ATTENDANCE PATTERNS, HATCHING CHRONOLOGY AND BREEDING POPULATION OF COMMON MURRES ON TRIANGLE ISLAND, BRITISH COLUMBIA FOLLOWING THE NESTUCCA OIL SPILL

Michael S. Rodway

TECHNICAL REPORT SERIES No. 87
Pacific and Yukon Region 1990
Canadian Wildlife Service

Environment Canada
Environnement Canada
Canadian Wildlife Service
Service Canadien de la faune
Canada

TECHNICAL REPORT SERIES
CANADIAN WILDLIFE SERVICE

This series of reports, established in 1986, contains technical and scientific information from projects of the Canadian Wildlife Service. The reports are intended to make available material that either is of interest to a limited audience or is too extensive to be accommodated in scientific journals or in existing CWS series.

Demand for these Technical Reports is usually confined to specialists in the fields concerned. Consequently, they are produced regionally and in small quantities; they can be obtained only from the address given on the back of the title page. However, they are numbered nationally. The recommended citation appears on the title page.

Technical Reports are available in CWS libraries and are listed with the DOBIS system in major scientific libraries across Canada. They are printed in the official language chosen by the author to meet the language preference of the likely audience. **To determine whether there is significant demand for making the reports available in the second official language, CWS invites users to specify their official language preference. Requests for Technical Reports in the second official language should be sent to the address on the back of the title page.**

SÉRIE DE RAPPORTS TECHNIQUES
DU SERVICE CANADIEN DE LA FAUNE

Cette série de rapports donnant des informations scientifiques et techniques sur les projets du Service canadien de la faune (SCF) a démarré en 1986. L'objet de ces rapports est de promouvoir la diffusion d'études s'adressant à un public restreint ou trop volumineuses pour paraître dans une revue scientifique ou l'une des séries du SCF.

Ordinairement, seuls les spécialistes des sujets traités demandent ces rapports techniques. Ces documents ne sont donc produits qu'à l'échelon régional et en quantités limitées; ils ne peuvent être obtenus qu'à l'adresse figurant au dos de la page titre. Cependant, leur numérotage est effectué à l'échelle nationale. La citation recommandée apparaît à la page titre.

Ces rapports se trouvent dans les bibliothèques du SCF et figurent aussi dans les listes du système de référence DOBIS utilisé dans les principales bibliothèques scientifiques du Canada. Ils sont publiés dans la langue officielle choisie par l'auteur en fonction du public visé. **En vue de déterminer si la demande est suffisamment importante pour produire ces rapports dans la deuxième langue officielle, le SCF invite les usagers à lui indiquer leur langue officielle préférée. Il faut envoyer les demandes de rapports techniques dans la deuxième langue officielle à l'adresse indiquée au verso de la page titre.**

ATTENDANCE PATTERNS, HATCHING CHRONOLOGY AND BREEDING POPULATION OF COMMON MURRES ON TRIANGLE ISLAND, BRITISH COLUMBIA FOLLOWING THE NESTUCCA OIL SPILL

Michael S. Rodway

Technical Report Series No. 87
Pacific and Yukon Region 1990
Canadian Wildlife Service

This series may be cited as:

Rodway, M.S. 1990. Attendance patterns, hatching chronology and breeding population of Common Murres on Triangle Island, British Columbia following the Nestucca oil spill. Technical Report Series No. 87. Canadian Wildlife Service, Pacific and Yukon Region, British Columbia.

Published by Authority of the
Minister of Environment
Canadian Wildlife Service

Cataloque No. CW69-5/87E
ISBN 0-662-17407-0
ISSN 0831-6481

Copies may be obtained from:
Canadian Wildlife Service
Pacific and Yukon Region
P.O. Box 340
Delta, British Columbia
Canada V4K 3Y3

ABSTRACT

At least 8,800, and probably in excess of 20,000 Common Murres died in British Columbia and Washington during the Nestucca oil spill in January and February 1989. Known mortality exceeded the estimated breeding population in British Columbia. Studies were conducted on Triangle Island, the most important colony in British Columbia, during the summer of 1989, to assess the possible impact on local breeding populations.

Total population was estimated to be 9,943 ± 202 birds, with 4,077 ± 83 breeding pairs. Estimates were higher than all previous counts, likely due to more complete coverage of the colony. Almost all birds on the east side of the island, representing about 17% of the total population, abandoned breeding ledges early in egg-laying. Murres at other sites successfully hatched young, though the ratio of breeding sites to total birds present was lower than values reported at other colonies.

Attendance on a study plot displayed a consistent bimodal pattern, with a minor peak in the morning and a major peak in the evening. Numbers were least variable between 1000 and 1300 h. Peak and median hatch occurred between 5 and 8 August. Timing was similar to that reported on past surveys, and was probably not affected by the oil spill. Breeding chronology on Triangle Island appears to be very late compared to other colonies.

There was no evidence to indicate that the Nestucca oil spill affected breeding populations in 1989. No dead or oiled murres were observed, and there was no apparent decline in overall numbers at the colony. Reproductive failures on the east side of the island could not be evaluated because of a lack of data from previous years.

RESUME

Un minimum de 8,800 (mais plus probablement 20,000) Marmettes Communes moururent en Colombie Britanique et Washington lors du déversement de pétrole Nestucca en janvier et février 1989. Le taux minimum de mortalité est plus élevé que l'estimé total de la population nichant en Colombie Britanique. Une étude fut conduite sur l'île Triangle, qui comprend la plus importante colonie de Marmettes Communes en Colombie Britannique, durant l'été de 1989 afin de déterminer l'impact du déversement sur les populations locales.

La population totale et nidificatrice sur l'île Triangle fut estimeé à respectivement 9943 +/- 202 oiseaux et a 4077 +/- 83 couples. Ces estimés sont plus élevés que tous les recensements précédents, probablement à cause d'une couverture plus complète de la colonie. Presque tous les oiseaux du côté est de l'île, représentant environ 15% de la population totale, désertèrent leurs nids tôt durant l'incubation. Les autres sites de nidification réussirent à produire des jeunes, bien que la proportion de sites de nidification par individu recensé fut moins élevée que lors d'études précédentes.

La présence d'adultes dans la région d'étude suivit une distribution bimodale, avec un pic mineur le matin et un pic majeur en soirée. Les nombres furent le plus constant entre 1000h et 1300h. Le pic et la médiane des dates d'éclosion eurent lieu entre le 5 et le 8 août. La chronologie de reproduction observée lors de cette étude fut similaire a celle reportée lors de recensements précédents au même endroit, et ne fut probablement pas affectée par le déversement de pétrole. Les oiseaux nichant sur l'île Triangle semblent cependant nicher très tard comparativement aux autres colonies.

Il n'y a aucune évidence indiquant que le déversement de pétrole Nestucca eut un impact sur les populations de Marmettes nichant en 1989. Aucune marmette pétrolée ou morte ne fut observée, et le nombre d'oiseaux nicheurs ne semble pas avoir diminué. Le succès reproducteur ne put être évalué a cause d'un manque de données de base.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (cont'd)

LIST OF FIGURES

LIST OF APPENDICES

ACKNOWLEDGEMENTS

This study was supported by Pacific and Yukon Region of Environment Canada, Conservation and Protection, Environmental Protection as part of the impact assessment of the Nestucca oil spill on the British Columbia Coast. S.P. Wetmore, Canadian Wildlife Service was the scientific authority for the contract.

Many thanks to K.R. Summers who shared long hours at the telescope scutinizing and counting breeding birds.

I am grateful to A.J. Gaston and G.W. Kaiser for providing helpful comments on a draft manuscript, and to A. Breault for translating the abstract into French.

INTRODUCTION

Attendance patterns, breeding chronology and population monitoring of Common Murres (*Uria aalge*) have been extensively studied on the Atlantic coasts of Canada and Europe (Bakken 1986, Birkhead 1978, Birkhead and Nettleship 1987, Harris 1989, Harris and Wanless 1989, Harris *et al.* 1983, Lloyd 1975, Mudge 1988, Piatt and McLagan 1987). In the eastern Pacific, some data is available from Alaska (Hatch and Hatch 1989, Murphy *et al.* 1986, Searing 1977), but there is little information about timing of breeding, colony attendance or population trends in the southern part of its range (Scott 1973). The impact of the Nestucca oil spill on wintering populations along the Washington and British Columbia coasts early in 1989 created a concern for local breeding populations. Difficulties of extrapolating data from one part of the species range to another, emphasized the need for regional baseline information (Harris *et al.* 1983, Mudge 1988).

Almost 13,000 birds were known to have died in Washington and British Columbia from the Nestucca oil spill (Rodway *et al.* 1989). Estimated mortality was 30-40,000 birds (Burger *in prep.*). Common Murres comprised 42% of dead birds found on beaches in British Columbia and approximately 80% of those found in Washington. Thus at least 8,800, and probably in excess of 20,000 Common Murres died during the spill. Known mortality exceeded the estimated breeding population in British Columbia (Rodway *in press*). Triangle Island is the only major colony of murres in British Columbia, supporting 95% of the provincial total (Rodway *in press*). Past estimates of the colony range from 3,000 (Carl *et al.* 1951) to 6,000 birds (Vermeer *et al.* 1976). The highest recent count was 4,910 birds in 1982 (Rodway *et al.* 1990).

A study of Common Murres on Triangle Island was undertaken between 27 July and 17 August 1989 to assess the impact of the Nestucca oil spill on breeding populations. The island was explored for dead birds, and live birds were examined for signs of oiling. Populations were estimated and results were compared to previous counts to detect possible declines. Breeding performance was evaluated by comparing timing of breeding and ratio of breeding birds to total birds (*k*) with past, anecdotal data from Triangle Island, and known chronology and *k* ratios in other parts of the species range.

METHODS

Birkhead and Nettleship (1980) outline two census methods: Type I - full scale method - providing precise estimates of breeding populations, and requiring intensive observations of individual breeding sites over a six week period; and Type II - counts of individuals - providing a record of mean numbers of birds, and requiring only 10 days to complete. During this study, time was not available to conduct a Type I census, but I was not content with a Type II census, the results of which are difficult to interpret because they provide no information about numbers of breeding birds. I combined the two types of census and conducted detailed observations of a sample of breeding birds through only one phase of the breeding cycle. Less information was obtained on the status and outcome of all breeding sites, but the ratio of breeding to total birds, and the timing of hatching was determined.

Photographic count: The optimum timing for counts occurs when numbers of birds are least variable. Birkhead and Nettleship (1980) recommended the period between the end of egg-laying and the beginning of fledging. Hatch and Hatch (1989) reported the least variation in daily counts from the middle of egg-laying to the beginning of fledging, allowing a more extended period suitable for censusing. Because of other work being conducted on Triangle Island, I chose the period between the beginning of hatching and the beginning of fledging, which is similar to that recommended by Birkhead and Nettleship. I determined the appropriate timing for counts by monitoring the onset of egg-laying, and estimating the

beginning of hatching from known incubation periods (Birkhead and Nettleship 1987, Harris and Wanless 1988).

The entire murre colony on Triangle Island is readily counted, and appropriate selection of sampling plots was not a concern (Harris *et al.* 1983, Mudge 1988). Birkhead and Nettleship suggest performing direct counts rather than counts from photographs for colonies < 10,000 birds. This is possible from the sea for the colony on Triangle Island, but the movement of the boat prevented accurate counts, and counts from photographs were chosen as the best alternative. Harris *et al.* (1983) also dismissed counts from boats as too inaccurate. Eleven photographic series of all occupied sites were taken between 27 July and 17 August. I initially allocated 20 days to take 10 photographic series. Pictures series were scheduled at two day intervals in an attempt to avoid serial dependance of counts taken on consecutive days (Harris *et al.* 1983), but intervals had to be adjusted as weather permitted. Series were begun at 1800 h, and required close to two hours to complete. An additional series, beginning at noon on 6 August, was taken for comparison. Counts were conducted in the evening rather than the middle of the day as recommended by Birkhead and Nettleship because: most sites on the east side of the island were vacant during the middle of the day; lighting conditions were better in the evening on the west side of Puffin Rock, where the majority of murres were located; initial observations of attendance patterns indicated a consistent diurnal trend making it feasible to interpret and compare counts performed at any time of day; and evening counts allowed us to conduct other studies during the day.

Pictures were taken from a 16 foot inflatable boat, using Kodak Ektapress 1600 ASA Professional print film in a Pentax Spotmatic camera with an 80 to 200 mm zoom lens. Counts were made from 10x15 cm prints with the aid of a low power magnifying lens, and a digital counter. The digital counter, designed and constructed by S. Boyd and D. Smith for counting Snow Geese from aerial photographs, had a pointed end that when depressed, tripped the counter and made a visible pin-prick on the photograph. The marks on the photograph prevented counting errors due to ommissions or double-counting.

Weather conditions were recorded at the beginning of each survey.

Attendance patterns and correction factor for photographic counts: Randomly chosen sites representing different areas of the colony are preferable for monitoring population parameters (Birkhead and Nettleship 1980, Harris *et al.* 1983, Mudge 1988). I inspected all sites visible from land, and found few suitable locations. It was possible to look down and clearly distinguish breeding birds at only two locations: above Murre Rock and on the south side of the west point of Puffin Rock. To look down on Murre Rock required perching on the edge of a cliff, so the site on the south side of the west point was chosen as the only suitable one (site 8 - Table 1; Appendix II, page 27). Other locations could have been used for monitoring attendance patterns, but were not appropriate for distinguishing breeding sites and following reproductive chronology. It was decided that intensive observations of the breeding status and attendance patterns of birds at one location would provide more meaningful results than monitoring attendance patterns at a number of sites. Future studies employing more observers could encompass both.

Attendance patterns were monitored during the same period that photographic counts were taken. Studies were conducted between 0700 and 2100 h on five days spaced at three day intervals between 2 and 14 August. The study area was divided into 17 subsections, using obvious features in the rock. Thirteen subsections were chosen that contained easily distinguishable breeding sites (Appendix I). Numbers of murres at individual subsections ranged from 4 to 232, with a total mean ($\pm$ 1 S.E.) at all 13 subsections of 617 $\pm$ 10 (S.D. = 69; N = 45), representing approximately 75% of all birds using that location, and 7.5% of the entire colony. Counts were made every hour by two observers (M. Rodway and K. Summers) using 20X telescopes. Each observer counted approximately half the birds, and always counted the same sections. This was intended to prevent possible distortion of the results due to biases introduced by different observers. I assumed that if one person always counted the

same section, the observer bias would be constant and would not affect the interpretation of overall results. Counts required 6-8 minutes to complete.

Photographs of the study site were also taken every hour, just before the telescope counts were made. Photographs were taken so that the study area filled the camera frame, which was similar to the magnification used when taking pictures from the water. Comparisons between hourly counts by telescope and counts from photographs were used to obtain a correction factor for population estimates derived from photographic counts of the entire colony.

Breeding chronology and ratio of breeding sites to total birds: I attempted to determine the breeding status of all murres present on 12 of the subsections used to monitor attendance patterns. Observations were made during the intervals between hourly counts. Observations were interupted every three hours, and observers moved away from the observation post for one hour, to allow puffins nesting in the area to deliver fish to their young. Over the five days at the study plot, two observers spent 55 hours each making observations. Different sections were watched by each observers, but sections were exchanged so that both observers inspected all locations, and cross-checking between observers was possible. Neither observer had previous experience, but this was not expected to affect results (Gaston *et al.* 1983). Each subsection was mapped and the location of each sitting bird recorded. I defined breeding sites as those which were always occupied by at least one bird. If birds moved from or abandoned a site, the location was deleted. A total of 275 breeding sites were identified. Observations on the status of each site were recorded using a method similar to that presented by Birkhead and Nettleship (1980) and used by Gaston and Nettleship (1981). On each day of observations, I was able to determine the status of only a portion of those breeding sites. The ratio of breeding sites to total birds (*k*) was obtained using the mean hourly counts for the 12 subsections observed.

Because the status was known for only a portion of the total breeding sites identified, the proportion of eggs that hatched during each three day interval (H_i) was calculated by:

$$H_i = c_i / (c_i + e_i)$$

where c_i is the number of chicks confirmed on the current day that were confirmed as eggs on the previous day; and e_i is the number of eggs reconfirmed on the current day that were confirmed on the previous day. From that proportion I calculated the cummulative percent hatch (H_c) by:

$$H_c = \{[(1 - H_p)H_i] + H_p\}100$$

where H_p is the cummulative proportion hatched on the previous day.

Breeding population: The breeding population estimate (P) is given by:

$$P = k(Tr + C)$$

where k is the ratio of breeding sites to total birds present on study areas; T is the total mean count from photographs of the whole colony; r is the ratio of telescope to photographic counts on the study plot; and C is an additional count of birds from the top of Puffin Rock that were obscured from the water.

Time: Times quoted are Pacific Daylight Savings Time.

RESULTS

Photographic counts: Thirty-seven sites frequented by murres around Triangle Island were identified and photographed (Table 1; Fig. 1; Appendix II). A number of photos were lost due to shutter problems, but I obtained between 7 and 11 counts from photos of each major site. Fewer counts were obtained of the small number of murres at sites 10 and 11, which were overlooked during the first photo series. The mean number (± 1 S.E.) of birds counted from photographs of all those sites was 5,839 ± 87 (Table 2).

Table 1. Location of sites used for photographic counts of murres in 1989.

Site number	Location
Puffin Rock	
1	Crevice on mid-east side.
2	Ridge and small, high cave south of site 1.
3	Edge of grass at upper south end of east side.
4	Ledge on upper south end of west side.
5	Ledge just north and below site 4.
6	SE side of low rock just north of southern sea-cave.
7	West side of low rock just north of southern sea-cave.
8	Lower rock and ridge just south of middle sea-cave.
9	Small ledge on cliffs above middle sea-cave.
10	Low crevice on north edge of middle sea-cave.
11	Small, grassy ridge above, and just north of middle sea-cave.
12	Ledges on south face of west point.
13	Eastern of two groups on upper southwest corner of west point.
14	Western of two groups on upper southwest corner of west point.
15	Edge of grass at south end of west side of west point.
16	Upper, grassy nose north of site 15.
17	Ledges at edge of grass below site 16.
18	Ledges on cliffs south of northern sea-cave.
19	Low cliff just south of northern sea-cave.
20	Low cliff just north of northern sea-cave.
21	Low cliff near north end of Puffin Rock; opposite Murre Rock.
Murre Rock	
22	Southeast side.
23	South end of west side.
24	North end of west side.
25	Northeast side.
Castle Rock	
26	West side of southwest pinnacle.
27	North side of southwest pinnacle.
28	East side of southwest pinnacle.
29	West side of main rock.
30	North side of main rock.
31	East side of main rock.
Southeast point	
32	East side of east rock.
33	East side of rock just north of south end.
34	Southwest side of rock just north of south end.
35	Edge of grass on east side of south end.
36	Top, south side of south end.
37	Lower, northwest corner of south end.

