

The Status of
Water Pygmyweed
(*Tillaea aquatica*)

in Newfoundland and Labrador



Photo: John E. Maunder

**THE SPECIES STATUS ADVISORY COMMITTEE
REPORT NO. 15**

February 20, 2008

ASSESSMENT

Assessment: Vulnerable	Current designation: None
Criteria met: D2. Area of occupancy < 20 km ²	
Reasons for designation: Qualifies as " <i>threatened</i> " under the SSAC/COSEWIC criteria D2, but the possibility of a catastrophic loss of populations is buffered by the number of locations and seed bank, therefore " <i>vulnerable</i> ". <ul style="list-style-type: none">• Geographically restricted to the southeastern Newfoundland• Area of occupancy < 0.01 km²• Known only from 6 localities in Newfoundland• Minute annual plant reliant only on seed bank for perpetuation• A large portion of the overall population occurs within highly disturbed sites	

The original version of this report was prepared by John E. Maunder on behalf of the Species Status Advisory Committee.

STATUS REPORT

Tillaea aquatica Linnaeus

Water Pygmyweed; Fr. tillée aquatique

Synonyms:

Bulliarda aquatica (Linnaeus) DeCandolle

Crassula aquatica (Linnaeus) Schönland in Engelmann and Prantl

Tillaeastrum aquaticum (Linnaeus) Britton

Family: Crassulaceae (Stonecrops)

Life Form: Herbaceous, annual, amphibious, succulent forb.

Taxonomic Clarifications

Moran (1992) pointed out that the species name *aquatica* “has been used [at one time or another] for most of the aquatic forms [of *Tillaea*] in North America”.

However, Bywater and Wickens (1984) concluded, following a detailed study of the New World representatives of the genus *Crassula* [= *Tillaea*], that a total of 6 *aquatic* species can be distinguished for North America.

Our Newfoundland form, and the specific subject of this report, is clearly *Tillaea aquatica* (*sensu stricto*) based upon the treatment of this species in Bywater and Wickens (1984). Nonetheless, many species treatments do not yet fully accommodate the apparently well-argued distinctions made by Bywater and Wickens (1984).

If Bywater and Wickens are correct in their overall assessment, and *Tillaea aquatica* (*sensu stricto*) does indeed possess a much more restricted distribution than has been formerly recognized - not normally occurring inland or at higher altitudes - then many of the published distributions for the species for North America may be of limited value, since they likely confound together the distributions of more than one legitimate taxonomic entity.

The global and national distribution and conservation status data, presented below, should definitely be viewed with some caution in light of such continuing controversy.

Distribution

Global:

North America: Canada [see more detail below]. United States of America: several northeastern and two western states *including* Maine, Massachusetts, Connecticut, New York, Maryland [possibly extirpated (NatureServe Explorer)], Oregon, California; plus Alaska (Bywater and Wickens 1984). St.-Pierre et Miquelon Archipelago: St.-Pierre, Miquelon (Rouleau and Lamoureux 1992).

[Additional records, of uncertain validity (see “Taxonomic Clarifications”, above), from NatureServe Explorer: New Hampshire, Vermont, Rhode Island, Pennsylvania (presumed extirpated), Delaware, Alabama, Minnesota, Arkansas, Louisiana, Texas, Oklahoma, Colorado (possibly extirpated), Utah, Idaho, Washington].

... with the main concentrations centered in northeastern, southern, and western regions (Den virtuella floren, 1998).

Eurasia: Japan, Korea, Mongolia [inland records of uncertain validity (see “Taxonomic Clarifications”, above)], and Russia, with the main concentrations centered in Japan (Den virtuella floren, 1998, Fu *et al.* 2001).

Europe: northern regions, including Iceland (Den virtuella floren, 1998).

National:

Canada: Newfoundland and Labrador (Newfoundland only), Prince Edward Island (extirpated?), New Brunswick, Québec, Northwest Territories [inland record, originally by Cody (1954), seems questionable] (Bywater and Wickens 1984).

[Additional records, of uncertain validity (see “Taxonomic Clarifications”, above), from NatureServe Explorer: Nova Scotia, Ontario, British Columbia, Yukon]

Provincial:

On the Island of Newfoundland, known only from 6 small isolated localities, all on the southern Burin and Avalon Peninsulas (Fig. 1).

