ON-LAND FORAGING BY LEACH'S STORM PETRELS *OCEANODROMA LEUCORHOA* COINCIDES WITH ANOMALOUS WEATHER CONDITIONS

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ABSTRACT

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We describe the first known documentation of on-land foraging by Leach's Storm Petrels *Oceanodroma leucorhoa*, a behaviour that has been documented only once before among members of the family Hydrobatidae. During a rain/windstorm from 15 to 17 July 2020 in eastern Newfoundland, individuals fed on coastally spawning and beach-cast capelin *Mallotus villosus*. This behaviour occurred in conjunction with a marine heatwave in the species' foraging range. Examination showed that wrecked birds were emaciated with negligible stomach contents. This finding, combined with the abnormal weather and foraging behaviour, suggests that these birds were in a weakened state preceding stranding in coastal waters. With the only other recorded instance of on-land foraging by hydrobatids occurring in highly emaciated birds concurrent with a marine heatwave, we suggest that this atypical behaviour is associated with birds experiencing extreme food stress linked to oceanic climate change.

Key words: Leach's Storm Petrel, *Oceanodroma leucorhoa*, capelin, *Mallotus villosus*, on-land foraging, wind, marine heatwave

INTRODUCTION

The Leach's Storm Petrel *Oceanodroma leucorhoa* is a small pelagic procellariiform that breeds in the North Atlantic and North Pacific oceans, with most nesting occurring on islets of Atlantic Canada (Pollet *et al.* 2020). They typically forage in offshore waters for small pelagic fishes (myctophids, ammodytids, etc.) and crustaceans (euphausiids, copepods, etc.) by gleaning prey from the ocean's surface (Hedd *et al.* 2009, Watanuki & Thiebot 2018, Pollet *et al.* 2020). Sightings of Leach's Storm Petrels from shore are rare, although they appear occasionally in coastal waters in large numbers due to strong onshore wind events and attraction to anthropogenic light sources (Montevecchi & McFarlane Tranquilla 2019, Wilhelm *et al.* 2021).

In recent years, the number of breeding Leach's Storm Petrels has plummeted across their range in the North Atlantic (Newson *et al.* 2008, Hansen *et al.* 2009, Wilhelm *et al.* 2015, Pollet & Shutler 2018, d'Entremont *et al.* 2020, Wilhelm *et al*. 2020). Likely causal mechanisms for these declines include strandings due to light pollution (Ronconi *et al.* 2015; Davis *et al.* 2017), effects from pollutants such as mercury (Goodale *et al.* 2008) and ocean plastics (Bond & Lavers 2013), predation (Stenhouse & Montevecchi 1999, Hoeg *et al.* 2021), changes in breeding habitat suitability (d'Entremont *et al.* 2020, Duda *et al.* 2020, Wilhelm *et al.* 2021), and shifts in the distribution and availability of prey associated with climate change (Poloczanska *et al.* 2016, Freer *et al.* 2019, Bashevkin *et al.* 2020).

The increasing frequency and duration of marine heatwaves (MHW) can have profound negative impacts on marine food web dynamics (Oliver *et al.* 2019, Sanford *et al.* 2019). For example, the deaths of nearly one million Common Murres *Uria aalge* and thousands of Cassin's Auklets *Ptychoramphus aleuticus* during the Northeast Pacific MHW of 2014–2016 was associated with reductions in prey abundance and quality induced by ocean climate (Jones *et al.* 2018, Piatt *et al.* 2020). Wrecks of Atlantic Puffin *Fratercula arctica* and Razorbill *Alca torda* along the eastern coast of the United States were likely associated with the Northwest Atlantic MHW of 2012 (Diamond *et al.* 2020). In addition to mass mortality events, unusual behaviours by seabirds have been linked to MHWs. The lowest recorded reproductive success and the first mass colony abandonment—across several colonies—of Northern Gannets *Morus bassanus* (Montevecchi *et al.* 2021) occurred during the Northwest Atlantic MHW of 2012, and the first documentation of on-land foraging by Hydrobatidae and Procellariidae occurred during the 2014–2016 Northeast Pacific MHW (Robinson *et al.* 2018). The ability of pelagic seabirds to locate and consume prey can be significantly affected by anomalous weather events such as heavy rain and wind, which can affect salinity stratification and increase both surface-water turbulence and turbidity (Schreiber 2001, Bashevkin *et al.* 2020).

