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BRITISH COLUMBIA SEABIRD COLONY INVENTORY: REPORT #5 - WEST COAST VANCOUVER ISLAND

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INTRODUCTION

Almost half a million seabirds are currently estimated to breed at 72 sites along the west coast of Vancouver Island (Rodway *in press* - Fig. WV-1; Table WV-1). There are 93 historic nesting sites in this region, but a number of small colonies of Pelagic Cormorants (*Phalacrocorax pelagicus*), Black Oystercatchers (*Haematopus bachmani*) and Glaucous-winged Gulls (*Larus glaucescens*) were not occupied on recent surveys (Rodway *et al.* in prep.; Vermeer *et al.* in prep.; this study). Storm-petrels (*Oceanodroma furcata* and *O. leucorhoa*), predominantly Leach's Storm-Petrels, comprise 80% of the total nesting seabird population, 90% of which nests on only two colonies, Gillam Islands and Solander Island. Solander Island supports most of the Cassin's Auklet (*Ptychoramphus aleuticus*) and Tufted Puffin (*Fratercula cirrhata*) populations breeding in the region.

The entire region was surveyed in 1975, and most colonies were located at that time (Campbell 1976). Previous and subsequent surveys of local areas provided comparative counts for surface-nesting species in specific areas (Campbell and Stirling 1968; Guiguet 1971; Hatler *et al.* 1978; Carter *et al.* 1984). Prior to 1988, population estimates for burrow-nesting species were based on explorations and incomplete sampling methods, and were difficult to compare between years.

The primary goal of the 1988 survey was to obtain baseline estimates for burrowing species that could be used to monitor future population trends and identify current and potential threats to those populations. All species were censused at all colonies between Gillam Islands and McQuarrie Islets, and on Cleland Island from 6 to 17 July (Fig. WV-1). Seabird Rocks was surveyed on 26 and 30 July. Colonies south of McQuarrie Islets which were known to support only surface-nesting species were not surveyed in 1988. Vermeer *et al.* (in prep.) censused Pelagic Cormorants and Glaucous-winged Gulls at all colonies along the west coast of Vancouver Island in 1989. Results from that survey are briefly summarized here (see Summary and Conclusions).

Breeding distribution and populations of Marbled Murrelets (*Brachyramphus marmoratus*), which are assumed to nest in this region, are unknown. Sealy and Carter (1984) derived at-sea population estimates of Marbled Murrelets in Barkley and Clayoquot sounds in 1982. Current population levels have not been investigated. Special survey methodology will be required to address the unique conservation problems presented by this species (Sealy and Carter 1984; Rodway 1990).

As part of follow-up studies to the Nestucca oil spill, which impacted the west coast of Vancouver Island in January and February of 1989 (Rodway *et al.* 1989), the senior author returned to Solander Island on 28 to 30 May 1989. The colony was resurveyed and results were compared to those obtained in 1988. Detailed data from both those surveys are presented in this report.

Known threats to nesting seabirds in this region include oil pollution, gill-net fisheries, human disturbance and predation. Checleset Bay and Barkley Sound attract many recreational boaters, and some colonies of cormorants may have declined or been abandoned as a result (Hatler et al. 1978). Carter and Sealy (1984) documented gill-net mortality of Marbled Murrelets, Common Murres (*Uria aalge*) and Rhinoceros Auklets (*Cerorhinca monocerata*) in Barkley Sound. Mink (*Mustela vison*) have been sighted on Cleland Island and were suspected on Thomas Island. They were likely responsible for much of the predation observed. The presence and impact of mink on those colonies should be monitored.

Many of the colonies in and north of Barkley Sound are included in the proposed Pacific Rim National Park, and Solander Island, Cleland Island, the islands in Checleset Bay, and Race Rocks have protective status as Provincial Ecological Reserves.

METHODS

Census methods were selected according to the area, habitat, and species of birds nesting on an island (Nettleship 1976). Because all colonies along the west coast of Vancouver Island are on small islands, it was possible to explore the entire area of those islands to determine colony extent and appropriate census techniques.

1. Total Count. Total nest counts were made for Pelagic Cormorants, Black Oystercatchers and Glaucous-winged Gulls unless nests were inaccessible. Population estimates equal the number of nests counted. In inaccessible areas, numbers of gull nests were estimated to be half the number of adults present on territories. Within the text, lists of nests counted use these abbreviations: Sta - Start; Emp - empty; E - egg; Y - young.

