., and W. L. McAtee, 1923. A biological survey of the Pribilof Islands, Alaska. Part I. Birds and Mammals. North American Fauna NO. 46, p. 1-128.

Scaly, S. G., 1973. Breeding biology of the horned puffin on St. Lawrence Island, Bering Sea, with zoogeographical notes on the North Pacific puffins. Pacific Science 27, 99-119.

———, and J. Bédard, 1973. Breeding biology of the parakeet auklet (Cyclorrhynchus psittacula) on St. Lawrence Island, Alaska. Astarte 6, 59-68.

Spring, L., 1971. A comparison of functional and morphological adaptations in the common murre (Uris aalge) and thick-billed murre (Uris lomvia). Condor: 73, 1-27.

Swartz, L. G., 1966. Sea-cliff birds, p. 611-678. In N. J. Wilimovsky and J. N. Wolf [cd.], Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Comm. Oak Ridge, Term.

Tuck, L. M., 1961. The murres. Their distribution, populations and biology / A study of the genus Uria, Queen's Printer, Ottawa. Canadian Wildlife Series: 1, 260 p.

Uspenski, S. M., 1958. The bird bazaars of Novaya Zemlya, Canad. Wildl. Serv., Translations of Russian Game Reports, No. 41. 159 p.

Plate 1

St. George Island on a clear day, 5 August 1975. Highest point of bluffs (1012 ft.) in foreground, St. George Village in background. Red-legged kittiwakes and thick-billed murres are seen.

