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LASKEEK BAY CONSERVATION SOCIETY

REPORT ON SCIENTIFIC ACTIVITIES IN 1991

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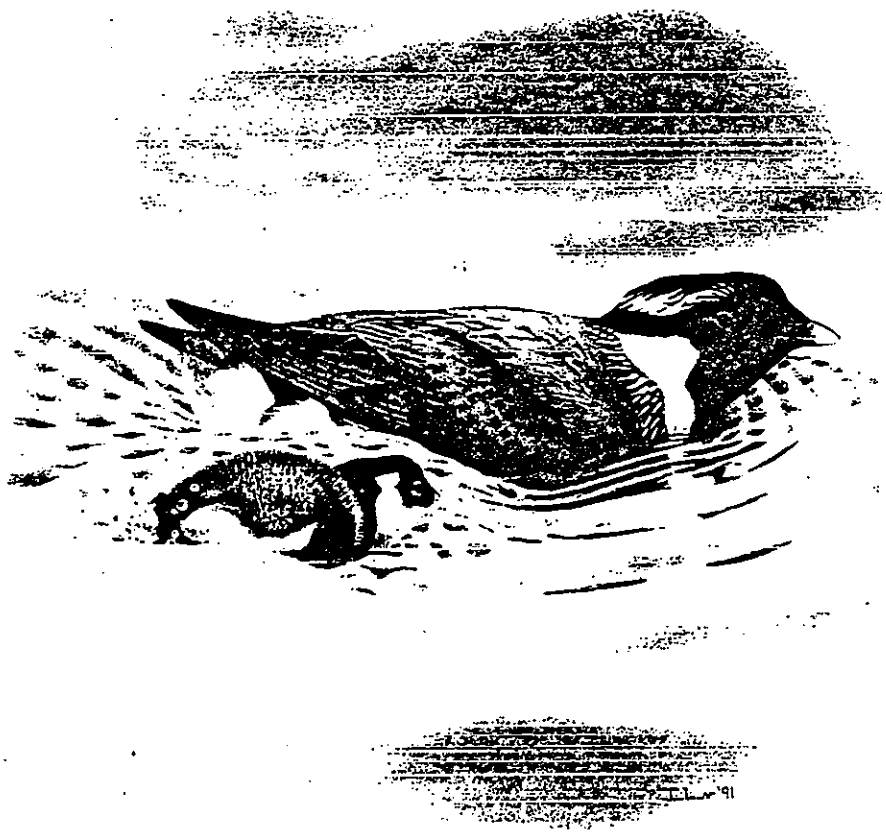
A. J. GASTON, A. LAWRENCE and C. FRENCH



APRIL 1992

LASKEEK BAY CONSERVATION SOCIETY

The **Laskeek Bay Conservation Society** is a volunteer group based in the Queen Charlotte islands. The society is committed to:

Increasing the appreciation and understanding of the natural environment through

sensitive biological research that is not harmful to wildlife or its natural habitat

interpretative and educational opportunities for residents of and visitors to the Queen Charlotte islands

Established in 1990, the Society is committed to a long-term seabird research programme in an Ancient Murrelet colony at Limestone Island. For further information , contact:

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BRIEF STATEMENT OF ACHIEVEMENTS

(1) The Ancient Murrelet banding project on East Limestone Island was continued between 26 March and 14 June, with 562 chicks and 340 adults captured, including 50 adults retrapped from earlier years.

(2) A subsidiary operation on George and East Copper islands in Skincuttle Inlet during 19-31 May resulted in the banding of 766 adult Ancient Murrelets, and the checking of permanent monitoring plots for Ancient Murrelets and Cassin's Auklets. Numbers of Ancient Murrelet burrows in study plots on George Island had increased by 27% since 1985.

(3) Repeats of boat surveys in the Laskeek Bay - Skedans Bay area suggested that the Marbled Murrelet population of the area is fairly stable from year to year.

(4) Incubation and breeding success of Ancient Murrelets were monitored at 27 burrows on East Limestone Island, from which 42 chicks departed; an average of 1.56 chicks/pair.

(5) Detailed observations of raccoon predation on East Limestone Island suggested that the two resident raccoons killed at least 11% of breeding Ancient Murrelets, and were a major cause of chick production being 36% lower in 1991 than in 1990.

(6) Censuses of songbirds were carried out by Jean-Louis Martin, with assistance from the Society on 25 islands in Skincuttle Inlet and Laskeek Bay. A preliminary report of these results, along with similar results obtained in 1989, is presented.

ACKNOWLEDGEMENTS

The research reported here could not have been carried out without the enthusiastic support of volunteers who took part in the work at Limestone Island and in Skincuttle Inlet; Laura Arnow, Frances Backhouse, Erik Berglund, Sylvie Blangy, Vincent Blewu, Katie Borserio, Chris Bowman, Janet Brown, Virginia Collins, Surya Forest, Joelle Fournier, Charlotte Husband, Jean-Louis Martin, Pamela Morninglight, Mary Morris, Diann Richardson, and Penny Richardson.

The Laskeek Bay Conservation Society gratefully acknowledges the contributions of the following groups and individuals:

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- Queen Charlotte Islands Museum and Natalie MacFarlane for storing our equipment
- Keith Hunter of MacMillan Bloedel for cedar stakes
- Steve Smith and Moira Lemon for directing the Skincuttle Inlet programme
- All those who donated money and bought t-shirts

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BACKGROUND

The Laskeek Bay Conservation Society was founded in 1990 by a group of conservationists and biologists mainly living in the Queen Charlotte Islands. The society organizes a volunteer programme to carry out educational activities based on biological monitoring and research in the Moresby Island area. The programme uses simple techniques, which cause a minimum of disturbance to the environment, while allowing as many people as possible to gain an appreciation for what is involved in ecological research. In addition, opportunities are provided for the interpretation of the local ecology to groups of interested visitors.

The scientific work continues and extends a programme that was initiated by the Canadian Wildlife Service in 1984, aimed at providing information on the biology and ecology of marine birds. The main species of interest is the Ancient Murrelet, a small diving bird which is more common in the Queen Charlotte Islands than anywhere else in the world. It has decreased substantially over most of its range across the North Pacific, mainly because of predators introduced either deliberately (foxes, raccoons), or accidentally (rats), by people. Ancient Murrelets have become much scarcer, or disappeared altogether, on several of the Queen Charlotte Islands, in one case because of predation by rats. Raccoons have probably been responsible for the disappearance of Ancient Murrelets and other burrow nesting seabirds from other islands. Knowledge about what is happening to Ancient Murrelet populations is important for the conservation of the species, both in Canada, and worldwide.

As well as studying Ancient Murrelets, the former Canadian Wildlife Service programme collected information about the feeding of marine birds and mammals in Laskeek Bay, and adjacent parts of Hecate Strait. In April and May these waters support large numbers of migrant marine birds, including Black-legged Kittiwakes, Sooty Shearwaters, Pacific Loons, and Common Murres. Numbers of kittiwakes and shearwaters fluctuate considerably from year to year, apparently in response to changes in local feeding conditions. Immature kittiwakes remain in Hecate Strait in large numbers in years when conditions for breeding in the Gulf of Alaska are poor. Hence, the events occurring in Laskeek Bay help us to understand patterns of environmental change occurring over much larger areas. By maintaining consistent annual observations of the numbers and age of kittiwakes and other birds feeding in the Laskeek Bay area we hope to improve our understanding of how local events are influenced by wider changes in the ecosystems of the Pacific.

The Marbled Murrelet, a bird which nests mainly in old-growth forest, has had its breeding habitat reduced by logging activities over much of its range. In 1989 the Canadian Wildlife Service carried out boat surveys to determine the numbers of Marbled Murrelets feeding at sea around Louise Island, especially along those stretches of coast where the old growth forest is slated to be felled over the next few years. Repeated surveys of these waters during and after the forest is cut should provide some indication of the effects of logging on the Marbled Murrelet population.

Most of the work of the Canadian Wildlife Service was carried out on Reef Island, but in 1989 a second camp was also occupied for a period on East Limestone Island, close to Louise Island. As this proved to be an easier island on which to work, the Laskeek Bay Conservation Society decided to make East Limestone the centre of its operations. In March and April of 1990 a small rustic cabin was erected on the north side of the island, a secure boat mooring was fixed in the cove on the west side (boat cove), and a network of rudimentary trails was cleared by removing major obstructions. The amount of clearing was kept to the minimum consistent with the aim of allowing people to move about the colony at night without undue inconvenience. The island was explored and mapped, and prominent features were named.

ACTIVITIES IN 1991, OVERVIEW

The camp on East Limestone Island was occupied by Laskeek Bay Conservation Society personnel from 26 March to 14 June. The camp was shared with biologists studying raccoons for the B.C. Ministry of Environment, who arrived on 16 March and continued to use the camp until July.

Raccoons. Trapping and radio-tracking of raccoons, and observations of scats and predation remains, continued throughout the season. In late March transects to monitor levels of predation on Ancient Murrelets were marked out with strings; these were placed in the same places as in 1990, and an additional transect was added. Each transect was 20 m wide, and ran directly inland from the coast to the limit of the area occupied by Ancient Murrelets. Transects were inspected by two people, walking abreast of one another, 5 m on either side of the guide string. They recorded and marked all signs of predation within 10 m on either side of the string. Transects were checked every three days. In addition, general surveys were carried out early in the morning, especially in areas where raccoons had been active the previous night, to locate fresh evidence of predations.

Boat surveys. Seven inshore boat surveys were carried out to estimate numbers of Marbled Murrelets and other marine birds, beginning at the end of March. Five sets were also carried in the open waters between Reef Island and the Skedans islands. These surveys were spread more or less evenly over the season. Boat surveys were conducted from a 4.5 m inflatable boat. The boat was run at a constant speed between landmarks, and the times of the start and end of the run, and of sightings of seabirds were recorded on a hand-held tape recorder. The position of each sighting could then be estimated from the time taken to reach the spot. Sightings of birds which were sitting on the water, or which flew up at the approach of the boat, were recorded as on the water, others were recorded as flying. A note was also made when birds were estimated to be more than 200 m from the boat's course. Other observations, of flight directions, or behaviour, were made where appropriate.

Observations from shore. In addition to the transects, daily observations were made from Cabin Cove of any marine bird activity visible from shore, and a regular log was kept of casual observations of birds and mammals throughout the area. From 11 April to 8 June a ten minute count of Ancient Murrelets flying over the gathering ground, to the east of Cabin Cove, was carried out nightly at about one hour before sunset. The count was made through a 25x telescope, fixed so that the navigation beacon on Low Island was at the top edge of the field. This count provided an index of the numbers of Ancient Murrelets waiting to visit the colony that night, and hence provided a warning about how much activity to expect on the colony.

Burrow monitoring. Beginning on 1 April, burrows marked as occupied in 1990 were inspected daily to discover whether eggs had been laid. We measured the first egg laid in each study burrow, as soon as it was laid, using calipers for the length and maximum diameter, and a spring balance for the weight. Only eggs weighed before the start of incubation give comparable weights, as the eggs begin to lose weight as soon as incubation begins, losing about 15% of their initial weight before the start of hatching.

After the first egg was laid each burrow was fitted with a temperature probe so that the temperature of the nest cup could be read by attaching a telethermometer to the end of the probe, which was situated 1-2 m from the burrow. In this way it was possible to follow the course of incubation in the burrows without the disturbance involved in directly inspecting them. After the probe had been put in place the temperature of the nest cup was checked daily until temperature records indicated that the clutch had been incubated for 30 days. The burrow was then inspected, and in most cases the eggs were either pipping or hatched. Chicks and adults in these burrows were removed for weighing and banding.

Chick trapping. On 5 and 6 May, six chick-trapping funnels were set up. They consisted of low fences made from transparent polyethylene sheets, designed to guide departing Ancient Murrelet chicks to the bottom of each funnel, where they could be captured, banded and sent on their way with the minimum of delay. The funnels were placed in exactly the same locations as in 1990 and were attended nightly from 9 May onwards, from darkness to at least 1 a.m., if no chicks were seen, or to 1 h after the last chick was recorded. During the same period, adult birds were captured on the ground, mostly as they arrived at the colony, banded, measured, weighed, and inspected for brood patches, and damage to feet and webs.

Banding Cassin's Auklets. On the nights of 3 and 27 May a party visited "Cassin's Castle", a small headland on the south side of Reef Island where there is a dense pocket of breeding Cassin's Auklets. Adult Cassin's Auklets were trapped in a mist net as they arrived at their burrows. Banding at this colony has been carried out since 1985, the intention of the trapping effort being to obtain recoveries of birds banded previously in order to estimate the survival of the adult birds.

Banding in Skincuttle Inlet. In addition to activities in the Limestone Island area, a small party, led by Steven Smith and Moira Lemon, visited the islands of Skincuttle Inlet to band Ancient Murrelets and to re-survey study plots that were set up there in 1985. Trapping of Ancient Murrelets was carried out on George and East Copper islands between 18-31 May and the study plots were resurveyed on 7-13 June.

