A Provisional Survey of the Macrofungi on Sand Dunes in Prince Edward Island National Park

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Abstract
This report describes the 16 species of macrofungi on the sand dunes of Prince Edward Island National Park, on the north shore of Prince Edward Island (PEI), Canada. This includes an undescribed *Russula* species originally documented from Kouchibouguac National Park, and other potential new and unidentified species.

Introduction
Prince Edward Island National Park (PEINP) consists of more than 26 km^2 of the north shore of PEI, including 7 km^2 of sand dunes (PEI, 2010), representing approximately 26% of the national park. Very little is known of the fungal diversity of these sand dunes despite fungi playing a crucial role in the survival, establishment, and growth of plants in coastal sand dunes. Fungi can benefit host plants by quickly exploiting nutrients in freshly buried sand, transferring nutrients, increasing soil aggregation, reducing water stress, increasing tolerance to salinity and salt spray, and transferring carbon between plants (Maun, 2009).

Previously documented inventories list 1265 fungi species for Nova Scotia, 537 for New Brunswick, and 75 for PEI (Malloch, 2010). More recently the 2020 Wild Species Report (Canadian Endangered Species Conservation Council, 2022) listed 92 macrofungi species for PEI, with only one sand dune macrofungus, *Laccaria trullissata*, a common fungus associated with *Hudsonia tomentosa* (Woolly Beachheather) (Redhead, 1989).

Although not included in inventories, several sand dune fungi have been identified on PEI by visiting mycologists. In September of 1994, Dr. Scott Redhead visited the sand dunes at Greenwich and documented four sand dune species, *Astraeus smithii*, *Leccinum arenicola*, *Laccaria trullisata*, and an undescribed white *Russula* (Redhead, 2022). In September of 2009, Dr. David Malloch visited sand dunes on Hog Island and Red Point and documented five sand dune species, *Inocybe cf serotina*, *Inocybe* sp., *Laccaria trullissata*, *Leccinum arenicola*, and *Scleroderma* sp. (Malloch, 2022).

The foredunes and the stable inland dunes were the focus of this survey. Foredunes, the first dune ridge parallel to the shore, are primarily vegetated by *Ammophila breviligulata* (American Marram Grass), have a high volume of shifting sand and are close to the shore. Foredunes can include embryo dunes (small dunes up to 2m in height), low dune scarps (eroded dunes, leaving a cliff-like face), blowouts (wind-eroded dune), and washovers (where storm surge breaches the dune). Stable inland dunes are characterized by tertiary (not dominated by lichens) and grey (dominated by lichens) dune vegetation including lichens and *Hudsonia tomentosa*.

The purpose of this survey was to better understand the diversity, distribution, and phenology of macrofungi on sand dunes. This report summarizes the species found, where and when they were found, highlights interesting discoveries, and makes recommendations for future efforts.

Methods

This survey was conducted primarily between April 13, 2022 and November 15, 2022. Some observations from the fall of 2021 were included since Hurricane Fiona's impact on the sand dunes prevented foredune observations in the fall of 2022.

To identify suitable locations to survey in stable dunes I focused on areas with a previously documented presence of *Hudsonia tomentosa* (Woolly Beachheather), an ectomycorrhizal species (Malloch and Thorn, 1985) commonly found on PEI stable dunes. Its presence was mapped (Fig. 1) using a spatial dataset from the Atlantic Canada Conservation Data Centre (AC CDC, 2022). Suitable foredune locations were identified using Government of PEI 2020 imagery (Gov PEI, 2020). An intelligent meander survey method (Selva, 2003) was used to focus fieldwork on appropriate habitats, the right time of year, and after suitable rain events.

Figure 1. Map illustrating presence of Wooly Beachheather (*Hudsonia tomentosa*) in Prince Edward Island National Park.

All observations were documented on iNaturalist including relevant information on location, date, habitat, photo, and morphological and microscopic characteristics as required. Specimens collected for identification purposes were used to generate spore prints before being dehydrated and documented for eventual addition to the New Brunswick Museum herbarium or DNA sequencing.

Seven specimens were sent to the Nanopore Sequencing lab at Mycota (Hoosier Mushroom Society in Indiana, US) to help identify and document findings with DNA sequencing. Sequences and related data were shared with the original iNaturalist observation and uploaded to GenBank.