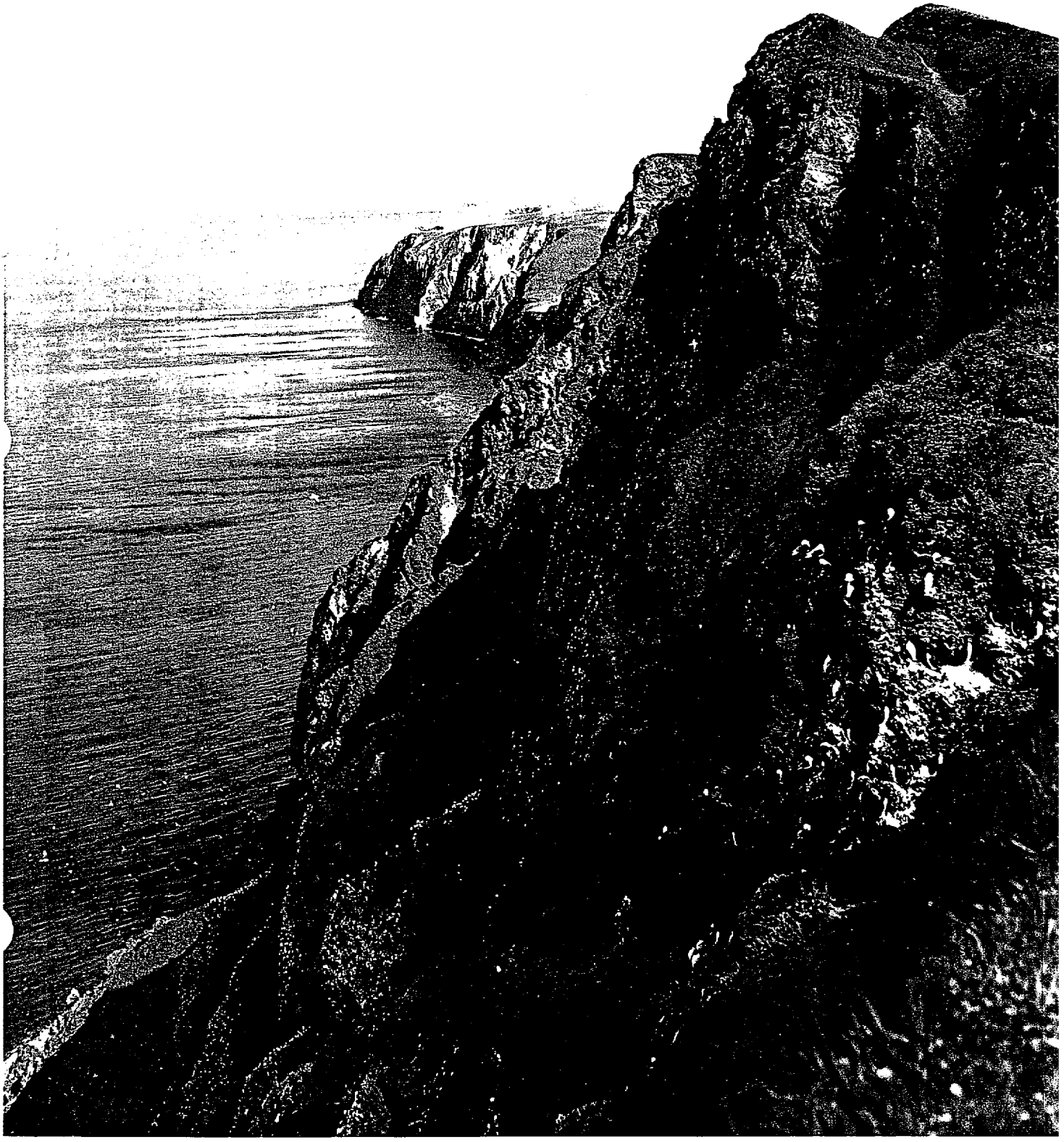
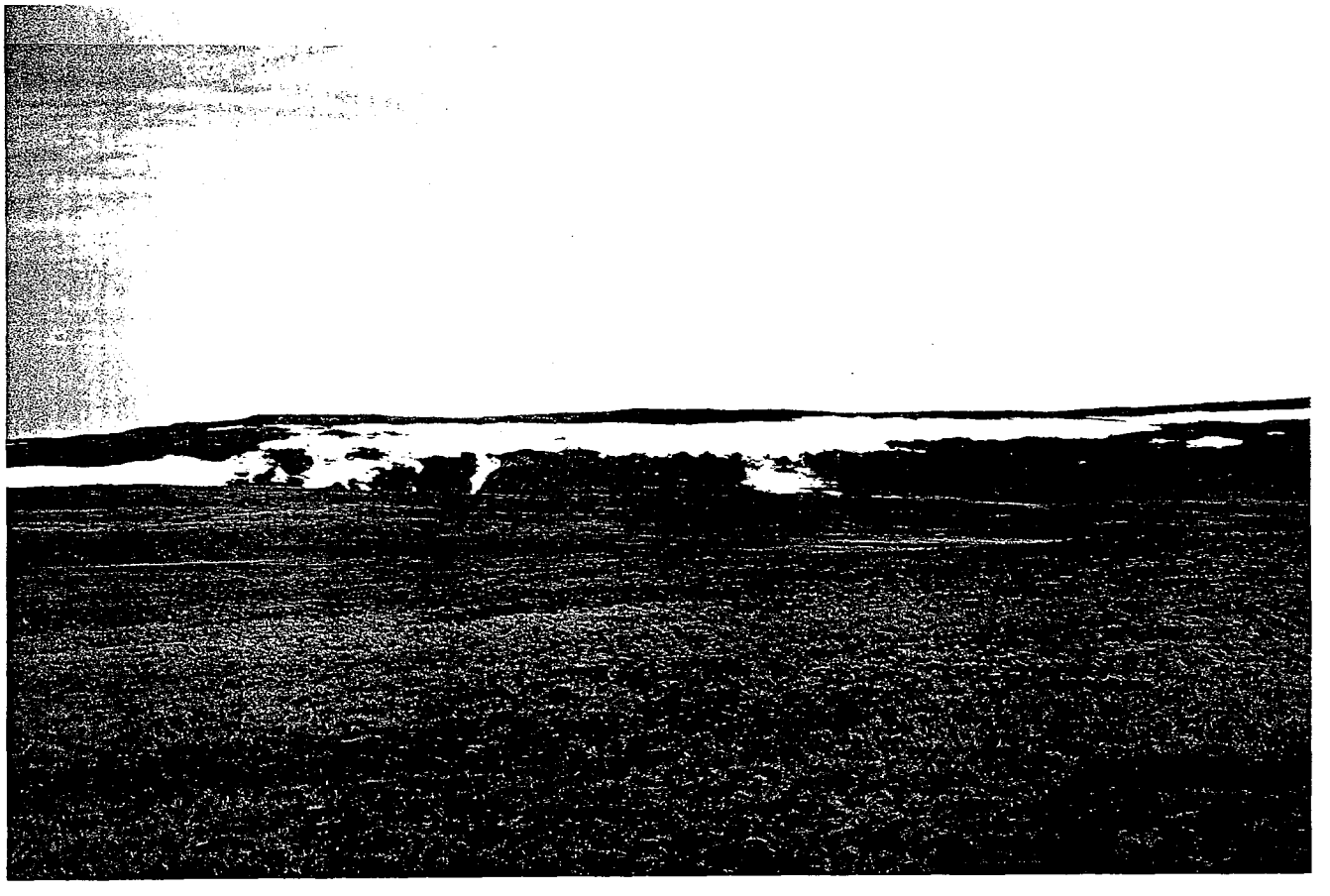


