

SEABIRD POPULATION UPDATE AND TRENDS FROM SIX COLONIES IN NORTHEASTERN NEWFOUNDLAND

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2018 Census Report

1. INTRODUCTION

The many islands of coastal northeastern Newfoundland support nationally and globally important populations of breeding seabirds including storm-petrels, terns, gulls, and auks (Chardine et al. 2013, Wilhelm et al. 2015). Strongly influenced by the productive southward-moving Labrador Current, non-breeding marine predators such as shearwaters and whales also visit the area to forage in summer. Seabirds in Newfoundland face diverse threats including marine and light pollution, legal harvesting, degradation of island colonies, predation pressure, and climate change (Croxall et al. 2012), as well as an environmental regime shift in the 1990's which altered the trophic structure of the community (Rose 2005), influencing prey availability. As seabird populations may act as environmental indicators (Diamond and Devlin 2003), it is important to monitor trends to understand change in marine ecosystems. The objective of this census effort is to update previous population estimates, standardizing the techniques utilized to achieve accurate approximation.

2. METHODS

2.1 Study area

Six islands in northeastern Newfoundland (Fig.1) were selected for seabird population estimates in 2018 due to supporting large colonies and having had previous estimates conducted in the past century.

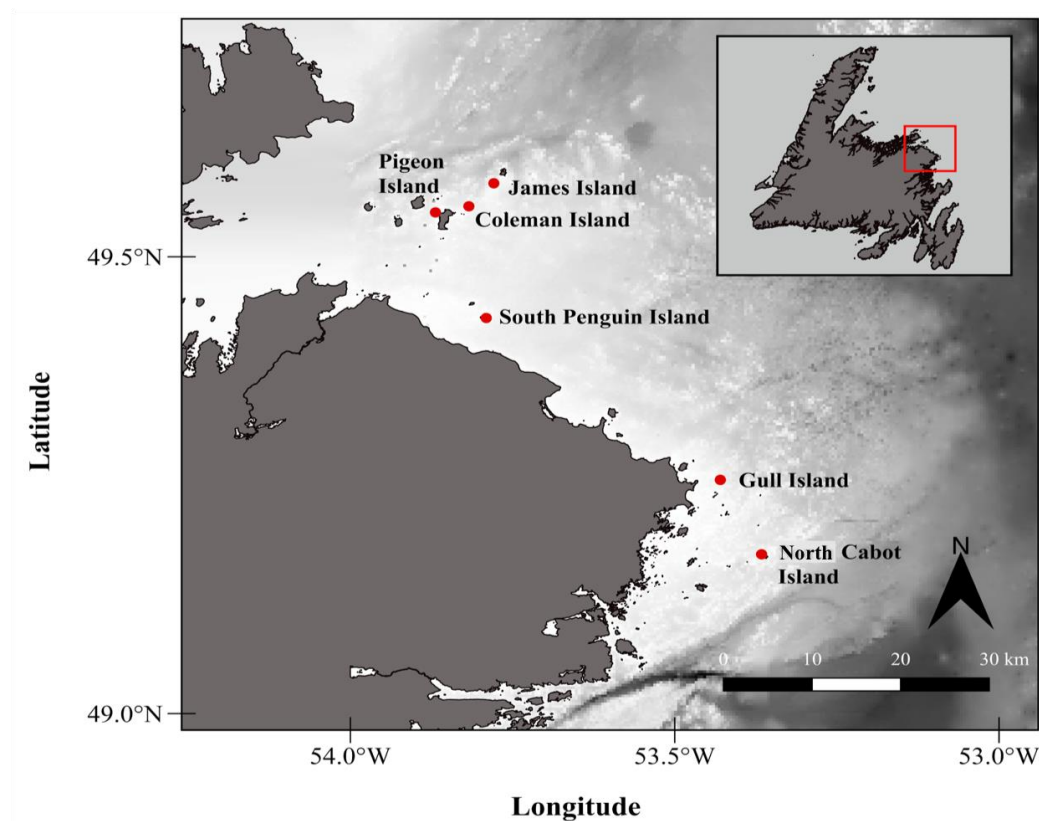


Figure 1. Map of northeastern Newfoundland including all islands censused in 2018.

2.1.1 Wadham Islands

The Wadham Islands are an archipelago of 7 islands and many smaller offshore islets, found within the Wadham Islands and adjacent Marine Area IBA, site: NF013. This area of 12,000 ha was designated to protect significant breeding populations of Atlantic puffins (*Fratercula arctica*) as well as large numbers of wintering common eider (*Somateria mollissima*) (BirdLife International 2018a).

James Island (also called Small Island) (N49.57989°, W53.57989°) is the second-most northerly of the group and is small and low-lying, located ~20 km northeast of Musgrave Harbour. The interior is dominated by iris (*Iris spp.*), raspberry (*Rubus spp.*), and grasses, while the coastline consists of bare rock and a bank of boulders on the eastern side. James Island supports the largest population of puffins in northeastern Newfoundland, the majority of which breed within the boulder bank and the adjoining area of sod burrows.

Coleman Island (also called Green Island) (N49.5549°, W53.8173°) lies ~3.5 km southwest of James Island and has similar habitat types and aspect, although larger, with marshy areas unsuitable for burrow-nesting seabirds. The interior is dominated by dense crowberry (*Empetrum nigrum*) with patches of cloudberry (*Rubus chamaemorus*), ferns and grasses. Areas of boulders on the south and east coast support crevice-nesting puffins and razorbills (*Alca torda*), while puffin sod burrows are found primarily inland of the southern boulder bank and on a small hillock to the southeast.

Pigeon Island (also called Pigeon Rock) (N49.54823°, W53.86882°) is ~50 m west of Peckford Island and is a small (<1 ha) rocky islet ~12 km from the mainland. Consisting primarily of bare rock with an interior of short sward, the island provides habitat for both crevice- and sod-nesters (black guillemots (*Cepphus grylle*), puffins and razorbills), as well as ground-nesting species including gulls and terns. Puffin sod burrows can be found on the south side of the island where the soil is deepest, while the north side is predominantly exposed rock.

2.1.2 Gull and North Cabot Island

Gull and North Cabot Islands lie within the Cape Freels Coastline and Cabot Islands IBA, site: NF025. Designated for its significant wintering population of common eider, the IBA also includes many small islands that support small colonies of various seabird species (BirdLife International 2018b).

Gull Island (N49.24988°, W53.43214°) is a small (<1 ha) rocky islet approximately 2.5 km east of Cape Freels, comprising of steep rocky cliffs with a small meadow vegetated primarily with silverweed (*potentilla sp.*) at the apex. Gull Island provides habitat suitable for crevices-nesting alcids (black guillemots, puffins and razorbills), as well as ground-nesting gulls, while a double-crested cormorant (*Phalacrocorax auritus*) colony is located at the highest point around an automated light station.

North Cabot Island (N49.17155°, W53.36881°) is the larger of the two Cabot Islands, previously known as the ‘Stinking Islands’, due to the masses of guano deposited on the island by seabirds and has a disused lighthouse and a solar-powered light station maintained by the Canadian Coast Guard. The majority of the island is vegetated by meadow and low scrub, supporting a mixed gull colony, while areas of boulders on the shore support small numbers of crevice-nesting alcids. A pond in the centre of the island attracts cormorants and migrating shorebirds. South Cabot Island (N49.16821°, W53.36048°) lies ~500 m to the southeast and has ~10,000 pairs of breeding common murre, the second-largest colony in northeastern Newfoundland after Funk Island (Wilhelm et al. 2015).

2.1.3 Penguin Islands

The Penguin Islands are located ~4.25 km from the mainland, roughly between the Wadham Islands IBA to the west, and the Cape Freels Coastline and Cabot Islands IBA to the east. South Penguin Island (N49.43322°, W53.79049°) is slightly larger than North Penguin Island, which is <2 km to the northwest. Both are flat, with vegetated interiors, and rocky shorelines. South Penguin Island features two sheltered lagoons on the northeast coast, which provide habitat for basking seals, moulting sea ducks, and migratory shorebirds in summer (pers. obs). Dense, wind-stunted balsam fir (*Abies balsamea*), grow in the centre of the island, supporting breeding Leach’s storm-petrel (*Oceanodroma leucorhoa*) (Fig. 2), fox sparrow (*Passerella iliaca*), common redpoll (*Acanthis flammea*) and until recently, bald eagle (*Haliaeetus leucocephalus*), as two old collapsed nests were found. The rest of the island is meadow with some marshy areas, with nesting common eider and gulls, while the interface of soil and boulders on the east side of the island have areas of sod puffin burrows. The banks of boulders themselves host puffins and razorbills.



