THE VEGETATION AND PHYTOGEOGRAPHY OF SABLE ISLAND, NOVA SCOTIA

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Abstract

Sable Island is a crescent-shaped emergent sandbar 42.5 km long, 1.4 km wide, occupying 3400 ha and located about 160 km east of the Nova Scotia mainland. A 1981 field survey and literature search were undertaken to provide a more complete information base on vegetation and floristics of the island. The field work included the description and mapping of plant communities, soil and water analysis, and collection of plant specimens with a view to producing a current annotated list of vascular plants. Literature searches included the documentation of historical descriptions of vegetation, terrain, floristic composition, and phytogeography.

Since at least 1505, the island has been treeless with low herb and shrub cover, and with erosion and shifting sand. Substrates are alkaline or acidic sand, with very little organic matter and low levels of nutrients. Wetland and aquatic habitats are either acidic or brackish with high sodium levels. The climate is maritime and moderate, with relatively little snow cover, high average wind speeds, and less sunshine than on mainland sites.

It is possible that a larger precursor of Sable Island was unglaciated during the Wisconsin epoch, and acted as a refugium for flora and fauna. Introductions of livestock and settlement have undoubtedly influenced the vegetation, but the effects are not easily assessed. Other biotic factors including the occurrence of bird colonies and pollinator availability have probably also affected floristic composition. Erosion has apparently increased recently, and both the size of the island and the total area of vegetation have decreased. Periodic connections between many inland pools and the sea have resulted in changes favouring halophytes and/or depauperate vegetation.

The vegetated terrain of the island accounts for approximately 40% of the land surface of 3425 ha. Several distinctive plant communities were identified, described, and mapped. These include i) a community dominated by *Honckenya peploides* comprising 0.6% of the island surface; ii) Marram-Forb grasslands dominated by *Ammophila breviligulata, Lathyrus maritimus, Achillea lanulosa,* and *Solidago sempervirens* comprising 8.7% of the island; iii) sparse grasslands, comprising 22.5%, within which two types are readily discernable. Marram Grasslands are dominated by *Ammophila breviligulata*, while Marram-Fescue grasslands also have abundant *Anaphalis margaritacea, Festuca rubra, Fragaria virginiana, Myrica pensylvanica* and *Rosa virginiana;* iv) Shrub Heath vegetation is dominated by *Empetrum nigrum, Juniperus communis, Myrica pensylvanica, Rosa virginiana,* and *Vaccinium angustifolum*, with many other species as well as lichens and bryophytes also present; and v) Cranberry Heath communities dominated by *Vaccinium macrocarpon*. The two heath communities together cover 4.3% of the island. In terms of plant association these Heath communities appear quite different from mainland communities, and they deserve protection and further study.

Freshwater pools with pH 5.0-5.7 have *Potamogeton epihydrus, P. oblongus, Polygonum hydropiperoides* var. *psilostachyum, Myriophyllum tenellum*, and *Fontinalis sullivantii*. Such ponds cover 0.8% of the island. Pond edge communities are dominated by a variety of forbs, graminoids and bryophytes. Brackish ponds cover 1.5% of the island surface. Characteristic submersed species include *Zostera marina, Ruppia maritima* and *Potamogeton pectinatus.* Shallower water and edges have dense swards of *Eleocharis parvula*. Various halophytic forbs and graminoids occur along the pool edges.

Circumstantial evidence based largely on the locations of different vegetation types, and patterns of sand deposition, suggests a succession from Marram-dominated communities to Marram-Fescue, and with lessening sand accumulation to Shrub Heath. This sere can be reversed by increased rates of sand deposition. It also appears that there is a succession from brackish to freshwater vegetation in ponds without recent influence of the sea.

Approximately 63% of the native island flora of 154 is characteristic of the general region, while 16% is boreal in affinity, 5% is southern, 2% is amphi-atlantic, and 9% is restricted. Three taxa are endemic. Of the restricted taxa, two *(Epilobium nesophilum* var. *sabulonense* and *Lathyrus palustris* var. *retusus)* were not found during our survey and are apparently extinct, while three *(Bartonia paniculata* var. *sabulonensis, Calopogon tuberosus* var. *latifolius,* and *Juncus pelocarpus* var. *sabulonense)* are rare on the island. Seventeen of the 19 significant (restricted or rare) taxa occur in vegetation types that together account for 5.8% of the island surface, including the heaths and freshwater pools.

The annotated list provides information on habitat, status and distribution on the island for 154 native and 69 introduced taxa. Comparison is provided with four previous botanical surveys.

L'île de Sable est une barre de sable émergeante, en forme de croissant, d'une longueur de 42.5 km et d'une largeur de 1.4 km. Sa superficie est de 3400 ha et elle est située à environ 160 km à l'est de la côte de la Nouvelle-Ecosse. En 1981, une étude de terrain et une recherche bibliographique out été enterprises dans le but d'obtenir une information de bas plus complète concernant la vegetation et la flore de l'île. Le travail de terrain a inclu la description et la cartographie des communautés de plantes, des analyses d'eau et du sol ainsi que la collecte de spécimens végétaux dans le but de produire une list commentée des plantes vasculaires. Les recherches bibliographiques ont englobé la documentation historique décrivant la végétation, le terrain, la composition de la flore et la phytogéographie.

Depuis au moins 1505, l'île a été dépourvue d'arbres et caractérisée par un faible couvert végétal constitué d'herbe et d'arbustes, de l'érosion et des déplacements de sable. Les substrats sont des sables alcalins ou acides, pouvres en matière organique et à faible teneur en sels nutritifs. Les marécages et les habitats aquatiques sont ou bien acides ou soumâtres avec des concentrations en sodium élevées. Le climat est maritime et modéré avec un faible couvert de neige, des vitesses moyennes de vent élevées et avec moins d'emoleillement que sur le continent.

Il est possible que, durant l'eu géologique du Wisconsin, un precurseur de l'île de Sable, de plus grande dimension, ne subit pas l'effet de la glaciation et servit de refuge à la flore et a la faune. La colonisation et l'introduction de chiptels on sans doute influencé la végétation mais leurs effets ne sont pas faciles à determiner. D'autres facteurs biotiques tel que la presence de colonies d'oiseaux et d'agents pollinisateurs ont probablement aussi influence la composition floristique. L'erosion s'est apparemment accrue recemment et la taille de l'ile ainsi que la surface totale du couvert végétal ont diminues. Des connections periodiques entre plusieurs etangs situés a l'interieur de l'ile et l'ocean ont provoque des changements favorisant les plantes halophytes et/ou un appouvrissement de la végétation.