Annotated Range Map

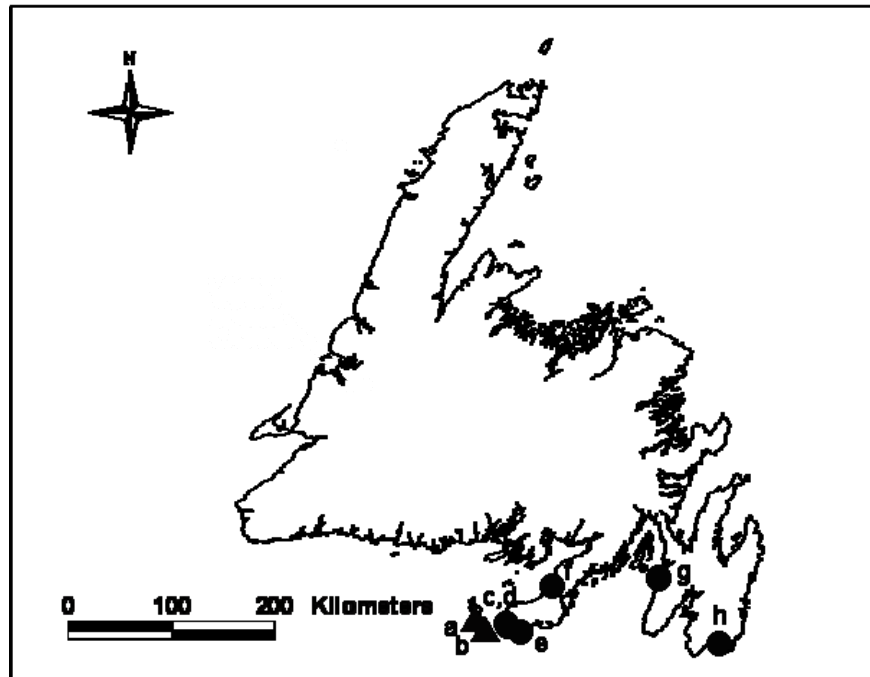


Figure 1. Known localities for *Tillaea aquatica* on St.-Pierre et Miquelon, and in Newfoundland: [a] Langlade (SPM), [b] St.-Pierre (SPM), [c] Point May, [d] Pieduck Point, [e] Taylor's Bay, [f] Garnish, [g] Argentia, [h] Portugal Cove South (all St.-Pierre et Miquelon records are historical).

Description

Tiny, tufted, succulent, semi-aquatic annuals, often growing in mats. Normally reddish, though sometimes tending towards yellowish, or even greenish. In Newfoundland, the tendency seems to be that plants are mainly reddish on the Avalon Peninsula, and mainly greenish on the Burin Peninsula. Tiny whitish flowers, and vase-like seed capsules with diverging tips, arranged in four's.

Habitat

Worldwide, the habitat of *T. aquatica* has been variously described as: sandy margins of fresh to brackish vernal or intermittent pools, riverbanks, brackish mudflats, and tidal shores. However, *T. aquatica* (*sensu stricto*) is probably

mainly coastal. As stated earlier, above, Bywater and Wickens (1984) were of the opinion that, at least in North America, most inland and higher elevation records refer to other *Tillaea* species. In Maine *T. aquatica* is exclusively intertidal, growing only slightly above the low tide line (Maine Department of Conservation 2004).

For Newfoundland, the habitat requirements of *T. aquatica* can be described more specifically: [1] wet depressions, margins of freshwater pools, and brackish shores, all subject to seasonal or intermittent flooding, [2] closeness to salt water with a definite marine influence, [3] substrate of *very* fine grey sand, possibly of glacial origin, with limited organic content, and [4] sparse competing vegetation. This habitat seems to be extremely restricted in Newfoundland. Nonetheless, within the specific parameters listed above, there is striking local variability.

Overview of Biology

General:

T. aquatica is a tiny amphibious, halophilic annual. Like many small aquatic plant species, it is succulent, and lacks functional stomata. In Newfoundland, flowering occurs during at least July and August, overlapping significantly with the fruiting season. Fruiting occurs during at least August through early Fall. No precise dates are available for Newfoundland. Apparently self-fertilizing and/or apomictic (asexual). Local dispersal probably by water; long-distance dispersal probably by birds (Bywater and Wickens, 1984; Brouillet *et al.* 2004). The lower leaves disintegrate during September and October. *T. aquatica* reproduces by seed. Milberg and Stridh (1994) estimated the seed bank of the species in Sweden to be 51,800/m² (to 6 cm depth) - a large figure, though perhaps not a surprising one since the estimated density of plants at Newfoundland sites is at least 1000/m².

Metabolism:

The most striking feature of the biology of *T. aquatica* is its propensity for inhabiting areas of seasonal or intermittent inundation. In some areas, such as California, the species inhabits true “vernal pools” (Moran 1992).

For aquatic plants living in such changeable habitats, the major challenge is coping with a bimodal lifestyle which demands the ability to live both underwater, and emerged above it (often during the hottest time of the year), for varying periods of time.

An additional challenge revolves around the fact that the shallow waters of intermittent pools often tend to exhibit dramatic diurnal changes in the

concentration of free CO₂. At night when water temperatures cool and normal respiration within the water column augments the CO₂ supply, CO₂ concentrations tend to be very high. During the day, when water temperature rises and photosynthesis quickly depletes the CO₂ supply within the water column, concentrations tend to be very low (Keeley 1999).

T. aquatica meets both of these challenges largely through its ability to alternate between “crassulic acid metabolism” (CAM) when submerged, and normal C₃ metabolism when exposed. CAM is a rare form of plant metabolism that involves dramatic diurnal fluctuations in internal acid concentrations (Keeley and Rundel 2003). It is found primarily in drought-resistant succulent species, but also in a small number of aquatic species, including *T. aquatica*.