Here we document Leach's Storm Petrels feeding on spawning and beach-cast capelin, which is, to our knowledge, the first recorded instance of this behaviour by the species and only the

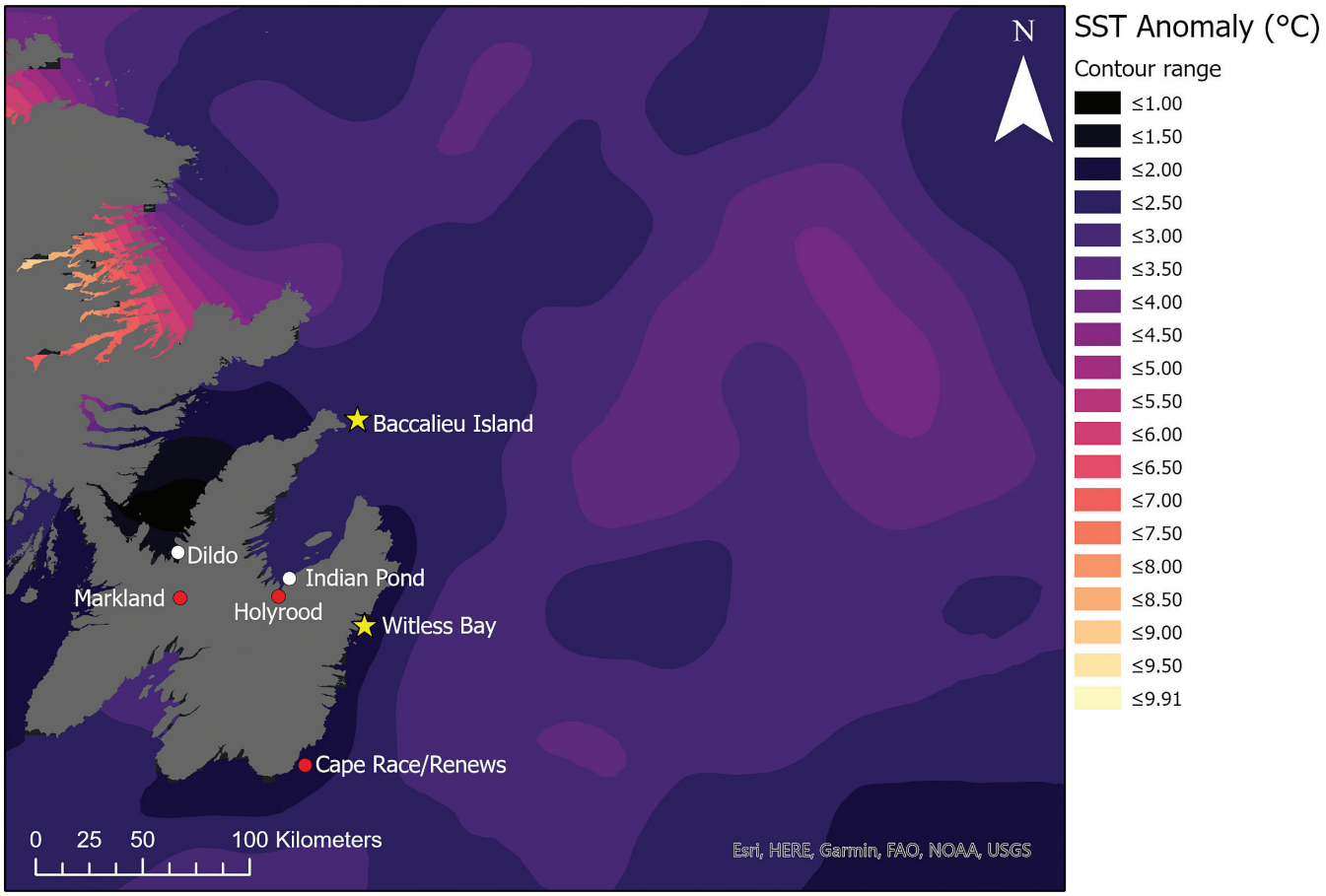

Fig.1. Sea surface temperature (SST) anomaly chart of waters surrounding the Avalon Peninsula, NL, Canada during the peak intensity of the marine heatwave that occurred 12–15 July 2020. Red dots indicate locations where carcasses were collected, white dots indicate locations where storm petrels were observed in-shore by citizen scientists, and yellow stars indicate locations of storm petrel colonies. On-land foraging behaviour was observed at Holyrood.

second recorded instance of a hydrobatid feeding on beach-cast fish (Robinson *et al.* 2018). This behaviour occurred during a period of strong onshore winds and heavy rainfall.

STUDY AREA

Observations and carcass collections took place across the Avalon Peninsula in the province of Newfoundland and Labrador (NL), Canada. The abnormal foraging behaviour was observed at Holyrood, NL (47.3846°N, 053.1247°W; Fig. 1), at the southernmost point of Conception Bay. Holyrood is approximately 80 km south of Baccalieu Island, the site of the world's largest colony of Leach's Storm Petrels (Wilhelm *et al.