CHICK BANDING AND WEIGHING

The first Ancient Murrelet chicks were captured on the night of 9 May, and the last on 6 June. The total caught was 562. Ninety percent of chicks were captured over a period of 18 nights, between 14 and 31 May. The peak of captures occurred on 26 May, when 48 were trapped, and the median date for all captures was 23 May; the same as in 1990 (Table 1, Figure 1). Assuming an incubation period of 32 days, and two days between hatching and departure, the median date of clutch completion was 19 April. As the two eggs are laid 8 days apart, the median date of laying for first eggs was 11 April. As in 1990, funnel #1 caught the fewest chicks (26), and funnel #6 caught the most (142).

The total number of chicks caught was 36% less than in 1990, and all funnels showed a decrease, ranging from 25% at funnel #4 to 50% at funnel #2 (Table 1). The difference observed between the two years was greater than that observed between any of the five years for which data were collected at Reef Island. In 1990 we estimated that the chicks trapped were produced by 570 pairs (based on 1.54 chicks/pair). This year 27 pairs in the study burrows on Limestone Island produced 42 chicks, an average of 1.56 chicks/pair. This suggests that only 360 pairs succeeded in rearing young in the same area. As the timing of breeding was identical between the two years, it seems unlikely that 1991 was a markedly worse year for breeding than 1990. Predation by raccoons may have caused most, perhaps all, of the difference in chick production.

Table 1. Numbers of chicks captured on East Limestone Island in 1991

DATE	FUNNEL 1	2	3	4	5	6	TOTAL	CUM. TOTAL
May 9-10	0	0	2	0	0	0	2	2
10-11	0	0	0	0	2	0	2	4
11-12	0	0	0	0	2	1	3	7
12-13	0	2	0	0	0	3	5	12
13-14	0	0	4	0	2	2	8	20
14-15	0	2	3	7	1	0	13	33
15-16	1	1	4	6	4	11	27	60
16-17	1	0	4	10	5	3	23	83
17-18	1	2	6	3	7	10	29	112
18-19	1	2	3	2	3	0	11	123
19-20	0	0	7	3	3	13	26	149
20-21	3	3	7	4	0	12	29	178
21-22	1	9	7	5	9	12	43	221
22-23	0	5	9	4	5	11	34	255
23-24	2	9	10	6	3	5	35	290
24-25	4	3	5	10	5	4	31	321
25-26	1	4	10	6	4	18	43	364
26-27	1	8	12	12	4	11	48	412
27-28	7	5	8	7	9	11	47	459
28-29	0	1	5	5	5	1	17	476
29-30	0	4	6	5	3	1	19	495
30-31	0	3	3	2	5	2	15	510
Jun 31-1	0	2	6	4	1	3	16	526
1-2	1	1	0	4	3	3	12	538
2-3	2	0	1	0	0	0	3	541
3-4	0	2	1	2	1	0	6	547
4-5	0	0	1	2	1	3	7	554
5-6	0	1	2	0	3	2	8	562
6-7	0	0	0	0	0	0	0	562
Totals	26	69	126	109	90	142	562	
1990 totals	37	137	192	146	163	198	873	
1991/1990	-30%	-50%	-35%	-25%	-45%	-28%	-36%	

The mean weight of chicks captured at departure averaged 27.1 g, with 90% of chicks between 24-30 g (Figure 2). Chick weights averaged nearly 28 g at the beginning of the departure period, but chicks captured after 30 May averaged less than 26.5 g (Figure 3). Similar trends were seen in all years at Reef Island, and in 1990 at Limestone Island.

The estimated median date of clutch completion (19 April) was the same as that for the earliest of the six years when dates were obtained at Reef Island (1987). During the Reef Island studies we found that in years when laying was early eggs were large and adult body weights were high. Also, years of early laying by the murrelets were associated with large numbers of shearwaters, kittiwakes and whales in nearby waters of Hecate Strait.

FIGURE 1
ANCIENT MURRELET CHICKS TRAPPED

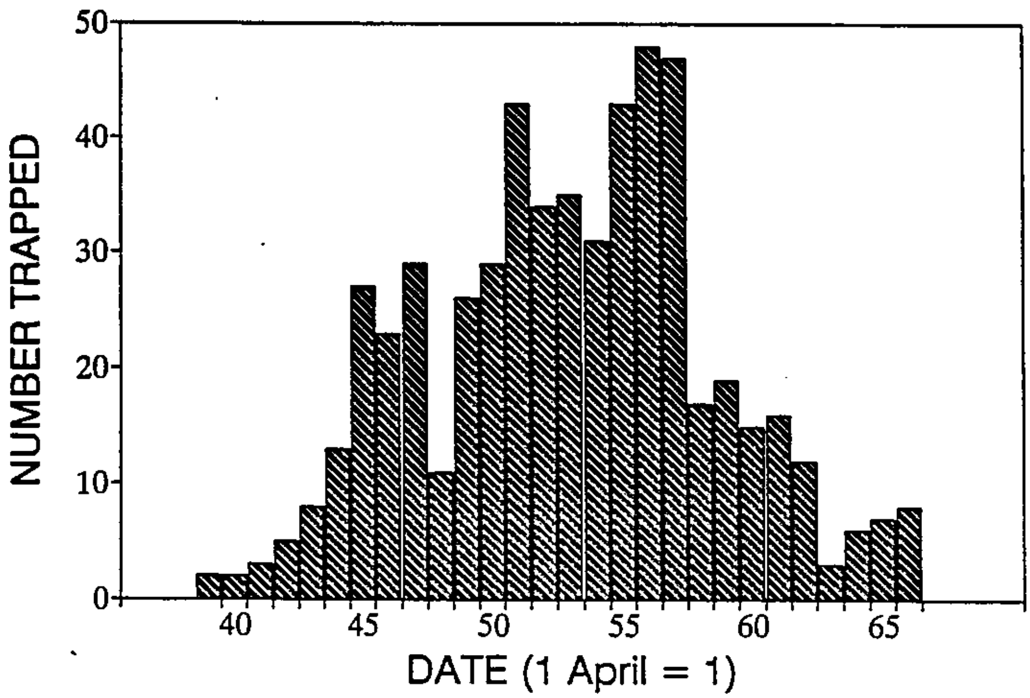


FIGURE 2
ANCIENT MURRELET CHICK WEIGHTS

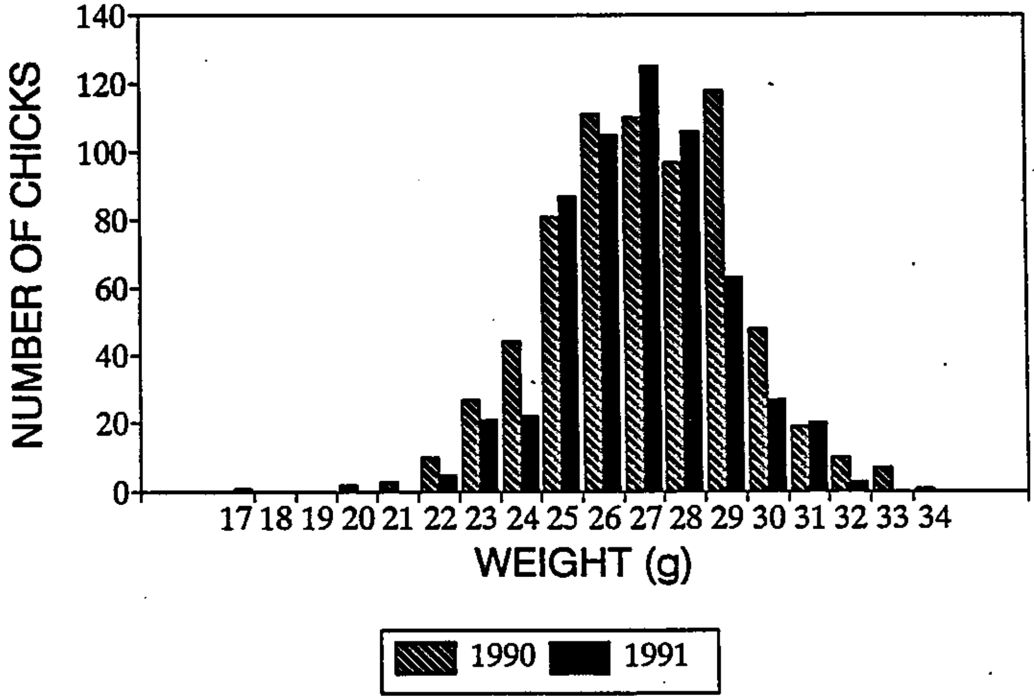
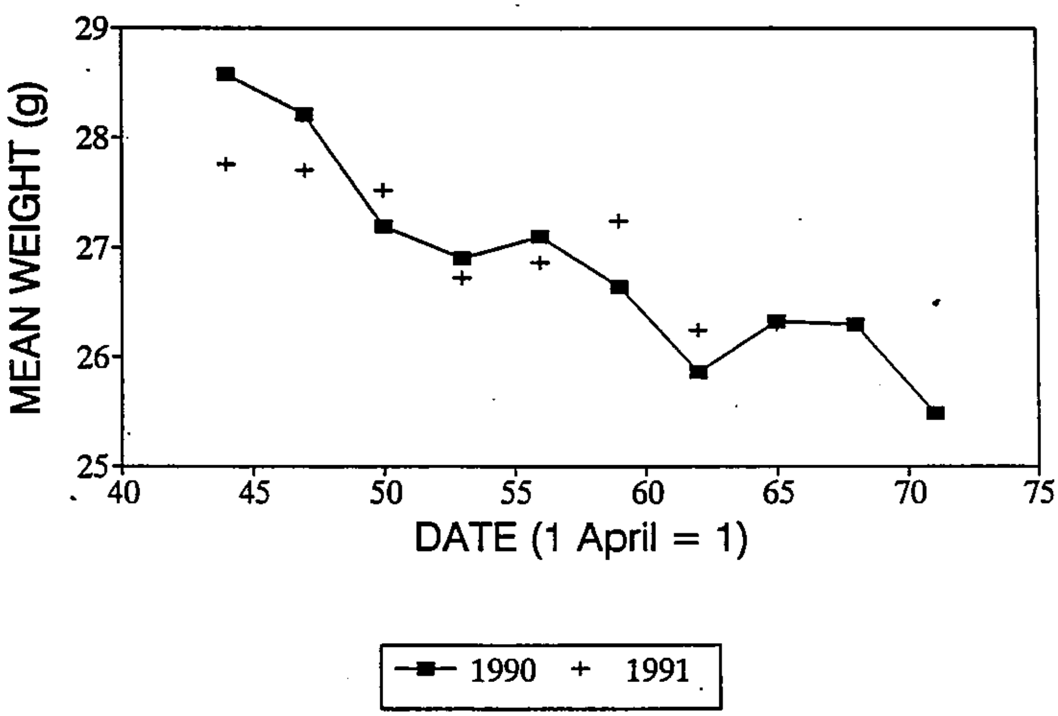


FIGURE 3
CHICK WEIGHT IN RELATION TO DATE



ADULT TRAPPING

Twenty-six Ancient Murrelets were trapped during 29 March-4 April, and another 314 from 7 May onwards. They included 13 birds banded on East Limestone Island in 1989, and 36 banded there in 1990. In addition five birds banded at Limestone Island in 1990 and one banded in 1989 were found dead, probably killed by raccoons. One bird banded as a chick on Reef Island in 1989 was found dead and one banded as a chick on Limestone Island in 1990 was retrapped alive. None of the birds captured during March and early April showed any sign of a brood patch. This is not surprising, because brood patches do not begin to develop in either member of the pair until after the female lays the first egg of her clutch. Of the 263 birds trapped in May and June, for which the brood patch was recorded, 40% had a full brood patch, and hence were presumably breeding, and 49% showed no sign of a brood patch, and were therefore non-breeding prospectors. The remainder had incomplete brood patches (<20 mm across), and were probably also non-breeders (Table 2).

Table 2.

Proportions of birds trapped in May and June 1990 and 1991 with and without brood patches (excludes found dead)

YEAR	STATUS	BROOD PATCH STATE		
		0	>0<20	FULL(>19)
1990	New	117(39%)	19(6%)	162(55%)
	Retrap	4(27%)	3(20%)	8(53%)
1991	New	115(53%)	22(10%)	82(37%)
	Retrap	13(30%)	8(18%)	23(52%)

The weights of both breeders and non-breeders trapped in 1991 were significantly lower than in 1990 (Table 3). The differences were especially striking for breeders trapped during 8-15 May, when mean weights were 6.8% lower than in 1990. Ancient Murrelets normally lose weight during the incubation period and in 1990 the difference in weight between birds trapped in the first half of May and those trapped in late May-early June was typical of what was found in all years at Reef Island. Events in 1991 seem to have proceeded rather differently, suggesting that after an initial abundance of food, as judged from the large eggs and early laying dates (see below), there was a deterioration in food supplies in early May. The weights of non-breeders recorded in 1991 were actually close to those that were normal at Reef Island during 1984-89 (924 birds averaged 185 g). Consequently, it seems that in 1990 conditions for non-breeders were exceptionally good. The situation in 1991 seems to have been more typical. Only two of our study burrows were abandoned after the start of incubation, so there was no indication that conditions were bad enough to cause breeders to desert.