Le couvert végétal de l'île représente environ 40% de la surface des terres (3425 ha). Plusieurs communautés distinctes de plantes furent identifiées, décrites et cartographiées. Celles-ci incluent: i) une communauté dominee par *Honckenya peploides* représentant 0.6% de la surface de l'île; ii) des prairies de type Marram-Ford dominées par *Ammophila breviligulata, Lathyrus maritimus, Achillea lanulosa,* et *Solidago sempervirens* représentant 8.7% de la surface de l'île; iii) des prairies *clairsemées,* comptant pour 25.5% de la surface, parmi lesquelles deux types peuvent être reconnus. Les prairies sont à oyat (Marram) dominées par *Ammophila breviligulata,* alors que dans les prairies à oyat et fétugue (Marram-Fescue) *Anaphalis margaritacea, Festuca rubra, Fragaria virginiana, Myrica pensylvanica* and *Rosa virginiana;* iv) La végétation arbustive des landes (Shrub Heath) est dominée par *Empetrum nigrum, Juniperus communis, Myrica pensylvanica, Rosa virginiana,* et *Vaccinium angustifolum,* avec plusieurs autres espèces ainsi que des lichens et des bryophytes; et v) Les communautés de landes à airelles (Cranberry Heath) sont dominées par *Vaccinium macrocarpon.* Ces deux communautés de lande combinées couvrent 4.3% de l'île. Du point de vue des associations de plantes, ces communautés different passablement de celles que se retrouvent sur le continent et elles méritent d'être protégées et etudiées plus a fond.

Potamogeton epihydrus, P. oblongus, Polygonum hydropiperoides var. *psilostachyum, Myriophyllum tenellum,* et *Fontinalis sullivantii* se retrouvent dans des étangs dont le pH varie de S.O. à 5.7. Ces étangs couvrent 0.8% de l'île. Les communautés des rives de ces étangs sont dominées par une varieté de plantes herbacées de glaminées et de bryophytes. Les étangs saumâtres couvrent 1.5% de la surface de l'île. Les espèces submergées caracteristiques sont *Zostera marina, Ruppia maritima* et *Potamogeton pectinatus.* Les eaux peu profondes et les rives sont densément récouvertes d'*Eleocharis parvula.* On rétrouve aussi le long des rives des etangs, une variété de plantes herbacées et graminées halophytes.

Des évidences indirectes baseis sur la localisation de différents types de végétations et les patrons de dépositions du sable, suggèrent une succession des communautés dominées par le oyat (Marram) vois des communautés dominées par le oyat et la fétuque (Marram-Fescue), et avec une diminution des dèpôts de sable vers les lande a arbustes (Shrub Heath). Cette succession peut être renversée par une augmentation de la vitesse de deposition du sable. Dans les étangs qui ne sont pas influencée directement par la mer, il semble y avoir une succession d'une végétation caractéristique des eaux soumîtres vers une végétation d'eau douce.

Approximativement 63% des 153 espèces endemiques de la flore de l'île sont caractéristique de toute la région, 16% ont une affinité avec la flore boréale, 5% avec la végétation du sud, 2% est "amphi-atlantique" et 9% sont restreintes a l'île. Trois taxons sont endemiques. Des taxons restreints, deux *(Epilobium nesophilum* var. *sabulonense* et *Lathyrus palustris* var. *retusus)* ne furent pas trouvées lors de notre etude et sont apparemment eteints, alors que trois autres *(Bartonia paniculata* var. *sabulonensis, Calopogon tuberosus* var. *latifolius,* et *Juncus pelocarpus* var. *sabulonense)* sont rares dans l'île. Dix-sept des dix-neufs taxons importants (restreints ou rares) se retrouvent dans des types de végétations qui dans l'ensemble represéntent 5.8% de la surface de l'île, en incluant les landes et les étanges d'eau douce.

Une list commenté fournit de l'information sur l'habitat, le status et la distribution, dans l'île des 154 taxons indigènes et 69 taxons introduits. Une comparison avec quatre études botaniques antérieures est inclue.

INTRODUCTION

Sable Island is a partially-vegetated emergent sandbar, located at *ca.* 44°N and 60°W, *ca.* 160 km east of the Nova Scotia mainland. The island is part of a much larger, shallow, submerged sand bank. Sable Island presently has a length of *ca.* 42.5 km, a maximum width of 1.4 km, a surface area of 3400 ha, inland freshwater and brackish ponds totalling some 38 ha (not including Wallace Lake), and vegetated terrain comprising some 1300 ha, or 39% of the island's surface area.

The first botanist to collect plants on Sable Island was Macoun in 1899. He was followed by Gussow in 1911, St. John in 1913, Erskine in 1953, Keddy in 1975, and the present authors in 1981. Species lists were published as a result of some of these surveys (St. John 1921; Erskine 1953; Keddy 1975). Macoun (1900) did mention a collection of 191 species, but a list was not included in the article. Some of Macoun's Sable Island collections are noted later (Macoun 1901). Although the lists of Gussow and Macoun were unpublished, St. John (1921) apparently corresponded with both of them and included their records in his compilation. St. John's list was well annotated and included descriptions (and illustrations) of new taxa (see Chapter 5), as well as an excellent historical and ecological account making it the classic work on the flora and history of the island. St. John's annotated list appears to have provided the basis for separation of the Macoun and Gussow reports (Erskine 1953).

The floristic surveys of Macoun, Gussow, St. John, Erskine, and Keddy are supported by specimen vouchers, and only Gussow's list, based on miscellaneous collections in DAO (See Holmgren *et al.* 1981 for herbarium acronyms) was not fully supported. Specimens supporting Macoun's work are in CAN and MTMG, those of St. John in GH, those of Erskine in NSPM and DAO, those of Keddy at CAN, and ours are at DAO and MICH.

The vegetation of Sable Island was described generally by St. John (1921) and somewhat more briefly by Erskine (1953). Keddy (1975) made a detailed qualitative (species lists) survey of the vegetation of ponds near No. 3 Life Saving Station with a view to establishing the status of certain endemic taxa. McLaren (1968, 1972) and Welch (1975) published maps of the vegetation of the island. The map of Welch was relatively detailed and included the major plant communities, although the species composition was not described in detail (see also Stobo & McLaren 1975).

