THE PHYTOGEOGRAPHY AND ECOLOGY OF THE MOSSES WITHIN THE SAN JUAN ISLANDS, WASHINGTON STATE

by

JUDITH STRACHEN HARPEL

B.S. California State Polytechnic University, Pomona, 1974
M.S. California State Polytechnic University, Pomona, 1980

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Abstract

Floristic work on bryophytes in the state of Washington has been confined mostly to the mainland with little information available for the San Juan Islands. After four years of field work and an extensive search of historical records from herbaria throughout the region, the San Juan Islands prove to contain a diverse moss flora within a small geographic area; this flora consists of 224 species and varieties, 33 families and 97 genera. Four species *Drepanocladus crassicostatus, Orthotrichum hallii, Tortula papillosa* and *Tortula laevipila* var. *meridionalis* are reported new for the State of Washington. *Tortula laevipila* var. *meridonalis* is new for the United States and represents the second North American location. Detailed ecological observations were made for each collection and distributions for each species have been mapped. Keys are presented to both genus and species.

The bulk of this flora is composed of circumboreal species that are derived from a once widespread Arcto-Tertiary flora. During the Pleistocene these islands were completely glaciated and the present flora represents, therefore, species that have migrated back into the region predominantly from southern refugial sites probably during the Hypsithermal Interval described by Deevey and Flint (1957). A cooling trend about 2000 yr. B.P. probably caused the southern element species to retreat southward throughout the region with fragments persisting only in those areas where favorable conditions also remained. The San Juan and adjacent islands can be interpreted as a "modern" refugium for southern mediterranean type climate species.

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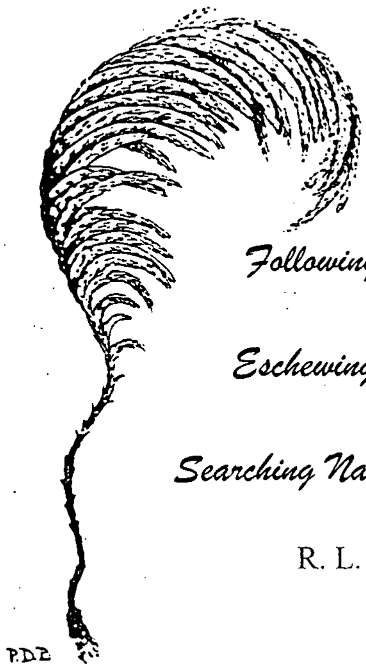


Following form while

Eschewing the obvious.

Searching Natures sweet moss.

R. L. Strachen

CHAPTER 1

Introduction

Floristic work on bryophytes in the State of Washington has been confined mostly to the mainland, with little published information available for the San Juan Islands and no attempt has been made to synthesize the available information. Earlier researchers in the state have included: T.C. Frye, who worked on the hepatics, *Sphagnum*, *Racomitrium*, and the Polytrichaceae of the Pacific Northwest, E. Lawton, who published a Moss Flora for the Pacific Northwest (Lawton 1971), and established a set of keys for the moss flora, but provided a very general picture of the distribution within the state. It is apparent that some areas in the state have not been extensively collected. R.R. Ireland collected in the state while he attended the University of Washington, but he has published only a portion of his data. G. Jones, W. Suksdorf, and C. Piper were early botanists who collected bryophytes but are better known for their vascular plant work.

Mrs. Betty Higinbotham, a bryologist from Washington State University, Pullman, spent her summers on San Juan Island, where she made some collections and has published a short list of the more common mosses in a local publication (Higinbotham 1985). Finally W.B. Schofield has collected within the adjacent Gulf Islands and on Vancouver Island, but has never collected extensively in the San Juans. Thus a data base exists for the Gulf Islands and the southern part of Vancouver Island but not for the San Juans. The lack of bryophyte floristic work combined with the unique climate, geological and vascular plant history of the San Juan Islands identified this area as one with promising research possibilities. Besides the lack of prior work and the unusual climatic and physical features that the San Juan Islands offer, there are advantages and disadvantages to working on islands.

The primary advantage to developing and interpreting a flora from a group of islands is that the boundaries of the flora are clearly defined, and when there has been little or no disturbance to the island it presents an excellent opportunity to study natural floristic patterns. Disturbance and accessibility are the most significant disadvantages to working in a group of islands. Both human and animal disturbance will have a greater impact on small areas and this may result in a change of species composition. Lack of access can prevent species from being found.

The present study was designed with the following primary objectives.

1. To develop a complete moss flora for the San Juan Islands through field work and a careful search of historical records.
2. To collect data on the habitat, substrata, and geological unit that each moss was found in or on, and to compare these relationships.
3. To determine the geographical distributions of the species and discuss their possible origins.
4. To prepare keys to the genera and species comprising the flora.
5. To map the distributions within the islands for each species

This study was designed to develop a comprehensive data base that can be used to assess any future changes that the islands may undergo. Also when equally comprehensive data exist for the adjacent areas, better conclusions can be made concerning the significance of the flora of these islands in relationship to these areas.

CHAPTER 2

Early Bryological Work Within The San Juan Islands

The first collections of plants were made in the Pacific Northwest approximately two hundred years ago. The two naturalists who first botanized the area were Tadeo Haenke and Jose Mocino. (Piper 1906.) Haenke, an Austrian, was with the Malaspina Expedition of 1791 and collected both flora and fauna; it is not known whether he obtained any bryophytes during his travels. Mocino, a botanist with the 1792 Royal Expedition of New Spain lists six bryophytes in the catalogue of animals and plants section of his Noticias De Nutka (Mozino 1970). Although he collected a few bryophytes, all of his work was confined to the Nootka Sound area of Vancouver Island and he apparently never visited the San Juan Islands. While the Spanish played a significant role in the exploration and naming of these islands, they contributed no bryological information.

Archibald Menzies was probably one of the most important botanists who worked in the region during this time. He was with Vancouver's 1792 Expedition and is best known for his extensive vascular plant collections. During his visit to the area, according to his journals, he collected some vascular plants from several of the islands (Newcomb 1923). He also lists the bryophytes that he collected during the expedition. To determine the specific localities of these bryophytes, a request was made to the Royal Botanic Gardens in Edinburgh (where the collections are held) for label information, but the results were disappointing. Most of his bryophyte collection labels were either "Northwest Coast of America or West-Coast of North America" (Long in litt. 1994). It is therefore, difficult to determine whether Menzies actually collected bryophytes from the San Juan Islands although he certainly visited them.

Although both John Scouler and David Douglas were in the Pacific Northwest in 1825 with the Hudson Bay Company, and collected bryophytes, neither of them visited the islands within San Juan County. When Scouler left the mouth of the Columbia River to head north, Douglas remained behind to explore that area. According to Scouler's journals he was on both Cypress and Lummi Islands in August of 1825 (Young 1905), but there is no record that he collected any bryophytes or visited any of the other local islands. Therefore it is reasonable to assume that neither of these botanists collected bryophytes within San Juan County.

The next major research event was the visit to the area by the United States Exploring Expedition led by Captain Charles Wilkes in 1841. This expedition is often referred to as the Wilkes Expedition; it was charged by Congress to explore all of the Southern Ocean. Ultimately the expedition proceeded up along the west coast of California and what was then called the Oregon Territory. According to Jackson (1985) the primary focus of this expedition was to survey and map all of the lands within the Southern Ocean and, if time permitted, to allow the civilian scientists to carry on their research. The ships under Wilkes' command were dispatched to various parts of the region at the same time; therefore, the scientists were not always able to explore all of the areas being mapped.

Keeping this in mind when reading his report, it is possible to determine how briefly Wilkes visited the San Juan Islands. After crossing the Straits of Juan de Fuca with a party of seven small boats, Wilkes and his men set out to explore: "On the 26th (July) we began the survey of this labyrinth of islands, which was continued the next day," (Wilkes 1849). They finished the survey on the 28th and when the news of the shipwrecked *Porpoise* arrived, they cut short the rest of the survey. Wilkes (1849) states: "I regretted that I had been deprived of the opportunity of examining the southeast end of Vancouver Island which I have reason to believe offers many fine harbors. Three days more would have enabled me to accomplish this portion to my satisfaction". During his entire narrative of this survey, Wilkes made no reference to stopping on any of the islands for research purposes, or that any of the civilian scientists who were with him did so.

The two naturalists assigned to this expedition, Mr. Pickering and Mr. Breckenridge collected both vascular plants and bryophytes, yet it appears that they did not collect within the islands. According to Sayre (1975a) all of the bryophytes from the entire expedition were sent to W.S. Sullivant for determination. A review of Sullivant's work, published in 1859 by Asa Gray, showed that the closest collection locality for all of the material was listed as Puget Sound, Oregon (Tan in litt. 1994). This locality probably was the Fort Nisqually area, which is now in Washington State. Wilkes, like the Spanish explorers before him, was also responsible for naming many of the islands. However, his expedition did not contribute significantly to the bryological information for the region.

In 1846 a treaty between the United States and Great Britain established the boundary between the United States and Canada as the Forty-Ninth Parallel of North Latitude. This boundary extended westward to "the middle of the channel which separates the continent from Vancouver's Island, and thence southerly through the middle of said channel and Fuca's Straits, to the Pacific Ocean" (Klotz 1917). While debate over who held jurisdiction over the San Juan Islands continued until 1872, these islands were included in the joint British and United States Forty-Ninth Parallel Boundary Survey carried out between 1857 and 1861.

The primary focus of this survey was to clearly define the boundary from the Strait of Georgia eastward to the Cascade Mountains. Dr. David Lyall, a Scottish physician and naturalist was assigned to this survey as ship's surgeon and botanist. While Lyall collected mainly vascular plants, his interest in cryptogams is revealed in a paper read to the Linnean Society of London on June 18th 1863. In this paper he states, "I have been fortunate in securing the services of Mr. William Mitten, A.L.S. in the arrangement and naming of my extensive collections of Mosses, Hepaticae, and Lichens, which thus have the value of being named by one of the most able and assiduous Cryptogamists in England" (Lyall 1864).

During the summers of 1858 and 1859 Lyall spent part of his time while on board the *Plumper*, surveying the area around the southeast corner of Vancouver Island and among the surrounding islands. It was during one of the numerous stops that Lyall collected a liverwort from Orcas Island. Mitten (1864) in his paper on the "Bryologia of the Survey" identifies Lyall's liverwort as *Frullania tamarisci* L. and gives the location as Vancouver and Orcas

Islands. Although Sayre (1975b) states that an intact set of Lyall's bryophytes from the entire survey consisted of 116 mosses and 19 liverworts, Mitten's paper (1864) mentions only the one San Juan Islands site. Therefore it appears that Lyall did not collect any mosses from these islands. His liverwort record, on the other hand, represents the earliest documented bryophyte record from these islands.

Benson (1986) states that "before the 1880's neither individuals nor local institutions pursued natural history work in the Puget Sound region. But by the early 1900's organized studies in the natural sciences were conducted through the zoology, botany and geology departments at the University of Washington, the marine station of the University at Friday Harbor and the new Washington State Museum". Rigg (1929) also points out that most of the botanical field work done after 1860 in the state was carried out by local residents and they appear to have worked mostly on the mainland. Therefore it is not surprising that for the next thirty-four years after Lyall's work there was little or no botanical research activity within the San Juan Islands.

It was not until 1892, when Louis F. Henderson spent several days in July collecting around the Eastsound and Mt. Constitution areas of Orcas Island (Sarah Gage, pers. comm. 1994), that botanical research occurred within the islands. His primary interest at this time was to obtain vascular plants for the upcoming World's Fair. Although he did collect bryophytes (Vitt et al. 1985), it would be difficult to determine if any were collected from Orcas Island during his visit because most of his original collections prior to 1906 were lost in a fire at the University of Idaho (Piper 1906).

The advent of the late 19th Century and the early 20th Century brought about change to both natural history and the San Juan Islands. American natural history during the 19th Century was dominated by amateurs and was a very popular pastime (Benson 1986). Burnham (1971) further comments that "local natural history societies flourished everywhere, even near the frontier, to foster and express the scientific interests of well educated and even self-educated Americans".

It was in this atmosphere that the Young Naturalists Society was formed in 1879 by a group of young Seattle area men. This group by 1885 had developed close ties with the University of Washington and was rapidly assembling substantial field collections. In 1894 new members included school teachers, several physicians and Trevor Kincaid (Benson 1986). When this society disbanded in 1904 its collections formed the beginnings of what is now the Burk Museum, and it had provided the ground work for the development of the Friday Harbor Biological Laboratory under Kincaid's guidance.

Hayner (1929) defines the period of development from 1881 to 1910 as the "Village Stage" for the San Juan Islands. During this stage, the population increased and several major industries were established. This increase in both population and economy brought about the construction of new roads, and easier access to and from the mainland. Thus the "Bryological Era" had begun within the San Juan Islands.

The "Bryological Era" in the San Juan's can be divided into two distinct periods based upon historical collecting information obtained from the herbaria of the University of Washington, Western Washington University, Portland State University, and the University of British Columbia. The first period starts in 1902 and continues until 1908. In 1902 and 1903 all of the collecting was done by either Dr. John W. Bailey or Mr. A.S. Foster. Dr. Bailey was a well known Seattle area physician who was extremely interested in bryophytes. He contributed to both A.J. Grout and J.M. Holzinger's moss Exsiccata and served as Secretary of the Sullivant Moss Society for several years (Frye, 1933).

There is some confusion as to the identity of Mr. A.S. Foster; Steere (1978) lists him as Adriance Sherwood Foster 1901- 1973, but this is impossible, as herbarium material collected from the San Juan's by A.S. Foster starts in 1902. While Foster always used his initials when he prepared his labels and published articles, there is some indication that the A.S. initials stood for Albert Scott. Holzinger (1921) listed Foster as a "teacher in the public schools of the state of Washington....". When a request was made to the Washington State Superintendents of Public Instructions Office, they reported that their records for the era listed a teacher certificate number for an Albert Scott Foster. Unfortunately all of the early information was sent to the state Archives Office and his file was disposed of. The only record that they have for a Foster was found in the Register of Life Diplomas Granted by the State of Washington in 1902. He is listed as A.S. Foster, 48 years old, and from the state of Indiana, at the time he was given his life teaching certificate. In one of his papers Foster makes reference to "my boyhood days in southern Indiana ..." (Foster 1904), thus confirming that he was the same teacher who was interested in bryophytes. While Foster published papers on both vascular plants and bryophytes, his interest in bryophytes is evident from his vast exchange of material with the well known bryologists John Holzinger and A.J. Grout. Foster sent material from Waldron island to Grout for determination and Grout used *Scleropodium colpophyllum* as number 392 in his exsiccata of North American Musci Pleurocarpi which was issued, according to Sayre (1971), in June of 1912.

Foster's contributions to northwestern United States bryology are also noted in a paper on the early history of the Sullivant Moss Society by Annie Morrill Smith (1917), "Then in field work we might fairly claim to have promoted exploration when we recall the collections of A.S. Foster in Oregon and Washington ...". During his work in the San Juan Islands, Foster collected on the following islands: San Juan, Henry, Orcas, Waldron, and he was the only person ever to collect bryophytes on Stuart. The contributions that both Bailey and Foster made to Northwest bryology also can be documented by Holzinger's proposing the new name *Bryum baileyi* for a species of *Bryum* collected by Bailey in the Seattle area. Holzinger (1905), states "I propose ... in recognition of my very efficient bryological friend Dr. John W. Bailey of Seattle...". Later that same year Holzinger changed the name to *Bryum fosteri*, as the name *B. baileyi* had already been used. Other collectors in this region during this early period included Mrs. Huggens, Mrs. Thomas, A.S. Pope, and J.B.Flett, but it was primarily Foster and Bailey who were responsible for most of the early collections.

It is interesting to note that the early pre-1904 collecting activity corresponds neatly to when the Young Naturalists Society was still active. Although there is no evidence that

Foster, Bailey or any of the other early collectors were members of the Society, their interests fit in well with the current hobby atmosphere of that era, and it is possible that they were members. By the time that the Society disbanded in 1904, the University of Washington had opened the Puget Sound Marine Station in Friday Harbor on San Juan Island. Even though the idea of a Marine Station was established in 1902, it was not until 1904 that the first classes were taught by Trevor Kincaid and Theodore C. Frye. (Howard 1963). Although formal classes taught on a regular basis did not occur until the summer of 1906 (Benson per comm. 1994), the influence of the Station began in 1904 when Frye started collecting bryophytes from the islands. Since early records for the Station are relatively scarce it is difficult to determine if formal bryophyte classes were offered before 1923, but based on the herbarium data it seems very unlikely. The last major bryophyte collecting activity during this first period occurred in 1908, after which little collecting was done until 1919.

During this period of bryological inactivity, Frye collected briefly in Roche Harbor, San Juan Island on July 11th 1911 and again in July of 1915 with Goete W. Turesson (the director of Algae at the Station) on Mt. Constitution, Orcas Island. These two days represent the only bryological field work done within these islands between 1910 and 1918, according to the herbarium records. This relative lack of collecting may be the result of Frye's absence from the Station as well as the negative influence of World War I. In 1913 Frye and G.B. Rigg led a survey of the Alaskan kelp beds to look for a new source of potash (Howard 1963). It was also during this time that A.S. Foster was asked to join the expedition and, when time permitted, they collected Alaskan bryophytes (Holzinger and Frye 1921).

Theodore C. Frye was by far the most significant collector of bryophytes in the San Juan Islands. It is interesting to note that the two periods of bryological activity correlate with his being director of the Station from 1905 to 1909, and again from 1914 to 1930. Although, according to herbarium data, Frye spent 91 days collecting within the islands he usually went back to the same locations and therefore did not collect extensively throughout the area. There are also problems with interpreting some of his labels and, combined with the lack of good field journals, it is often difficult to relocate some of his old collecting sites.

In spite of these difficulties, Frye's enthusiasm for plant ecology, bryology and teaching is reflected in the second period of the "Bryological Era" which began in 1919 and continued until 1930. From 1919 until 1930 all of the bryological research was directly related to the Station. Florence Spaulding, a student who took the Botany Research Class at the Station in 1920, began collecting bryophytes on Blakely Island in July of 1919. While there, she collected *Eurhynchium oreganum* and *Fontinalis antipyretica.* The north side of Shaw Island was visited on July 7th 1921 by Anna M. Daugherty, also a student at the Station in 1920. She collected the following species of mosses: *Anacolia menziesii, Bartramia pomiformis, Neckera douglasii, Metaneckera menziesii,* and *Ulota phyllantha.* Their independent visits appear to be the only early bryophyte records for both of these islands. In 1922, during the month of July, Frye collected in the Friday Harbor area and Daugherty visited the Mt. Constitution area on Orcas Island.

In 1923, the herbarium records indicate that a formal course in bryophytes was offered. During this time Frye was the instructor, and Daugherty (now a high school teacher in Seattle) was the teaching assistant. This class spent 34 days in the field and collected on Orcas, San Juan and Sucia Islands. Herbarium labels list the following people as collectors: Lois Clark from the University of Idaho, A.M. Daugherty, T.C. Frye, Lena Hartage, a University of Washington student, C.M. Roberts from Pennsylvania State University, M. Wentworth, a student and Station Librarian, Catherine Smith, an Auburn High School teacher, and Jean Berger, a Bellingham High School teacher. Many of the labels provided only "Class of 1923". Dr. Bailey also collected in 1923, but it is unlikely that he was enrolled in the class. This also was the year that the University began work on the new buildings at the Point Caution location, which ultimately provided more laboratory and classroom space.

Relatively little is known about the bryophyte collections of 1924. All of the herbarium labels list either Frye, Hartage or the "Class of 1924" and represent collections from only San Juan and Orcas Islands. They spent a total of 10 days in the field and it is doubtful that a formal bryophyte class was held that year.

The bryophyte class of 1925 provides the most historical information about itself. According to an unpublished student report in the University of Washington's Department of Biomedical History Archives, this class was "notable for the number of new species which were collected in the vicinity of the station and on the islands". Dr. Frye was listed as the Director of Bryophytes, Dr. Lois Clark taught the liverworts and Chas. M. Roberts served as the teaching assistant. Of the six students, all but one of them were either Junior High or High School Biology or General Science teachers. These students were as follows: H.A. Millican from Yakima High School, Sylvia E. Smith from Roosevelt Junior High in Decatur Illinois, Estella Peterson from Shelton High School, Glen Osborn from Bellevue High School, Doris Mullen from Wenatchee High School and finally Carra E. Horsfall from Reed College in Portland Oregon. Doris Mullen appears to have been a very discriminating collector and she is responsible for several historical collections from San Juan Island, including *Andreaea rupestris* and *Climacium dendroides*. Later she was the teaching assistant in the Normal Botany and Algae Classes taught in 1929 and 1940. This class also apparently traveled more throughout the islands and collected on Orcas, San Juan, Spieden and Sucia. In 1926 the only bryophyte collections were made in July by Frye and J.E. Kirkland. With the exception of July 17th, when Kirkland collected *Timmia austriaca* on Spieden Island, all other collections were from Friday Harbor on San Juan Island.

Even though the Marine Station could have provided the students access to a research vessel for inter-island travel, and commercial transportation was readily available, most of the collection localities remained consistently the same from year to year. This was probably a result of Frye's influence, and most of the collecting was done either on San Juan Island or Orcas Island. Favorite spots on San Juan Island included Sportsman Lake, Trout Lake, Roche Harbor, Friday Harbor and on the new Station grounds on Point Caution. The Class of 1925 had the first really good opportunity to thoroughly collect the Point Caution area as they were the first students in a bryophyte class to be held at the new site. Common collection locations on Orcas Island included Eastsound, Twin Lakes, Rosario, and one of their favorite locations, Mt. Constitution. Often their label information would be rather vague, such as the "north side of Orcas Island", or "near Eastsound"; thus, it is difficult to relocate some of their early collecting sites.

In 1930 Frye collected throughout the year within the Friday Harbor area on San Juan Island. This was Frye's last year as the director of the Station and a serious decline in the bryological activity within the islands, coincided with his departure. From this point on there was very little bryological collecting activity. On July 4th, 1931, Ruth D. Svihla, a bryologist, visited and collected briefly on San Juan Island. In 1937 Elizabeth Young, Frye's daughter, collected at Friday Harbor. Presumably both of these collections were the result of short visits to the Station and did not represent formal research. Based on the herbarium data, Frye's last field work in the San Juan's occurred on July 1st 1944 when he collected on San Juan Island

After 1944, most collecting represented casual trips to the area by students, although several well-known bryologists visited the area briefly. Elva Lawton, according to her field notes, made a trip to the Mt. Constitution area on July 22, 1956. While there, she collected *Polytrichum piliferum, Racomitrium heterostichum, R. canescens* var. *ericoides, R. canescens* var. *elongatum* and *Grimmia trichophylla.* Robert Ireland, a graduate student working under the direction of Lawton, visited Friday Harbor on May 19, 1962, and collected *Grimmia trichophylla* var. *muhlenbeckii.* Matia Island was visited by Larry Goodhew, Lawrence O'Flaherty, Dale Durrwachter and James Gregory on February 18th 1962. Their visit may have represented part of a class assignment as they collected extremely large quantities of 18 species of moss. It is possible that they may have been responsible for the extinction of two species from the island. David Largent, another University of Washington student, collected around the Station grounds on Oct. 23, 1965. W. B. Schofield visited San Juan Island briefly in 1970 and collected 12 mosses from around the ferry terminal area.

Mrs. Betty Higinbotham, a past President of the American Bryological and Lichenological Society, had a summer home on San Juan Island. In a meeting with her in 1990 she indicated to me that she had never made extensive collections of bryophytes within the islands. In 1985 she wrote a short article entitled "The Mini-Plant World of Mosses and Lichens" which was published in the local San Juan Islands Almanac (Higinbotham 1985). In this article she lists some of the most common species of mosses and lichens but this list is not offered as a comprehensive survey of the region's flora. According to the herbarium labels at Western Washington University, Mrs. Higinbotham collected *Racomitrium canescens* var. *ericoides* from the Mt. Dallas area, San Juan Island on April 4th, 1975. A recent search of her bryological collections located at the Washington State University herbarium in Pullman revealed a fairly large number of specimens still in the original collecting bags. Most of the collections came from San Juan Island, but she also made trips to Lopez, Orcas, Shaw and Speiden Islands. Although she had indicated that she did very little collecting within the islands, her field work resulted in 61 species and 196 packets of bryophytes. All of these bryophytes were obtained during brief visits to their summer home between 1973 and 1984.

Prior to the detailed exploration and collections represented by the thesis research reported here, essentially all bryological research done within the San Juan Islands has been the result of casual or class collecting and there has never been a serious attempt to develop a comprehensive flora for the area. Although the classes held at the University of Washington Marine Station provided many specimens, all came from frequently revisited locations and a systematic survey of all of the islands was never attempted. Between 1858 and 1984 approximately 244 field days were spent in collecting bryophytes from only 10 of the islands found within San Juan County. The material gathered during this 126 year period has resulted in a species list of approximately 137 species for the islands. Of these, a few species were collected that were not rediscovered during the present study. See Appendix A for a list of species not relocated during the present study.

These early collectors were fortunate to be able to do field work during the time when the islands were less disturbed by human activity than is the case today. Their collections hold historical significance in that many of the areas that they repeatedly visited are now destroyed as sites for bryophytes or have undergone other major changes. One of the best examples of this is reflected in the early work done by G.B. Rigg on the peat resources and sphagnum bogs within the islands (Rigg and Richardson 1934). Although his work concerned palynological records and was not intended as floristic, he did map all of the existing bogs; today most of these bogs no longer exist (see Chapter 5 p. 75 for further details).