The banding operation in Skincuttle Inlet was extremely successful, with 725 adult Ancient Murrelets banded in 10 nights on George Island and 41 banded in one night on East Copper Island. Unfortunately, no birds banded at either Reef or Limestone islands were retrapped, so no evidence was obtained that birds from the Laskeek Bay area disperse as far as Skincuttle Inlet. However, the operation showed that George Island is an excellent place to band large numbers of murrelets, and a return visit may be made in a few years.

Table 3. Weights of adult Ancient Murrelets captured on East Limestone Island in 1991. Dates given are for the night beginning. Birds with brood patches >19 mm in diameter probably bred.

BROOD PATCH	DATES	1990 (g) Mean	s.d.	N	1991 (g) Mean	s.d	N	t
All	29 Mar-4 Apr	214.5	10.54	31	207.9	15.55	25	1.88
>19mm	8-15 May	221.4	20.56	51	206.4	15.97	32	3.51**
	16-25 May	217.2	19.52	68	208.9	19.19	53	2.34*
	26 May-13 Jun	204.9	18.56	28	209.6	19.69	13	0.74
Nil	8-15 May	195.1	17.82	32	184.8	11.33	23	2.44*
	16-25 May	195.5	13.33	50	184.34	11.52	76	4.99**
	26 May-13 Jun	192.0	11.34	25	186.4	9.11	32	2.07
In burrows with chicks		-	-		212.3	13.43	32	

* P<0.05   ** P<0.01

EGG SIZE

Eggs laid in 1991 were among the largest measured in the Queen Charlotte Islands (Table 4). This may have been connected to the fact that 1991 was a year of early breeding. At Reef Island in years when egg laying began early the eggs tended to be larger than in later years (Figure 4). In 1991 we estimated the median date of clutch completion at Limestone Island as 19 April; as early as the earliest date recorded at Reef Island during 1984-89.

Those eggs laid at the beginning of the season tended to be larger than those laid later (Figure 5). This trend was not always apparent at Reef Island, and never to the extent that it occurred in 1991 at Limestone Island (Table 5). We shall see in future years whether this is a peculiarity of Limestone Island, or an effect found only in 1991. Along with the low weights of adult birds during the first half of May (see above), the sharp decline in egg weight as the season progressed suggests that there was a period after the start of egg-laying when feeding conditions were unusually poor.

Table 4. Measurements of Ancient Murrelet eggs from the Queen Charlotte Islands

Locality	Year	Weight(g)			Length(mm)			Breadth(mm)			Ref
		Mean	s.d.	N	Mean	s.d.	N	Mean	s.d.	N	
Reef I.	1984	43.8	3.2	57	58.7	2.0	98	37.1	1.2	98	(1)
	1985	46.7	3.3	53	59.3	1.9	99	37.9	1.1	99	(1)
	1986	45.7	2.8	52	59.3	2.1	52	37.6	1.1	52	(1)
	1987	47.6	3.4	50	60.0	2.2	50	38.1	1.1	50	(1)
	1988	45.3	2.6	41	59.3	2.0	41	37.5	0.9	41	(1)
	1989	46.4	3.2	39	59.3	2.4	39	37.9	1.5	39	(1)
Limestone I.	**1991**	**48.1**	**4.4**	**26**	**59.5**	**2.1**	**26**	**37.8**	**0.9**	**26**	
Ramsay I.	1984				59.4	1.7	39	37.3	1.1	39	(2)
Frederick I.	1981				60.3	2.9	53	37.8	1.5	53	(3)
Langara I.	1970	44.9	-	15	59.4		200	37.4		200	(4)
	1988				58.4	1.8	13	37.9	1.2	13	(5)
Helgesen I.	1986	44.3	3.8	10	58.2	2.2	22	37.5	0.9	22	(6)

(1) Gaston (1992); (2) Lemon and Rodway (pers. comm.); (3) Vermeer and Lemon (1986); (4) Sealy (1976); (5) Bertram (1989); (6) Rodway et al. (1990)

Table 5. Fresh weights of Ancient Murrelet eggs from Reef and Limestone islands, relative to date of laying.

Year	Regression of weight on date (weight=A-(date*B)	Estimated weights	
		15 April	15 May
1984	45.04-(date*0.066)	44.05	42.07
1985	47.57-(date*0.056)	46.73	45.05
1986	48.74-(date*0.122)	46.91	43.25
1987	51.08-(date*0.061)	50.16	48.34
1988	45.90-(date*0.036)	45.36	44.28
1989	47.36-(date*0.047)	46.65	45.24
1991	53.17-(date*0.464)	49.92	36.00

FIGURE 5
EGG WEIGHTS IN 1991

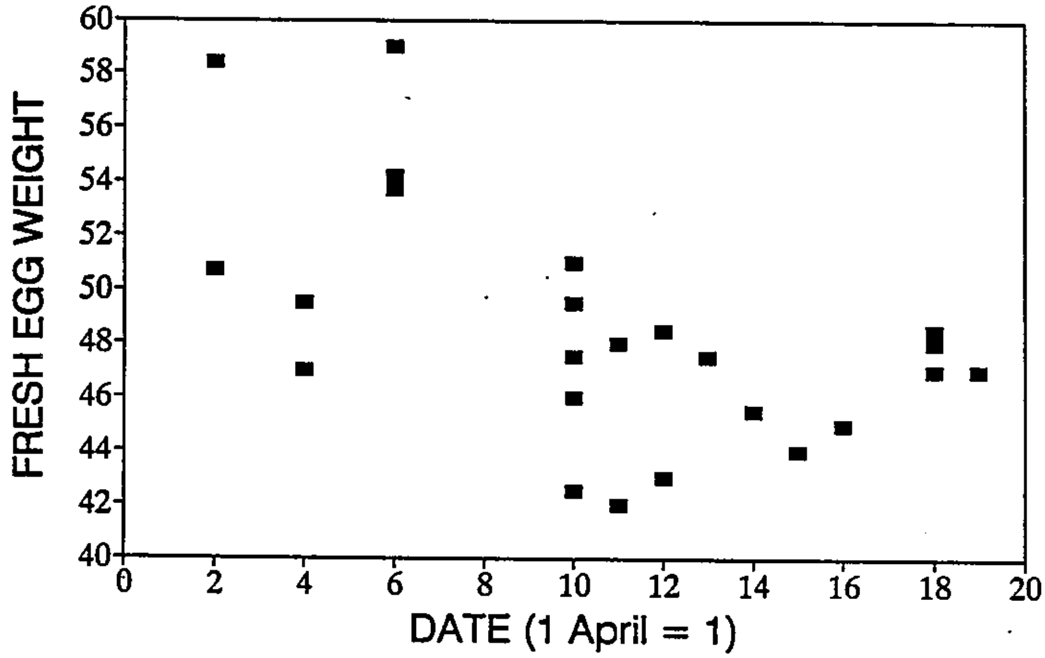
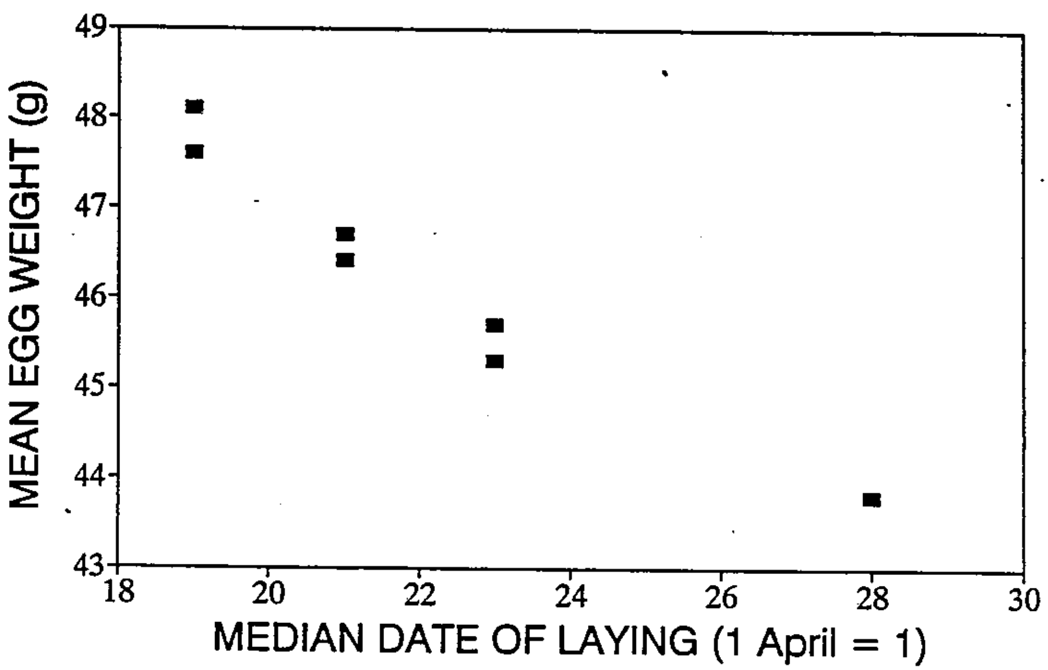


FIGURE 4
MEAN EGG WEIGHT vs MEDIAN LAYING DATE



INCUBATION

The use of temperature probes placed inside burrows after the laying of the first egg enabled us to monitor incubation behaviour without disturbing the birds. At empty nests the temperatures ranged from 6-8°C, while those where birds were incubating gave readings of 9-20°, depending on how close the probe was to the nest cup. We followed 27 burrows by this means, but for a variety of reasons we obtained useful information from only some of the burrows.

A few eggs were laid before we began burrow checks, so dates of first eggs were obtained for only 15 nests; these ranged from 4-18 April. Incubation began on average 10.4 days later (range 6-18, s.d. 3.0, N=14). The time from the start of incubation to hatching varies depending on whether the birds break their incubation at any point. This happened at 15/23 nests where we were able to follow the entire incubation period, with periods of neglect ranging from 1-5 days. Most occurred within 3 days of the start of incubation, and the latest break occurred after 11 days. Incubation periods (from start of incubation to hatching) ranged from 30-34 days, while the number of days of actual incubation ranged from 29-31 days, with more than half of the eggs hatching after 30 days of incubation. We knew the number of days that the chicks spent in the burrow before leaving for the sea at 15 burrows; four broods left after one day, nine after 2 days and two after 3 days.

Table 6. Incubation periods and number of days for which eggs were actually incubated.

Year	Incubation period									Days incubated					
	29	30	31	32	33	34	35	36	37	28	29	30	31	32	33
Reef Island															
1984		1	2	1			2			1	2	2	1		
1985	1	1	3	2	1	2	1	2	1	1	1	6	5		1
1988											4	15	7		
1989											10	44	9	3	
Totals	1	2	5	3	1	2	3	2	1	2	17	67	22	3	1
Limestone I.															
1991		3	7	4	1	2					1	12	6		

COUNTS OF ANCIENT MURRELETS ON THE GATHERING GROUND

Evening counts of birds flying over the gathering ground located to the east of Limestone Island were made from Cabin Cove between 1900-2030 hrs , using the same methods as in 1990. Numbers seen in a ten minute watch ranged from 0 to 478, with the highest counts falling mainly between 16 May and 1 June (Figure 6). Five counts of over 200 birds were made, all between 17-31 May.

Numbers of birds seen on the evening count were much affected by wind speed. At wind speeds estimated to be below 10 knots some birds were always present and most counts were of over 100 birds. At greater wind speeds the numbers counted were generally lower, and sometimes none were seen at all (Figure 7). Not all of this effect can be attributed to changes in numbers of birds, because conditions for observation were poor when high winds brought heavy seas. However, the numbers seen on the evening watch corresponded well with the experience of banders operating on the colony, where there was a good correlation between the numbers of birds counted at sea and the numbers caught (Figure 8). However, there is a danger that the observations of large numbers of birds on the gathering ground affected the eagerness with which banders set about catching them, so the two measures cannot be regarded as necessarily independent.