Since CAM allows the uptake and utilization of CO₂ from the root zone over the majority of the 24 hour day - thus alleviating the inherently low availability of dissolved inorganic carbon in the water column (Madsen 1987, Boston *et al.* 1987) - it may confer an advantage over competing plants which do not possess CAM. For this reason, the maintenance of intermittent-inundation conditions in areas where *Tillaea* occurs is almost certainly essential to its continued survival.

Population Size and Area of Occupancy

In Newfoundland there are 6 known populations of *T. aquatica*. Additional populations may exist in remote areas along the Province’s south coast. Typically, the species has been undercollected; three of the 6 known populations (Pieduck Point, Taylor’s Bay, and Garnish), were discovered only recently, by John Maunder, during focused searches associated with the preparation of this report, in the Fall of 2006).

Because of the very small size of individual plants, the typical mat-like growth form, and the semi-buried nature of the growth habit, it is very difficult to determine the total population size of individuals very accurately. Of necessity a statistical approach will be employed below. Approximate area of occupancy, plus approximate density of occurrence will be used to calculate very approximate population estimates of individuals.

Point May: (locality completely flooded during the Fall 2006 visit)

Approximate area of occupancy: unknown (but, apparently not remarkable)

Approximate density of occurrence: unknown

Estimated population of individuals: unknown

Pieduck Point:

Approximate area of occupancy: 50m²
Approximate density of occurrence: 1000/m²
Estimated population of individuals: 50,000

Taylor's Bay:

Approximate area of occupancy: 3m²
Approximate density of occurrence: 1000/m²
Estimated population of individuals: 3000

Garnish:

Approximate area of occupancy: 5m²
Approximate density of occurrence: 1000/m²
Estimated population of individuals: 5000

Argentia:

Approximate area of occupancy: 55m²
Approximate density of occurrence: 1000/m²
Estimated population of individuals: 55,000

Portugal Cove South: *(these figures are particularly approximate – the area was partially-flooded during the Fall 2006 visit; however, the observer, John Maunder, had prior anecdotal personal experience concerning general population size at this site)*

Approximate area of occupancy: 500m² [rough estimate]
Approximate density of occurrence: 1000/m² [rough estimate]
Estimated population of individuals: 500,000 [rough estimate]

Total Area of Occupancy: 613m² plus unknown Point May figures - perhaps 700m²

Total Population: 613,000 plus unknown Point May figures - perhaps 700,000

Traditional and Local Ecological Knowledge.

No published or other evidence has been found regarding the aboriginal use of *T. aquatica* in Newfoundland. Arnason *et al.* (1981) do not mention the species in their study of eastern Canada ethnobotany.

Trends.

Trends are different for different localities.

Point May: This small site is still poorly understood. It is probably more or less stable. It does not seem to be seriously impacted by the adjacent town.

Pieduck Point: The very small site is relatively isolated, but does have gravel road access. In some ways, disturbance by ATVs is probably providing “enhanced” habitat, and thus, probably, continuing future opportunities for “artificially-supported” population expansion.

Taylor’s Bay: Disturbance by ATVs is probably at least maintaining the present artificially-enhanced habitat. The area is sparsely populated by humans, and conditions may *not* change appreciably in the near future.

Garnish: Unknown.

Argentia: The re-discovery of *T. aquatica* on the Argentia Peninsula, in 2006, 82 years after its original discovery there [but, not exactly at Fernald’s original discovery site], was a bit of a surprise. It is remarkable that the species has managed to survive the extreme havoc created by the construction of the U.S. Naval Base and airport on the site during the 1940’s, the subsequent havoc created by the gradual conversion of the site to a commercial industrial park during the 1980’s and 1990’s, *and* the added extreme havoc created by recent “site reclamation” (ie. hazardous waste mitigation) activities, that have resulted in extensive excavations and the creation of huge piles of excavated earth all over the Argentia Peninsula. Its preference for sites on the extreme margin of the land may have been its salvation. However, given that only two, very small, very closely-situated, coastal sub-sites are still known, the prospect for the future, at this locality, seems uncertain.

Portugal Cove South: *T. aquatica* was first discovered at this site in 2001 by John Maunder in the artificially-created sand pits. Its occurrence in the area prior to that time is unknown. Its relative profusion at this locality is apparently entirely owing to the gradual, expansion of the total area of its habitat since sometime after 1967. With reference to the relevant [rather sparse selection of] air photos extant: photo A 20056-47, taken on August 3, 1967, shows no pits; while photo A

31372 44-48, taken in 1983, shows all but the newest, westernmost pit. However, significantly, the newest, westernmost pit is uncharacteristically deep, and may not contribute further to *Tillaea* expansion. On the other hand, ongoing natural development of pond-like vegetation in the oldest (ie. easternmost) of the pits, as it matures towards pond-like status, will almost certainly result in the eventual demise, or at least significant reduction, of *T. aquatica* at that specific locality. Maturation of the next oldest pit may also be taking place, to some extent, though perhaps more in a terrestrial sense. The long term future of *T. aquatica* at Portugal Cove South is thus, undoubtedly, somewhat fragile.

Threats and Limiting Factors

Threats are different for different localities.

Point May: Despite extreme closeness to the town, threats may be minimal.