Total numbers of Pigeon Guillemots (*Cepphus columba*) seen around colonies were counted, but no standardized observation techniques were employed (see Nettleship 1976), and no attempt was made to estimate actual nesting populations.

2. Partial count. On Seabird Rocks, colony area of burrowing species was too small to be effectively sampled with line transects, but too extensive to perform a total burrow count in the time available. To obtain estimates of burrow numbers a partial count was conducted. All burrows were counted in about half the colony area. Numbers of burrows in the rest of the colony were estimated by counting burrows in representative portions of different habitat areas, and then extrapolating burrow density to the remainder of each habitat area sampled.

3. Line Transects With Quadrats. Line transects were used to estimate breeding populations of burrowing species on all colonies except Seabird Rocks (see Partial Count).

3.1. **Transect location.** Transects were run throughout accessible colony areas. On all transected colonies except Solander Island, evenly spaced transects were run on parallel bearings across colony islands. Transects were spaced 50-75 m apart. On Solander Island, placement was modified due to steep terrain. We attempted to sample 1% of the area of a colony. That value was the maximum sampling effort we found possible within the time allotted.

3.2. **Quadrats:** Quadrats were set at predetermined intervals along transect lines. Along shore, the first quadrat occurred at the edge of the vegetation, unless that was inaccessible. Plots ranged in size from 1x1 m to 3x3 m, and spacing varied from 5 to 15 m. The size was selected so that an average of at least one burrow occurred in each quadrat. The density of burrowing encountered in most areas was best sampled with smaller, more frequent plots (Savard and Smith 1985).

Burrows were counted within each quadrat and their entrance characteristics recorded: location (ie, under grass tussocks, tree roots, shrubbery, ferns etc.), accessibility (whether it was obscured, or obstructed), and signs of activity (droppings, feathers, etc.), both at the entrance and in the tunnel. Each burrow entrance was explored to elbow length. If within this distance, entrances connected into the same tunnel, only one burrow was recorded and the number of entrances was noted. Habitat parameters were measured: distance from shore, altitude, slope, percent and species composition of ground cover, shrub cover, and forest canopy. To place the quadrat in the context of the overall habitat, tree species, percent composition, and average size (for forested islands), and general terrain features were documented for the area surrounding each quadrat within a radius equal to half the distance between quadrats. Evidence of predation (eggshells, carcasses, feather piles) within each

quadrat was recorded. Detailed analyses of habitat data are not included in this report but will be presented in subsequent documents.

3.3. **Colony area**: Colony area was defined to include all portions of an island where burrows with recent signs of activity (droppings, feathers, regurgitated food, fragments of eggshell or egg membrane, worn entrances or tunnels, excavation, or fresh nesting material) were located. If burrows were located, but no signs of recent activity were observed in an area, the colony was considered abandoned. If there were no burrows within a quadrat, the surrounding area was searched for colony evidence to determine if the plot fell within the colony and should be used in density calculations.

Distance, elevation, and slope measurements taken along the transects, as well as during the exploration, were used to draw colony areas on detailed topographic maps or air photos. The horizontal surface area of the colony was measured on that map with a compensating polar planimeter. Adjusting for slope, the area of the colony was given by:

$$C_s = A_h T^2 (\cos \Theta)^{-1}$$

where C_s is the colony surface area, A_h is the area on the map, T is the scale of the map, and Θ is the mean slope along the transects. The colony area calculations take into account the average uphill slope, but not the undulations between quadrats or between transects. Therefore our calculations give a conservative estimate of the total surface area available to birds for nesting.

3.4. **Burrow density**: Counts from all plots within colony areas were used to calculate average burrow densities. Densities are quoted plus or minus one standard error. On figures, burrows/ha is abbreviated to b/ha.

3.5. **Burrow occupancy**: The percentage of burrows that actually contained nesting birds was determined by complete examination of a sample of burrows. If an adult, egg, chick, or freshly hatched egg membrane was found, the burrow was considered occupied. Burrows were considered empty if all tunnel branches were explored and none of the above were found. Signs such as a well worn entrance or droppings were not used to distinguish between occupied and empty burrows. Exploring burrows longer than an arm's reach required digging one or more access holes until the end was reached. Excavated holes were immediately patched with sticks and soil. To minimize disturbance, adults were not pulled from burrows except to confirm species identification.

