The world's largest known nesting colony of Leach's Storm-Petrels on Baccalieu Island, Newfoundland

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Leach's Storm-Petrel (Oceanodroma leucorhda). *Photograph/Geoff LeBaron/VIREO 105/7/009.*

THE BREEDING RANGE OF LEACH'S Storm-Petrel (*Oceanodroma leucorhoa*) in the Northwest Atlantic is centered in eastern Newfoundland. Owing to the species' nocturnal and burrow-nesting habits, the breeding populations and distributions of storm-petrels, first documented in Newfoundland by Peters and Burleigh (1951), have historically been grossly underestimated and are not presently well known. Storm-petrel colonies in Newfoundland are vastly larger than all others in the Northwest Atlantic (Huntington 1963; Montevecchi, *in prep.*), but few quantitative data on colony populations have been generated.

The colony of Leach's Storm-Petrels on Baccalieu Island, Newfoundland, has gone largely unrecognized as an important nesting site for the species (Brown *et al.* 1975; Nettleship 1980). In the present paper, we estimate the breeding population of storm-petrels based on measurements of burrow densities in all nesting habitats and on quantitative estimates of the island's surface areas. Our population figure, which is compared with those of other colonies throughout the world, yields new perspectives of the energy consumption of these birds in the marine ecosystem of the Northwest Atlantic.

Study Area

Baccalieu Island (~6.3 × 1 kilometer, 48°07'N, 54°12'W) is situated off the northeastern tip of Newfoundland's Avalon Peninsula (Figure 1). Leach's Storm-Petrels nest in a variety of habitats over the entire island, but principally occupy grassy-hummocked slopes, boreal forest and *Empetrum* heaths. Smaller, less defined habitats such as herb (grassy areas with more than 60 percent fern or tall herb cover), grassy meadow, and heath mixed with herb or grasses are also utilized by nesting storm-petrels (Sklepkovych 1986). The densest concentrations of storm-petrels occur in the grassy-hummocked areas along

TABLE 1. Percentage (number) of burrow occupancy in grassy-hummocked, forest, and heath habitat plots.

Habitat	Contour	%	Occupied Burrows	%	Burrows With Eggs/Chick
Grass	Level	74.6	(47/63)	69.8	(44/63)
	Slope	67.5	(56/83)	60.2	(50/83)
	Total	70.5	(103/146)	64.4	(94/146)
Forest	Level	71.4	(10/14)	50.0	(7/14)
	Slope	72.4	(21/29)	72.4	(21/29)
	Total	72.1	(31/43)	65.1	(28/43)
Heath	Plots	55.6	(10/18)	50.0	(9/18)
	Transects	52.4	(11/21)	52.4	(11/21)
	Total	53.8	(21/39)	51.3	(20/39)
Grand Mean (Sum)		68.0	(155/228)	62.3	(142/228)

Figure 1. Aerial photograph of Baccalieu Island, located off the northeastern tip of Newfoundland's Avalon Peninsula between Conception and Trinity bays. Photograph/ Canadian Dept. of Mines, Energy, Resources.

the eastern side of the island (Figure 2), and medium and low density concentrations are found in forest and heath regions, respectively. Northern Fulmars (*Fulmarus glacialis*), Northern Gannets (*Sula bassanus*), Black-legged Kittiwakes (*Rissa tridactyla*), Common and Thick-billed murres (*Uria aalge* and *U. lomvia*), Razorbills (*Alca torda*), Atlantic Puffins (*Fratercula arctica*), Black Guillemots (*Cepphus grylle*), Herring Gulls (*Larus argentatus*), and Great Black-backed Gulls (*L. marinus*) also nest on Baccalieu Island, making up the greatest diversity of breeding seabirds at any site in Newfoundland and Labrador (Montevecchi and Tuck 1987). Red foxes (*Vulpes vulpes*) are the island's only resident mammals (Maccarone and Montevecchi 1981; Sklepkovych 1986).

Methods

A Numonics digitizer (Model 1210) was used to estimate the two-dimensional surface area and major habitats of Baccalieu Island from a 1:8650 scaled map. For comparison and additional information, three 1:25,000 aerial photographs (Canadian Dept. Energy, Mines, Resources) comprising the southern, central, and northern portions of the island were also used. A grid of 150-1 cm^2 quadrats was laid over the aerial photographs, and each quadrat was examined with a magnifying lamp or stereoscopic glasses, and the percentage of each habitat type was visually estimated.