Plate 2

St. George Island on a foggy day, June 1975. Zapadni beach, North end. R. Squibb (left) and L. Craighead counting birds *on* reference ledge. This is one of two short sandy beaches on the island.

Plate 3

St. George Id., Ulakaia Ridge least auklet colony (site 56) showing locations of fixed quadrats. 1. to r. 175 m., 450 m., 750 m. 22 June 1976



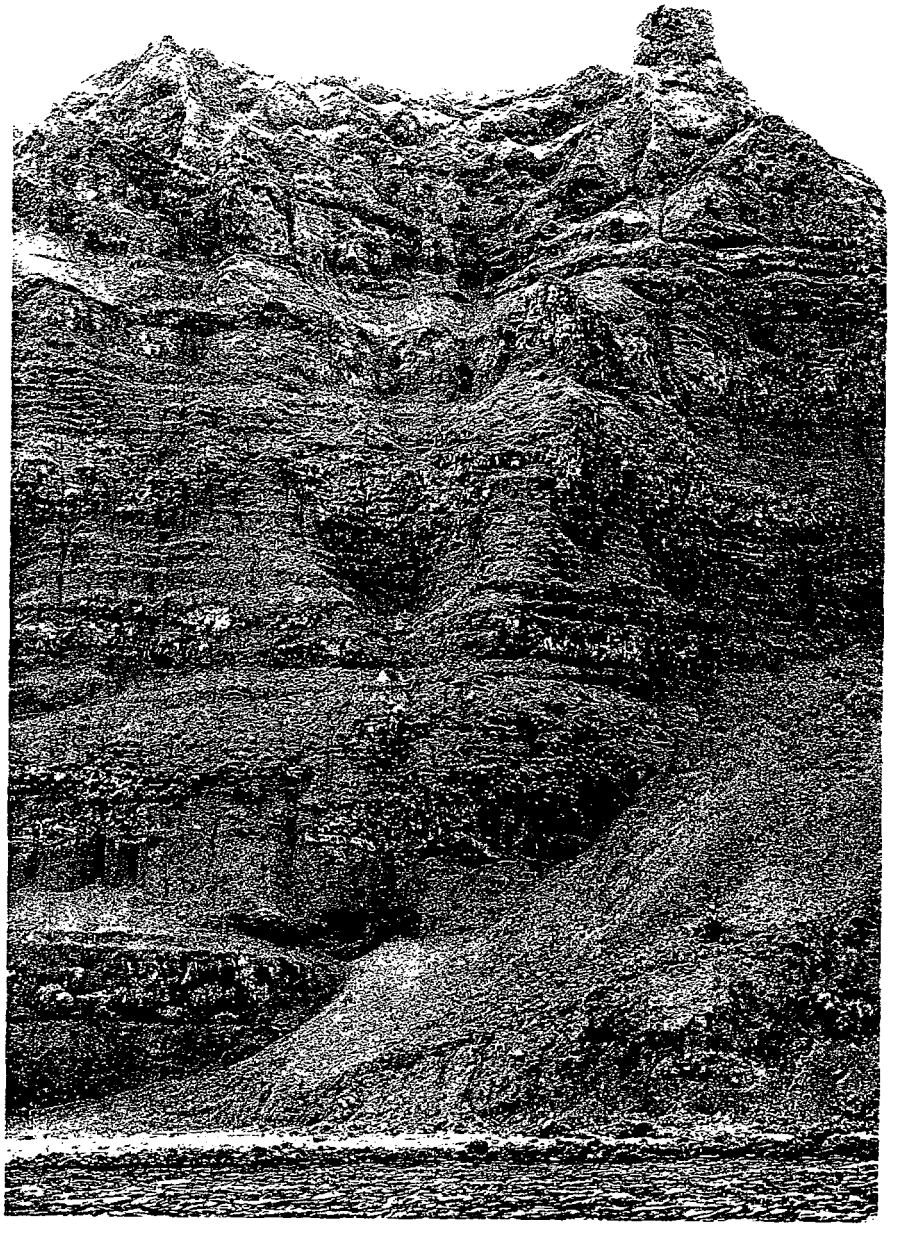
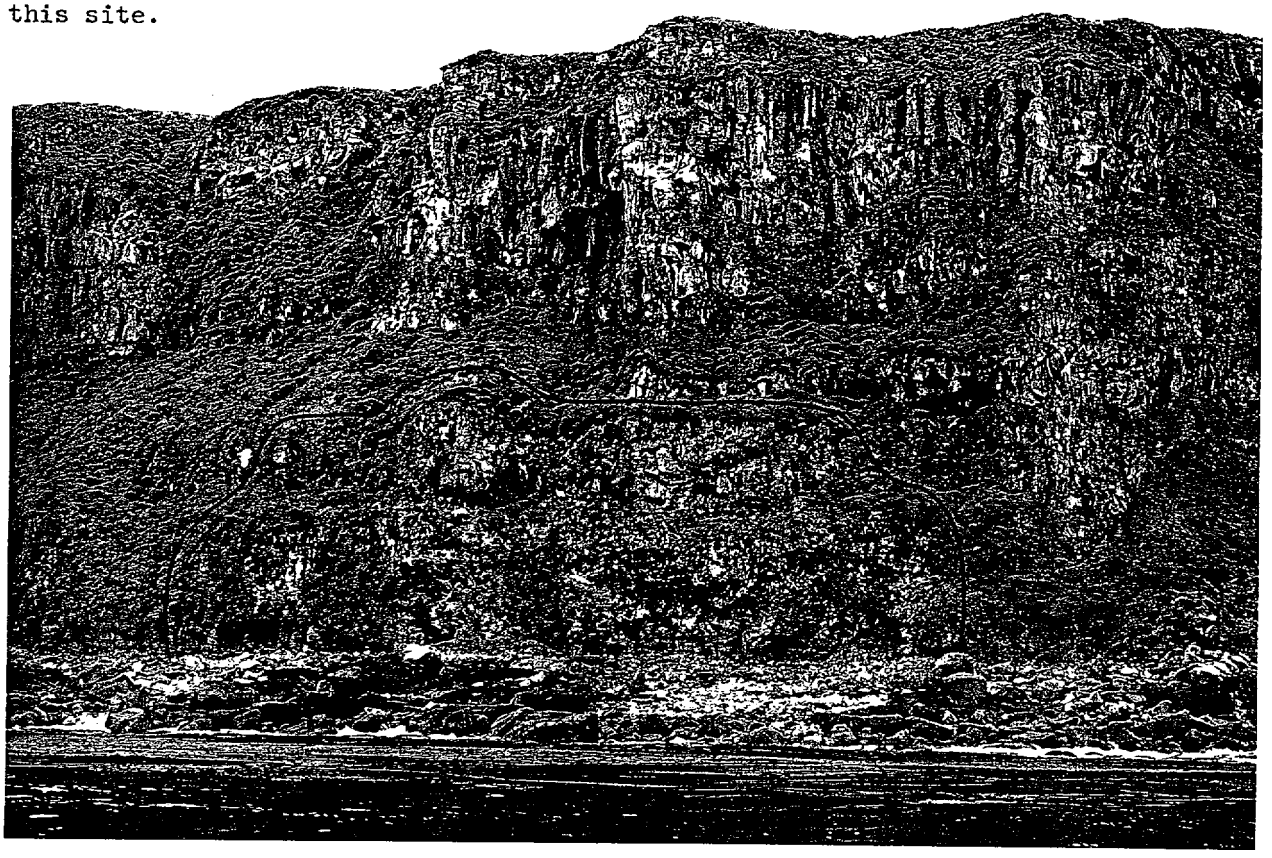


Plate 4

St. George Id. , high bluffs, **5 Aug. 1976.** Promontory Point on right.