Pieduck Point: No threats in particular. While ATV traffic may seem destructive, it is ultimately creating new habitat.

Taylor's Bay: No particular threats. While ATV/vehicular traffic may seem to be destructive, it ultimately creates, or at least maintains, new habitat. There is limited human habitation in the immediate vicinity, and Taylor's Bay is not an area where future growth or development is anticipated.

Garnish: The prospect for this population is very concerning. The simple grading of the tiny roadside site could destroy it.

Argentia: Unchecked continuing site modification may present a critical threat. That said, the two known sub-sites are extremely peripheral, in a geographic sense.

Portugal Cove South: [1] location within the town, [2] location very near the main highway, [3] possible threats from resumed sand-pitting within the existing sand-pits, [4] possible future construction on site (though a wet site prone to salt water flooding), [5] general physical abuse by ATVs and larger vehicles, [6] cosmetic in-filling of the old sand-pits by town (ie. "municipal landscaping"), [7] general municipal projects on the site (possibly grant-driven), [8] possible re-routing of the highway along the beach (to avoid future saltwater flooding during storms), [9] changing water levels of the pond (either up or down) due to re-engineering of the pond outflow to the sea.

Rank or Status

Global	
G-rank	G5
IUCN	not assessed
National	
N-rank	NNR (not ranked)
National General Status	3
COSEWIC	not assessed
Provincial	
Provincial General Status	2
Newfoundland S-Rank	S1
Newfoundland General Status	2
Labrador S-Rank	not present
Labrador General Status	not present
Adjacent Jurisdictions	
Nova Scotia S-Rank	S2
Nova Scotia General Status	3
Prince Edward Island S-Rank	S1 (extirpated?)
Prince Edward Island General Status	0.1 (extirpated?)
New Brunswick S-Rank	S2
New Brunswick General Status	3
Québec S-Rank	S3
Québec General Status	3
St.-Pierre et Miquelon	three historical localities

[Note: Where available, ranking data from the biodiversity databases of the individual Provinces has been used. Otherwise, General Status ranks are based upon the “General Status of Species in Canada (2005)”, and S-Ranks are based upon “NatureServe Explorer”. Where there is apparent discrepancy, NatureServe Explorer ranks are considered to be the least current.]

Existing Protection.

None.

Special Significance

None in particular.

However, a comment. The special challenges involved in conserving tiny species in small isolated seasonal or intermittent aquatic habitats are many (Keeley and Zedler 1998). In the United States, the debate about whether or not temporary water bodies constitute legitimate habitats for conservation continues to be very contentious (Zedler 2003).

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Collections Examined

Provincial Museum of Newfoundland and Labrador (NFM):
Seven herbarium collections.

TECHNICAL SUMMARY

Distribution and Population Information	Criteria Assessment
<i>Extent of occurrence (EO)(km²)</i>	± 8200 km ²
<i>Area of occupancy (AO) (km²)</i>	± 0.001 km ²
<i>Number of extant locations</i>	6
<i>Specify trend in # locations, EO, AO (decline, stable, increasing, unknown)</i>	unknown
<i>Habitat trend: specify declining, stable, increasing or unknown trend in area, extent or quality of habitat</i>	probably stable on balance, prone to stochastic events
<i>Generation time (average age of parents in the population) (indicate years, months, days, etc.)</i>	< 1 year (plants are annuals)
<i>Number of mature individuals (capable of reproduction) in the Provincial population (or, specify a range of plausible values)</i>	perhaps 700,000 (tiny plants growing densely together)
<i>Total population trend: specify declining, stable, increasing or unknown trend in number of mature individuals or number of populations</i>	variable, but probably stable overall
<i>Are there extreme fluctuations (>1 order of magnitude) in number of mature individuals, number of locations, AO and/or EO?</i>	Unknown
<i>Is the total population severely fragmented (most individuals found within small and isolated populations)</i>	Yes
Rescue Effect (immigration from an outside source)	
<i>Does species exist elsewhere?</i>	yes
<i>Status of the outside population(s)? [adjacent Provinces and territories only]</i>	Nova Scotia, New Brunswick, and eastern Québec, sensitive. Rare and historical in St.-Pierre et Miquelon
<i>Is immigration known or possible?</i>	unknown
<i>Would immigrants be adapted to survive here?</i>	unknown; likely
<i>Is there sufficient habitat for immigrants here?</i>	unknown

Appendix A. Population Information

Recently Verified Occurrences/Range Use (recorded within the last 25 years)

Verified occurrences consist of observations supported by the collection of a voucher specimen (i.e. a sample to be identified/confirmed by experts and deposited in a herbarium).

Point May:

August 25, 1987. [Observers: R. Etcheberry (in company with R. Noseworthy). Collections deposited in the personal herbarium of R. Etcheberry (RE 787), St.-Pierre et Miquelon; and at MT (Université de Montréal).]. (Roger Etcheberry, pers. com. October 8, 2006)

August 13, 2005. Valid identification and record. [Diagnostic photos taken: H. Clase (see: Maunder (ongoing)).]