To obtain a representative sample of the entire colony, we attempted to determine the occupancy of every burrow within surveyed quadrats. Where that was not feasible, we selected plots from different areas of the colony and explored every burrow in each plot selected. For Cassin's Auklets on Solander Island in 1989 we selected plots randomly and fixed the sample size at five burrows per plot. On other colonies plot selection was arbitrary and number of burrows in each sample varied. Occupancy tables within colony accounts indicate the distribution of quadrats where occupancy data was obtained.

Occupancy was not determined on small Cassin's or Rhinoceros auklet colonies. In those cases the median British Columbia occupancy rate for each species was used to estimate nesting population (see Rodway *et al.* 1988).

Occupancy rate was calculated according to the formula:

$$R = \frac{\bar{x}}{\bar{y}}$$

where x_i is the number of occupied burrows in the i^{th} quadrat, and y_i is the total number of occupied plus empty burrows in the i^{th} quadrat and $\bar{x}$ and $\bar{y}$ are, respectively, the mean of the x_i and y_i over all quadrats.

The variance of R is calculated from:

$$Var(R) = \frac{\bar{x}^2}{\bar{y}^2}\left[\frac{s_x^2}{\bar{x}^2} + \frac{s_y^2}{\bar{y}^2} - \frac{2s_{xy}^2}{\bar{x}\bar{y}}\right]$$

where s_x is the standard error of $\bar{x}$, s_y is the standard error of $\bar{y}$, and s_{xy}^2 is the covariance of $\bar{x}$ and $\bar{y}$ (Kendall and Stuart 1963).

The standard error of R is the square root of Var(R).

3.6. **Total burrows and nesting population estimates:** The total number of burrows (**B**) is the product of the overall average density of burrows, as determined in the quadrats, and the total area of the colony. **B** multiplied by the occupancy rate, (**R**) gives an estimate of nesting pairs (**P**). Calculations are quoted plus or minus one standard error.

$$P = BR$$

The variance of P is calculated from

$$Var(P) = B^2\,Var(R) + R^2\,Var(B) - Var(B)\,Var(R)$$

The standard error of P is the square root of Var(P).

4. Distinguishing species:

The burrows of different species are often mixed. This presents problems for surveyors when burrow contents cannot be determined. Identification of burrows must then be based on indicative signs found in the burrow or at the burrow entrance. We developed a set of criteria for distinguishing burrows of storm-petrels, Cassin's Auklets, Rhinoceros Auklets and Tufted Puffins: size of entrance; wear at the entrance; droppings in and around the burrow entrance; regurgitated food (for Cassin's Auklet); feathers found in the burrow; eggshell fragments found in the burrow; and odour.

Storm-petrels (*Oceanodroma furcata* and *O. leucorhoa*) were found nesting in conjunction with Cassin's Auklets, Rhinoceros Auklets and Tufted Puffins. Little difficulty was encountered differentiating storm-petrel burrows according to size (5-7cm wide). The musty odour of petrels was also helpful.

Cassin's Auklets were found nesting in the same areas as Rhinoceros Auklets and Tufted Puffins. The size of burrows of those species are generally distinct: Cassin's Auklet burrows are 10-12 cm wide, Rhinoceros Auklet burrows are 12-15 cm wide, and Tufted Puffin burrows are 15-18 cm wide. Droppings, regurgitated food, eggshell fragments, and feathers provided more conclusive evidence.

Rhinoceros Auklets and Tufted Puffins have relatively clean burrow entrances compared to Cassin's Auklets, which often leave white fecal streaking along the approach and into the entrances of their burrows. This distinction is less useful in grassy areas, and during rainy weather, since droppings do not accumulate under those conditions. The droppings of Rhinoceros Auklets are large, generally globular, pale yellow with black, viscous blobs, and are often deposited to one side of the burrow entrance. Tufted Puffin droppings are whitish or yellowish, and are often released during flight or take-off, though they are sometimes deposited near the burrow entrance. Cassin's Auklet droppings have a more arresting odour than either Rhinoceros Auklet's or Tufted Puffin's, as does their regurgitated food, some of which they invariably lose at the entrance to their burrows when delivering it. The entrance and vicinity of Rhinoceros Auklet and Tufted Puffin burrows are more extensively trampled and worn than those of Cassin's Auklets.

Abdominal feathers (which are often lost in burrows) of each species can be distinguished by their colour pattern (size is not reliable). The overall colour of Cassin's Auklet and Rhinoceros Auklet feathers are similar, but the colour pattern of the feather plumules are distinct. Cassin's Auklet plumules are mostly dark with a tip of white, while the colour of Rhinoceros Auklet plumules is uniform greyish white and is similar to that of the base of the main feather. Abdominal feathers of Tufted Puffins have dark rather than white ends. Eggshell fragments of all three species are white and are difficult to distinguish unless a substantial portion of the shell is present and can be identified by size.