* 2020), and ~29 km northwest of the Witless Bay Ecological Reserve, which is home to two substantial colonies at Great Island and Gull Island (Wilhelm *et al.* 2015; Fig. 1). The beach at Holyrood and the small beaches in the surrounding North Arm and South Arm of Holyrood Bay are capelin spawning sites, with near-annual sightings (CON 2020). Wrecks of storm petrels have occurred previously at Holyrood in the fall; it is less common for them to occur here during their incubation period (June–July). In addition, most storm petrels recovered from wrecks occurring in the fall have been juveniles (Wilhelm *et al.* 2021).

Beginning late in the day on 15 July 2020, strong winds from the northeast (gusts to ~12 m/s; Fig. 2) associated with an intense rainstorm began over the Avalon Peninsula and continued until mid-afternoon on 17 July 2020. More than 100 mm of rain fell on the region during this three-day event, exceeding the monthly average rainfall for July and breaking the record for the most rainfall in one day (15 July) in July since 1996 (ECCC 2020).

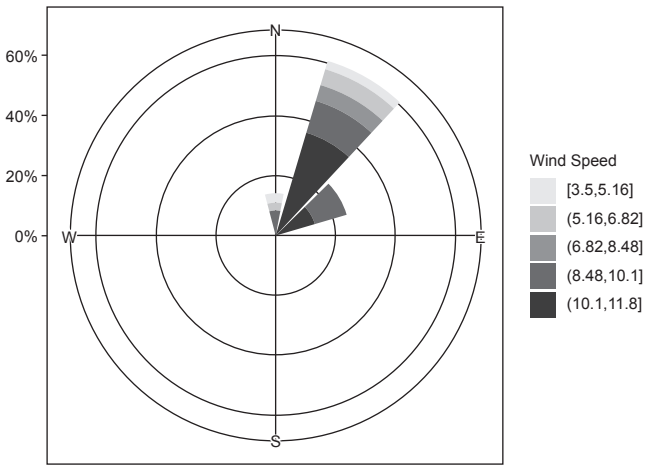

Fig. 2. Windrose plot depicting wind direction and speed (m/s) for 15–17 July 2020 at St. John's International Airport. Percentages indicate the proportion of time that maximum wind gusts were within a given range during the event.