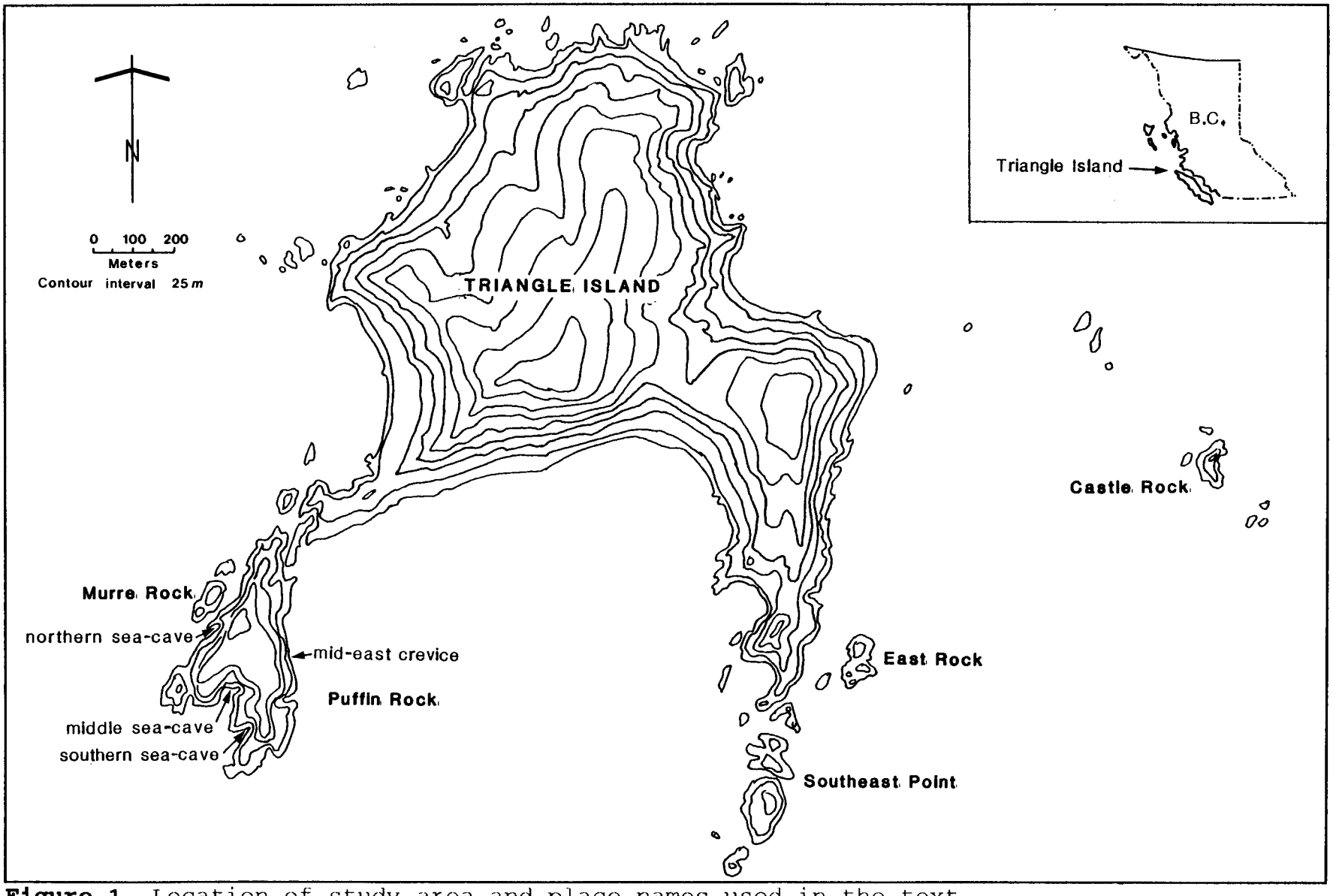


Figure 1. Location of study area and place names used in the text.

Table 2. Photographic counts of Common Murres on Triangle Island in 1989. Photos were taken between 1800-2000 h except for the additional count conducted at noon on 6 August. The noon count was not included in the mean. Daily totals are listed for the most complete counts.

Site number	Date															
	27 Jul	29 Jul	1 Aug	4 Aug	6 Aug	10 Aug	12 Aug	13 Aug	15 Aug	16 Aug	17 Aug	Mean	S.D.	S.E.	N	6 Aug (noon)
1	39	49	43	41	39	44	0	2	39	45	33	34	16	5	11	8
2	3	5	14	3	8	9	3	2	10	18	18	8	6	2	11	1
3	0	46	27	0	2	0	0	0	3	2	0	7	14	5	11	0
4	42	29	30	34	21	23	x	x	23	26	19	27	7	2	9	10
5	36	34	26	39	39	44	x	35	39	41	39	37	5	2	10	32
6	182	202	202	186	145	134	x	156	161	151	165	168	22	7	10	110
7	254	349	336	362	355	365	262	x	317	303	399	330	44	15	10	307
8	393	541	559	497	523	x	x	513	487	486	456	495	46	16	9	392
9	12	0	14	19	11	11	12	17	24	16	13	14	6	2	11	14
10	-	-	30	30	-	29	-	x	20	34	32	29	4	2	6	19
11	-	-	-	-	-	-	-	-	23	22	14	20	4	3	3	18
12	18	47	56	41	46	29	x	40	41	36	41	40	10	3	10	16
13	365	404	297	382	359	330	x	409	421	374	382	372	36	12	10	268
14	517	524	440	500	515	592	x	510	561	584	584	533	45	15	10	446
15	470	488	fog	466	329	x	x	x	406	382	401	420	53	22	7	323
16	78	96	fog	111	88	x	x	x	90	82	103	93	11	4	7	46
17	165	155	fog	176	133	x	x	x	132	156	132	150	16	7	7	84
18	139	168	fog	168	111	x	152	120	119	144	128	139	20	7	9	49
19	179	156	fog	149	176	139	127	150	137	135	148	150	16	5	10	99
20	57	53	fog	55	58	x	x	66	59	52	53	57	4	2	8	42
21	179	184	fog	193	214	x	194	x	215	196	210	198	13	5	8	163
22	165	141	fog	173	135	125	164	156	x	124	118	145	19	7	9	115
23	149	152	fog	179	189	175	174	x	x	183	165	171	13	5	8	139
24	476	547	fog	449	428	x	389	x	438	403	484	452	47	18	8	327
25	296	237	fog	187	432	184	284	x	233	237	220	257	71	25	9	200
26	63	75	fog	62	54	82	x	66	72	72	67	68	8	3	9	17
27	196	207	fog	240	250	213	x	213	199	209	194	209	14	5	8	0
28	63	46	fog	44	*	35	x	53	62	54	41	50	9	4	8	0
29	22	167	fog	38	x	x	x	162	132	159	163	120	58	24	7	0
30	0	336	fog	235	*	505	x	400	453	460	399	349	153	58	8	0
31	*	146	fog	166	*	141	x	174	150	171	148	157	12	5	7	0
32	99	1	fog	0	2	63	126	91	82	103	76	64	44	15	10	0
33	119	147	fog	204	170	136	114	129	131	150	136	144	25	8	10	34
34	134	145	fog	198	150	77	125	137	x	146	146	140	29	10	9	56
35	0	40	fog	0	0	32	38	x	25	39	46	24	18	6	9	0
36	68	144	fog	60	38	49	95	102	x	122	120	89	35	12	9	0
37	92	83	fog	159	33	x	60	135	x	47	44	82	42	16	8	0

Totals:	Maximum						Mean		S.E.	Minimum
All sites	6144	5846				5964	5937	5839	87	3335
Sites that were always occupied	4874	4860				4535	4655	4646	53	3326

*: murres flew off at our approach. x: photo ruined by shutter problem. -: photograph not taken.

Murres successfully hatched young at most sites around Puffin Rock, but were unsuccessful at almost all sites on the east side of the island, including Castle Rock. At 12 sites (1, 3, 9, 27-32, and 35-37) birds were absent from the nesting ledges during at least part of the survey. At 1200 h on 6 August, there were no murres on ledges or on the water in the vicinity of sites 27-32 and 35-37. I explored Castle Rock at that time and found 119 depredated eggshells under cliff ledges and gathered into piles in the middle of the rock. The only locations on the east side of the island at which breeding birds remained tenaciously on territories were 26, 33, and 34. Murres would gather at unsuccessful sites during the late afternoon, and large numbers were regularly present at 1800-2000 h when photographic counts were conducted. Those birds were easily disturbed and frequently flew off nesting ledges at the approach of the boat, even when more than half a kilometer away.

If only sites at which murres were present on all counts are included, the mean number ($\pm$ 1 S.E.) counted from photographs was 4646 $\pm$ 53 (Table 2).

Attendance patterns: Total counts at the 13 subsections monitored on the study plot (Appendix I) ranged from 524 to 760 and averaged 617 $\pm$ 10 (1 S.E.). The mean number of birds present from 1800 to 2000 h constituted 8.2% of the total population estimated at breeding sites at that time.

Daily attendance patterns were similar on all observation days (Table 3). Numbers of birds peaked around 2000 h, with a second, lower peak occurring in the early morning. Lowest numbers were present in the afternoon between 1300 and 1600 h (Table 4; Fig. 2).

Comparison of counts from photographs to counts by telescope: On the study plot, counts from photographs were more variable, and always less than counts by telescope (Tables 5 to 7). This result is the same as that found by Harris and Lloyd (1977) and Gaston *et al.* (1985), but contrary to that reported by Gaston and Nettleship (1981). Gaston and Nettleship attributed the better agreement between their direct and photographic counts to their use of an experienced photo analyst, and a selection of good quality photographs. On Triangle Island, counts from photographs were influenced by the quality of photographs and the density of birds. Poor light conditions, high shadow, contrast between areas of white guano and dark cliffs, and improper camera settings all reduced the quality of photos and made individual birds difficult to discriminate. Where birds were tightly grouped, only birds in the forefront were clearly distinguishable.

By comparing hourly counts by telescope to counts from photographs, I calculated a mean ratio of 1.44 $\pm$ 0.02 (Table 7). That ratio was used to adjust the estimate of total numbers of murres derived from photographic counts.

Table 3. Hourly counts by telescope of murres present on study plot in 1989. A dash indicates that no counts were conducted at that time.

	2 August							Hour							
Site	7	7:30	8	9	10	11	12	13	14	15	16	17	18	19	20	21
A	18	15	19	13	16	13	14	11	10	12	23	22	25	29	35	32
B	37	39	40	39	41	30	26	31	30	30	44	46	49	54	58	58
C	15	17	16	15	15	12	12	13	11	10	15	17	24	20	22	19
D	61	68	68	63	57	56	53	55	59	57	62	66	76	74	63	73
E	7	4	4	4	4	4	4	5	4	4	5	6	8	7	6	8
F	24	25	25	29	24	32	26	25	25	28	32	33	29	31	36	31
G	30	31	35	35	30	31	30	32	29	28	30	41	44	35	36	37
K	103	-	-	-	-	104	100	102	105	109	112	130	132	130	134	133
L	130	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N	26	-	-	24	19	20	18	18	18	16	21	22	23	24	22	22
O	32	30	26	26	26	29	22	22	27	28	34	38	30	32	35	26
P	50	53	50	51	44	49	50	45	43	49	52	53	54	62	57	53
Q	-	-	-	38	36	35	34	36	37	42	42	48	51	50	55	48
Rest	255	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Totals:																
A-K,N-Q						415	389	395	398	413	472	522	545	548	559	540
A-G,N-Q				337	312	311	289	293	293	304	360	392	413	418	425	407
A-G,O-P	274	282	283	275	257	256	237	239	238	246	297	322	339	344	348	337
Overall	831 (using calculated number for site Q based on percentage of maximum)															

	5 August							Hour							
Site	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
A	12	11	9	11	11	9	9	9	10	10	21	26	21	25	24
B	29	27	25	25	19	22	22	22	20	25	40	37	50	47	57
C	16	19	15	15	15	14	13	13	15	14	15	15	20	20	19
D	68	67	69	66	54	57	56	58	64	72	70	69	70	79	71
E	6	9	6	6	6	5	4	4	5	5	5	6	7	9	8
F	28	27	29	28	27	28	23	25	30	27	26	30	31	37	31
G	32	31	28	27	29	26	30	27	30	32	36	34	35	36	38
K	113	106	111	114	101	103	95	96	98	107	108	114	114	131	133
L	-	-	-	-	-	-	-	-	-	-	162	-	-	-	-
N	11	15	15	17	15	15	12	16	15	17	21	17	20	27	23
O	28	25	27	19	21	15	16	14	18	19	15	23	28	38	29
P	47	57	48	50	48	39	44	39	38	44	41	45	58	59	59
Q	35	43	37	35	37	33	33	30	40	45	50	50	50	50	46
Totals:															
A-K,N-Q	425	437	419	413	383	366	357	353	383	417	448	466	504	558	538

	8 August							Hour							
Site	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
A	15	14	15	14	9	9	13	11	10	13	13	14	21	19	19
B	36	25	27	27	31	28	28	29	27	26	35	38	38	40	43
C	16	19	17	16	13	14	15	13	12	12	15	17	18	18	16
D	62	66	66	60	56	57	57	54	61	66	63	60	61	75	75
E	7	7	5	7	5	7	7	4	6	7	7	6	9	7	6
F	32	25	25	27	25	23	25	23	26	21	26	25	28	29	30
G	35	34	31	27	31	31	30	28	31	30	35	32	34	35	38
K	120	116	107	120	102	109	112	103	108	104	110	122	120	128	128
L	177	161	159	144	142	143	150	138	148	155	171	197	213	232	206
N	22	17	20	19	17	18	18	16	15	15	20	21	26	29	28
O	28	22	27	25	23	25	25	22	26	25	32	30	34	37	31
P	53	46	47	45	47	47	44	46	45	44	46	49	58	55	55
Q	41	43	45	33	39	38	36	37	40	39	47	47	52	56	51
Totals:	644	595	591	564	540	549	560	524	555	557	620	658	712	760	726

cont'd

Table 3. (cont'd)

Site	11 August 7	8	9	10	11	12	Hour 13	14	15	16	17	18	19	20	21
A	17	12	11	10	12	10	11	14	10	17	18	15	23	22	19
B	31	25	25	25	29	30	29	25	22	28	33	33	37	34	40
C	16	16	17	15	13	14	15	15	13	14	13	18	15	16	17
D	64	61	59	60	60	57	59	64	60	58	62	67	71	70	65
E	5	6	6	8	7	7	5	6	6	7	9	6	6	11	8
F	28	31	28	26	30	29	29	25	27	30	30	32	32	38	33
G	33	35	29	29	34	27	28	28	24	26	30	32	31	30	33
K	118	108	105	108	107	103	101	111	107	111	109	106	111	125	119
L	158	144	145	134	136	139	141	161	149	161	166	179	184	200	197
N	19	16	15	16	19	19	16	18	16	18	21	23	24	25	21
O	31	26	26	26	26	25	24	22	21	21	26	32	29	30	33
P	49	55	51	56	48	47	47	46	48	52	51	53	53	53	56
Q	42	42	36	33	36	38	36	41	40	45	44	49	44	48	42
Totals:	611	577	553	546	557	545	541	576	543	588	612	645	660	702	683

Site	14 August 7	8	9	10	11	12	Hour 13	14	15	16	17	18	19	20	21
A	13	11	13	13	12	11	12	13	18	19	22	20	19	27	23
B	38	38	27	28	31	28	29	32	35	40	47	39	45	45	54
C	17	17	15	14	16	14	13	14	18	19	18	18	18	20	19
D	69	66	64	61	60	67	61	71	70	62	64	72	71	70	77
E	4	7	5	5	5	4	6	5	7	7	7	6	6	9	6
F	28	30	27	26	25	30	30	32	31	39	36	30	34	31	34
G	32	31	27	28	28	30	28	33	36	35	38	37	43	37	38
K	114	111	114	105	106	103	107	112	122	120	115	124	124	126	118
L	165	153	152	149	142	150	143	148	181	186	194	200	219	217	205
N	16	16	17	16	16	18	14	19	20	18	21	20	24	20	19
O	27	27	32	23	26	27	24	26	29	28	30	36	37	30	27
P	54	53	48	46	42	47	48	50	57	53	57	55	57	62	53
Q	45	46	44	40	42	50	46	52	54	46	55	54	60	54	49
Totals:	622	606	585	554	551	579	561	607	678	672	704	711	757	748	722

Table 4. Common Murre attendance patterns on Triangle Island, August 1989.

Hourly total number of birds counted by telescope as a percentage of the maximum number counted.

Date	7	8	9	10	11	12	Hour 13	14	15	16	17	18	19	20	21
2 Aug[a]	78.7	81.3	79.0	73.9	73.6	68.1	68.7	68.4	70.7	85.3	92.5	97.4	98.9	100	96.8
5 Aug[b]	76.2	78.3	75.1	74.0	68.6	65.6	64.0	63.3	68.6	74.7	80.3	83.5	90.3	100	96.4
8 Aug	84.7	78.3	77.8	74.2	71.1	72.2	73.7	68.9	73.0	73.3	81.6	86.6	93.7	100	95.5
11 Aug	87.0	82.2	78.8	77.8	79.3	77.6	77.1	82.1	77.4	83.8	87.2	91.9	94.0	100	97.3
14 Aug	82.2	80.1	77.3	73.2	72.8	76.5	74.1	80.2	89.6	88.8	93.0	93.9	100	98.8	95.4

[a] sites A-G,O-P
[b] sites A-K, N-Q

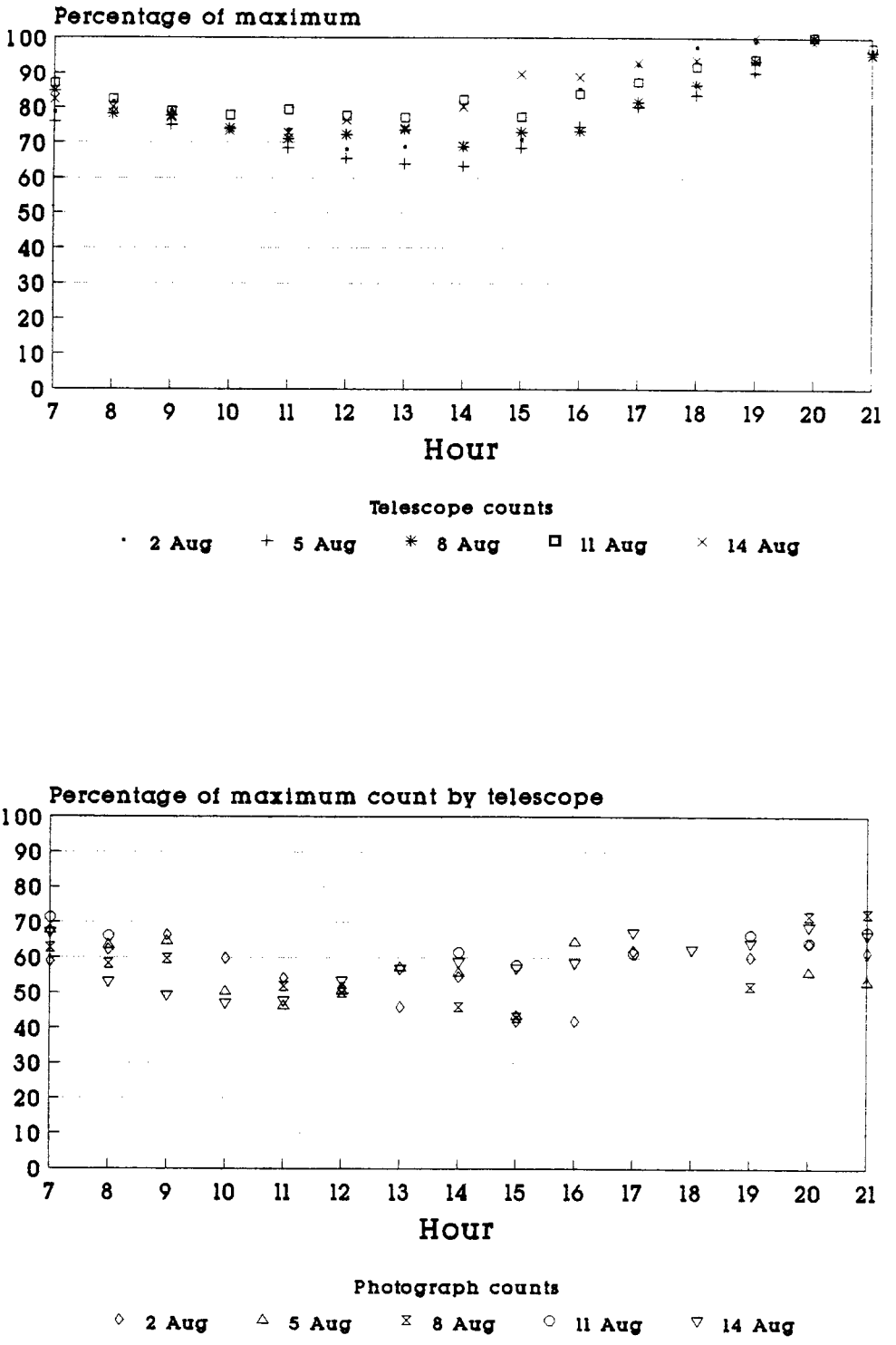


Figure 2. Attendance patterns of Common Murres on Triangle Island in 1989 determined by direct telescope counts and by counts from photographs.

