Leach's Storm Petrel *Oceanodroma leucorhoa* population trends on Bon Portage Island, Canada

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Abstract

Regular estimates of breeding populations are important for detecting declines and for implementing appropriate conservation measures in a timely manner. In Atlantic colonies, Leach's Storm Petrels *Oceanodroma leucorhoa* are in decline at most colonies that have been surveyed. Consequently, the species has recently been uplisted from 'Least Concern' to 'Vulnerable' by the International Union for the Conservation of Nature. On Bon Portage Island, the largest Leach's Storm Petrel colony in Nova Scotia, the last survey was completed in 2001. The aim of this study was to update the population estimate for this colony. Our results suggested that the current population is 38,916 ± 8,749 pairs, a 20% decline in 16 years. Several factors are most likely responsible for this decline, but loss of breeding habitat may be the principle cause on this island.

Introduction

Leach's Storm Petrels *Oceanodroma leucorhoa* are seabirds with a broad geographic range that breed in the northern hemisphere, primarily in the North Atlantic (Huntington *et al*. 1996). Recent surveys have detected sharp population declines at important breeding colonies in Newfoundland, including the world's largest colony on Baccalieu Island (Robertson *et al*. 2006; Wilhelm *et al*. 2015; S. Wilhelm, pers. comm.). Furthermore, this trend is also occurring across the Atlantic, in some United Kingdom breeding colonies (Newson *et al*. 2008; Bicknell *et al*. 2009) and in Iceland (E. Hansen, pers. comm.). Consequently, in December 2016, the International Union for the Conservation of Nature (IUCN) uplisted Leach's Storm Petrel from 'Least Concern' to 'Vulnerable' (IUCN 2016). Given alarming declines in important parts of the species' range, it has become a priority to obtain up to date information about population sizes at larger colonies to monitor global population trends and inform conservation measures.

The largest colony in Nova Scotia, Canada, is on Bon Portage Island (43°28'N, 65°44'W; Huntington *et al*. 1996). Breeding surveys of Leach's Storm Petrel were completed on Bon Portage in 1983 (MacKinnon 1988), 1997/8 (Oxley 1999), and 2001 (DS, unpubl. data) with population estimates ranging from 47,379 (95%

confidence interval [CI] ±11,169) to 57,603 (95% CI ± 12,434). Large confidence intervals are common for population estimates of burrow-nesting species, because accurate assessment of nocturnal burrowing species is a challenge (Oppel *et al*. 2014; Rexer-Hubert *et al*. 2014).

Breeding Leach's Storm Petrels mostly excavate nesting burrows in forested (spruce/fir) and meadow (fern, grass-herb) habitats (Stenhouse & Montevecchi 2000; Wilhelm *et al*. 2015) and the configuration of these vegetation types partly determines distributions of Leach's Storm Petrel burrows on any given island. As such, a change in vegetation type over time may change the distribution of potential habitat for burrows and may influence breeding population size. For a survey to be representative, it requires either systematic sampling across all habitats, or stratified random sampling, and incorporation of ratios of each vegetation type in population estimates (Gregory *et al*. 2004).

The aims of this study were to repeat an island-wide survey of Leach's Storm Petrels on Bon Portage Island, and compare results to previous survey efforts in 1983, 1997/8 and 2001. We used the same methods as Oxley (1999) and Shutler (2001) to facilitate comparisons and estimate population trends.

Methods

Bon Portage Island lies about 4 km off the southern tip of Nova Scotia; the island is c.3 km long, 500 m at its widest, and low-lying, with the highest elevation being c.8 m above the high-water mark. The majority of the Leach's Storm Petrel breeding colony is in the southern part of the island in a forest where Black Spruce *Picea mariana* and Balsam Fir *Abies balsamea* are the predominant tree species. The remaining portion of the population is located on the northern end of the island, also in a forest of black spruce and balsam fir. To a lesser extent, some Storm Petrels also breed in more open habitat, located at both ends of the island, consisting of mostly Bracken Fern *Pteridium aquilinum*.

Following recommendations of Nettleship (1976) for surveying small islands, MacKinnon (1988) used a stratified random sampling method to determine population size of Leach's Storm Petrels on Bon Portage in 1983. He used five transects, 400–600 m long and 200 m apart at the southern part of island, where most of the Leach's Storm Petrels breed. Along transects, 26 5 × 5 m study quadrats were randomly positioned (Table 1) to estimate burrow densities and occupancy rates. MacKinnon (1998) identified suitable habitat using a planimeter on four aerial, 1:10,000 scale, Kodachrome photographs taken by Maritime Resource Management Service in 1978.