This previous botanical work on Sable Island provides a good background of botanical information, but it is nevertheless lacking in several respects. There has never been a detailed quantitative description of the plant communities. The available lists contain names that are out-of-date, and they require nomenclatural updating. Furthermore, the previous lists give little indication of the status, habitat or distribution of various taxa on the island. Various other aspects such as the factors affecting floristic composition, phytogeography, and rare and restricted taxa are also in need of more extensive discussion. By addressing all of these topics, we intend to provide a more complete information base on the vegetation and floristics of Sable Island.

Most of the information included here was collected during our field survey of 14-26 August 1981, with some additional work in 1982 and 1983. Preliminary reports have appeared (Freedman & Catling 1982; Freedman, Catling & Lucas 1982) and some of our information has been included in environmental impact studies conducted for Mobil Oil Ltd.

Methods

(a) *Soil Chemical Analysis*

Duplicate surface soil (0-5 cm) samples were collected at each of the terrestrial plant communities that we described quantitatively. These samples were combined by site, air-dried, sieved at 20 mesh, well-mixed, and then submitted for analysis to the Soils Lab, Soils and Crop Branch, Nova Scotia Department of Agriculture, Truro. The various analytical methods used were as follows:

i) *Organic Matter.* Organic matter was measured by loss on ignition at 430°C of a 2.00 g soil sample. Combustions were made in a Luidbergh furnace.

ii) *pH.* pH was measured in a 1:1 soil:water mixture. This was allowed to equilibrate for 30 min., and the concentration of H^+ was then measured with a Corning 130 digital pH meter.

iii) *Total Nitrogen, Phosphorus, Potassium, Calcium, and Magnesium.* Soil samples of 0.50 g were digested in a hot sulfuric acid-hydrogen peroxide mixture. Nitrogen and phosphorus concentrations were measured using an autoanalyzer. Potassium, calcium, and magnesium concentrations were measured by flame atomic absorption spectrophotometry.

iv) *Exchangeable Potassium, Magnesium, and Calcium.* Soil samples of 2.5 g were shaken for 15 min. in N ammonium acetate (pH 5). The soil:extractant ratio was 1:25. The concentrations of these cations were then measured by flame atomic absorption spectrophotometry.

v) *Available Phosphorus.* Soil samples of 2.5 g were shaken for 1 min. in 25 ml of 0.05 N ammonium fluoride and 0.1 N hydrochloric acid. Soluble phosphate was then measured using a Technicon Auto Analyzer.

vi) *Water-soluble Nitrate and Ammonium.* Soil samples of 5 g were shaken for 30 min. in distilled water, and the nitrate and ammonium concentrations were then analyzed using Corning ion-specific electrodes.

(b) *Water Chemical Analysis*

All analytical techniques used in water analysis are described by Horwitz (1975). pH was measured directly using a Beckman Zeromatic II pH meter and conductivity was measured using a conductivity bridge. Sodium and calcium were determined by flame atomic absorption spectrophotometry. Chloride was measured by sodium thiosulphate titration.

(c) *Description of Plant Communities*

All field work was carried out over August 15-25, 1981. The various terrestrial plant communities of the island were subjectively divided into seven categories, on the basis of distinctive occurrences of dominant species or groups of species. These seven terrestrial communities were: Sandwort, Marram-Forb, Marram, Marram-Fescue, Shrub Heath, Cranberry Heath, and Pondedge Herbaceous. Additional aquatic plant communities occurred in or at the edges of the fresh and brackish-water ponds.

Quantitative descriptions were made at a total of 27 sites for the first six of the above terrestrial communities (Fig. 1). The seventh terrestrial community (Pondedge Herbaceous) and the aquatic communities were not sampled quantitatively due to their very heterogenous nature, but they were qualitatively described in terms of relative abundance and species composition.

Quantitative data were collected using 20 random placements per site of a 0.5 x 0.5 m quadrat. Visual estimations were made of the species-specific cover, and an attempt was made to take into account foliage overlap (i.e. leaf area index), so that total cover was more than 100% in some cases. Using these field data, calculations

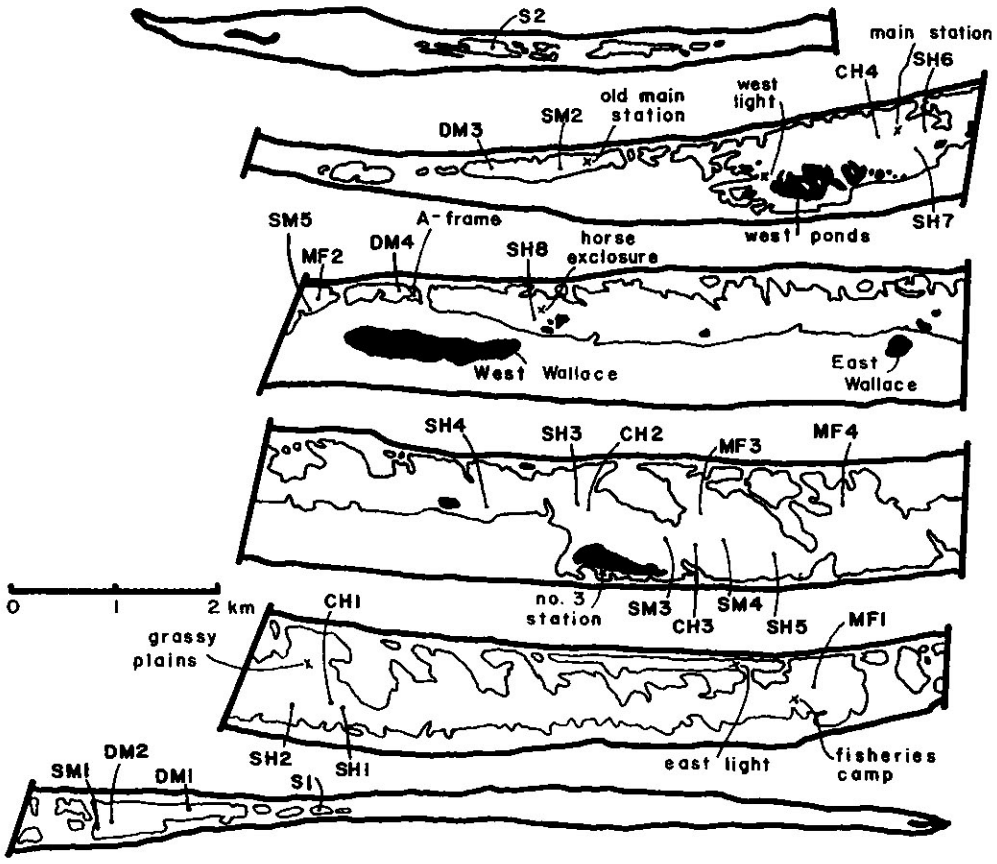

Fig 1. Locations of sites on Sable Island where quantitative descriptions of plant communities were made.

were made for each site of total and species-specific cover (%, $\bar{X} \pm$ S.E.), relative cover (%), and frequency (%) of each species, and community richness ($\bar{X}$ species/quadrat) and diversity ($-\Sigma p_i \ln p_i$, where p_i = relative frequency). These methods are summarized in various standard references (Kershaw 1964; Goldsmith & Harrison 1976; Smith 1980).