Table 5. Hourly counts from photographs of murres present on study plot in 1989.

	2 August						Hour								
Site	7:30	8	9	10	11	12	13	14	15	16	17	18	19	20	21
A	18	15	12	15	10	10	12	9	10	8	15	x	18	21	24
B	28	34	27	36	29	24	23	29	15	28	29	x	39	43	40
C	15	14	17	14	11	13	13	10	6	7	14	x	15	13	14
D	40	42	37	30	33	36	31	42	35	30	47	x	41	32	43
E	4	3	4	5	1	3	4	3	3	2	5	x	5	5	5
F	17	14	21	17	15	15	13	17	12	16	19	x	17	18	15
G	26	29	36	30	25	26	23	23	20	20	32	x	24	26	28
K	83	-	-	-	82	82	73	83	66	64	76	x	93	92	88
L	131	-	-	-	-	-	-	-	-	-	-	x	161	-	-
N	16	-	13	20	14	14	12	15	11	10	22	x	12	22	15
O	20	22	34	23	23	7	9	20	10	5	12	x	19	23	9
P	37	43	43	38	42	45	32	37	35	30	42	x	31	42	36
Q	31	-	35	27	12	23	23	23	21	22	44	x	32	36	32
Rest	249	-	-	-	-	-	-	-	-	-	-	x	288	-	-
Totals:															
A-K,N-Q					297	298	268	311	244	242	357	x	507	373	349
A-G,N-Q			279	255	215	216	195	228	178	178	281	x	253	281	261
A-G,O-P	205	216	231	208	189	179	160	190	146	146	215	x	209	223	214
Overall	715												795		

	5 August						Hour								
Site	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
A	12	17	10	11	6	8	9	8	8	12	x	x	x	12	8
B	21	31	17	20	18	18	20	17	21	33	x	x	x	31	18
C	19	16	13	14	12	12	14	12	11	14	x	x	x	16	17
D	47	35	44	39	32	33	43	48	27	43	x	x	x	36	38
E	6	7	2	4	2	4	4	4	2	6	x	x	x	3	2
F	22	18	20	19	12	18	20	16	20	23	x	x	x	22	15
G	30	25	28	24	24	19	29	28	20	28	x	x	x	24	26
K	107	90	92	74	70	84	87	88	78	99	x	x	x	85	88
L	-	-	-	-	-	-	-	-	-	-	x	x	x	-	-
N	13	11	10	11	11	18	11	11	7	14	x	x	x	13	13
O	28	24	35	11	11	15	16	16	7	11	x	x	x	13	14
P	45	40	56	33	34	30	38	36	20	39	x	x	x	26	32
Q	28	39	33	21	27	23	29	27	22	37	x	x	x	31	26
Totals:															
A-K,N-Q	378	353	360	281	259	282	320	311	243	359	x	x	x	312	297

	8 August						Hour								
Site	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
A	8	6	12	x	5	7	x	8	7	x	x	x	5	13	17
B	31	21	23	x	22	17	x	24	20	x	x	x	31	25	38
C	16	14	17	x	11	10	x	10	6	x	x	x	15	10	13
D	45	40	35	x	23	31	x	31	31	x	x	x	35	39	47
E	4	4	4	x	3	4	x	3	3	x	x	x	6	3	6
F	22	16	18	x	16	14	x	13	16	x	x	x	19	20	25
G	32	28	23	x	21	22	x	20	25	x	x	x	19	23	26
K	87	94	93	x	80	82	x	70	61	x	x	x	64	102	97
L	135	132	129	x	125	117	x	113	106	x	x	x	111	198	165
N	14	9	14	x	11	13	x	8	8	x	x	x	13	16	19
O	16	20	21	x	18	13	x	10	5	x	x	x	11	21	20
P	25	31	35	x	28	25	x	17	26	x	x	x	39	38	37
Q	41	27	30	x	31	26	x	22	12	x	x	x	26	38	40
Totals:	476	442	454	x	394	381	x	349	326	x	x	x	394	546	550

cont'd

Table 5. (cont'd)

Site	11 August 7	8	Hour 9	10	11	12	13	14	15	16	17	18	19	20	21
A	16	11	x	x	x	x	x	11	6	x	12	x	14	16	16
B	21	24	x	x	x	x	x	18	17	x	22	x	25	23	27
C	12	16	x	x	x	x	x	13	11	x	13	x	13	13	12
D	43	37	x	x	x	x	x	35	39	x	37	x	40	39	41
E	4	4	x	x	x	x	x	3	2	x	5	x	3	4	4
F	20	20	x	x	x	x	x	18	15	x	18	x	17	13	23
G	28	29	x	x	x	x	x	23	23	x	26	x	21	20	21
K	90	91	x	x	x	x	x	84	91	x	80	x	87	83	85
L	147	127	x	x	x	x	x	123	123	x	121	x	156	146	147
N	16	14	x	x	x	x	x	13	10	x	15	x	14	16	16
O	20	18	x	x	x	x	x	15	11	x	15	x	16	13	15
P	42	41	x	x	x	x	x	39	31	x	36	x	35	37	38
Q	41	31	x	x	x	x	x	35	26	x	29	x	25	28	28
Rest	-	-	x	x	x	x	x	-	-	x	-	x	255	-	-
Totals: Overall	500	463	x	x	x	x	x	430	405	x	429	x	466 721	451	473

Site	14 August 7	8	Hour 9	10	11	12	13	14	15	16	17	18	19	20	21
A	10	7	7	6	7	8	10	11	14	14	18	12	10	20	17
B	36	24	19	18	17	21	25	20	22	28	35	22	33	38	38
C	13	12	10	12	8	10	11	13	13	13	13	16	12	14	12
D	52	41	39	34	34	40	38	47	36	33	33	36	34	47	43
E	3	2	3	2	2	3	3	3	3	3	4	2	2	5	5
F	24	17	18	16	17	20	15	24	18	21	24	18	20	22	18
G	33	26	21	18	16	27	28	29	24	24	26	25	27	28	32
K	98	77	76	77	86	83	95	88	83	79	97	91	94	92	92
L	131	119	108	99	100	115	126	123	123	129	159	152	165	158	162
N	12	10	9	8	12	9	10	8	13	18	16	18	13	15	10
O	22	13	9	10	9	12	10	13	12	17	15	15	14	8	7
P	42	28	22	32	29	32	31	35	40	38	34	33	27	39	34
Q	31	25	31	24	24	24	28	30	30	25	33	30	34	35	32
Rest	-	-	-	-	-	-	-	-	-	-	-	294	-	-	-
Totals: Overall	507	401	372	356	361	404	430	444	431	442	507	470 764	485	521	502

x: photo ruined by shutter problem

Table 6. Hourly total number of birds counted from photographs as a percentage of the maximum number counted by telescope in 1989.

Date	Hour 7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2 Aug[a]	58.9	62.1	66.4	59.8	54.3	51.4	46.0	54.6	42.0	42.0	61.8	x	60.1	64.1	61.5
5 Aug[b]	67.7	63.3	64.5	50.4	46.4	50.5	57.3	55.7	43.5	64.3	x	x	x	55.9	53.2
8 Aug	62.6	58.2	59.7	x	51.8	50.1	x	45.9	42.9	x	x	x	51.8	71.8	72.4
11 Aug	71.2	66.0	x	x	x	x	x	61.3	57.7	x	61.1	x	66.4	64.2	67.4
14 Aug	67.0	53.0	49.1	47.0	47.7	53.4	56.8	58.7	56.9	58.4	67.0	62.1	64.1	68.8	66.3

[a] sites A-G,O-P
[b] sites A-K, N-Q
x: photo ruined by shutter problem

Table 7. Comparison of Common Murre counts by telescope and from photographs in 1989. Only counts on 8, 11 and 14 Aug, which included all sites, were used to calculate means.

Hourly total number of birds counted by telescope.

	Hour														
Date	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2 Aug*					415	389	395	398	413	472	522	545	548	559	540
5 Aug*	425	437	419	413	383	366	357	353	383	417	448	466	504	558	538
8 Aug	644	595	591	564	540	549	560	524	555	557	620	658	712	760	726
11 Aug	611	577	553	546	557	545	541	576	543	588	612	645	660	702	683
14 Aug	622	606	585	554	551	579	561	607	678	672	704	711	757	748	722

Hourly total number of birds counted from photographs.

	Hour														
Date	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2 Aug*					297	298	268	311	244	242	357	x	507	373	349
5 Aug*	378	353	360	281	259	282	320	311	243	359	x	x	x	312	297
8 Aug	476	442	454	x	394	381	x	349	326	x	x	x	394	546	550
11 Aug	500	463	x	x	x	x	x	430	405	x	429	x	466	451	473
14 Aug	507	401	372	356	361	404	430	444	431	442	507	470	485	521	502

Ratio between total number counted by telescope and total number counted from photographs.

	Hour														
Date	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2 Aug					1.40	1.31	1.47	1.28	1.69	1.95	1.46		1.08	1.50	1.55
5 Aug	1.12	1.24	1.16	1.47	1.48	1.30	1.12	1.14	1.58	1.16				1.79	1.81
8 Aug	1.35	1.35	1.30		1.37	1.44		1.50	1.70				1.81	1.39	1.32
11 Aug	1.22	1.25						1.34	1.34		1.43		1.42	1.56	1.44
14 Aug	1.23	1.51	1.57	1.56	1.53	1.43	1.30	1.37	1.57	1.52	1.39	1.51	1.56	1.44	1.44

	Mean	S.D.	S.E.	N
Total number counted by telescope	617	69	10	45
Total number counted from photographs	441	57	10	33
Ratio	1.44	0.13	0.02	33

* sites A-K;N-Q
x: photo ruined by shutter problem

From the top of Puffin Rock, I took detailed photographs of areas I could obtain a clearer view of than from the water (Table 8). The top of Murre Rock is not visible, and its southeast side (site 22) can only be viewed obliquely from the water. Counts from those photographs were adjusted to counts at 1800 h, according to attendance patterns determined on the study plot, and then compared to mean photo-counts from the water. Photographic counts from land of the six sites listed in Table 9, exceeded mean counts from the water by 1535. For population calculations, that number was added to the total count after the total count had been adjusted by the ratio of telescope counts to counts from photographs. Counts from land of the areas not visible from the water were made from detailed, close-up photographs that were more comparable to telescope counts than to the less detailed photographs taken of the study plot, which, for comparative purposes, were taken at the same scale as those from the water.

Table 8. Counts from land of murres not visible from the water during photographic surveys in 1989. Numbers were adjusted to 1800 h using the mean proportions listed on Table 2. Maximum and minimum figures are from Table 5.

Site	Date	Time	No. of birds	adjusted to 1800h	amount > mean
6	19 Aug	1220	256	279	111
13	19 Aug	1220	426	464	92
15	15 Aug	1620	523	585	165
22	15 Aug	1620	778	870	725
Top of Murre Rk.	15 Aug	1620	263	294	294
25	15 Aug	1620	425	425	148
Total to add to mean					1535
Total to add to minimum (X 3335/5839)					877
Total to add to maximum (X 6144/5839)					1615

Table 9. Numbers of breeding sites identified in subsections of the study plot in 1989.

Area	No. of breeding sites
A	6
B	14
C	8
D	38
E	4
F	10
G	20
K	65
L	48
N	7
P	34
Q	21
Total	275

Breeding chronology: A total of 275 breeding sites were identified and mapped in areas A-N and P-Q on the study plot (Table 9). Over six days of observations, the status of 226 (82%) of those sites was verified (Table 10). Fourteen of the verified sites did not contain eggs or chicks, though mock incubation or brood shifts were observed. Adults at those sites may have been nonbreeding site holders (Gaston and Nettleship 1982), and the proportion of empty sites - 6.2% of total verified sites - indicates the possible error of over-estimation in the criteria used to define breeding sites. The error may have been less than that if birds at those sites lost eggs prior to the observation period. There may have been more breeding sites than those identified if unsuccessful pairs abandoned sites before, or during the study period.

Chicks had just begun to hatch when intensive observations were begun, and 76.7% of hatching occurred during the study period between 2 and 17 August. We determined the hatching date, to within three days, of 69 chicks (Table 10). The peak of hatching, and the median hatch date, occurred between 5 and 8 August when 36.2% of chicks hatched (Fig. 3). Using an average incubation period of 33 days (Birkhead and Nettleship 1987, Harris and Wanless 1988), indicates that peak egg-laying occurred in the first week of July. No chicks were observed fledging during the study period.

Table 10. Status of Common Murre breeding sites monitored for reproductive chronology on Triangle Island, August 1989.

Status	Date 2 Aug	5 Aug	8 Aug	11 Aug	14 Aug	17 Aug
Daily observations:						
Confirmed empty sites[a]	9	6	8	7	5	1
Confirmed eggs	51	85	59	47	38	27
Confirmed hatched in interval[b]	-	8	30	12	8	11
Additional chicks confirmed[c]	3	20	62	99	125	80
Total confirmed	63	119	159	165	176	119
Unreconfirmed sites[d]	-	9	19	37	43	107
Unconfirmed sites[e]	212	147	97	73	56	49
Total sites	275	275	275	275	275	275
Cummulative observations:						
Confirmed empty sites	9	10	13	14	14	14
Confirmed eggs	51	97	108	110	110	111
Eggs lost	-	0	0	2	3	3
Confirmed hatched	-	8	38	50	58	69
Additional chicks confirmed	3	20	54	76	99	107
Total chicks confirmed	3	28	92	126	157	176
Hatching chronology:						
Eggs confirmed previous count	-	51	85	59	47	38
Status confirmed this count	-	46	73	55	43	34
- eggs reconfirmed	-	38	43	41	34	23
- chicks hatched	-	8	30	12	8	11
- eggs lost	-	0	0	2	1	0
Percent hatched	-	17.4	41.1	22.6	19.0	32.3
Cumulative percent hatched	5.6	22.0	58.2	67.6	73.8	82.3

[a] no egg or chick present but adult always occupying site.
[b] chicks known to have hatched within 3-day interval.
[c] timing of hatching unknown.
[d] sites that were confirmed on previous days but not confirmed on current day.
[e] sites always occupied by adult, but presence of egg or chick not verified.

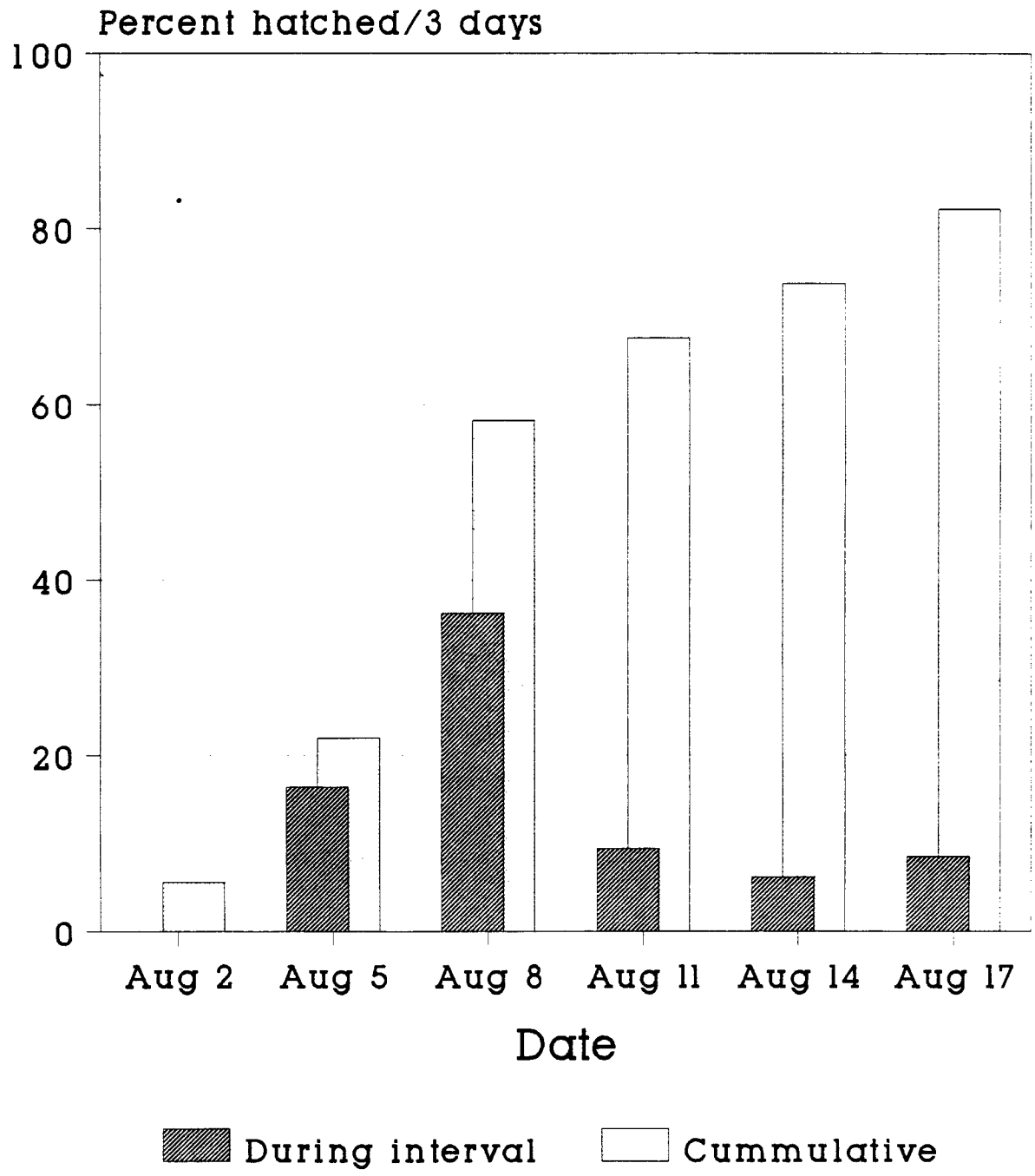


Figure 3. Hatching chronology of Common Murres on Triangle Island in 1989

1989 Breeding population: The breeding population of Common Murres on Triangle Island in 1989 was calculated to be 4,077 ± 83 pairs (Table 11). That estimate includes birds at all sites. An estimate of successfully nesting birds can be derived if sites that were vacant at some time during the surveys are excluded from the calculation. Excluding those locations gives an estimate of 3,372 ± 49 pairs that successfully hatched young in 1989.

Table 11. Calculation of 1989 Common Murre breeding population.

Number of murres on sites monitored for reproductive chronology (A-N,P-Q) between 1800-2000 h when photographic counts of entire island were conducted. Only counts on 8, 11 and 14 Aug, which included all sites, were used to calculate means.

Mean	S.E.	Minimum	Maximum
673	15	515	705

Ratio of breeding sites to total birds counted on study sites (*k*).

Mean	Minimum	Maximum
0.41	0.53	0.39

Total counts from photographs of murres around Triangle Island.

Mean	S.E.	Minimum	Maximum
5839	87	3335	6144

Total counts adjusted by ratio of telescope to photograph counts on study plot.