In conclusion, although Frye and his students had a tremendous impact on bryological research within the San Juan Islands, they did not carry out a formal survey of the region. When Frye's work is combined with the earlier collection data, and the casual collections of recent years, a reasonably large species list can be developed for the area. Yet all of this earlier work was not sufficiently systematic to produce a bryophyte flora for the San Juan Islands.

CHAPTER 3

Description of the Study Area

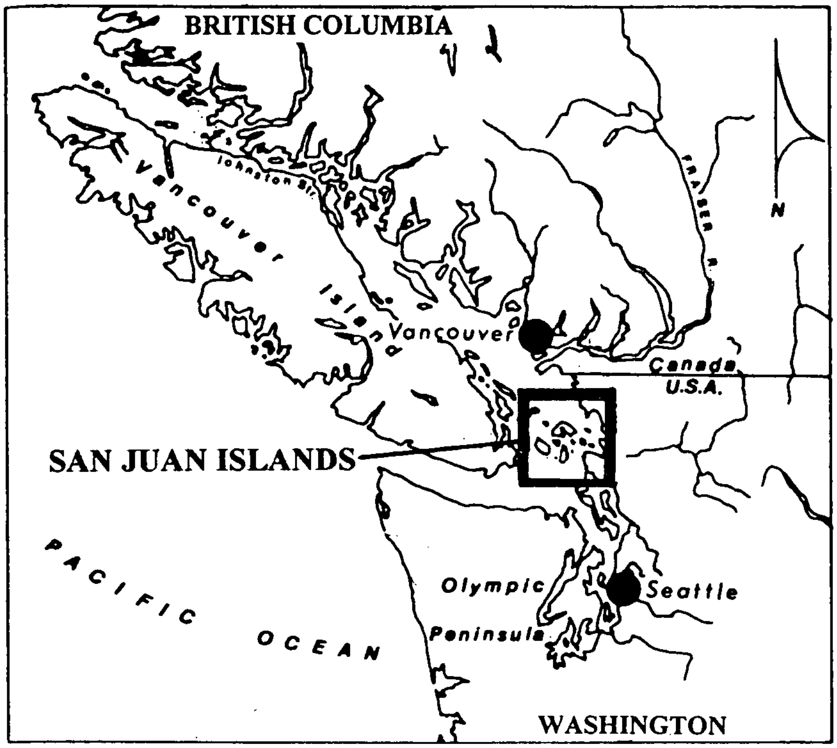
The San Juan Islands are part of the San Juan archipelago which is located in the northwestern part of Washington State between Vancouver Island, Canada and mainland Washington (See Figure 1.). The center of the area is located at 48 30'N latitude and 123 0'W longitude. These islands vary in size from less than one hectare (0.4 acre) to the largest at 14,744 hectares (36,432 acres). Elevation ranges from sea level to 734.4 m. (2,409 ft.) on the summit of Mt. Constitution. The archipelago includes 428 islands exposed at low tide, of these 175 are named. Together they represent a land mass of 445.5 square kilometers (172 square miles) (Russell 1975).

Roy McLellan, the first geologist to survey the San Juan Islands extensively, describes the islands as "In a restricted sense the San Juan Islands consist only of the area included within San Juan County, Washington. To the eastward occur islands belonging to Skagit and Whatcom Counties and these are commonly regarded as part of the San Juan Island Group" (McLellan 1927). Although these islands are considered part of the San Juan Island Group, for the purposes of the present study only the Islands within San Juan County were surveyed. A discussion on the climate, geology, glacial history, soils, vegetation and Late Pleistocene and Holocene vegetation and climate for the islands found within San Juan County follows.

Climate

Good (1931) states "plant distribution is primarily controlled by the distribution of climatic conditions". Longton (1980) in a paper on the physiological ecology of mosses comments; "temperature and availability of water are shown to be significant in controlling vegetative growth, while temperature and photoperiod appear to be involved in regulation of clearly defined seasonal cycles of gametangial and sporophyte development". Wind patterns also play an important role in the distribution of moss spores (Zanten 1978).

Figure 1. Location map for the San Juan Islands.



Modified from Hebda (1983)

The climate of a region, therefore, has a significant influence on the distribution patterns of mosses

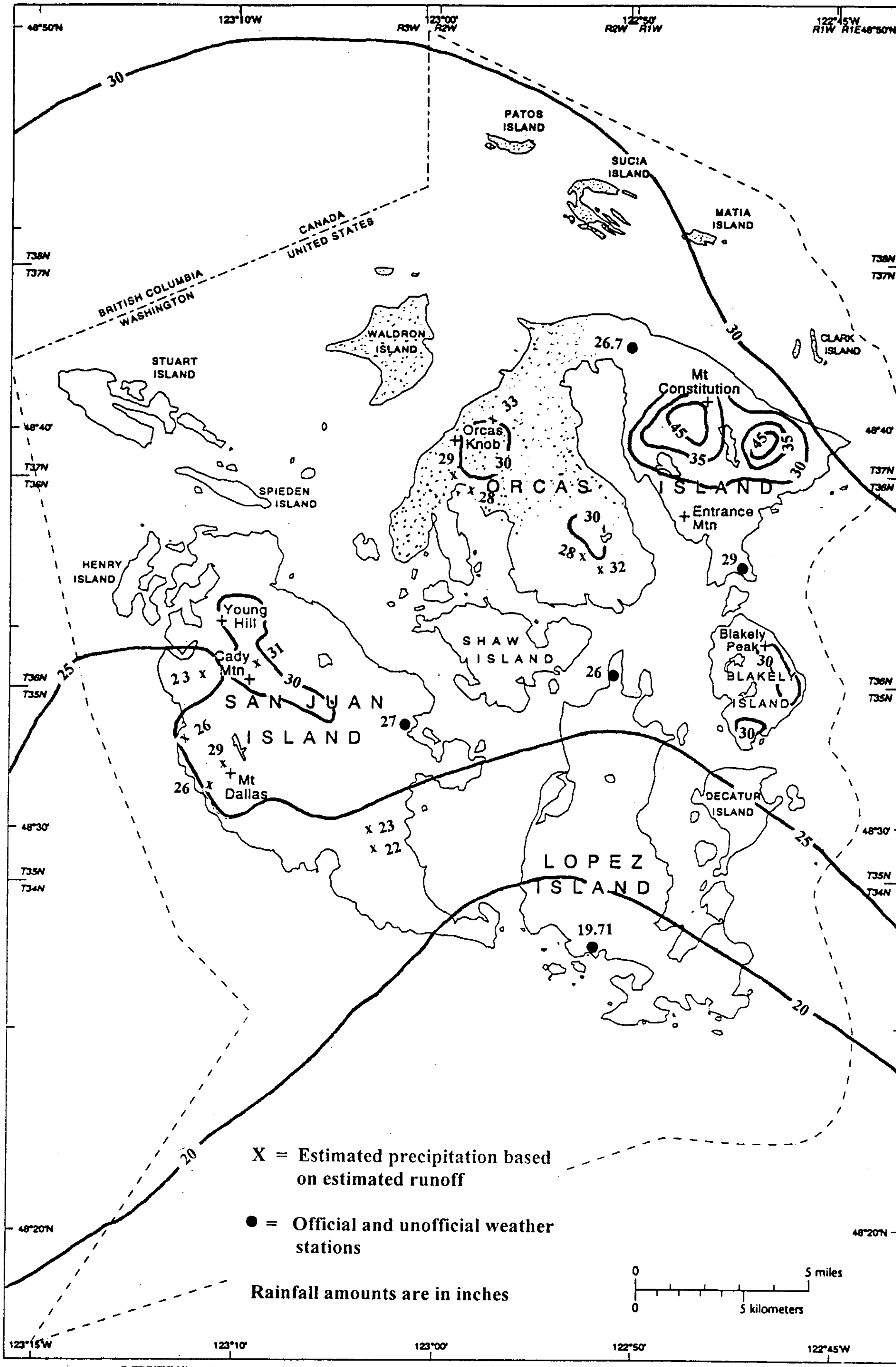
The climate of the San Juan Islands is characterized by relatively short, cool, dry summers and mild moderately wet winters, with 60% of the rainfall occurring during the winter (Dietrich 1975). This climatic pattern results from the prevailing south southeast winter winds and the "rainshadow effect" created by the Olympic Mountains. During the summer months the semipermanent "Pacific High" that becomes established in the area prevents storms from entering the region. Combined with the cool, southwest summer winds and the blocking of the warm dry continental air mass by the Cascades, the summers are cool and dry. The San Juan Islands can be considered to be part of the Mediterranean type climate found along the Pacific Coast of North America.

Both Krajina (1959, 1965) and Chapman (1952) describe this region as within Koppen's Csb- Mediterranean type climate. This climatic region includes the southeastern portion of Vancouver Island, across the Georgia Strait, north to Texada Island and along the mainland coast southward to the Lower Fraser Delta in British Columbia. Chapman (1952) cautions that there are significant local differences within this region; Krajina (1965) refers to this as "Csb-Mediterranean subhumid").

While there were only three official U.S. weather stations within the islands Diertrich (1975) used both official U.S. and nearby Canadian weather stations to prepare an isohyetal map of estimated mean annual precipitation for the county, (Figure 2.). Weather data accumulated from the three official U.S. weather stations within the islands were also assembled by Phillips in his 1966 paper on the weather of San Juan County, (Table 1.).

Maunder (1968) describes seven patterns of high pressure systems and nine patterns of low pressure systems that occur in the Pacific Northwest. The high pressure patterns usually dominate during the summer months, while the low pressure systems dominate the winter months. The wind patterns within the islands are predominantly from

Figure 2. Isohyetal map of the San Juan Islands.



Based on Dietrich (1975)

Table 1. Temperatures and precipitation from known stations in the San Juan Islands

Location	Mean Daily Temperatures (F)	Precipitation (Inches)
Friday Harbor (San Juan Island)	Jan. = 7.4° C (45.4°) July = 23.9° C (75.1°)	Snow = 114.3 mm (4.5") Rain = 696.0 mm (27.4")
Olga (Orcas Island)	Jan. = 6.4° C (43.6°) July = 21.2° C (70.2°)	Snow = 195.6 mm (7.7") Rain = 731.5 mm (28.8")
Richardson (Lopez Island)	Jan. = not given July = not given	Snow = not given Rain = 500.4 mm (19.7")

based on Phillips (1966)

the south or southeast during the winter months, and from the west or northwest in the summers. Occasionally, during the winter seasons, low pressure systems form off the coast, thus large cold air masses from the Fraser River Canyon produce strong northeasterly winds. These winds are often destructive and result in large quantities of blown down timber. During the summer months the winds are usually light and occur during the afternoon from the west.

Three of the sixteen patterns of high and low pressure systems described by Maunder (1968) could have provided the right surface wind conditions necessary for the long distance dispersal of moss spores from the mainland. These three patterns are as follows: (1) a high pressure system is centered west of central California/Oregon and a low pressure system is in the Gulf of Alaska, (2) a low pressure system is centered between 45 and 50 N latitude and finally, (3) a low pressure area is centered over the Gulf of Alaska. All three of these patterns result in a southwesterly to westerly air flow that could have carried moss spores into the islands. See the discussion under phytogeography for additional details in Chapter 6, p. 81.

Geology and Soils

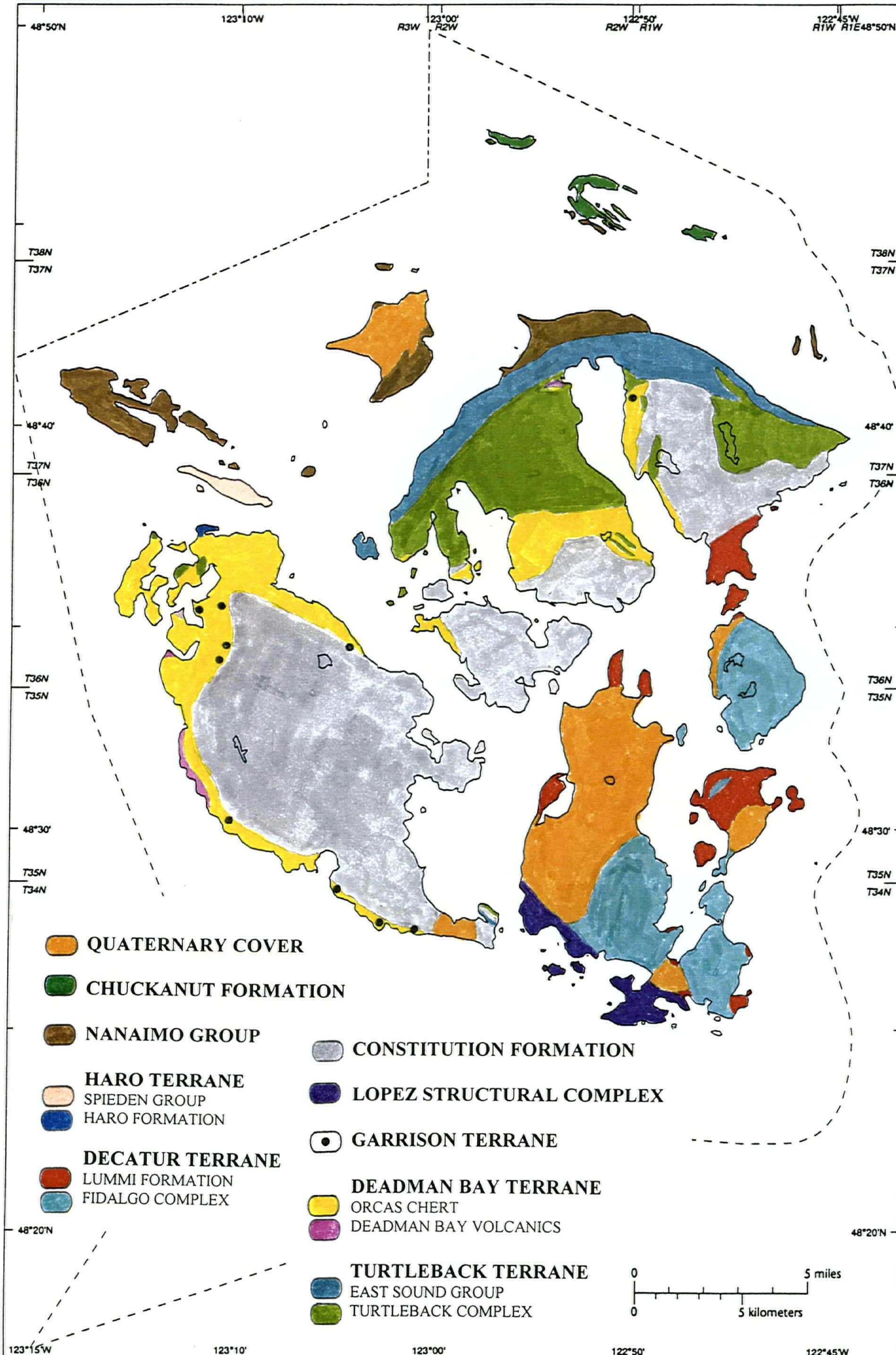
The composition and physical nature of the substratum plays an important role in the distribution of mosses (Richardson 1981). Some species such as *Racomitrium lanuginosum, R. heterostichum, R. elongatum, Andreaea rupestris* and *A. megistospora* are restricted to acidic substrata, while others such as *Eucladium verticillatum*, *Crumia latifolia* and *Conardia compacta* are confined to alkaline or calcareous substrata. The geology and soils of a region significantly influence the distribution of the mosses.

McLellan (1927) comments that "the San Juan's probably represent the down-turn of an ancient piece of orogenic crusts most of which was long since consumed". In a more recent work Danner (1966) proposes that "the San Juan Islands compose the older core of an ancient mountain system that once extended across the Pacific Northwest from Vancouver Island into Central Washington". Cowan (pers. comm. 1994) hypothesizes that these islands are composed of terranes that formed around 90-100 million years ago that subsequently they collided with the Wrangellian terrane. According to the paleomagnetic data it appears that these terranes may have formed near the latitudinal position of Baja California (Brandon et al. 1988). While there is debate as to where the terranes collided, Cowan (pers. comm. 1994), feels that the collision took place off the Baja California coast and that the resulting terranes migrated northward until they reached their current position about 55 million years ago. Thus, by the early Tertiary Period, these islands were in their current position.

Brandon et al. (1983, 1988) describe fourteen lithologic units within the islands. These rock units range from Early Paleozoic to Quaternary in age and can be divided into four groups. First, the San Juan Thrust System is composed of a series of thrust faults and nappes ranging in age from the early Paleozoic to the Late Cretaceous. It includes the following nine units: Constitution Formation, Deadman Bay Volcanics, East Sound Group, Fidalgo Complex, Garrison Terrane, Lopez Structural Complex, Lummi Formation, Orcas Chert, and the Turtleback Complex. The rocks within these units were subjected to Late Cretaceous thrusting and high-pressure metamorphism. Thus they represent some of the oldest bedrock material in the Islands. The second group, the External Units, were formed during the Late Triassic to Early Cretaceous and may or may not have been subjected to the Late Cretaceous thrusting. They also did not undergo the high-pressure metamorphic conditions that affected the earlier units. The following three units are included in this group: Haro Formation, Nanaimo Group, and the Spiedon Group. These units occur either in front of or below the San Juan Thrust System. Third, the Post Orogenic Unit group contains only the Chuckanut Formation, an Eocene deposit composed of nonmarine sandstone and conglomerate. This formation is exposed only on Patos, Sucia, Matia and Puffin Islands, where it replaces the Nanaimo Group. The fourth group contains only the Quaternary Cover, which is composed of glacial till and sediments that were deposited during the Pleistocene and Recent Epochs. While Brandon (1988) does not break this group into individual units, McLellan (1927) divides it into four formations: the Colwood Formation, composed of sediments and alluvium deposited during the Recent Epoch; the Vashon and Admiralty Formations, composed of glacial tills and sediments that were deposited during the Pleistocene; and finally the Puyallup Formation, composed of interglacial sediments deposited during the Pleistocene. These deposits range in size from clay particles to gravely till and can be up to 45.7 m (150 ft.) thick in some areas. The Quaternary Cover deposits are also responsible for the abundant sand spits and tombolas found throughout the islands. Thus, these older structures have provided a wide variety of rock types that can be found among the islands. Figure 3. shows the locations, and Table 2. contains further descriptions of these formations.

While a large variety of rock types occur within the islands, the limestone deposits found in the Deadman Bay Volcanics and East Sound Group (on Orcas and San Juan Islands) are the most significant geological features with respect to the bryophytes. When these limestone deposits occur associated with fresh water, an unusual habitat is es

Figure 3. Geology of the San Juan Islands.



Based on Brandon et al. (1988)

Table 2. Geologic Formations in the San Juan Islands

Tectonic Group	Name of Unit	Age	Lithologic Description
RECENT	QUATERNARY COVER	Pleistocene & Recent	glacial till and sediments
POST OROGENIC	CHUCKANUT FORMATION	Eocene	Nonmarine sandstone and conglomerate
THE EXTERNAL UNITS	NANAIMO GROUP	Late Cretaceous	Marine and nonmarine sandstone, conglomerate, and shale
	HARO TERRANE		
	Haro Formation	Late Triassic	marine volcaniclastic sandstone and conglomerate with minor silicic tuff
	Spieden Group	Late Jurassic & Early Cretaceous	marine sandstone and conglomerate derived from an arc-volcanic source
THE SAN JUAN THRUST SYSTEM	DECATUR TERRANE		
	Lummi Formation	Latest Jurassic & Early Cretaceous	clastic marine sequence
	Fidalgo Igneous Complex	Middle & Late Jurassic	An ophiolite with younger superimposed volcanic arc
	LOPEZ STRUCTURAL COMPLEX	Late Cretaceous	a fault zone, with sandstone, pebbly mudstone, pillow lava and chert
	CONSTITUTION FORMATION	Jurassic or Early Cretaceous	volcaniclastic sandstone, with imbedded mudstone, ribbon chert, pillow lava, and green tuff
	GARRISON TERRANE	Permian to Early Triassic metamorphism	high-pressure metamorphic rocks, of mafic schist with minor quartz-mica schist. greenschist to albite-epidote amphibolite facies
	DEADMAN BAY VOLCANICS		
	Orcas Chert	Triassic & Early Jurrassic	ribbon chert, minor pillow basalt and limestone
	Deadman Bay Volcanics	Early Permian to Triassic	pillow basalt with minor interbedded Tethyan-fusulinid limestone and ribbon chert
	TURTLEBACK TERRANE		
	East Sound Group	Eearly Devonian to Early Permian	an arc-volcanic sequence with minor interbedded limestone, with non-Tethyan fusulinids
	Turtleback Complex	probably Cambrian	a plutonic complex consisting of tonalite and subordinate gabbro

Based on Brandon et al. (1988)

established that supports a variety of calcicolous mosses. Tufas, formed by the precipitation of $CaCO_3$ on the surfaces of calcicole mosses can often be found in such habitats (Flugel 1982). The limestone deposits are also of interest because they do not occur extensively in the adjacent islands or on the mainland. Thus the tufa formations that occur within the islands represent distinctive habitats. These limestone deposits have been quarried extensively, and while they contributed significantly to the island's early economy, they have been badly disturbed as a consequence. Therefore the distinctive calcareous habitats are now somewhat limited in the islands.

During the Pleistocene Epoch the islands were extensively glaciated. Easterbrook (1969) has documented three periods of glaciation and associated interglacial periods. The Stuck Glaciation period followed by the short Puyallup Interglacial began around 70,000 years B.P. Approximately 40,000 years B.P. the Salmon Springs Glacial period began, persisting until about 28,000 years B.P. This was followed by the Olympia Interglacial which persisted until about 19,000 years B.P. During these early periods of glaciation the islands were completely covered by thick deposits of ice or were submerged by marine water.

The final episode of glaciation began around 19,000 years B.P. and has been called the Fraser Glacial period. During this period of glaciation the Puget and Juan de Fuca Lobes advanced southward at different rates of speed. The Juan de Fuca Lobe advanced across the San Juan and adjacent islands as well as the southern tip of Vancouver Island, ultimately ending in the western Strait of Juan de Fuca about 17,000 years B.P. While the Juan de Fuca Lobe was advancing, the Puget Lobe had already pushed south of Seattle by around 15,000 years B.P. (Waitt & Thorson 1983). Easterbrook (1969) divided the Fraser Glacial period into the following: The Vashon Stade, a period of glacial advance that occurred between 19,000 - 13,000 years B.P. and covered the top of Mt. Constitution with a layer of ice that was approximately 915 - 1097 meters (3000 - 3600 ft.) deep; The Everson Interstade, a time of glacial retreat between

13,000 - 11,000 years B.P.; and finally, The Sumas Stade, (11,000 - 10,000 years B.P.) a small advance of ice that probably did not go very far beyond the United States - Canada border, see Table 3.

Recent research by Dethier et al. (1995) states that "As the Fraser ice retreated, marine waters invaded the northern Puget Sound and adjacent areas of British Columbia, inundating most of the San Juan Islands ...". Abundant invertebrate fossils representing cold water species with cool-temperate to Arctic affinities indicate that these marine waters were cold. The macrofossils further suggest that this marine environment was similar in temperature to that which is more characteristic of the northern Gulf of Alaska at the present time. Dethier et al (1995) also suggest that the Sumas Stade had no significant influence on the climate. Thus, by about 13,500 years B.P. the higher regions of the islands (such as Mt. Constitution, Orcas Knob, and Dallas Mt.) were probably above water, ice free, and were surrounded by a cool marine environment (see Figure 4.).

As the glaciers retreated, large quantities of outwash and interglacial sediments, composed of various types of sand and gravel, were left on the islands. Glacial till, a hard compacted sediment, was deposited over both the earlier sediments and on bedrock. This material, known as Vashon Till, covers most of Lopez and Decatur Islands and is composed of all sizes of lithic material, including clay. On the southwest side of Lopez Island the depth of the till was measured at 16.1 m (53 ft.) (Russell 1975). Both McLellan (1927) and Russell (1975) note that large granite boulders, (called glacial erratics) were deposited along with this till and can be found scattered throughout the islands. The final glaciomarine drift deposits were left on top of the earlier deposits as the Fraser Ice retreated. This fossil-rich material is widespread and probably is 10-15 feet thick (Russell 1975).