(d) *Mapping of Plant Communities*

Plant community mapping was done using colour 1:20,000 scale photographs of Sable Island. The transect for these was flown at 3050 m above sea level on June 19, 1981, and the photos were taken with a Wild RC-8 camera fitted with a 15.2 cm lens. Mapping was done by tracing recognizable community boundaries onto clear plastic overlays under a binocular microscope or a stereoscope. This mapping process was aided by ground truthing done over August 15-25, 1981, in order to establish the locations of known community types for later comparison with airphoto interpretations. Not all community types could be recognized on the airphotos, so that the mapping was limited to the following vegetation types: Dense Grasslands (equivalent to the Marram-Forb community type); Sparse Grasslands (incorporating both the Marram and the Marram-Fescue communities); Heath (in-

corporating both the Shrub Heath and the Cranberry Heath communities); Pond-edge Herbaceous; Sandwort; Brackish Ponds; Freshwater Ponds; and Unvegetated. This is a somewhat more comprehensive treatment than that used in an earlier vegetation map of Sable Island (Welch 1975). The areas of each of these vegetation types were determined by cutting them out of the plastic overlays with fine scissors or scalpels, weighing the pieces, calculating area in cm^2 from the constant ratio of area: weight of the plastic overlays, and then converting these to terrain area by correcting for the 1:20,000 linear scale of the airphotos.

(e) *Annotated List*

Specimens documenting our list are at DAO and MICH and were collected from 14-26 August 1981 with a few additional collections in 1982. All identifications were made using the most recent available literature. Information from previous lists is incorporated. In some cases where names are brought up-to-date, the older generic or species name used in reference to the flora is listed in brackets following the current species name.

1. *EARLY DOCUMENTATION OF VEGETATION AND TERRAIN*

Many of the early explorers and other travellers recorded their impressions of Sable Island. The earliest probable reference to the island was contained in an ancient Icelandic saga describing the voyage of Biorn Heriulfsen in 986 who, having passed Newfoundland and Nova Scotia (Helluland and Markland), came in sight of a barren sandy island (Oxley 1886). Much later, a Portuguese chart of 1505 recorded Sable Island, known to them as Santa Crus Island, and which was stocked with cattle and swine (Oxley 1886). Other early references were by the Frenchman Baron de Lery in 1538, and the Englishman Sir Humphry Gilbert in 1583 (Oxley 1886).

Later, Des Barres (1776-77) described Sable Island as having a length of some 45 km, a width of 2.4 km, and a large inland lake (Wallace Lake) having a length of 22 km. He named several distinctive topographic features, including the Naked Sand Hills, Mount Knight, Evans Cliff, Mount Luttrell, the Vale of Misery, and Ram Head. He described the island as having a " . . . broken face, and hove up in little hills, knobs, and cliffs, wildly heaped together, within which are hollows and ponds of freshwater, the skirts of which abound with cranberries, blueberries, juniper, etc." These place names and brief descriptions indicate that the sand dunes were shifting and dynamic at those times, as they are today, and that plant communities that exist today were also present in the late 1700's.

Morris (1802) provided some relatively detailed descriptions of the vegetation of Sable Island: " . . . the grass in general is tall thick and very strong. Three kinds—one spindling and soft, one long and flat-leaved also soft in some places thick, this I observed the sheep delight in along the valleys. From the lake westward are a variety mixed with the grass, bayberries, blueberries, strawberries, wild tansey, wild parsnip, running blackberry, Prince's pine . . . the soil in the valleys are about 4 inches thick, blackish mixed with black sand and decayed vegetables. The eastern valleys . . . horse paths in all directions, in some of those valleys lyes no end of cranberries . . . about the east end of the lake there is considerable clover grass, I expect the white kind. The grass at the east end is in general thicker and stouter than at the west end, but the peas are scarce . . . the lake or great pond is about 1/2 mile wide at the greatest width . . . and what I have sounded 1 to 4 fathoms deep. There is an abundance of manure around the pond, especially at the west end decayed eel and sea grass. In the lake there is a thick eel grass on the bottom which in high winds in the autumn comes on shore at the head of the lake. The water is shoal, the bottom is black rank and greasy composition, about 3 inches . . . I expect this will make good manure."

At about the same time Blunt (1806) described the face of Sable Island as broken, with little hills, knobs, and cliffs wildly heaped together. He also mentioned the presence of freshwater ponds, and noted that the " . . . south shore is, between the cliffs, so low that the sea breaks quite over in many places when the wind blows on the island." This obviously refers to the occurrence of eroded blow-outs, through which seawaters could flood inland during storm surges. Blunt (1806) described the Naked Sand Hills as being some 45 m high, and he mentioned another hill (the Ram's Head) that was higher (Scott (1902) referred to hills of up to 61 m in height in 1808). Today, the highest point on the island is only ca. 25 m (Welch 1975).

Other relatively detailed descriptions of the character of Sable Island were made by Gilpin (1858). He described the view from a high vantage point: "There it all lies spread like a map at my feet,—grassy hill and sandy valley fading away into the distance." He noted the presence of 30-40 species of "shrubs and plants". He also described the vegetation: " . . . tall coarse grasses cover the surface of the ground, alternating with sandy barriers and snowy peaks of blown sand . . . the wild rose, blue lily, and wild pea enamel the valleys. Strawberries, blueberries, and cranberries are in abundance . . . measured by bucketsful . . . as autumn heats the luxuriant green, the tall, mallow, gay golden rods and wild China asters are swept by the heaving gales."

Gilpin (1858) also described the dynamic nature of the sand dunes: " . . . there are those still alive who once filled a happy hour where now the sea breaks five miles from dry land. The abrupt sandcliff rocks to a fall from the unceasing beat of the waves at its feet till a more than ordinary hurricane sweeps it into the lake or spreads it into a shallow bar. By this process five or six miles have gone at the west end, and changes the same are still going on. The winds, too, are perpetually sweeping the naked sand-hills into the lake or forming fantastic cones from the loose and shifting sand."