To estimate the island's surface area contour analysis was performed on a 1:50,000 map (Canadian Dept. Energy, Mines, Resources). Fifteen transections were drawn perpendicular to longest transverse axis of the island at approximately equal intervals. Cross-sections of the island were plotted and scaled relative to the planar distance (X), and then measured using the Numonics digitizer (Y). The ratio of these values (Y/X) provided an estimate of the proportional increase in surface area of each segment resulting from the island's contour, and the mean of these ratios was used as an estimate of overall increase in surface area due to slope. This procedure assumed that habitats are equally distributed over different contours and as a consequence tends to underestimate grassy-hummocked and forest habitats, because much of the relatively level terrain of the island is composed of heath. Owing to differences in the nesting densities associated with these habitats (see Results), the procedure will also tend to underestimate the breeding population. Two-dimensional considerations of habitat areas would generate errors that greatly exceed those produced by our contour estimation procedure.

A census of holes was made in each habitat to estimate the density of potential storm-petrel burrows. To cover most areas of the island, 57 relatively equidistant sites were preselected on a map. The sampling scheme was stratified according to slope and geographic location. Randomness of the exact location of study plots and transects at these sites was attained by travelling a random compass direction (N, E, S, W) for a distance determined from a random numbers table between 100 and 500 meters in heath, 50 and 100 meters in forest and 25 and 50 meters both in mixed heath and in grassy meadow habitats. Estimates of hole densities in grassy-hummocked and herb habitats were obtained from data collected in association with studies of red fox hunting strategy (Sklepkovych 1986). Both the number of burrows at fox digging sites and at random adjacent control sites were included in the estimates of hole density, which were similar to those at randomly selected sites (Sklepkovych 1986).

During May and June 1984, five-by-ten meter occupancy plots were established in typical grassy-hummocked (n = 4) and forest (n = 4) habitats. Each plot was subdivided into four equal quadrats ($12.5m^2$) of which one was chosen at random. Two plots in each habitat were in areas with ≥30° slope and two were on areas with little or no slope (0–5°). In heath habitat, the density of holes (potential burrows) was very low and variable, and therefore, two 100-meter-square plots were set up in heath areas with high burrow densities (i.e. on the island's periphery), and two 4 x 100-meter transects were set out randomly in typical heath habitat. Holes were examined between July 12 and 22, early in the chick period approximately five to six weeks after egg-laying (Montevecchi unpubl. data; Morse and Buchheister 1979). Diagrams of plots were drawn indicating hole position, distance to adjacent holes, connections between burrows, burrow lengths, general vegetational features and the presence of nest material, adults, chicks, and eggs. Holes ≤20 centimeters long were typically inactive and were not considered to be burrows. Nest chambers with multiple entrances were counted once. The number of confirmed nests excluded burrows that were probable nests but in which nest chambers were inaccessible. For heath, forest, and grass habitats exact occupancy values were used in calculating density; for all other sub-habitat estimates, the overall proportion of nesting burrows and grand mean of the occupancy rates of the three sampled habitats were used.

Results

Physical Habitat Characteristics—The total two-dimensional surface area of Baccalieu Island was calculated to be 523 hectares, approximately 60 percent of which is ≥75 meters above sea level. Analysis of island contour revealed 31–100 percent increases in area ($\bar{X} \pm SD = 59 \pm 19\%$) due to topography, suggesting that the surface area of Baccalieu Island is actually 832 hectares, with 688 hectares providing potential nesting habitat for Leach's Storm-Petrels.

Analysis of aerial photographs and maps yielded estimates of 315 hectares (38%) of heath, 286 hectares (34%) of forest, and 46 hectares (6%) of grassy-hummocked habitats. Smaller, less defined habitats made up 41 hectares (5%), and non-nesting regions (including exclusive puffin nesting habitat, see Montevecchi and Tuck 1987) comprised 144 hectares (17%).

Burrow Occupancy and Density at Habitat Plots.—Table 1 summarizes the percentages of burrow occurrence and occupancy by known nesters at plots and transects in grassy-hummocked, forest, and heath habitats. Sixty-eight percent (155/228) of all accessible nests were occupied by either an adult, chick and/or egg. Percentage of occupancy was similar between grassy-hummocked (71%) and forest (72%) habitats and lower, though not significantly, within the heath habitat (54%). The presence of an egg or chick was used to confirm that a nest was occupied by a breeding pair, the percentage being approximately equal in each habitat (grassy-hummocked 92%; forest 90%; heath 95%; combined $\bar{X}$ = 92% (142/155). Therefore, a minimum of 62.3% (% occupancy × % breeding) of all accessible burrows (N = 228) was estimated to be occupied by breeding pairs. Nearly identical occupancy rates have been found on Great Island, Witless Bay, Newfoundland and on Little Duck Island, Maine. (R. Butler [Department of Science & Math, Univ. Maine, Farmington] *pers. comm.*).

Study plots varied in size and number within and between habitats and therefore, two measurements were calculated: the grand mean of holes in each habitat, in order to obtain a variance estimate, and the mean density of holes based on the total number of holes encountered/total area sampled. In the former measurement, plots

Figure 2. The grassy-hummocked slopes on the eastern side of Baccalieu Island, where Leach's Storm-Petrels nest in abundance. Photograph/B. O. Sklepkovych.