FIGURE 6
GATHERING GROUND COUNTS, 1991

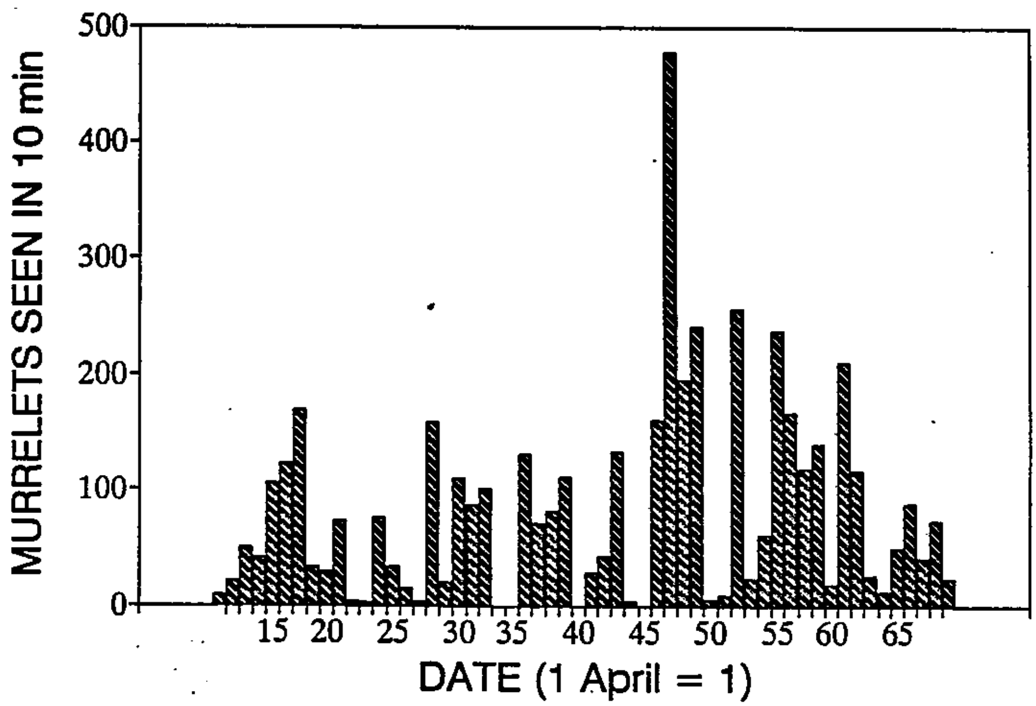


FIGURE 7.
COUNTS IN RELATION TO WIND SPEED

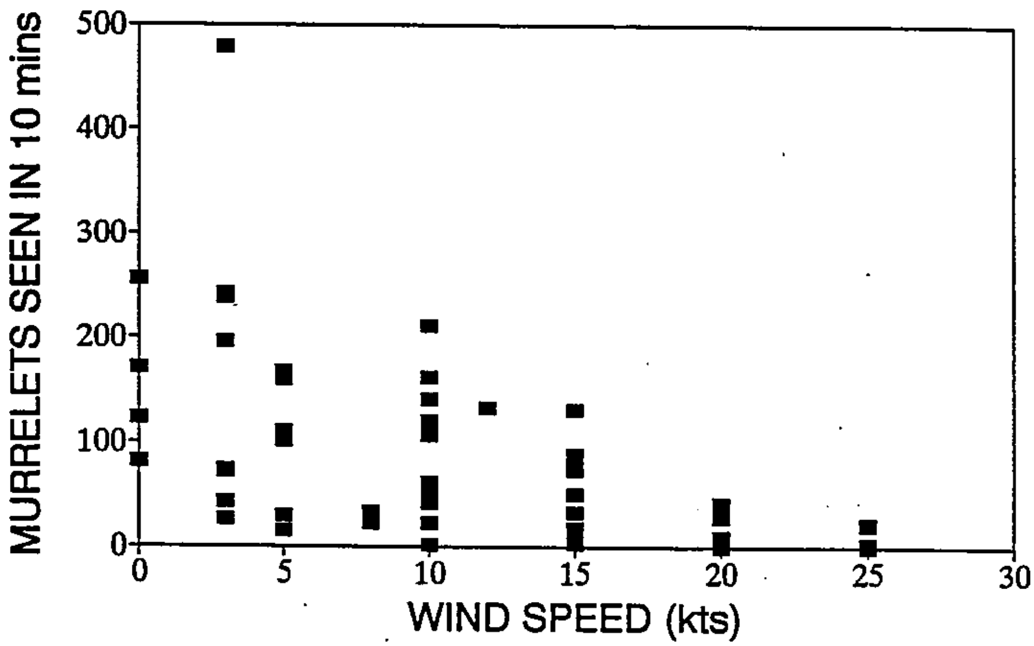
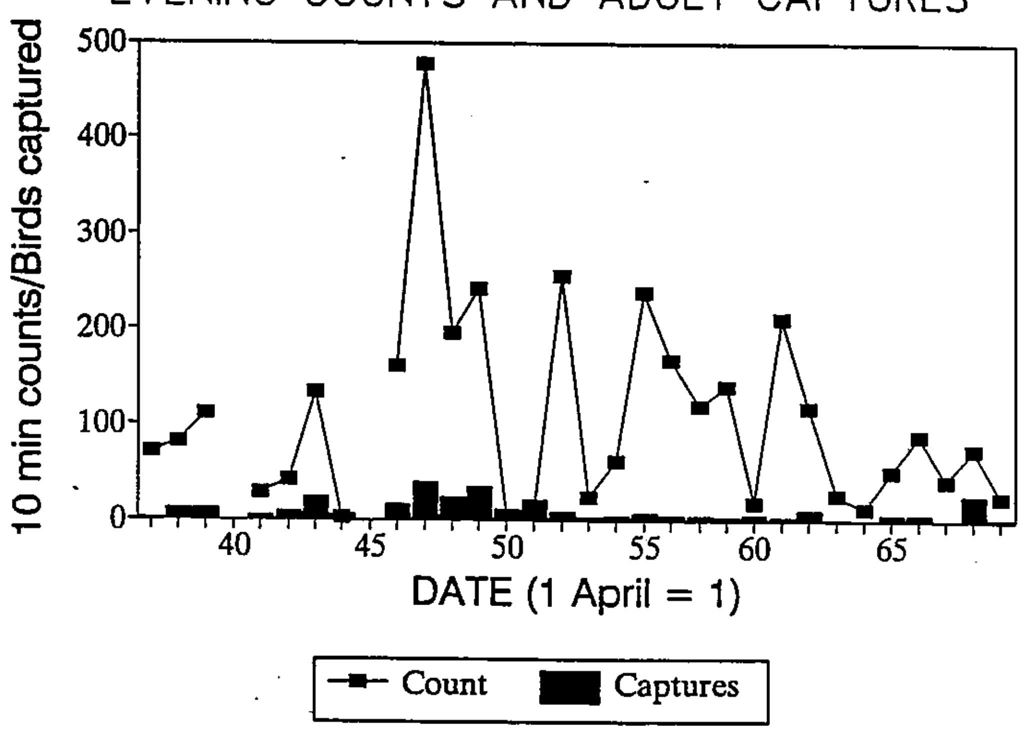


FIGURE 8
EVENING COUNTS AND ADULT CAPTURES



PREDATION BY RACCOONS ON SEABIRDS

Seven strip transects, covering an area of 2.56 ha (17% of the colony area) were searched for predation remains at three day intervals throughout the season. Five of the transects were the same as those used in 1990. In addition, spot checks were carried out in the early morning to investigate areas where radio-tracking had shown raccoons to be active the previous night. Some fresh carcasses that were collected were kept under observation from a distance to record the behaviour of scavengers, and the type of remains they produced. Signs of predations were classified as follows;

(1) Feather piles. These consisted of large numbers of contour feathers (breast, back, scapulars) scattered over an area up to 5 m in diameter, but normally concentrated in a clump. Complete single or paired wings were sometimes associated with these piles, and occasionally feet. Wings found without associated contour feathers, either single, or attached in pairs to the pectoral girdle, were also included in this category.

(2) Burrow digging. Some burrows were enlarged through the entrance tunnel, while in other cases the predator dug down from above. Several holes within a radius of 5 m were treated as a single predation event, unless other evidence suggested that more than one occupied burrow had been entered. Squirrels also dig holes in the ground on East Limestone Island, but theirs are smaller, are not associated with murrelet burrows and usually contain cone scales.

(3) Broken eggs. All broken egg remains found on the surface were considered to be the result of predation, except those with thick inner membranes found after the beginning of chick departures. The latter were probably dragged from burrows during family departures. Whole eggs, sometimes with hairline cracks, are found on the surface from time to time, apparently having been laid there. These would be liable to predation by Deer Mice or avian scavengers. Hence, not all broken eggs resulted from raccoon predation.

(4) Carcasses. Whole bodies, sometimes with variable amounts of flesh eaten from the breast. In practically all cases the head had been severed cleanly from the body. This appears to be characteristic of raccoon predation, as similar remains were observed on the island in 1990.

Ignoring predation remains found on the first survey, on 28-29 March, we found 78 feather piles, 17 burrow diggings, 17 broken eggs and 10 carcasses on transects carried out up to 8 June. The highest number of predation remains (32) was found on Transect #6, and the lowest (5) on transect #1. Highest numbers of predation remains on transects were found between 11 April and 10 May (Figure 9). The majority of carcasses were found during April; after mid-May practically all predation remains encountered consisted of feather piles (Table 7). However, during April predation transects were inspected in the morning, whereas after 10 May all were inspected in the afternoon.

Observations of carcasses showed that they were usually scavenged by birds within a few hours of dawn.

To estimate the number of birds killed by raccoons we assumed that some feather piles, diggings and eggshells resulted from predations also represented by other evidence. For instance, a bird pulled from a burrow might have been transported some distance before being converted to a feather pile, and the two forms of evidence recorded separately. Consequently, in estimating the total numbers of birds killed we halved the counts for all categories except carcasses. This gave an estimate of 66 birds killed within the transects up to 8 June (10 carcasses + 112 other remains/2). Extrapolating this to the entire colony suggests that 388 birds were killed, of which a little over half (197) were killed by 30 April.

Wings found both on and off transect were collected throughout the season and measured (carpus to longest primary). This was done in order to differentiate between breeders and non-breeders, as breeding Ancient Murrelets have been shown to have longer wings than non-breeders (Gaston 1992). The lengths of wings collected in April were generally greater than those collected in May, the differences corresponding quite closely to those observed at Reef Island between breeders and non-breeders.

FIGURE 9
NUMBER OF PREDATIONS, 1991

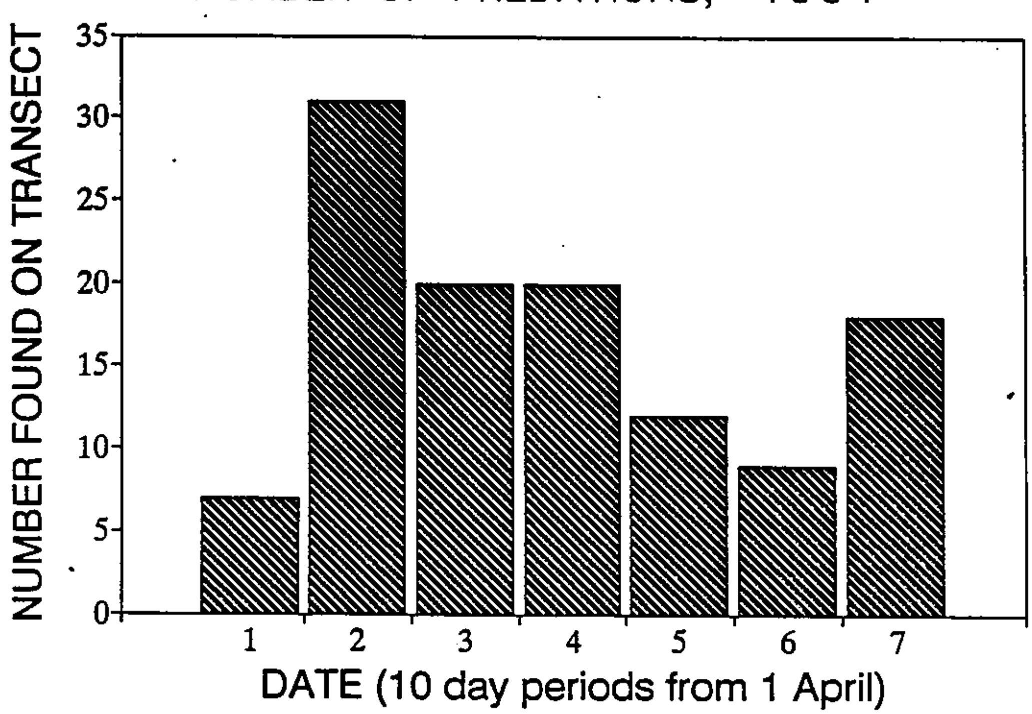


Table 7. Predation remains found on transects in 1991

DATE	FEATHER PILES	BURROW DIGGING	BROKEN EGGS	CARCASSES
31 Mar - 30 Apr	28	10	9	10
1 - 15 May	19	4	6	0
15 May - 8 June	31	3	2	0
Totals	78	17	17	10

Table 8. Length of Ancient Murrelet wings from predations remains found on East Limestone Island in 1991

DATE	WING LENGTH		
	Mean	s.d.	N
<11 April	139.65	5.20	20
11-20 April	140.18	3.64	44
21-30 April	140.81	2.76	47
May	138.67	3.40	51
Breeders (Reef Island)*	140.2	3.20	533
Non-breeders (Reef Island)	138.1	3.20	859

* Reef Island data from Gaston (1992)

Limestone Island wings, April vs May, $t=2.69$, $P<0.01$

Observations of carcasses found in the early morning suggested that most were removed by avian scavengers. Ninety percent had disappeared within 2 h of daybreak. In some cases evidence of the predation remained in the form of feather piles or cleaned, inverted skins (inversion was performed by Northwestern Crows), but in other cases no sign of the predation could be found. Bald Eagles, which were seen scavenging carcasses on several occasions, can swallow Ancient Murrelets whole, and this may have accounted for the disappearance of some remains. Other remains were removed from the colony area. A concentration of wings, and cleaned carcasses was found near the southeast corner of the island, in an area where crows frequently nested and roosted.