Similar observations were made at about the same time by Bayfield (1860). He described the topography of Sable Island as follows: "Sable Island seen from the north, at a distance of 9 to 10 miles presents the appearance of a long range of sand-hills, some of which are very white . . . in some parts it is wholly or partially covered with grass, in others scooped out by the winds into crater-shaped hollows, or thrown up into sand-hills, not exceeding the height of 75 feet [23 m] above high water. Between these ridges a long pond, named Salt-water Lake [Wallace Lake], said to be gradually filling with blown sand, but still in some parts 12 feet deep, extends from the west end to the distance of 11 miles, and a low valley continues from it 6 1/2 miles more to the north-east end of the island . . . many of the sand-hills are seen to have been partly removed by the waves, so as to have formed steep cliffs next to the sea. In other parts, they are covered by grass, and defended by a broad beach . . . " Various other mid to late 19th century authors described the instability of Sable Island, and recorded changes in the length of the island, usually resulting from the removal of stretches of exposed sandbars at the west end (e.g. Howe 1850; Halleck 1866; MacDonald 1886).

Although these early reports clearly suggest that the island has changed little in character (although perhaps much in size and position) during historical times, the fact remains that no information is available for the period preceding the release of livestock in 1505.

2. *FACTORS AFFECTING FLORISTIC COMPOSITION*

Species and infraspecific taxa to a greater or lesser extent, are adapted to specific ecological conditions, both biotic and abiotic. The presence or absence of a particular species may be due to various interacting factors. Mainly, limiting factors include physical and chemical properties of the soil; chemical properties of water

and climate are discussed below. Other factors such as geological history (which involves migration, dispersal and isolation) and catastrophic events (including erosion, deposition, flooding and human impacts) are also briefly considered. Although these factors may not provide a complete explanation, they aid a great deal in gaining an understanding of the nature of the vegetation of Sable Island.

(a) *Soil and Water*

Both the chemical and physical composition of soil and the chemical composition of water affect floristic composition, since different taxa of plants are frequently adapted to different substrates. The chemical composition of soils collected from six terrestrial plant communities on Sable Island is summarized in Table I. These soils are of very poor nutritive quality, since they contain small quantities of organic matter and major nutrients. The best developed soils occur in the heath communities, but even these contain less than 4% organic matter within the surface 5 cm, and they have virtually no profile development below this depth.

Table I Chemical characteristics of surface soils (0-5 cm) on Sable Island.[1]

Plant Community	pH	Organic Matter (%)	Total N (ppm)	Total P (ppm)	Total K (ppm)	Total Ca (ppm)	Total Mg (ppm)	NO_3-N (ppm)	NH_4-N (ppm)	Avail. P (ppm)	Exch. K (ppm)	Exch. Ca (ppm)	Exch. Mg (ppm)
Shrub Heath	5.7	2.5	1020	60	440	800	380	1.6	21	7.1	45	380	160
		1.8	410	20	210	160	80	0.7	14	3.0	22	160	71
Cranberry Heath	4.9	4.0	1020	62	600	790	440	2.0	10	9.2	28	178	105
		2.7	360	20	120	360	260	1.5	2	4.7	10	121	93
Marram-Forb	5.4	0.6	580	60	460	920	460	3.9	7	8.6	15	63	30
		0.2	15	30	150	360	180	1.4	5	1.1	1	18	4
Sparse Marram	6.0	0.5	450	40	350	580	280	2.2	7	7.8	11	41	19
		0.1	60	20	130	60	15	1.7	1	0.0	5	15	11
Marram-Fescue	5.4	0.8	560	40	280	590	280	2.5	9	5.9	14	84	36
		0.2	110	23	80	160	80	1.0	2	1.4	3	46	18
Sandwort	6.0	0.05	450	45	600	720	400	8.5	10	9.8	19	51	31
		0.03	150	7	280	90	30	1.7	1	2.8	2	1	1

[1] ±SD of five replicate samples per community type.

The shrub heath soils are relatively moist due to their higher content of organic matter. The Cranberry heath soils are also moist due to their low elevation. Both of these soils are relatively acid and nutrient-poor. The soils of the various other terrestrial communities are almost purely inorganic, and they tend to be drier.

With respect to mineralogy, the soils are comprised almost entirely of sand-sized particles, with *ca.* 84% of the bulk consisting of particles between 0.25 and 0.5 mm in diameter, and 99.8% between 0.13 and 1.0 mm (Willmore & Tolmie 1956). These sand grains are highly rounded in contour, as a result of long-term scouring by wind and wave action (Willmore & Tolmie 1956).

Aquatic and wetland habitats on Sable Island vary greatly in pH, sodium and chloride concentration (Table II). Lower pH, sodium, and chloride are characteristic of inland freshwater pools originating from rain and ground water table. Higher pH, sodium, and chloride are characteristic of brackish pools that are influenced by seawater, which can intrude as a result of storm surges. It is well known that differences between fresh and brackish water can create different plant associations (e.g. Moyle 1945).

Table II Chemical analysis of selected ponds on Sable Island

	pH	Na(mg/1)	Conductivity (μmhos)
Fresh Pools	5.0-7.3	13-38	76-320
Brackish Pools	27.1	1840-2100	1640

Table III Climatic data for Sable Island, compared with Halifax and Truro, N.S.[1]

	Sable Island	Halifax	Truro
Temp. (°C) max.	10.1	11.5	10.9
Temp. (°C) min.	5.1	3.6	0.0
Temp. (°C) mean	7.7	7.6	5.5
Mean Precipitation (mm)	1270	1319	1101
Mean Snowfall (cm)	127.8	210.8	243.1
Sun (mean no. of hours)	1459	1883	1749
Average Wind Speed (km hr^{-1})	25.8	18.2	14.1

[1]Data from Atmospheric Environment Service, Environment Canada.