Figure 2. Leach’s storm-petrel burrow below balsam fir on South Penguin Island, 2018.

2.2 Species

Census effort focused on Leach's storm-petrel, Atlantic puffin, razorbill, and black guillemot. On Pigeon and Gull Islands where transects were employed to cover the entire area, nest counts of other species such as double-crested cormorants, Arctic terns (*Sterna paradisaea*), common terns (*Sterna hirundo*), herring gulls (*Larus argentatus*), great black-backed gulls (*Larus marinus*), black-legged kittiwakes (*Rissa tridactyla*), and common eider have been included. However, on the larger islands where specific habitat was searched for auks and storm-petrels only, populations of the other species were estimated by counting all the adults visible from a single point multiple times throughout the day and selecting the resulting highest count. Therefore, population estimates of these other species from James, Coleman, and South Penguin Islands are not quantified, but merely counts of individual adults and therefore a guide only. The exception is North Cabot Island where simultaneous gull research allowed accurate counts of nests of both herring and great black-backed gulls.

2.3 Breeding bird populations

2.3.1 Population estimates

To estimate numbers of breeding seabirds, pre-existing protocols described in Wilhelm et al (2015) were used. Active nests of ground- or crevice-nesting species (gulls, terns, razorbills, puffins, black guillemots) were counted, while each hole of burrow-nesting species (puffins, storm-petrels) were assigned to one of the following categories: (1) extra entrance to a burrow, (2) too short to be a burrow (<30 cm in length), or burrow (≥ 30 cm in length). Each burrow was assigned a status (i.e. empty, adult, adult and egg/or chick, chick, or unknown if status could not be confirmed). If a surveyor could not reach their arm into a burrow far enough into a puffin burrow to confirm status, a wooden spoon was used to extend their reach. In the case of narrow storm-petrel burrows, endoscopes were used to assess status. Due to the difficulty of counting holes in plots of boulders, only adults, eggs and chicks were counted in such plots. Additionally, for razorbills and black guillemots that flush readily from their nesting crevices, counts of all individuals on the water <100 m from the island were conducted.

For islands small enough to be thoroughly searched (e.g., Pigeon Island, Gull Island), surveyors walked transects to ensure no nests were missed. Starting at one side of the island, surveyors walked 3 m apart, placing pin-flags as they went, back and forth across the island until the entire area was covered. All areas were covered except the inter-tidal zone, which cannot support breeding birds. For larger islands, where more than 200 holes are present, suitable breeding habitat was delineated with a handheld GPS. These included areas of boulder piles used by puffins and razorbills, areas of puffin burrows dug into soil, and dry vegetated areas used by storm-petrels. These areas were made into separate polygons using ArcGIS using a Lambert Azimuthal Equal Area projection, and locations within were randomly selected. These locations were then visited, and a 3 x 3 m plot was created by laying rope anchored by pegs at each corner. All holes within were then assessed using the

methods above. Habitat type and slope were broadly categorized to allow comparison of burrow density among plots. For large areas of exposed rock with a low density of cracks supporting razorbills and black guillemots, a transect method was employed to ensure no burrows were missed in that area.

In order to examine habitat change over time, maps from Robertson and Elliott (2002) for James Island were georeferenced in ArcMap 10.4 and habitat polygons from 1979 and 2001 were replicated for Atlantic puffins and razorbills. As the previous census of Leach's storm-petrels in 2001 used a grid-based methodology, polygons include grid squares where storm-petrels were present. The same process was repeated for a 1979 survey of the Atlantic puffin colony on South Penguin Island.

Occupancy rate was calculated by dividing the number of occupied burrows (i.e. those containing at least an adult and/or an egg/chick) by the total numbers of burrows for which contents were assessed (i.e. occupied and empty burrows) and calculated per plot. Burrows with unknown contents as well as extra entrances and short burrows were not included. Burrow density was calculated as the total number of burrows (including active, empty, and unknown, but excluding short burrows and entrances) divided by the size of the plot (9 m²). The average and standard error (SE) were calculated for both occupancy and burrow density. To obtain estimates of breeding pairs, the product of average occupancy and average burrow density was multiplied by the total area of delineated habitat. Separate calculations were made for different habitat types. For areas containing puffin sod burrows and/or storm-petrel plots, SE of population estimates was calculated by multiplying the standard error of burrow density by the average occupancy by the total area of delineated habitat. For areas of crevice nests as occupancy was not calculated, SE of burrow density was multiplied by habitat area to obtain an overall SE of population estimate. On islands where a species breeds in different habitat types, i.e. puffins in sod and crevice burrows, population estimates were calculated separately, and estimated numbers of breeding pairs added together.

2.3.2 Census effort

Census effort was focused in two time periods, an initial series of island visits focused on delineating habitat and resolving alcid population estimates, followed by a second visit to islands with storm-petrels to estimate their numbers. This was due to the relatively late and extended breeding phenology of storm-petrels when compared to the alcids. We could be sure that census effort in early July would coincide with alcids either incubating eggs or brooding small chicks, while some early chicks may have fledged by late July. However, in late July we could ensure we would not miss late egg-laying by storm-petrels.

3. RESULTS

The first recorded hatch dates for seabird species in the study area in 2018 were: July 7 for black guillemot, July 8 for razorbill, July 11 for Atlantic puffin, and July 25 for Leach's storm-petrel (pers. obs). Therefore, the dates of census effort should reasonably reflect

periods when all breeding pairs can be expected to be incubating an egg or raising a chick, therefore maximizing the effectiveness of the project.

3.1 James Island

3.1.1 Habitat delineation

On June 30 - July 1 habitat types were delineated and alcid occupancy estimated, and on July 31 storm-petrel occupancy was estimated. Puffin sod burrows were found at the interface of boulders and soil around most of the island, with an additional isolated area on a low mound in the south, while crevices containing puffin and razorbill nests were found throughout the boulder bank on the south and east coastline. These three areas were each designated as separate polygons (Fig. 2). Systematic transects of the vegetated interior revealed an association between storm-petrel burrows and slope, and/or raspberry, while flat areas of short and/or tall grass were not productive unless puffin sod burrows were present. Therefore, as none of the 13 plots in flat vegetated habitat with no puffin burrows had storm-petrel burrows, this area was excluded from analysis (Fig. 4). Of note there were storm-petrel burrows dug into the bases of grass tussocks where available.

Table 1. Census results from James Island 2018, including species, estimated number of active nests (including number of adults recorded on the water <100 m from the island for razorbills in parentheses), and previous census results.

Species	Active nests in 2018	Previous census results
Leach's storm-petrel	1,578 \pm 421	1,038 pairs (2001), 11,938 pairs (1984)
Ring-billed Gull	1	Not reported.
Herring gull	~30	50 individuals (2001)
Great black-backed gull	~8	50 individuals (2006)
Arctic tern	0	125 pairs (1945)
Atlantic puffin	16,859 \pm 3,506	6,190 pairs (2001), 19,745 pairs (1994)
Razorbill	2,757 \pm 610 (1,180)	273 pairs (2001)
Common murre	23	Not reported.

3.1.2 Population estimates

Atlantic Puffin

Puffins were estimated to use an area of 20,281 m² in 2018; consisting of both sod burrows and crevices. Sod burrow density averaged 1.06 \pm 0.20 burrows/m² (n=6 plots), with an average occupancy rate of 0.85 \pm 0.08, while crevice density averaged 0.53 \pm 0.17 burrows/m² (n=5 plots). After the addition of 52 occupied crevices counted via area search,

we estimate a total of $16,859 \pm 3,506$ pairs of puffins bred on James Island in 2018, $14,894 \pm 2,884$ in sod burrows and $1,913 \pm 622$ in crevices.