Pieduck Point (Northeast of Point May):

September 24, 2006. ATV track to beach, in coastal sedge meadow. Edges of puddles in track. [Observer: J. E. Maunder. Collection: (Provincial Museum of Newfoundland and Labrador (NFM), collections not yet catalogued). Diagnostic photos taken: J. E. Maunder (see: Maunder (ongoing)).]

Taylor's Bay:

September 24, 2006. Old car track to beach. Edges of puddles in track. In coastal sedge meadow. [Observer: J. E. Maunder. Collection: (Provincial Museum of Newfoundland and Labrador (NFM), collection not yet catalogued). Diagnostic photos taken: J. E. Maunder (see: Maunder (ongoing)).]

Garnish:

September 25, 2006. Edge of main road, between road and beach, at west end of town. Edges of shallow, wet depression. Disturbed ground. [Observer: J. E. Maunder. Collection: (Provincial Museum of Newfoundland and Labrador (NFM), collection not yet catalogued). Diagnostic photos taken: J. E. Maunder (see: Maunder (ongoing)).]

Argentia:

September 20, 2006. Argentia Peninsula; northwest corner, just south of Latine Point. Two closely-situated sub-localities (here considered to be one functional locality). Shallow depressions, intermittently flooded by rain or marine spray. [Observer: J. E. Maunder. Collection: (Provincial Museum of Newfoundland and Labrador (NFM), collections not yet catalogued). Diagnostic photos taken: J. E. Maunder (see: Maunder (ongoing)).]

Portugal Cove South:

July 24, 2001. Intermittently-flooded, human-excavated sand pits between the high rocky barrier beach and shore highway, and a medium sized pond (Portugal Cove South Pond) behind it. [Observer: J. E. Maunder. Collection: NFM 6764 (Provincial Museum of Newfoundland and Labrador). Diagnostic photos taken: J. E. Maunder (see: Maunder (ongoing)).]

August 11, 12, 2003. Same locality. [Observers: J. E. Maunder and Nathalie Djan-Chékar. Diagnostic photos taken: J. E. Maunder (see: Maunder (ongoing)) and the cover of the present report.]

September 19, 2006. Same location. Slightly expanded area of occupancy. [Observer: J. E. Maunder. Diagnostic photos taken: J. E. Maunder (see: Maunder (ongoing)).]

Recent Search Effort (areas searched within the last 25 years with estimate of effort)

General rare plant surveys of the west and northeast coasts of the Island were conducted by members of the Newfoundland Rare Plant Project (*q.v.*), specifically during 1999 to 2001, when 1645 individual sites were surveyed and 7622 plant collections were made. Additional general rare plant surveys have been conducted within the Province by various National Parks personnel, and by J. E. Maunder of the Provincial Museum and H. Mann of Sir Wilfred Grenfell College (early 1970's to present), as well as by N. Djan-Chékar of the Provincial Museum (2002 to present). Significant additional general collecting has been conducted, on the south coast of the Island, by R. Etcheberry, of St.-Pierre et Miquelon (1986, 1987, 1989, 1990, 1992, and 1993).

Targeted rare plant surveys were conducted by personnel from the Université de Montréal, during the course of the preparation of the publication "The Rare Vascular Plants of the Island of Newfoundland" (Bouchard *et al.* 1991), in: 1984 and 1985 (Gros Morne National Park), 1986 (southwest coast, and the general Port au Port area), 1987 (Great Northern Peninsula), 1988 (Baie Verte Peninsula,

Notre Dame Bay, and central and eastern Newfoundland), 1989 (Gros Morne National Park, and the south coast), and 1990 (west coast, and Great Northern Peninsula).

Geographically focused rare plant surveys were conducted by personnel from the Université de Montréal, during the course of the preparation of contracted rare plant reports for Port au Choix National Historic Park (Bouchard *et al.* 1993), L'Anse aux Meadows National Historic Park (Bouchard *et al.* 1993), Gros Morne National Park (Anions, 1994; Bouchard *et al.*, 1985, 1986, 1991, 1994, 1996; and Brouillet *et al.*, 1998), and Terra Nova National Park (Brouillet *et al.* 1997). Additional geographically focused rare plant surveys were conducted in the Squid Cove and Doctors Brook areas, and the Labrador Straits region by C. Hanel (2004, 2005a, 2005b).

As well, on the west coast of the Island, B. Hellquist and G. Crow surveyed for aquatic species in 1986.

The southeastern areas of Newfoundland, particularly the southeastern Avalon Peninsula, and the Burin and Connaigre Peninsulas, have been searched most extensively in recent years by J. E. Maunder, Curator of Natural History, Provincial Museum of Newfoundland and Labrador [1977-2004]. It is difficult to estimate specific effort. However, in preparation for the writing of this present report, an additional two day focused search was conducted, that resulted in the relocation of the historical (1924) *Argentia* locality, and the discovery of three *new* localities on the southern part of the Burin Peninsula.

Additional searching has been conducted, on the South Coast of the Island, in particular, by R. Etcheberry, of St.-Pierre et Miquelon.