Our estimate of the number of Ancient Murrelets killed by raccoons is affected by several potential confounding factors. Some remains must have disappeared without being detected, either removed from the colony area, or swallowed whole. Our estimate of the amount of double counting involved in the predation remains that we recorded may be too high, because none of the experimental carcasses observed resulted in two sets of potentially identifiable predation remains. Some birds were killed before the end of March, and probably some were killed after we ceased transect observations on 8 June. All of these factors suggest that our estimate is likely to be very conservative.

The evidence from wing-lengths suggests that the majority of birds killed in April were breeders, but that a high proportion of those killed in May were prospecting non-breeders. The number of Ancient Murrelets breeding on East Limestone Island was estimated at 1151 pairs in 1989 (Gaston et al. 1981). If a similar number of birds bred in 1991, and if all those birds killed before 1 May (197) and one third of those killed later in the season (64) were breeders, raccoons killed 11% of the breeding population. If the breeders were killed randomly from the available birds then this would result in the removal of one bird from at least 20% of pairs and the consequent failure of those breeding attempts. However, some predations involved two birds taken from the same burrow, so the actual number of breeding attempts disrupted by the death of one or both members of the pair may have been slightly lower. The 36% decrease in the production of chicks within our trapping area suggests that the actual number of breeding attempts affected by raccoon predation was probably higher than we have estimated on the basis of predation remains. This supports the suggestion that our estimate of the total number killed is very conservative.

SURVEYS AT SEA

Five coastal and five offshore surveys of marine birds at sea were carried out between 29 March and 10 June. Generally, there was a higher diversity of species seen on coastal surveys, especially those carried out before the end of April. Twenty-four species were recorded on coastal surveys, whereas only 15 were seen on offshore surveys (Table 9). Pelagic and Double-crested cormorants were the most numerous species recorded on the first two coastal surveys, while Pigeon Guillemots and Marbled Murrelets predominated after the beginning of May. On offshore surveys in Skedans Bay Ancient Murrelets, Marbled Murrelets and Glaucous-winged Gulls were common, with Pacific Loons being seen in substantial numbers on 2 May (Table 10).

Numbers of Marbled Murrelets seen in the Skedans Bay - Laskeek Bay area were comparable with those seen in previous years (Table 11). As in earlier years, numbers of Marbled Murrelets increased sharply after mid-April, to peak in mid-May. Assuming an effective transect width of 100 m (half the maximum transect width used) we estimated that between 256 and 552 Marbled Murrelets were present in the area bounded by the Skedans Islands, Louise Island and the Low Islands in May (Table 12).

On 16 April a coastal survey was conducted around the entire coast of Louise Island. On those parts of the coast not included in Table 9 (Skedans to the mouth of Selwyn Inlet) the commonest species recorded were Double-creasted (14) and Pelagic (6) cormorants, Bufflehead (118), Barrows Goldeneye (32), White-winged (25) and Surf (38) scoters, Harlequin Duck (31), Common Merganser (25), Marbled Murrelet (22) and Pigeon Guillemot (26). A flock of 150 Surfbirds was also seen. The fairly low numbers of Marbled Murrelets seen suggest that the small numbers seen in the Skedans Bay area at that date cannot be accounted for by birds feeding in the more sheltered waters of Cumshewa and Selwyn inlets. Probably most Marbled Murrelets move into the waters around Louise Island after the middle of April.

Table 9. Birds seen on coastal boat transects (400 m from shore) in the Skedans Bay - Laskeek Bay area, 1991

SPECIES	29 Mar	16 Apr	2 May	18 May	1-10 Jun
Common Loon	0	2	4	5	0
Pacific Loon	0	0	0	5	0
Red-necked Grebe	0	2	0	0	0
Horned Grebe	2	0	0	0	0
Pelagic Cormorant	42	14	1	7	0
D-crested Cormorant	48	56	1	0	0
Mallard	0	9	2	0	0
Green-winged Teal	0	0	63	0	0
Greater Scaup	0	0	0	0	4
Bufflehead	15	27	9	0	0
Common Goldeneye	4	0	0	0	0
W-winged Scoter	9	17	3	4	0
Surf Scoter	4	0	0	0	0
Harlequin Duck	3	40	4	5	0
Common Merganser	0	2	2	3	0
G-winged Gull	12	18	21	27	2
Pigeon Guillemot	4	40	64	59	36
Marbled Murrelet	1	17	204	179	86
Ancient Murrelet	0	0	0	4	0
Rhinoceros Auklet	0	1	0	0	0
Transects	D-G	D-J	D-M	D-M	D-J
Species recorded	11	13	12	10	4

Table 10. Birds seen on open water transects in Skedans Bay in 1991. Inshore = transects 1 & 7; Offshore = transects 3, 4 & 5

Species	29 March		20 Apr		2 May		18 May		1-10 June	
	Insh	Off	Insh	Off	Insh	Off	Insh	Off	Insh	Off
Pacific Loon	0	0	0	0	33	0	6	0	12	3
Common Loon	1	0	0	1	0	0	0	0	0	0
Sooty Shearwater	0	0	0	0	0	0	0	0	0	1
Pelagic Cormorant	1	0	2	0	5	0	1	1	0	0
D-crested Cormorant	2	0	0	0	0	0	0	0	0	0
Brandt's Cormorant	1	0	0	0	0	0	0	0	0	0
G-winged Gull	0	12	0	0	0	2	1	0	0	171
Black-legged Kittiwake	0	0	0	0	0	0	0	0	0	12
Parasitic Jaeger	0	0	0	0	0	0	0	0	0	1
Common Murre	0	0	0	1	0	0	0	0	0	0
Pigeon Guillemot	2	1	0	0	3	0	10	1	0	3
Marbled Murrelet	0	0	5	0	9	1	70	9	35	8
Ancient Murrelet	0	5	0	4	0	349	8	650	26	86
Cassin's Auklet	0	0	0	0	0	0	0	0	1	0
Rhinoceros Auklet	0	0	3	0	0	0	0	4	1	58

Table 11. Comparison of numbers of Marbled Murrelets seen in the Skedans Bay - Laskeek Bay area in 1989, 1990 and 1991

DATE	1989		1990		1991	
	Coastal[1]	Offsh[2]	Coastal	Offsh	Coastal	Offsh
Up to 9 April	-	-	6	-	1	0
10-19 April	-	-	-	-	17	-
20-29 April	-	-	38	-	-	5
30 Apr - 9 May	-	-	-	-	205	16
10-19 May	-	-	50	104	144	85
20-29 May	74	-	25	165	-	-
After 29 May	68	-	14	35	86	52

1; transects D-J

2; transects 1,3,5 and 7

Table 12. Estimates of numbers of Marbled Murrelets present in the area bounded by the Skedans islands, Louise Island, the Limestone islands, South Low Island and Low Island in 1991 (based on an effective transect width of 100 m on either side of the boat).

Zone	Area (km^2)	Transect covered	29 March		16-20 Apr		2 May		18 May		1-10 June	
			Seen	Est.	Seen	Est.	Seen	Est.	Seen	Est.	Seen	Est.
Coastal	12.0	20%	0	0	7	34	39	190	7	34	16	78
Inshore	14.0	15%	0	0	5	34	9	60	70	466	35	234
Offshore	15.5	17%	0	0	0	0	1	6	9	52	8	46
Totals	41.5	17%	0	0	12	68	49	256	86	552	59	358

SURVEY OF PERMANENT SEABIRD MONITORING PLOTS IN SKINCUTTLE INLET

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In 1985 the Canadian Wildlife Service surveyed a number of permanent monitoring plots for burrow-nesting seabirds on East Copper Island (Cassin's Auklets) and George Island (Ancient Murrelets) in Skincuttle Inlet (Figure 10, Table 13). The corners of the square plots were marked with colour-coded metal stakes and an aluminum tag engraved with the plot number was fixed to an obvious tree within each plot. The position of each plot was marked on a map of the island. The distance to the nearest shore was measured and, in the case of the Ancient Murrelet plots which were set back in the forest, a metal tag was fixed at the shore engraved with the distance and direction to the plot. The Cassin's Auklet plots were all adjacent to the shore.

Each plot was mapped and the positions of trees, stumps, logs and other features were recorded. The location of burrows was mapped in relation to these features and a detailed description of each burrow was recorded. Burrows were examined by feeling through the entrance; no excavation was performed. All signs of occupation by birds (egg shells, membranes, feathers, etc.) were recorded.

On 4 and 5 June 1991 six observers resurveyed the monitoring plots on East Copper and George islands. All plots were relocated and examined in the same way as during the original survey. The positions of new burrows were added to the original maps. Burrows less than 30 cm deep and without nest chambers were recorded as "starts"; these were mapped, but not counted in the total number of burrows.

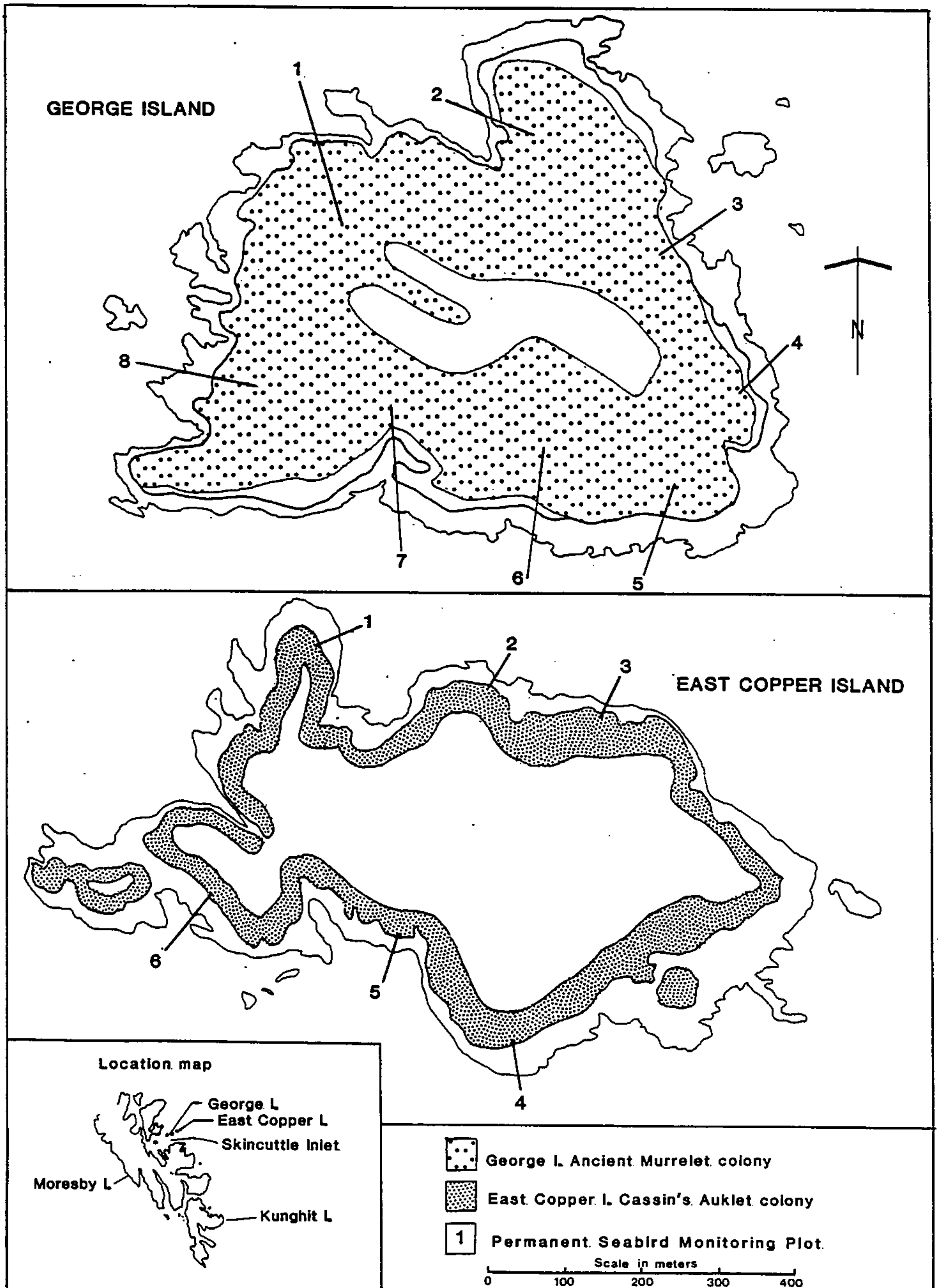

Fig. 10. Permanent Seabird Monitoring Plot locations on George Island and East Copper Island.

Results. The numbers of Ancient Murrelet burrows increased on all plots, with increases ranging from 3%-64% (Table 14). The total on all plots rose from 258 burrows in 1985 to 327 burrows in 1991 (27% increase). A small number of burrows recorded in 1985 were no longer present in 1991. On plot 7 a large tree had fallen in the centre of the plot, destroying several burrows. Plots 6, 7 and 8, which showed the lowest increases, were all situated on the south and west sides of George Island. As was evident at Reef Island, it appears that recruitment to the colony is concentrated in certain areas.