Mean	S.E.	Minimum	Maximum
8408	171	4802	8847

Total adjusted counts plus birds counted from land that were not visible from the water. A standard error could not be calculated for those single counts. In combining the estimates, the standard error was increased proportionally.

Mean	S.E.	Minimum	Maximum
9943	202	5679	10462

1989 Breeding population estimate (*k* x total birds at breeding sites).

Mean	S.E.	Minimum	Maximum
4077	83 pairs	3010 pairs	4080 pairs

DISCUSSION

Population:

Population estimates in 1989 exceeded all previous estimates. Mean corrected counts from photographs taken between 1800 and 2000 h gave a total population of 9,943 ± 202 birds. The breeding population was estimated to be 4,077 ± 83 pairs. Carl *et al.* (1951) estimated 3,000 birds present on cliffs at the end of June 1949, Vermeer *et al.* (1976) made a thorough count of 5,384 birds on Puffin Rock plus 550 on Castle Rock on 29 July 1975, and Rodway *et al.* (1990) counted 4,910 birds on Puffin Rock on 10 July 1982 and 3,456 on Puffin Rock plus 500 on Castle Rock between 16 and 19 July 1985.

Survey methods and timing may account for different estimates. Past counts were made from land and were limited by the number of visible birds. Three areas for which I have counts from three different years provide comparisons for specific sites. Results suggest that numbers were highest in 1982 and lowest in 1985 (Table 12). Comparisons are confounded by the timing of counts; counts in 1982 and 1985 were made in July, approximately one month earlier than those in 1989. Attendance patterns at that time (early egg-laying) are more variable, and comparisons are difficult to interpret, though trends were the same at all three sites. That numbers at those three locations were not highest in 1989 indicates that the higher overall estimate in 1989 is probably attributable to more complete coverage of the colony.

Table 12. Comparison of counts of murres from land at specific sites in 1982, 1985 and 1989. Site numbers are those assigned in 1989.

Location	Site No.	1982	1985	1989
S side W pt.	13,14	1140	540	790
W side W pt.	15	648	400	523
Murre Rock	22,25,top	1843	740	1466

Breeding on Castle Rock had not been verified before this study, but birds have been sighted on ledges there on all other visits except 1984, when all breeders failed (Rodway *et al.* 1990). Many murres layed eggs there in 1989, though breeding was disrupted during egg-laying or early incubation periods.

Why murres were unsuccessful at 12 locations around Triangle Island in 1989 is unknown. Weather was not severe and I observed no evidence of disturbance during egg-laying and incubation periods. Glaucous-winged Gulls (*Larus glaucescens*) were likely responsible for the 119 depredated eggshells found under cliff ledges and gathered into piles in the middle of Castle Rock on 6 August. One pair of ravens (*Corvus corax*), which are known egg predators at colonies in the Bering Sea (E. Murphy pers. comm.), nest on the east side of Triangle Island, but were never observed in the vicinity of murre nesting ledges. There was one severed murre head on the rocks, probably a result of Peregrine Falcon (*Falco peregrinus*) or Bald Eagle (*Haliaeetus leucocephalus*) predation. Whether egg predation contributed to abandonment or was a result of eggs being neglected is unknown. We never observed incubating birds on Puffin Rock leave their nests, even if closely approached by falcons, eagles, crows (*Corvus caurinus*) or gulls. Puffins, gulls and some roosting murres would flush off nesting slopes whenever an eagle or falcon passed over, but incubating or brooding murres stayed tenaciously at nest sites, albeit with vigorous head-bobbing, neck-craning and vocalization directed at the intruder. I did find small numbers of depredated murre eggs in the vicinity of gull nests on Puffin Rock early in the murre's incubation period, which suggests that they may have been more easily displaced from nests at that time. However, it seems unlikely that predators were the sole cause of abandonment at Castle Rock or other sites.

Breeding chronology:

Though there are no previous studies of murres on Triangle Island, past records do give an indication of breeding chronology in previous years. Carl *et al.* (1951) reported freshly laid eggs in the last week of June 1949. No sign of incubation was found in 19 eggs collected. Vallée (Vallée and Carter 1987) noted the bulk of egg-laying between 25 and 30 June in 1980, and the first chicks on 18 and 17 August in 1980 and 1981 respectively. First fledging was observed on 1 September 1980, and large numbers of chicks and adults departed on 8 September 1980 and 2-5 September 1981. During visits in 1982 and 1985, incubating birds were recorded in mid-July (Rodway *et al.* 1990). No chicks were observed during those studies, which ended on 31 July in 1982 and 25 July in 1985. Past records suggest a similar breeding chronology as that determined in this study.

In 1989, peak hatching occurred between 5 and 8 August. Extrapolating, using a 33-34 day incubation period and a 22-24 day fledging period (Birkhead and Nettleship 1987, Harris and Wanless 1988, Hatch and Hatch 1989), indicates that peak egg-laying occurred in the first week of July, and peak fledging occurred by the end of August or early September.

The breeding season on Triangle Island is later than that reported for other colonies in the eastern Pacific. Egg-laying began by the end of May, and peak fledging occurred during the last half of July at Yaquina Head, Oregon between 1969 and 1971 (Scott 1973). Peterson and Sigman (1977) noted egg-laying between 7 and 18 June, and hatching between 18 and 22 July at Cape Pierce, Alaska. At the Semidi Islands, Alaska, egg-laying began between 6 and 9 June and first fledging occurred at the beginning of August over three years of studies (Hatch and Hatch 1989). The season on Triangle Island is approximately one month later than in Oregon and two weeks later than Alaska.

In the eastern Atlantic, hatching generally occurs in June or the beginning of July (Bakken 1986, Birkhead 1978, Harris and Wanless 1988). On the Atlantic coast of Canada, similar timing was reported in southern Newfoundland (Piatt and McLagan 1987). Further north, off the Labrador coast, median hatching occurred approximately one month later (Birkhead and Nettleship 1987), but still one to two weeks earlier than Triangle Island. It appears that Common Murres on Triangle Island regularly breed later than in most other parts of their range.

Why Common murres on Triangle Island breed later than in other parts of their range is unknown, but is likely related environmental conditions in the region. There is no indication that the Nestucca oil spill affected breeding chronology, since the timing of breeding in 1989 appears similar to that in past seasons. The difference in timing in different areas emphasizes the need for accurate information on local breeding biology.

Attendance patterns:

Birkhead and Nettleship (1980) report that diurnal attendance patterns are generally consistent for a particular colony, but vary between colonies. Results from this study support that conclusion. Diurnal patterns during the nestling period on Triangle Island in 1989 demonstrated a consistent bimodal trend. Peaks occurred in the morning and evening on all five survey days. Maximum numbers always occurred in the evening. The overall pattern was similar to that reported by Hatch and Hatch (1989) during the incubation period in Alaska, but there was more variation between days on the Semidi Islands, peaks occurring in the morning on some days and in the evening on others. Other studies indicate peaks in the morning (Lloyd 1975, Searing 1977) or evening (Bakken 1986), or fairly constant numbers through the middle of the day (Birkhead 1978).

There is no past information on attendance patterns on Triangle Island.

Ratio of breeding sites to total birds:

The ratio of breeding sites to total birds present (*k*) on the study plot on Triangle Island was lower than that estimated in other studies. Values for *k* determined over a short period are generally less than those determined over the entire breeding period, because birds that have lost eggs or chicks are not detected (Harris 1989). Estimates for *k* from full scale studies range from 0.61 to 0.69 (Birkhead 1978, Hatch and Hatch 1989, Harris 1989), except for a high of 0.81-0.89 reported in Harris (1989). Values derived from shorter studies, by counting incubating or brooding birds, range from 0.45 to 0.79 (reported in Harris 1989). The value of 0.41 determined on Triangle Island falls below all other studies.

CONCLUSION

There was no evidence to indicate that the Nestucca oil spill affected breeding populations in 1989. I saw no oiled or dead murres on Triangle Island, and there was no apparent decline in total numbers of murres in the summer of 1989 following the spill. Murres bred unsuccessfully at specific sites on the east side of the island, and the ratio of breeding birds to total birds at the study plot was lower on Triangle Island than at other colonies, but there was insufficient baseline data from Triangle Island to evaluate those events.

RECOMMENDATIONS FOR FUTURE STUDIES

I was not able to evaluate the results of this study because of a lack of adequate baseline information. Annual counts would determine normal population fluctuations and breeding parameters, facilitate statistical interpretation of results, and detect changes in breeding populations or parameters as a result of environmental perturbation (Birkhead and Nettleship 1980).

Numbers of birds on the study plot were least variable between 1000 and 1300 h (Table 13), and counts conducted at those times may yield most accurate results, but counts conducted at different times provide additional data. Counts in the middle of the day include successful breeders but may miss unsuccessful birds. Counts in the evening are required to identify all sites, and to estimate total populations using the area. If counts had been made only in the middle of the day in 1989, they would have missed almost all murres on the east side of the island, including Castle Rock, and would not have detected reproductive failures at those locations.

Table 13. Variability of numbers of murres counted on the study plot over 3 h intervals in 1989. Only counts from 8, 11 and 14 August, which included all sites, were used in calculations.

	Hour				
	7-9	10-12	13-15	16-18	19-21
Mean	598	554	572	641	719
S.D.	26	12	46	52	34

Consideration must be made of lighting conditions at different times of day. Lighting conditions on the west side of Puffin Rock are poor during the morning and mid-afternoon, and best in the evening. Light conditions are better in the morning on the east side of the island. High quality photographs would be obtained if the two areas were surveyed at different times.

The methodology used in 1989 for monitoring attendance patterns, hatching chronology and proportion of breeding sites to total birds, is replicable, and should provide comparable results if used on future surveys. Greater confidence could be placed on results if studies were conducted over the entire breeding season at a number of locations around Triangle Island. There are other sites suitable for monitoring attendance patterns, but few that are appropriate for studies of breeding birds. It may be possible to construct blinds, prior to the breeding season, near locations used by dense concentrations of murres on the west side of Puffin Rock, that would allow observers to be close enough to identify and monitor individual breeding sites.

SUMMARY OF POPULATION STATISTICS

	Sites at which young hatched	All sites
	Mean ± S.E.	Mean ± S.E.
Mean counts from photographs:	4646 ± 53	5839 ± 87
Ratio of telescope to photographic counts:	1.44 ± 0.02	1.44 ± 0.02
Adjusted counts from photographs:	6690 ± 120	8408 ± 171
Adjusted counts plus counts of birds not visible from the water:	8225 ± 148	9943 ± 202
Ratio of breeding sites to total birds:	0.41	0.41
Breeding population in 1989:	3372 ± 61 pairs	4077 ± 83 pairs

LITERATURE CITED

Bakken, V. 1986. A method for assessing changes in the breeding population of Guillemots *Uria aalge* on Vedoy, Rost. Fauna norv. Ser. C, Cinclus 9:25-34.

Birkhead, T.R. 1978. Attendance patterns of guillemots *Uria aalge* at breeding colonies on Skomer Island. Ibis 120:219-229.

Birkhead, T.R. and Nettleship, D.N. 1980. Census methods for murres, *Uria* species: a unified approach. Canadian Wildlife Service Occassional Paper 43. 25pp.

Birkhead, T.R. and Nettleship, D.N. 1987. Ecological relationships between Common Murres, *Uria aalge*, and Thick-billed Murres, *Uria lomvia*, at the Gannet Islands, Labrador. I. Morphometrics and timing of breeding. Canadian Journal of Zoology 65:1621-1629.

Burger, A.E. *In prep.* Effects of the Nestucca oil spill on seabirds along the southwest coast of Vancouver Island in 1989. Technical Report Series. Canadian Wildlife Service, Pacific and Yukon Region, British Columbia.

Carl, G.C., Guiguet, C.G. and Hardy, G.A. 1951. Biology of the Scott Island Group, British Columbia. Provincial Museum Report No. 10. pp. 21-63.

Ford, G., Wiens, J.A., Heinemann, D. and Hunt, G.L. 1982. Modelling the sensitivity of colonially breeding marine birds to oil spills: guillemot and kittiwake populations in the Pribilof Islands, Bering Sea. Journal of Applied Ecology 19:1-31.

Gaston, A.J. and Nettleship, D.N. 1981. The Thick-billed Murres of Prince Leopold Island. Canadian Wildlife Service Monograph No. 6.

Gaston, A.J. and Nettleship, D.N. 1982. Factors determining seasonal changes in attendance at colonies of the Thick-billed Murre *Uria aalge*. Auk 99:468-473.

Gaston, A.J., Noble, D.G. and Purdy, M.A. 1983. Monitoring breeding biology parameters for murres *Uria* spp.: levels of accuracy and sources of bias. Journal of Field Ornithology 54:275-282.

Gaston, A.J., Cairns, D.K., Elliot, R.D. and Noble, D.G. 1985. A natural history of Diggs Sound. Canadian Wildlife Service Report Series No. 46. 63pp.

Harris, M.P. 1989. Variations in the correction factor used for converting counts of individual Guillemots *Uria aalge* into breeding pairs. Ibis 131:85-93.

Harris, M.P. and Wanless, S. 1988. The breeding biology of Guillemots *Uria aalge* on the Isle of May over a six year period. Ibis 130:172-192.

Harris, M.P., Wanless. S. and Rothery, P. 1983. Assessing changes in the numbers of Guillemots *Uria aalge* at breeding colonies. Bird Study 30:57-66.

Hatch, S.A. and Hatch, M.A. 1989. Attendance patterns of murres at breeding sites: implications for monitoring. Journal of Wildlife Management 53:483-493.

Lloyd, C.S. 1975. Timing and frequency of counts of cliff-nesting auks. British Birds 68:505-513.

Mudge, G.P. 1988. An evaluation of current methodology for monitoring changes in the breeding populations of Guillemots *Uria aalge*. Bird Study 35:1-9.

Murphy, E.C., Springer, A.M. and Roseneau, D.G. 1986. Population status of Common Guillemots *Uria aalge* at a colony in western Alaska: results and simulations. Ibis 128:348-363.

Peterson, M.R. and Sigman, M.J. 1977. Field studies at Cape Pierce, Alaska - 1976. *In*: Bartonek, J., Lensink, C., Gould, P., Gill, R. and Sanger, G. *Environmental Assessment of the Alaskan continental shelf. Annual reports of the principal investigators for the year ending March, 1977. Vol. IV. Receptors - Birds.* U.S. Dept. Comm. and U.S. Dept. Int. 757pp.

Piatt, J.F. and McLagan, R.L. 1987. Common Murre (*Uria aalge*) attendance patterns at Cape St. Mary's, Newfoundland. Canadian Journal of Zoology 65:1530-1534.

Rodway, M.S. *In press.* Status and conservation of breeding seabirds in British Columbia. *In*: Croxall, J.P. (ed.) *A supplement to: Status and conservation of the world's seabirds.* ICBP Technical Publication.

Rodway, M.S., Lemon, M.J.F., Savard, J-P.L. and McKelvey R. 1989. Nestuuca oil spill: impact assessment on avian populations and habitat. Technical Report Series No. 68. Canadian Wildlife Service, Pacific and Yukon Region, British Columbia.

Rodway, M.S., Lemon, M.J.F. and Summers, K.S. 1990. British Columbia seabird colony inventory: Report #4 - Scott Islands. Census results from 1982 to 1989 with reference to the Nestucca oil spill. Technical Report Series No. 86. Canadian Wildlife Service, Pacific and Yukon Region, British Columbia.

Scott, J.M. 1973. Resource allocation in four syntopic species of marine diving birds. Ph.D. thesis. Oregon State University.

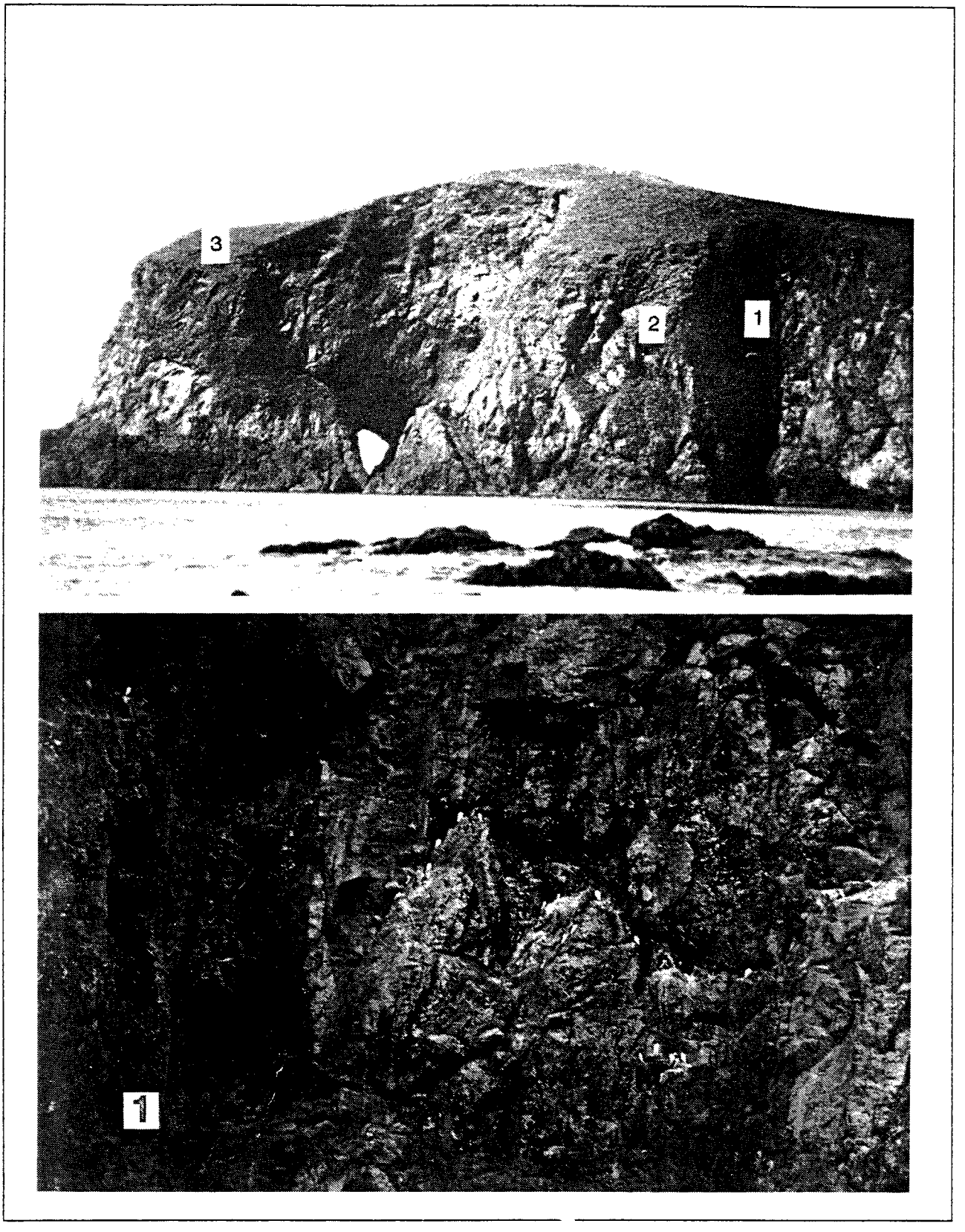
Searing, G.F. 1977. Some aspects of the ecology of cliff-nesting seabirds at Kingkok Bay, St. Lawrence Island, during 1976. Environmental Assessment of the Alaskan Continental Shelf - Annual Reports 5:263-354.

Vallée, A.J. and Carter, H.R. 1987. Breeding phenology of Common Murres on Triangle Island, British Columbia, in 1980 and 1981. Pacific Seabird Group Bulletin 14(1):71.