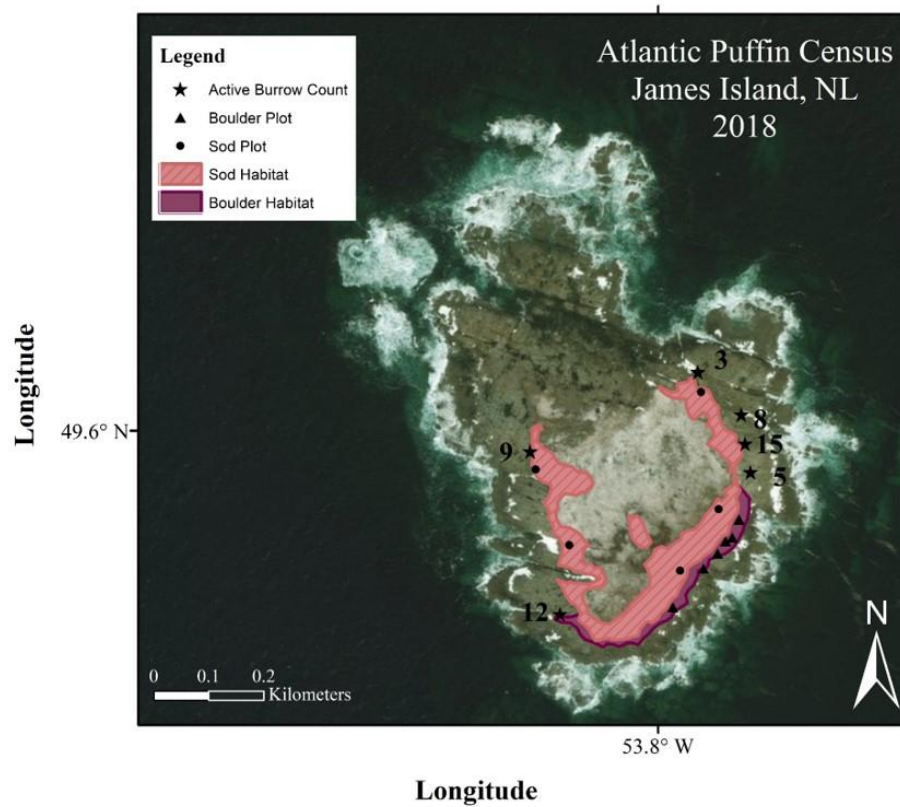


Figure 3. Extent of Atlantic puffin colony by habitat type on James Island, 2018.

Razorbill

Razorbills utilized $3,586 \text{ m}^2$ of boulder habitat in 2018, with crevice density averaging 0.69 ± 0.17 burrows/ m^2 ($n=5$ plots). An additional 287 occupied crevices within areas of large cracks and bare rock were added resulting in a total of 2757 ± 610 pairs breeding in 2018.

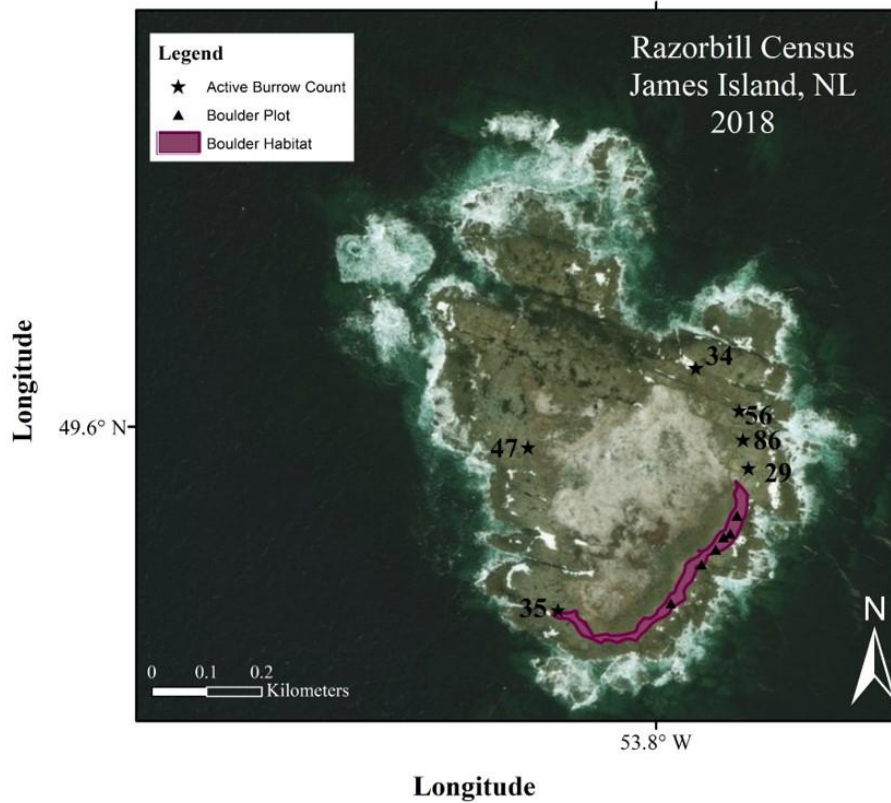


Figure 4. Extent of razorbill colony on James Island, 2018.

Leach's Storm-petrel

Storm-petrels occupied an estimated area of 5,003 m² in the vegetated interior of the island, with burrow density averaging 0.22 ± 0.06 burrows/m² (n=15 plots), with an average occupancy of 0.72 ± 0.07 , and an area of 16,107 m² among puffin sod burrows, with a burrow density averaging 0.16 ± 0.05 burrows/m² (n=9 plots), with an average occupancy of 0.30 ± 0.15 . We estimate a total of $1,578 \pm 421$ pairs of storm-petrels bred on James Island in 2018, 803 ± 200 in the interior and 776 ± 221 among puffin sod burrows.

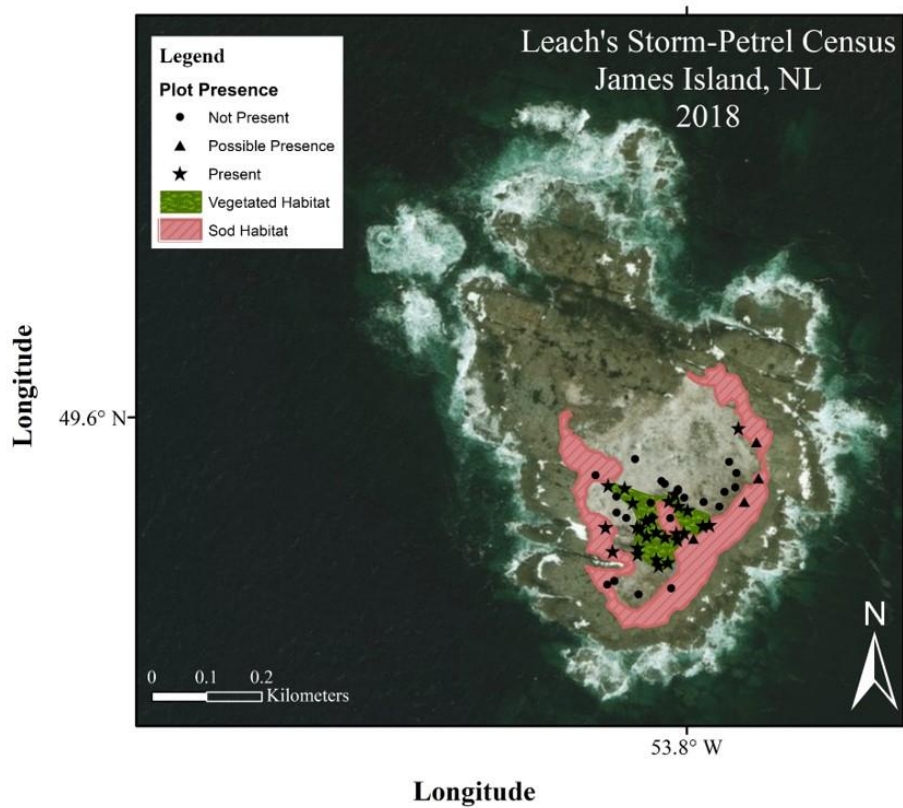


Figure 5. Extent of Leach's storm-petrel colony by habitat type on James Island, 2018.