On East Copper Island the numbers of Cassin's Auklet burrows had remained fairly stable, with 238 burrows recorded in 1985 and 241 burrows in 1991. Four plots showed increases of 2%-22%, one was stable, and one had decreased by 16% (Table 15). As in the case of the Ancient Murrelet plots, a few burrows had collapsed and filled, or were completely blocked. Some "starts" recorded in 1985 were full burrows in 1991, containing evidence of breeding.

Discussion. These surveys showed that it is possible to relocate monitoring plots after six years and that results can be obtained from only a small number of person-days. Although there was some uncertainty about the status of a few burrows, the results appeared clear cut in most cases. They suggested that the number of Ancient Murrelets burrows on George Island increased between 1985 and 1991, while numbers of Cassin's Auklets burrows on East Copper Island remained stable. Assuming a similar occupancy, the population of Ancient Murrelets on George Island is probably increasing. We cannot tell how representative these trends are of populations of these two species in the rest of Gwaii Haanas. However, if similar repeat surveys can be carried out at other colonies where permanent plots were set up (Ramsay and Rankine islands), we may be in a better position to assess overall population trends. A repeat visit to Ramsay Island, where there are permanent plots for Cassin's Auklets and Ancient Murrelets, is planned for 1992.

Table 13. Details of monitoring plots set up for seabirds on George and East Copper islands in 1985 by the Canadian Wildlife Service

ISLAND	PLOTS	SIZE	BURROWS/PLOT (range)	TOTAL BURROWS IN PLOT	TOTAL BURROWS IN COLONY	% COLONY IN PLOTS
Ancient Murrelet						
George	8	20x20	32 (11-49)	258	15118	1.7
Cassin's Auklet						
East Copper	6	10x10	42 (21-60)	252	12955	1.9

Table 14. Numbers of Ancient Murrelet burrows recorded in permanent monitoring plots on George Island in 1991

STATUS	PLOT 1	2	3	4	5	6	7	8
1985	31	49	11	32	37	23	37	38
1991								
"Old" burrows	29	46	11	30	35	21	27	31
"New" burrows*	16	27	7	11	12	5	11	8
Total	45	73	18	41	47	26	38	39
% increase	45	49	64	28	27	13	3	3

* These numbers do not include new "starts"; short tunnels without any nest chamber, apparently in process of construction

Table 15. Numbers of Cassin's Auklet burrows recorded in permanent monitoring plots on East Copper Island in 1991

STATUS	PLOT					
	1	2	3	4	5	6
1985	19	27	56	48	52	36
<u>1991</u>						
"Old" burrows	17	27	46	43	46	36
"New" burrows*	3	6	1	5	7	4
Total	20	33	47	48	53	40
% change	5	22	-16	0	2	11

* These numbers do not include new "starts"; short tunnels without any nest chamber, apparently in process of construction

BIRD AND MAMMAL RECORDS AROUND EAST LIMESTONE ISLAND

Humpback Whale. On 4 May two adults and one juvenile were seen from East Limestone Island passing northwards close to Low Island. 1-3 large whales seen spouting from East Limestone Island on 16 May may have been of this species.

Orca. Three females, one male and one calf were seen from the East Limestone Island cabin passing northwards on 15 May. On 1 June two were seen near the cabin and on 4 June a male, two females and two calves were seen.

Steller's Sealion. Five hundred were estimated on 27 May and 400 on 11 June on Sealion Rocks, off Reef Island.

Harbour Seal. About 30 were hauled out at the east end of Reef Island on 28 May.

River Otter. Seen several times on East Limestone Island, where one was caught during raccoon trapping in April.

Raccoon. Three adults, the male "Gordo" from 1990, and a female "Becky" trapped and collared in March 1991, and an uncollard animal, were present on East Limestone Island throughout the period when the camp was occupied. Becky produced at least one kit in April. The activities of raccoons have been extensively documented elsewhere (Masselink and Van den Brink 1992).

Red Squirrel. Much more common on East Limestone Island than in 1990 and seen throughout the period when camp was occupied.

Yellow-billed Loon. One in winter plumage not far south of Sandspit on the way to Limestone Island, 26 March.

Pacific Loon. About 40 were feeding on a herring ball near Skedans village on 19 May.

Horned Grebe. One or two were seen daily until 2 April, but not recorded thereafter.

Sooty Shearwater. Small numbers seen near the east end of Reef Island on 28 May, in strong SE winds.

Fork-tailed Storm-Petrel. Invariably seen or heard in the vicinity of Cassin's Tower on nocturnal circumnavigations of the island. The remains of several that had been eaten by a predator were found on or near Cassin's Tower, and some burrows in that area appeared to be of the right size for Storm-Petrels. If they are breeding on Limestone Island it is the only island known in the Queen Charlottes where Storm-Petrels co-exist with Deer Mice.

Pelagic Cormorant. Seen throughout the season, but the large aggregations seen in April 1990 were not recorded, except on 28 March when 250 flew past Cabin Cove between 18:50 and 19:10 h.

Brandt's Cormorant. One in Cabin Cove on 28 March.

Double-crested Cormorant. Seen almost daily until 25 April, but not recorded thereafter, except for a single bird on 2 May. On 29 March 71 were present on a survey of roosts in Skedans Bay and off Reef Island.

Canada Goose. Twenty-five flew north on 28 March, 150 On 23 April, 100 On 30 April, several hundred on 2 May and 200 on 7 May.

Pacific Brant. Flocks of 7-50 were seen flying north on four dates between 15 April and 7 May. About 50 were present on eastern Louise Island on 24 May.

Bald Eagle. One pair nested on East Limestone Island, but their success is unknown. Twice seen feeding on loons on East Limestone Island; one Pacific, one Common.

Red-tailed Hawk. Seen on six dates from 13 May onwards.

Peregrine Falcon. Three young were reared on East Limestone Island. At Reef Island a pair reared 2 young at the western eyrie, but no birds were seen at the eastern site.

Blue Grouse. Heard drumming on five dates between 10 April and 23 May.

Sandhill Crane. Fourteen flew over on 14 April.

Black Oystercatcher. Three pairs were present on East Limestone Island, but no young were hatched before mid-June. Pairs were also present on West Limestone I. (1), Low I. (1), South Low I. (2), Kingsway Rock (1) and Reef I. (at least 4, including 2 with chicks in early June).

Black Turnstone. Flocks of up to 17 were seen on East Limestone Island on four dates in April.

Whimbrel. Flocks were seen on 17 and 24 May.

Red-necked Phalarope. Twenty between Limestone and Reef islands on 24 May.

Glaucous-winged Gull. At Kingsway Rock on 10 June there were 64 occupied nests; 54 with three eggs, 8 with two eggs and 2 with 1 egg. Eight empty cups were also present. At Low Island on 11 June there were 7 empty nests, 3 nests with one egg and one with two eggs and on the islets at the east end of Reef Island there were 3 nests with three eggs and one with two eggs.

Thayer's Gull. One adult in Cabin Cove on 28 March.

Black-legged Kittiwake. About 20 in breeding plumage were seen off Cumshewa Inlet on 26 March and 12 off Vertical Point on 29 April. Flocks were seen passing to the east of Limestone Island in strong winds on 23 April and 14 May. Small numbers also seen on boat surveys.

Marbled Murrelet. See section on marine surveys.

Cassin's Auklet. One dead adult was found near the boat cove on East Limestone Island. Evidence that several burrows had been dug out was found at Cassin's Tower on 31 March.

Tufted Puffin. Not seen in 1991

Rhinoceros Auklet. Heard several times at night on East Limestone Island.

Saw-whet Owl. One birds was seen near camp, but none was heard calling.

Hairy Woodpecker. One nest on East Limestone Island had young on 12 June.

Flicker. One nest with young on East Limestone Island on 16 June.

Red-breasted Sapsucker. At least eight nests with chicks were present on East Limestone Island in early June.

Rufous Hummingbird. Two nests were found on East Limestone Island.

Western Flycatcher. First recorded on 25 April.

Northwestern Crow. About 20 nests were found in "Crow Valley", of which about half contained young in early June.

Chestnut-backed Chickadee. One nest found with young on 3 June.

Winter Wren. Fledged young seen on East Limestone Island on 29 May.

Orange-crowned Warbler. First recorded on 25 April.

Townsend's Warbler. First recorded on 18 April.

Swainson's Thrush. First recorded on 7 June.

Hermit Thrush. Not recorded until 14 April.

Varied Thrush. Heard singing from 27 March. Fledged young seen on 25 May.

Fox Sparrow. Not recorded on East Limestone Island.

Other species recorded (other than those listed in Tables 9 and 10)

- Golden-crowned Kinglet
- Savannah Sparrow
- Raven
- Chestnut-backed Chickadee
- Brown Creeper
- Song Sparrow
- Dark-eyed Junco
- Red Crossbill
- Pine Siskin

THE EFFECT OF HABITAT, ISLAND SIZE AND ISLAND ISOLATION ON LAND-BIRD DIVERSITY IN OLD GROWTH FOREST IN GWAII HAANAS

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INTRODUCTION

Factors determining the occurence of species on islands, whether those surrounded by open water, or by other radically different habitat types, have been studied extensively since the seminal work of McArthur and Wilson (1967). Many studies of birds have shown that large islands support more species than small islands in the same area, and this is thought to occur because large islands support larger populations, which are therefore less prone to extinction (McArthur and Wilson 1967), because large islands support a greater diversity of habitats, creating niches for more species (Lack 1976), or because large islands intercept more dispersing birds (Connor and McCoy 1979, Haila 1983). Numerous modifications have been appended to the core theory of island biogeography, taking into account the effects of historical factors, unique island ecosystems, and the nature of the source area. Despite that, few attempts have been made to critically test the foundations of the theory, such as the extent to which colonisation and extinction really occurs.

During the last decade attention has switched to the importance of species identity (as opposed to species numbers), to the role of their ecology in determining distributions and to the need for an ecological understanding of the island concept (Haila 1990). All these factors are likely to be important when the implications for conservation are considered. In this study we tried to improve understanding of the ecology and distribution of land birds among the islands of Gwaii Haanas in the Queen Charlotte archipelago. We analyze variations in numbers of species, species composition, and species distributions in relation to the area and isolation of each island, the habitat structure and the ecology of individual species. To overcome the problems just mentioned, we used a standardized technique of point count censuses to determine the presence, and relative abundance of species, combined with a detailed measurement of habitat variables at each census point.

The islands used in this study included most of those off the East coast of Moresby Island from Skedans south to Skincuttle Inlet (Figure 1). During spring 1989 we studied thirty nine islands in Laskeek Bay and the northern part of Juan Perez Sound, ranging in size from 1 to 400 ha, and also Louise Island 35 000 ha, as a reference (Fig. 1 and Table 1). As Louise Island is separated from the much larger Moresby island by only a 50 m wide channel we considered that it would probably support the same birds. During spring 1991 another set of 23 islands in Island Bay and Skincuttle Inlet and two large reference islands (South Moresby and Burnaby, the latter again only separated from South Moresby by a narrow channel) were censused following the same protocol (Figure 1 and Table 2). In 1991 we also resurveyed 10 of the islands surveyed in 1989, covering the entire range of island area censused.

Islands were grouped into 7 size classes (Class R is the reference class made of very large islands: Burnaby (6,600 ha), Louise (35 000 ha) and South Moresby, class 1: 400 ha, class 2: 250 ha, class 3: 40-50 ha, class 4: 10-21 ha, class 5: 5-9.9 ha, class 6: 1-4.9ha (Table 1 and 2). We sampled more islands in the smaller size classes in order to have similar sample sizes (number of point counts) in each class.

The vegetation of the islands studied is rather uniform, consisting of a climax evergreen forest of Western red cedar Thuia plicata, Western hemlock Tsuga heterophylla and Sitka spruce Picea sitchensis, with an admixture of alders where disturbance has taken place (logging, landslips, etc.). On the larger islands, this forest, containing trees up to 60m high, generally has a closed canopy a sparse understory, and a ground cover dominated by mosses. In the areas censused on South Moresby vegetation structure changes when going towards the interior of the island. The abundance of Western red cedar and locally of Lodgeole pine Pinus contorta tends to increase, and the abundance of Western hemlock and Sitka spruce decreases, canopy height becomes lower and shrub cover becomes denser (Appendix 1, 2). Canopy height is generally lowest on the smallest islands. On some islands, especially Reef Island, substantial areas of unmixed Lodgepole pine, with a rather open canopy, occur on dry, south-facing slopes or on acid bogs. In such areas there is a dense ground cover of grasses. Except for where logging has taken place (Louise Island only), the only unforested areas occur on exposed headlands or near the summit of mountain peaks (Louise island, South Moresby).

Where the forest meets the shore, especially on headlands, and on exposed coasts (usually south and east exposures), the canopy tends to be more open and an understory of grasses and forbs occurs. Shrubs, especially Salal, occur densely where deer browsing is reduced or absent, usually on the smallest islands (Appendix 1,2). All of our censuses were carried out in mature forest below 150 m asl. However, the area of forest on the smallest islands is necessarily small, so that on those islands the census points tended to be closer to the forest edge than on the larger islands. We tried to minimize this bias by censusing larger islands so that the distances from point count centers to the shore were similar to those on smaller islands (see below).