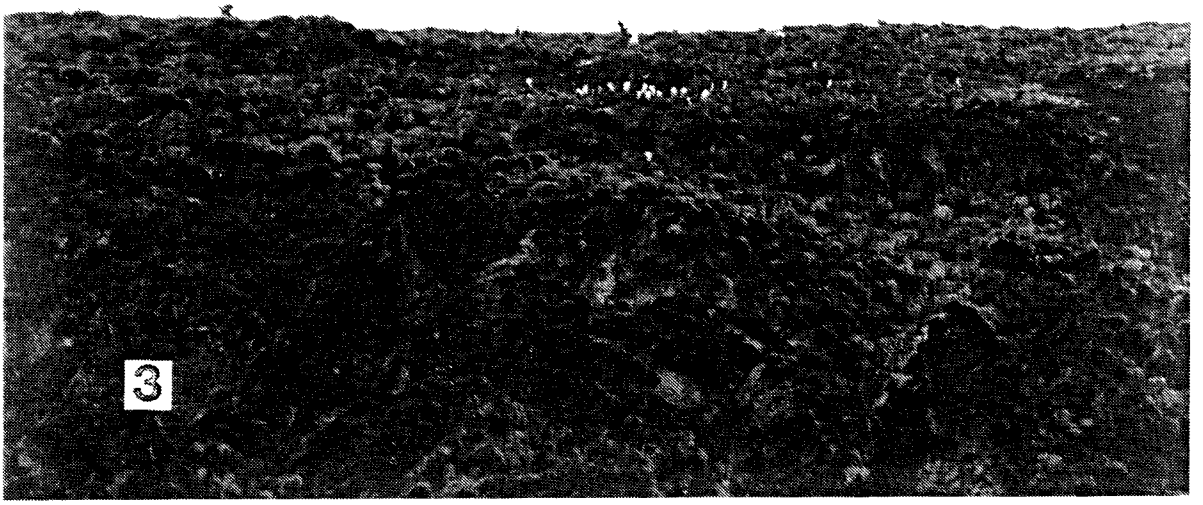
Vermeer, K., Summers, K.R. and Bingham, D.S. 1976b. Birds observed at Triangle Island, British Columbia, 1974 and 1975. Murrelet 57:35-42.

APPENDIX I. Delineation of sub-sections on the study plot used to monitor attendance patterns and breeding chronology on Triangle Island in 1989.

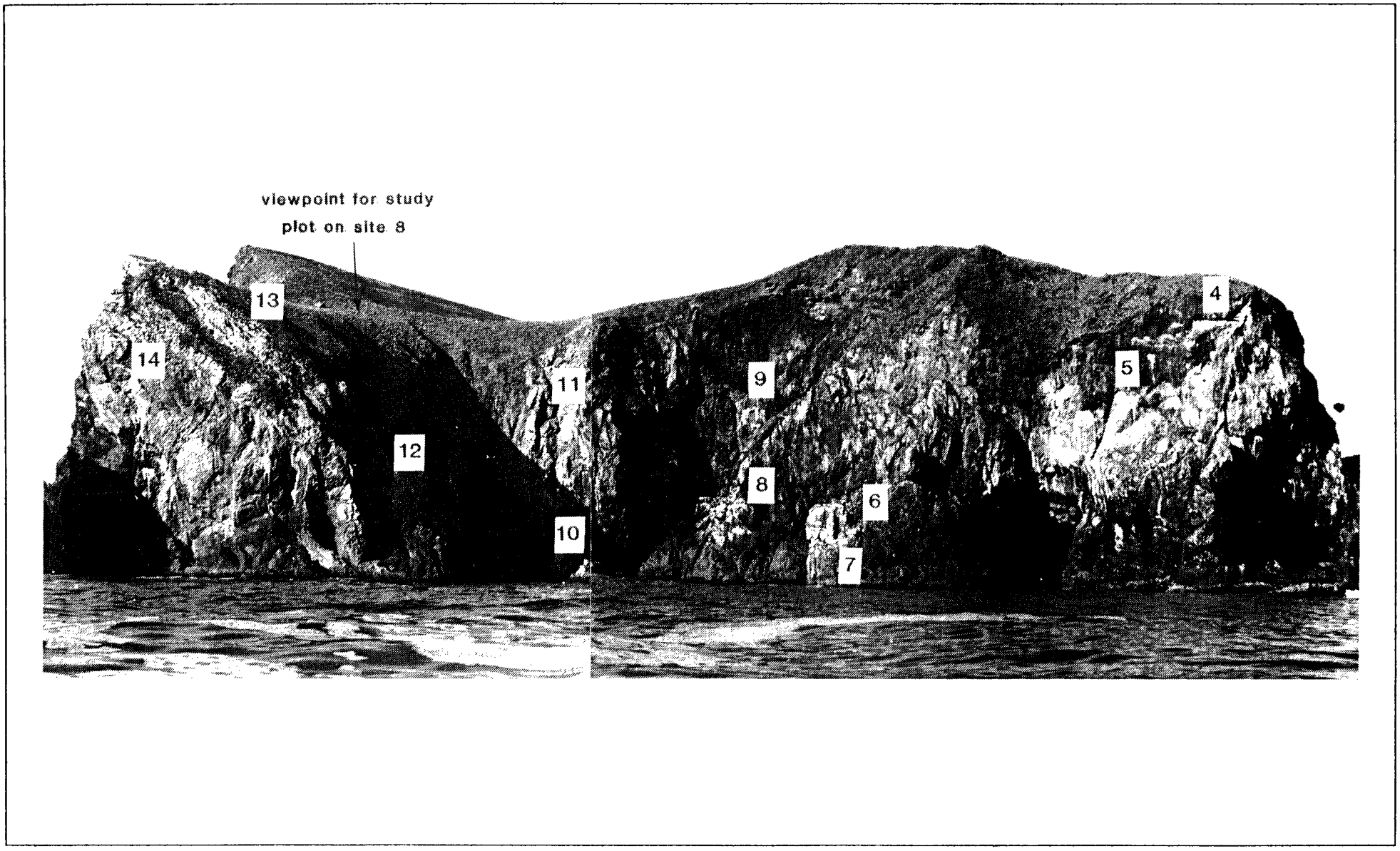
APPENDIX II. Photographs of sites frequented by Common Murres on Triangle Island in 1989. Numbers on photographs correspond to sites listed on Tables 1 and 2.



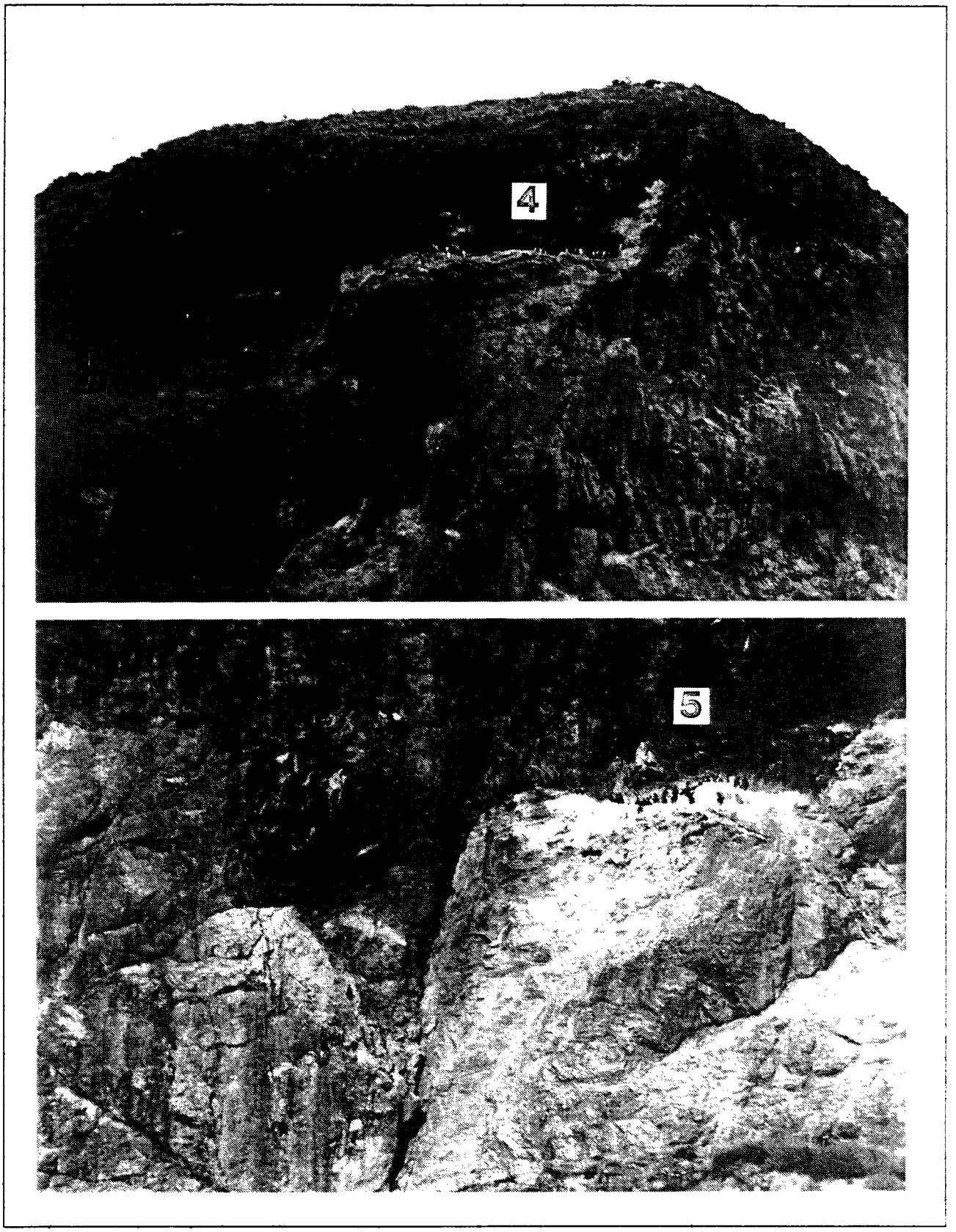
APPENDIX II. (cont'd)



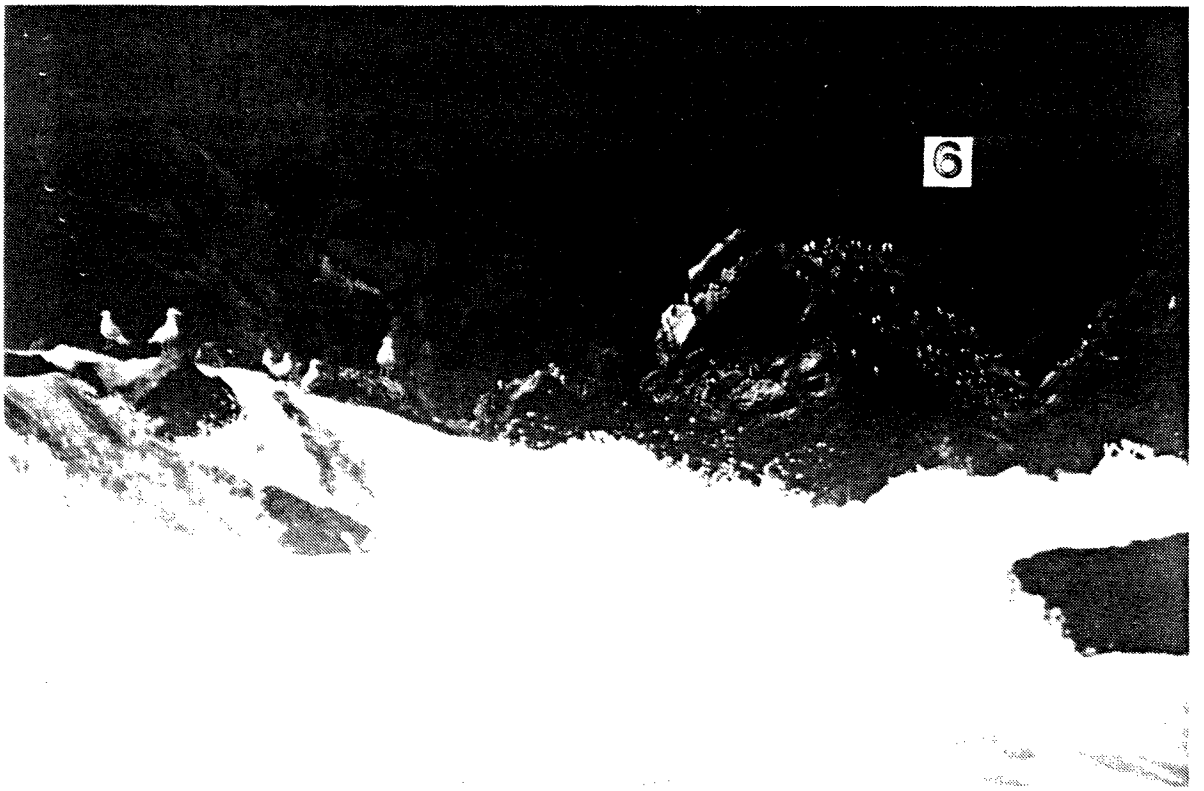
APPENDIX II. (cont'd)



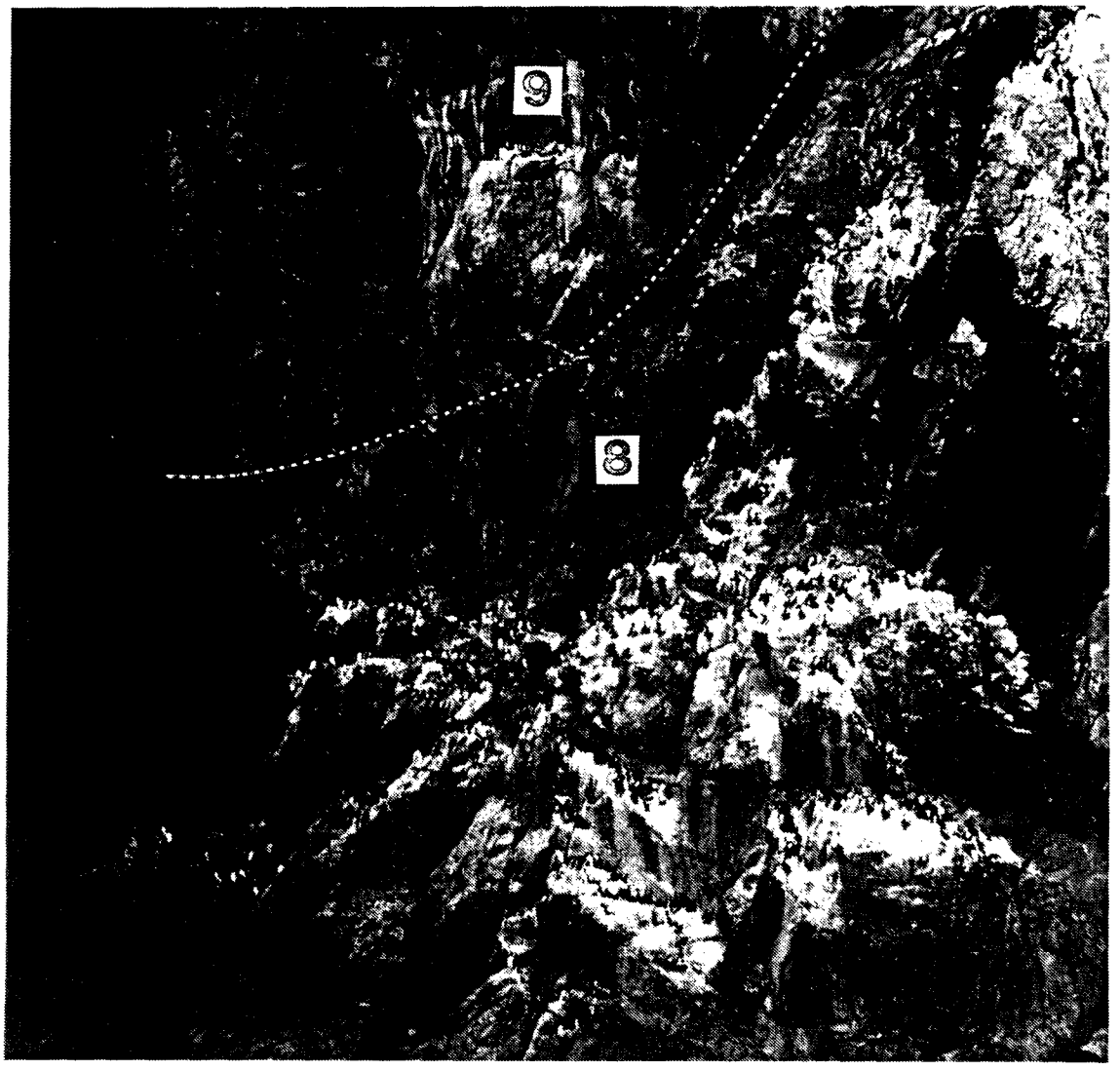
APPENDIX II. (cont'd)

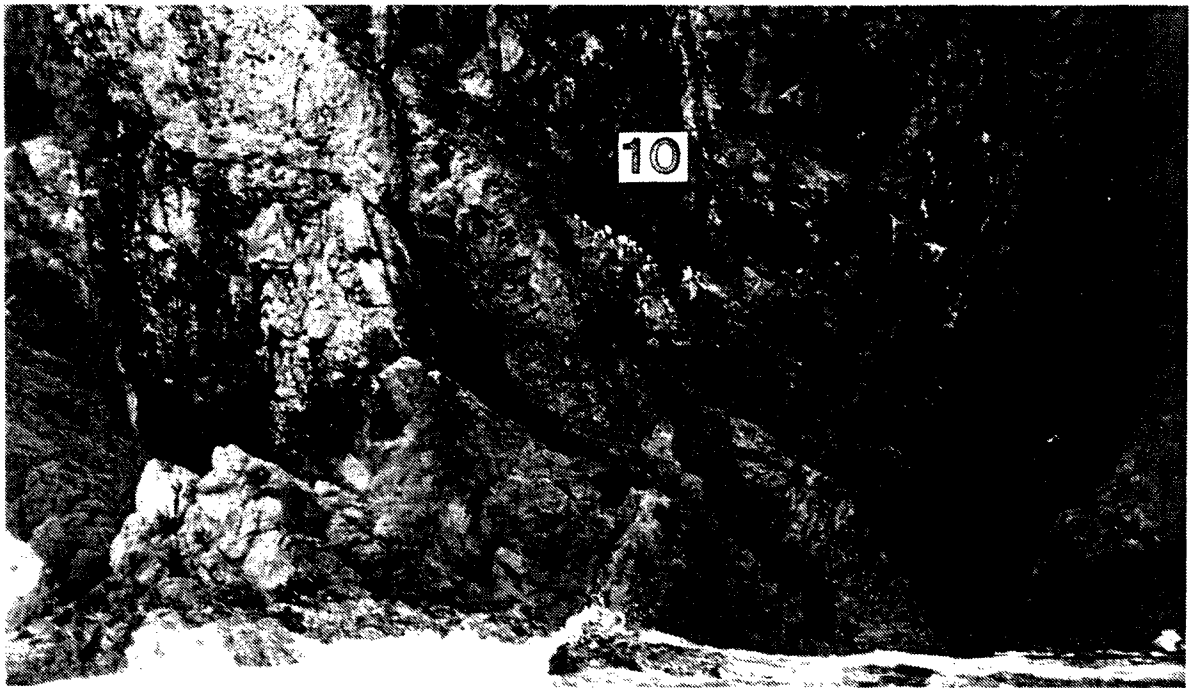


APPENDIX II. (cont'd)