OBSERVATIONS AND METHODS

Hundreds of Leach's Storm Petrels were reported in Holyrood Harbour during 15–17 July 2020, as evident on social media and through citizen science reporting (eBird 2020, iNaturalist 2020; Table 1). On 16 July 2020, ~20–40 storm petrels were observed and photographed feeding coastally on capelin and spawn in shallow waters (Fig. 3), including a few individuals feeding on spent capelin on the beach (Fig. 4).

By 17 July 2020, the number of storm petrels in the harbour had decreased; seven storm petrel carcasses were collected from Holyrood Beach for analysis. On 18 July 2020, another carcass was retrieved ~31 km inland from Holyrood, in the community of Markland (Fig. 1), and nine carcasses floating off the southeastern Avalon Peninsula were collected between Cape Race and the town of Renews (~80 km southeast of Holyrood, Fig. 1).

All carcasses were weighed and measured (culmen, tarsus, and wing cord), then necropsied to determine sex and assess stomach contents for organic matter and plastics. Based on fat deposits within the body cavity, birds were assigned a body condition score 1–5: 1 = no fat, 2 = little fat, 3 = moderate fat, 4 = fat, and 5 = considerable fat (Thompson 2009). External and internal injuries were noted.

As indicated by the Marine Heatwave Tracker app (Schlegel 2020), a MHW was centred northeast of Holyrood (49.375°N, 050.125°W) immediately before and during the event reported here (Fig. 5). This app characterizes MHWs based on criteria

Fig. 3. Leach's Storm Petrels *Oceanodroma leucorhoa* engaging in feeding frenzies on spent capelin near shore at Holyrood, NL, Canada. (Photos: BM, taken from land)

Fig. 4. An adult Leach's Storm Petrel *Oceanodroma leucorhoa* feeding on dead, beach-cast capelin on land at Holyrood, NL, Canada. (Photo: DB)

TABLE 1
Observations recorded in eBird and iNaturalist of Leach's Storm Petrels (LESP) *Oceanodroma leucorhoa* in Conception Bay, Newfoundland, Canada during the marine heatwave of July 2020

Date	Time (NST)[a]	Observers	Location	No. of LESP
16 July	14h21	1	Holyrood	500
17 July	09h15	2	Holyrood	30
17 July	09h23	1	Holyrood	30
17 July	09h45	2	North Arm	20
17 July	10h05	1	Holyrood	4
17 July	10h15	1	Holyrood	200
17 July	12h11	1	Holyrood	200
17 July	12h50	1	Holyrood	100
17 July	13h35	3	Holyrood	7
17 July	14h04	1	Indian Pond	30
17 July	15h00	2	Holyrood	100
17 July	17h38	1	Holyrood	10
18 July	11h26	1	Holyrood	3

[a] NST = Newfoundland Standard Time (GMT−3:30)

set by Hobday *et al.* (2016), whereby a MHW is defined as anomalously high sea surface temperature (SST) values above the 90th percentile threshold, based on multi-decadal climatology records, for at least five days in a given region. MHWs can be categorized based on multiples of local temperature differences, with Moderate (I), Strong (II), Severe (III), and Extreme (IV) levels being defined as 1–2×, 2–3×, 3–4×, and > 4× above the 90th percentile threshold of SST anomalies (Hobday *et al.* 2018). We calculated the average SST anomalies for each day for the geographic range of the MHW (48.125°N, 050.875°W to 49.875°N, 049.125°W).