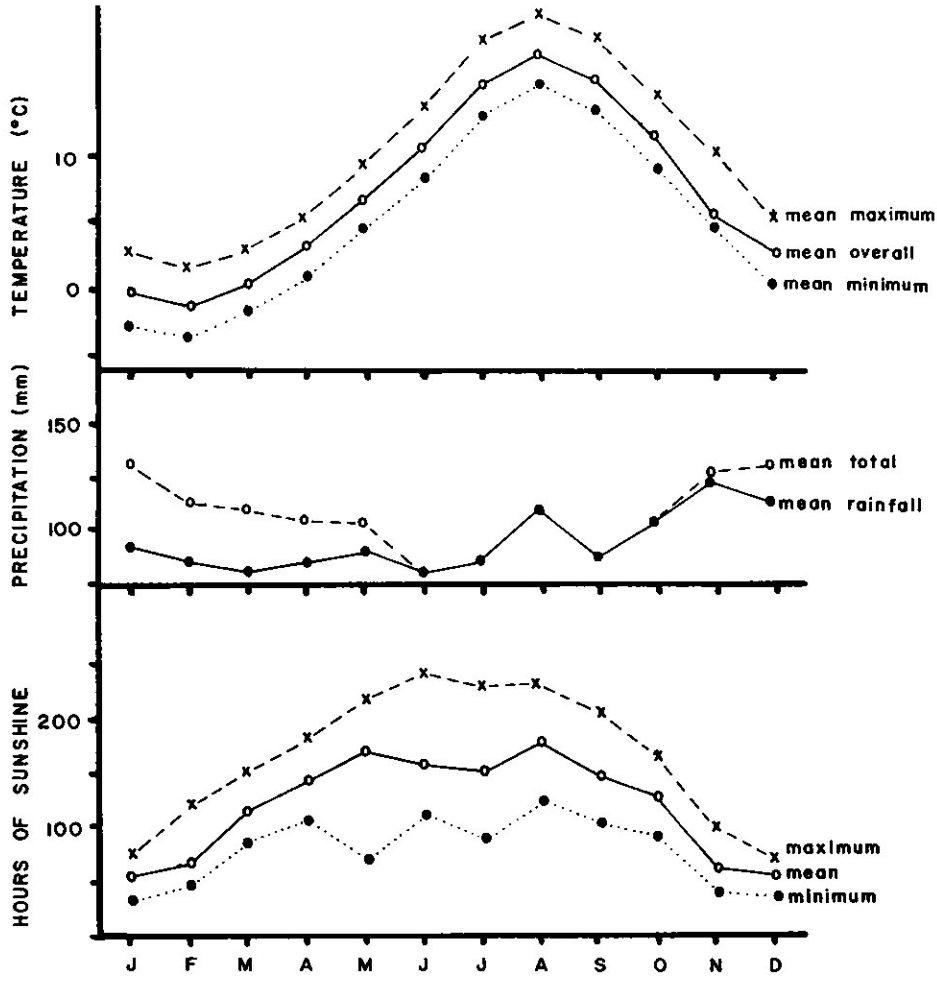

Fig 2. The seasonal course of temperature, precipitation, and sunshine at Sable Island. Data are from the Atmospheric Environment Service, Environment Canada.

(b) *Climate*

The climate of Sable Island is maritime and moderate for all variables except windspeed, as compared (Table III) with nearby locations that are coastal maritime (e.g. Halifax) or continental (e.g. Truro). The relatively moderate temperature regime includes a lower mean maximum, a higher mean minimum, and a similar or slightly higher mean annual temperature than either Truro or Halifax (Table III, Fig. 2). Mean precipitation is intermediate between that of Halifax and Truro, but a relatively small quantity is received as snow (Table III, Fig. 2).

The climatic characteristics of Sable Island have undoubtedly influenced the development of its vegetation. For example, the relatively lower temperatures during the growing season simulate the temperature regime to which certain boreal plant species are adapted. On the other hand, the higher minimum temperatures and less frequent frosts correspond to conditions in continental areas at lower latitudes, and are thus conducive to the presence of plants having a more southerly distribution. Thus, the moderate maritime climate of Sable and other islands may often result in an intermingling of typically northern and typically southern elements of flora and fauna (see Section 4). In addition, the relatively high average wind speeds (Table III) of Sable Island have an abrasive and dessicating effect, with a pronounced influence on floristic composition. Recent evidence for this is the fact that of the thousands of trees and shrubs planted on the islands (see Section 2(d)), the few survivors occurred in very protected places.

(c) *Recent Geological History*

Prests' (1970) glacial map of Canada indicates that Sable Island was glaciated, and the presence of subsea moraines suggests that glaciation extended well onto the present Nova Scotia shelf (James & Stanley 1968). However, Matthew (1979) has speculated that Sable Island may be a remnant of a broad emergent area of continental shelf that was unglaciated, although it may have been very near to the glacial edge. During the glacial period the emerged portion of the Nova Scotian shelf may have approximated the present 100 m depth contour, which would correspond to an island 240 km long and 80 km wide (Terasmae & Mott 1971).

Studies of existing ice-marginal sites in Iceland and elsewhere (Lindroth 1970) suggest that plants could have occurred quite near to the late Wisconsin glacial margins. Proof that Sable Island was a glacial refugium requires the discovery of fossil material dated from the glacial period. Since the oldest fossil material from Sable Island has been dated at about the time of deglaciation, *i.e.* 11,000 years ago, there is no paleoecological proof of the refugium theory (James & Stanley 1968; Terasmae & Mott 1971). However, the lack of older fossils does not require that the refugium concept be rejected. Older fossils may still be found, but even if they are not, their absence may have been caused by the eastward migration of the island over geological time (Terasmae & Mott 1971) which could have prevented older fossil material from accumulating. Thus, the possibility remains that there has been a continuity of land surface, and of habitats available on Sable Island, and its much larger pre- and postglacial precursors, which could have acted as a refugium. Both Howden (1975, discussing beetles) and Roland and Smith (1969, discussing vascular plants) considered a refugium on the Sable Island bank to be a reasonable possibility. The evidence, both for and against, is summarized by Holland (1981). Whether a result of evolution over the past 10,000 years or representing a relict from a much earlier time, the fact remains that there is some unique variation on Sable Island, in both flora and fauna.

An early postglacial climatic warm period is thought to have influenced Sable Island as evidenced by the presence of paleosoil and a fossil fauna characteristic of a

warmer climate than exists at present on the island (Medcof *et al.* 1965). However, the palynological work of Terasmae and Mott (1971) suggests that the vegetation on the island over the last 11,000 years has always been very similar to that which exists now. The lack of woody peat on the island and palynological evidence suggests that widespread forests did not exist, and this is also suggested by the earliest historical accounts (see section 1, also St. John 1921, p. 33). The increasing penetration of the Labrador current along the Atlantic coast resulted in gradual cooling (Holland 1981), and by 6,000 B.P. the Atlantic coastline of Nova Scotia was washed by summer-cold water.