Plate 5

St. George Id. , Pinnacle Point (ledge 53) outlined, 29 July 1976. Dailyledge-attendance counts were carried out from the beach below this site.



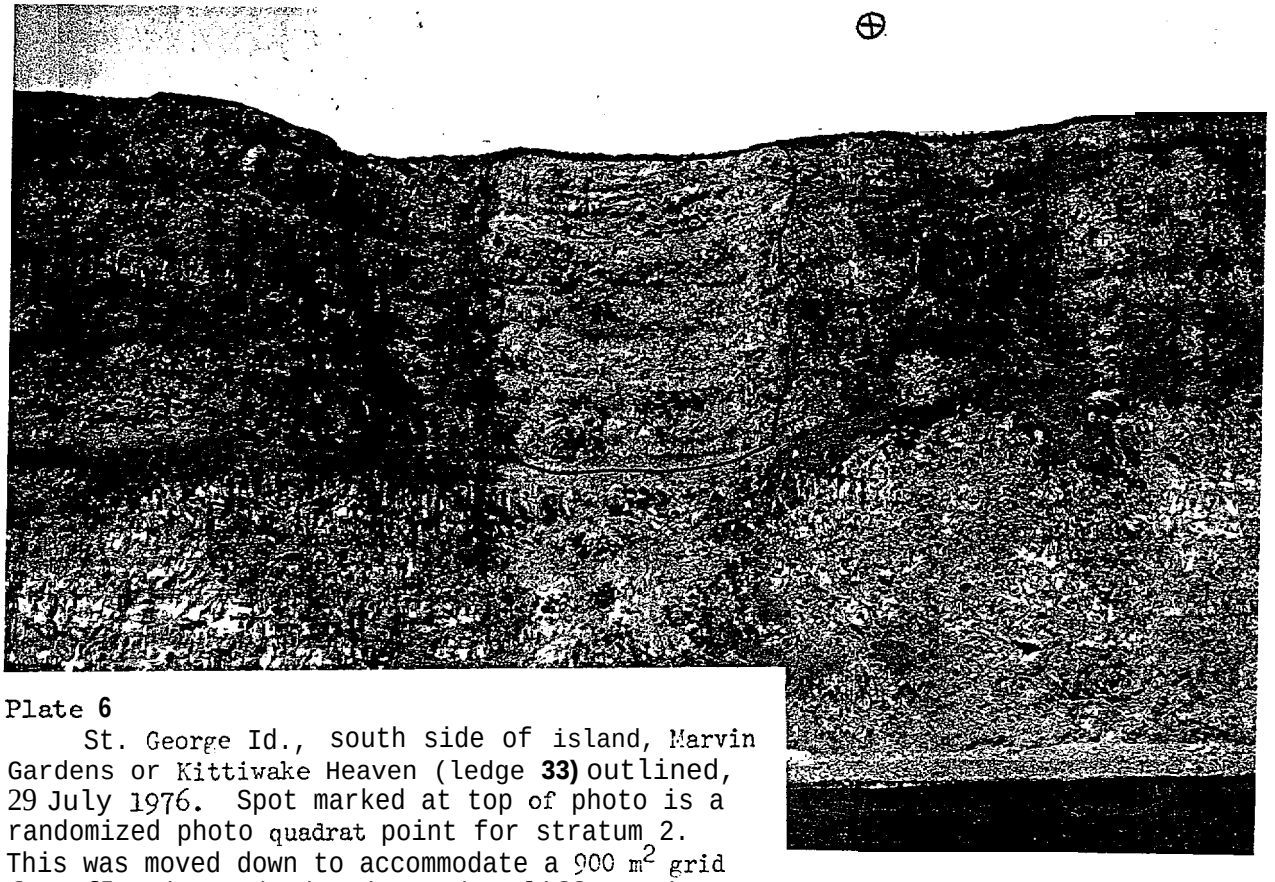


Plate 6

St. George Id., south side of island, Marvin Gardens or Kittiwake Heaven (ledge **33)** outlined, 29 July 1976. Spot marked at top of photo is a randomized photo quadrat point for stratum 2. This was moved down to accommodate a 900 m^2 grid from 65 m above the beach to the cliff top (95 m , in height) , a sample from stratum 2. This grid is approximated by a small plastic overlay.