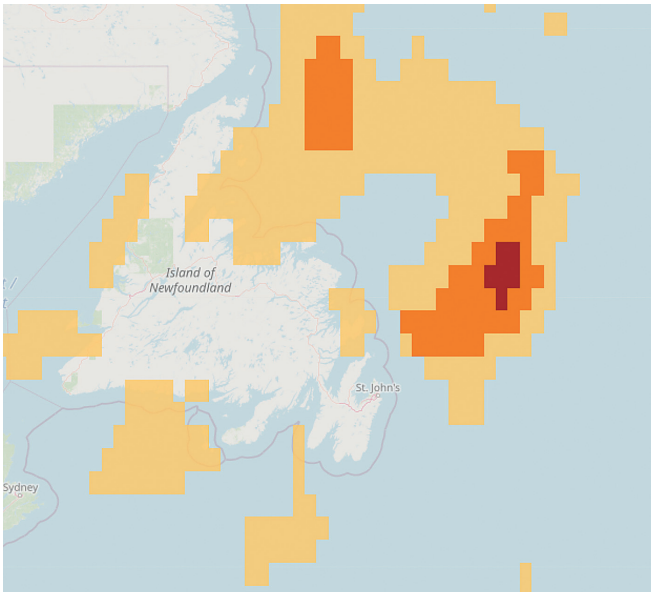

Fig. 5. The marine heatwave in the Northwest Atlantic at peak intensity on 14 July 2020, as depicted by the Marine Heatwave Tracker app (Schlegel 2020, scale bar not available). Light orange, dark orange, and red signify areas impacted by Moderate (I), Strong (II), and Severe (III) marine heatwaves, respectively.

RESULTS AND DISCUSSION

Our results are highly consistent with the first documentation of on-land foraging for Hydrobatidae reported by Robinson *et al.* (2018). During the period 15–17 July 2020, several hundred Leach's Storm Petrels were observed near shore (Table 1), with many feeding coastally on spawning capelin. Three major foraging patterns were observed: 1) collecting fresh capelin spawn from the surf; 2) capturing live capelin from near-shore waters and relocating to open water, where feeding frenzies of many individuals would ensue to fight over the fish (Fig. 3); and 3) stationary land-based feeding on dead, beach-cast capelin (Fig. 4).

Though capelin has previously been documented in the diets of Leach's Storm Petrels in small amounts (Hedd & Montevecchi 2006, Hedd *et al.* 2009), this is, to our knowledge, the first documented record of the species feeding on spawning capelin in a coastal environment, as well as the first documentation of land-based foraging. As noted above, Leach's Storm Petrels are known to forage coastally in Newfoundland waters when blown into bays and inlets during storms (BM and WAM pers. obs.), but they have never previously been recorded feeding on land. Other hydrobatids have been known to forage in the intertidal zone (Gill 1977, Thomas *et al.* 2006), but until Robinson *et al.* (2018) described on-land foraging by Fork-tailed Storm Petrels *Oceanodroma furcata* during the Northeast Pacific MHW of 2014–2016, this behaviour had not been documented.

Stomach contents and body condition of salvaged birds indicated that this abnormal on-land foraging behaviour may have been associated with extreme food stress (see Robinson *et al.* 2018). All collected carcasses were heavily emaciated with minimal to no fat deposits in the body cavity; 15 of 17 carcasses were scored with a body fat index of 1 (no fat deposits), and the two others were scored with a body fat index of 2 (little fat). Stomach contents included non-food items such as plastics, seaweed, fir and spruce needles, and a parasitic worm. While the presence of a large piece of latex in the stomach of one bird could have contributed to death due to obstruction of the digestive tract, all other carcasses lacked large plastic pieces. This observation led us to suggest that plastic ingestion was not a cause of death.