(d) *Livestock, Cultivation and Settlement*

The grazing of pigs, cattle, sheep, or horses can be a significant factor determining the composition of plant communities. Likewise, cultivation of the soil and the effects of settlement (including buildings and waste disposal) can have effects on vegetation. These factors have influenced the floristic composition of Sable Island for several hundred years, as is indicated by the following historical account.

Various old maps and charts indicate that by the early 1500's Sable Island was familiar to Old World fishermen and traders, including the Spanish, Portuguese, and later, the French (Patterson 1894). These travellers had a policy of introducing livestock to offshore islands of the Americas (Campbell 1974), and in 1552 " . . . did put into this same island neat (sic) and swine to breed, which were since exceedingly multiplied." (Patterson 1894). The 1552 introductions were reported by a Portuguese fisherman to Sir Humphrey Gilbert's expedition of 1583. Gilbert's flagship was subsequently wrecked on Sable Island, and the survivors reported that the introduced cattle had greatly multiplied. There were no reports of horses at that time (Patterson 1894).

Between 1598 and 1603, French settlers were placed on Sable Island by de la Roche (St. John 1921). They lived off the land, presumably exploiting the Portuguese cattle and growing vegetables, and in addition they were supplied once a year with wine and clothing from the homeland. The survivors were evacuated in 1603 (Campbell 1974), although some of them apparently returned for a brief time to continue a trade in furs (Gilpin 1858), probably seal and perhaps the occasionally reported black fox.

In 1633, John Rose of Boston, returning from Sable Island following a shipwreck, reported foxes and 800 head of cattle, which survived by grazing on pastures of dune grass and beach pea (Halleck 1866; Patterson 1894). His reports prompted an exploitation of the stock by Acadians and New Englanders, and by 1668 Nicholas Denys reported that there was no livestock left on Sable Island (Christie 1980).

The return of livestock to Sable Island and the commencement of cultivation appears to have come with settlers sent to the island by le Mercier in 1738. Horses, sheep, cattle, and pigs were imported, and for fifteen years the settlers farmed and raised livestock. The le Mercier venture was abandoned in 1753, but livestock was left on the island (Campbell 1974).

Between 1753 and 1801 several attempts were made to live on Sable Island. Finally, the rumoured presence of wreckers who lured helpless ships onto the shoals by showing false navigation lights, the continuing cattle raids, and several high-profile shipwrecks prompted the establishment of life-saving stations by the Nova Scotia government (Campbell 1974). This began the settlement and agricultural exploitation of the island that continued until the mid-1900's. During this period livestock was kept, the feral horse population was controlled, subsistence farming was carried out, and numerous introductions of flora and fauna occurred.

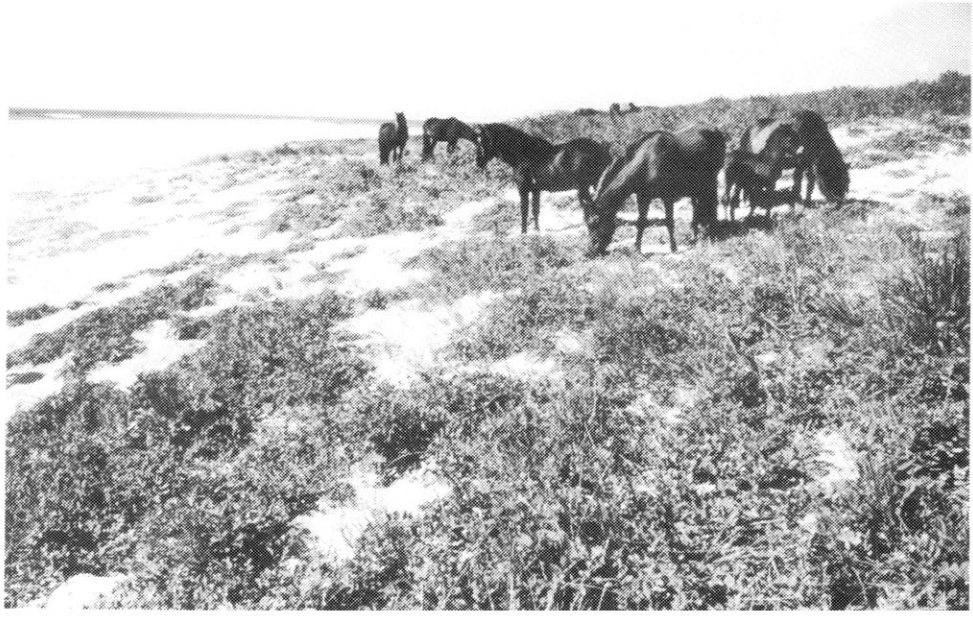

Fig 3. A gang of 11 wild horses grazing on Beach Pea *(Lathyrus maritimus)* and Marram *(Ammophila breviligulata)* near Main Station.

Fig 4. A decumbent Scots Pine *(Pinus sylvestris)*. This one is a recent planting and not a survivor of the great afforestation attempt of 1901.

The mandate of the government-appointed superintendent of the island was to " . . . carefully preserve and diligently encourage the growth and increase of all cattle, horses, and other livestock found on the island or sent by the commissioners . . . and not to suffer any to be exported upon any account or pretense whatever without license from this government first hand and obtained . . . report quality of stock and whatever measures may be useful for its preservation and increase . . . " (Morris 1802). Early reports from the superintendent stated the belief that there was sufficient forage on the island to support about 250 head of cattle, 2200 sheep, and 150 goats (Morris 1802). These predictions were probably optimistic, and they undoubtedly overestimated the carrying capacity of the island. In any case, over the years approximately 60-90 head of cattle and some sheep, hogs, and mainland horses were kept, while the feral horse population ranged between about 70 to 250 (miscellaneous superintendents' reports on file in the Public Archives of Nova Scotia). During the summers, these animals grazed the Sable Island grasslands. In winter, the diets of the cattle and the domestic horses were supplemented by harvested hay. Island fodder mainly consisted of dune grasses and beach pea, in addition to cultivated hays. Roughly 120 tonnes of hay would be collected in the autumn, most of which was made of wild forage. To some extent, these supplies were supplemented by feed shipments from the mainland (misc. superintendents' reports).