Surveyed Sites

Cavendish Sandspit is foredune habitat with dune scarps, embryo dunes and washovers. Survey effort has been focused on the first kilometre from the campground access point due to summer access restrictions for Piping plover, *Charadrius melodus,* recovery. Due to the damage caused by Hurricane Fiona, Cavendish Sandspit could not be surveyed in 2022 and most of the observations reported here were from the fall of 2021.

Robinsons Island Sandspit is foredune habitat with mostly embryo dunes. An earlier inventory included *Hudsonia tomentosa* on the west side of the island, but it was either incorrect or has been lost to erosion, as stable dune habitat was not found during the survey. Access restrictions for Piping plover recovery prevent adequate survey of the sandspit except in the early spring and fall.

Brackley Beach grey dunes consists of a cluster of stable dunes south of Robinsons Island Road and west of the Brackley Beach parking lot. The first dune to the west of the parking lot is a tertiary dune, while the smaller dunes to the south are grey dunes. A larger dune further west is still active with no stable dune vegetation.

Tracadie Harbour includes the foredune between the end of Beach Road to the trail end from Watts Road, and Tracadie 'Island' to the east, with extensive stable dune habitat. Hurricane Fiona breached the interior of the stable dunes with storm surge, which limited fungal fruiting to higher parts of the dunes.

Greenwich includes foredune and stable dune habitat. Unfortunately given the damage from Hurricane Fiona the foredune habitat was not surveyed. The primary survey effort at Greenwich was on the large parabolic dune north of the Tlaqatik Trail, and to a lesser extent the older forested dune ridge that crosses the Greenwich Dunes Trail. While the parabolic dune was out of reach of the Hurricane Fiona storm surge, there was evidence of a high amount of sand movement, burying the *Hudsonia tomentosa*, which could impact fruiting diversity.

Results

In 2022, the five different sites were surveyed 26 times (Table 1). An estimated 6 visits to Cavendish Sandspit were also completed in the fall of 2021. Blooming Point, not described above, was not surveyed as planned in October 2022 because of the damage from Hurricane Fiona and questionable access. Robinsons Island recorded no observations as the, in season, visit on September 3rd was fruitless, likely due to dry conditions.

Cavendish Sandspit was visited 8 times, Robinsons Island 3 times, Brackley Beach grey dunes 4 times, Tracadie Harbour 5 times, and Greenwich 6 times. Fungi were found starting mid June on the foredunes and mid August on the stable dunes.

Table 1. Location, date and observation notes from site visits conducted between April 2022 and November 2022.

Location	Date	Observed
Cavendish Sandspit	13-Apr-22	scouting trip out 2.5km, no fungi observed
Brackley Beach grey dunes	02-May-22	last year's *Astraeus smithii* abundant, scouted *Hudsonia* observation 2km east of parking lot, no *Hudsonia* present
Greenwich	07-May-22	scouting trip, no fungi observed

Robinsons Island Sandspit	14-May-22	scouting trip, no fungi observed and *Hudsonia* location either incorrect or lost due to erosion
Robinsons Island Sandspit	23-May-22	no fungi observed
Cavendish Sandspit	12-Jun-22	no fungi observed
Cavendish Sandspit	23-Jun-22	*Coprinous* sp.
Cavendish Sandspit	04-Jul-22	*Peziza ammophila*
Tracadie Harbour	23-Jul-22	*Peziza ammophila*, *Psathyrella arenulina*, no fungi observed on grey dunes
Greenwich	06-Aug-22	no fungi observed on forested grey dunes, on the parabolic dunes last year's *Astraeus* and likely last year's *Laccaria*
Cavendish Sandspit	09-Aug-22	no fungi observed
Brackley Beach grey dunes	26-Aug-22	*Laccaria trullisata*
Tracadie harbour	28-Aug-22	*Leccinum arenicola* on grey dunes
Robinsons Island Sandspit	03-Sep-22	no fungi observed
Greenwich	18-Sep-22	*Laccaria trullisata*
Tracadie Harbour	03-Oct-22	*Laccaria trullisata*, fresh *Astraeus smithii*
Greenwich	22-Oct-22	*Laccaria trullisata*, *Hebeloma* sp.
Cavendish Sandspit	23-Oct-22	no fungi observed
Brackley Beach grey dunes	27-Oct-22	*Hebeloma* sp., fresh *Astraeus smithii*, *Cortinarius impolitus.* This is the only location *Cortinarius impolitus* was observed.
Greenwich	29-Oct-22	*Hebeloma* sp., *Laccaria* sp*, Cortinarius psammocola*, *Hygrocybe conicoides*
Tracadie Harbour	30-Oct-22	*Hebeloma* sp., *Cortinarius psammocola, Russula* sp., *Laccaria* sp.
Tracadie Harbour	05-Nov-22	*Hebeloma* sp., *Cortinarius psammocola*, *Laccaria* sp.
Brackley Beach grey dunes	11-Nov-22	*Cortinarius impolitus*, fresh *Astraeus smithii*
Cavendish Sandspit	11-Nov-22	no fungi observed
Greenwich	13-Nov-22	*Hebeloma* sp., *Cortinarius psammocola*, *Cortinaritus* sp., *Laccaria maritima*
Cavendish Sandspit	15-Nov-22	no fungi observed