Of the 17 collected carcasses, 13 were dry and relatively fresh, while four were heavily waterlogged and/or in advanced stages of decay. The mass of relatively fresh salvaged birds (i.e., dry and not in initial stages of decay) averaged 35.22 g (n = 13), approximately 14 g below normal mass for breeding adults during incubation (average incubation mass is 48–53 g; Montevecchi *et al.* 1983, Pollet *et al.* 2020) or about 65% of their expected body mass at this time of year. The birds collected in this study also had a much lower average mass than Leach's Storm Petrels collected in previous wrecks in Atlantic Canada (Krug *et al.* 2021, Wilhelm *et al.* 2021). The average mass of recently fledged birds associated with fall wrecks off eastern Newfoundland in 2018 and 2019 (range = 45.3–54.0 g, n = 565; Wilhelm *et al.* 2021) were heavier than what was found in this event. Therefore, it is notable that all wrecked Leach's Storm Petrels in the present event were emaciated, while emaciation is not common in other stranding events.

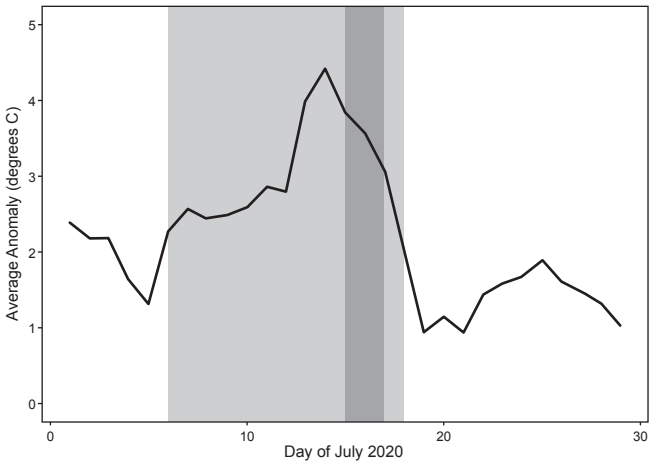

Fig. 6. Average sea surface temperature anomaly for each day in July 2020 in the geographical centre of the marine heatwave (MHW; 48.125°N, 050.875°W to 49.875°N, 049.125°W). Dates of the MHW are indicated by the light grey band (06–19 July 2020), and the dates of the stranding event of Leach's Storm Petrels *Oceanodroma leucorhoa* in Holyrood, NL, Canada, are indicated by the dark grey bar.

Given that strong onshore winds (maximum gusts of 11.8 m/s) were recorded during this event (Fig. 2) with relatively calm winds before and after, wind-forcing is the most parsimonious explanation for both the occurrence and strandings of storm petrels along the coast. In addition, the emaciated state and negligible stomach contents of the dead birds collected from all three locations would indicate that they were suffering from food stress.

A MHW (Category III, "Severe") occurred 06–19 July 2020 (Schlegel 2020, Fig. 5) within the known foraging range of Leach's Storm Petrels from Baccalieu Island and Gull Island (Hedd *et al.* 2018). The average SST anomaly during the MHW was 3.63 ± 0.42 °C (n = 13 days), with a peak intensity of 6.62 °C above normal on 14 July 2020 (Schlegel 2020; Fig. 6). Such departures from typical water temperatures may have altered the abundance and distribution of pelagic prey (Bashevkin *et al.* 2020). The average SST anomaly during the MHW was similar (3.83 ± 0.46 °C, n = 14 days) to that associated with observed on-land foraging by Fork-tailed Storm Petrels during the Northeast Pacific MHW in 2016 (Robinson *et al.* 2018). Torrential rains (i.e., salinity stratification, turbulence, etc.) coinciding with the marine heatwave in our study may have further deteriorated already poor foraging conditions induced by abnormally warm waters (see discussion in Schreiber 2001).

The weakened state of Leach's Storm Petrels and their negligible stomach contents in our study was similar to the condition of beach-cast birds from the only previous documentation of on-land foraging behaviour by hydrobatids (Robinson *et al.* 2018). On-land foraging may result from a combination of food stress and extreme weather events, a scenario likely to become increasingly regular, given climate projections (Oliver *et al.* 2019). Therefore, it is important to continue monitoring coastal environments for abnormal behaviours and strandings of pelagic birds to better understand the influences of our changing climate upon marine animals and ecosystems.

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