Schlots et al. (1962) describe four types of soil associations found throughout the islands (see Figure 5., and Tables 4. and 5.). The Bellingham-Coveland-Bow association, composed of "poorly drained to imperfectly drained soils of the basins and low glacial till

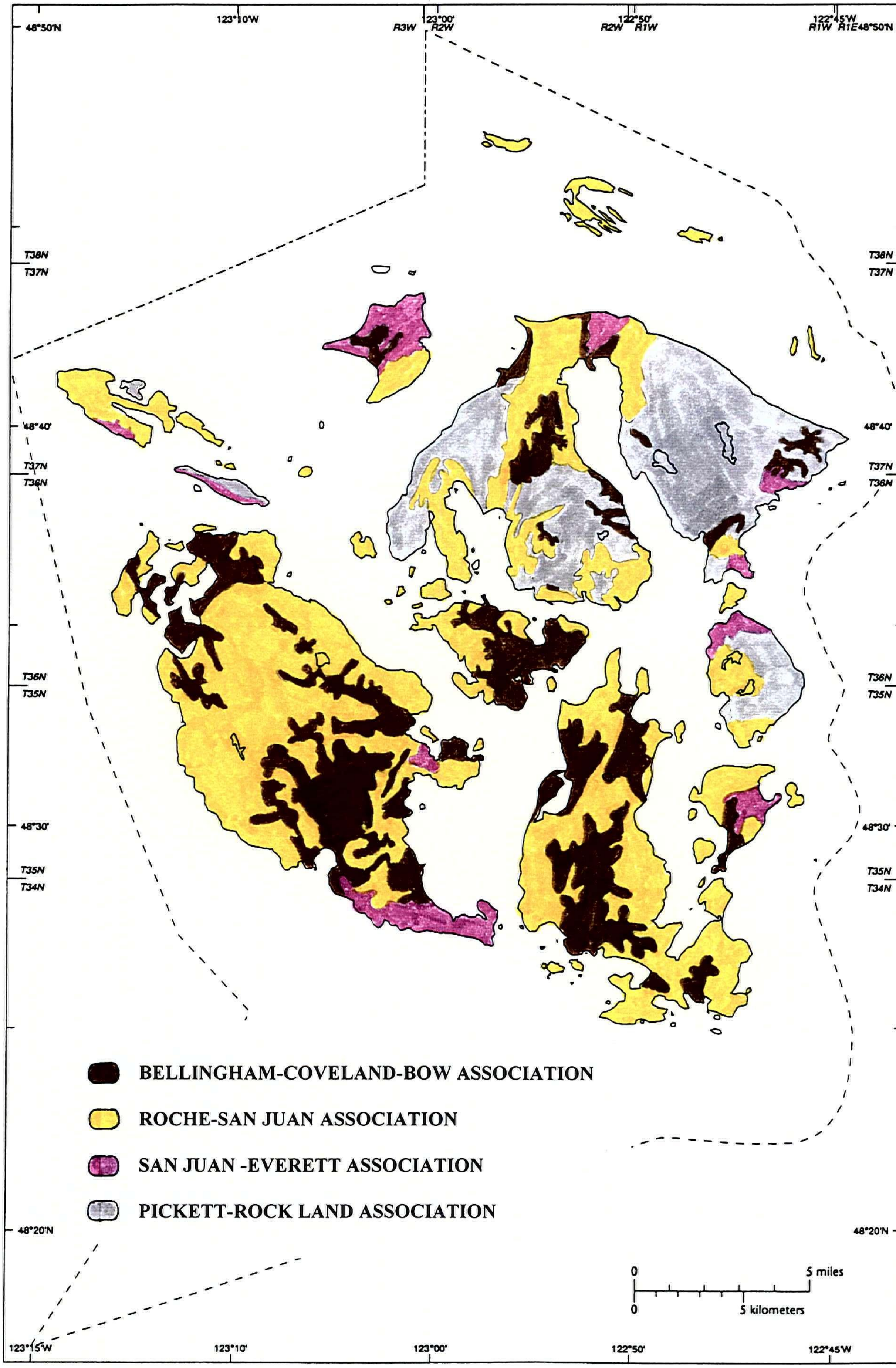
Table 3. Glacial history in the Puget Trough.

<table>
<tr><th>Yr. B.P.</th><th colspan="2">Geological / Climatic Units</th><th>Event</th></tr>
<tr><td>0</td><td colspan="2" rowspan="2">Cool and Moist</td><td rowspan="2">Quercus pollen decreases and Thuja-Chamaecyparis pollen increases. (L. Heusser 1983)</td></tr>
<tr><td>1000</td></tr>
<tr><td>2000</td><td rowspan="7">HYPSITHERMAL</td><td rowspan="7">Warm and Dry</td><td rowspan="5">Garry Oak-Douglas Fir Subzone is well established in the Saanich Inlet, on Vancouver Island. (L.Heusser 1983)
—— Mt. Mazama Eruption ——</td></tr>
<tr><td>3000</td></tr>
<tr><td>4000</td></tr>
<tr><td>5000</td></tr>
<tr><td>6000</td></tr>
<tr><td>7000</td><td rowspan="6"></td></tr>
<tr><td>8000</td></tr>
<tr><td>9000</td><td rowspan="11">FRASER GLACIATION</td><td rowspan="2">Cool and Moist
SUMAS STADE</td></tr>
<tr><td>10000</td></tr>
<tr><td>11000</td><td rowspan="2">EVERSON INTERSTADE
Cool and Dry</td></tr>
<tr><td>12000</td></tr>
<tr><td>13000</td><td rowspan="7">VASHON STADE</td><td>Vashon Ice retreats rapidly north of islands, stops at US/CAN border. (Waitt et al. 1983) In the San Juan Islands, higher areas were above water and ice free. (Deither et al. 1995)</td></tr>
<tr><td>14000</td><td></td></tr>
<tr><td>15000</td><td>Puget Lobe advances to the Seattle area, then begins to retreat. (Waitt et al. 1983)</td></tr>
<tr><td>16000</td><td></td></tr>
<tr><td>17000</td><td>Alpine Glaciers greatly diminished. (Waitt et al. 1983)</td></tr>
<tr><td>18000</td><td>Juan de Fuca Lobe advances to the western strait of Juan de Fuca.
(Waitt et al. 1983)</td></tr>
<tr><td>19000</td><td></td></tr>
<tr><td>20000</td><td colspan="2" rowspan="4">OLYMPIC INTERGLACIAL
(Easterbrook 1969)</td><td>Alpine Glaciers at maximum positions. (Waitt et al. 1983)</td></tr>
<tr><td>21000</td><td></td></tr>
<tr><td>22000</td><td></td></tr>
<tr><td>23000</td><td></td></tr>
</table>

Figure 4. Marine Limit at about 13,500 yr. B.P., submerged area is shaded.

Based on Deither et al. (1995)

Figure 5. Soils in the San Juan Islands.



Based on Scholts et al. (1957)

Table 4. Soil types found in the San Juan Islands (after Schots et al. 1962)

1. Bellingham - Coveland - Association
   - a. Bellingham Soils — fairly large areas
   - b. Coveland Soils — less extensive in the area
   - c. Bow Soils — most extensive in the area
   - d. Norma Soils — few small areas
   - e. Semiahmoo Soils — few large areas, and a number of smaller areas
   - f. Tanwax Soil — " " " " " " " " "
   - g. Orcas Soils — " " " " " " " " "
   - h. Roche-Rock Outcrop Complex — small but prominent areas

2. Roche - San Juan Association
   - a. Roche Soils — fairly extensive areas
   - b. San Juan Soils — " " "
   - c. Rock land — large areas
   - d. Alderwood Soils — fairly large areas
   - e. Everett Soils — small isolated areas
   - f. Indianola Soils — " " "
   - g. Pickett Soils — " " "
   - h. Coveland Soils — " " "
   - i. Semiahmoo Soils — " " "

3. San Juan - Everett Association
   - a. San Juan Soils — small areas
   - b. Everett Soils — small areas
   - c. Indianola Soils — small areas
   - d. Roche Soils — " "
   - e. Alderwood Soils — " "

4. Pickett - Rock land Association
   - a. Pickett Soils — are dominant
   - b. Rock land — " "
   - c. Semiahmoo Soils — small isolated areas
   - d. Orcas Soils — " " "
   - e. Tanwax Soils — " " "

Table 5. Soil units in the San Juan Islands

SOIL UNIT	SURFACE TEXTURE	SUBSOIL	NATIVE VEGETATION
Alderwood	gravely or stony, medium texture	cemented till	doug fir, lodgepole pine, willow, alder, big leaf maple, willow
Bellingham	clay or silt loam	clay or silt loam	red cedar, hemlock, alder, big leaf maple
Bow	silt loam	clayey	doug fir, hemlock, alder, big leaf maple, salal, oregon grape, ocean spray
Coveland	silt loam	clayey, clay loam, sandy clay loam	probably was grass and sedges
Everett	gravely or stoney moderatly coarse texture	loose, gravelly, sandy, porous	doug fir, lodgepole pine, madrona, salal, oregon grape, sword fern, moss
Indianola	moderatly coarse stoney, little gravel	loose, gravelly, sandy, porous	doug fir, lodgepole pine, red cedar, alder, big leaf maple, salal, oregon grape, ocean spray, sword fern
Norma	loam	sandy loam, clay loam or clay	doug fir, sitka spruce, white fir, lodgepole pine, willow, ocean spray, bracken fern, sedges
Orcas	moss peat, bog	pale-brown, spongy fibrous peat	sphagnum, hypnum moss, spirea, lodgepole pine
Pickett	medium textured and stoney	sandstone bedrock	doug fir, red cedar, lodgepole pine, a few madrona
Roche	brown, medium textured may be gravely or stoney	dense, slowly permable glacial till	doug fir, lodgepole pine, willow, alder, salal, oregon grape
Roche-Rock	stones, 12 - 24 inches, on surface	?	grass
Rock Land	rock outcrops of basalt, sandstone & argillite	bedrock	little cover, soils are too shallow
San Juan	dark-colored, moderatly coarse textured, gravelly, or stony	coarse textrued & cemented moderatly fine textured glacial till	grasslands
Semiahmoo	muck, derived from sedge peat	sedimentary peat	sedges
Tanwax	finely divided sedimentary peat	finely divided organic material including alage, excreta from marine animals	reed canary grass

based on Schlots et al. (1962)

plains on glaciated uplands". The topography of this association is nearly level to gently sloping, and it occurs on most of the larger islands. The Roche-San Juan association is composed of "dominantly moderately well drained to well drained soils of the glacial till plains and rocky uplands". This is the largest association in the area and it is characterized by a predominantly gently rolling to rolling topography that covers most of San Juan Island. The San Juan-Everett association is characterized by "somewhat excessively drained soils on glaciated uplands and outwash plains". Very small examples of this association are found throughout the islands, mainly in rolling to steep areas on Waldron and San Juan Islands. Finally, the Pickett-Rockland association is composed of "dominantly well drained soils on uplands". It occurs on fairly steep, irregular, rolling to steep or precipitous topography, and is mostly found on Orcas and Blakely Islands.

Vegetation

The vascular plant vegetation influences the distribution of mosses by providing substrata and microhabitats. This is especially evident in the epiphytic mosses, which are often restricted to certain tree species. Therefore, an overview of the vascular plant flora is given below.

Franklin and Dyrness (1973) place the San Juan Islands in the Puget Sound Area of the *Tsuga heterophylla* Zone. The Puget Sound Area is unusual because it is composed of plant communities that differ from most of the *Tsuga heterophylla* Zone, and they often do not occur anywhere else in western Washington. Several of these plant communities are found within the San Juan Islands, and include populations of *Juniperus scopulorum* (Rocky Mountain juniper) on open rocky slopes near salt water, stands of *Populus tremuloides* (quaking aspen) in riparian areas on glacial till soils, and clusters of *Betula papyrifera* (paper birch) in stream valleys and riparian areas on San Juan and Orcas Islands.

Using Krajina's (1959) classification system the San Juan Islands are in the Coastal Douglas Fir Zone. This temperate Mediterranean coniferous forest is a response to the rain shadow effect generated by the Olympic Mountains. Although this zone is dominated by *Pseudotsuga menziesii*, the following species are also present: *Abies grandis* (grand fir), *Arbutus menziesii* (madrona), *Pinus contorta* (lodgepole pine), *Thuja plicata* (western red cedar), *Tsuga heterophylla* (western hemlock), *Gaultheria shallon* (salal), *Holodiscus discolor* (ocean spray), *Berberis nervosa* (Oregon-grape), and *Polystichum munitum* (sword fern).

Krajina (1965) divides this zone into two subzones: The drier Garry Oak- Douglas Fir subzone, composed of the following species; *Quercus garryana* (Garry oak), *Camassia quamash* (camas), *Collinsia grandiflora* (large-flowered collinsia), *Plectritis congesta* (sea blush), and *Zygadenus venenosus* (poison-camas); The wetter Madrono-Douglas Fir subzone, composed of the following species; *Arbutus menziesii* (madrona), *Pinus contorta* (lodgepole pine), *P. monticola* (western white pine), *Thuja plicata* (western red cedar), *Gaultheria shallon* (salal), *Holodiscus discolor* (ocean spray), *Berberis nervosa* (Oregon-grape), and *Polystichum munitum* (sword fern).

Atkinson and Sharpe (1985) make several interesting comments concerning the vascular flora of the San Juan Islands: (1) "the absence or scarcity of many species typical of wet coniferous forest zone is a striking element of the San Juan Island's". These missing or scarce species include; *Acer circinatum* (vine maple), *Rhododendron macrophyllum* (Pacific rhododendron), *Achylys triphylla* (vanilla-leaf), *Rhamnus purshiana* (cascara), and *Vaccinium ovatum* (evergreen huckleberry). (2) The flora is "host to a number of taxa usually associated with dry habitats east of the Cascades". Some of the 21 eastern taxa are *Juniperus scopulorum* (Rocky Mountain juniper), *Woodsia scopulina* (Rocky Mountain woodsia), *Opuntia fragilis* (prickly pear cactus), *Poa scabrella* (pine blue grass), and *Camissonia contorta* (contorted-pod evening-primrose). They relate the first two observations to the dry conditions brought about by the rain shadow effect of the Olympic mountains.

Finally (3). "the presence of a relic late glacial flora on the summit of Mt. Constitution, where several subalpine and northern species linger". Among these species are *Athyrium distentifolium* (alpine lady-fern), *Aster sibiricus* (arctic aster), *Epilobium alpinum* (alpine willow-herb), *Erigeron trifidus* (dwarf mountain daisy), and *Saxifraga bronchialis* (matted saxifrage).

While the San Juan Islands are classified as being in the Coastal Douglas Fir Zone, and have a good representation of plants from both of the subzones, the Mt. Constitution area still retains some of the unusual and distinct subalpine - alpine elements, possibly surviving from the time when the site may have been first colonized. Many of the moss species found during the present study exhibit these similar distribution patterns. The discussion under phytogeography provides further details.

Late Pleistocene and Holocene Vegetation and Climate

The importance of the relationship between temperature and moisture to the distribution of vegetation has been clearly demonstrated by Krajina, (1959, 1965) and Franklin and Dyrness, (1973). The fossil arboreal and non-arboreal pollen found in peat deposits can be used to reconstruct and infer past changes in climatic and vegetation patterns (Pielou 1991).

During the Late Pleistocene, from approximately 14,000 yr. B.P. to 10,000 yr B.P., coastal Washington and Southern British Columbia were covered predominately with *Pinus contorta* and *Alnus* sp., and the climate was cool and moist (C. Heusser 1960, L. Heusser 1983, Hebda 1983, Barnosky 1984, 1985, Mathewes 1985). It was during this cool moist period around 13,500 yr. B.P. that the higher areas in the San Juan Islands were ice free and also exposed above the cool marine waters (Deither et al. 1995). Thus plants could have re-colonized the Islands as early as 13,500 yr. B.P.

Beginning around 10,000 yr. B.P. a warm, dry period began in the Puget Trough, (Hibbert 1979, Barnosky, 1981, 1984, Mathewes & Heusser 1981, L. Heusser, 1983, Mathewes 1985). This hypsithermal period lasted until around 3000 yr. B.P., and was characterized by the appearance of *Quercus*, and *Pseudotsuga* pollen and *Pteridium* spores in the palynological record. At the same time there was a decrease in the amount of pollen from *Pinus* and other temperate species. This hypsithermal event is well documented in the marine core samples from the Saanich Inlet on Vancouver Island. L. Heusser (1983) found that large quantities of *Quercus* pollen had been deposited during this period and comments that Krajina's (1965) Garry Oak-Douglas Fir Subzone was well established in the Sannich Inlet by about 7000 yr. B.P.. Following this warm period, about 3000 yr. B.P., an increase in *Tsuga heterophylla* and *Thuja* type pollen indicates that a moist cooling trend had begun in the Puget Trough, (Hibbert 1979, Barnosky 1981, 1985, Hebda 1983, L. Heusser 1983).This cool moist climate has persisted throughout the region today (see Table 6).

Little palynological research has been done within the San Juan Islands. Hanson (1943) examined the pollen deposits in two Orcas Island bogs, one near the summit of Mt. Constitution and the other a lowland bog at Killebrew Lake. He states that in both bogs, "lodgepole pine was the predominant species when the lowest pollen-bearing sediments were deposited". The large numbers of *Pinus contorta* (lodgepole pine) now found in the Orcas Island bogs are not unusual because *Pinus contorta* was an early dominant pioneer species within the Puget Trough. Although Hanson (1943), did not date his pollen cores, he did note a layer of ash in all of the bogs that he studied. In the Mt. Constitution bog, the ash layer was found between 7.0 and 7.5 meters, and in the Killebrew Lake bog the layer occurred around 7.0 meters. Hanson (1943) attributes this ash layer to an eruption of Glacier Peak, but more recent work by Powers (1964) and Sarna-Wojcicki et al. (1983) found this ash layer to have originated from Mt. Mazama. This provides the ash layers in the bogs a date of about 6700 yr. B.P. At about 6700 yr. B.P. the pollen deposits from the Mt. Constitution bog indicate that the surrounding vegetation was composed mostly of *Pinus contorta* and *Pinus monticola*, with moderate amounts of *Abies grandis* and *Picea sitchensis.* Both *Pseudotsuga menziesii* and *Tsuga heterophylla* were poorly represented at this time. In the Killebrew Lake bog the dominant tree species were, *Pseudotsuga menziesii* and *Tsuga heterophylla*, with minor amounts of *Pinus contorta, Abies grandis* and a trace amount of *Picea sitchensis* pollen.

During his study Hanson (1943) omitted the deciduous trees, herbs, and grasses because they were poorly represented in the pollen deposits. It is difficult to determine accurately when *Quercus* entered the islands. Using L. Heusser's (1983) reports based on nearby Sannich Inlet, if the Garry Oak-Douglas Fir Subzone was well established by 7000 yr. B.P., it is reasonable to assume that it would also be well established in the San Juan Islands at approximately the same time. Hanson's (1943) Killebrew Lake bog pollen records show a marked increase in *Pseudotsuga menzesii* pollen levels coinciding with a decrease in the *Pinus contorta* and *Pinus monticola* pollen around the time of the Mt. Mazama ash layer (6700 yr. B.P.). Correspondingly, the appearance of *Pseudotsuga menziesii* pollen in the Mt. Constitution bog does not occur until

Table 6. Pollen records in the Puget Trough

yr. B.P	Geological-Climatic Unit	Bear Cove. Vanc. Isl.	Sannich Inlet, Vanc.Isl.	San Juan Isls., WA Mt. Const.	San Juan Isls., WA Kille. Lake	Nisqually Lake, WA	Davis Lake, WA	Battle Gr. Lake, WA
0.0			Thua type moister & cooler	Pinus contorta Pseudotsuga menzesis Tsuga heterophylla	Pseudotsuga Tsuga heterophylla			
1000		Tsuga heterophylla-Cupressaceae (Thuja) cool & moist				Pseudotsuga -Tsuga- Thuja Forest cool & moist	Pseudotsuga -Tsuga- Thuja forest Temperate & wet	Pseudotsuga -Tusga- Thuja Forest Cooler & Moist
2000								
3000	HYPSI-THERMAL		Garry Oak-Doug Fir Subzone well established warmer & drier					
4000		Tsuga heterophylla-Picea Moderate warm & dry				Pseudotsuga - Alnus- Thuja Forest		
5000								
6000	MT. MAZAMA ASH LAYER			Pinus contorta P. monticola	Pseudotsuga menziesi Tsuga hetrophylla		Pseudotsuga -Alnus Woodland Maximum warmth & dryness	Oak Savannah & Pseudotsuga -Alnus Woodland Warm & Dry
7000		Picea-Pseudotsgua-Alnus-Pteridium warmer & drier	Alnus-Pteridium warmer & wetter					
8000						Oak Savannah Pseudotsuga - Pine Woodland		
9000		Picea-Tsuga mertensiana-Alnus cool & moist						
10000	SUMAS STADE		Pinus cool & moist			Pinus Parkland	Cool & Wet mixed Pinus - Abies Woodland	Picea-Pinus-Tsuga Woodland
11000	EVERSON INTER-STADE	Pinus-Alnus cool & dry	cool & moist					
12000							Picea-Tsuga Woodland Picea-Tsuga Woodland	
13000	VASHON STADE			High Points Ice Free & Above Water			Pinus Woodland Cool & Dry	
14000			Glacial Ice				Picea-Pinus Parkland Tundra	
15000	UNNAMED INTER-STADE						Picea Parkland Tundra	Picea-Pinus Parkland
16000								
	Easterbrook (1969) Waitt et al (1983)	Hebda (1983)	Heusser (1983)	Hanson (1943)	Hanson (1943)	Hibbert (1979)	Barnosky (1985)	Barnosky (1985)

just above the ash layer; while the *Pinus contorta* level remains fairly high, it does show a small decrease. The *Pinus contorta* levels have probably remained high throughout the Mt. Constitution bog profile as a result of the unusual edaphic condition in the area (Hanson 1943), and therefore may not have responded to the overall changes in climate. Since pine tends to be a prolific pollen producer, and would have been near the area of deposition, it is likely to be over-represented in the profile and reflect local conditions rather than the general vegetation of the island.

The cooling, moist trend that began around 3000 yr. B.P. is well documented in the pollen records by the increase of *Thuja* type and *Tsuga heterophylla* pollen, (L. Heusser 1983, Hebda 1983). Although *Thuja* type pollen was not recorded by Hanson (1943) in the Orcas Island bogs, he does show the distribution of *Tsuga heterophylla*. In the Killebrew Lake pollen profile, *Tsuga heterophylla* pollen appears throughout the entire depth of the bog. It reaches it's highest concentrations just below the Mazama ash layer (6700 yr. B.P.) and remains relatively high throughout the rest of the profile. The Mt. Constitution bog shows a different pattern, here the *Tsuga heterophylla* pollen starts to appear in small amounts above the ash layer and reaches its highest concentrations at the two meter depth. In both bogs *Tsuga heterophylla* does not become the dominant species. It would appear that the dry Mediterranean type climate has prevented both *Tsuga heterophylla* and *Thuja plicata* from becoming well established within the islands. The vegetation patterns in the islands today reflect the dry Mediterranean type climate that occurs within the rain shadow of the Olympic Mountains.

So little palynological work has been done in the islands that caution must be used in trying to interpret the patterns of vegetation succession. Additional palynological research would result in a better understanding of the earlier patterns of vegetation and might show when and where *Quercus* first arrived in the islands. Since there are pollen profiles for most of the Puget Trough, it would be interesting to see just how the San Juan Islands fit into the overall picture.

CHAPTER 4

Methods and Materials

The flora discussed here is based on collections of mosses made over a period of four years, from 1990 to 1993. A small number of mosses were collected during a brief visit to the islands in 1988. The Islands were visited during every month of the year except December and January. Historical collections made by earlier botanists were examined from the following herbaria: University of British Columbia, (UBC), University of Washington, (WTU), Washington State University at Pullman, (WS), Western Washington University, (WWB), Portland State University, (HPSU) and the herbarium at the Friday Harbor Laboratories, (FHL). These appear to represent most of the historically significant collections.

Permission to collect specimens on private property was obtained from numerous owners as well as the following agencies: the U.S. Fish and Wildlife Service, Refuge Islands; the U.S. National Park Service, San Juan Island National Historical Park; The Nature Conservancy; The San Juan Preservation Trust; Washington State Parks, the University of Washington, and Seattle Pacific University.

Transportation to and from some of the islands was provided by the U.S. Fish and Wildlife Service, The Nature Conservancy, the U.S. Mail Boat, and Washington State Parks Department. The larger islands were accessed from the Washington State Ferry system. A total of 28 islands were visited, resulting in 6021 collections made from 159 sites. See Table 7. and Figure 6. provide details of the collecting locations.

Prior to visiting an island a careful literature search was done to determine the locations of any unusual features, i.e. caves, limestone outcrops, etc. Species that are often associated with these types of sites, as well as the common ones, were collected. Historical locations were also visited whenever the label information was sufficient to locate the old collecting site.

Table 7. Collecting locations.