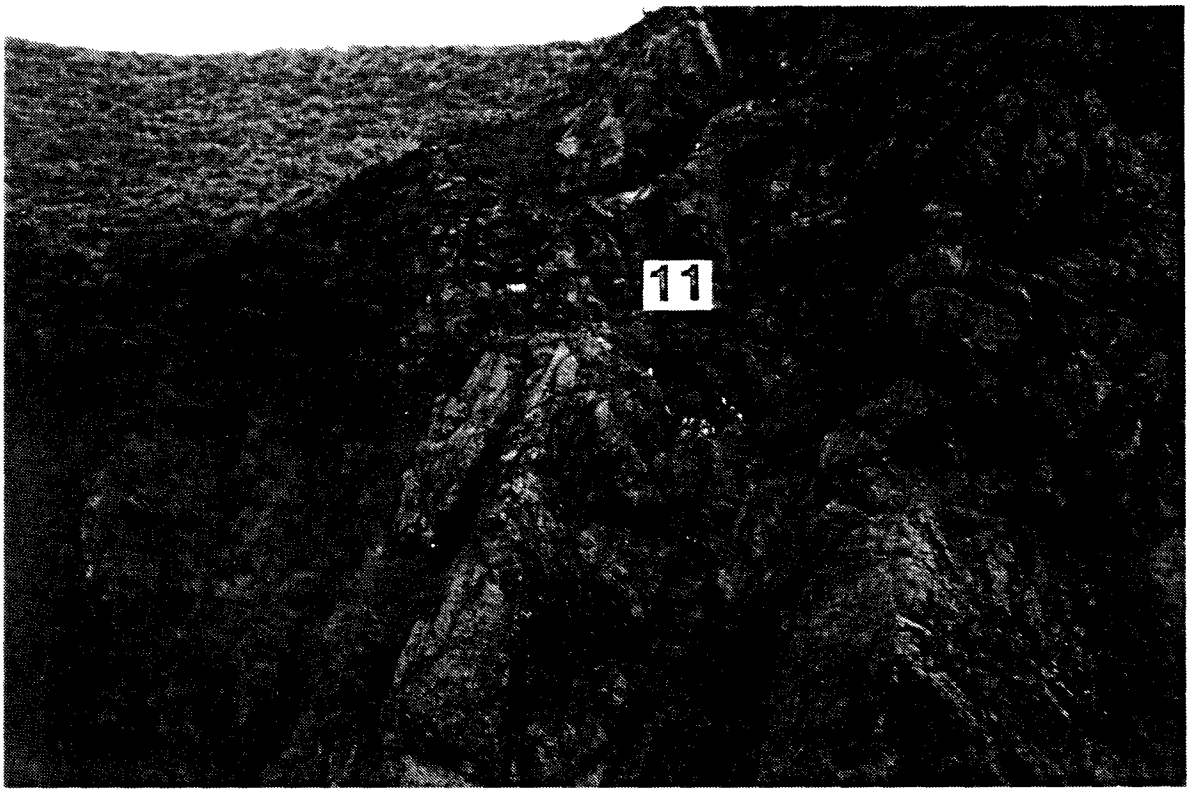


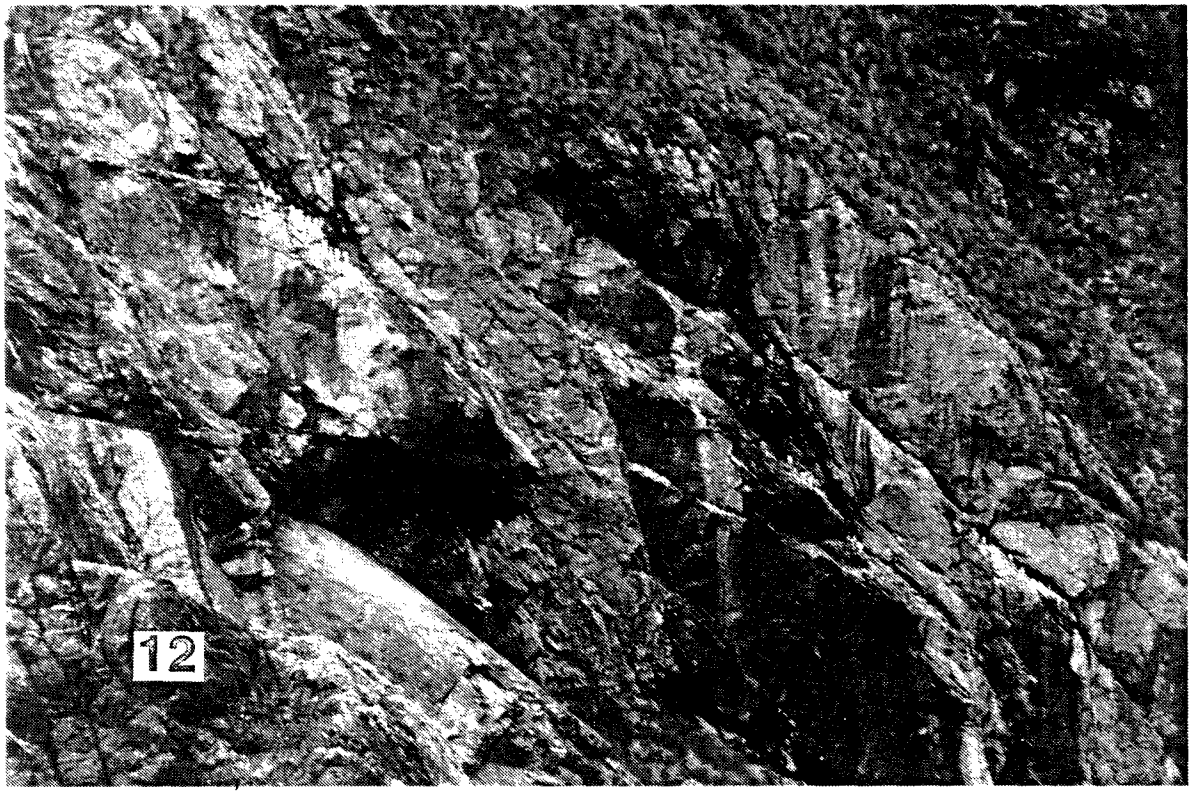
APPENDIX II. (cont'd)



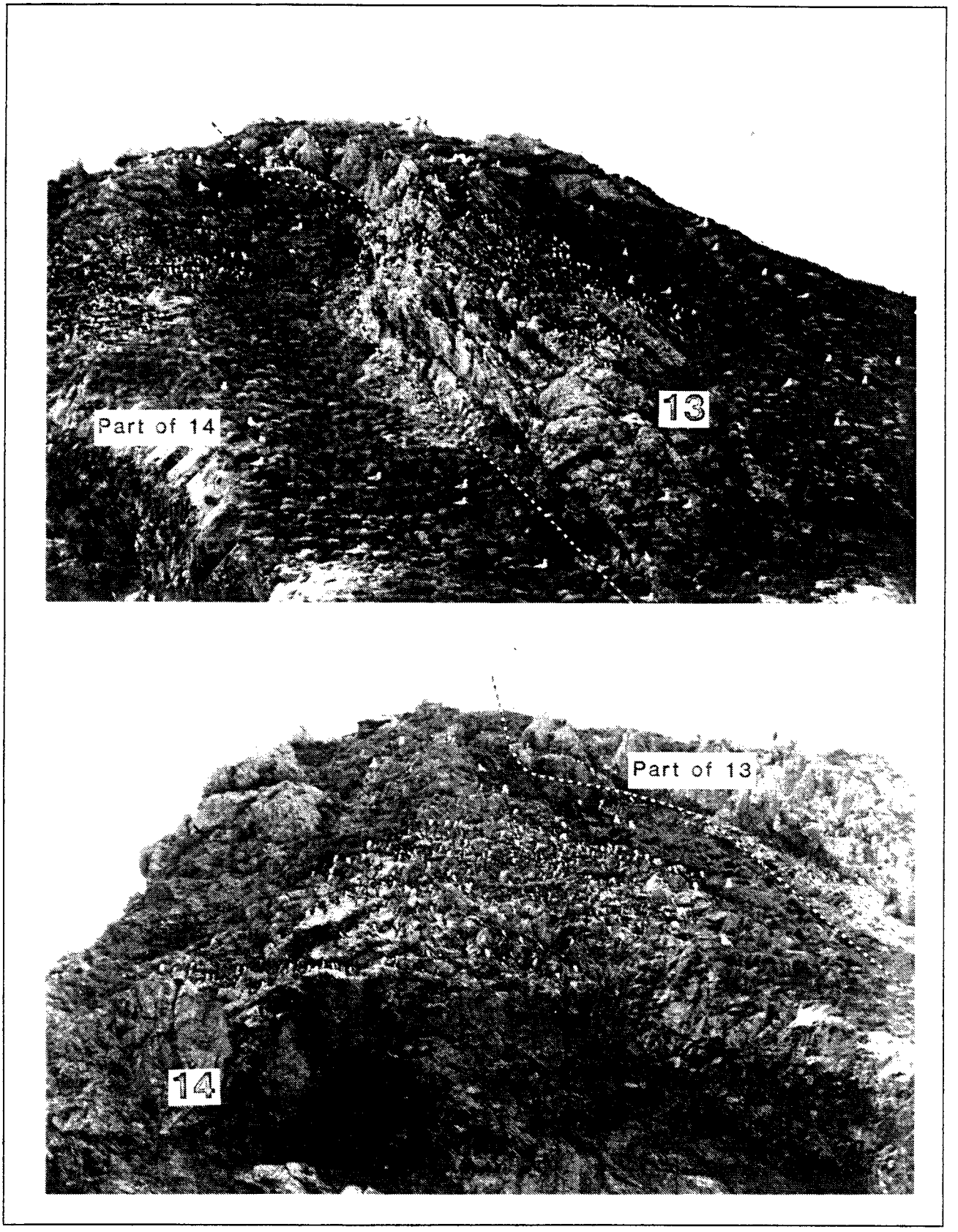


APPENDIX II. (cont'd)

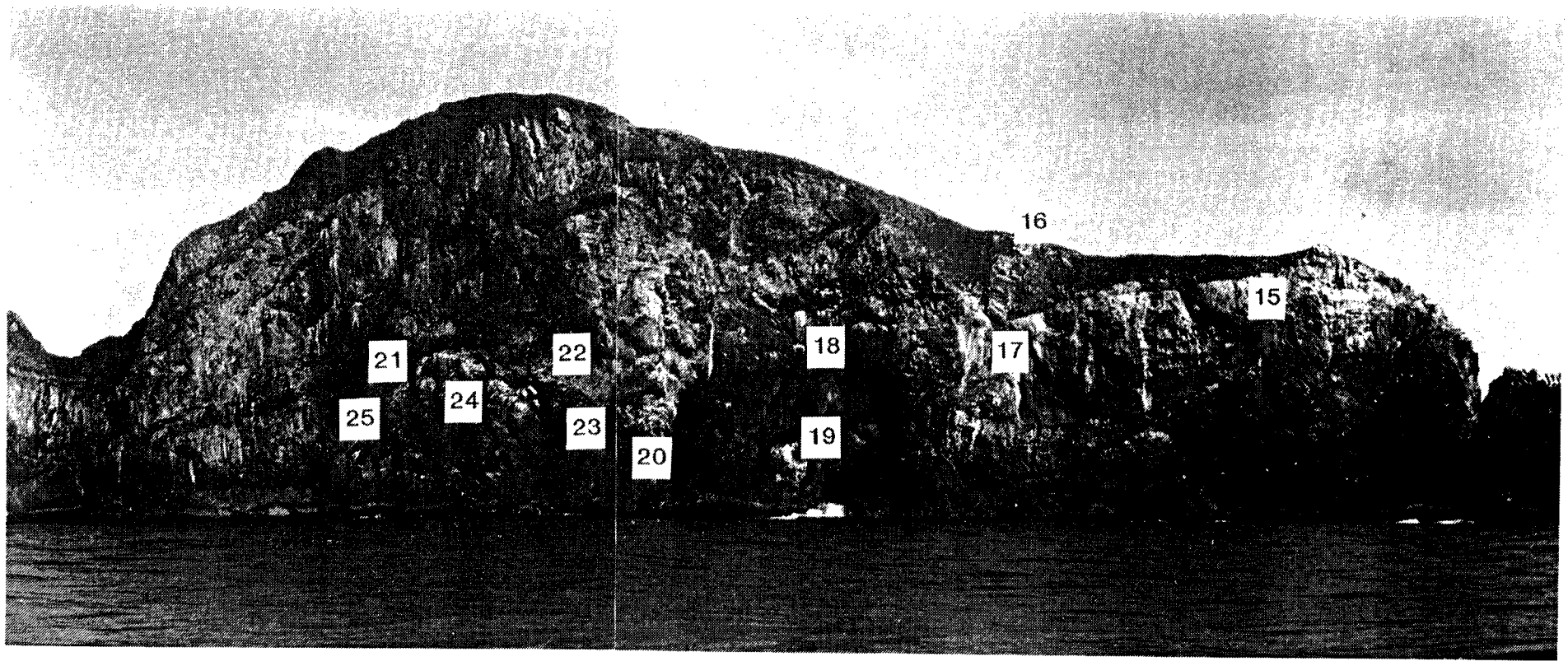




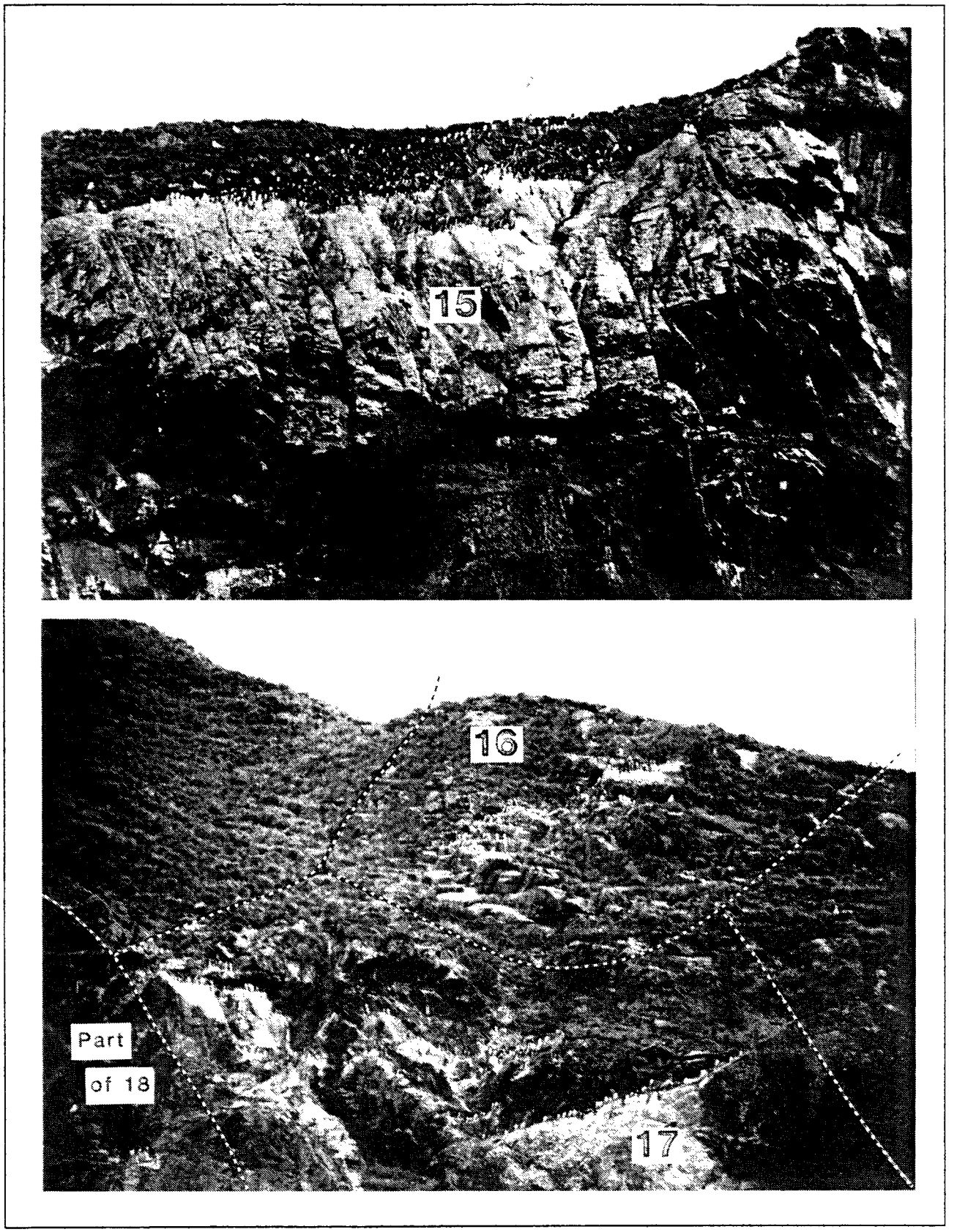
APPENDIX II. (cont'd)



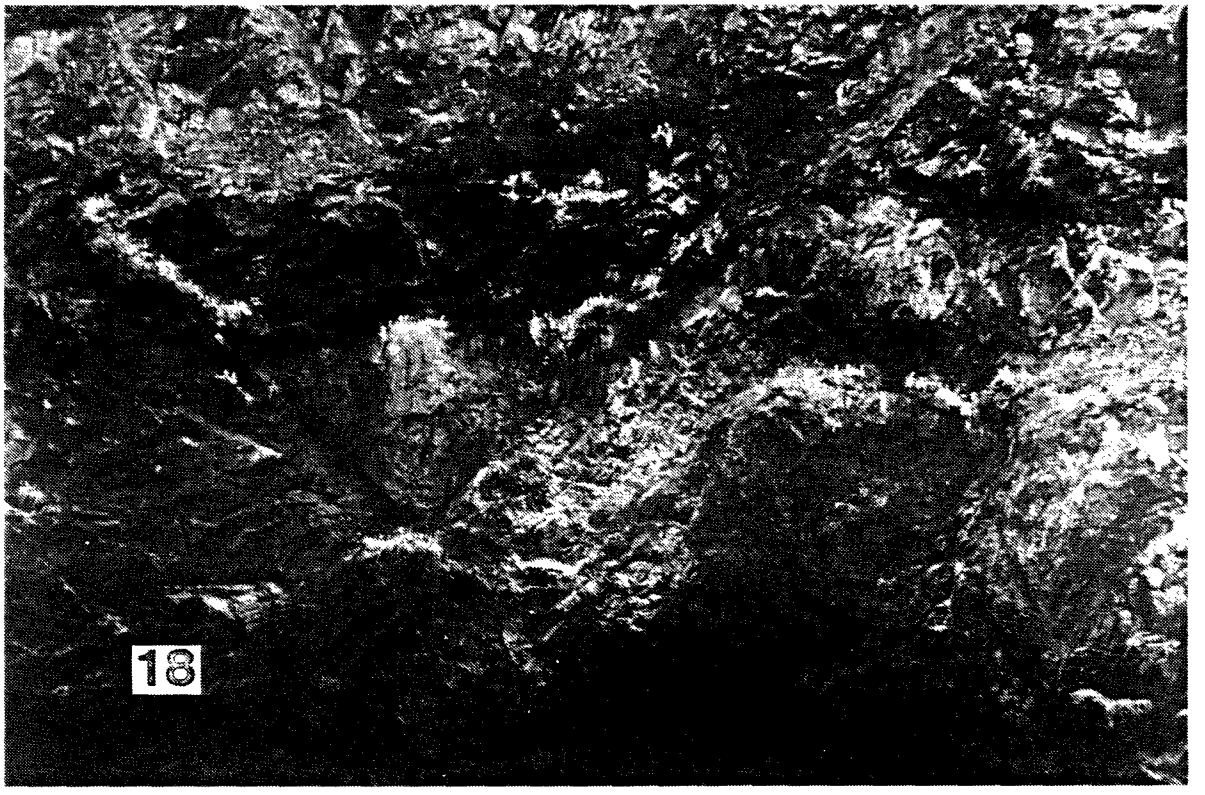
APPENDIX II. (cont'd)