5. Predation:

During exploration, notes were kept of all signs of predation or mortality encountered. Areas around Bald Eagle (*Haliaeetus leucocephalus*), Peregrine Falcon (*Falco peregrinus*), and Common Raven (*Corvus corax*) nests, and around river otter (*Lutra canadensis*) runs and dens were examined in detail. This gave an indication of the degree and the kind of species being preyed upon. To quantify the level of predation, we calculated the density of prey remains recorded in quadrats, using the minimum possible number of birds represented by the evidence found. We assumed that one feather pile represented one bird. Estimates only allow coarse comparisons between colonies because surveys occurred at various times in the nesting season. It underestimates total predation because plots only sample remains left within the colony before the end of the season.

6. Staging:

Near dusk, during part of the breeding season, Rhinoceros Auklets aggregate on the water adjacent to colony areas, and then circle in large wheels around nesting slopes, in typical puffin fashion (Harris 1984; see Rodway *et al.* 1990). This behavior occurs on Cleland Island (Rodway pers. obs.), but it was not monitored in 1988. Thus no specific information on staging was available for this report.

7. Time:

Times quoted are Daylight Savings Time. Subtract one hour from Daylight Savings Time to calculate Pacific Standard Time.

WV-410 CLELAND ISLAND

92 E/1

Including rock off northwest corner (named "Murre Reef")

Location: Clayoquot Sound west of Vargas Island. 49°10'20"N 126°05'24"W

Land status: Provincial Ecological Reserve.

Date of visit: 7-9 July 1988.

Colony access: Boat landings on the southeast beach and on the northwest beach at high tide.

Base camp: There is a small research cabin above the northwest beach. No water is available.

Observers: A. Burger, D. Garnier.

Census method: Line transects: 33 quadrats, 3x3 m (except for plots 7 & 8 on transect 2 which were 1x1 m for storm-petrels and 3x3 m for other species), surveyed at 15 m intervals along 5 parallel transects run 50 m apart across the island at 76 or 256° (Fig. WV410-1). Transects 1,3 and 5 were begun on the west side, and transects 2 and 4 were begun on the east side. Lengths of transects in order from 1 to 5 were 63, 131, 126, 100, and 32 m. Burrow occupancy was determined in arbitrarily selected plots along transects. Contents of additional Rhinoceros Auklet burrows were determined in a 5x5 m plot located at the northwest corner of the colony (Fig. WV410-1). A total count was conducted of Glaucous-winged Gull nests.

Description: Cleland Island has been described and lists of flora and fauna given by Campbell and Stirling (1968), Ward (1973) and Hartwick (1974). The island, formerly known as Bare Island, is devoid of trees, but has a lush covering of grass, forbs and shrubs over the higher central area, which rises to 10 m elevation, surrounded by extensive perimeter rock. There are small, shell beaches around the island. The total area of the island is 7.7 ha, 3.2 of which are vegetated. Salmonberry and wild rose (*Rosa* sp.) form a thicket down the middle of the vegetated section, with *Elymus*, *Heracleum*, *Maianthemum* and other forbs covering areas to either side. Bracken mixes with shrubs and herbs in some areas.

Nesting species:

Storm-petrel: Storm-petrels were nesting in grass and forb habitat along the west and southeast sides of the island (Fig. WV410-1). Burrows occurred along the perimeter but not in the center of the salmonberry and rose thicket. Density tended to be higher along transects 2 and 3 between 15 and 45 m from the western edge of the vegetation (Table WV410-1). In the nine burrows in which species were identified, Leach's Storm-Petrels outnumbered Fork-tailed Storm-Petrels 8 to 1 (Table WV410-2). All Leach's Storm-Petrels were incubating; the Fork-tailed Storm-Petrel burrow held a chick.