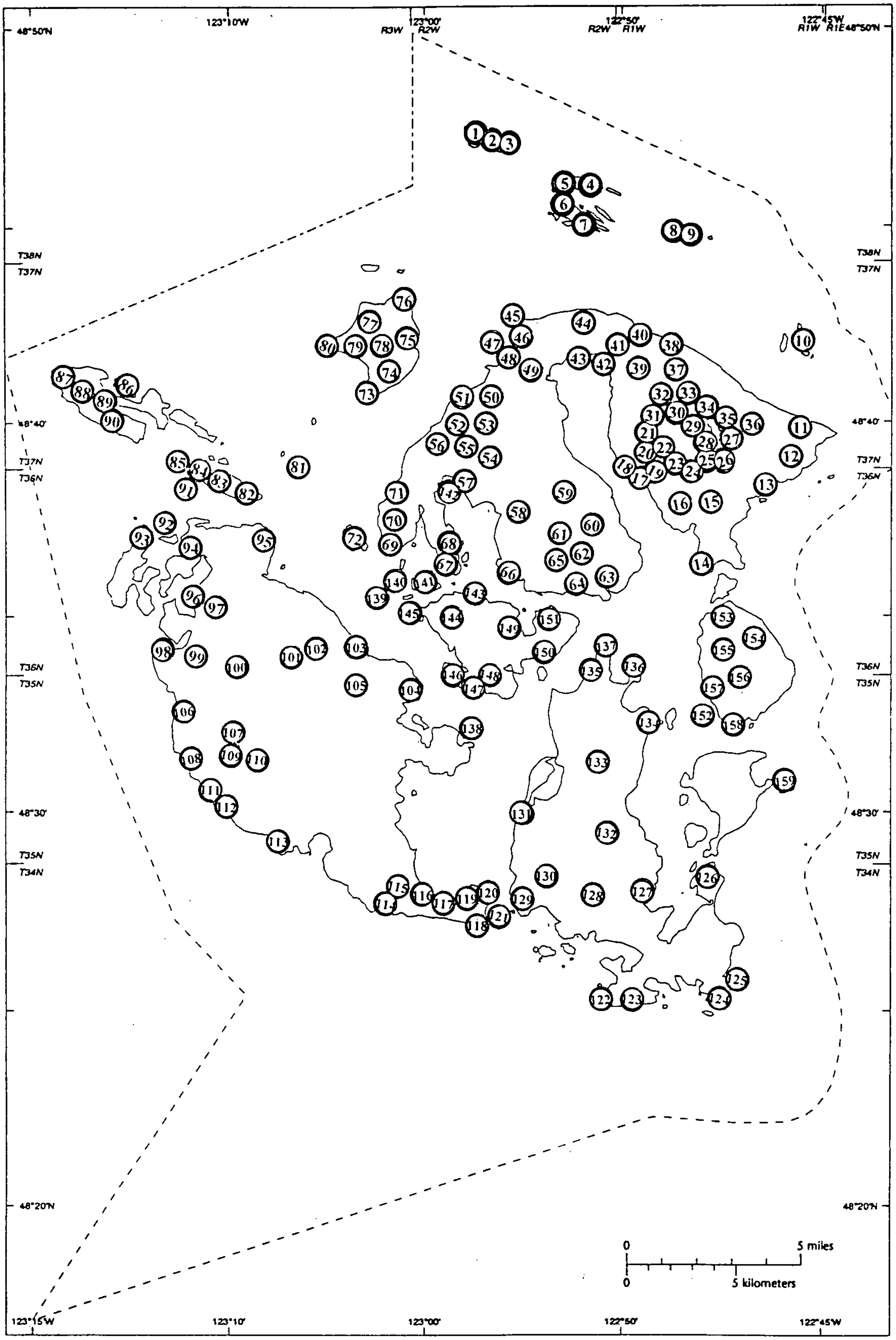
No.	Island	Location	T. R. S.	Lat. & Long.
1	Patos	West end of island	T38N R2W Sec. 17	48 47'N 122 57'W
2	Patos	Middle of Island	T38N R2W Sec. 16	same as above
3	Patos	East end of island	T38N R2W Sec. 15	same as above
4	Sucia	N.side of Echo Bay & Ewing Cove area	T38N R2W Sec. 23,24	48 45'N 122 52'W
5	Sucia	Shallow Bay & end of Echo Bay	T38N R2W Sec. 23	same as above
6	Sucia	Service roads & mixed woodland area	T38N R2W Sec. 23	same as above
7	Sucia	Mud Bay, Fossil Bay, Johnstone Pt., & EV. Henry Pt.	T38N R2W Sec. 25 & 26	same as above
8	Matia	West end of Island	T38N R1W Sec. 29	48 45'N 122 50'W
9	Matia	Middle & East end of Island	T38N R1W Sec. 28	same as above
10	Clark	entire island	T37N R1W Sec. 13	48 42'N 122 45'W
11	Orcas	Eagle Lake area	T37N R1W Sec. 25,26	48 36'N 122 46'W
12	Orcas	Along Doe Bay Road	T37N R1W Sec. 35	48 38'N 122 47'W
13	Orcas	Doe Bay Resort	T36N R1W Sec. 2	48 38'N 122 47'W
14	Orcas	Obstruction Pass area and C.G.	T36N R1W Sec. 16	48 37'N 122 50'W
15	Orcas	Olga Doe Bay Cemetary	T36N R1WSec. 9	48 38' N 122 50'W
16	Orcas	Entrance Mountain area	T36N R1W Sec. 8	48 37'N 122 50'W
17	Orcas	East Sound Beach & Palisades area	T36N R1W Sec. 6	48 38'N 122 51'W
18	Orcas	Rosario Resort & trail to Cascade Lake	T37N R1WSec. 31	48 38'N 122 52'W
19	Orcas	E. end of Cascade Lake, & Sunrise Rock area	T37N R1W Sec. 32	48 38'N 122 51'W
20	Orcas	Cascade Lake loop trail, west of the foot bridge	T37N R1W Sec. 31	same as above
21	Orcas	Trail to Cascade Lake from Cold Springs	T37N R1W Sec. 29 & 32	48 40'N 122 50'W
22	Orcas	Along the road next to Cascade Lake	T37N R1W Sec. 31	48 39'N 122 50'W
23	Orcas	Envin. Learning Center, & trails to Cascade Falls	T37N R1W Sec. 32 & 33	same as above
24	Orcas	Doe Bay Rd. by the water tanks	T36N R1W Sec. 4	48 38'N 122 50'W
25	Orcas	Trail to Cascade Falls from Mountain Lake	T37N R1W Sec. 33	48 39'N 122 50'W
26	Orcas	Mt. Lake Loop Trail, below the dam, & dirt road junction	T37N R1W Sec. 33 & 34	48 40'N 122 49'W
27	Orcas	Mt. Lake Loop Trail	T37N R1W Sec. 34	48 40'N 122 48'W
28	Orcas	Mt. Lake Campground area	T37N R1W Sec. 33	same as above
29	Orcas	Road up to Mt. Constitution	T37N R1W Sec. 33	48 39'N 122 50'W
30	Orcas	Trail from Mt. Constitution to Cold Springs	T37N R1W Sec. 21, 28, 29	48 40'N 122 50'W
31	Orcas	Trail from Cold Springs to Mt. Lake	T37N R1W Sec. 29	48 40'N 122 50'W
32	Orcas	Trail from Cold Springs to Mt. Lake	T37N R1W Sec. 20	same as above
33	Orcas	Mt. Constitution and Summit Lake area	T37N R1W Sec. 21	48 40'N 122 50'W
34	Orcas	Bonnie Sliger Memorial Trail	T37N R1W Sec. 21,	48 37'N 122 50'W
35	Orcas	Mt. Lake Loop Trail	T37N R1W Sec. 27	48 40'N 122 48'W

No.	Island	Location	T.R.S.	Lat. & Long.
36	Orcas	Mt. Picket area, & South Ridge Trail	T37N R1W Sec. 27, 34	48 40'N 122 47'W
37	Orcas	Buck Mountain area	T37N R1W Sec. 17	48 41'N 122 51'W
38	Orcas	Buckhorn Road to Racoon Point	T37N R1W Sec. 17	48 42'N 122 51'W
39	Orcas	Day Lake area	T37N R1W Sec. 17	48 41'N 122 50'W
40	Orcas	Buckhorn Area	T37N R1W Sec. 7	48 42'N 122 52'W
41	Orcas ck	Road into the Day Lake & Buck Mt. area	T37N R1W Sec. 18	48 44'N 122 52'W
42	Orcas	East Sound, below Oyster Ship Resturant	T37N R2W Sec. 25	48 42'N 122 53'W
43	Orcas	Madrona Point Park	T37N R2W Sec. 14	48 41'N 122 54'W
44	Orcas	East Sound	T37N R2W Sec. 11	48 43'N 122 55'W
45	Orcas	Point Doughty	T37N R2W Sec. 9	48 43'N 122 57'W
46	Orcas	Beach between Pt. Doughty and Camp Orkila	T37N R2W Sec. 9	48 43'N 122 57'W
47	Freeman	entire island	T37N R2W Sec. 16	48 42'N 122 57'W
48	Orcas	Camp Orkila	T37N R2W Sec. 15,16	48 41'N 122 57'W
49	Orcas	Enchanted Forest Road	T37N R2W Sec. 15	48 42'N 122 56'W
50	Orcas	Woodlawn Cemetary	T37N R2W Sec. 21	48 40'N 122 57'W
51	Orcas	Old Red Q Rock Quarry	T37N R2W Sec. 20	48 41'N 122 57W
52	Orcas	Turtleback Road	T37N R2W Sec. 29	48 40'N 122 57'W
53	Orcas	Turtleback Road	T27N R2W Sec. 28	same as above
54	Orcas	West Crow Valley Rd. near jct. of Nordstrum Lane	T37N R2W Sec. 33	48 39'N 122 57'W
55	Orcas	Turtleback Road	T37N R2W Sec. 32	48 40'N 122 57'W
56	Orcas	Orcas Knob	T37N R2W Sec. 29, 30, 31, 32	48 40'N 122 58'W
57	Orcas	Along Deer Harbor Rd. across from Massacre Bay	T36N R2W Sec. 5	48 37'N 122 58'W
58	Orcas	Mt. Woolard Area, along main road	T36N R2W Sec. 10	48 37'N 122 55'W
59	Orcas	Mt. Woolard Area	T36N R2W Sec. 11	same as above
60	Orcas	Martin Lake	T36N R2W Sec. 12	48 37'N 122 52'W
61	Orcas	Mt. Woolard Area, Ladd Lake	T36N R2W Sec. 14	48 37'N 122 55'W
62	Orcas	Killebrew Lake	T36N R2W Sec. 13,14	48 36'N 122 54'W
63	Orcas	Guthrie Cove Road	T36N R2W Sec. 13	48 36'N 122 50'W
64	Orcas	Road to Grindstone Bay	T36N R2W Sec. 23	48 36'N 122 55'W
65	Orcas	Montfort Prop. & Roads from Mt. Woolard area to Grindstone Bay	T36N R2W Sec. 14	same as above
66	Orcas	Area around the Ferry Terminal	T36N R2W Sec. 21	48 36'N 122 57'W
67	Orcas	Pole Pass Road Area	T36N R2W Sec. 17,22	48 36'N 122 59'W
68	Orcas	Camp Four Winds	T36N R2W Sec. 17	48 37'N 122 59'W
69	Orcas	Spring Pass Develp. Loop Road	T36N R2W Sec. 13	48 36'N 123 01'W
70	Orcas	Spring Pass Road	T36N R2W Sec. 12	same as above
71	Orcas	Public Beach No. 240	T36N R3W Sec. 1	48 38'N 123 00'W
72	Jones	Entire Island	T36N R3W Sec. 11,14	48 37'N 123 02'W
73	Waldron	Point Disney	T37N R3W Sec. 23	48 41'N 123 02'W
74	Waldron	Between Pt. Disney & Mail Bay	T37N R3W Sec. 13,24	same as above
75	Waldron	Mail Bay	T37N R3W Sec. 13	same as above
76	Waldron	Point Hammond Area	T37N R3W Sec. 1, 12 T37N R2W Sec. 6, 7	48 43'N 123 01'W
77	Waldron	Along the road by the School	T37N R3W Sec. 12	48 43'N 123 02'W
78	Waldron	Road to the Cemetary	T37N R3W Sec. 13	48 42'N 123 02'W

No.	Island	Location	T.R.S.	Lat. & Long.
79	Waldron	Cowlitz Bay Marsh	T37N R3W Sec. 14, 23	48 41'N 123 02'W
80	Waldron	Road to and Sandy Point Area	T37N R3W Sec. 14,15	48 42'N 123 03'W
81	Flattop	Entire Island	T36N R3W Sec. 4	48 38'N 123 05'W
82	Spieden	Green Point and Dock Area	T36N R3W Sec. 7	48 38'N 123 07'W
83	Spieden	Center of Island around houses and north side of the Island	T36N R3W Sec. 6 T36N R4W Sec. 1, 12	same as above
84	Spieden	Area around the airstrip	T36N R4W Sec. 1	same as above
85	Spieden	West End of the Island	T36N R4W Sec. 2	same as above
86	Satellite	Entire Island	T37N R4W Sec 21,22, 27, 28	48 41'N 123 11'W
87	Stuart	Co. Rd. to and Turn Point Area	T37N R4W Sec. 20	48 41'N 123 12'W
88	Stuart	Co. Rd., by Schools & Cemetery	T37N R4W Sec. 28,29	same as above
89	Stuart	Above the Reid Harbor Dock	T37N R4W Sec. 28	same as above
90	Stuart	Stuart Island State Park	T37N R4W Sec. 28	same as above
91	Sentinel	Entire Island	T36N R4W Sec. 2	48 38'N 123 10'W
92	Posey	Entire Island	T36N R4W Sec. 14	48 37'N 123 10'W
93	Henry	North East End of Island	T36N R4W Sec. 15	48 36'N 123 11'W
94	San Juan	Roche harbor, Resort and Old Rock Quarries	T36N R4W Sec. 23	48 37'N 123 07'W
95	San Juan	Ruben Tarte Co. Park	T36N R3W Sec. 17	48 36'N 123 06'W
96	San Juan	SJINHP, British Camp & Bell Pt.	T36N R4W Sec. 26	48 35'N 123 07'W
97	San Juan	SJINHP, Mt. Young, & Cemetry	T36N R4W Sec. 25	same as above
98	San Juan	Old Mitchell Bay Rock Quarry	T36N R4W Sec. 34	48 35'N 123 10'W
99	San Juan	Mitchell Bay Rd, near jct. with West Side Road	T36N R4W Sec. 35	48 34'N 123 10'W
100	San Juan	Cady Mountain	T35N R3W Sec. 6	48 33'N 123 07'W
101	San Juan	Egg Lake Rd. across from Egg Lake	T36N R3W Sec. 32	48 35'N 123 05'W
102	San Juan	Sportsman Lake	T36N R3W Sec. 33	48 35'N 123 02'W
103	San Juan	Euereka Area, Old Kiln Site	T36N R3W Sec. 34	48 35'N 123 02'W
104	San Juan	U.W. Friday Harbor Labs, & Pt. Caution	T35N R3W Sec. 1, 12	48 32'N 123 00'W
105	San Juan	Beaverton Valley Bog and Area	T35N R3W Sec. 10	48 32'N 123 02'W
106	San Juan	Smallpox Bay	T35N R4W Sec. 11	48 32'N 123 10'W
107	San Juan	Trout Lake	T35N R3W Sec. 18	48 32N 123 07"W
108	San Juan	Lime Kiln State Park	T35N R4W Sec. 23	48 30'N 123 10'W
109	San Juan	Mt. Dallas and Area	T35N R4W Sec. 24	48 31'N 123 07'W
110	San Juan	Mt. Ben, Top and Side	T35N R4W Sec. 24	48 31'N 123 07'W
111	San Juan	Deadman Bay	T35N R4W Sec. 24	48 30'N 123 07'W
112	San Juan	Along the West Side Road	T35N R4W Sec. 24,25	same as above
113	San Juan	McGinitie Property	T35N R3W Sec. 32	48 30'N 123 05'W
114	San Juan	SJINHP, American Camp, Grandma's Cove	T34N R3W Sec. 11	48 27'N 123 00'W
115	San Juan	SJINHP, American Camp, around the Visitor Center	T34N R3W Sec. 1	48 27'N 123 02'W
116	San Juan	SJINHP, American Camp,trail to and around Jakles Lagoon	T34N R2W Sec. 7	48 27'N 123 00'W
117	San Juan	SJINHP, American Camp, Mt. Finlayson & Third Lagoon	T34N R2W Sec. 7	same as above
118	San Juan	Cattle Point Picnic Area	T34N R2W Sec. 8	48 27'N 122 57'W
119	San Juan	Mt. Finlayson Swamp	T34N R2W Sec. 8	48 27'N 122 57'W
120	San Juan	Cape San Juan Area, "Goose Control"	T34N R2W Sec. 5	48 28'N 122 57'W
121	Goose	Entire Island	T34N R2W Sec. 8	48 27'N 122 57'W

No.	Island	Location	T.R.S.	Lat. & Long.
122	Lopez	Iceberg Point	T34N R2W Sec. 23,24	48 26'N 122 53'W
123	Lopez	Agate Beach Co. Park	T34N R2W Sec. 24	48 26'N 122 52'W
124	Lopez	Point Colville	T34N R1W Sec. 21	48 25'N 122 48'W
125	Lopez	Watmough Head	T34N R1W Sec. 21	48 25'N 122 48'W
126	Lopez	Sperry Penn. Camp Nor'Wester	T34N R1W Sec. 5	48 28'N 122 50'W
127	Lopez	Hunter Bay, Bill's Property	T34N R1W Sec. 6	48 28'N 122 51'W
128	Lopez	Jct. of Center Rd. & Mudbay Rd.	T34N R2W Sec. 2	48 27'N 122 55'W
129	Lopez	Shark Reef Sanctuary	T34N R2W Sec. 9	48 27'N 122 56'W
130	Lopez	Center Church Cemetary	T34N R2W Sec. 3	48 28'N 122 54'W
131	Lopez	Rock Point	T35N R2W Sec. 28	48 30'N 122 57'W
132	Lopez	Lopez Hill	T35N R2W Sec. 36	48 29'N 122 53'W
133	Lopez	Hummel Lake	T35N R2W Sec. 23	48 31'N 122 53'W
134	Lopez	Spensor Spit State Park	T35N R1W Sec. 7	48 32'N 122 52'W
135	Lopez	Odlin Co. Park	T35N R2W Sec. 2	48 33'N 122 53'W
136	Lopez	Humphery Head	T35N R2W Sec. 1	48 33'N 122 52'W
137	Lopez	Upright Head. Ferry Terminal	T36N R2W Sec. 36	48 34'N 122 55'W
138	Turn	Entire Island	T35N R2W Sec. 17	48 32'N 122 57'W
139	Yellow	Entire Island	T36N R3W Sec. 23	48 35'N 123 02'W
140	McConnel	Entire Island	T36N R3W Sec. 24	48 36'N 123 01'W
141	Crane	Entire Island	T36N R2W Sec. 19	48 36'N 123 00'W
142	Skull	Entire Island	T36N R2W Sec. 5	48 38'N 122 59'W
143	Shaw	Broken Point, & Yanson Farm	T36N R2W Sec. 20,21	48 33'N 122 57'W
144	Shaw	Ben Nevis Mt. & Loop Road	T36N R2W Sec. 29	48 35'N 122 57'W
145	Shaw	Neck Point	T36N R2W Sec. 30 T36N R3W Sec. 25	48 35'N 123 00'W
146	Shaw	Hicks Bay & Point George	T35N R2W Sec. 5	48 33'N 122 57'W
147	Shaw	U.of W. Caretakers Home site	T35N R2W Sec. 4	same as above
148	Shaw	U. of W. Preserve, along Hoffman Rd.	T36N R2W Sec. 33	same as above
149	Shaw	Along Smugglers Cove Road	T36N R2W Sec. 27	48 35'N 122 56'W
150	Shaw	San Juan Co. Park	T36N R2W Sec. 34	48 33'N 122 55'W
151	Shaw	Along the Road to Pt. Hudson	T36N R2W Sec. 26	48 35'N 122 55'W
152	Willow	Entire Island	T35N R1W Sec. 9	48 32'N 122 50'W
153	Blakely	Around the Post Office	T36N R1W Sec. 28	48 37'N 122 48'W
154	Blakely	Blakely Peak & Spencers Cabin Areas	T36N R1W Sec. 27,34	48 34'N 122 48'W
155	Blakely	Horseshoe Lake	T36N R1W Sec. 33	48 34'N 122 48'W
156	Blakely	Spencer Lake	T35N R1W Sec. 3, 4	same as above
157	Blakely	Thatcher Bay Area	T35N R1W Sec. 4	same as above
158	Blakely	Road to and S. End of Island	T35N R1W Sec. 9, 10	same as above
159	James	Entire Island	T35N R1W Sec. 14,23	48 31'N 122 46'W

Figure 6. Map of collecting locations in the San Juan Islands.



Where possible, collections were made from every habitat and sub-habitat on each island. When accessible, collections were made from the high point on each island. An attempt to quantify the area covered by collecting was made using an existing grid system. The United States is divided up into a system of townships each six miles square. Each township is composed of 36 one mile square sections, thus each island has "x" number of sections covering the area. Table 8 gives the total number of sections on each island and the total number of sections that were visited. The other three columns in Table 8 reflect the total number of sub-habitats visited, total number of mosses collected (collections), and the total number of species for each island. In some cases, such as Lopez Island, there are 50 sections, but collections were made from only 17 of them. Several reasons are responsible for not collecting in all of the sections on an island. In some cases the sections covered mostly ocean and only a tiny piece of the section was on land, thus not warranting a visit. On Lopez, there is a large amount of agricultural land, thus once this habitat had been visited it did not merit repeat trips just to collect in a specific section. Finally, in some cases, most of the section was on private land and access was denied.

Ecological data were recorded on pre-stamped paper bags. (see Appendix B). Data recorded included: geographic location, (township, range, section, latitude, longitude), substratum (including vascular plant species if the moss was an epiphyte), available light, and exposure, (when relevant).

Collecting numbers were assigned after the collections were sorted. If, during the identification process, another species was found that was significant enough to be labeled separately, a lower case letter, i.e. a, b, c, was assigned to the original collecting number. Field data were then entered into a Paradox 4.5 database for future analysis. Mosses were placed in herbarium packets and labeled. Voucher specimen are deposited in the following herbaria: University of British Columbia, (UBC), University of Washington, (WTU), U.S. National Park Service, San Juan Islands National Historical Park, (only material collected

Table 8. Number of sections visited on each island.

Island	Total No. of Sections	Total No. of Sections Collected In	Total No. of Sub-habitats	No. of Collections	No. of Species
BLAKELY	10	9	14	245	78
CLARK	1	1	5	53	37
CRANE	1	1	11	97	51
FLATTOP	2	1	4	35	23
FREEMAN	1	1	4	17	15
GOOSE	1	1	2	16	10
HENRY	5	1	5	42	28
JAMES	2	2	6	43	26
JONES	2	2	9	85	47
LITTLE MAC	1	1	3	21	17
LOPEZ	50	17	16	570	99
MATIA	2	2	9	85	47
McCONNELL	1	1	7	40	27
ORCAS	88	52	20	2181	192
PATOS	3	3	7	78	46
POSEY	1	1	4	24	19
SAN JUAN	75	37	20	1073	152
SATELLITE	4	4	6	36	28
SENTINEL	2	2	6	90	51
SHAW	16	14	14	284	84
SKULL	1	1	3	40	25
SPIEDEN	5	4	12	132	62
STUART	9	3	12	315	82
SUCIA	4	4	9	149	55
TURN	2	2	3	29	20
WALDRON	11	9	12	170	65
WILLOW	1	1	3	27	19
YELLOW	2	2	7	40	26

on Park Service property). A small study collection was given to the U.S. Fish and Wildlife Service office in Olympia.

Identification of the mosses collected during this study was carried out utilizing the following floras: Lawton (1971), Flowers (1973), Grout (1928-1941), Crum (1984), Crum and Anderson (1981), Frisvoll (1983, 1988), Vitt (1973), plus considerable reference to critically determined herbarium specimens at UBC, especially with reference to taxonomically troublesome taxa.

CHAPTER 5

Ecology

Both habitat and substrata within it play an important role in the distribution of mosses. Daubenmire (1968) states that habitat is "usually used to denote a rather specific kind of living space or environment, i.e. a constellation of interacting physical and biological factors which provide at least minimal conditions for one organism to live or for a group to appear together." Species diversity is influenced by the complexity of the habitat, stability, succession, productivity and composition (Slack 1977).

Richards (1932) comments, "an obvious approach to the ecological problem is to study exceptional habitats such as caves, hot springs and mountain tops, where the influence of certain factors is shown in an extreme degree. It has thus happened that we are better informed about the ecology of the mosses in such places than those of our ordinary woods" Although the unusual habitats in the San Juan Islands were thoroughly explored during the present study, equal attention was also paid to the "common woods", and every attempt was made to gather information on habitat and substratum for each moss collected. The interpretation of that information follows.

Moss Species As Related To Habitat and Sub-habitat

The moss flora of the San Juan Islands is comprised of 224 species (and varieties) found in a variety of habitats. For the purpose of this study the following six general habitat types were established: Maritime, Meadows and Ridges, Disturbed Sites, Rock Outcrops, Wetlands and Woodlands. Because mosses usually occupy microhabitats, these six general habitat types were further divided into 23 smaller vegetation units that were called sub-habitats. (See Table 9 for descriptions and representative locations, and Table 10 for the sub-habitats collected in, on each island, and Appendix C for a complete list of species associated with each sub-habitat, and see Appendix D for a list of acronyms).