Sixteen species of fungi were observed at 4 different sites in PEINP (Table 2). Five species were found in foredunes and 11 were found in stable dunes. Thirteen were previously unreported in PEI and at least one in Canada. Seven were sequenced for DNA.

Table 2. Annotated species list: Species, sites observed and notes on survey observations, DNA results, typical or observed life history characteristics, and plant associations for species observed during surveys conducted between April 2022 and November 2022 and the fall of 2021.

Species	Location	Notes
Agaricus bisporus	Cavendish sandspit	Very odd for the common white button mushroom to be growing on sand dunes, only observed at this site.
Astraeus smithii	Brackley Beach, Tracadie Harbour, Greenwich	This barometric earthstar is common around *Hudsonia tomentosa*. Thought it fruits in the fall, its loose fruit bodies can be found year round, often blown away from its original habitat.
***Coprinus* sp.**	Cavendish sandspit	DNA did not help indicate what this species might be. Undescribed or lacking reference DNA. Appears to fruit at night.
Cortinarius "sp-PEI02"	Greenwich	The stipe of this *Cortinarius* is yellowish.
Cortinarius impolitus	Brackley Beach	Known only from this location on PEI, the cap flesh tends to be chocolate brown and the stipe white
Cortinarius psammocola	Tracadie Harbour, Greenwich	Very abundant when fruiting, the stipe is purplish.
***Hebeloma* sp.**	Brackley Beach, Tracadie Harbour, Greenwich	Very abundant when fruiting, the stipe is entirely white.
Hygrocybe conicoides	Greenwich	Grows further from its likely *Hudsonia* host, or perhaps it is saprotrophic.
***Laccaria* sp.**	Tracadie Harbour, Greenwich	This was identified as the IUCN red list species *Laccaria maritima*, however DNA results draw this into question, more work needed.
Laccaria trullisata	Brackley Beach, Tracadie Harbour, Greenwich	DNA results indicate that this may be something else and the species needs further review.
Leccinum arenicola	Tracadie Harbour	Likely there are two sand dune species of Leccinum on PEI and what is referenced as *Leccinum arenicola* may be something else. Waiting on DNA results.
Melanoleuca cinereifolia	Cavendish sandspit	DNA sequence indicates this may be a different species than its European version, more effort needed.
Peziza ammophila	Cavendish sandspit, Tracadie Harbour	Common foredune species.
Psathyrella arenulina	Cavendish sandspit, Tracadie Harbour	Common foredune species.

***Russula* sp.**	Tracadie Harbour	Undescribed species, only known from this location on PEI and Kouchibouguac National Park.
Thelephora terrestris	Greenwich	Common on *Hudsonia tomentosa*

Discussion

Surveying macrofungi is challenging due to specific fruiting seasons, moisture requirements, and the short lifespan of sporocarps (fruiting bodies). This is further complicated by a lack of knowledge on species diversity and their phenology. The 2022 field season proved to be particularly challenging. The season was dry with long periods between rain events, limiting ideal fruiting conditions. During the peak of the fruiting season, Hurricane Fiona damaged the dunes and limited access, and likely impacted the diversity of fungi found.