Due to random dispersion patterns of nesting burrows, long rectangular quadrats give survey estimates with narrower confidence intervals (Peterson *et al*. 2001). Accordingly, subsequent surveys made on Bon Portage Island used 2.5- × 10-m quadrats. Oxley (1999) used six transects, 400–600 m long and 150 m apart, and selected 79 quadrats in 1999 and 83 in 1998, laid out at 30-m intervals along

Table 1. Summary of methods for 1983 (MacKinnon 1988), 1997, and 1998 (Oxley 1999), 2001 (DS, unpubl. data), and 2017 (this study) surveys of Leach's Storm Petrels *Oceanodroma leucorhoa* on Bon Portage Island.

Method descriptor(s)	1983	1997, 1998	2001	2017
# transects, distance apart (m)	5, 200	6, 150	6, 150	9, 150
# quadrats	26	79 (1997), 83 (1998)	83	131
Quadrat selection	Random	30-m interval	30-m interval	30-m interval
Quadrat dimensions (m)	5 × 5	2.5 × 10	2.5 × 10	2.5 × 10
Time of census	July	August	August	July

transects at the southern end of the island (Table 1). An additional 11 quadrats on two transects were surveyed at the northern end of the island. Suitable habitat was identified using 1:10,000 aerial photographs from 1989 taken by the Nova Scotia Department of Natural Resources. Finally, the survey completed by Shutler in August 2001 followed the same protocol as Oxley (1999), and had 83 quadrats along six transects (independent of transects used by Oxley) in the southern part of the island. Shutler did not survey the northern part of the island.

In 2017, we completed a survey between 20 and 21 July, which was timed to coincide with the late incubation portion of the breeding season when one is most likely to detect breeding adults on eggs or chicks (ILP pers. obs.). Similar to Oxley (1999), we had six transects on the south end of the island and three transects on the north end for a total of 131 2.5-×10-m quadrats (Figure 1). As for the previous two surveys, transects were 150 m apart but were positioned independent of those previously used and quadrats were 30 m apart.

To determine burrow density and occupancy rates, we used playback of Leach's Storm Petrel vocalizations recorded on Kent Island (Elliot 1993). The call was played at c.100 decibels at the entrance of a burrow for 10 seconds and we waited for 15 seconds for a response. Storm Petrel species respond to various degrees to call playback, depending on the time of year and the time of day (Ratcliffe *et al*. 1998) with call playback at night detecting the highest proportion of occupied burrows (Ambagis 2004; Mitchell *et al*. 2004). However, playback does not always elicit a response, so if no response was elicited, we employed the 'grubbing'

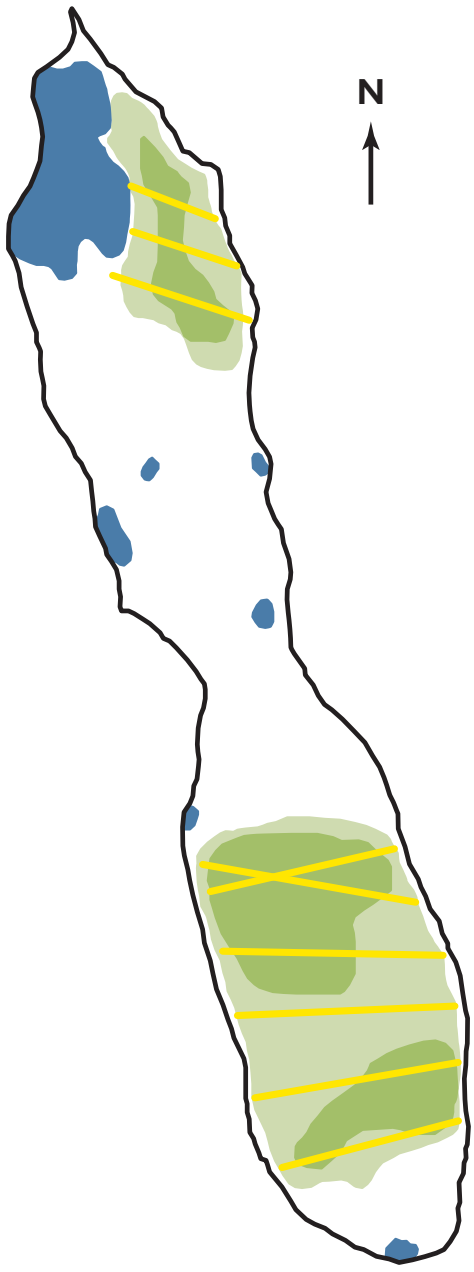

Figure 1. Bon Portage Island. Areas indicated in blue are water bodies, light green areas are former suitable habitat, dark green areas are current suitable habitat, and thick yellow lines are transect locations for the 2017 survey.