Table 9. Habitats and sub-habitat for the San Juan Islands

General Habitat	Sub-habitat Code	Description	Example Location
MARITIME	MAR	All sites, below 20 feet elevation along the margins of the islands. (excluding seeps),soil banks, rocky shoreline	all shorelines within the islands
	MSE	Beach bank seeps, seasonal or continuous, usually of soil or may be rocky	Matia Island, Toe Point Cove
	MCS	Exposed limestone areas along the beach, may be seasonal or continuous wet areas, usually on rock	Orcas Island, in the East Sound area
MEADOWS AND RIDGES	OGS	Open grassy slopes usually in full sun, treeless areas without rock outcrops	San Juan Island, American Camp
	OMP	Open meadows, pastures, and lawns, usually in full sun, treeless and often disturbed	Orcas Island, lawns in Moran State Park Shaw Island, old pastures
DISTURBED SITES	ORS	Open rocky slopes in full sun, grassy areas with scattered small rock outcrops	Orcas Island, Entrance Mountain area
	CEM	Cemeteries, on old marble, cement, and granite headstones	most of the islands
	DAI	Airstrips, usually mineral soil, active or abandon	most of the islands
	DDE	Developed sites, i.e. housing, commercial buildings, old walkways etc.	all of the islands, Stuart Island, Turn Point
	ORQ	Old rock quarries, both limestone and sandstone	San Juan Island, Roche Harbor Sucia Island, Fossil Bay area
ROCK OUTCROPS	OOC	Open calcareous areas, in full sun and dry	San Juan Island, Lime Kiln Point
	OON	Open noncalcareous, in full sun, may be basalt or sandstone outcrops	Orcas Island, top of Mt. Constitution Waldron Island, Pt. Disney
	OSN	Shaded noncalcareous, wet or dry, usually forested sites	Orcas Island, in Moran State Park
WETLANDS	WBO	bogs, sphagnum, carex sedge, or old wet peat deposits, mostly in full sun, but may be shaded	Orcas Island, Summit Lake San Juan Island, Beaverton Valley area
	WLA	Lakes, along the margins, and on floating logs etc.	San Juan Island, Sportsman Lake
	WPO	Ponds, seasonal and continuous wet, may be forested depressions, or in full sun	Orcas Island, in the Mt. Pickett area
	WSE	Seeps, non marine, may be forested or non forested, full time or seasonal	Orcas Island, along the Crow Valley road
	WSM	Swamps and marshes, may be seasonal or constantly, wet areas with trees, shrubs or cattails	San Juan Island, Egg Lake area Waldron Island, Cowletz Bay Marsh, Lopez, Camp Norwester
	WST	Streams and creeks, mostly constantly wet areas, forested or in full sun	Orcas island, Cascade Creek
WOODLANDS	CWO	Coniferous forested areas, mixed, Doug Fir. W. Hemlock, Grand Fir, Red Cedar, some Yew and scattered stands of Juniper	Orcas Island, Moran State Park San Juan Island, Small Pox Bay
	DWO	Deciduous forest areas of Garry Oak, Alder, and Maple	San Juan Island, English Camp
	MWO	Mixed stands of conifers and deciduous trees, including Madrona	Orcas Island, Pt. Doughty Sucia Island, trail to Shallow Bay from Fossil Bay
	OAO	Old apple orchards, mostly with apple trees, abandoned or active orchards	Blakely Island, old homestead site

Table 10. Islands and sub-habitats from which collections were taken.

	Maritime				Meadows & Ridges			Disturbed Sites			Outcrops				Wetlands					Woodlands		
ISLAND	**MAR**	**MSE**	**MCS**	**OGS**	**OMP**	**ORS**	**CEM**	**DAI**	**DDE**	**ORQ**	**OOC**	**OON**	**OSN**	**WBO**	**WLA**	**WPO**	**WSE**	**WSM**	**WST**	**CWO**	**DWO**	**MWO**	**OAO**
Blakely	X					X			X	X		X	X		X		X	X	X	X	X	X	X
Clark	X												X					X		X		X	
Crane	X	X			X	X		X	X			X	X					X		X		X	
Flattop	X											X	X							X			
Freeman	X					X						X	X										
Goose	X					X																	
Henry	X									X			X							X		X	
James	X					X						X	X							X		X	
Jones	X					X						X	X				X			X	X	X	X
Little Mac	X	X				X																	
Lopez	X	X			X	X	X		X			X	X		X	X	X	X	X	X	X	X	
Matia	X	X							X			X	X		X			X		X		X	
McConnell	X				X	X						X	X							X			X
Orcas	X	X	X		X	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X
Patos	X					X			X			X								X	X	X	
Posey	X								X			X									X		
San Juan	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Satellite	X			X								X	X							X		X	
Sentinel	X			X								X	X							X		X	
Shaw	X	X			X	X			X			X	X			X	X	X		X	X	X	X
Skull	X					X						X											
Spieden	X			X		X		X	X			X	X							X	X		
Stuart	X					X		X	X			X	X			X		X		X	X	X	X
Sucia	X	X				X			X			X				X				X	X	X	
Turn						X						X								X			
Waldron	X	X			X	X	X	X				X						X		X	X	X	X
Willow												X	X							X			
Yellow	X				X	X			X			X								X		X	

Three general habitats have the highest moss diversity: Woodlands, with a total of 135 species (60.2% of the flora), Rock Outcrops with 131 species (58.4%), and Wetlands, with 129 species (57.5%). This high moss diversity is the result of the availability of numerous micro-habitats and the constant availability of water. The remaining three general habitats, Disturbed Sites, Maritime, and Meadows and Ridges showed the lowest moss diversity by having fewer than 100 species or 50.0 % of the flora (Table 11). This lower diversity is probably the result of less water and fewer sites availability as well as frequency of "weedy" species (species that occupy sites which have undergone human disturbance and are not usually found elsewhere). Representative species found within each sub-habitat are noted below.

The Maritime habitat was divided into the following three sub-habitats; MAR includes all sites below 20 feet elevation along the margins of the islands, excluding seeps. This sub-habitat contained a variety of substrata and varied from exposed rocky shore lines with beach logs, to humus and duff areas above the beach. A total of 79 species (35.2 % of the flora) occurred within this sub-habitat. Two species, *Schistidium maritimum* and *Ulota phyllantha*, occurred predominantly on the exposed rocky shores. Above the shoreline, usually on humus and duff, *Eurhynchium oreganum*, *Dicranum scoparium* and *Plagiomnium insigne*, were common. Occasionally, *Ulota phyllantha* occurred on tree or shrub branches that projected out over the beach bank.

Both the MSE (beach bank seeps) and MCS (calcareous beach bank seeps) sub-habitats were characterized by seasonal or continuous water seepage, thus resulting in some unusual microhabitats. The MSE sub-habitat occurred on non-calcareous soil (sometimes on rock or soil over rock) along the beach bank overhang in full to partial shade. A total of 28 species (12.5 % of the flora) occurred in these areas. Common species included *Amblystegium serpens*, *Eurhynchium praelongum* and *Pohlia cruda*.

The MCS sub-habitat consisted of soil or soil over rock in both full shade and full sun, along or just above the shoreline. These calcareous seepages were confined to the few limestone outcrops available on the islands. The limited number of limestone outcrops determined that

Table 11. Moss diversity in the habitats.

Legend: MAR, all sites below 20 ft. elev., excluding seeps, MSE, beach bank seeps, MCS, calcareous beach bank seeps, OGS, open grassy slopes, OMP, open meadows, pastures and lawns, ORS, open rocky slopes, CEM, cemeteries, DAI, airstrips, DDE, developed sites, ORQ, old rock quarries, OOC, open calcareous outcrops, OON, open non-calcareous outcrops, OSN, open shaded non-calcareous outcrops, WBO, bogs, WLA, lakes, WPO, ponds, WSE, seeps, non-maritime, WSM, swamps and marshes, WST, streams and creeks, CWO, coniferous woodlands, DWO, deciduous woodlands, MWO, mixed coniferous and deciduous woodlands, OAO, old apple orchards. Note: Many of the species occur in more than one habitat.

Sub-Habitat	No. of Species	% Fora	General Habitat	Total No. of Species	% Flora
MAR	79	35.2			
MSE	28	12.5	Maritime	96	42.8
MCS	11	4.9			
OGS	25	11.1			
OMP	25	11.1	Meadows & Ridges	73	32.5
ORS	53	23.6			
CEM	12	5.3			
DAI	21	9.3	Disturbed Sites	74	33.0
DDE	66	29.4			
ORQ	32	14.2			
OOC	20	8.9			
OON	115	51.3	Outcrops	131	58.4
OSN	86	38.3			
WBO	46	20.5			
WLA	56	25.0	Wetlands	129	57.5
WPO	41	18.3			
WSE	44	19.6			
WSM	51	22.7			
WST	52	23.2			
CWO	116	51.7			
DWO	66	29.4	Woodlands	135	60.2
MWO	88	39.2			
OAO	14	6.25			

only 11 species (4.9 %) of the flora) including *Crumia latifolia, Eucladium verticillatum,* and *Hymenostylium recurvirostre* occurred within this sub-habitat. Tufa formations were often formed within these sites when the water supply was constant.

The Meadows and Ridges habitat was divided into the following three sub-habitats: open grassy slopes (OGS), open rocky slopes (ORS), and open meadows and pastures (OMP). Open grassy slopes (OGS) are usually treeless, covered by grasses, and in full sun. Common substrata included dry soil, limited humus and duff, small rocks and occasionally pieces of decayed wood. A total of 25 species (11.1 % of the flora) occurred within this sub-habitat. Common species included *Brachythecium albicans*, *Polytrichum juniperinum*, and *Weissia controversa*. The open rocky slope (ORS) sub-habitat consisted of small, low rock areas scattered throughout the grassy slopes. Species on these low rocky areas included *Polytrichum piliferum*, *Racomitrium ericoides*, *Didymodon vinealis*, and, occasionally, *Hedwigia stellata*. A total of 53 species (23.6 % of the flora) occurred within this sub-habitat. Finally, the OMP or open meadows and pastures sub-habitat consisted of pastures, lawns or open meadows in full sun. These areas were often disturbed and usually had more water available to them than the other two sub-habitats. Only 25 species (11.1 % of the flora) were found within this area, usually on damp or dry soil. Two species, *Pseudoscleropodium purum* and *Rhytidiadelphus squarrosus*, occurred only in this sub-habitat. Other common species included *Brachythecium albicans*, *Bryum pseudotriquetrum*, and *Leptodictyum riparium*. In spite of the availability of extra moisture this sub-habitat was fairly low in species diversity, possibly the result of disturbance and competition from vascular plants.

The Disturbed Sites habitat was divided into four sub-habitats based on the type of disturbance that had occured. Sometimes, imported headstones in cemeteries bring in an "exotic" moss species; thus, cemeteries (CEM) on each of the islands were checked for this possibility. Only 12 species (5.3 % of the flora) were found in this sub-habitat in spite of headstones constructed from a variety of rock materials, and no "exotic" introduced species were found. Common species found on the headstones included *Dicranoweisia cirrata*, *Didymodon vinealis*, *Homalothecium pinnatifidum* and *Tortula muralis*. Species found on dry soil included *Brachythecium albicans* and *Ceratodon purpureus*.

Airstrips (DAI) both active and abandoned, were often composed of raw mineral soil. A total of 21 species (9.3 % of the flora) occurred within this sub-habitat. Common species included *Polytrichum juniperinum*, *Racomitrium heterostichum* and *Ceratodon purpureus*. Several uncommon species found occasionally in or along the edges of the tire ruts were *Physcomitrium pyriforme* and *Pleuridium acuminatum*. Developed Sites (DDE) included old walkways, and housing or commercial building sites. These disturbed areas were usually colonized by "weedy" species that often did not occur in other less disturbed sub-habitats. A total of 66 species (29.4 % of the flora) was found in this sub-habitat. The following species were usually present in these sites: *Tortula muralis*, *Grimmia pulvinata*, and *Ceratodon purpureus*.

Old Rock Quarries (ORQ) were common on several of the islands, and were composed of limestone or sandstone. Thirty-two species (14.2 % of the flora) were found within this sub-habitat and the most common substratum was rock. Occasionally, trees grow in some of the old quarries, thus providing both shade and additional microhabitats for several species. These old quarries are usually open pits exposed to full sun and thus were very dry sites. Common species on rock included *Didymodon vinealis*, *Racomitrium ericoides*, and *Ptychomitrium gardneri*.

The general Rock Outcrop habitat was divided into three sub-habitats, based on the amount of light exposure and the composition of the rock material. OOC, or open calcareous rock outcrops, were dry sites in full sun and usually composed of limestone. Only 20 species (8.9 % of the flora) occurred within this sub-habitat and included the following species: *Bryum capillare*, *Tortella tortuosa*, and *Gymnostomum aeruginosum*. OON or open non-calcareous rock outcrops were large open areas containing a variety of rock materials. These large exposed areas provided numerous microhabitats and 114 species (50. 8 % of the flora) occurred within this sub-habitat. The following species were found: *Pseudobraunia californica*, *Hedwigia stellata*, *Isothecium cristatum*, and a variety of species of *Racomitium*. When the crevices or rock ledges provided shade or occurred on the north slope, the following species were usually present: *Anacolia menziesii*, *Amphidium californicum*, *Claopodium bolanderi.*

Shaded non-calcareous outcrops (OSN) were located within the forested areas, thus the shade helped to increase the available moisture in the microhabitats. A total of 87 species (38.8 % of the flora) was collected from this sub-habitat. Common species included *Amphidum californicum* and *A. lapponicum*, *Bartramia pomiformis*, *Encalypta ciliata*, and *Anacolia menziesii.* When moisture was present as seepage the following species were often present: *Porotrichum bigelovii*, and *Dichodontium pellucidum.*

Although several of the islands have fresh water lakes, for the most part there is not an abundance of surface water present. In many cases, where a stream or lake did exist it has been modified. When a fresh water source is present (disturbed or undisturbed) it forms a distinct microhabitat that may contain a variety of species that are dependent on the high moisture conditions. Therefore the Wetlands habitat was divided into five sub-habitats based on the type or source of the water available. The highest moss diversity occurred in the lake (WLA) sub-habitat, with 56 species (25 % of the flora). This sub-habitat contained a wide variety of substrata including floating logs (or docks), over-hanging tree or shrub branches, standing dead trees, and the shoreline which varied from rock cliff faces to humus and duff banks. This variety of substrata probably is responsible for the high moss diversity of this area. A few of the species associated with the wetter substrata included *Calliergon giganteum*, *Climacium dendroides* and *Sanionia uncinata.*

The Streams (WST) sub-habitat contained 52 species (23.2. % of the flora). This sub-habitat was best represented on Orcas Island where several large creeks or streams drain from Mt. Constitution. Species associated with these streams included *Scleropodium obtusifolium*, *Brachythecium frigidum*, and *Fissidens ventricosus.* In one area where the creek flowed over a small lens of limestone *Fissidens grandifrons*, a calcicole, appeared in several locations. Because this sub-habitat also included the bounding creek or stream bank, it increased the number of substrata, thereby increasing the moss diversity. The Swamp and Marsh (WSM) sub-habitat showed the third highest moss diversity with 51 species (22.7 % of the flora). This high diversity again is the result of the large number of substrata occurring in the sub-habitat. These seasonal or constantly wet areas were associated with either trees, shrubs or cattails. Areas dominated by cattails or covered by dense shrub layers generally were not species rich. This is probably a response to the vascular plants that out-compete the mosses by reducing the available sites for colonization. On the other hand, when trees were present, the moss diversity increased as a result of the increased number of available microhabitats. Species commonly associated with this sub-habitat included *Amblystegium serpens* and *Drepanocladus aduncus*, both found on wet soil, *Onocophorus wahlenbergii* on the base of trees, and *Plagiomnium medium* on decayed wood.

The Bog and bog like (WBO) sub-habitat was one of the most unexpected in the islands. It was restricted to San Juan and Orcas Islands. The bogs were composed of either sedges (*Carex* sp.), sphagnum, or were old peat deposits, and in many cases they had experienced some form of disturbance. A total of 46 species (20.5 % of the flora) occurred in these bogs. Dominant species included a variety of species of *Sphagnum* and *Aulacomnium palustre*. *Pohlia sphagnicola* and *Bryum uliginosum* were found only in the Orcas Island *Sphagnum* bogs. Forty four species (19.6 %) were found in the non-maritime seep sub-habitat (WSE). This low number of species is most likely due to the limited amount of fresh water sites within the islands.

The wetland with the lowest moss diversity was the Pond (WPO) sub-habitat. Most of the man- made ponds were extremely poor in species composition because of the continuity of disturbance, either from grazing animals or fluctuating water levels in response to irrigation needs. The seasonal or constantly wet forest floor depressions that ponded water during wet periods had a high species composition and thus are responsible for most of the 41 species (18.3 %) found in this sub-habitat. Common species in the forested sites included *Fontinalis antipyretica* and *Leptodicytum riparium*. *Drepanocladus crassicostatus* and *Bryum flaccidum* were found in a shallow depression on wet soil along a road in full sun.

The Woodlands habitat was divided into four sub-habitats based on tree species composition. While there are areas on Mt. Constitution that have a few old trees, true old growth forest is not represented within the islands. Thus the coniferous woodlands (CWO) are all second growth *Pseudotsuga menziesii* (Douglas fir), *Tsuga heterophylla* (western hemlock), *Abies grandis* (grand fir), and *Thuja plicata* (red cedar). *Taxus brevifolia* (yew) is also scattered throughout the area although it is not abundant, and *Juniperus scopulorum* (Rocky Mountain juniper) occurs in small clusters on some of the drier sites. This sub-habitat had the highest diversity with a total of 116 species (51.7 % of the flora). A wide range of substrata were found throughout the sub-habitat and included: humus and duff, damp and dry soil, decayed wood, epiphytes, and a variety of small rock types. Forest floor species composition is usually rather high as there is less litter accumulation. Common forest floor species included *Rhytidiopsis robusta*, *Trachybryum megaptilum*, and *Pleurozium schreberi*. Rock species included *Grimmia trichophylla*, *Racomitrium lawtonae*, and *Cynodontium jenneri*. *Dicranella heteromalla* and *Pohlia nutans* often occurred on soil banks along the trails. Species associated with the coniferous tree trunks included *Hypnum circinale* and *Dicranum tauricum*. With the exception of one juniper tree on Posey Island which was leaning, mosses were not found on this substratum.

The deciduous woodlands (DWO) sub-habitat is composed of stands of Garry oak, alder, or big leaf maple trees. This sub-habitat is scattered throughout the islands but has been greatly impacted by human development. The predominant substratum found in this sub-habitat are the tree trunks and branches which provide excellent sites for a variety of corticolous species. Common species found on the trunks of trees include *Plagiomnium venustum*, *Claopodium crispifolium*, *Homalothecium nuttallii*, *Isothecium myosuroides*, and *Orthotrichum lyellii*. Species on branches included *Tortula ruralis*, *Orthotrichum consimile*, and *Ulota obtusiuscola*. A total of 66 species (29.4 % of the flora) occurred in this sub-habitat. These tree stands are often isolated patches in the middle of large open areas where grasses dominate the ground cover.

This fact, combined with the accumulation of leaf litter, acted to prevent an abundance of moss species from establishing under these stands of trees.

Mixed Woodlands (MWO) were composed of both coniferous and deciduous trees as well as madrona. This sub-habitat had 90 species (40.1 % of the flora). These wooded areas often had an understorey of *Gaultheria shallon* (salal) or *Holodiscus discolor* (ocean spray) thus decreasing the availability of ground sites. The deciduous trees consistently had the same epiphytic species mentioned above, while the coniferous trees usually had *Hypnum circinale* and *Dicranum tauricum* on the trunks. *Arbutus menziesii* (madrona) rarely had epiphytic species because of the shedding nature of the bark. Occasionally, *Eurhynchium oreganum* or *Isothecium myosuroides* could be found growing up the base of an old, well established madrona tree.

Old Apple Orchards (OAO) had the lowest moss diversity for woodlands, with only 14 species (6.2 % of the flora). This is because the only substratum available for colonization was on the tree trunk or branches. Usually these orchards were in open grassy areas and thus ground species could not become established. Occasionally in the abandoned orchards fallen branches or trunks would provide additional substratum for such species as *Aulacomnium androgynum*. The epiphytic species on trees and branches were consistently the same as in the deciduous tree sub-habitat.

Since mosses are "well known to be sensitive to subtle differences in micro-environment" (Bates 1982), substratum plays an important role in their distribution.

Moss Species As Related To Substratum

Classification of bryophytes on the basis of substratum has been carried on since the late 1800's (Gams 1932). While "most bryophytes have a sharply defined and rather narrow ecological range" (Richards 1932), others occur on a variety of substrata. Knowing whether a moss has an obligate or facultative relationship with it's substratum is often important when making a species determination. For this study, 18 substratum categories were established and data were recorded for each species collected. See Table 12. for these categories and their definitions.

The rock substratum showed the highest moss diversity with 160 species (71.4 %) of the flora. This probably results from the vast number of microhabitats and the variety of rock material available for colonization. An additional reason for this large number of species is that most rock outcrops do not accumulate much soil: therefore, vascular plants can not become well established, and the competition for the bryophytes is lessened. The second highest diversity occurred on the soil substratum, with 141 species (62.9 % of the flora). The lowest diversity occurred in the aquatic substratum, with only 15 species (6.6 % of the flora). This reflects the lack of abundance of fresh water within the islands, thus fewer aquatic species can become established. Peatlands showed the second lowest moss diversity, with 28 species (12.5 % of the flora), again emphasizing the lack of suitable sites. Living-wood, dead-wood and humus and duff all represent less than 50.0 % of the flora. See Table 13. for a complete summary and Appendix E for a list of species associated with substratum.

Rocks offer a wide variety of microhabitats for mosses to colonize. These sites include fissures and crevices, ledges, smooth or rough surface texture, and small "caves". Mosses growing on rock may be either obligate or facultative epiliths (Gams 1932). Several of the obligate species found during this study were *Andreaea megistospora*, *Grimmia trichophylla*, *Orthotrichum rupestre* and *Schistidium maritimum*. Facultative species found on this substratum included *Bryum capillare*, *Eurhynchium praelongum*,

Table 12. Definitions of substrata.

General Substratum	Substratum (sub-code)	Definitions
Water	AQ	Aquatic
Dead-Wood	BL	Beach logs
	DW	Decayed wood
	FL	Floating logs
Living-Wood	EP	Epiphytic
	FO	Folicolous
Humus & Duff	HD	Humus and duff
Peat	PE	Peatlands
Rock	RA	Slate
	RB	Basalt
	RC	Conglomerate
	RG	Granite or acidic
	RL	Calcareous & cement
	RO	Unknown material
	RS	Sandstone
Soil	SC	Clay
	SD	Dry
	SW	Wet

Table 13. Moss diversity according to substratum.

Legend: The percentages in this table reflect the occurrence of a species on more than one type of substratum. AQ, aquatic, BL, beach logs, DW, decayed wood, EP, epiphytic, FL, floating logs, HD, humus & duff, PE, peatlands, RA, slate rock, RB, basalt rock, RC, conglomerate rock, RG, granitic, acidic rock, RL, cement and calcareous rock, RO, unknown rock, RS, sandstone rock, SC, clay soil, SD, dry soil, SW, wet soil.

Substratum	No. of Species	%	Combined Substratum	Total No. of Species	%
AQ	9	4.0	Aquatic	9	4.0
BL	4	1.78			
DW	79	35.2	Dead-wood	82	36.6
FL	1	0.44			
EP	66	29.4	Living-wood	66	29.4
FO	1	0.44			
HD	55	24.5	Humus & Duff	56	25.0
PE	28	12.5	Peat	28	12.5
RA	5	2.2			
RB	17	7.5			
RC	48	21.4			
RG	26	11.6	Rock	163	72.7
RL	76	33.9			
RO	149	66.5			
RS	25	11.1			
SC	33	14.7			
SD	109	48.6	Soil	142	63.3
SW	74	33.0			

Hypnum cupressiforme, *Isothecium myousorides*, *Tortula princeps*, and *T. ruralis*. These species are found on rock because a shallow layer of humus has accumulated on the rock surface, thus allowing them to become established.

The chemical nature of rock also plays an important role in determining which species will be able to survive on a particular substratum. Often the pH of a substratum can be estimated on the basis of the moss species found growing on it. This is particularly true with the obligate calcicoles such as *Crumia latifolia*, *Eucladium verticillatum*, and *Gymnostomum aeruginosum*. Siliceous or acidic rock obligates include *Andreaea rupestris*, *Bartramia pomiformis*, *Encalypta ciliata*, *Pohlia cruda*, and *Schistidium apocarpum*.

Six types of rock material were easily distinguished in the field; when the nature of the substratum was known, it was recorded. Unfortunately much of the time the rock material was not easily identified: therefore, 146 species, or 65.1 % of the flora, were recorded as "rock unknown" (RO). A brief discussion of each rock substratum follows. Since slate (RA) was not a common rock material within the islands, only 5 species (2.2 % of the flora), occurred on this substratum. Two species found on this substratum were *Amphidium lapponicum* and *Schistidium maritimum*.

Basalt (RB) was also an uncommon rock substratum; only 17 species (7.5 % of the flora), were found on this substratum. Representative species included *Bryum dichotomum*, *Pseudobraunia californica*, and *Schistidium maritimum*. Conglomerate rock (RC) formations were on a restricted number of the islands, but the rough texture of this type of rock material plus the diversity of rock fragments in it provided habitat for 48 species (21.4 % of the flora). Common species on this substratum included *Claopodium bolanderi*, *Didymodon vinealis* var. *vinealis*, *Grimmia trichophylla*, and *Hypnum subimponens*.

Granite rock material (RG) was restricted to glacial erratic boulders that were scattered throughout the islands. Crum (1973) comments in a discussion on the moss flora of the Great Lakes area, "glacial erratics present some variety in substrate, of slight importance"; thus these erratic boulders often have unique species associated with them. This is especially true when the rock material differs substantially from the surrounding surface material. Therefore, these rocks were of particular interest. Unfortunately they did not show this unique pattern of unusual species and all of the species found on them were common to the islands in general. Among the species found were *Dicranoweisia cirrata*, *Orthotrichum rupestre*, *Ptychomitrium gardneri*, and *Ulota phyllantha*, all species that prefer an acidic substratum. A total of 26 species (11.6 % of the flora), occurred on these erratic boulders.