In addition to the cultivation of hay, some of the Sable Island terrain was used for growing vegetables for the residents. Root crops were especially successful, with a combined annual harvest of about 300 bushels of potatoes, carrots, beets, parsnips, and turnips, (Fig. 5). Each of the five stations had its own garden plot, with the largest being at main station. In total, perhaps 4 hectares were under cultivation for vegetables (misc. superintendents' reports; Christie 1980).

The vegetable crops were raised in plots where cattle manure and eelgrass were used to enhance the tilth and nutrient content of the soils. One early report from the superintendent suggested that the muck from the bottom of Wallace Lake would make a good soil conditioner and fertilizer (Morris 1802). Drought, very wet seasons, and plagues of locusts were occasionally blamed for crop failures (Boutilier 1884-1912).

In addition to cultivated crops, wild cranberries were harvested and shipped to the mainland. Reports indicate that shipments ranging from 100 to 300 barrels of berries had been systematically harvested, cleaned, and sorted in the late autumn. The area of harvest appears to have been towards the east, possibly in the vicinity of the grassy plains (Howe 1850; Boutilier 1884-1912).

There were occasional attempts to grow exotic plants on the island, either to provide fodder or to stabilize the dunes. A tussock-forming grass was introduced from the Falkland Islands, but the attempt failed. Several plantings of trees and shrubs occurred, the most impressive of which was the great afforestation attempt of 1901, in which about 69,000 conifer seedlings of 25 species, 14,000 hardwood seedlings of 79 species, and 20 kg of pine seeds were planted, as were hundreds of shrubs and 1,000 willow cuttings (Saunders 1902, 1903). By 1913 there were only 13 surviving plants (St. John 1921; Boyce 1953).

Since no studies were ever conducted, it is impossible to know what the effects of livestock, cultivation and habitation have been. However, several authors referred to the loss of large areas of vegetation during the latter part of the 1800's (Patterson 1894; Macoun 1901). Other studies have suggested that an accelerated destabilization of dune systems occurred during this period of intensive agriculture, and that sands from unstabilized dunes advanced over considerable areas (Patterson 1894; Willmore & Tolmie 1956; Cameron 1965; Terasmae & Mott 1971).

Fig 5. Turnips, potatoes and squash grown at Main Station, Sable Island in 1921. (Illustration from a photograph in the Thomas H. Raddall papers, Dalhousie University Archives).

The effect of the feral horses is not yet clear. However, it seems likely that excessive grazing in certain areas has increased erosion, and this would be especially important during years of peak population. Of course the horses recycle nutrients and minor disturbance probably creates habitat for certain species. Thus, the erosion damage may be fully or partly compensated for. The horse population has varied from 200 to 300 in a cyclic pattern over the past 20 years and is apparently under natural control (Lock 1971). Ongoing studies, including exclosure plots are attempting to clarify the relationship between horses, vegetation, and erosion.

The feral horses may have had other effects. Keddy (1975) suggested that the trampling and grazing of the wild horses on Sable Island has reduced the number of species which some ponds and their border areas can support. Decumbent and low-growing species are prevalent around the most used pools and aquatics are sometimes absent. In addition, differential grazing could have a very direct affect on species composition. The introduction of domestic animals which are allowed to run wild has severely impacted the vegetation of many islands, leading to both the extinction of species and habitats, and severe erosion (e.g. Melville 1979; Van der Werf 1979).

The existing vegetation of Sable Island is remarkable and valuable, but it is likely that it was even more diverse and interesting prior to its first visitation and exploitation by European man in the early 1500's.

(e) *Erosion and Deposition*

Continual erosion and deposition of sand on Sable Island probably results in relatively short-lived plant communities (as compared with mainland sites) and the island has apparently been continuously changing over the past several thousand years (St. John 1921; Terasmae & Mott 1971). There have been major changes in the island during historical times (see also Section 1 and Macoun 1900). An entire vegetated dune ridge that formerly occupied the seaward side of Wallace Lake has

been eroded away, and in one period of rapid erosion the western end of the island was disappearing at a rate of 1.5 miles/year requiring the continuing relocation of the lighthouse. MacDonald (1886) cited an instance when thousands of tons of sand were carried from the beach and strewn over the island, smothering vegetation, so that hundreds of horses died for want of food (St. John 1921, p. 20). Surveys made in the late 1700's indicate that Sable Island was 48 km long and 3 km wide, whereas now it is 32 km long and less than 1 km wide. It appears that erosion has dominated in the recent history of Sable Island.

Changes in water chemistry (see 2(a)) have been caused by the loss of dunes, with subsequent periodic connections developing between the sea and the inland pools or Wallace Lake. For example, the presently brackish pools at No. 3 station were fresh during St. John's survey in 1913, and had freshwater plant communities (St. John *loc. cit.*; Keddy 1975). This complex of pools was the only known station for *Epilobium nesophilum* var. *sabulonense* and other wetland species (St. John 1921, p. 90). The former and some other taxa were eliminated from the flora when the pond complex was inundated by the sea and made brackish (Keddy 1975).

(f) *Bird Colonies*

Large and dense colonies of gulls and terns may affect vegetation mechanically (trampling, displacement plucking, etc.) or by guano deposition, to the extent that a distinct flora can be associated with bird colonies (Gillham 1961; Sobey & Kenworthy 1979; Hogg and Morton 1983). Colonies are local on Sable Island, but they may move with time, since certain types of vegetation may provide optimal nesting habitat. However, this may change through time as a consequence of succession or the birds' presence. The effects of bird colonies on Sable Island vegetation have not yet been studied.

(g) *Other Factors*

The occurrence of plant species can be limited by pollinator availability. The diversity of pollinators on Sable Island is very low, with the abundant leaf cutting bee *Megachile melanophaea* acting as the principal pollinator of many plants.

3. *PRESENT VEGETATION*

Vegetated terrain accounts for ca. 39.1% of the total Sable Island area of 3425 ha (Table IV). This is considerably smaller than that reported in earlier studies (57% in 1952 and 47% in 1972, according to Welch (1975)). These differences reflect differences in the methods that were used to delimit plant communities, and/or real declines in vegetated areas due to inundations of established plant communities by sand.

Table IV Surface areas of the major vegetation types on Sable Island.

Community	Area (ha)	Percent of Total
Sandwort	20.3	0.6
Marram-Forb	299.4	8.7
Sparse Grasslands	772.1	22.5
Heath	147.0	4.3
Lakeside Herbaceous	23.6	0.7
Freshwater Ponds	26.3	0.8
Brackish Ponds —Lake Wallace	39.7	1.1
—others	12.1	0.4
Unvegetated	2084.5	60.9
Total	3425.0	