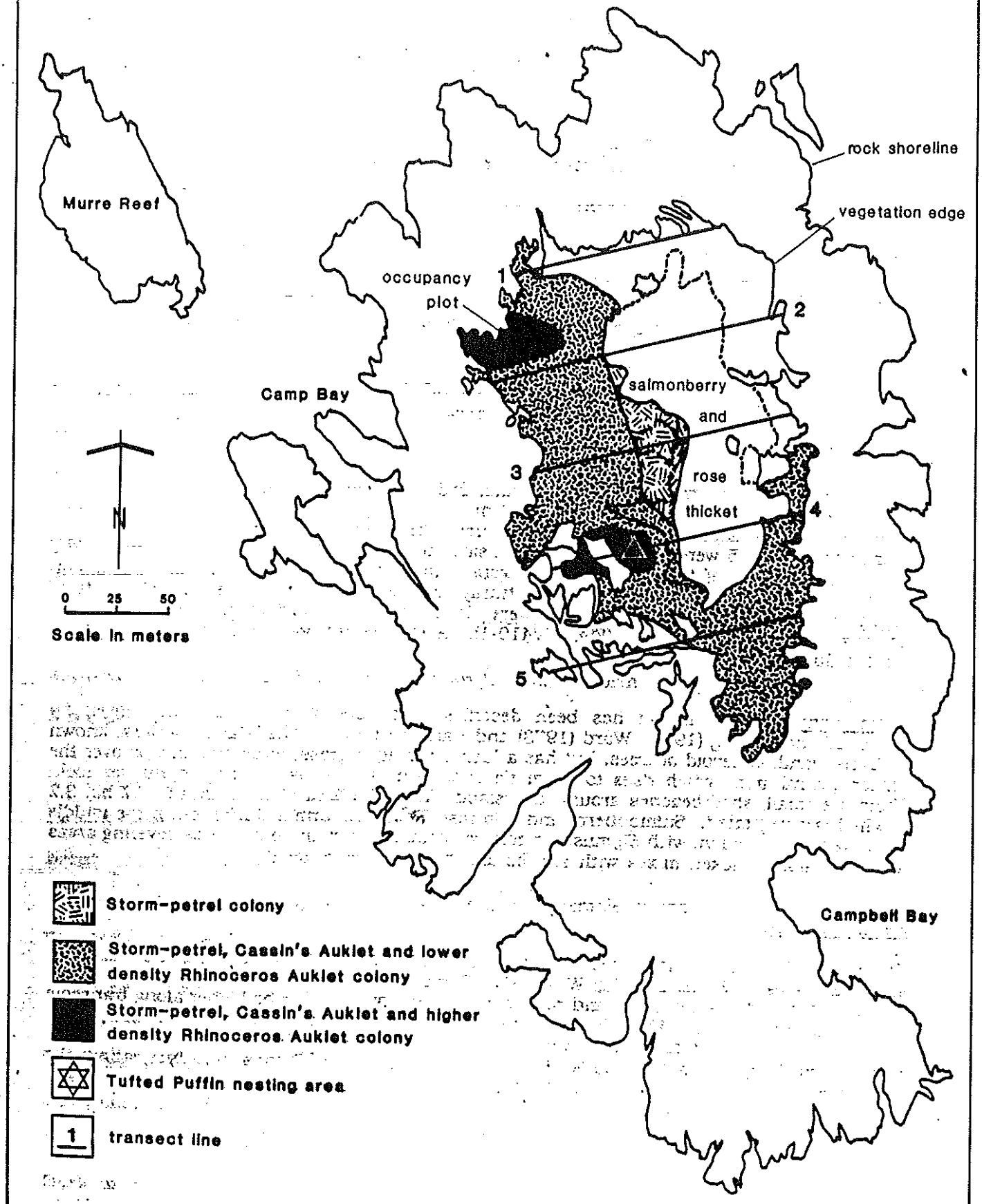

Figure WV410-1. Seabird colony areas on Cleland Island in 1988. Scale is distorted between the main island and "Murre Reef".

1988 Population estimate:

Number of sample plots: 17 (137 m^2 - 0.9% of colony)

Average density: 4765 ± 2338 burrows/ha

Colony area: 1.6 ha

Total burrows: 7624 ± 3741

1988 Occupancy rate: 83.3 ± 17.5% (10 of 12 known)

Species ratio: 11% Fork-tailed to 89% Leach's Storm-Petrels

1988 Nesting population:

Fork-tailed Storm-Petrel: 699 ± 366 pairs

Leach's Storm-Petrel: 5652 ± 2960 pairs

Table WV410-1. Number of storm-petrel burrows in 3x3 m plots along transects on Cleland Island in 1988. Plots considered outside the colony are indicated by a dash.

Transect	Plot 1	2	3	4	5	6	7	8	9
1	-	-	-	-	-				
2	-	-	-	-	-	-	3[a]	3[a]	1
3	0	3	3	5	0	2	-	-	-
4	0	1	-	-	0	0	1		
5	0	3	0						

[a] plots were 1x1 m.