Censuses were conducted from 22 April to 3 June 1989 and from 19 May to 4 June 1991. We used 20 min. point counts with limited distance. The same observer (JLM) censused all point-counts, spending 20 min at each point recording the numbers and identity of each species observed within 50 metres. Variation in the abundance of a species among different samples was estimated either by variation in the proportion of counts on which it was observed or by variation in the average number of individuals seen per count.

In order to ensure that there was no overlap between observations, we left at least 200 metres between adjacent points. The distance to the forest edge rarely exceeded 150 m and was never below 50m. Hence, the number of counts possible on an island was limited by the island's area. Species that occurred outside the 50 m radius covered by the point count were also noted as supplementary species.

For each point we recorded a standardized description of the vegetation within the 50 metre radius. We estimated maximum and main canopy height (defined as the height of the highest vegetation layer with >25% cover, the vegetation structure (% cover at 0-0.25, 0.25-0.50, 0.50-1, 1-2, 2-4, 4-8, 8-16, 16-32, >32 m); the proportion of the ground covered by herbaceous vegetation, moss, dead wood and bare soil and the proportion covered by the dominant plant species. We also recorded island features such as area (ha) and isolation (distance to the closest large island).

This study is part of a comparative project by JLM to compare the distribution patterns of species among islands in various temperate wooded archipelagos (Simberloff and Martin 1991).

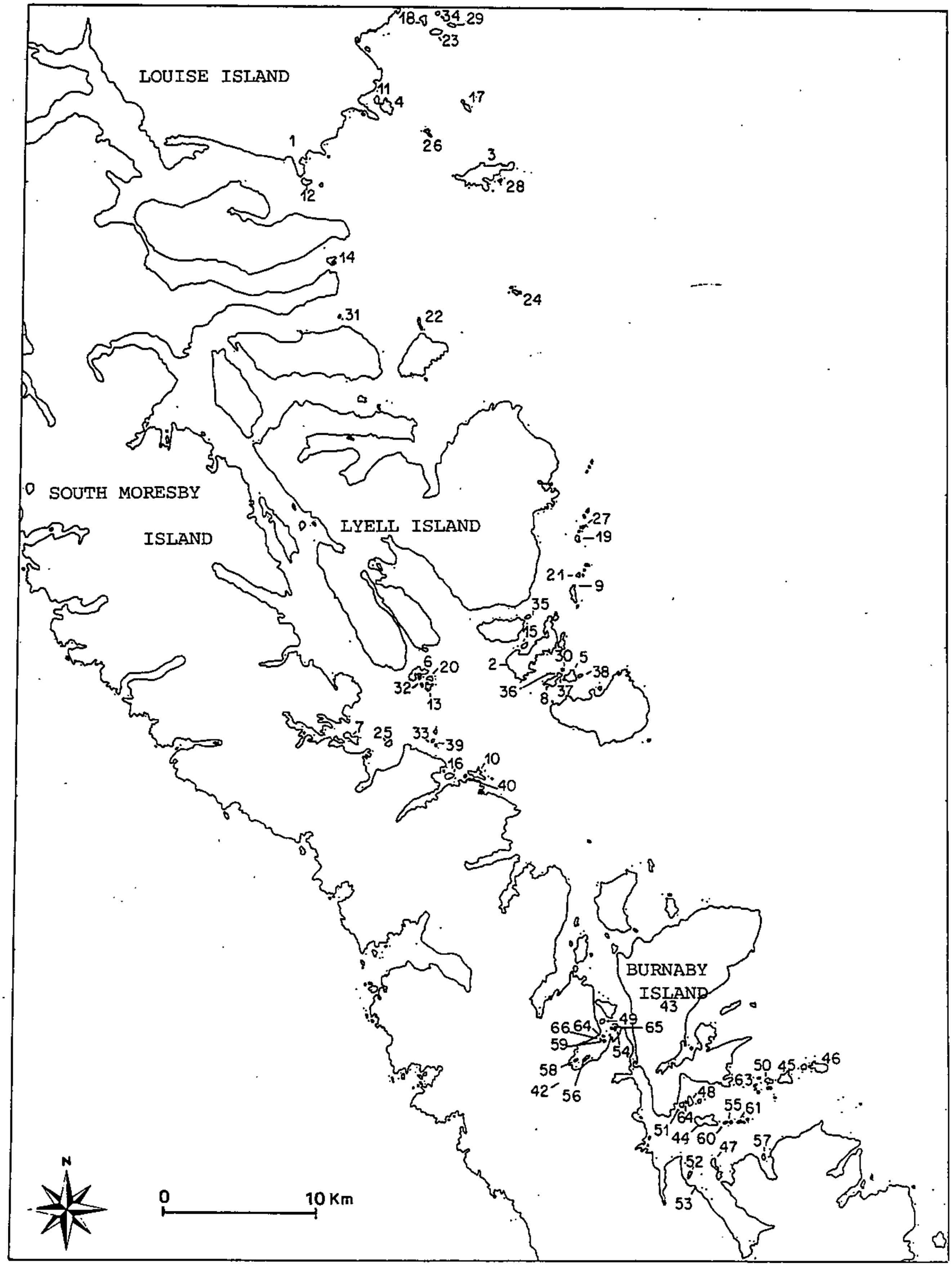

FIGURE 1. General location of the islands censused during 1989 and 1991. See Table 1 and 2 for island names.

TABLE 1. Main features of the data for the 1989 sample. R = Reference area (Louise Island), n = identifying number for the island, ACR = island acronym; N_I = number of point counts per island; A = average island area within an island class; S_{TOT} = total number of bird species recorded for the island class; N = number of point counts per island class; S_{MB} = total number of species observed on point counts in the island size classes; s = average number of species observed per point count; a/N = slope of the cumulative richness curve.

ISLAND CLASS	n	ACR	ISLANDS	AREA	N_I	A	S_{TOT}	N	S_{MB}	s	a/N
R	1	Lou	LOUISE	35,000.0	24	35,000.0	24	24	19	7.0	0.08
1	2	Mur	MURCHISON	400.0	16	400.0	15	16	13	6.5	0.06
2	3	Ree	REEF	249.0	22	249.0	27	22	17	6.6	0.09
3	4	Eli	LIMESTONE E	48.0	5	43.0	22	19	18	5.9	0.15
	5	Hou	HOUSE	44.0	5						
	6	Bin	BISCHOF N	40.0	5						
	7	Del	DELABECHE	40.0	4						
4	8	Hot	HOTSPRING	21.0	3	14.8	25	25	21	5.6	0.12
	9	Agg	AGGLOMERATE	20.5	4						
	10	Mar	MARCO	20.0	4						
	11	WLi	LIMESTONE W	16.0	2						
	12	Has	HASWELL	13.3	3						
	13	Bse	BISCHOF SE	12.0	3						
	14	Hel	HELMET	10.4	2						
	15	Mur	MURCHISON I	10.0	2						
	16	Hut	HUTTON	10.0	2						
5	17	Low	LOW	9.6	2	6.3	19	16	16	6.2	0.18
	18	Skw	SKEDAN W	8.2	3						
	19	Tas	TAR S	6.0	1						
	20	Bic	BISCHOF C	6.0	2						
	21	Ksw	KAWAS SW	5.6	1						
	22	Til	TILUL	5.6	2						
	23	Sks	SKEDAN S	5.6	2						
	24	Los	LOST	5.3	1						
	25	Siv	SIVART	5.0	2						
6	26	Slo	SOUTH LOW	4.5	2	2.0	17	16	11	3.8	0.06
	27	Kan	KAWAS N	3.8	1						
	28	Lre	LITTLE REEF	3.5	1						
	29	Ske	SKEDAN E	2.9	1						
	30	Ho1	HOTSPRING I1	2.0	1						
	31	Fpo	FLOWER POT	2.0	1						
	32	Biw	BISCHOF W	2.0	1						
	33	Hol	HOSKIN LARGE	2.0	1						
	34	Skn	SKEDAN N	1.7	1						
	35	Far	FARADAY N	1.5	1						
	36	Ho3	HOTSPRING I3	1.5	1						
	37	Ho2	HOTSPRING I2	1.0	1						
	38	Hu1	HOUSE I1	1.0	1						
	39	Hos	HOSKIN SMALL	1.0	1						
	40	Mar	MARCO SMALL	1.0	1						
TOTAL							30	138	24		0.00

TABLE 2. Main features of the data for the 1991 sample. CL = island area classes as in Table 1 (R = Reference areas (SM = South Moresby island)), n = identifying number for the island, ACR island acronym. Numbers in second column refer to island identification number; N_I = number of point counts per island; A = average island area within an island class; N = number of point counts per island class; S_{MB} = total number of species observed within main belts in the island size classes; s = average number of species observed per point count; a/N = slope of the cumulative richness curve.

CL	n	ACR	ISLANDS	AREA	N_I	A	N	S_{MB}	s	a/N
R	42	R1	Island Bay (SM)		5		16	20	7.31	0.31
	42	R2	Island Bay (SM)		4					
	43	R4	Burnaby	6,600.0	7					
3	44	Bol	Bolkus	52.2	4	36.5	14	17	8.21	0.07
	45	Geo	George	32.7	6					
	46	ECo	East Copper	24.7	4					
4	47	Lij	Long Island Jedway	17.0	2	15.5	5	11	7.00	0.40
	48	Swa	Swan	14.0	3					
5	49	IB3	Island Bay 3	7.5	1	6.5	6	18	9.17	0.50
	50	Ski	Skincuttle	7.1	2					
	51	Swi	Swan islet	6.0	1					
	52	Bou	Boulder	5.6	2					
6	53	SPi	Sea Pigeon	4.2	1	2.3	14	21	6.00	0.21
	54	IB1	Island Bay 1	3.5	1					
	55	Bo2	Bolkus islet 2	3.1	1					
	56	IB7	Island Bay 7	3.0	1					
	57	Har	Harriet	3.0	1					
	58	IB8	Island Bay 8	2.5	1					
	59	IB5	Island Bay 5	2.2	1					
	60	Bo1	Bolkus islet 1	2.1	1					
	61	Bo3	Bolkus islet 3	2.0	1					
	62	RIs	Rock islets	1.7	1					
	63	SIs	Swan islet small	1.5	1					
	64	IB4	Island Bay 4	1.2	1					
	65	IB2	Island Bay 2	1.2	1					
	66	IB6	Island Bay 6	1.0	1					
TOTAL							55	25		0.05

In the smaller 1991 sample a total of 25 species were recorded during census counts of which 21 were recorded on the smaller islands and 20 on the larger ones (Table 2). In addition, Peregrine Falcon , Red-tailed Hawk, Tree Swallow, Pine Grosbeak and a newcomer to South Moresby, the European Starling, were all observed outside the point count censusing. For individual island size classes, values of a/N varied from 0.06 to 0.18 in 1989 and 0.07 to 0.50 in 1991, indicating some variation in the relationship of S_{MB} to actual species richness for different island size classes. However, the variation in a/N was unrelated to island size. In addition, the mean number of species recorded per count (s), as a proportion of all the species recorded in that size class (S_{MB}), was also poorly related to island size (Tables 1 and 2).

The numbers of species recorded per count increased slightly, but significantly, with island size in the 1989 sample. However, most of this trend was created by the difference between the smallest island class, where s averaged 3.8, and the rest where s varied from 5.6 to 7.0. When islands in the smallest class were ommitted, there was no relationship between s and island area.

The total number of species observed on each of the 10 islands censused in both years (Table 3) shows that: 1) the total number of species observed per island each year follows the species/area relationship, and 2) that there is a fair amount of apparent species turn over between the two years for a given island. This turnover may be caused by real local extinction or local colonisation and by sampling effect (i.e some species were missed in one year).

Considering individual islands, the number of species observed decreases with island area, as it would in mainland samples of decreasing area, but no dramatic decrease in the number of species observed for a given sample size is observed when comparing counts taken from a few large islands to counts taken from many smaller islands.

TABLE 3. List of land bird species observed on the 10 islands that were visited both in 1989 and 1991. 1 = species recorded in 1989 only, 2 = species recorded in both years, 3 = species recorded only in 1991. Louise, Reef and South Low islands were more intensely prospected in 1989, East Limestone Island was more intensely surveyed in 1991.