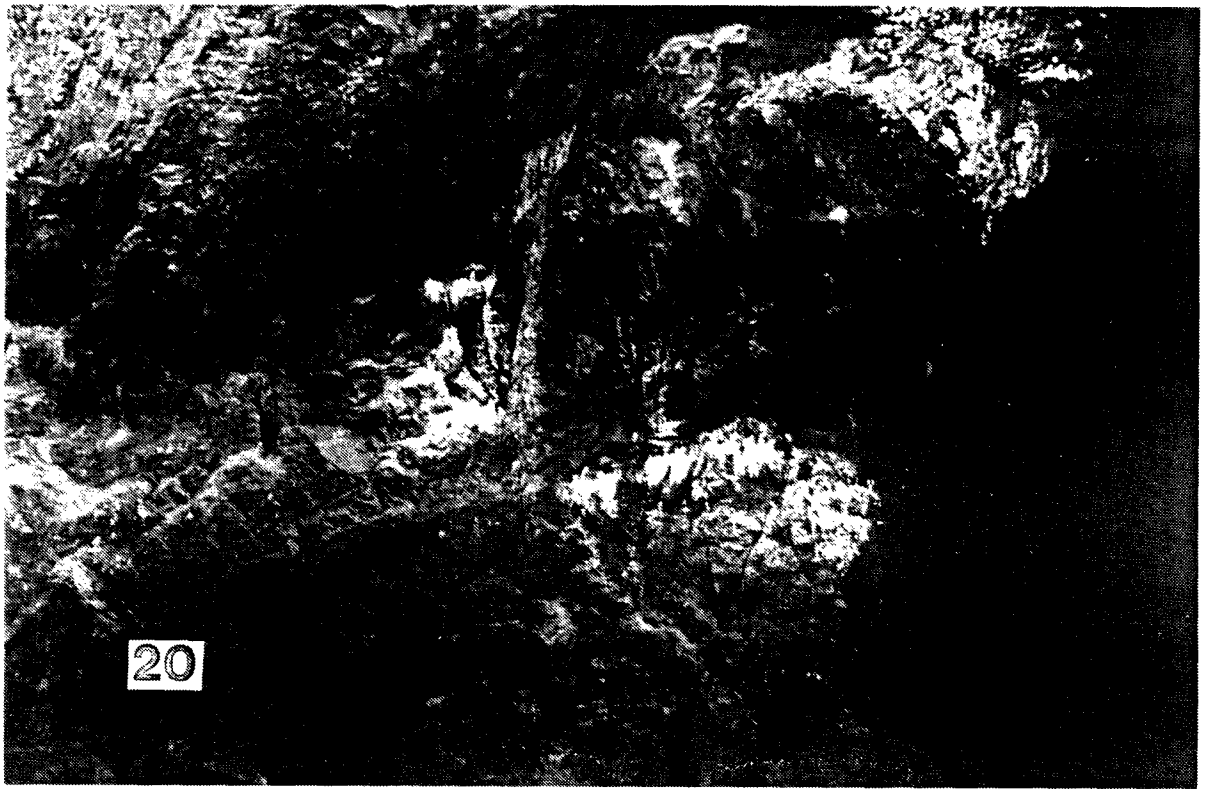
APPENDIX II. (cont'd)



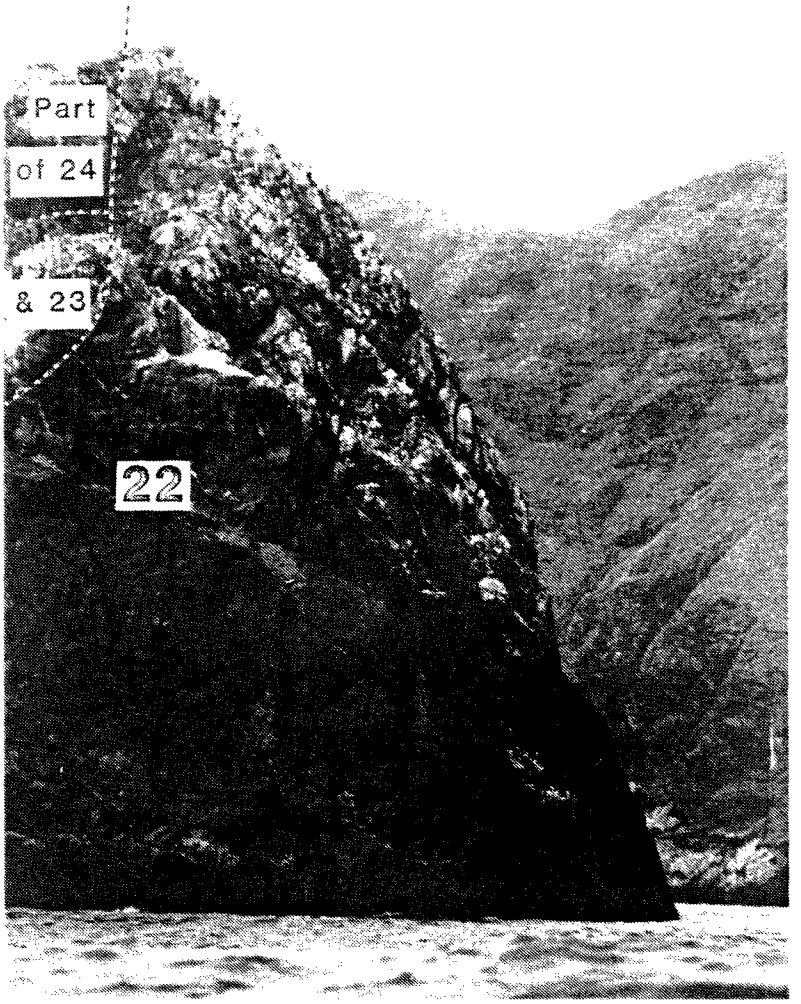
APPENDIX II. (cont'd)

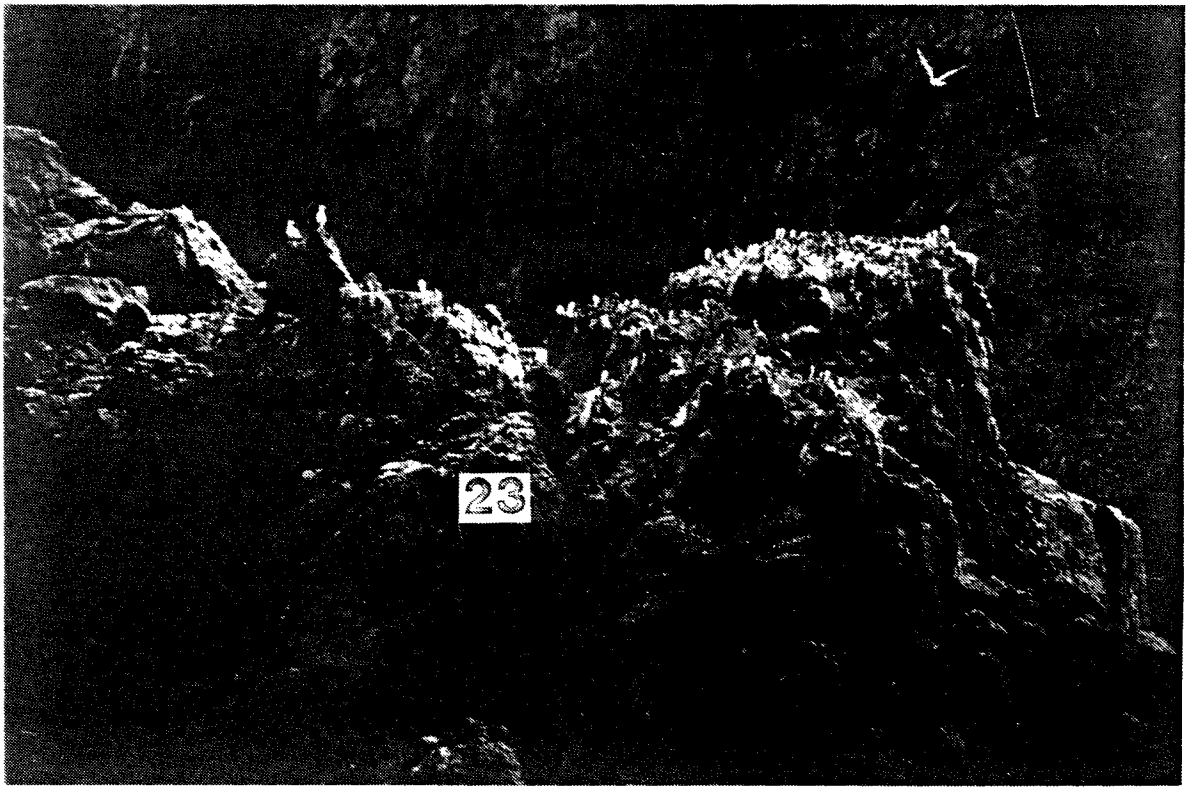


APPENDIX II. (cont'd)

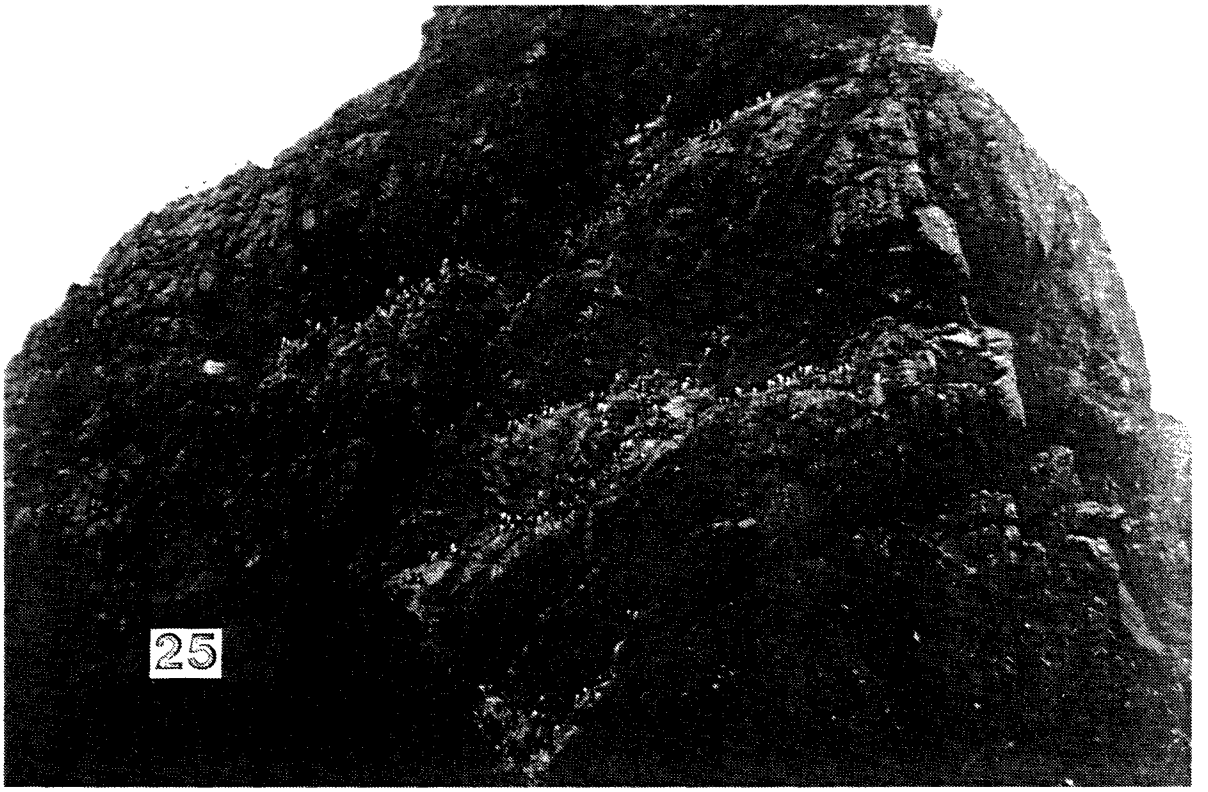


APPENDIX II. (cont'd)

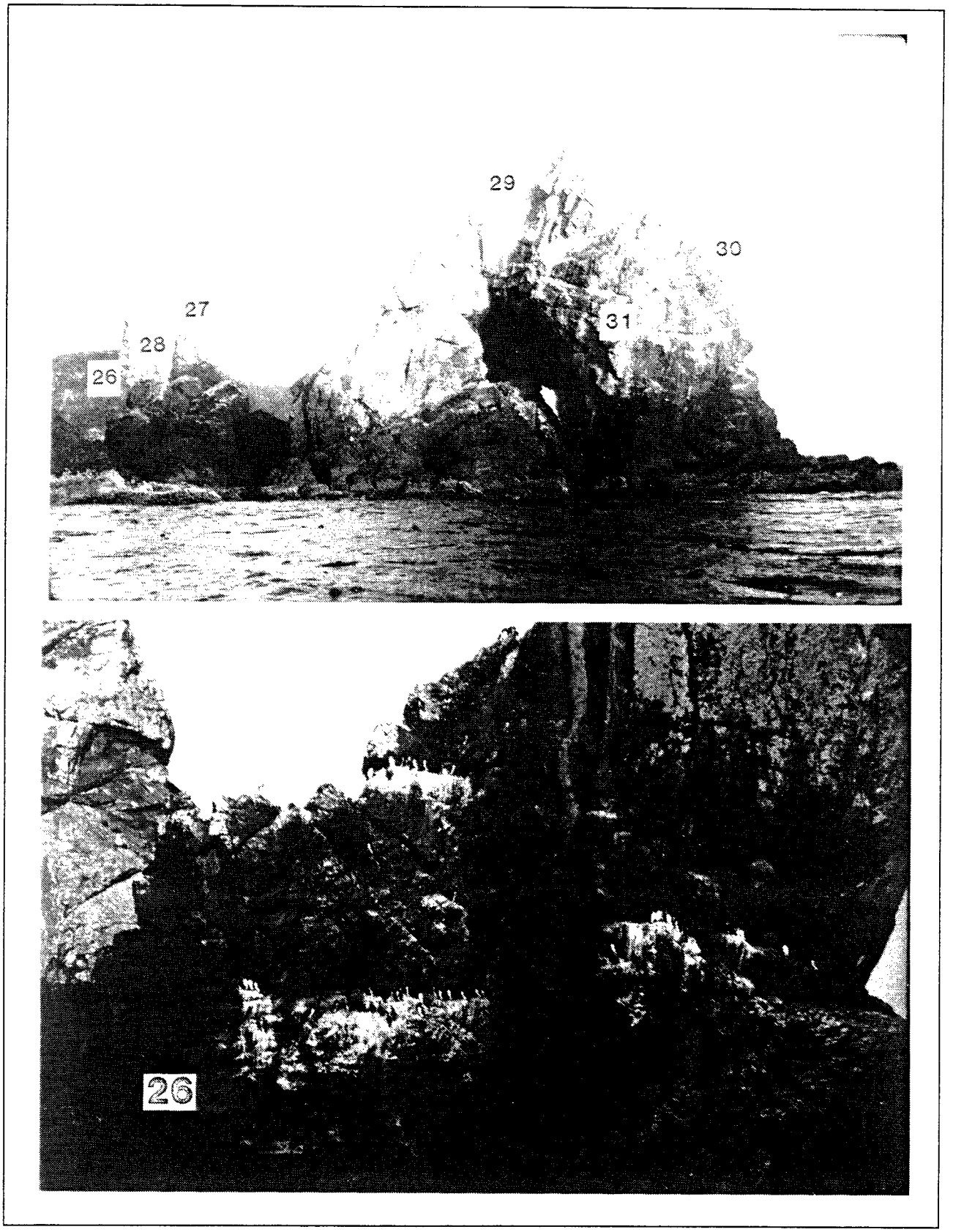




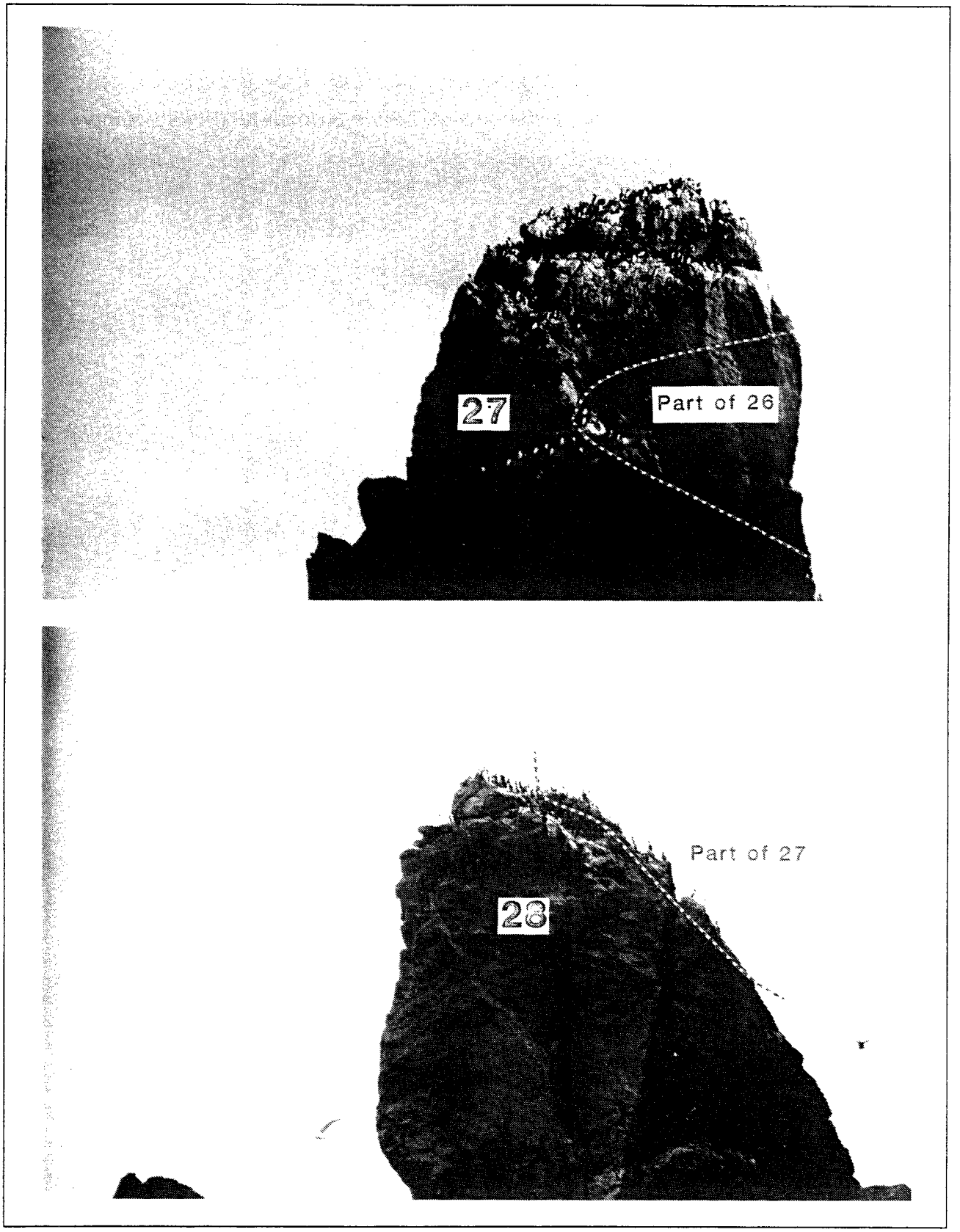
APPENDIX II. (cont'd)