Historical Verified Occurrences/Range Use (recorded prior to the last 25 years)

August 26, 1924. *Argentia*. Sandy and peaty margin of pond back of barrier beach. ["not too far away from the [coastal boat] wharf"] [Observers: M. L. Fernald, B. Long, and B. Dunbar. Collection: G 26737. GH (Gray Herbarium); specimen seen by E. Rouleau (Cody, 1954).] (Ref. also: Fernald 1926).

Additional Historical Verified Occurrences/Range Use from the Geographically Contiguous Archipelago of St.-Pierre et Miquelon (recorded prior to the last 25 years):

Records provided by R. Etcheberry of St.-Pierre et Miquelon (pers. com. October 8, 2006); see also, Rouleau and Lamoureux (1992).

St.-Pierre:

Summer 1950. Le Hors. Terrains boueux, rivages du Cap au Diamant, *in* : LE GALLO, C., 1954 - Les plantes vasculaires des Iles St. Pierre et Miquelon. Nat. Can. 5:6-7, 8-9, 10-11. Leg. p. 202 (Nat. Can. n° 10-11) [Considered to be verified by subsequent collections from the same locality (see below).]

September 6, 1980. Diamant (ca 46°45'40" N, 56°13' W), marais à gauche de la route. Brackish pond near the sea. Observer: R. Etcheberry. Collection deposited in the personal herbarium of R. Etcheberry (RE 177), St-Pierre et Miquelon.

September 13, 1980. Same area as the Etcheberry collection. Observer: Daniel Abraham. Personal collection of D. Abraham. Verified by R. Etcheberry.

Miquelon:

Brother Arsène (1927) stated: "I think I found *Tillaea aquatica* in 1902 near the Grand Barachois, but it was late in season, the flowers were gone, and I did not take specimens, hoping to make a future collection [record remains unconfirmed]

Langlade:

September 10, 1982. Langlade (south part of the Isthmus ca 46° 53'50 N, 56°19'50"W, West of Marais Olivier. Observer: R. Etcheberry. Collection deposited in the personal herbarium of R. Etcheberry (RE 653), St-Pierre et Miquelon.

Other Observations (unverified occurrences)

1998. A collection from "Point May" [actually from a small pond just to the northwest, at Lories], reported by Clase (1999), has proven NOT to represent this species upon examination of the specimen at the Provincial Museum of Newfoundland and Labrador (NFM) [specimen not available at time of writing] by J. E. Maunder.

Potential Sites Unexplored

The southeastern bias of present *Tillaea aquatica* records, on the Island, is quite consistent with the distributional patterns of some other Newfoundland species, both plant and animal. While more northern regions of Newfoundland may, possibly, harbour *T. aquatica* (the species has been reported from one site on the Québec “North Shore” west of Blanc Sablon, and also from one location in Hudson Bay), it is basically a southern coastal [but *not* “coastal plain”] species in our region. However, the south coast of Newfoundland remains poorly botanized, in relation to other areas of the Island. It seems likely that a small number of additional sites may harbour *T.a aquatica*. The most likely places to look are probably the sheltered reaches within Baie d’Espoir, and the extensive area of sandy beaches near Burgeo.

Appendix B. Supplementary Details

Taxonomic Clarifications

Genus:

NatureServe Explorer, and the General Status of Species in Canada (2005), both continue to follow Kartesz (1994) in including *Tillaea* within the genus *Crassula*. However, recent molecular data (ie. Eggli *et al.* 1995, Van Ham and 't Hart 1998) has demonstrated that there is sufficient sequence divergence ($\pm 4.8\%$) between the two taxonomic entities to justify their separation. Meades *et al.* (2000) adopted this line of argument. Others continue to contest it.

Ultimately, *Tillaea* appears to be the correct name (Brouillet *et al.* 2004; Luc Brouillet, Flora of North America project, personal communication, October 19, 2006).

Species:

Moran (1992) pointed out that the species name *aquatica* “has been used [at one time or another] for most of the aquatic forms [of *Tillaea*] in North America”. However, Bywater and Wickens (1984) concluded, following a detailed study of the New World representatives of the genus *Crassula* [= *Tillaea*], that a total of 6 *aquatic* species can be distinguished for North America.

Of these, three are very similar:

1. *aquatica* (*sensu stricto*): longitudinally striate, minutely wrinkled, dull seeds; extremely short pedicels in fruit; and a *much more restricted distribution* than has been formerly recognized, the species being “restricted to low altitude, usually near sea level, coastal conditions, often within tidal and splash zones.”
2. *saginoides*: longitudinally striate, minutely wrinkled, dull seeds; elongated pedicels in fruit; inhabiting fresh water, often inland and at higher altitudes.
3. *solierii*: smooth, shiny, waxy seeds; inhabiting fresh water, somewhat inland, in more southern localities.

Our Newfoundland form, and the specific subject of this report, is clearly *Tillaea aquatica* (*sensu stricto*).

Nonetheless, many species treatments do not yet fully accommodate the apparently well-argued distinctions made by Bywater and Wickens (1984). Notably, Moran (1992) questioned the separation of *T. aquatica* and *T. saginoides*.