3.1.3 Comparisons with earlier surveys

The number of breeding puffins has increased dramatically since last estimated in 2001 (Robertson and Elliot 2002), from 6,190 to $16,859 \pm 3,506$. This is similar to an estimate of 19,745 pairs by Russell and Montevecchi 1994 (1996), although not as high as Cairns and Verspoor's (1980) estimate of 25,000 pairs in 1979. The area utilized by puffins has changed since 2001 (Fig. 6). Areas on the western side of the colony have contracted, while areas in the south have expanded to include areas utilized during the prior survey in 1979. The razorbill colony has not changed size or position since mapped in 2001 (Robertson and Elliot 2002), presumably due to being restricted by suitable habitat, although the number of birds has increased (Fig. 7). Storm-petrel numbers may have increased slightly; however, the area where burrows are found has decreased since 2001 (Fig. 8).

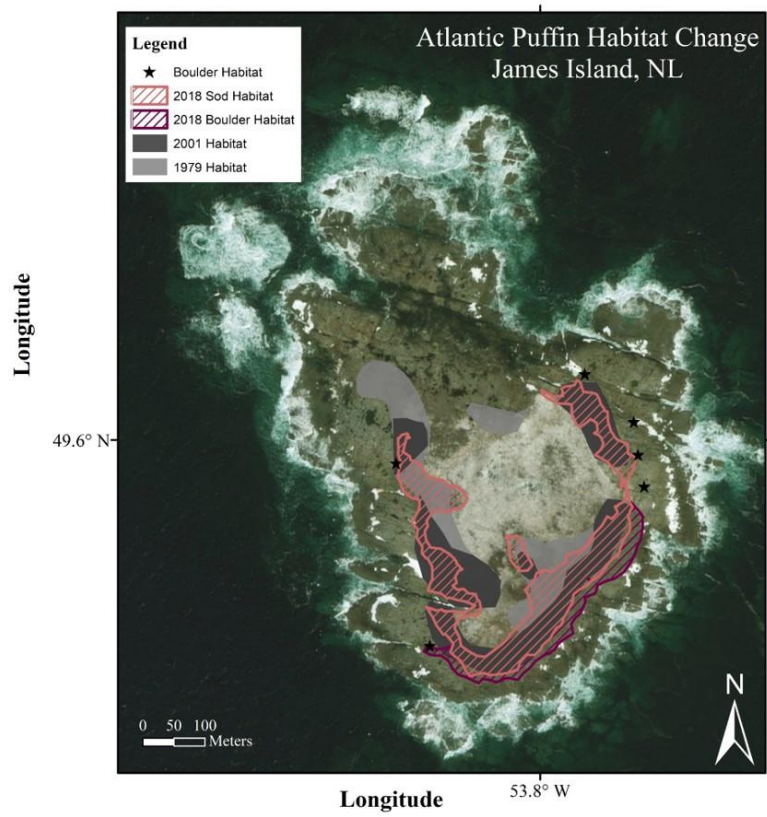


Figure 6. Comparison of the extent of Atlantic puffin colony on James Island among 1979, 2001, and 2018 censuses.

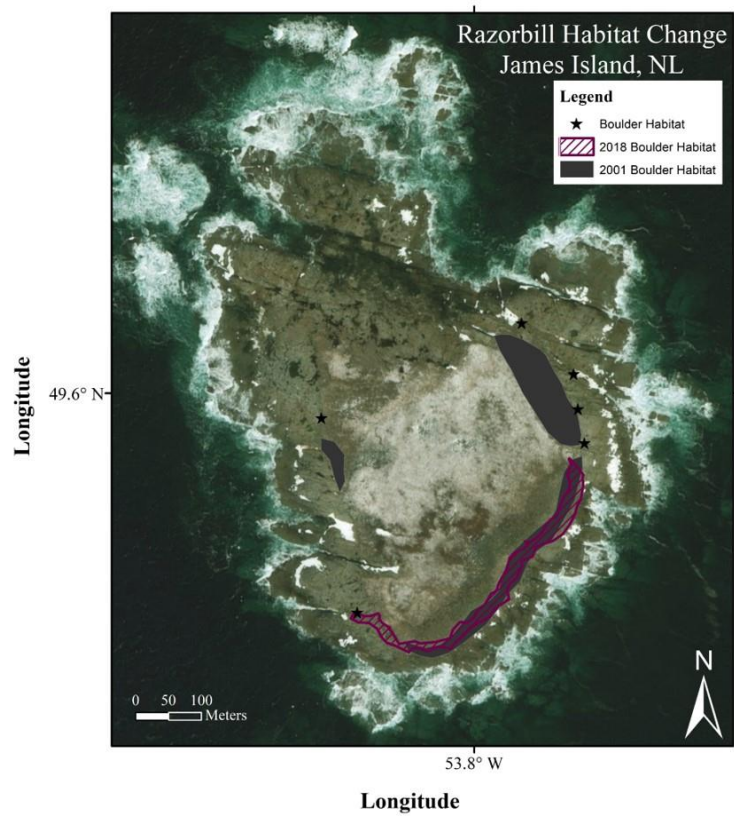


Figure 7. Comparison of the extent of razorbill colony on James Island between 2001 and 2018.

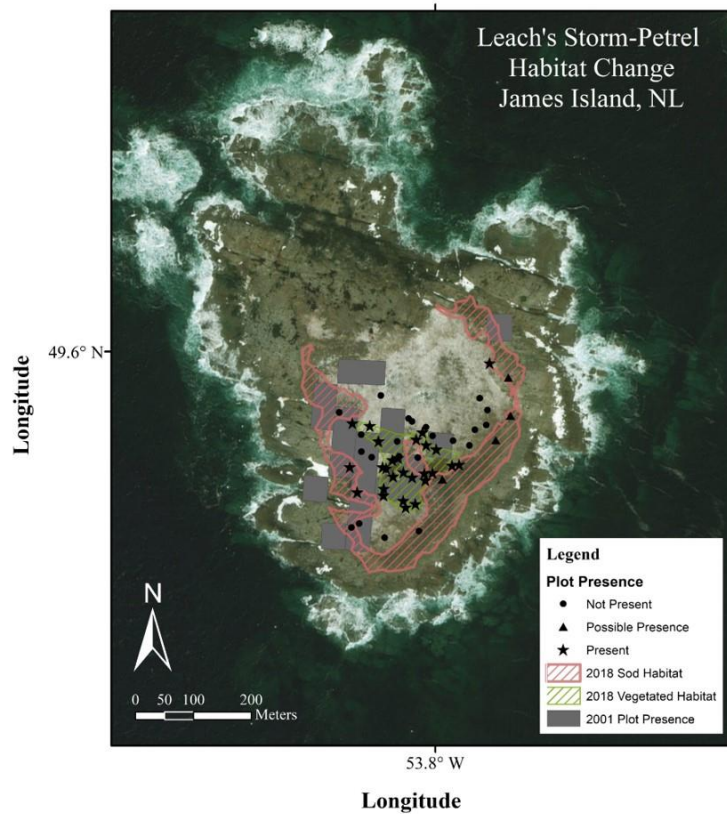


Figure 8. Comparison of the extent of Leach's storm-petrel colony on James Island between 2001 and 2018.

3.2 Coleman Island

3.2.1 Habitat delineation

On July 11, habitat types were delineated and alcid occupancy estimated, while on July 29, storm-petrel occupancy was estimated. Storm-petrel habitat was deemed suitable if dry enough to support burrows. Areas of bog were surveyed via transect, but as no burrows were found, they were excluded. The most densely occupied area was a grassy hillock in the southeast of the island among puffin burrows, and within two small sloping areas of <50 cm high fern. The remaining suitable habitat includes much of the vegetated interior of the island and any areas of puffin sod burrows. Overall, active burrows were only found within plots with a sloping aspect unless there were puffin burrows in the plot, suggesting slope is important for storm-petrels.