technique wherein observers reached into a Storm Petrel hole to determine whether the hole was in fact a burrow, and to determine whether the burrow was active (see below). In previous surveys, if the end of the burrow could not be reached, observers did not use playback, but instead excavated a hole to reach the end of the burrow. In the 2017 survey, if we could not find the end of the burrow, we did not further disturb the habitat; however, we applied the occupancy rate (see below) to those burrows. For all surveys, active burrows were defined as those where observers either detected an adult, an egg, or a chick, or for which there was a response to play-back (2017 only). The occupancy rate was calculated by dividing the number of known active burrows by the number of known empty burrows. Knowing the burrow density and the occupancy rate, we could then calculate occupied burrow density by multiplying by the total suitable area to give us a final estimate. This method thus incorporates burrows for which we did not know contents.

During previous surveys, low-lying easily flooded areas, which are unsuitable for breeding storm-petrels, were not encountered in the forested area in the south of the island. However, during the 2017 survey, some quadrats in that part of the island fell in areas that had no burrows, likely because they were flooded. Therefore, subsequent to the survey, we used current satellite photos of the island (Google Earth 2017), with geo-referencing from handheld GPS positions in the field to delineate areas of unsuitable Leach's Storm Petrel nesting habitat (Figure 1). After determining the total suitable breeding area, the estimated size of the population of Leach's Storm Petrel breeding on Bon Portage Island was extrapolated by multiplying the average density of occupied burrows by the area of suitable habitat.

Results

We surveyed a total of nine transects and 131 quadrats (3,275 m^2 overall). Of those quadrats, 46 (35.1%) were in unsuitable habitat, characterized as areas that were too wet and would have likely drowned eggs, nestlings, or adults. In the remaining 85 quadrats, burrow density was 4.55 ± 4.61 burrows/quadrat (0.18 ± 0.18 burrows/m^2), and the occupancy rate was 0.56 The occupied burrow density was 2.55 ± 2.59 active burrows/quadrat (0.10 ± 0.10 active burrows/m^2). The total suitable area was estimated at 381,077 m^2 (35% less area than in the last survey). The estimated population was 38,916 pairs (95% CI ± 8749, Table 2).

Table 2. Summary of results for 1983 (MacKinnon 1988), 1997, and 1998 (Oxley 1999), 2001 (DS, unpubl. data), and 2017 (this study) surveys of Leach's Storm Petrels *Oceanodroma leucorhoa* on Bon Portage.

Results	1983	1997	1998	2001	2017
Burrow density/m^2	0.29 ± 0.27	0.31 ± 0.19	0.30 ± 0.22	0.35 ± 0.25	0.18 ± 0.18
Occupancy rate	0.34	0.23	0.33	0.28	0.56
Occupied burrow density/m^2	0.10 ± 0.14	0.07 ± 0.09	0.10 ± 0.09	0.08 ± 0.08	0.08 ± 0.09
Suitable breeding area (m^2)	517,000	585,400	585,400	585,400	381,077
Suitable habitat sampled (%)	0.13	0.34	0.35	0.35	0.86
Population estimate (pairs)	54,000	47,379	57,603	48,243	38,916
95% CI of population estimate	146,000	11,169	12,434	10,701	8,749

Discussion

We surveyed Nova Scotia's largest colony for the first time in 16 years, and results indicate a decline of 20% in the breeding population on Bon Portage Island, which we believe is largely attributable to a loss of breeding habitat on the island (Great Horned Owl *Bubo virginianus* predation may be a minor contributor, accounting for an annual mortality of < 1% of the population; Pollet & Shutler 2019). Burrow density and occupancy at other islands in Atlantic Canada range from 0.04 to 1.87/m^2 and from 0.34 to 0.72, respectively (Robertson *et al*. 2006; Wilhelm *et al*. 2015), making burrow density values for Bon Portage Island on the low side. A decline in suitable habitat with the same number of birds would increase the occupied burrow density, yet density has been relatively stable, suggesting that one possible factor for the decline in population is the low adult survival observed on Bon Portage Island (Fife *et al*. 2015). Potential causes of these declines are discussed below.