Table WV410-2. Occupancy of storm-petrel burrows on Cleland Island in 1989.

Location Transect	Plot	Fork-tailed Empty	Fork-tailed chick	Leach's Adult +egg	Leach's Cold egg	Total Occup.	Total known
2	8			1		1	1
3	3			2		2	2
3	4		1	3	1	5	5
3	6	2				0	2
4	2			1		1	1
4	7			1		1	1
Total		2	1	8	1	10	12

Black Oystercatcher: An overall count of oystercatcher nests was not obtained. Five nests were confirmed: 1 held 1 egg; 2 held 2 eggs; 1 held 3 eggs; and 1 held 1 egg 1 chick. Nests were composed primarily of shell chips with some rock bits.

Glaucous-winged Gull: Gulls were nesting in perimeter rocky and grassy areas. A total of 1622 nests were counted (Table WV410-3). Nests were made of grass plus some *Fucus* in nests close to the water. The majority of birds were still incubating. Two dead chicks were recorded.

Table WV410-3. Glaucous-winged Gull nests on Cleland Island in 1988.

	Contents									
Start	Empty	1E	2E	3E	2E1Y	1E2Y	1E1Y	3Y	2Y	1Y	Total
32	55	156	387	664	23	46	49	46	89	75	1622

Common Murre: No murres were observed nesting.

Pigeon Guillemot: A total of 205 birds were counted around the island at 1430 h on 8 July. Two nests were found: 1 under a log with 1 egg; and 1 with 2 eggs in a burrow.

Cassin's Auklet: Cassin's Auklets burrows were found over most of the same area as storm-petrels. They did not extend as far from shore along transect 3 as storm-petrels, and tended to be most abundant near the shore edge of the vegetation (Fig. WV410-1; Table WV410-4). Chicks had already fledged at the time the survey was conducted and no occupancy was determined.

1988 Population estimate:

Number of sample plots:	15 (135 m^2 - 0.9% of colony)
Average density:	733 ± 277 burrows/ha
Colony area:	1.5 ha
Total burrows:	1073 ± 406
1988 Occupancy rate:	not determined
Use median British Columbia rate:	75% (Rodway *et al.* 1988)
1988 Nesting population:	805 ± 305 pairs

Table WV410-4. Number of Cassin's Auklet burrows in 3x3 m plots along transects on Cleland Island in 1988. Plots considered outside the colony are indicated by a dash.

Transect	Plot 1	2	3	4	5	6	7	8	9
1	-	-	-	-	-				
2	-	-	-	-	-	-	1	0	1
3	3	0	0	0	-	-	-	-	-
4	2	0	-	-	2	0	0		
5	0	0	1						

Rhinoceros Auklet: Rhinoceros Auklets were nesting in the same area as Cassin's Auklets (Fig. WV410-1; Table WV410-5). Two areas near the northwest (940 m^2) and southwest (680 m^2) ends of the colony were identified as having higher density burrowing during exploration (Fig. WV410-1). Sampling of those areas along transects was not sufficient to allow calculation of different densities. The contents of 4 burrows were determined along transects: 3 held chicks and 1 held an incubating adult. Of 6 burrows in the 5x5 m occupancy plot, 2 held chicks, 1 held an incubating adult, and 3 were too deep to dig. This sample of 7 burrows with known contents was considered too small to calculate an occupancy rate, and the median rate for British Columbia was used to estimate nesting population.

1988 Population estimate:

Number of sample plots:	15 (135 m^2 - 0.9% of colony)
Average density:	880 ± 370 burrows/ha
Colony area:	1.5 ha
Total burrows:	1288 ± 542
1988 Occupancy rate:	not determined
Use median British Columbia rate:	77% (Rodway *et al.* 1988)
1988 Nesting population:	992 ± 417 pairs

Table WV410-5. Number of Rhinoceros Auklet burrows in 3x3 m plots along transects on Cleland Island in 1988. Plots considered outside the colony are indicated by a dash.

Transect	Plot 1	2	3	4	5	6	7	8	9
1	-	-	-	-	-				
2	-	-	-	-	-	-	0	0	1
3	0	3	4	0	-	-	-	-	-
4	0	0	-	-	0	0	2		
5	0	2	0						

Tufted Puffin: A maximum of 10 puffins were seen. Two burrows were encountered in plot 7 on transect 4, and a total of six pairs were estimated nesting in that area (Fig WV410-1). Breeding was not confirmed.