Table 2. Census results from Coleman Island 2018, including species, estimated number of active nests (including number of adults recorded on the water <100m from the island for razorbills in parentheses), and previous census results.

Species	Active nests in 2018	Previous census results
Leach's storm-petrel	2,906 \pm 662	5000 pairs (1984)
Herring gull	~35	50 individuals (2001)
Great black-backed gull	~5	50 individuals (2005)
Common tern	4	85 pair (tern sp. 2006)
Atlantic puffin	12,649 \pm 4,520	950 pairs (1984), 3000 pairs (1973)
Black guillemot	(25)	25 pairs (1984)
Razorbill	1,346 \pm 528 (527)	10 pairs (1984)

3.2.2 Population estimates

Atlantic Puffin

Puffins were estimated to use an area of 23,900 m² in 2018; consisting of both sod burrows and crevices. Sod burrow density averaged 0.78 \pm 0.20 burrows/m² (n=5 plots), with an average occupancy rate of 0.62 \pm 0.10, while crevice density averaged 0.58 \pm 0.27 burrows/m² (n=8 plots). After the addition of 38 occupied crevices counted via area search, we estimate a total of 12,649 \pm 4,520 pairs of puffins bred on Coleman Island in 2018, 6,329 \pm 1,592 in sod burrows and 6,282 \pm 2,929 in crevices.

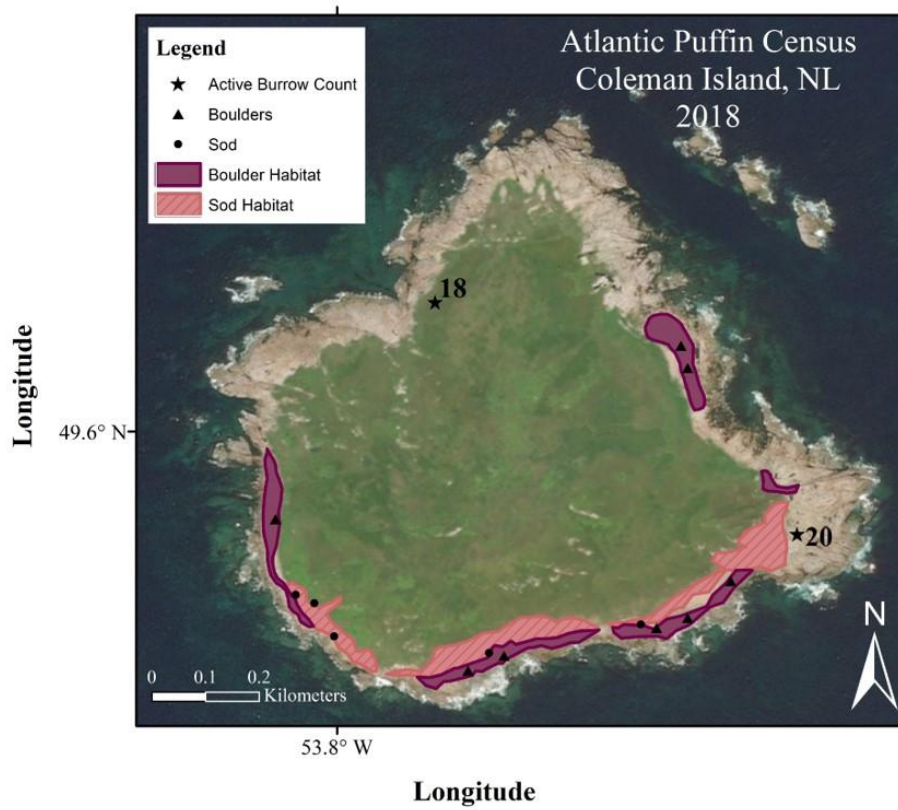


Figure 9. Extent of Atlantic puffin colony by habitat type on James Island, 2018.

Razorbill

Razorbills utilized 10,769 m² of boulder habitat in 2018, with crevice density averaging 0.13 ± 0.05 burrows/m² (n=8 plots), resulting in a total of $1,346 \pm 528$ pairs breeding in 2018. 527 adults were counted on the water from shore on July 11, with most individuals close to the southeastern and western coastline.

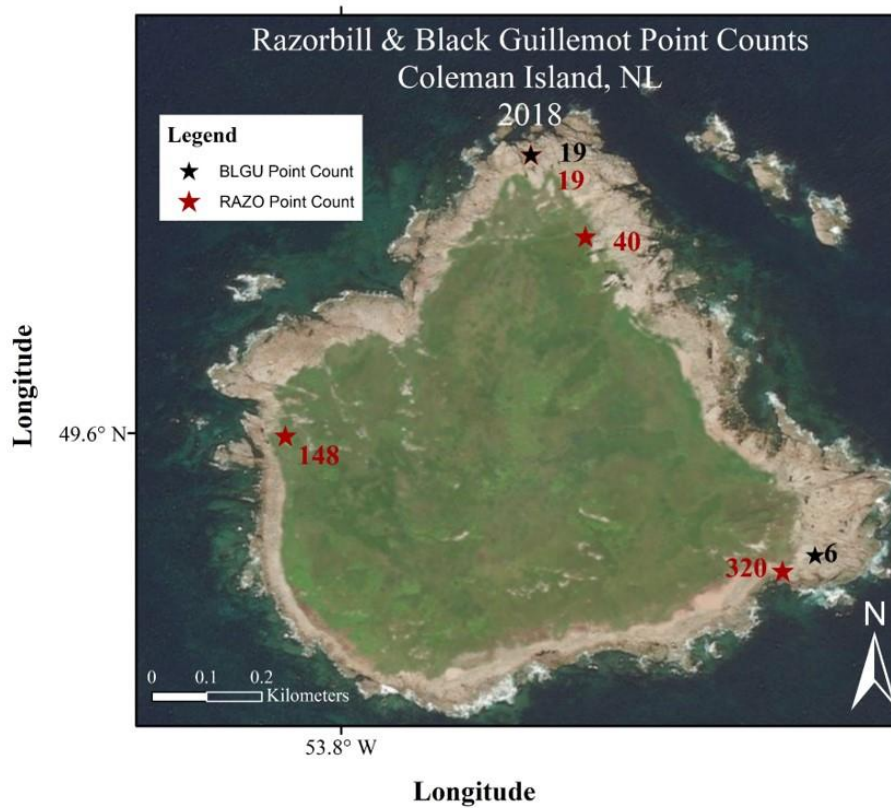


Figure 10. Areas where adult black guillemots and razorbills were recorded <100 m from shore via point count on Coleman Island, 2018.

Leach's Storm-petrel

Storm-petrels occupied a total estimated area of 87,845m², consisting of 73,814m² of vegetated habitat in the interior, 13,236m² among puffin sod burrows, and 795m² of fern dominated habitat. Burrow density averaged 0.04 ± 0.02 burrows/m² (n=31 plots), with an average occupancy of 0.22 ± 0.16 in vegetated habitat, 0.52 ± 0.29 burrows/m² (n=4 plots), with an average occupancy of 0.31 ± 0.12 in puffin sod burrow areas, and 0.52 ± 0.29 burrows/m² (n=3 plots), with an average occupancy of 0.61 ± 0.11 in fern dominated habitat. In total, we estimate $2,906 \pm 662$ pairs of storm-petrels bred on James Island in 2018, predominantly in areas of puffin sod burrows ($1,953 \pm 510$ pairs), with fewer in the vegetated interior (704 ± 13 pairs) and fern patches (249 ± 139).