For a colony the size of the one on Bon Portage Island, estimates of population size are generally obtained via extrapolation of surveyed burrows to an entire island or colony (Catry *et al*. 2003; Lawton *et al*. 2006). Extrapolation will also compound survey errors, so to increase the ability to detect a significant trend, it is important to limit error that may come from temporal or spatial variability (Parker & Rexer-Huber 2016). Whereas some colony-nesting seabirds are very synchronous breeders, Leach's Storm Petrels are not (Blackmer *et al*. 2005). It is therefore important to perform surveys at a time during the breeding season that reduces the probability of missing failed breeders that may abandon a colony early in the breeding season, while at the same time detecting late breeders. To achieve this, one may have to undertake multiple surveys during a single year, but this is labour intensive and prone to damaging fragile nesting habitat of burrow-nesting species.

MacKinnon's (1988) and our 2017 survey were completed in July, whereas Oxley and Shutler's surveys were completed in August. One consequence of performing surveys in August is the likelihood of underestimating a population, because eggs or chicks depredated early in the season will not be included. Indeed, the 1997 and 2001 surveys in August have a lower occupancy rate (0.23 and 0.28, respectively) than in our survey, conducted in July (0.56; Table 2). Based on recent work performed on Bon Portage Island, the median hatch day is 26 July (ILP unpubl. data). To reduce disturbance in the early period of incubation (Blackmer *et al*. 2004), whilst ensuring that most of the burrows that failed during incubation were accounted for, we performed our survey in the third week of July. We recommend that future survey efforts on Bon Portage Island also be conducted around this time. Furthermore, to reduce disturbance associated with conducting surveys during late incubation, we recommend using the call playback technique, and when burrows are grubbed because no response is heard, not to take adults out of their burrows.

When conducting surveys, the likelihood of false negative detections increased when we could not reach the end of a burrow, due to it being either too long or having too many bends around roots or rocks. False negative detections result in

Figure 2. Adult Leach's Storm Petrel *Oceanodroma leucorhoa* off Bon Portage Island. © *Ingrid Pollet*

an underestimate of a population. It is therefore paramount that burrow-checking be done in a very rigorous manner. By using call playback, we reduced disturbance to birds while being more efficient with our time. Leach's Storm Petrels are more likely to respond to call playback during the night than during the day (Mitchell *et al*. 2004); because we did the survey during the day, grubbing after an absence of call playback response increased our detection probability compared to when using call playback alone. However, we could have increased detection probability if we had excavated burrows for which we could not reach the end; we deemed this an unwarranted disturbance to the fragile nesting habitat.

Although the 1.33% annual decline observed on Bon Portage Island is similar to that in other colonies (Wilhelm *et al*. 2015), causes of declines may differ spatially and temporally, and could result from a combination of factors. For example, avian and mammalian predation has been reported in Scotland (Bicknell *et al*. 2009), Newfoundland (Stenhouse & Montevecchi 1999), and Nova Scotia (Pollet & Shutler 2019). Offshore oil and gas platforms within the foraging range during the breeding season are also a potential source of decline, via collision or flare mortality (Ronconi *et al*. 2015), yet most Leach's Storm Petrels from Bon Portage island probably do not encounter offshore platforms during their foraging movements (Pollet *et al*. 2014a). However, they may encounter similar threats during their migration, for which we have limited data (Pollet *et al*. 2014b). In addition, mercury is present in high concentration in Leach's Storm Petrels compared to other seabirds of the Gulf of Maine and while no short-term effects have been detected (Pollet *et al*. 2017), long-term effects still need to be assessed. In the case of Bon Portage Island, a change in vegetation and thus a loss of breeding habitat may be a key factor in the decline. Over the years, vegetation has changed on the island, with large patches of Sphagnum Moss (*Sphagnum* spp.) appearing. This habitat is not suitable for burrow-nesting species and suggests that parts of the island have for unknown reasons experienced changes in drainage and vegetation. Whereas MacKinnon (1988) estimated a suitable breeding area of 517,000 m^2, and Oxley (1999) estimated a suitable area of 585,400 m^2, we estimated only 381,077 m^2, which translated into a 35% decline in suitable habitat. This drop in suitable habitat could in part explain the 20% decline in breeding population size we estimated on Bon Portage Island, and we believe provides support for the hypothesis that habitat loss is the principle cause of the decline for this colony.

Leach's Storm Petrel is an abundant breeding species in the northern hemisphere, but several breeding colonies have experienced sharp declines in recent decades (Robertson *et al*. 2006; Newson *et al*. 2008; Bicknell *et al*. 2009; Wilhelm *et al*. 2015), and it is now considered a 'Vulnerable' species by the IUCN. In the Pacific Ocean, Leach's Storm Petrels have not been the focus of research during the last decades. It is therefore crucial to perform surveys to estimate population size at other breeding colonies to monitor trends and take appropriate conservation actions when required.

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