Predation: No predation was recorded in 1988. A mink was observed on the island in 1982, and at least 12 Rhinoceros Auklets were suspected to have been killed by mink (Kaiser unpubl.). In 1985, four decapitated Tufted Puffins were found in burrows, also suspected to have been killed by mink (Kaiser unpubl.).

Associated species:

Brandt's Cormorant

Peregrine Falcon - 1 female

Western Gull - 2

Glaucous-winged/Western Gull hybrid - some

Ancient Murrelet - 1 adult

Northwestern Crow - 10

Other birds and mammals sighted:

Sooty Shearwater - 1

Brant - 3

Harlequin Duck - 5

Whimbrel - 2

Black Turnstone - 1

Western Sandpiper - 1

Table WV-1. Summary of seabird breeding populations on the west coast of Vancouver Island. Estimates are of breeding pairs, except numbers in brackets for Pigeon Guillemots and Tufted Puffins, which represent individual birds. Total populations are given as individual birds to include numbers of Pigeon Guillemots and Tufted Puffins at colonies where no breeding population estimate was obtained. Data codes and sources are explained on previous page.

SITE CODE	SITE NAME	FTSP	LSPE	BRCO	PECO	BLOY	GWGU	COMU	PIGU	CAAU	RHAU	TUPU	HOPU	TOTAL BIRDS	SURVEY YEAR(S)
WV-010	Gillam Islands	42000t	72000t		8	13	646		11x(45)			S(3)		229382	1988
WV-020	Rowley Reefs				1	2								6	1988
WV-030	Rugged Islands					1	2		S(2)					8	1988
WV-040	Gould Rock					4	0							8	1988
WV-050	Clerke Islet					3	29		2x(8)					72	1988
WV-060	Hackett I.						0							0	1988
WV-070	Guilliams I.					0(4)								0	1988
WV-080	Solander I.	0t	70000t		464	1	347e		1x(107)	34000t		3100t(700)	S(6)	215937	1988,89
WV-090	Yule Rock					(2)	0		(0)					0	1988
WV-100	O'Leary Its.				41	1	117		4x(5)					326	1988
WV-110	Cuttle Its.					0	0		(0)					0	1988
WV-120	Skirmish Its.					1								2	1988
WV-130	Bunsby Is.					7	124							262	1988
WV-140	Clara It.					4	93		3x(29)					223	1988
WV-150	Thomas I.	0t	7300t			10	7		S(16)					14650	1988
WV-160	"St. Pauls" Its.					0	0		(0)					0	1988
WV-170	"Favourite" Its.					0	0							0	1988
WV-180	"Amos" Reefs				0				(0)					0	1988
WV-190	Hohoae I.				0									0	1988
WV-200	White Cliff Head				1				(0)					2	1988
WV-210	Moos It.		E		0	17	148		S(5)			(0)		335	1988
WV-220	Thornton Is.	S	700t		125	13	1053		1x(19)			S(4)		3805	1988
WV-230	"Mimulus" Its.					5	222							454	1988
WV-240	"Crag" Rocks				0	3	75							156	1988
WV-250	Munsie Rocks				0	9	28		S(3)					77	1988
WV-260	Nipple Rks.				0	3	149		S(2)					306	1988
WV-270	Volcanic Its.		50e		89	6	153		1x(12)			2 (2)		612	1988
WV-280	Diver It.					5	33		(0)					76	1988
WV-290	"Calm" Rocks					6	5		S(4)					26	1988
WV-300	Grassy I.		0			16	188		S(23)					431	1988
WV-310	Clark I.				0	5	16		3x(29)			S(5)		76	1988
WV-320	McQuarrie Its.				2	37	203		3x(18)			(0)		502	1988
WV-330	White Rock					1								2	1975
WV-340	Ensanada It.					1	1		5e(6)					10	1975
WV-350	Cameron Rks.					1								2	1975

cont'd

Table xx. (cont'd)