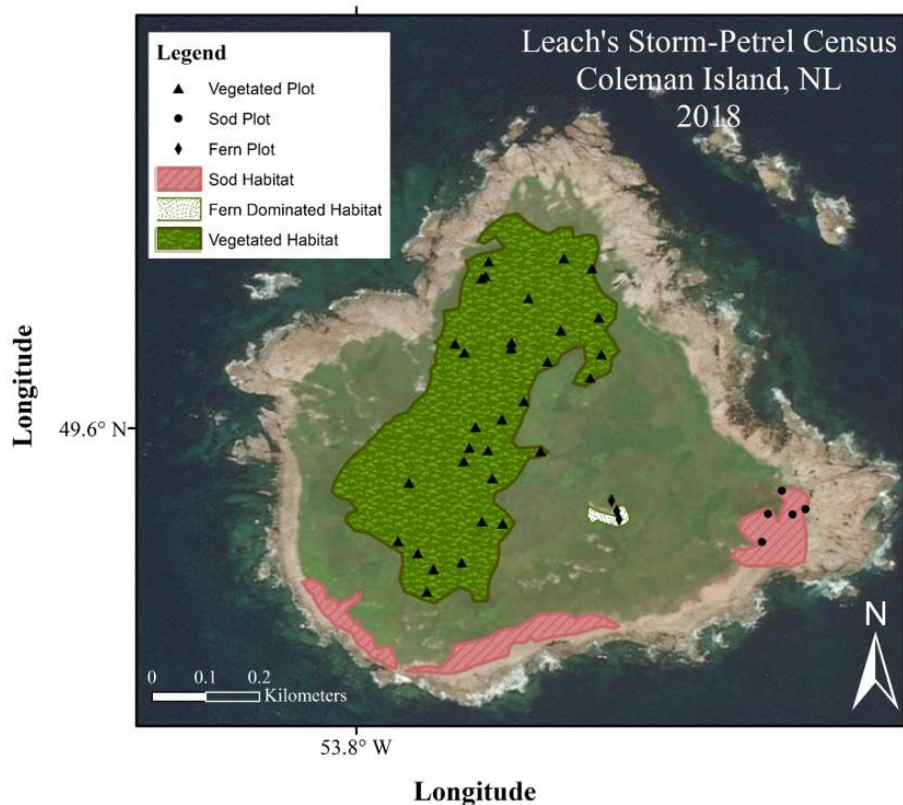


Figure 11. Extent of Leach's storm-petrel colony by habitat type on Coleman Island, 2018.

3.2.3 Comparisons with earlier surveys

The current estimate of $2,906 \pm 662$ breeding pairs of storm-petrels is substantially lower than the previous estimate of 5,000 in 1984. Networks of eroded storm-petrel burrows were visible in many areas across the island, suggesting suitable habitat may be less available. Vole presence was also uniform, which may be a potential source of competition for burrows or predation of eggs and chicks. However, Atlantic puffin and razorbill populations are higher than those previously reported, suggesting a major recent increase.

3.3 Pigeon Island

3.3.1 Habitat delineation

The census took place on June 29 using the full count method due to size of the island.

3.3.2 Population estimates

Black guillemots

While 10 black guillemot nests were found, 160 adults were present in the area around Pigeon Island and along the north-west side of Peckford Island on June 29, followed by 180 on July 11, 2018, supporting similar observations from July-August 2017 (pers. obs). Therefore, Peckford Island potentially supports the largest colony of the species in the Wadham Islands or Cabot Islands IBAs.

Table 3. Census results from Penguin Island 2018, including species, estimated number of active nests (including number of adults recorded on the water <100m from the island for black guillemots in parentheses), and previous census results. Two eider nests were also recorded.

Species	Active nests in 2018	Previous census results
Great black-backed gull	4	Not reported
Arctic tern	1	28 pairs (2006), 226 pairs (1984)
Atlantic puffin	22 + 0-17	20 pairs (1973)
Black guillemot	10 (40)	Present (1984)

3.3.3 Comparisons with earlier surveys

This census effort confirms nesting black guillemots, as well as similar numbers of puffins. However, Arctic terns have decreased significantly from 226 pairs in 1984, to a single pair.

3.4 Gull Island

3.4.1 Habitat delineation

The census took place on July 18, 2018, and a full count of all nests was conducted due to the size of the island. However, to minimize disturbance to the cormorants, a buffer zone of 20 m around the colony was not censused meaning some areas were not searched. This also meant a rigorous cormorant census was impossible but ≥ 68 active nests were counted, including a small sub-colony of 12 active nests South of the main colony on the edge of the meadow which were not present in 2017 (pers. obs).

Comparisons with earlier surveys

This census revealed major differences from previous efforts, including extirpation of black-legged kittiwakes, and common terns, as well as far fewer puffins. However, these may be due to the presence of a mink in 2017 and 2018. While three freshly killed storm-petrels were found, nesting was unconfirmed despite concentrated effort, potentially due to the soil being too compacted. Historically low in numbers, a decrease in habitat quality may have led to the extirpation of this species. In contrast, razorbills are now present having been unrecorded in previous censuses.

Table 4. Census results from Gull Island 2018, including species, estimated number of active nests (including number of adults recorded on the water <100m from the island for razorbills and black guillemots in parentheses), and previous census results.

Species	Active nests in 2018	Previous census results
Leach's storm-petrel	0	25 pairs (1945)
Double-crested cormorant	≥68	45 pairs (2015)
Herring gull	9	50 individuals (2000)
Great black-backed gull	1	50 individuals (2005)
Black-legged Kittiwake	0	300 individuals (2005)
Common tern	0	175 pairs (1945)
Atlantic puffin	9	100 pairs (1945)
Black guillemot	3 (7)	Present (1979)
Razorbill	10 (163)	Not reported

3.5 North Cabot Island

3.5.1 Habitat delineation

Transects to estimate alcid occupancy were conducted on July 5 along the coastline. Vegetated areas could not be systematically searched for storm-petrel burrows due to the presence of a dense gull colony, however no puffin burrows in soil exist on the island.

Table 5. Census results from North Cabot Island 2018, including species, habitat type, number of active nests, and previous census results.

Species	Active nests in 2018	Previous census results
Leach's storm-petrel	~0-5	100 pairs (1945)
Herring gull	250	50 individuals (2005)
Great black-backed gull	14	50 individuals (2005)
Black-legged Kittiwake	43	Not reported
Atlantic puffin	10	Not reported
Black guillemot	4	Not reported
Razorbill	35	Not reported

Comparisons with earlier surveys

Herring gulls have increased dramatically since 2005, and puffins, razorbills and black guillemots breed in low numbers around the island, which had previously been unreported. This increase in density and diversity may be a result from the relatively recent closure of lighthouse infrastructure and lack of human presence. While 43 kittiwake nests on a low cliff in the center of the island were counted with adults present in June, only four had chicks in July, suggesting predation events or a failure to breed. Storm-petrels were heard at night however, no burrows were located.

3.6 South Penguin Island

Table 6. Census results from South Penguin Island 2018, including species, habitat type, number of active nests, and previous census results.

Species	Active nests	Previous census results
Leach's storm-petrel	8,537 \pm 1,758	7800 pairs (1979)
Double-crested cormorant	0	60 pairs (2005)
Herring gull	~25	300 individuals (2005)
Great black-backed gull	~5	50 individuals (2005)
Tern sp.	0	80 pairs (2005)
Atlantic puffin	8,881 \pm 1,539	755 pairs (2013), 1200 pairs (1973)
Razorbill	5	Not reported

3.6.1 Habitat delineation

On July 14 habitat types were delineated and alcid occupancy estimated, while on July 28, storm-petrel occupancy was estimated. After performing transects in areas of suitable habitat in the meadow, no storm-petrel burrows were found. However, burrows were found throughout the forested area, both where mature trees had died leaving open areas of knee-high fern, and where live trees formed dense cover. Areas of such dense trees seemed to have more burrows when nearer the edge of the forested area, as supposed to areas in the centre, possibly because the birds are forced to move over the ground some distance to reach their burrows due to the density of cover. Further, storm-petrel burrows were located among puffin sod burrows on the north shore. Therefore, polygons for both puffin sod burrow habitat and forest were created and plots randomly assigned within.

3.6.2 Population estimates

Atlantic puffin

Puffins were estimated to use an area of 10,346m² in 2018; consisting of both sod burrows and crevices. Sod burrow density averaged 1.2 ± 0.20 burrows/m² (n=4 plots), with an average occupancy rate of 0.82 ± 0.04 , while crevice density averaged 0.61 ± 0.11 burrows/m² (n=4 plots). After the addition of 175 occupied crevices counted via area search, we estimate a total of $8,881 \pm 1,539$ pairs of puffins bred on Coleman Island in 2018, $6,113 \pm 1,088$ in sod burrows and $2,592 \pm 451$ in crevices.