TABLE 2. Estimates of the numbers of nesting pairs of Leach's Storm-Petrels in different habitats on Baccalieu Island, Newfoundland.

Habitat	*Area (N) of Plots (m²)*	*Density (Holes/m²)*	*Est. Density Occupied Burrows*	*Est. Surface Area (ha)*	*Corrected Est. (Breeding Pairs)*
Heath	3100 (23)	0.046	0.017	314.8	54,000
Forest	577 (24)	0.941	0.604	286.2	1,730,000
Grassy-Hummocked	379 (83)	4.166	2.131	52.2	1,111,000
Herb	126 (21)	4.010	2.495	15.4	385,000
Meadow	700 (7)	0.143	0.088	10.8	10,000
Mixed	63 (3)	0.704	0.478	14.6	70,000
Non-Nesting	—	—	—	137.7	—
Total	—	—	—	831.7	3,360,000

≤$2m^2$ were excluded from analysis in an effort to reduce bias toward small plots, then each plot regardless of size was weighted equally. The grand means of the hole densities are presented below, but the mean density of holes of all the plots in a habitat was considered a better estimate and was used to calculate storm-petrel numbers.

Burrow density was the highest in herb and grassy-hummocked habitats and differed significantly among habitat types ($\chi^2_2 = 126.6$, $P < .001$; see Table 2). In other large storm-petrel colonies in Newfoundland, high nesting densities are also found in areas with thick fern cover (R. Butler [Science & Math Dept., Univ. Maine Farmington], *pers. comm.*, Montevecchi, *pers. obs.*). Overall the mean number of holes in grassy-hummocked habitat was similar between areas of low (0–29°) and intermediate (30–59°) slope at $4.3 \pm 0.4m^{-2}$ and $4.2 \pm 0.3m^{-2}$, respectively, and lower ($3.6 \pm 1.2m^{-2}$) within steep (60–90°) areas. In coniferous forests, hole density increased with slope (0–29°, 0.7 ± 0.05; 30–59°, 1.7 ± 0.3; 60–90°, 2.9 ± 1.4). There were no significant differences in the mean lengths of occupied burrows in sloped and level plots within grassy-hummocked (overall $\bar{X} \pm = 38.4 \pm 10.0$ cm) or forest (overall $\bar{X} \pm = 37.5 \pm 12.0$ cm) habitats. Northern ($0.036 \pm 0.013m^{-2}$) and southern ($0.050 \pm 0.008m^{-2}$) heath regions had about five times the density of holes as did the central heath region ($0.008 \pm 0.003m^{-2}$) along the rock backbone of the island. The heath also provided nesting substrate along the island's periphery; this sub-habitat was estimated at five percent of total heath habitat (Sklepkovych 1986).

Table 2 delineates the components of our estimate of the breeding population of Leach's Storm-Petrels on Baccalieu Island. The vast majority of nesting burrows are associated with forest and grassy-hummocked habitat. The estimated breeding population based on contour corrections for the island's surface area is 3,360,000 nesting pairs, with lower and upper 95 percent confidence limits of 3,130,000 and 3,590,000 nesting pairs, respectively.

Discussion

Leach's Storm-Petrels are the most abundant breeding seabirds in the Northwest Atlantic. Owing to their nocturnal and burrow-nesting habits, they are difficult to census. Their colony sites have often been overlooked and their numbers underestimated (Montevecchi and Tuck 1987). Though data on the breeding populations of marine birds in the Northwest Atlantic has increased tremendously in recent decades, Leach's Storm-Petrels remain enigmatic in this regard. On the basis of the present census, this species is now estimated to comprise 80 percent of the seabird population breeding in Newfoundland (Cairns *et al.* 1986a) and to make up a comparable high proportion of the breeding seabird population of the entire Northwest Atlantic region. The major colonies of Leach's Storm-Petrels in Newfoundland are shown in Figure 3.

The Leach's Storm-Petrel population of Baccalieu Island is now the largest documented in the scientific literature. The next largest known colony is located on the Japanese island of Daikokujima, where a breeding population of 1,000,000 pairs has been estimated (Hasegawa 1986). Colonies on Gull and Great Islands in Witless Bay on Newfoundland's east coast (Fig. 3) have been estimated to contain approximately 530,000 and 250,000 nesting pairs, respectively (Nettleship 1980), though the numbers of nesting pairs on these islands may be much higher (L. M. Tuck *in litt.*). Moreover, in Newfoundland and in Alaska (see Lensink 1986) and elsewhere the sizes of many large colonies still require systematic estimation, and many colonies remain to be "discovered."