Although sandstone (RS) occurred on several of the islands, only 25 species, (11.1 % of the flora) were on this substratum. The low species diversity is probably the result of the unstable surface of the sandstone which makes establishment difficult. Most of the species on this substratum were in rock crevices or fissures. The following facultative sandstone species included *Antitrichia californica*, *Eurhynchium oreganum*, and *Leucolepis acanthoneuron*. Obligate rock species included: *Dicranoweisia cirrrata*, *Didymodon vinealis* var. *vinealis*, and *Racomitrium ericoides*.

Species composition varied according to the type of calcareous rock (RL) material, and the presence or absence of water on the substratum. Since cement or concrete is composed of lime it was included in this substratum group. These cement structures included walls, curbs, chimneys, and dams. Species associated with dams often reflected the additional moisture that was present, and included the following species *Didymodon tophaceus*, *Hymenostylium recurvirostre*, and *Gymnostomum aeruginosum*. Species associated with drier sites such as curbs and walls included: *Didymodon vinealis* var. *vinealis*, *D. vinealis* var. *flaccidus*, and *Tortula muralis*.

Naturally occurring limestone deposits in conjunction with seepages contained very interesting species. There, obligate calcicoles such as *Crumia latifolia*, *Eucladium verticillatum*, *Gymnostomeum aeruginosum* and *Hymenostylium recurvirostre* all could be found, occasionally forming tufa deposits. Dry limestone outcrops on the other hand often had the same species as found on cement, along with the following species: *Didymodon fallax*, *Orthotrichum anomalum*, and *Schistidium apocarpum*. When both the wet and dry limestone substrata are combined, a total of 76 species (33.9 % of the flora) are represented.

The terrestrial substratum was divided into the following three general categories: humus and duff (HD), peatlands (PE), and soil. Soils were further divided into soil dry (SD), soil wet (SW), and clay soil (SC). These divisions were based on the moisture content, texture and amount of organic material present at each of the collecting sites. In general the soils within the islands are composed of glacial till and outwash, are well drained, and lack large amounts of loam. Thus, they are not very rich soils and usually have been exposed to recent disturbance. Since moss diversity is dependent upon soil richness, moisture, shading and the amount of disturbance present, it was unexpected to find 141 species (62.9 % of the flora) occurring on this substratum. An examination of the species composition makes this large number easier to understand. With the exception of a few species, most of the mosses found were those that colonize disturbed areas. The largest number, 109 species (48.6 % of the flora), occurred on dry soil (SD) and included the following species: *Bryum capillare*, *Ceratodon purpureus*, *Funaria hygrometrica*, and *Polytrichum juniperinum*, all in sunny, open areas, often mixed with the surrounding vascular plant weeds and grass. *Atrichum selwynii* and *Dicranella heteromalla* were found in shaded sites on bare mineral soil along trails and on upturned tree root systems. Most of the above species respond well to soil disturbance and thus were found on over 50 % of the islands.

Wet soils (SW) occurred along stream banks, lake margins and in seepy areas. Common species found in these locations included *Brachythecium frigidum*, *Bryum pseudotriquetrum*, *Calliergonella cuspidata*, and occasionally, *Philonotis fontana*. A total of 74 species (33.0 % of the flora) occurred on this substratum. Although this low number of species does not reflect the normal species richness often found in these moist soil sites, the lack of suitable wet soil habitats limited the potential for a large number of species to become established.

As a result of the limited number of clay deposits known from the islands, only 33 species (14.7 % of the flora) occurred on this substratum. Although the clay soil (SC) substratum was restricted, the following two species (that are confined there to clay deposits) were collected: *Dicranella howei*, and *Dicranella pacifica*. Other species found on, but not restricted to, the clay substratum included: *Fissidens bryoides*, *Fissidens limbatus*, *Leptobryum pyriforme*, and *Pleuridium acuminatum*.

Humus and duff (HD) is described as the organic constituent of the soil, and is composed of partially decomposed plant and animal litter (Lincoln et al. 1982). Thus, "humus is a factor of first importance" (Grebe 1917), and often provides a suitable substratum over soil and rock for the establishment of mosses that otherwise would not be present. A total of 55 species (24.5 % of the flora) occurred predominately in the coniferous woodlands. At the higher elevations in the Mt. Constitution area, extensive mats of *Rhytidiopsis robusta, Trachybryum megapitlum*, and *Rhytidiadelphus triquetrus* were found. Lower elevation species included *Dicranum scoparium*, *Eurhynchium oreganum*, *Plagiomnium insigne*, and occasionally *Hylocomium splendens*. Thin layers of humus often form in more open areas over rocks allowing the following species to become well established: *Tortula princeps*, *Tortula ruralis*, and *Isothecium myosuroides*.

Peatlands (PE) generally are low in species diversity especially when of small size, and usually species of *Sphagnum* dominate this substratum (Schofield 1976). Although low in diversity (only 28 species, or 12.5 % of the flora), these acid-rich substrata contained some of the more unusual species in the islands. Two species, *Bryum uliginosum* and *Pohlia sphagnicola*, were found only within the bog complex. Common *Sphagnum* species included *S. fuscum*, *S. recurvum* and *S. squarrosum*. Among the other common species found were *Aulacomnium palustre*, *Pleurozium schreberi*, and *Polytrichum strictum*.

Aquatic (AQ) bryophytes occur either as floating mats, or attached to rocks or wood fragments in streams and lakes. The following species often formed floating mats: *Drepanocladus aduncus*, *Fontinalis antipyretica*, and *Leptodictyum riparium*. Species often attached to rocks in or along the margin of lakes, in streams, or in waterfalls include *Brachythecium frigidum*, *Fissidens ventricosus*, and *Porotrichum bigelovii*. *Fissidens grandifrons*, a calcicole, occured only in those streams where enough calcium was being leached into the water from the surrounding limestone. A total of 15 speceis (6.6% of the flora) was found in aquatic areas.

Floating logs (FL), decayed wood (DW), and beach logs (BL) were combined as dead-wood substrata. Together, 86 species (38.3 % of the flora) occurred on these substrata. Decayed wood, which included rotten logs, stumps, and standing dead trees, had the highest diversity with 76 species (33.9 % of the flora). Common species found on this substratum included *Dicranum fuscescens*, *Rhizomnium glabrescens*, and *Tetraphis pellucida*. Beach logs (BL) provided an extremely poor substratum because of their proximity to salt water and instability. Thus only 4 species (1.78 % of the flora) occurred on these logs. *Bryum capillare* and *Ulota phyllantha* were common, while *Orthotrichum lyellii* and *Schistidium maritimum* were found only once. Floating logs (FL) usually half submerged, were found in several of the lakes. A total of 6 species (2.6 % of the flora) was found on this extremely wet substratum. The following species were the most common: *Bryum pseudotriquetrum* and *Philonotis fontana*.

Species occurring on living-wood were divided into two substratum groups: epiphytic (EP), including those species growing on the trunks or branches of trees or shrubs, and foliicolous (FO), including those species growing on the leaves of trees or shrubs. Vitt et al. (1973) reported the first occurrence of this substratum for Western North America when four species of *Orthotrichum* were found on *Thuja plicata* leafy branches. Only one species, *Orthotrichum consimile*, was found on *Thuja plicata* leafy branches confined to a shallow damp drainage on Orcas Island. This tree was within a small grove of *Acer macrophyllum* trees which probably served as the dispersal source for this *Orthotrichum*. Thus, the close proximity to a good source of spores, and the increased humidity from the drainage, combined to allow this *Orthotrichum* to colonize the *Thuja*.

The epiphytic (EP) substratum has both obligate and facultative species occurring on usually deciduous trees. Obligate mosses included *Orthotrichum consimile*, *O. lyellii*, *Ulota megalospora*, and *Ulota obtusiuscula*. All occur on the limbs or trunks of *Alnus rubra* (red alder), *Acer macrophyllum* (bigleaf maple), and *Quercus garryana* (Garry oak). Occasionally, these species of moss were found on *Holodiscus discolor* (ocean spray). *Isothecium cristatum* and *Scleropodium cespitans* were usually found near the base of deciduous trees. A few of the facultative species included *Antitrichia curtipendula*, *Homalothecium fulgescens*, *Isothecium myousroides*, *Metaneckera menzesii*, *Neckera douglasii* and *Zygodon viridisimus* var. *rupestris*. These facultative epiphytes occurred on both tree trunks and on rocks. A total of 66 species (29.4 % of the flora) was found on this substratum.

Since a geologic formation or unit is composed of a variety of different types of rock substrata, data were collected to determine if there was any correlation between these units and the distribution of mosses.

Moss Species As Related To Geologic Unit

While numerous studies have been made concerning the relationship of mosses to rock substrata (Nagano 1969), it appears that little research has been carried out that relates entire geologic units to species diversity. Therefore, during this study, the geologic units from which any moss was collected were recorded. See Table 14. for a complete summary. Two formations, the Garrison Terrane and Haro Formation were discussed in the geological section of this paper yet collections were not made from either of these formations because access was denied or the formation was too small to easily identify in the field. See Appendix F for a complete list of species associated with geological unit.

The Constitution Formations (CF) showed the highest diversity, with 188 species 83.9 % of the flora) occurring on this geologic unit. This high species diversity may result from several factors. First, the Constitution Formation occurs widely among the islands, covering all of Crane and Turn, and most of San Juan, and Shaw. On Orcas Island it covers several extensive areas, including the Mt. Constitution and Mt. Woolard regions. (see Figure 3). Thus, it is one of the largest geologic units (38.5 % of the area) represented in the islands. Second, most of the higher elevation areas that Deither et al. (1995) proposed to have been above water and ice free by 13,500 yr. BP occur within this formation. Thus, it is possible that these areas, having been available for occupation earlier, were colonized by more species. Finally, at the present time, these higher areas tend to be characterized by greater precipitation than other elevations in the islands and, thus, increase the potential for a variety of species to colonize or presist in the area.

Two other geologic units contained over 50 % of the flora. They were the Turtleback Complex (TC) with 151 species (67.4 % of the flora), and the East Sound Group (EG) with 121 species (54.0 % of the flora). Both of these geologic units occur predominately on Orcas Island where they form large bands of material along the northern side of the island. Jones Island is also composed entirely of the East Sound Group. Although the East Sound Group represents only 5.28 % of the area within the islands, the variety of rock material found in

Table 14. Moss diversity as related to geological unit.

Legend: CF, Constitution Formation, CK, Chuckanut Formation, DB, Deadman Bay Volcanic, EG, East Sound Group, FC, Fiadalgo Complex, LF, Lummi Formation, LS, Lopez Structural Complex, NG, Nanaimo Group, OC, Orcas Chert, QC, Quaternary Cover, SG, Spieden Group, TC, Turtleback Complex.

Geological Unit	% of Island Area	No. of Species	% of Flora
CF	38.54	188	83.9
CK	.96	73	32.5
DB	.63	60	26.7
EG	5.28	121	54.0
FC	10.06	96	42.8
LF	3.81	60	26.7
LS	1.87	65	29.0
NG	4.84	98	43.7
OC	12.61	104	46.4
QC	11.72	74	33.0
SG	.45	68	30.3
TC	11.21	151	67.4

this formation substantially increased the species diversity. The high moss diversity found on the Turtleback Complex probably is the result of both the variety of rock material that occurs in this formation, and the fact that this complex also appears at the higher elevations on Orcas Island.

Two species, *Andreaea megistospora* and *A. rupestris*, were restricted to the Constitution Formation. *A. megistospora* was found only in the Mt. Constitution area on Orcas Island. *Andreaea rupestris* also occurred on Mt. Constitution, but a historical collection from the Mt. Dallas area on San Juan Island indicates that, at one time, it occurred on both of the islands.

The following geologic units had between 40 and 50 % of the flora: Orcas Chert (OC) with 104 species (46.4 % of the flora), the Nanaimo Group (NG) with 98 species (43.3 % of the flora), and finally the Fidalgo Complex (FC) with 96 species (42.8 % of the flora). While these three units were limited in distribution they contained some of the more unusual rock materials with respect to the geology of the islands. Most of the limestone deposits occurred in the Orcas Chert, thus the obligate calcicole species were found on this unit. The Nanaimo Group, composed of sandstone, conglomerate, and shale, and the altered igneous rocks rich in greenschist found in the Fidalgo Complex, all provided a variety of substrata for the colonization of mosses. Thus, the greater diversity of substrata probably compensated for the limited distribution of these geologic units.

Less than 40 % of the flora occurred on the Chuckanut Formation (CK) and Quaternary Cover (QC). The Chuckanut Formation, with 73 species (32.5 % of the flora), is found, in the islands, only on Matia, Patos and Sucia Islands. It is composed of non-marine sandstone (a poor substratum for bryophytes), and conglomerate, which provided a variety of substrata for colonization. While the Quaternary Cover occurs on over half of Lopez and Waldron Islands, it is composed of glacial tills and sediments. Thus, it is reasonable to assume that the 74 species (33.0 % of the flora) were found on substrata other than soils.

Relatively low moss diversity occurred on the Lummi Formation (LF) and Deadman Bay Volcanics (DB) with only 60 species (26.7 % of the flora), the Lopez Structural Complex (LS), with 65 species (29.0 % of the flora), and the Speiden Group (SG), with 68 species (30.3 % of the flora). With the exception of the Spieden Group, which occurs only on Spieden Island, these units occur mainly on Lopez and Orcas Islands. Thus, their restricted distribution may determine the low moss diversity. Other than the calcicole species there seems to be a weak correlation between species distribution and geologic unit. It also seems reasonable that the higher moss diversity occurs on the largest geologic unit, probably as a result of the increased number of substrata for colonization. Thus, while understanding the geologic formations is important in helping to locate good collecting sites, there is no strong correlation between species distributions and the geologic units.

Two unusual features within the San Juan Islands merit particular attention, these are the limestone deposits (mentioned above) that occur scattered throughout the islands, and the bogs and bog like areas found on San Juan and Orcas Islands.

Unusual Habitats And Substrata

Limestone Deposits

One of the most interesting features within the San Juan Islands is the numerous limestone deposits. Danner (1966) surveyed the islands for these deposits and developed a list of 107 sites. The majority are dry and have been extensively disturbed by quarrying over the years. Although these dry, limestone sites host the calcicolous species *Didymodon fallax*, *Orthotrichum anomalum*, and *Schistidium apocarpum*, for the most part they are low in species diversity. When the limestone deposits occur in conjunction with freshwater (i.e. a stream, spring, or seepage) then a distinctive group of calcicole species may be present, and tufa deposits are often formed. Among the species found in these wet areas are *Crumia latifolia*, *Eucladium verticillatum*, *Gymnostomum aeruginosum*, and *Hymenostylium recurvirostre*. Several of these species were involved in extensive tufa formation.

Tufa is a "variety of calcium carbonate (CaCO) deposited in freshwater" (Danner 1966), and according to Flugel (1982) it is often "...formed by the precipitation of calcite onto plants, (usually algae and mosses)...". Parihar and Pant (1975), comment that the dense moss cushions provide "spongy surfaces which can absorb, retain and expose copious thin films of water for effective evaporation and consequent diffusion of CO from the calcareous spring water thus causing the precipitation of CaCO (calcite)". These tufa formations occur only in areas where the water carries a high percentage of carbonates (CO). Shacklette (1965) investigated a stream in Alaska containing 8.8 % carbonates and found only bryophytes growing in and around the stream. He further commented that "the mosses were so heavily coated with calcite that only the tips were pliable". Because the growth rate of mosses exceeds the rate of carbonate deposition "the process of getting cemented below and growing above is continued and the tufa also "grows" up" (Parihar and Pant 1975). Crum (1973) names these tufa formations based on species composition; thus, a tufa composed of *Eucladium verticillatum* would be called a eucladiolith, if it were composed of *Didymodon tophaceous* it would be a didymodonolith. Several of these tufa deposits were noted on the islands, one composed mostly of *Crumia latifolia* and another of *Eucladium verticillatum*. Other sites high in carbonates did not have tufa formations but still supported the following species: *Didymodon tophaceous*, *Gymnostomum aeruginosum*, and *Hymenostylium recurvirostre*.

Although there is a substantial amount of literature concerning tufa deposits (Crum 1973, Emig 1918, Parihar & Pant 1975, Pentecost 1996, Richards 1932, Richardson 1981, Shacklette 1965, and Taylor 1919), none deals with moss tufa deposits in Washington State. Although Danner (1966) discusses and maps the tufa deposits, he states that "Algae and mosses also are able to induce the precipitation of calcium carbonate in the form of tufa, but their contribution to the formation of deposits in western Washington has not been investigated". The tufa deposits in the San Juan Islands represent one of the more unusual microhabitats within the state of Washington.

Up until the summer of 1996 (when it was found on the Olympic Peninsula), *Crumia latifolia* was known in Washington from only the San Juan Islands. Therefore, additional field work throughout the state is needed to provide a better understanding of the distribution patterns for these unusual calcicole mosses. Finally, because "...limestone is one of the most commercially important rocks..." (Danner 1966), it would be prudent to locate and protect these unusual calcareous microhabitats before they have been exploited commercially.

Bogs and Bog Like Habitats

On the other end of the pH spectrum, peatlands also provide some of the more unusual habitats in the islands. Crum (1988) defines a bog as "an ombrotrophic peatland, that is, one deriving water and nutrients only from the atmosphere; a highly acid and nutrient-poor peatland dominated by *Sphagnum*". These water-logged environments provide a very distinct substratum for vascular plants and mosses. Typical vascular plants confined to the "bogs" include *Drosera rotundifolia* (sundew), *Eriophorum chamissonis*, and *E. gracile* (cotton-grass), *Kalmia microphylla* (western swamp laurel), *Ledum groenlandicum* (Labrador-tea), *Pinus contorta* (lodgepole pine), and two species of *Vaccinium, V. oxycoccus* var. *intermedium* (wild cranberry) and *V. uliginosum* var. *occidentale* (bog billberry). Mosses include *Sphagnum capillifolium, S. fuscum, S. henryense, S. magellanicum, S. palustre, S. recurvum, S. rubellum, S. squarrosum, S. subsecundum, Aulacomnium androgynum, Bryum uliginosum, Calliergonella cuspidata, Pleurozium schreberi, Pohlia sphagnicola*, and *Polytrichum strictum*.

In 1934, Rigg and Richardson discussed the development of eight sphagnum bogs in the San Juan Islands. Peat cores made during their study indicated that these bogs formed in post-glacial depressions, that formerly were lakes, and with the exception of Blakely bog (which has a sand bottom), all of the peat deposits rest on the typical blue clay found throughout the region.

A survey of Washington State peat resources, published by Rigg's in 1958, listed all of the known peat deposits and sphagnum bogs within the islands, and gave detailed location information. In two publications (Rigg and Richardson 1934, Rigg 1958), the following eight sphagnum bogs were listed: the San Juan peat area, Blakely Island peat area, Killebrew Lake peat area, Orcas No. 2 peat area, Orcas No. 1 peat area, Cold Springs peat area, Constitution No. 1 peat area, Constitution No. 2 peat area.

Rigg (1925) defines the term sphagnum bog as "that stage in the physiographic succession of an area during which its surface is entirely devoid of ordinary "hard" soil and is composed almost entirely of living *Sphagnum*, immediately under which is fibrous brown peat composed mainly or entirely of partially disintegrated *Sphagnum*". Understanding Rigg's concept of *Sphagnum* bogs was important when trying to interpret his papers or locate some of his eight bogs. Based on the above information, every attempt was made to visit these unusual bog sites. The results of these visits are discussed below.

The San Juan peat area is about 9.7 km (six miles) northwest of Friday Harbor in the Beaverton Valley area on San Juan Island. This deposit was once 6.1 hectares (15 acres) in size, with five acres in *Sphagnum*. Rigg (1958) indicates that this bog had been drained and burned over the years, thus destroying much of the bog and natural vegetation. When the bog was visited during the present study there was no evidence of *Sphagnum* or any of the typical vascular plants associated with a bog ecosystem, and the area was being used as pasture land.

Only one bog was located on Blakely Island, near the old Thatcher Bay Post Office. Rigg and Richardson (1934) describe this bog as being the smallest one noted in the islands and, at that time, contained undisturbed native vegetation. In 1958, Rigg again stressed that this bog was still in its natural state. Although three days were spent on Blakely Island, we were unable to locate this bog. A local resident suggested that when the new power line was installed, it may have eliminated the bog. The possible destruction of this bog is unfortunate because it would have provided an excellent opportunity to study the difference between low and high elevation bog systems.

The remaining six bogs range from close to sea level to near the top of Mt. Constitution on Orcas Island. The first of these, Killebrew Lake is located about 1.2 km (3/4 mile) north of Grindstone Bay, According to Rigg and Richardson (1934), a bog about 106.6 m by 152.4 m (350 x 500 feet) in size, was present, but it had been burned and pastured, thus destroying most of the natural bog vegetation. In his more recent survey, Rigg (1958) describes the Killebrew Lake area as having 12.1 hectares (30 acres) of peat and about four acres of *Sphagnum* bog. During a visit to this lake we did not find the four acres of *Sphagnum* bog, but instead we found two very small patches of *Sphagnum henryense* mixed in with sedges, and there was no evidence of vascular plants normally found in bog sites. It is possible that Rigg was mistaken in his 1958 report, or the prior and succeeding damage to the bog has been so severe that the bog has essentially disappeared.

Two bogs, (Orcas No.1, nine acres in size, and Orcas No. 2, 7.3 hectares (18 acres in size), are located fairly close together in the Mt. Woolard area, about 3.2 km (2 miles) northeast of the town of Orcas. At one time the upper bog (Orcas No. 2) was mined for peat (pers. comm. M. Grubb), although this ceased when the bog was dammed and made into a lake. This lake now contains a small island covered with *Spiraea douglasii* (hardhack), *Salix* sp. (willow), and *Pinus contorta* (lodgepole pine). Along the margins of the island, *Ledum groenlandicum* (Labrador-tea), *Sphagnum fuscum* and *S. henryense* are found. In the center of the island, *Dicranum scoparium*, *Hylocomium splendens*, and *Rhytidiadelphus triquetrus* were found on the drier sites. The lower bog (Orcas No. 1) was destroyed when it was excavated and made into a small pond.

On the southwest slope of Mt. Constitution near the Cold Springs area, several shallow peat meadows are found. Rigg (1958) refers to this as the Constitution No.1 peat area, and describes it as part *Sphagnum* bog and part sedge meadow, with some drainage running through it during the winter months. Although Rigg & Richardson (1934) classified these meadows as *Sphagnum* bogs, they fit the description of a fen better. Crum (1988) describes a fen as "a grass, sedge or reed-dominated peatland ..., that develop under the influence of mineral-rich, aerated water at or near the surface".

At the present time these meadows are dominated by *Carex* sp. (sedges) and lack the typical bog type vascular plants. Mosses found in the meadows included *Eurhynchium praelongum*, *Leptodyctium riparium*, *Fontinalis antipyretica*, *Sphagnum henryense* and *S. subsecundum*. The presence of *Sphagnum subsecundum*, a species that "grows in mineral-rich, open habitats, in sedge mats" (Crum 1988), combined with the other moss species found, further supports the concept that the Constitution No.1 peat area is not a bog, but a fen.

Finally, what is likely the only true *Sphagnum* bog within the San Juan Islands, occurs in Summit Lake near the top of Mt. Constitution. Rigg and Richardson (1934) referred to this location as the Constitution No. 2 peat area. Near the center of the lake a floating mat island has been formed and the following mosses were found: *Aulacomnium palustre*, *Bryum uliginosum*, *Calliergonella cuspidata*, *Pleurozium schreberi*, *Pohlia sphagnicola*, *Polytrichum strictum*, *Sphagnum capillifolium*, *S. fuscum*, *S. magellanicum*, *S. palustre*, *S. recurvum*, *S. rubellum*, *S. squarrosum*, and *S. subsecundum*. The typical bog vascular plants included: *Eriophorum chamissonis* and *E. gracile* (cotton-grass), *Drosera rotundifolia* (sundew), *Vaccinium oxycoccus* (wild cranberry), bog billberry, *Ledum groenlandicum* (Labrador-tea), *Kalmia occidentalis* (western swamp laurel) and several very stunted *Pinus contorta* (lodgepole pine) trees. This rich and unusual area is located within Moran State Park and is relatively inaccessible. Thus, unless there is a drastic change in the lake water level this area should remain fairly pristine.

Two other areas, both on San Juan Island, were found to have *Sphagnum* growing in them. Dr. Eugene Kozloff at the Friday Harbor Biological Laboratories suggested that I examine a small boggy area in the lower portion of the Beaverton Valley. Rigg (1958) referred to this site as a fresh-water deposit with little or no *Sphagnum*. Although attempts to ditch and drain the area have left fewer than two acres of *Sphagnum*, it harbored a rather interesting flora. Mosses collected at this site included *Aulacomnium palustre*, *Calliergonella cuspidata*, *Dicranum scoparium*, *Polytrichum juniperinum*, *Rhytidiadelphus triquetrus*, *Sphagnum capillifolium*, *S. henryense* and *S. recurvum*. The presence of *D. scoparium*, *P. juniperinum*, and *R. triquetrus* suggests a change in the hydrology of the area towards drier conditions. At the present time this area is under private ownership and is being grazed by cattle.

The second *Sphagnum* location occurs in Sportsman Lake, also located in the Beaverton Valley. When this site was visited a few small clumps of *Sphagnum squarrosum* were found growing on floating mats composed of tree and shrub roots along the west side of the lake. Rigg (1958) also mentions this site, but again refers to it as a fresh-water deposit with little or no *Sphagnum*.