If Bywater and Wickens *are* correct in their overall assessment, and *Tillaea aquatica (sensu stricto)* does indeed possess a *much more restricted distribution* than has been formerly recognized - not normally occurring inland or at higher altitudes - then many of the published distributions for the species for North America may be of limited value, since they likely confound together the distributions of more than one legitimate taxonomic entity.

Complicating matters, in our area, is the fact that Bywater and Wickens (1984) recorded the mostly western *T. saginoides* for Massachusetts and western Nova Scotia. This indicates that it should be watched for in this Province.

The global and national distribution and conservation status data, presented below, should definitely be viewed with some caution in light of such continuing controversy.

Description (Fig. B-1, B-2, B-3)

Tiny, tufted, semi-aquatic annuals, often growing in mats. Normally reddish, though sometimes tending towards yellowish, or even greenish. [In Newfoundland, the tendency seems to be that plants are mainly reddish on the Avalon Peninsula, and mainly greenish on the Burin Peninsula.] **Roots** weak, fibrous. **Stems** slender, often branching from base, erect or ascending; in Newfoundland, usually only ca. 1-2 cm long. **Leaves** linear-lanceolate to elliptic-oblong, ca. 4-8 × 1 mm [in Newfoundland, often smaller]), entire (ie. margins without teeth or other indentations), apex acute, with the bases of each opposite pair connate (ie. united). **Lower leaves** disintegrating with age. **Flowers** tiny, axillary or rarely terminal, sessile, 4- or rarely 5-merous. **Sepals** triangular, ca. 0.6-0.9 mm long, apex rounded-obtuse. **Petals** white or greenish-white, rhomboid-ovate, 1.4-1.7 x 0.8-0.9 mm, twice as long as sepals, apex obtuse. **Stamens** shorter than petals. **Carpels** ovoid-oblong. **Styles** short. **Pedicels** very short, even at fruiting. **Follicles** usually 9-12-seeded. **Seeds** reddish-brown, cylindrical, ca. 0.5 mm, longitudinally striate, minutely-wrinkled, dull. (Adapted from Fernald (1950), Bywater and Wickens (1984), and Fu *et al.* (2001), with additions.)



Photos: John E. Maunder

Figure B-1. Description: [a] reddish form, in flower, in sand pits at Portugal Cove South, August 11, 2004, [b] greenish form, in fruit, at Taylor's Bay, September 24, 2006.



Photos: John E. Maunder

Figure B-2. Description: [a] flower bud, [b] flower, [c] maturing follicles (ie. seed capsules); all photos from Portugal Cove South, August 11, 2004.



Photos: John E. Maunder

Figure B-3. Description (Reduced leaves in late season): [a] reddish form, from Argentina, September 20, 2006, [b] greenish form, from Pieduck Point, September 24, 2006. Note very short pedicels.

Habitat (Fig. B-4 to B-9)

At Point May, the habitat occurs on the brackish margins of a small barachois pond (Figure B-6a) subject to drastic water level changes, sometimes including major filling by ocean waves overtopping the cobble ocean beach. Associated sparse vegetation includes: the rare mudwort *Limosella australis*.

At Pieduck Point and Taylor's Bay, the habitat occurs on the margins of temporary puddles on an ATV track, and an old cart track, respectively, each leading through shore sedge meadows to nearby ocean beaches (Figures B-6b and B-7b). At Pieduck Point, the associated sparse vegetation includes: the grass *Agrostis stolonifera*, the rushes *Juncus articulatus* and *Juncus bufonius*, and the buttercup *Ranunculus repens*. At Taylor's Bay, the associated vegetation includes: the grass *Poa annua* and the rush *Juncus articulatus*.

At Garnish and Argentina, the habitat occurs in and around very shallow depressions just behind the ocean beach that may be intermittently flooded by either rainwater or marine spray (Figures B-7, B-8). Associated sparse vegetation includes: the silverweed (*Argentina anserina*), the seaside plantain (*Plantago maritima* subsp. *juncooides*), and the grass *Poa annua*, with the buttercup *Ranunculus cymbalaria* in adjacent wet runnels at one of the two Argentina sub-localities.

At Portugal Cove South, the habitat occurs in intermittently-flooded, human-excavated sand pits between the high rocky barrier beach and shore highway, and a medium sized pond (Portugal Cove South Pond) (Figures B-9). Some overtopping of the barrier beach, by ocean waves, occurs during heavy storms. Associated sparse vegetation includes: the water-starwort *Callitriche verna*, and, to a lesser extent, the grass *Agrostis stolonifera*, and the quillwort *Isoetes echinospora*.

T. aquatica tends to gravitate towards the wet margins of isolated puddles on *disturbed ground*, even where such habitats are apparently well-separated from similar habitats elsewhere... Where do such tiny populations come from, and how do they continue to maintain themselves?

There may be, in actual fact, a low background level of wider occupancy by this apparently open-ground species, in supposed "micro-clearings" within more densely vegetated natural terrain? ... Intriguingly, at Pieduck Point and Taylor's Bay, small patches of *T. aquatica* can be seen transitioning between the wet edges of disturbed-area pools, and the margins of adjacent, more densely vegetated, sedgy meadows (Figures B-6b, B-7b). But, to be sure, the prospect of actually locating individual *T. aquatica* plants at any distance into such more densely vegetated habitats, assuming that such individuals exist, seems very slight because of the tiny size of the plants!