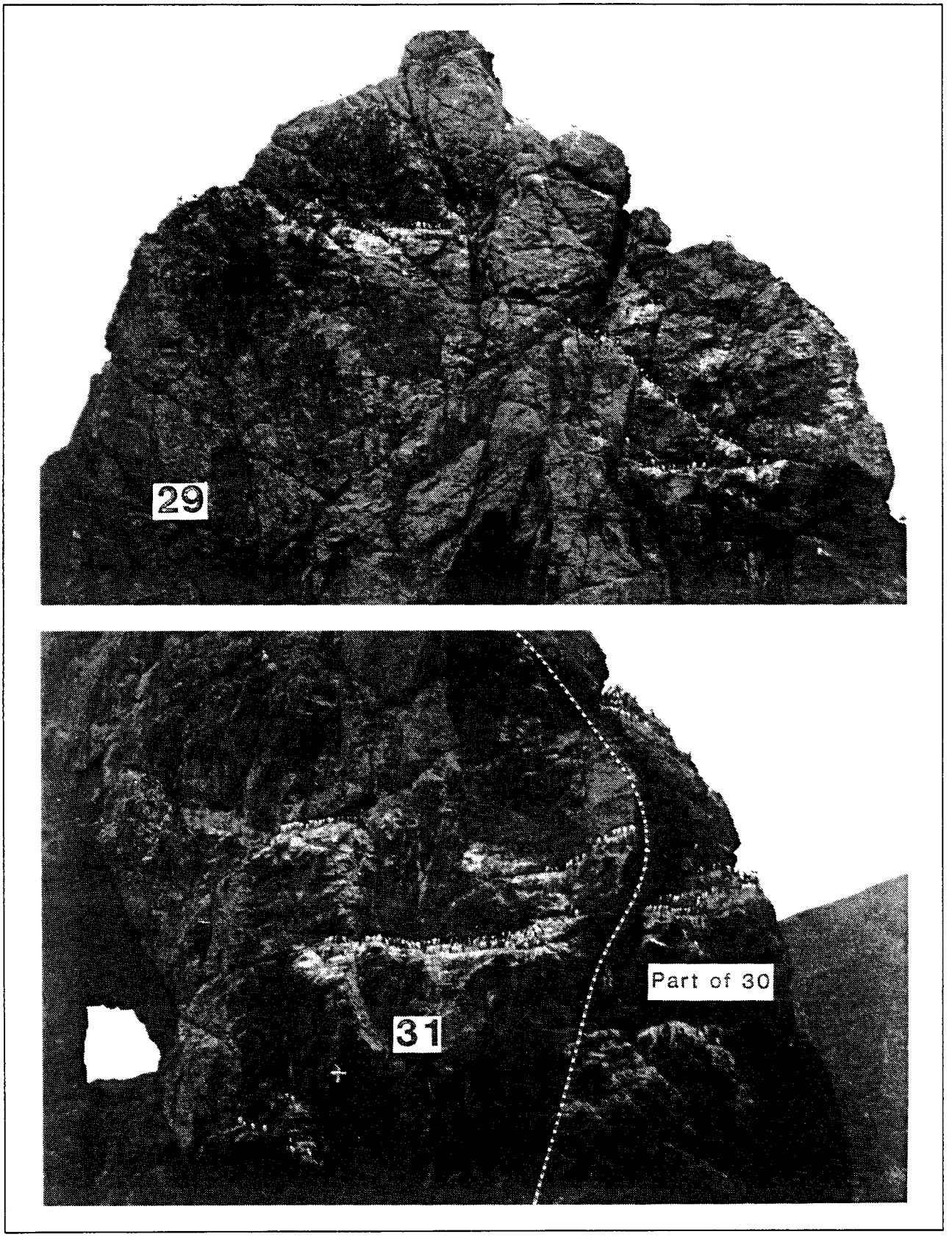
APPENDIX II. (cont'd)



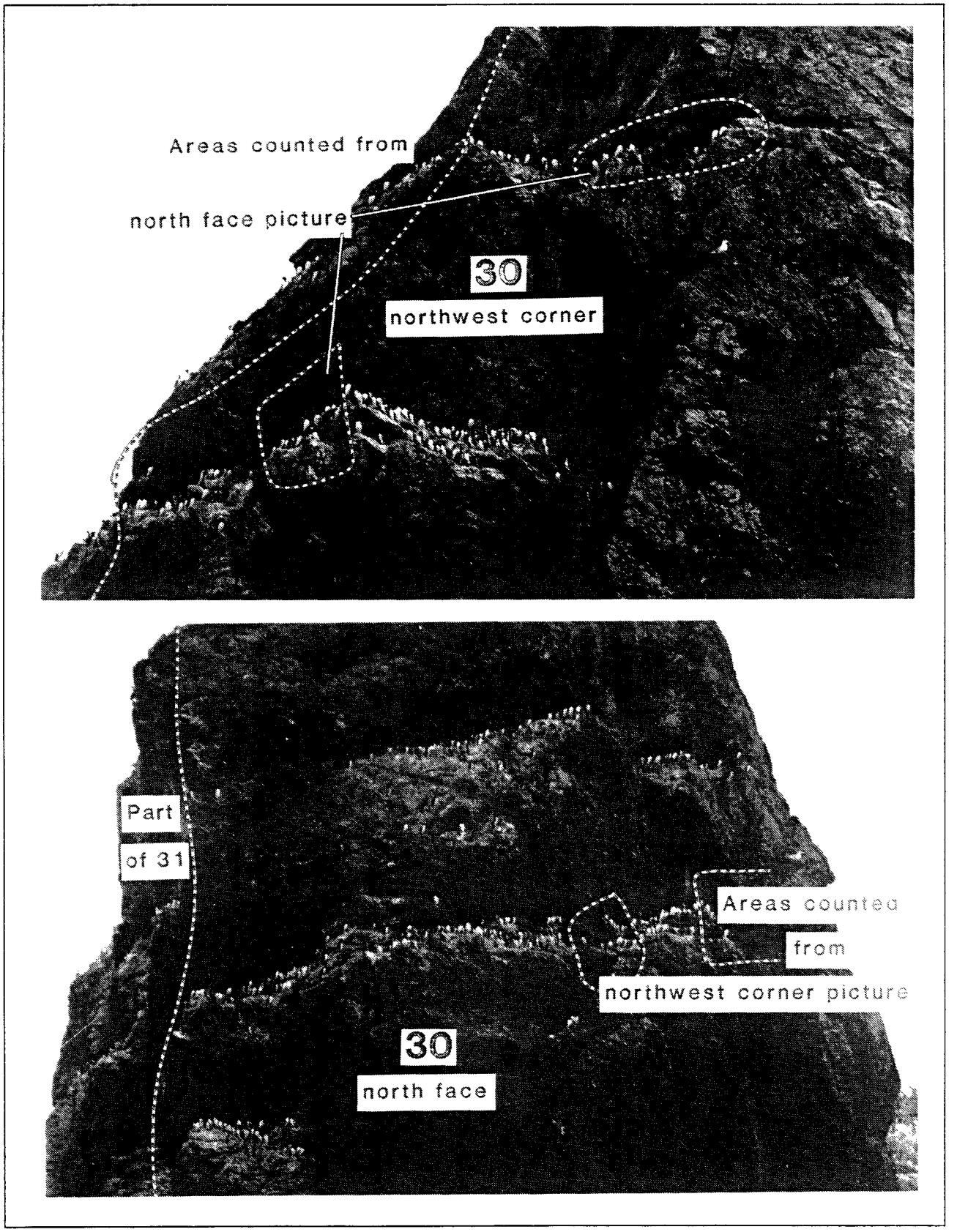
APPENDIX II. (cont'd)



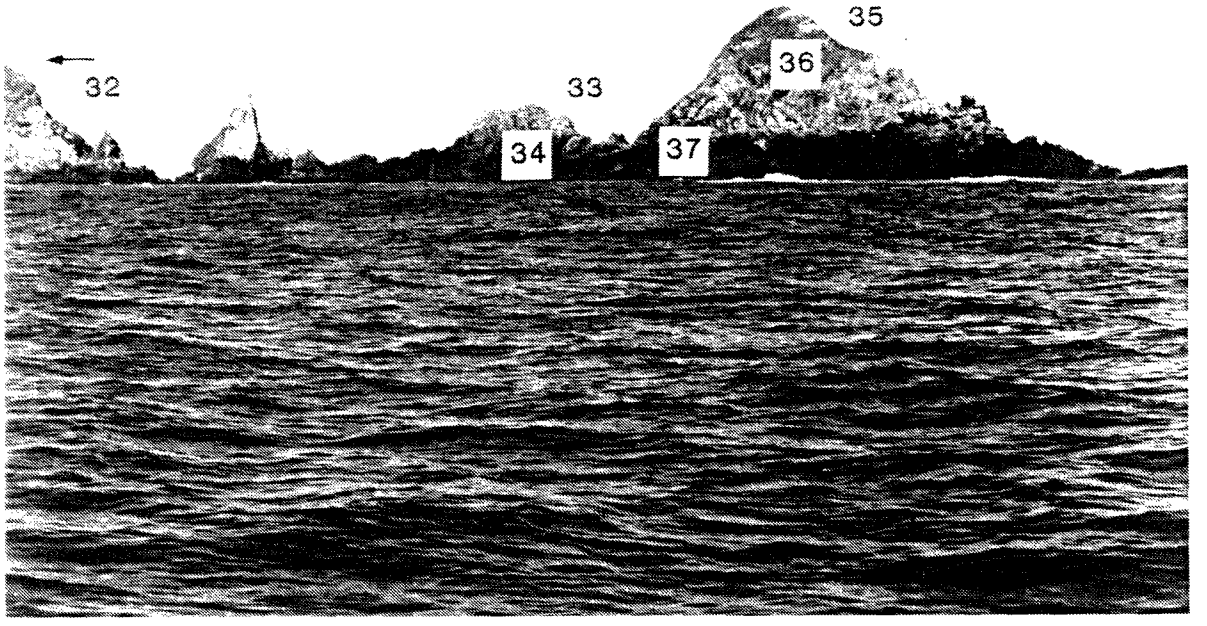
APPENDIX II. (cont'd)

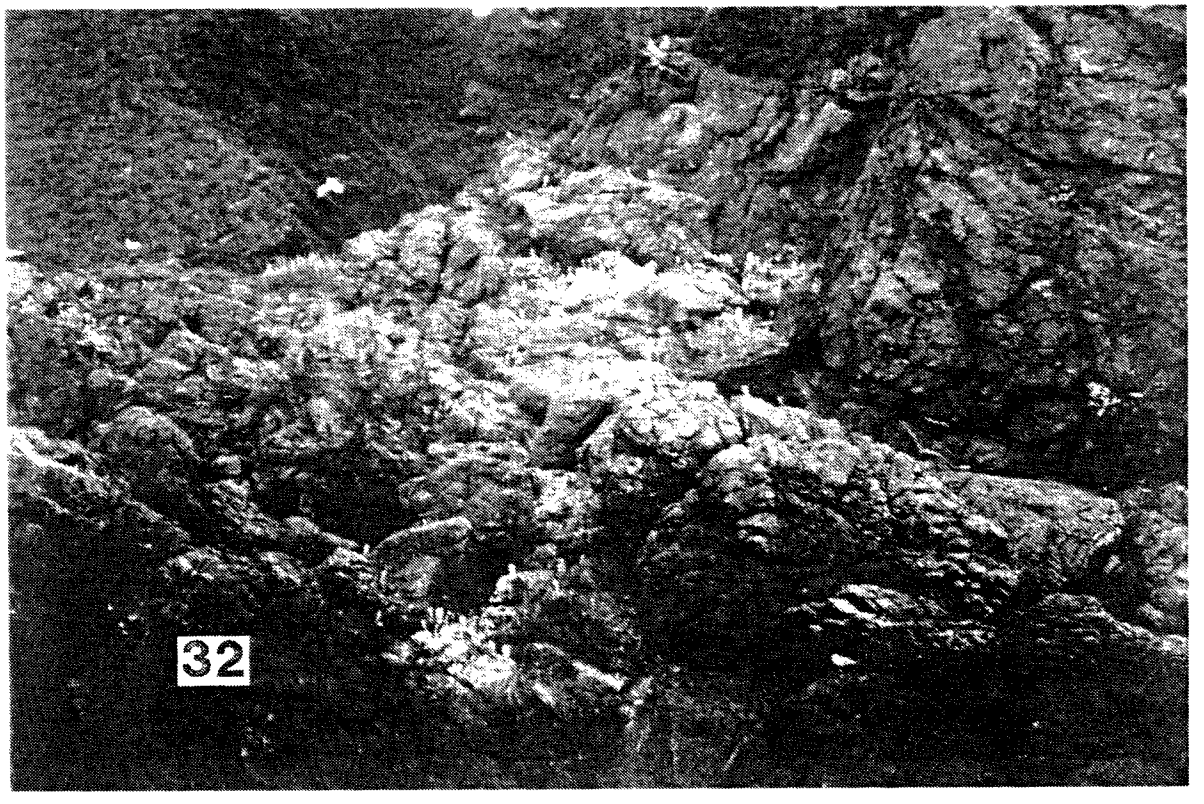


APPENDIX II. (cont'd)

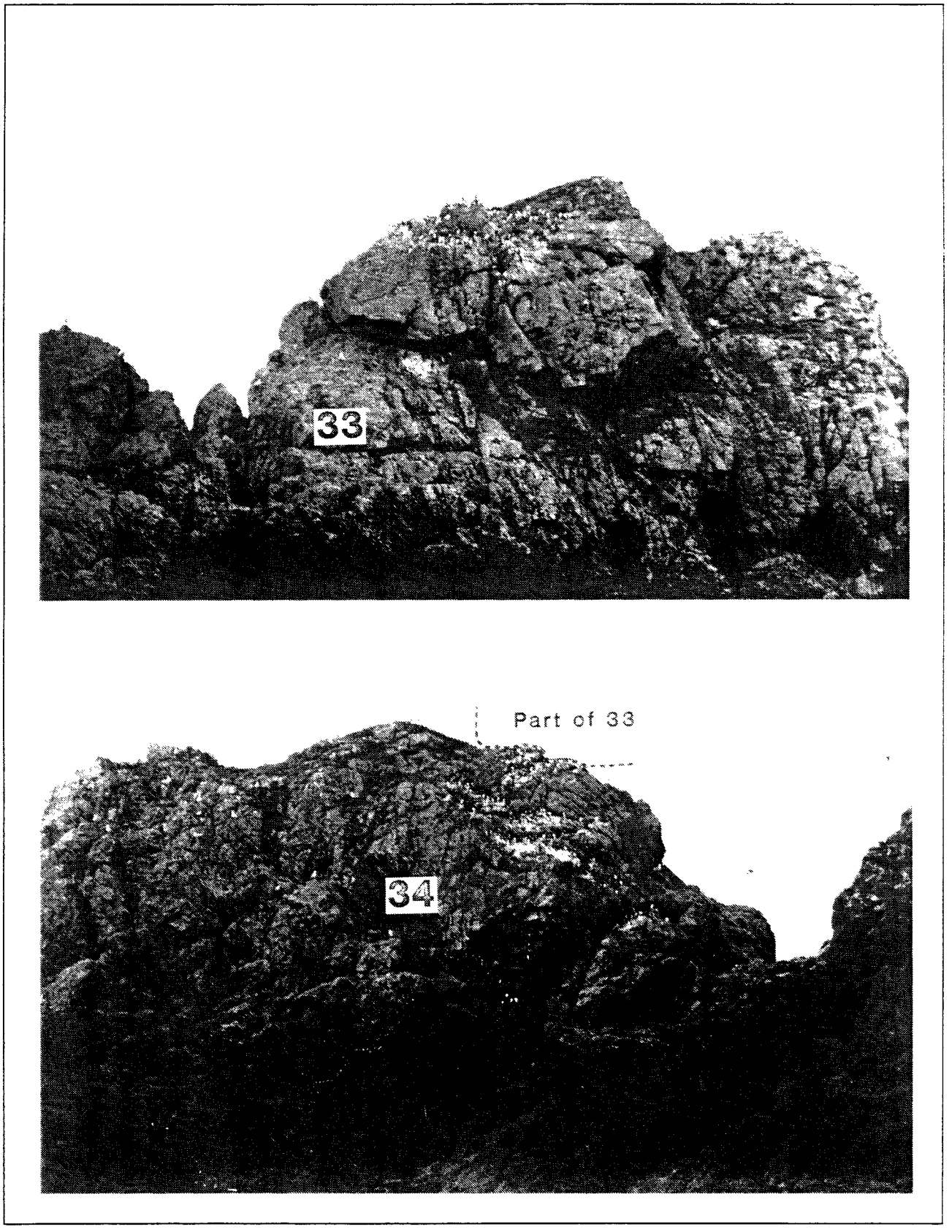


APPENDIX II. (cont'd)

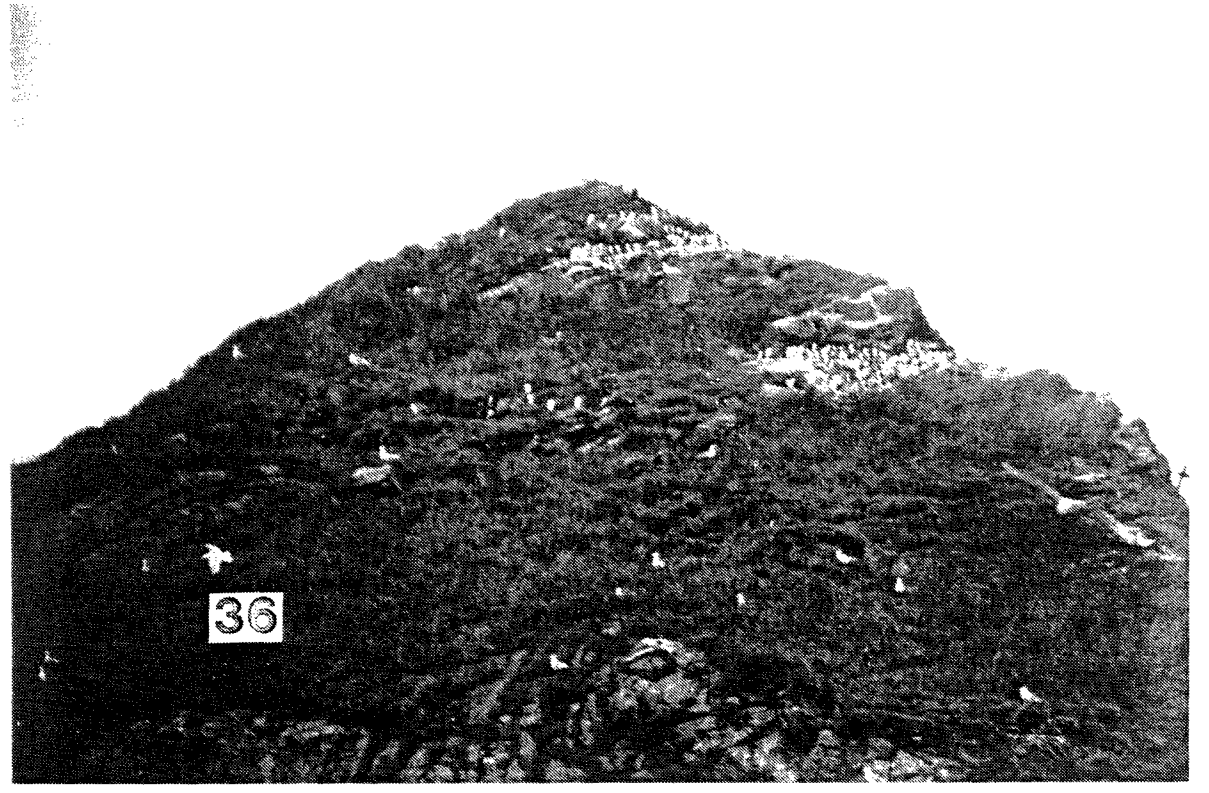




APPENDIX II. (cont'd)



APPENDIX II. (cont'd)



APPENDIX II. (cont'd)