These bog and bog like habitats and peat deposits are valuable resources for two reasons. First they are the only locations within the islands where the unusual bog type vascular and moss species can survive, and second, these peat deposits hold a wealth of palynological information. Although the climate is well suited for the development and maintenance of bogs, they have become a rare resource in Washington State. All of these remaining unusual bog habitats merit further protection.

CHAPTER 6

Phytogeography

A complete inventory of the flora in an area reveals patterns in distributions and raises questions as to how these patterns originated. This chapter discusses and interprets the world and the regional Pacific North American distribution patterns for the moss flora in the San Juan Islands. Summaries of the distribution elements are given in Tables 15. and 16. A complete list of species and their distributions is given in Appendix G and H . Because the islands have been subjected to a great deal of human disturbance through time, a section of this chapter focuses on these disturbances and how they have influenced the distribution of the mosses found in the islands today.

The basic goals of phytogeography are to determine and record species from a fixed location and to map the distribution of these species. The first task is accomplished through field work and the establishment of vouchers within a herbarium. Vouchers are an important part of this process as they establish a reliable data base, and make it possible for any errors in determination to be found and corrected. Before any phytogeographical comparisons can be made, floras must be developed. When the floristic information is accumulated from current fieldwork and historical collections, distribution maps can be made, and the species may then be assigned to geographical elements (Stott 1981). Elements are based on recurring patterns.

Finally an increasing number of floristic manuals are needed. According to McLaughlin (1989) "At the present time the network of available local floras is inadequate ... More floras need to be compiled - and published - for all floristic areas of the western United States...". McLaughlin's comments are based on vascular plant floras; extensive bryophyte floras with good habitat data are even more scarce.

Several factors influence the distribution of bryophytes. Historical events, including continental drift, climatic change through time and in space, glaciation or mountain uplift, interacted to determine present bryophyte patterns. Human activities have altered the distribution patterns through transport of species and the disturbance of habitat. Ecological factors are summarized by van der Pijl (1972) who states that plant migration can happen only

Table 15. The world distributions of the mosses in the San Juan Islands

Element	No. of Species	% of flora
Endemic Western North America	43	19.19
Circumboreal	92	41.07
Circumtemperate	4	1.78
Circumpolar	29	12.90
North Pacific	4	1.78
Pacific North America - Mediterranean	15	6.69
Western North America -Western Europe	16	7.14
Western North America - Eastern North America	1	.044
Western North America - Eurasia	8	3.57
Widespread	5	2.23
Unclassified	7	3.12
Total	224	100.0

Table 16. The Pacific Northwest distributions of the mosses in the San Juan Islands.

Element	No. of Species	% of flora
Coastal	27	12.05
Coastal - disjunct Humid Interior	47	20.98
Dry Interior - disjunct Coastal	9	4.01
Rocky Mountains - disjunct Coastal	2	.892
Mediterranean Climate	25	11.16
Widespread	114	50.89
Total	224	100.0

when dispersal occurs at the right time and place, and establishment follows on a suitable substratum. Specific habitat and substratum requirements are discussed in Chapter 5.

While bryophytes tend to show much wider distribution patterns than do the vascular plants, in general their patterns are similar, suggesting that similar historical and biological events influenced them (Schofield 1992a). The wide bryophyte distribution patterns may have resulted from the supposed ancient age of the bryophytes, which has provided a long time for them to establish these ranges. Furthermore, the production of large numbers of small wind blown diaspores needed for long-range dispersal may be equally important (Schofield 1992a). The dispersibility of moss spores by wind is well documented, and may occur over short or long-range distances (Crum 1972, Schuster 1983). Establishment and colonization occur mainly in areas that have "unsaturated or unexploited niches" brought about by some catastrophic event, such as volcanism or glaciation (Schuster 1983). Therefore the climatic events of the Tertiary helped to shape the bryophyte distribution patterns found at present in the world

Floristic History

According to Axelrod (1958) a Madro-Tertiary Geoflora was present in southwestern North America by the Early Cenozoic and was located between the Arcto-Tertiary and Neotropical-Tertiary Geofloras. Expansion of this flora over wide regions began after the Eocene as the drier, warmer climate began to spread. Remnants from this migration can be seen in the vascular flora in the San Juan Islands today, and include the following species: *Arbutus menziesii*, *Berberis nervosa*, and *Quercus garryana* whose fossil equivalents are well represented in the Madro-Tertiary Geoflora. Axelrod (1975) also proposes that some of the genera may have been derived from the semi-arid regions of Europe to North America that extended their range via a southerly route that he calls the Madrean-Tethyan link. Examples of vascular plants that could have utilized this route include: *Galium*, *Juniperus*, *Pinus*, and *Quercus*.

Palynological evidence from the postglacial sediments in the Saanich Inlet, British Columbia also support the early presence of the Madrean element in this geographic region. L. Heusser (1983) found large amounts of *Quercus* pollen in the late Tertiary core samples, indicating that a warmer dry climate had moved into the area. Since this mediterranean type climate developed in the late Tertiary (Axelrod 1973) and the area remained isolated from other areas with mediterranean type climates, Raven (1977) feels that this isolation may be used to explain the high endemism found in California. This same explanation possibly could be used to interpret the large number of endemic bryophyte species in this climatic zone of western North America.

After the middle Miocene a variety of species began to enter this region from the north. Wolfe (1969) indicates that even though these species entered from the north they may not have evolved in that immediate area, rather they may have originated in Eurasia and simply migrated through Alaska. Some of the northern element vascular plant species include *Salix hookeriana* (Hooker's willow), and *Gaultheria shallon* (salal), both of which are common understory species in the San Juan Islands. *Alnus sinuata* (Sitka alder), a species that is now restricted to a few scattered colonies in the San Juan Islands, and finally *Acer circinatum* (vine maple) and *Rhododendron macrophyllum*, both of which are missing from the island flora (Atkinson and Sharpe 1985), but are widespread on the adjacent mainland.

The origin of the bryophytes of the northern European element is not clearly understood. These mosses include a number of widespread wetter climate and mainly forest species such as *Plagiothecium undulatum*, *Bryum miniatum*, *Dicranum tauricum* and *Hookeria lucens* (Schofield 1984). A number of moss species are disjunct between Japan and Pacific Northwest America. Among these are *Claopodium crispifolium*, *Hypnum subimponens*, *H. dieckii*, and *Pogonatum contortum*. The mosses noted above represent fragments or centers of three different distribution patterns (Schofield 1965).

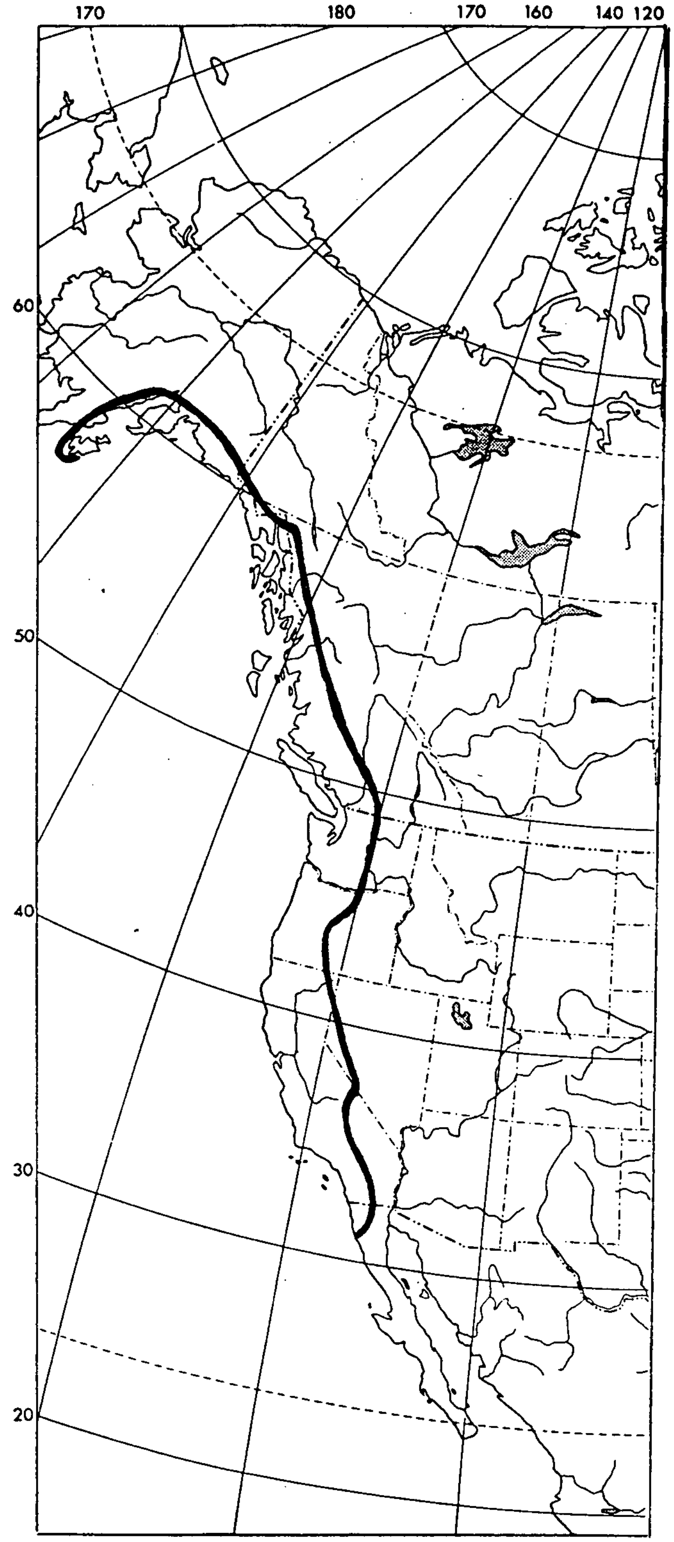
Floristic Patterns

While many floristic distribution patterns have been described in detail for the vascular plants found throughout the world, only a few bryophyte floristic patterns have been described (Herzog (1926), Miller (1982), Schuster (1983), and most recently by Schofield (1992a). Using the bryofloristic kingdoms established by Schofield (1992a) the San Juan Islands are located in Pacific North American Region of the Holarctic Floristic Kingdom. This kingdom is dominated by a high proportion of temperate elements, a vast array of environments, and occupies the largest land mass in the world (Schofield 1992a). Schofield (1992a) attributes the relative uniformity of the floristic character found in the northern portions of the kingdom to the recent colonization of the region following the retreat of the glaciers, as well as to the wide distribution of similar climates with similar habitats. The southern portion of this kingdom on the other hand reflects the spatial and climatic isolation that occurred in the region, and led to an increase in endemism. This corresponds nicely with Raven's (1977) views on the high endemism found in California. It is, therefore, not unexpected that 96.4 % of the San Juan Islands flora reflects this holarctic pattern and that 19.19 % of the flora is composed of Western North America endemic species.

The Pacific North American Region (see Figure 7.), is one of the richest bryofloristic regions in North America, with approximately 15 % of the moss species and 10 % of the hepatics occurring as endemics. (Schofield 1969, 1980, 1984, 1992a). There are also a number of genera that reach their greatest diversity in the world, including the following taxa: *Buxbaumia* (3 spp.), *Claopodium* (4 spp.), *Encalypta* (11 spp), *Homalothecium* (11spp.), and *Racomitrium* (14 spp.), (Schofield 1984).

Schofield (1992a) divides this region into a northern portion, characterized by a wetter, cooler climate, and a southern portion, with a drier, warmer climate. These two climatic sections, combined with the isolation of the region by the surrounding high mountains, creates a very distinct bryofloristic region, rich in monotypic genera and abundant, widespread endemic species (Schofield 1992a). Representative monotypic genera include: *Alsia*, *Dendroalsia*, *Leucolepis*, *Pseudobraunia*, and *Rhytidiopsis*. *Claopodium bolanderi*, *Hypnum circinale*, *Plagiomnium insigne*, and *Porotrichum bigelovii* are among the widespread endemic species found in the region. The large number of distinct and well differentiated endemics suggests that these taxa have been in this region for a long time, and survived the glaciation in either northern or, more probably, southern refugia.

Figure 7. Pacific North American Region, based on Schofield (1992a) and Takhtajan (1986).



The northern portion of this region contains a large number of taxa showing disjunctions with Atlantic Europe and south-east Asia, while the southern portion (although not as diverse and less well documented) is characterized by drought tolerant species, and is rich in endemic monotypic genera mixed with disjunct taxa from the Mediterranean region. This southern mediterranean flora may have migrated along the Tethys Sea shoreline, suggesting that it is a relictual fragment in the Pacific Northwest, (Schofield 1992a) or it may have evolved here within the Northwest (Schofield 1994) These drought tolerant species often extend into the northern portion of this region where suitable habitats exist. The San Juan Islands represent such an area because they harbor a unique blend of both southern area species (favored by a climate that is a result of the rainshadow effect created by the Olympic mountains) and the northern area species.

Phytogeographic elements were assigned to the 224 species and varieties of moss found within the San Juan Islands on the basis of both world distribution and Pacific Northwest distributions, see Tables 17. and 18. These elements were further divided into continuous distribution patterns (including endemics), and disjunct distributions. Godfrey (1977) defines a continuous distribution as "the type of distribution shown by any taxon occupying more or less all sites suitable for it within the boundaries of one given region". An endemic distribution is composed of species that occur in a restricted area usually confined to one region. Disjunct distributions occur when a species occupies two or more areas that are widely separated, yet have suitable habitat occurring in between them (Godfrey 1977). These disjunct patterns have developed as a result of millions of years of floristic change that occurred since the Tertiary period.

World Continuous Distributions

Forty one percent of the species found in the San Juan Islands reflect a Circumboreal distribution pattern. "Circumboreal species are generally considered to have distributions resulting from a modification of a widespread pre-Pleistocene distribution" (Worley 1972). Representative species include: *Aulacomnium androgynum*, *Dicranum fuscescens*, *Fontinalis antipyretica*, and *Hylocomium splendens* (See Figure 8).

Table 17. World phytogeographic elements in the Northern Hemisphere.

1. CONTINUOUS DISTRIBUTIONS
a. Circumboreal (CB)
b. Circumtemperate (CT)
c. Circumpolar (CP)
d. Endemic Western North America (WNA)
e. North Pacific (NP)
f. Widespread
2. DISJUNCT DISTRIBUTIONS
a. Bipolar (BP)
b. Pacific North America - Mediterranean
c. Western North America - Eastern North America
d. Western North America - Eurasia
e. Western North America - Western Europe

Table 18. Pacific Northwest phytogeographic elements.

1. CONTINUOUS DISTRIBUTIONS
a. Coastal (C)
b. Mediterranean Climate (MC)
c. Widespread (W)
2. DISJUNCT DISTRIBUTIONS
a. Coastal - Humid Interior (CHI)
b. Dry Interior - Coastal (DIC)
c. Rocky Mountain - Coastal (RMC)

Figure 8. The Circumboreal pattern in the Northern Hemisphere of the world distribution of *Hylocomium splendens*. (based on Schofield 1974)

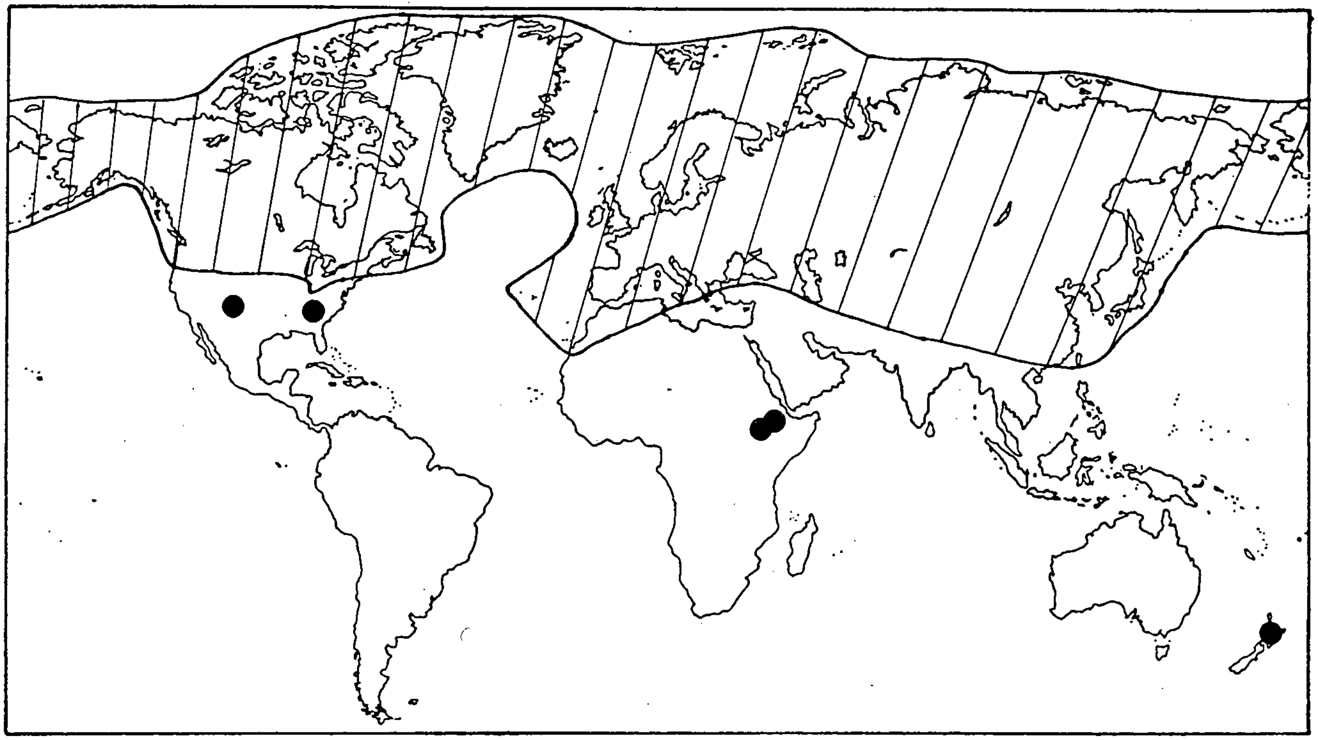
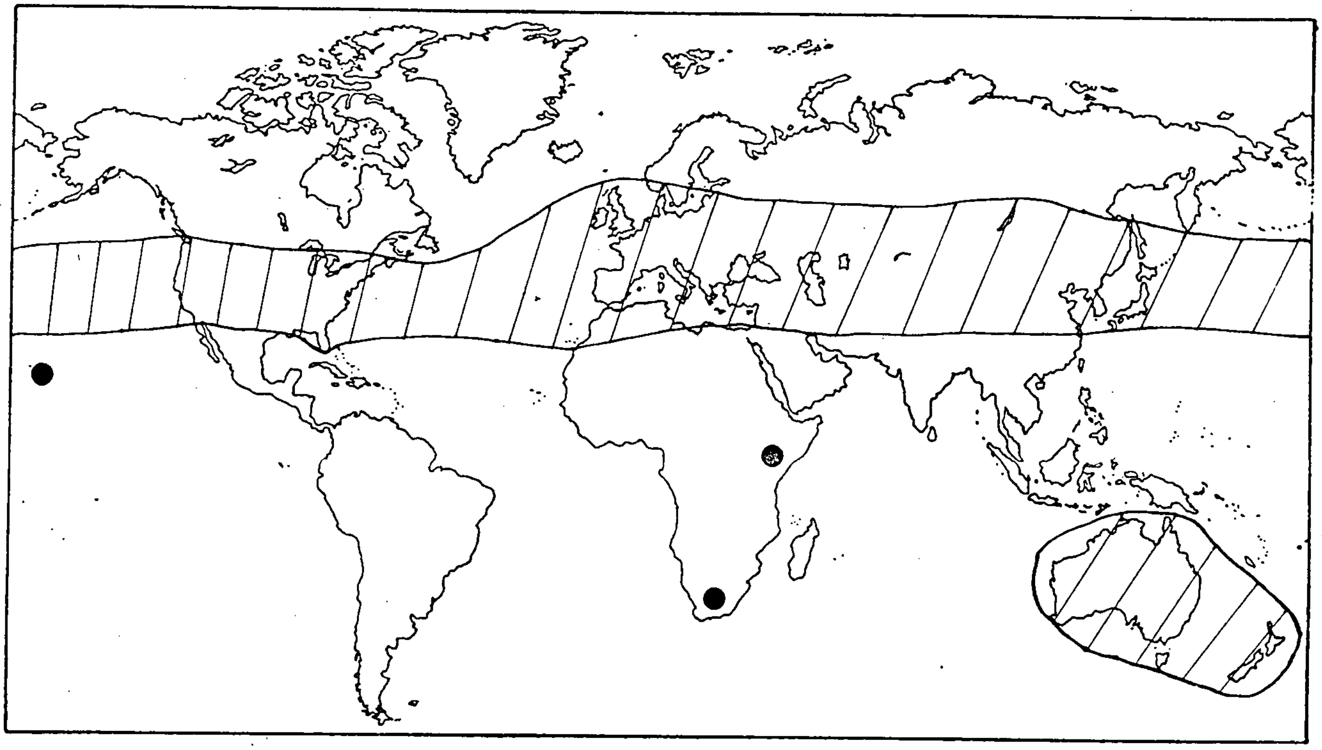


Figure 9. The Circumtemperate pattern in the Northern Hemisphere of the world distribution of *Grimmia laevigata*. (based on Crum and Anderson 1981, Ignatov and Afonina 1992, Nyholm 1956)



Only four species (1.78 %); *Didymodon fallax*, *Grimmia laevigata* (see figure 9), *G. pulvinata*, and *Phascum cuspidatum* reflect a Circumtemperate distribution pattern. While 29 species (12.9 %) reflect a Circumpolar distribution. Among these species are: *Aulacomnium palustre* (see figure 10), *Calliergon giganteum*, *Leptodictyum riparium*, *Sphagnum squarrosum*, and *Warnstorfia fluitans*.

The North Pacific distribution pattern has been discussed at length by Schofield (1965, 1969, 1980,1984) and appears to reflect three possible patterns of origin. One theory is that the center of this distribution was located in Japan and the North American populations reflect remnants of a wider distribution. Another theory is that hyperoceanic North America was the center of origin and that fragments extended into Japan. The final theory is that the flora is a fragmented amphi-Pacific distribution. North Pacific element mosses found in the San Juan Islands include the following four species: *Claopodium crispifolium*, *Hypnum dieckii* (see figure 11.), *H. subimponens*, and *Pogonatum contortum*, and represent only 1.78 % of the flora. Three of the species, *Hypnum dieckii*, *H. subimponens* and *Pogonatum contortum* are examples of the fragmented amphi-Pacific distribution pattern which "appear to be ancient relict populations of Tertiary times" (Schofield 1980). *Claopodium crispifolium* has its greatest distribution in Pacific North America and is disjunct as a few populations in Japan, thus implying an hyperoceanic North American center of origin, and expanded the range along the Aleutian Chain.

Widespread or cosmopolitan species are those that occur on all or on most of the continents throughout the world. The following five species (2.23 %) exhibited this distribution pattern: *Bryum argenteum*, *Ceratodon purpureus*, *Funaria hygrometirca*, *Pseudoscleropodium purum*, and *Weissia controversa*. With the exception of *Pseudoscleropodium purum* all of the above species were found on open, inorganic substrata. While *Pseudoscleropodium purum* is considered to be widespread in the Northwest it was found only once on soil mixed in among the grass in an old agricultural field.