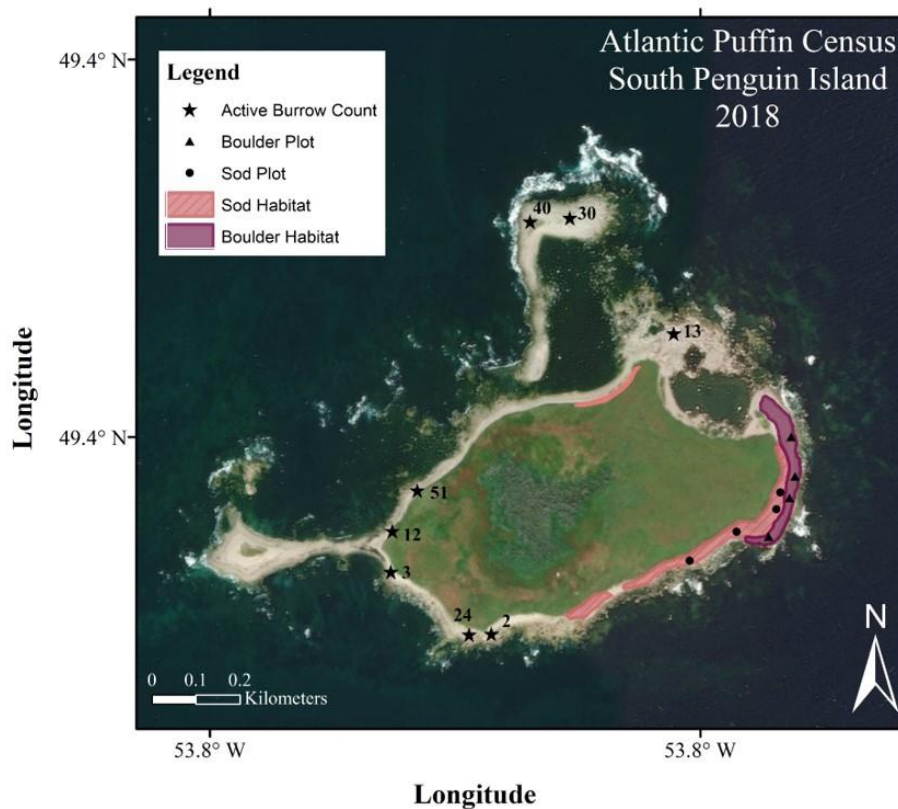


Figure 12. Extent of Atlantic puffin colony by habitat type on South Penguin Island, 2018.

Razorbill

Five pairs of razorbill were confirmed in 2018, the first record for the island.

Leach's storm-petrel

Storm-petrels occupied a total estimated area of 23,161m², consisting of 22,780m² of forest habitat, and 381m² among puffin sod burrows. Burrow density averaged 0.48 ± 0.10 burrows/m² (n=6 plots), with an average occupancy of 0.77 ± 0.17 in the forest, and 0.41 ± 0.15 burrows/m² (n=3 plots), with an average occupancy of 0.82 ± 0.10 in puffin sod burrow areas. In total we estimate $8,537 \pm 1,758$ pairs of storm-petrels bred on South Penguin Island in 2018, concentrated in the forested area ($8,409 \pm 1,711$ pairs).

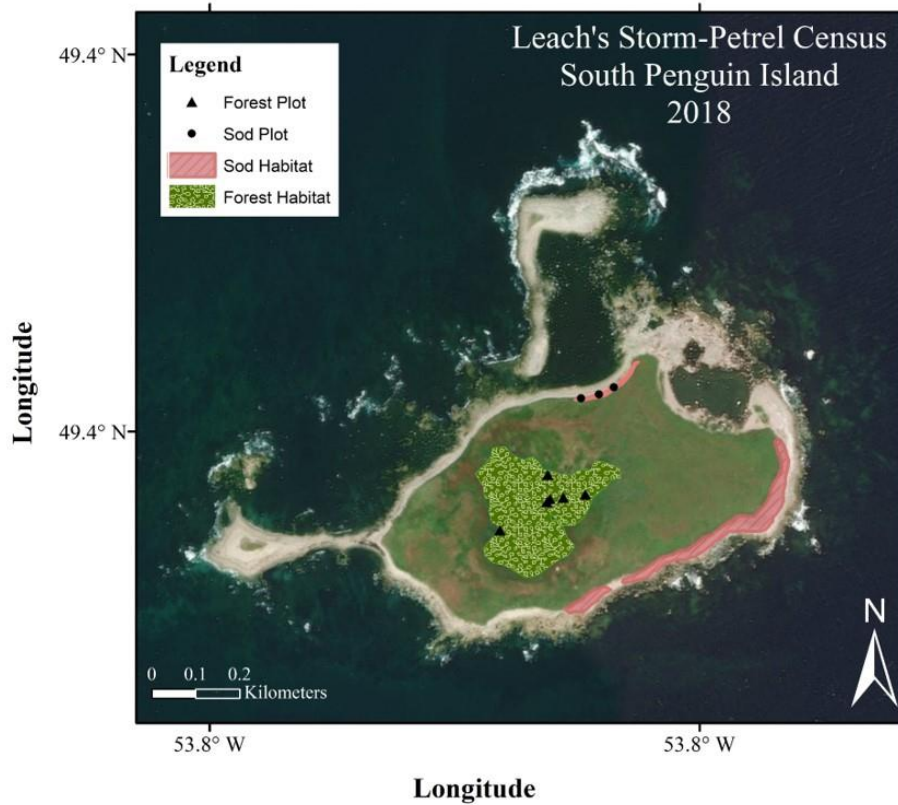


Figure 13. Extent of Leach's storm-petrel colony by habitat type on South Penguin Island, 2018.

3.6.3 Comparisons with earlier surveys

The Leach's storm-petrel population has remained similar to the previous estimate, however Atlantic puffins have increased substantially from 755 in 2013 to $8,881 \pm 1,539$. The area of puffin sod burrows has expanded along both the east and south sides of the island since 1979 when compared with a map from a census effort in that year (Fig. 14).

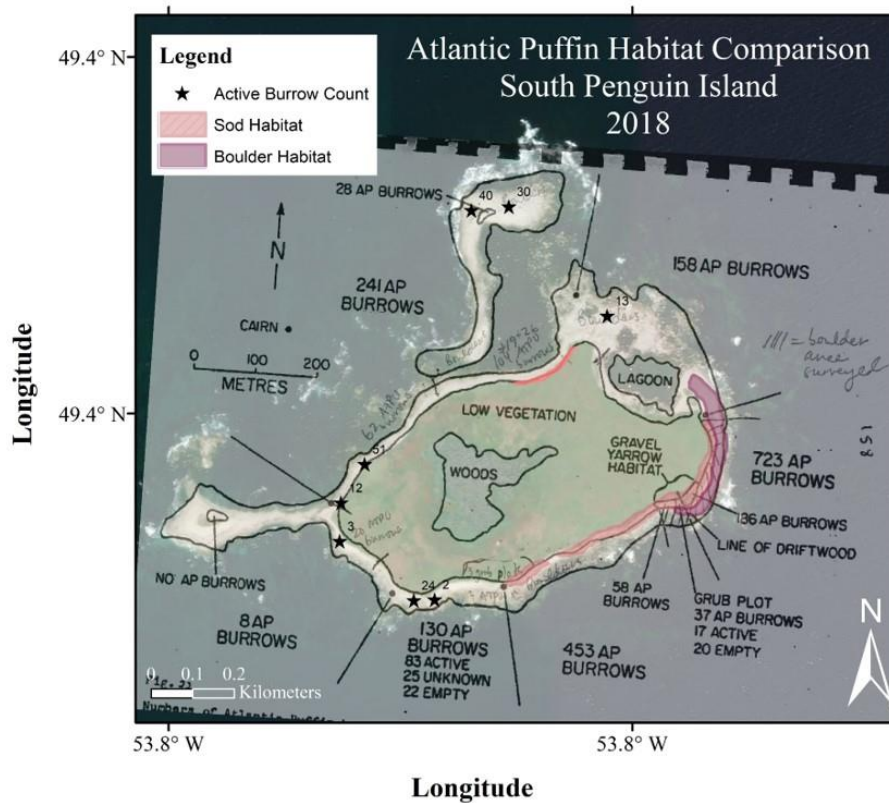


Figure 14. Comparison of the Atlantic puffin colony on South Penguin Island between 1979 and 2018.