SITE CODE	SITE NAME	FTSP	LSPE	BRCO	PECO	BLOY	GWGU	COMU	PIGU	CAAU	RHAU	TUPU	HOPU	TOTAL BIRDS	SURVEY YEAR(S)
WV-360	Justice Rk.					2								4	1975
WV-370	"Kanim" Coast				24+				S(49)					97	1982
WV-380	Monks It.					1	54							110	1982
WV-390	Leeke Its.					1								2	1975
WV-400	Plover Reefs					2	10		2S(2)					26	1975
WV-410	Cleland I.	700t	5700t			45e	1622	0	2x(205)	800t	1000t	S(10)		19949	1986,88
WV-420	La Croix Group					5	1							12	1975
WV-430	Clayoquot Spit					1								2	1970
WV-440	Gowlland Rocks					1	2		(1)					7	1975
WV-450	"Portland" Rock					1								2	1975
WV-460	"White" I.			0	9	2	61							144	1975,77
WV-470	"Schooner" I.					1	1S							4	1975
WV-480	Lovekin Rk.						0							0	1966
WV-490	Green Point					1								2	1972
WV-500	Sea Lion Rks.			5	25	1	133							328	1977,82,89
WV-510	Cormorant Rock				0	1								2	1972,73
WV-520	Florencia It.				79	7	346	0	S(12)			S(1)		877	1975,82
WV-530	Fletcher's Beach				24									48	1970
WV-540	George Fraser Is.						0							0	1975
WV-550	Starlight Reef			51		10	279	0	S(11)					691	1982,88,89
WV-560	Great Bear Rk.			0	0	4	247		S(8)					510	1982
WV-570	Alley Rock				0	0	20e		S(4)					44	1982
WV-580	Hankin I.				0									0	1975
WV-590	Willis I.					0								0	1975
WV-600	Turtle I.					0	0							0	1975
WV-610	Wouwer I.						0		(1)					1	1975
WV-620	Cree Island								(0)					0	1975
WV-630	Austin I.				0									0	1982
WV-640	Effingham I.				0									0	1982
WV-650	Village Reef					4								8	1975
WV-660	Faber Islets					1	2							6	1975
WV-670	Dempster I.				5									10	1982
WV-680	Gibralter I.				0									0	1982
WV-690	Swale Rock					0								0	1975
WV-700	Rutley Is.				6+									12	1982
WV-710	Baeria Rocks				0	2	175							354	1988
WV-720	Weld Island				0									0	1982

cont'd

METHODOLOGICAL CONSIDERATIONS AND RECOMMENDATIONS

The goal of the inventory program was to establish baseline estimates of breeding seabird populations using replicable survey techniques. Total counts conducted at the appropriate time are readily compared. Partial counts are adequate to detect substantial changes in nesting distribution and population on small colonies. Changes in population estimates for large colonies are more difficult to interpret. The level of precision of estimates derived from systematic sampling along transects depends on the precision of three components which enter into their calculation: colony area, burrow density and burrow occupancy rate. Each component has its own sources of error.

In the methods presented in this report, there is no measure of error for colony area calculations, and its level of precision is unknown. Distance, slope and elevation measurements taken along transects help delineate nesting areas, but precise identification of colony boundaries depends on thorough exploration, careful observations and detailed and explicit note-taking. Sources of error arise whenever observations or field notes are not comprehensive enough to allow unequivocal definitions of colony limits. Training of observers in what evidence to look for, and how to record it unambiguously, is an essential element of an inventory program and directly influences the quality of data obtained. Having some of the same assistants in sequential years, helped maintain an experienced core of surveyors. Accuracy of mapping and measuring colony areas also depends on the scale and quality of available maps or air photos.

The standard error of the average burrow density has been calculated for each site. The level of precision and accuracy depends on burrow distribution, sampling intensity and appropriate selection of quadrat size and spacing. Compromises were made between the level of precision desired and the time required to obtain that level. Average densities for small colonies often have large standard errors because they were sampled with few plots.

Burrow occupancy rates were determined for storm-petrels at all colonies, and for all species on Solander Island. Storm-petrel burrows are relatively easy to explore and all burrows within surveyed plots were examined except on Cleland Island and Seabird Rocks where time was limited. Some burrows were not accessible because they were located under tree roots or logs, and others were not dug because they were too fragile. Storm-petrel occupancy on Cleland Island and Seabird Rocks was determined in arbitrarily chosen plots or areas.

Digging alcid burrows, especially Rhinoceros Auklet burrows, is a laborious and time-consuming task, and it was generally not feasible to determine the occupancy of burrows within all surveyed quadrats. For Cassin's Auklets on Solander Island, quadrats were selected randomly and a fixed sample size was obtained at each plot selected. This method facilitates statistical analysis and comparison, and we recommend it for future surveys. Time was not available to obtain adequate occupancy samples for Cassin's and Rhinoceros auklets on Cleland Island or Seabird Rocks. Research on the variation in occupancy rates within and between colonies, and over time, is required to assess and improve sampling methodology.