In recent years, much research attention has focused on population energetics and ecosystem modelling. With regard to marine systems, the lack of information about breeding populations of storm-petrels has led to their being virtually ignored in all

Leach's Storm-Petrel (Oceanodroma leucorhda). *Photograph/Geoff LeBaron/VIREO 105/07/008.*

considerations of the energy requirements of breeding seabird communities. Based on the present information, Cairns *et al.* (1986b) have provisionally estimated that these small animals consume over 50 percent of the energy taken by marine birds that breed in Newfoundland. These considerations allow us to develop more realistic and comprehensive models of the breeding seabird community of the Northwest Atlantic. In this regard, the censusing of Leach's Storm-Petrels is a very important step in understanding and defining the avian component of the marine ecosystem.

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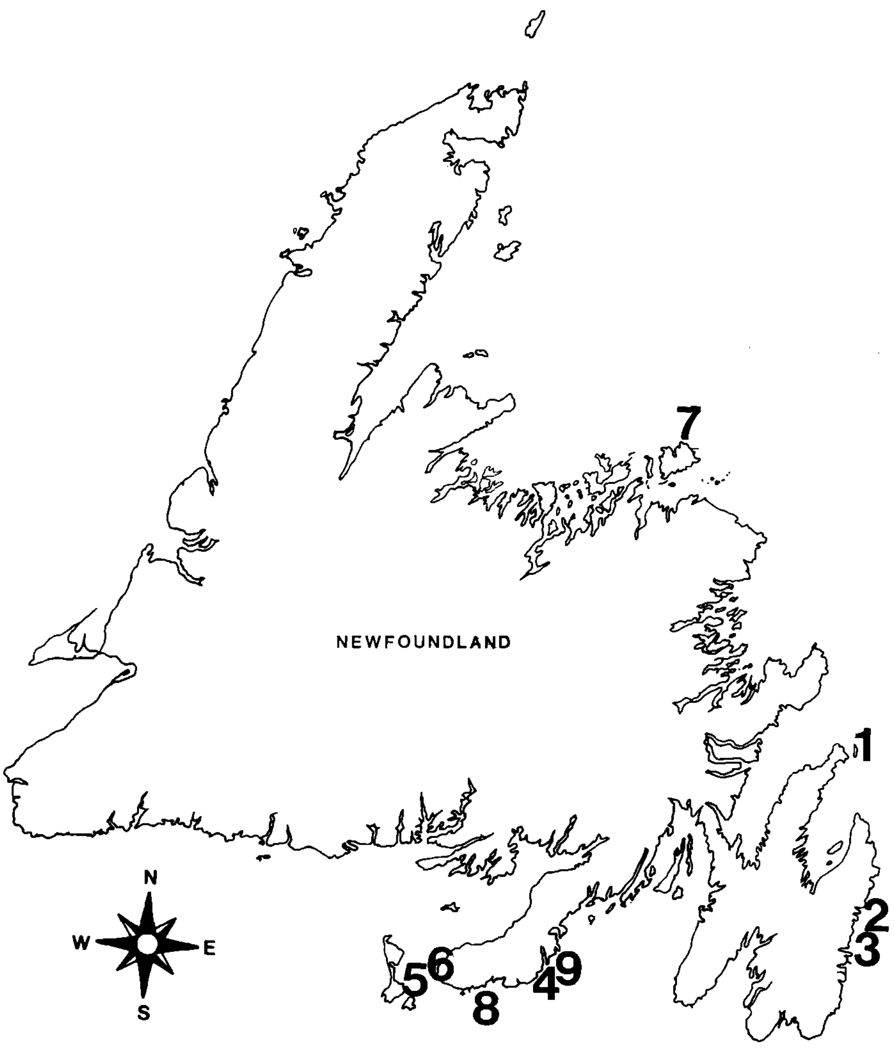

Figure 3. The major colonies of Leach's Storm-Petrels in Newfoundland and on St. Pierre et Miquelon. Estimated numbers of breeding pairs are given in parentheses. Sources of estimates are given in Cairns et al. (1986a). 1 — Baccalieu Island, 48°07'N, 54°48'W (3,360,000), 2 — Gull Island, 47°15.8'N, 52°46.3'W (530,000), 3 — Great Island, 47°11'N, 52°49'W (250,000), 4 — Corbin Island, 46°57.9'N, 55°12.8W (100,000), 5 — Grand Columbier, 46°49'N, 56°10'W (100,000), 6 — Green Island, 46°52.7'N, 56°05.3'W (72,000), 7 — Little Fogo Islands, 49°48'N, 54°07'W (38,000), 8 — Middle Lawn, 46°52.3'N, 55°37.1'W and Offer Lawn, 46°51.4, 55°37.3'W (230,000), 9 — Iron Island, 47°02.5'N, 55°07.5'W (10,000).

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