4 DISCUSSION

4.1 Overall trends

When comparing meta-population sizes of different species (Table 7), overall trends suggest a relatively stable Leach's storm-petrel population, a decrease in black-legged kittiwakes and terns, and a large increase in alcid populations. While lack of previous data may play a role in these findings, this provides insight into the population trends on a larger scale.

Leach's storm-petrel

Classified as Vulnerable on the IUCN Red List due to a decline of $\geq 30\%$ over three generations (Birdlife International 2017), Leach's storm-petrel are declining in the North Atlantic both in the UK (Newson et al. 2008), and in eastern Canada and the USA. While overall, the breeding population of Leach's storm-petrels in the study area seems to have remained relatively stable since the last estimates, the population on James Island shows no significant sign of recovery to the numbers recorded in 1984 (11,938 pairs), and those on South Penguin Island and Coleman Island have declined.

Table 7. Comparison of total active nests for all species and from all censused islands combined (James, Coleman, Pigeon, Gull, North Cabot, South Penguin Islands) between 2018, and totals from most recent previous census efforts (ranging from 1945-2003 depending on species and island).

Species	Total active nests 2018	Previous census totals
Leach's storm-petrel	13,021	13,963 pairs
Black-legged Kittiwake	43	300 pairs
Common tern	4	260 pairs
Arctic tern	1	153 pairs
Atlantic puffin	38,430	8,015 pairs
Black guillemot	85	25 pairs
Razorbill	4,153	283 pairs

Black-legged kittiwake

The only colony previously recorded in the study area was on Gull Island and although there was some sign of prospecting in the area, no birds bred there in 2017-2018. However, a small colony of 43 active nests on South Penguin was discovered, although only four nests produced chicks.

Arctic and common terns

Tern numbers have clearly decreased, with all colonies depressed or disappeared. Although adult terns of both species are observed frequently in the study area, no healthy colonies exist within or between the Wadham Islands in the west and the Cabot Islands in the southeast. While Deadman's Bay Provincial Park (49.3132, -53.6247) does support a small Arctic tern colony, productivity was zero due to or partly due to human disturbance in both 2017 and 2018 (pers.obs).

Atlantic puffin

The largest puffin colony in North America, Great Island in Witless Bay, Newfoundland, declined between 1979 and 1984, but then increased rapidly from 1984 to 1994 (Robertson et al. 2004), appearing to have stabilized when censused in 2011 (Wilhelm et al. 2015). This census similarly reveals a sizable increase in the estimate of breeding pairs of puffins in the study area, with large colonies on James, Coleman and South Penguin Islands. The colonies on Coleman and South Penguin Island have increased substantially from any previous estimates, while the numbers on James Island are similar to an estimate conducted in 1984, prior to a decline reported in 2001. While location of burrows on James Island has changed somewhat since 2001, the overall area used by puffins remains similar, supporting an increase in burrow density and occupancy.

Black guillemot

There are few pairs of black guillemots in the study area, potentially due to lack of suitable breeding habitat, however, observations of ~180 adults on the western coast of Peckford Island in the Wadham Islands archipelago suggest the largest colony in the area remains to be described.

Razorbill

Razorbill populations in Canada and the USA having been increasing in recent decades (Gaston et al. 2009), as well as expanding northwards (Gaston and Woo 2008). This census effort supports these trends with a substantial increase in razorbills from previous estimates, including the first reported breeding on Gull, South Penguin, and North Cabot Islands.

Ring-billed gull

Historically reported as breeding on multiple islands in the area, only a single nest was found in 2018, on James Island, which subsequently failed. A colony of ~150 pairs that was present until recently (within the previous 5 years) on Southern Cat Island (49.3056, -53.5881) <1 km North of Lumsden, has also disappeared (pers.com).

4.2 Use of endoscopes

Two models of endoscope were used to assess storm-petrel burrow occupancy, one from Potensic (www.ipotensic.com) compatible with Android cell phones, and one from Dr. Meter (www.drmeter.com) with wi-fi connectivity, compatible with both iPhones and Android cell phones. These allowed an extension of vision beyond the reach of a surveyor's arm to observe the contents of burrows. However, some were still too long to confirm status, and those with sharp corners were still problematic to navigate. Even so, being able record burrow contents without requiring the bird or egg to be touched was valuable and use of this technology allowed the successful classification of more burrows that would otherwise be possible, while reducing the necessity to excavate burrows.

4.3 Seabird predation

James Island

A systematic search around the coastline of the island on July 1 resulted in 87 depredated adult puffins, 3 predated puffin eggs and 20 predated razorbill eggs. These were judged to be depredated within the previous month based on condition, with many being fresh. All puffins had been predated by gulls, gauged by the 'inside-out' condition of the carcasses, with the skin intact. Five gull pellets containing storm-petrel remains were also found, confirming predation pressure from gulls on puffins and storm-petrels on the island.

Coleman Island

Herring and great black-backed gulls both breed on the island, and 19 gull pellets comprising of storm-petrel remains were found on July 29, suggesting some predation pressure. Meadow vole (*Microtus pennsylvanicus*) presence was also very clear, with many seen on both census

dates, while tunnels, paths, and dropping piles were ubiquitous in all vegetated areas. Remains including skulls allowing accurate identification were found in gull pellets (Fig. 15). However, no direct sign of predation from voles such as extracted eggs or dead chicks were discovered. Also of note were multiple areas of apparently old, collapsed networks of storm-petrel burrows that were found across the island, perhaps indicating a greater presence in previous years.



Figure 15. Meadow vole remains found in gull pellet. Coleman Island, July 2018.

Gull Island

When visited on July 10 2017, a mink (*Neovision vision*) was observed and eggshell fragments were found as well as ~15 dead adult razorbill and puffin cached in cracks (pers. obs). While no mink were seen in 2018, fresh scat was found and two freshly killed whole puffins were found cached nearby in the manner consistent with that of mink. Three fresh, whole storm-petrels killed by cervical dislocation were also found cached in separate cracks (Fig. 16), and six large gull chicks (<2 weeks old) were also found dead but whole. Therefore, we conclude that one or more mink were present in 2018, which may account for the low numbers of seabird chicks and eggs recorded. Also, of note, a dead cormorant predated in the manner of a bald eagle was found in the meadow.



Figure 16. Leach's storm-petrels killed and cached by mink. Gull Island, July 2018.

North Cabot Island

A gull behavioral study conducted by the University of Manitoba revealed herring and great black-backed gulls depredating common murre eggs and chicks, with eggshell found within the gull colony at multiple sites. Kleptoparasitism of murre by gulls was also recorded. Two freshly depredated adult common murre and one razorbill were also found on the coast, suggesting predation pressure from gulls at multiple levels.

South Penguin Island

Signs of a coyote (*Canis latrans*) were found on July 14 on the beach on the west side of the island, and two fresh scats were located on July 28, although no animal was seen. However, if present for long, this predator may account for the total lack of either gull or eider chicks/eggs found. Fresh remains (wings and plucked body feathers) of 9 adult storm-petrels were found, suggesting predation by nocturnal raptor such as Northern saw-whet owl (*Aegolius acadicus*), or short-eared owl (*Asio flammeus*). While discarded storm-petrel egg-shell was found at multiple spots, one looked as if it had been predated due to yolk visible in the shell. Sign of rodents (presumably meadow voles as with Coleman Island) were abundant in the drier areas of the meadow, where tunnels through the grass and burrows chewed into the vegetation were plentiful. No such sign was found under the tree canopy however, suggesting some partitioning between the species.

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