Photo: John E. Maunder

Figure B-4. General Habitat: *Tillaea aquatica* growing sparsely, and in the open, on fine mud at the edge of an intermittent pool. Portugal Cove South. September 19, 2006.



Photo: John E. Maunder

Figure B-5. General Habitat: *Tillaea aquatica* growing more densely, in association with other plants, on fine mud at the edge of an intermittent pool. Portugal Cove South. September 19, 2006.



Photos: John E. Maunder

Figure B-6. Habitat: [a] Point May - brackish barachois pond, viewed from the barrier beach, showing the pond flooded by ocean waters following Tropical Storm Florence, [b] Pieduck Point near Point Crewe - ATV track leading through sedge meadow to nearby beach.



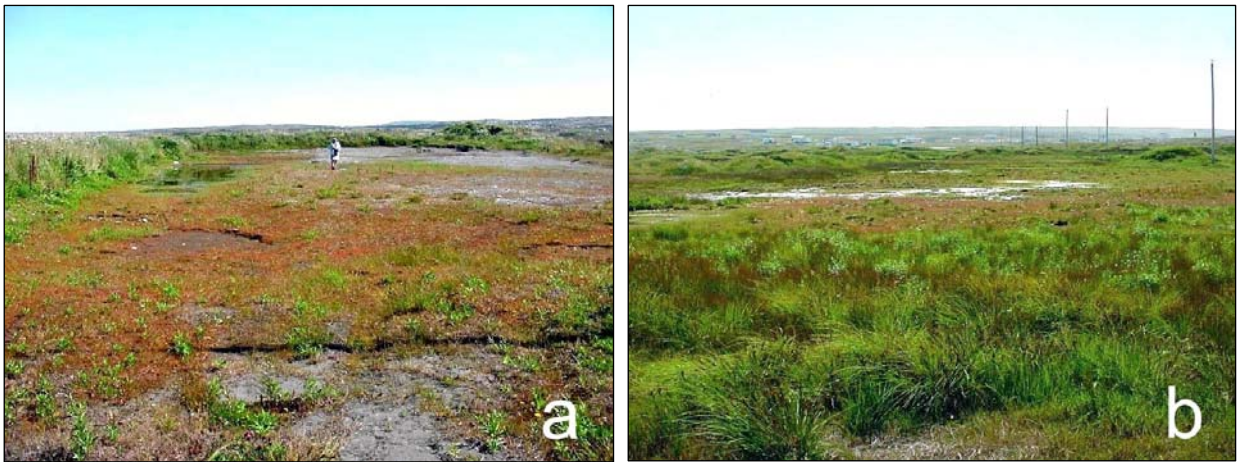
Photo: John E. Maunder

Figure B-7. Habitat: [a] Garnish - shallow depression, disturbed area, just behind ocean beach, [b] Taylor's Bay - old car track leading through sedge meadows to nearby beach.



Photos: John E. Maunder

Figure B-8. Habitat (Argentina): [a] very shallow depressions, just behind the ocean beach, northern sub-locality, [b] southern sub-locality. Both views looking seaward, near Latine Point.



Photos: John E. Maunder

Figure B-9. Habitat (Portugal Cove South): [a] human-excavated sand pits, looking N, [b] longer view, looking E.

Overview of Biology

Metabolism:

The key achievements of CAM are the inhibition of transpiration and photorespiration, and thus water loss; and the ability of the plant to assimilate CO₂ during the greater part of the 24 hour day.

When utilizing CAM, *Tillaea* assimilates CO₂ at night, when ambient concentrations are highest, fixing it within the plant as malic acid. It then decarboxylates the malic acid during the day, releasing CO₂ internally. Assimilation of dissolved inorganic carbon during the day is by the classic C₃ pathway if CO₂ is not limiting (Newman and Raven 1995, Keeley 1999). When utilizing CAM, *Tillaea* also recycles and retains CO₂ within its tissues at a relatively high concentration, possibly as a result of the diffusive resistance to CO₂ inherent in the structure of its succulent, astomal leaf (Madsen 1987, Newman and Raven, 1995). High internal concentrations of CO₂ enhance nitrogen-use efficiency, and thus decrease photorespiration. The mechanism that allows *Tillaea* to distinguish between inundation and stranding conditions, and thereby switch between CAM and C₃ metabolism, is not yet well understood (Cockburn 1985). The likely contribution of CAM toward *Tillaea*'s salt tolerance is also not well understood (Lüttge 1993). On the down side, CAM is less energy efficient than C₃ or C₄ metabolism, and results in slower plant growth. The possession of CAM seems to be broadly linked to competitive advantage (Newman and Raven, 1995).

Collections Examined

Provincial Museum of Newfoundland and Labrador:

NFM 6764, NDC 04-5 (collection not yet accessioned). [See Appendix A for details]

Additional recent collections were made, at Pieduck Point, Taylor's Bay, Garnish, and Argentia, by John Maunder, during the course of the preparation of this report (but these collections have not yet been fully processed or accessioned): [see Appendix A for details]