Given a lack of other alternatives, *Hudsonia* is the presumed ectomycorrizhal partner to many different fungi in stable dunes, though likely *Hudsonia ericoides* would be compatible, or even *Lechea maritima* which is also from the Family *Cistaceae* (Rock-rose Family). *Arctostaphylos uva-ursi* is also a presumed ectomycorrhizal host to at least one *Leccinum* species. Not all *Hudsonia* seem to be acceptable given that the old, forested dune ridge in Greenwich, that crosses the Greenwich Dunes Trail and terminates at the parabolic dune, has many smaller *Hudsonia* patches and open sand, yet none of the dune fungi fruiting on the parabolic dune were found in this habitat.

Most stable dune species seemed to prefer fruiting in the exposed sandy spaces adjacent to *Hudsonia*. *Leccinum* sp. were mainly observed growing in the thick of their ectomycorrhizal partner, as does *Thelephora terrestris*, suggesting a preference for that location. *Hygrocybe conicoides*, a saprotrophic fungus, was observed near or far from *Hudsonia*, but only in stable dune habitat. *Laccaria* species originally thought to be *L. maritima* will grow in open sand near *Hudsonia*, or further away in grassier habitat. Outside PEINP (at Black Pond) the waxcap *Hygrocybe jackmanii* was found growing with *Empetrum nigrum* (Black Crowberry).

Foredune species also seemed specific to their habitat requirements, with fruiting more common closer to the leading edge of *Ammophila breviligulata* growth than further back from the shore. This is likely due to the reduced vigor of *Ammophila breviligulata* as sand accretion is reduced and the importance of the nutrients from salt spray (Maun, 2009). Dune scarps significantly reduce available habitat for foredune species of fungi unless the dune scarps are low. Embryo dunes and washovers tend to provide more favorable habitat as demonstrated by Cavendish Sandspit. Hurricane Fiona significantly damaged the foredunes across PEI. Six weeks after Fiona, on November 6th, nine *Psathyrella arenulina* were observed on the South Rustico embryo dune. These were the only foredune fungi observed post Hurricane Fiona in 2022.

As fungal diversity is poorly understood, it is hard to determine which species are rare or uncommon.

There were, however, many interesting discoveries, and ultimately more questions, with each species observed. Here are some of the highlights:

- *Laccaria* sp which is an IUCN red list species, or a species previously known only from the Gulf states in Southeast North America.
- There are potentially two species of *Leccinum* growing on the sand dunes – *Leccinum arenicola* and a *Leccinum* sp. not yet identified. They differ in morphology and ectomycorrhizal partners.
- *Melanoleuca cinereifolia* is likely a different species than its European counterpart.
- An undescribed *Russula* sp., first found in Kouchibouguac National Park in 1981, was documented in PEINP on the stable dunes at Tracadie 'Island'.
- *Agaricus bisporus*, the common white button mushroom found in grocery stores, is growing wild on sand dunes at Cavendish Sandspit.
- Two fungi could not be classified beyond genus at this time.

In the 2022 season 28 species of macrofungi were observed on the sand dunes of PEI. Future effort in surveying both foredune and stable dune habitat in PEINP will undoubtedly document more of these species, and others yet to be discovered.

Priorities for next year's survey:

- Locate undescribed white *Russula* sp. observed in 1994 in Greenwich. More specimens are required to describe species and DNA sequence.
- Collect more of the undescribed *Russula* sp. found at Tracadie Harbour, only one partial mushroom was found this year. More specimens are required at different ages to describe this species.
- Survey foredunes of Greenwich and Blooming Point.
- Scout and survey Greenwich and Blooming Point stable dunes for more habitat varieties, including dunes with *Empetrum nigrum* (Black Crowberry). *Hygrocybe jackmanii* which is known from two locations, one in Labrador location and one at Black Pond in eastern PEI is assumed to associate with *Empetrum nigrum*.
- Survey the forested dune ridge at Greenwich in more detail.
- Document changes to foredune fungi in response to Hurricane Fiona damage.
- More field observations of *Laccaria* and *Leccinum* spp. to reduce current knowledge gaps in field identification, phenology, and habitat requirements.

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