SPECIES	ISLAND									
	Lou	Ree	Eli	Hot	Skw	Sks	Slo	Ske	Ho3	Ho2
BEAG	2	2	1	3		1	2	1		1
SHHA	1									
PFAL	1	2								
BGRO	1									
SAPS	2	2	2		3				1	
HAIR	2	2	3	1	3					3
FLIC	3		3	1						
HUMM	2	2	3	1	2	2	2	3	3	
WFLY	2	2	2	2	3	2		3		
TSWA		1			3	3				
CROW	2	2	2	2	2	2	2	2	2	2
RAVE	2	2	2		3					
CHIC	2	2	2	2					1	2
NUTH	1	2		1						
CREE	1	2	2	2	3	3				
WREN	2	2	2	2	2	2	2	3		
ROBI	2	1								
VARI	2	2	2	2						
HERM	2	2	2	2	3					3
SWAI	2	2	2		3	3	2	3		
KING	2	2	2	2						
OWCW	2	2	2	2	2	2	2	2	2	2
TOWN	2	2	2	2	2	1	1			1
WILS		1								
SISK	2	1	2	1			1	3		
CROS	2	2	2	2	2		3	2		1
JUNC	1	1	3							
FOXS	3	2		2	2	2	2	2		
SONG	2	2	3	2	2	2	2	2	2	2
Total spp.										
1989	24	27	16	17	8	9	10	6	5	7
1991	21	21	20	14	16	10	9	10	4	6
BOTH	19	21	15	13	8	7	8	5	3	4

Key to acronyms:

BAEA = Bald Eagle, SSHA = Sharp-shinned Hawk, PFAL = Peregrine, BGRO = Blue grouse, SAPS = Read breasted sapsucker, HAIR = Hairy woodpecker, FLIC = Northern flicker, HUMM = Rufous Hummingbird, WFLY = Western flycatcher, TSWA = Tree Swallow, CROW = Pacific crow, RAVE = Common raven, CHIC = Chestnut backed chickadee, NUTH = Red breasted nuthatch, CREE = Brown creeper, WREN = Winter wren, ROBI = American robin, VARI = Varied thrush, HERM = Hermit thrush, SWAI = Swainson's Thrush, KING = Golden crowned kinglet, OCWA = Orange crowned warbler, TOWN = Townsend's warbler, WILS = Wilson's warbler, SISK = Pine siskin, CROS = Red crossbill, JUNC = Dark-eyed junco, FOXS = Foxs sparrow, SONG = Song sparrow.

TABLE 4. Average number of individuals oberved per point count for each species in the 7 sampling classes in the 1989 sample. For class definitions see Table 1; N = number of point counts per class; r = correlation coefficient of regression of island classes on species scores, p = level of significance of r (ns = non significant, * = p < 0.05 (absolute values of r greater than 0.71), ** = p < 0.01. Species are ranked according to decreasing values of r.

CLASSES	R	1	2	3	4	5	6	r	p
N	24	16	22	19	25	16	16		
SISK	0.54	0.56	0.50	0.31	0.12	0.06		+0.96	**
VARI	0.58	0.62	0.23	0.26	0.24			+0.87	*
CROS	0.75	0.87	0.91	0.47	0.32	0.31	0.12	+0.86	*
CREE	0.33	0.31	0.18	0.31	0.20	0.12		+0.86	*
CHIC	0.97	0.94	0.73	0.68	0.92	0.37	0.62	+0.86	*
WFLY	0.58	0.94	0.41	0.74	0.40	0.37		+0.82	*
JUNC	0.12							+0.61	ns
ROBI	0.08							+0.61	ns
SAPS	0.62		0.09	0.10	0.04			+0.59	ns
TOWN	1.58	1.12	1.18	1.53	1.04	1.19	0.44	+0.57	ns
HAIR	0.17	0.06	0.09	0.05	0.12	0.12		+0.41	ns
HERM	0.29	0.31	0.27	0.68	0.64	0.06	0.12	+0.39	ns
NUTH		0.12	0.04	0.16				+0.37	ns
BGRO	0.04				0.04			+0.32	ns
RAVE	0.12			0.10	0.04	0.06		+0.26	ns
KING	0.17	0.12	0.59	0.16	0.20	0.37	0.06	+0.11	ns
WREN	0.97	0.94	0.91	1.10	1.32	1.31	0.81	-0.07	ns
WILS					0.08			-0.20	ns
FLIC					0.12			-0.20	ns
CROW	0.29	0.19	0.18	0.10	0.44	0.75	1.94	-0.64	ns
OCWA	0.21		0.32	0.21	0.28	0.75	0.75	-0.80	*
FOXS					0.36	1.06	0.62	-0.84	**
SONG			0.32	0.05	0.20	0.56	1.25	-0.88	**
HUMM	0.04		0.04	0.05	0.21	0.69	0.62	-0.90	**

TABLE 5. Average number of individuals oberved per point count for each species in the 5 sampling classes of the 1991 sample. For class definitions see Table 1; N = number of point counts per class; r = correlation coefficient of regression of island classes on species scores, p = level of significance of r (ns = non significant, * = p < 0.05 (absolute values of r greater than 0.87); ** = p < 0.01. Species are ranked according to decreasing values of r.

CLASS	R	3	4	5	6	r	P
N	16	14	5	4	14		
CHIC	1.25	1.14	1.00	0.83	1.00	0.82	n.s.
CROS	0.44	0.93	0.80	0.83	0.14	0.30	n.s.
JUNC	0.31	0.00	0.00	0.00	0.00	0.71	n.s.
ROBI	0.06	0.00	0.00	0.00	0.00	0.71	n.s.
BGRO	0.06	0.00	0.00	0.00	0.00	0.71	n.s.
WILS	0.19	0.00	0.00	0.00	0.00	0.71	n.s.
WFLY	1.19	0.93	1.80	0.83	0.29	0.70	n.s.
RAVE	0.19	0.36	0.20	0.00	0.00	0.67	n.s.
CREE	0.19	0.29	0.40	0.17	0.14	0.60	n.s.
HAIR	0.19	0.29	0.00	0.17	0.07	0.60	n.s.
VARI	0.75	0.50	0.00	0.67	0.07	0.50	n.s.
NUTH	0.25	0.00	0.00	0.17	0.00	0.45	n.s.
WREN	1.12	1.64	1.40	1.17	0.93	0.40	n.s.
SISK	0.00	0.14	0.00	0.00	0.00	0.35	n.s.
HERM	0.44	0.79	0.20	0.67	0.36	0.30	n.s.
FLIC	0.06	0.00	0.00	0.33	0.00	0.11	n.s.
KING	0.31	0.57	0.00	0.67	0.14	0.10	n.s.
TOWN	0.56	1.71	1.20	1.33	0.64	-0.10	n.s.
OCW	0.00	0.36	0.00	0.00	0.36	-0.29	n.s.
FOXS	0.00	0.29	0.00	0.83	0.21	-0.41	n.s.
SAPS	0.44	0.00	0.60	0.50	0.50	-0.56	n.s.
SWAI	0.00	0.00	0.00	0.00	0.07	-0.71	n.s.
SONG	0.00	0.00	0.00	0.50	1.00	-0.89	*
HUMM	0.06	0.07	0.40	0.33	0.86	-0.90	*
CROW	0.19	0.57	1.00	1.33	1.50	-1.00	**

Species composition, area and vegetation structure

We studied changes in species composition among island classes by analyzing the variation in the frequency with which individual species were observed among the island classes (Spearman correlation rank test).

The variation of the average number of species observed per point count among island classes (a different way to look at variation in observation frequency among samples) and their analysis by a Spearman rank correlation test reveal (Tables 4 and 5) that land bird species can be ranked along a gradient of response to decreasing island area, from species showing a significant decrease in observation frequency when island area decreases (these species are often missing from the smaller islands), to species showing a significant increase in their observation frequency as island area decreases. The latter species reach their highest frequencies of observation in the smaller island class. Whereas the former response pattern is consistent with expectations from species area curves, the latter one contradicts these expectations and presumably depends on the fact that, for certain species, small islands present more suitable habitat than large islands.

Although we exclusively censused islands uniformly covered by Northwest Pacific coastal forest, variation in vegetation structure and abundance of dominant plant species occurs and may affect bird species occurrence. We especially wanted to identify what variation in vegetation occurs in parallel with variation in island area and what does not by examining the correlation matrix computed for habitat variables (our unpublished results).

Average values of vegetation structure and composition for each sampling class are shown in Appendices 1 and 2). Our results for the 1989 sample show that variables such as the % of cover in vegetation layer 16-32m, the % of cover of Hemlock, or the % of cover of Alder are positively correlated with island area. The percent of cover of Alder, in turn, is positively correlated with the % of cover in the 16-32 m layer. Three variables (% of cover in the 1-2 m and in the 0.5-1 m layer and % of cover of Salal are negatively correlated with island area. The other habitat variables vary independently of island area.

Preliminary results show that the group of species which are more frequently observed on the smaller islands (they have negative Spearman rank correlations in Tables 4, 5) have distributions that are also correlated with high cover of Salal (and thus dense bush cover), with higher % cover of Sitka spruce, and with lower canopies. Examples are Northwestern Crow, Rufous Hummingbird, and Fox and Song Sparrows. Conversely, the distributions of the Common Raven, Pine Siskin, Varied Thrush, Red breasted Sapsucker, Dark eyed Junco, American Robin and Blue Grouse are primarily restricted to larger islands (although significance level are not always reached in the Spearman rank correlation test). The Winter Wren and the Golden-crowned kinglet are examples of species with ubiquous distribution, not affected by island size. It may be relevent that these are the smallest birds, and hence presumably require smaller areas for feeding.

CONCLUSIONS

When completed,the analysis and interpretation of these results should provide us with a better grasp of the determinants of land bird distribution and land bird ecology in the islands of South Moresby. In particular the respective role of island area, island isolation and vegetation features in these distribution will probably be clarified. Our observations can also serve, together with other data sets already collected on land bird distribution on these islands, as a base for the future monitoring of land bird population in this area.

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APPENDIX 1. Mean values of habitat variables recorded for each island size class. All are given as proportion (%) of cover, except for MAXC (maximum height of canopy) and CHEI (canopy height), both of which are in metres. HEML = western hemlock, SPRU = Sitka spruce, CEDA = western red cedar, ALDE = alder spp., ELDE = elder, CRAB = crabapple, SALA = salal, HERB = herbs, MOSS = mosses, BSOI = bare soil, DWOO = dead wood, OV32 - 0.5-1 are height classes in metres, OV32 = over 32 m, N = numberr of point counts in each island area class.

CLASSES	R	1	2	3	4	5	6
N	24	16	22	19	25	16	16
HEML	32.4	62.4	43.5	41.6	27.8	15.7	21.8
SPRU	42.5	20.4	41.1	24.1	40.6	52.5	53.8
CEDA	13.1	11.3	2.9	25.8	22.8	14.4	17.6
ALDE	12.1	5.6	9.8	5.9	5.4	8.0	3.8
ELDE	0	0	0.5	0.3	0	1.4	0.1
CRAB	0	0	0	0.5	0.2	0.3	1.1
SALA	0	4.9	3.4	12.8	15.3	28.9	61.6
HERB	9.2	3.4	23.3	10.2	6.6	14.1	10.6
MOSS	47.7	39.6	39.7	54.3	46.4	35.6	15.6
BSOI	39.4	57.3	34.4	36.2	41.8	30.3	56.2
DWOO	24.0	39.1	23.7	17.2	23.4	19.7	8.8
MAXC	36.4	43.7	34.3	38.6	38.3	32.1	30.7
CHEI	30.1	32.8	25.9	32.4	32.1	28.1	26.1
OV32	16.9	27.3	13.0	28.9	38.3	10.3	14.5
CHEI	30.1	32.8	25.9	32.4	32.1	28.1	26.1
OV32	16.9	27.3	13.0	28.9	38.3	10.3	14.5
16-32	46.6	32.0	40.1	23.0	16.8	32.6	19.6
8-16	4.5	9.4	13.2	7.3	6.9	13.1	8.9
4-8	5.6	5.3	5.9	9.3	7.7	6.6	4.5
2-4	4.1	4.2	5.9	9.3	7.7	6.6	4.5
1-2	3.4	6.9	5.2	17.4	11.5	24.3	56.9
0.5-1	0.5	0.6	2.8	5.2	3.7	18.3	12.5

APPENDIX 2. Mean values of habitat variables recorded for each island size class. Conventions as in Appendix 1.

CLASSES	R	3	4	5	6
N	16	14	5	6	14
HEML	42.81	56.07	49.00	50.17	42.36
SPRU	24.87	39.64	31.00	41.67	31.43
CEDA	31.25	0.71	20.40	7.67	28.36
ALDE	1.06	4.00	0.00	0.67	0.00
ELDE	0.13	0.36	0.20	0.17	0.07
CRAB	0.00	0.00	0.00	0.00	0.29
SALA	18.00	0.50	6.40	0.00	39.64
HUCK	3.56	2.50	2.40	2.50	4.57
SALM	0.00	0.07	0.00	0.00	0.00
HERB	0.37	2.14	0.00	0.00	0.71
MOSS	83.94	53.57	73.00	57.50	37.50
BSOI	13.25	40.36	25.00	42.50	55.79
DWOO	41.25	39.29	39.00	36.67	25.36
MAXC	46.69	40.43	44.60	42.17	36.79
CHEI	37.69	34.07	37.00	36.17	30.71
OV32	28.75	33.21	28.00	47.50	16.50
16-32	25.94	27.50	36.00	15.00	36.43
8-16	13.31	13.29	8.80	3.67	9.29
4-8	10.81	10.29	5.20	7.83	6.71
2-4	9.25	6.64.	8.00	11.50	8.28
1-2	17.19	4.07	7.40	15.17	40.93
.5-1	1.31	0.14	3.00	6.83	8.21
.25-.5	0.00	0.07	0.00	5.83	2.14
0-.25	0.00	0.71	0.00	0.00	1.43