Pseudoscleropodium purum (European species) was first reported in the Pacific Northwest when Lawton (1960) noted that the species was found in a lawn and flower bed in the Seattle area. At that time she suggested that the material had been introduced into the area

Figure 10. The Circumpolar pattern of the Northern Hemisphere of the world distribution of *Aulacomnium palustre*. (based on Schofield 1974)

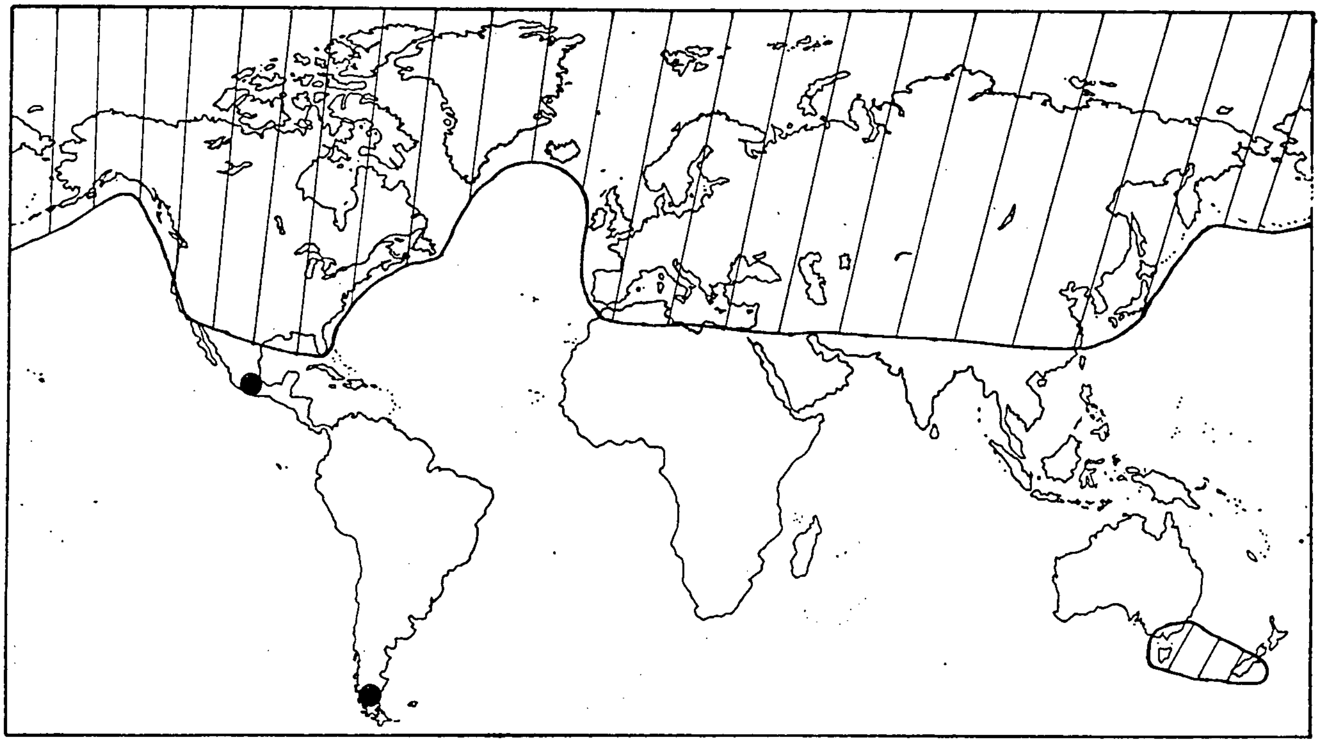
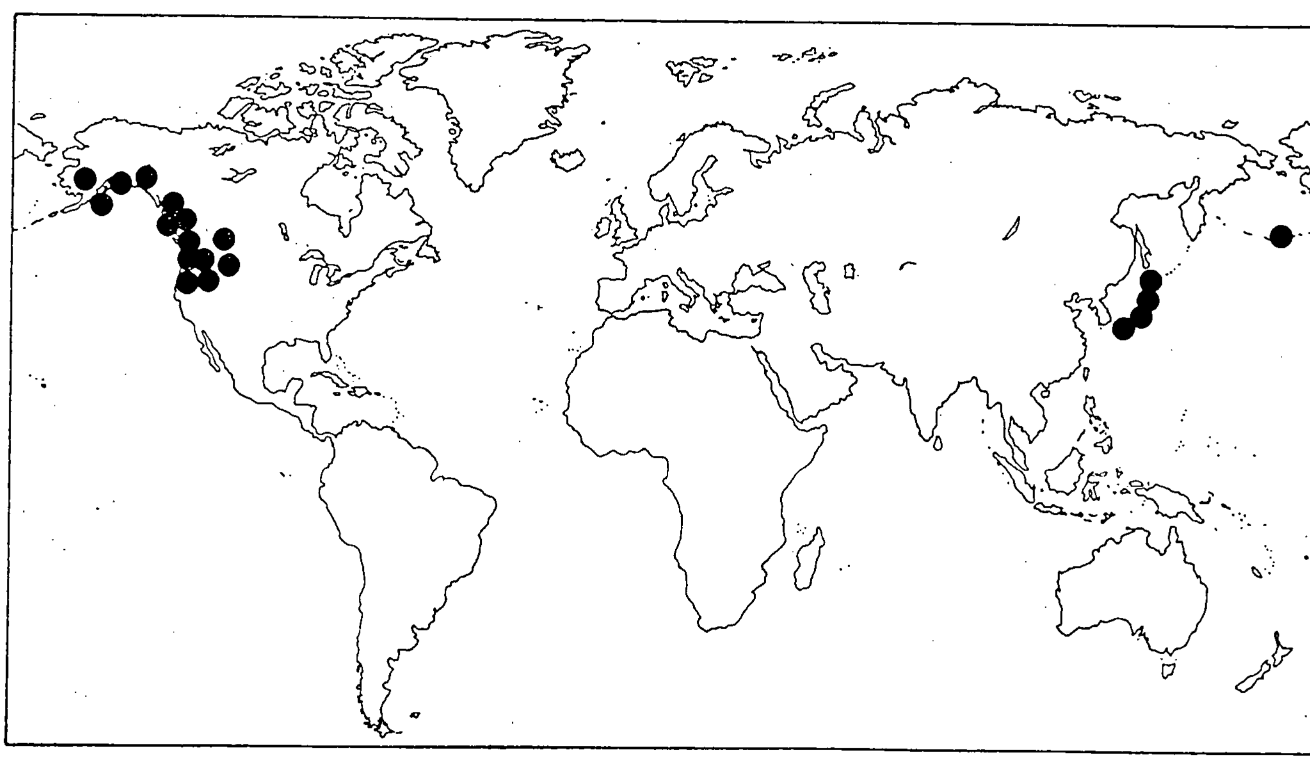


Figure 11. The North Pacific pattern of the world distribution of *Hypnum dieckii*. (based on Schofield 1965)



by way of imported garden plants. Dickson (1967) announced the discovery of this species on the islands of St. Helena and Tristan da Cunha, and suggested that the moss was first introduced to St. Helena from Europe. The introduction to Tristan da Cunha from St. Helena most likely occurred when crates of young trees packed in *P. purum* were shipped to the island and the moss was scattered when the trees were planted. It is likely that this moss was introduced to the Shaw Island site by the original property owner, a landscape architect who brought in non-native plant material to landscape around his home. Although this introduction was probably from the Seattle area where *P. purum* has become fairly well established, and not directly from European material, it has become well accepted that this species has been introduced throughout the world by human horticultural interests and activities.

Seven species (3.12 %) were assigned to the unclassified category because either they did not fit into a particular world distribution pattern, or the species concept was not clear; therefore, defining the distribution was not possible. Among the species placed in this group were *Antitrichia curtipendula, Crumia latifolia, Isothecium myosuroides, Pleuridium acuminatum* and *Sphagnum recurvum*. For a complete list of the world distribution patterns see Appendix G.

Endemic Western North American species composed 19.2 % of the San Juan flora. This phytogeographic element represented the third largest component of the flora. These endemic species can be divided into three groups based on their distributions. The first group is composed of those species that are widespread in the islands and elsewhere, such as *Anacolia menziesii, Claopodium bolanderi, Eurhynchium oreganum*, and *Neckera douglasii*. The second group is composed of species that are widespread elsewhere, but are uncommon in the islands (probably a result of not enough suitable habitats), and include *Dicranella pacifica, Rhytidiopsis robusta*, and *Ulota megalospora*. Finally the third group includes the endemic species that occur only in the mediterranean climate areas. These drought tolerant species include: *Amphidium californicum, Homalothecium arenarium, H. nuttallii, H. pinnatifidum* (all widespread throughout the islands), *Trachybryum megaptilum, Alsia californica, Dendroalsia abietina* (see Figure 12.), and *Fissidens ventricosus* (all with limited distributions in the islands.) Schofield

(1969) suggests that these endemic species survived during the Pleistocene in forested areas south of the glacial boundary, and could have re-entered the region during the hypsithermal interval (Deevey and Flint 1957) when the climatic conditions became warmer.

Disjunct World Distributions

Disjunctions can generally be interpreted as the result of two possible explanations, long-distance dispersal from a parent population, or persistent fragments from a more continuous historical distribution, that has been disrupted by climatic change, continental drift or a catastrophic event (Godfrey 1977). The bryophyte disjunct patterns used in this paper were recognized and discussed by Schofield and Crum (1972), and Schofield (1969, 1980).
A total of 40 species (17.85 % of the flora) showed some type of disjunct distribution pattern, with the largest percentage of species (13.83 %) disjunct between Western North America and Western Europe or Pacific North America and Mediterranean Europe. The Western North American - Western Europe element is composed of both oceanic and alpine species that are probably persistent remnants of an early Tertiary circumboreal flora (Schofield 1969). Representative species include *Andreaea megistospora* (see Figure 13.), *Bryum miniatum*, *Hedwigia stellata*, and *Plagiothecium undulatum*. *Andreaea megistospora* occurs from sea level to subalpine elevations in oceanic regions, and is found in coastal Alaska, British Columbia, Scotland, England, Ireland, Wales, Norway, and in two Washington State locations (Murray 1987). The San Juan collection represents the third location for this species within the state of Washington, and its occurrence reflects the cool humid environment found on Mt. Constitution.

Eight species (3.57 %) occur as disjuncts between Western North America and Eurasia. This element represents a mixture of taxa that were part of an ancient Temperate amphi-Pacific Tertiary flora and part of the Circumboreal Tertiary flora (Schofield 1965, 1969, 1984). During the Pleistocene glaciations these taxa probably survived in the unglaciated areas of Alaska and the Yukon, Coastal Alaska and British Columbia refugial sites or south of the glacial boundary (Schofield 1980). Migration of these taxa occurred after the glaciers retreated and the climate became favorable for recolonization. The "persistence of these species in western North America

Figure 12. The Western North American Endemic pattern of the world distribution of *Dendroalsia abietina*. (based on Manuel 1974 and Schofield 1980)

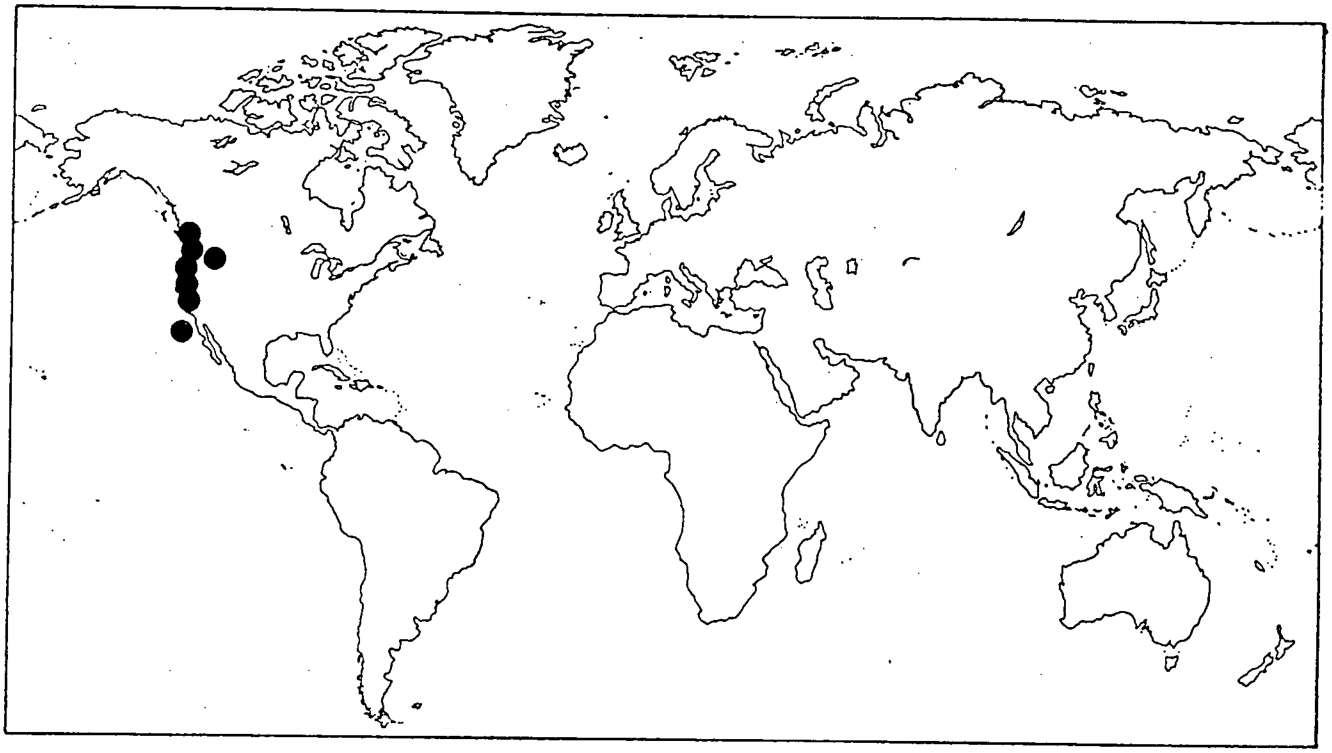
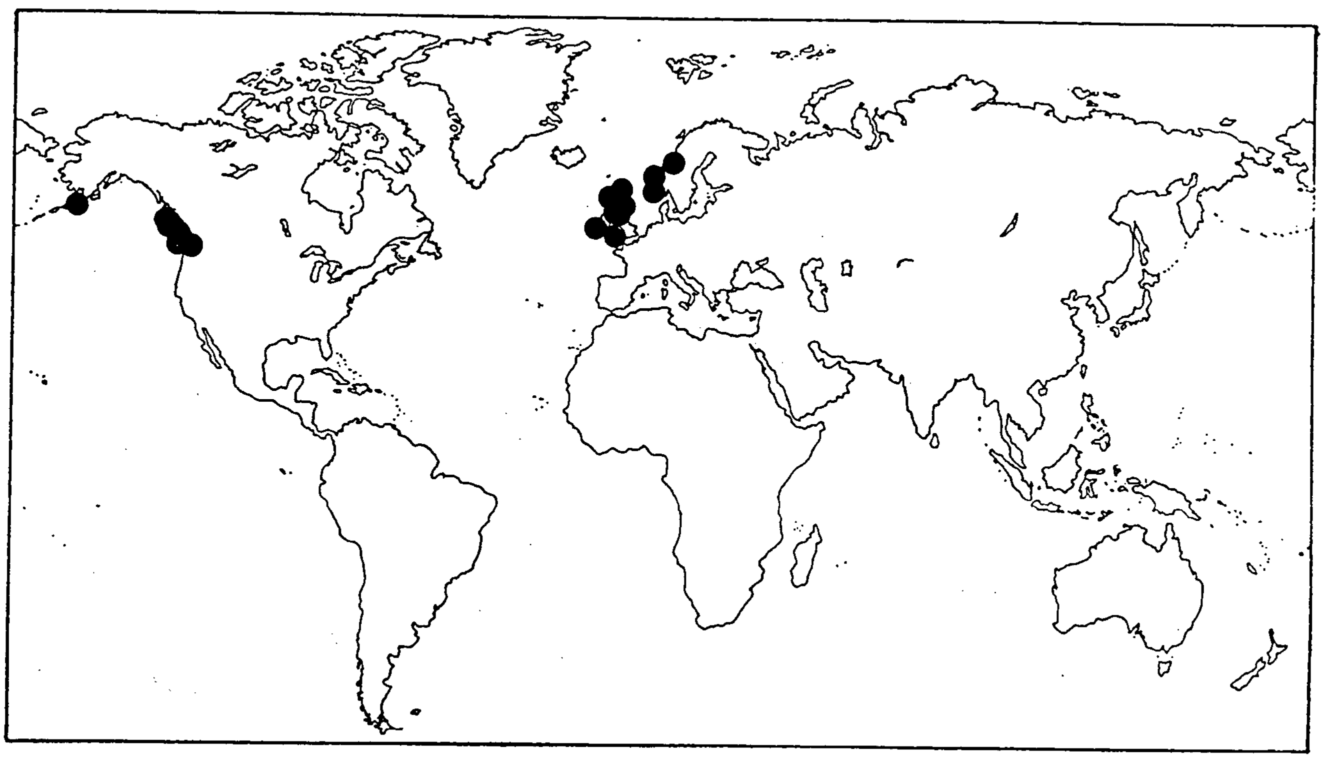


Figure 13. The Western North American - Western Europe disjunct pattern of the world distribution of *Andreaea megistospora*. (based on Murray 1987)



is related to continued availability of suitable conditions over a very extended period of time" (Schofield 1984). Representative species of this element include *Didymodon vinealis* var. *vinealis*, *Epipterygium tozeri*, *Grimmia trichophylla*, *Orthotrichum hallii* (see Figure 14), and *Plagiothecium undulatum*.

The recent location of *Orthotrichum hallii* in the Altair Mountains of China by Tan (Lewinsky-Haapasaariana and Tan 1995) is of particular interest because it was originally known only from western North America. Vitt (1971) considers this species to be a more recently evolved taxon in the North American flora, therefore it probably migrated to Asia from western North America, although until further populations of *O. hallii* are found in China it is difficult to speculate how it got into Asia. The Pacific North American distribution of *O. hallii* is discussed later in this chapter.

Two species, *Hookeria lucens* and *Pseudoleskea stenophylla* follow this disjunct distribution pattern and occur on the mainland fairly frequently, but were not found in the San Juan Islands flora. The absence of the *Hookeria* is not surprising because it is restricted to damp or wet soil in moist wooded areas, and this habitat is not common in the islands. *Pseuodleskea stenophylla*, on the other hand, is commonly found on the branches and trunks of living trees, particularly understory species such as *Acer circinatum* (vine maple) on the mainland. Since vine maple is not found in the islands at the present time it is possible that the *Pseudoleskea stenophylla* did not extend its range back into the islands for the same reasons that prevented the vine maple from returning.

The Western North America - Eastern North America element is represented by one North American endemic species, *Heterocladium macounii* (see Figure 15). Ten other taxa reflect this distribution pattern only in North America but are essentially circumboreal in their world distributions. Schofield (1969, 1972, 1980) discusses this element extensively and proposes that these species were once part of a widespread flora that became fragmented during the Pleistocene glaciation. It is most likely that these taxa survived south of the glacial boundaries, migrating northward after the glaciers retreated. *Heterocladium macounii* is thought to be a refugial species in eastern North America because it is found only in unglaciated areas in

Figure 14. The Western North American - Eurasia disjunct pattern of the world distribution of *Orthotrichum hallii*. (based on Lewinsky-Haapasaari and Tan 1995, Vitt 1973)

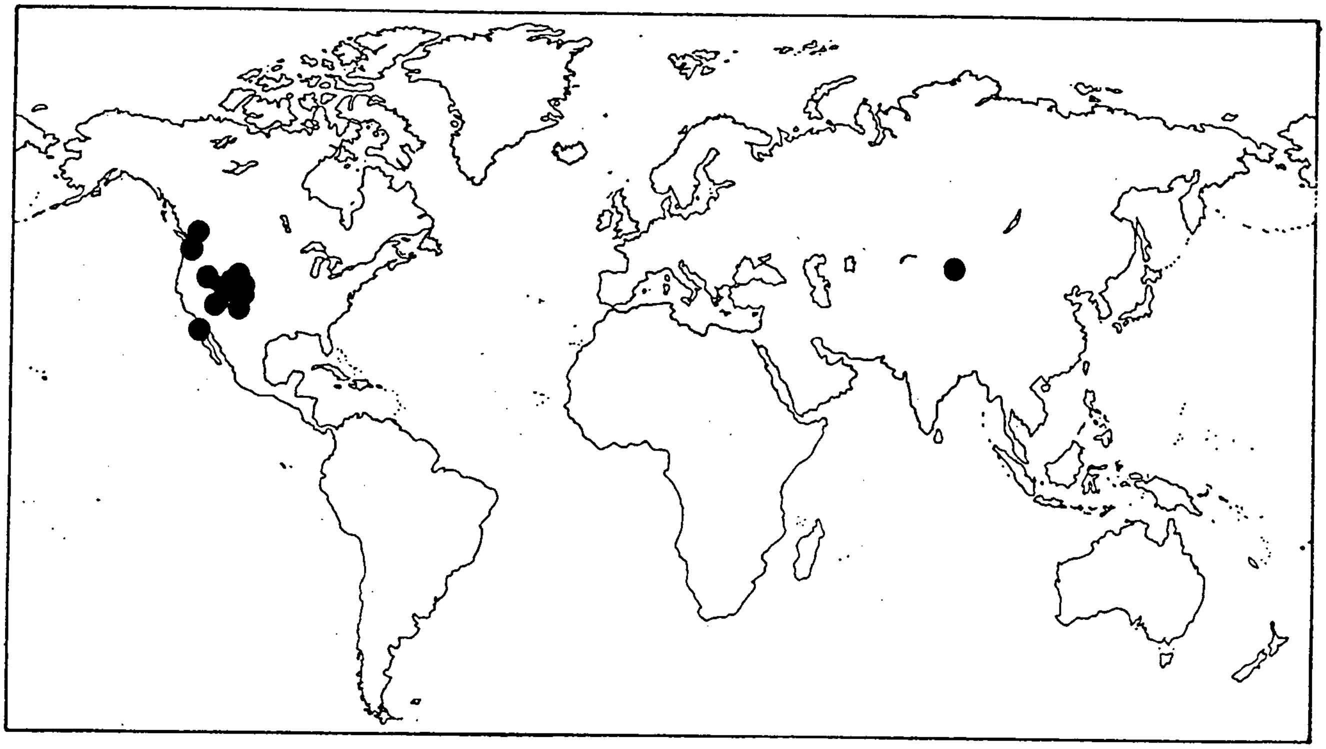
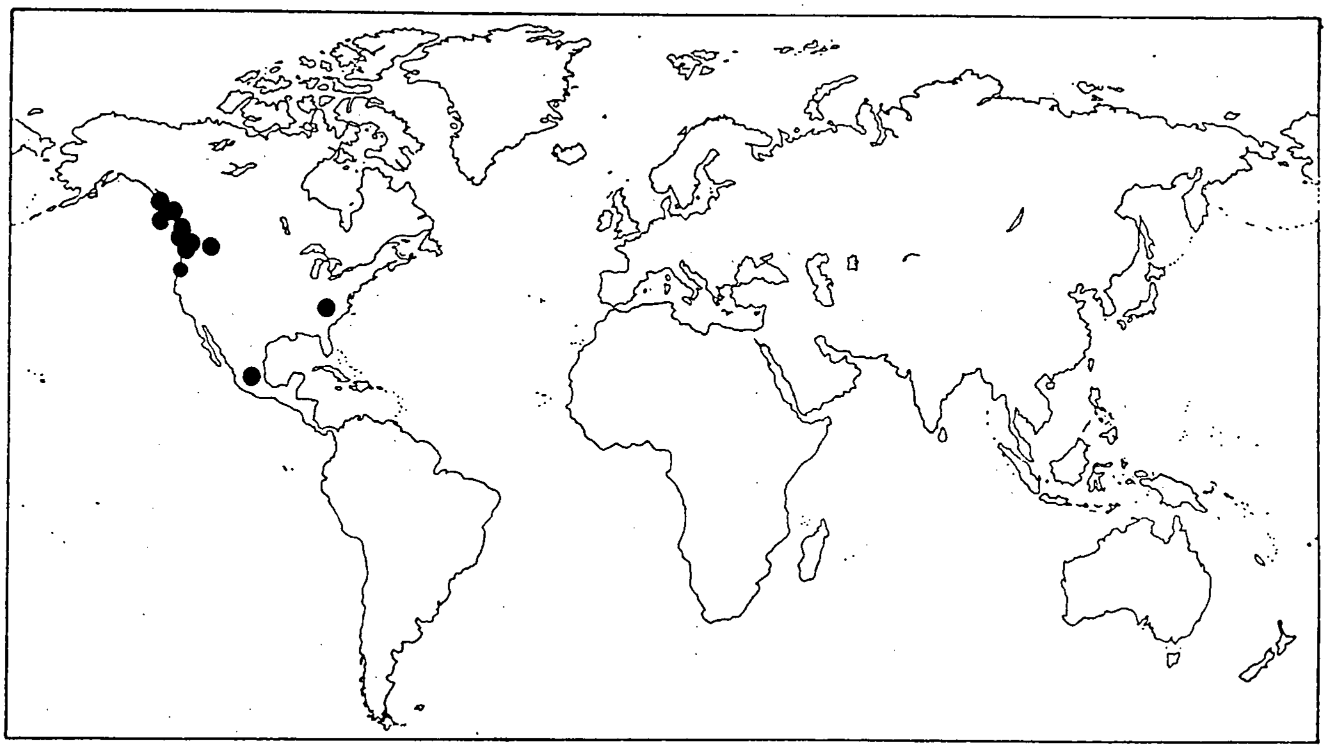


Figure 15. The Western North American - Eastern North American disjunct pattern of the world distribution of *Heterocladium macounii*. (based on Schofield 1985)



the southern Appalachians in the east, in the west it is widespread. Schofield (1985a) suggests that the widespread occurrence of this species could be the result of the western populations reproducing sexually, giving the species greater heterozygosity and a consequent wider habitat tolerance. Species that have a wider world distribution but show this east-west disjunction in North America include *Dryptodon patens*, *Neckera pennata*, *Pseudotaxiphyllum elegans*, *Tortula papillosa* (all woodland species), and *Schistidium maritimum* and *Ulota phyllantha* (both maritime species).

While *Tortula papillosa* is common throughout the northeastern states, Steere (1940) comments that a "single small collection from California, correctly named, has been seen". Schnooberger (1942) also remarks in her paper on the distribution of *Tortula papillosa* that the only western locality is in California. Therefore, the four collections of this species from two of the San Juan Islands represent the second western North American locality and the first report of this species for Washington state. Although this epiphytic species is similar to *Tortula latifolia* (a common western species) it can be readily distinguished by its blunt leaves.

Neckera pennata presents another interesting distribution pattern, although it does occur in the Rocky Mountains and south into Arizona. The *Neckera* that is found in that region appears to be different morphologically and in habitat from the eastern material. While this Rocky Mountain type was recognized as *N. pennata* var. *tenera* by Flowers (1973) and has been called *Neckera oligocarpa* by others, at the present time it is usually included with *Neckera pennata.* Further work needs to be done to resolve this taxonomic problem. In the meantime the material collected in the San Juan Islands resembles the eastern material and not this Rocky Mountain type.

The bipolar disjunct species were identified in Appendix I only to provide a better understanding of the overall world distributions for the species found within the San Juan Islands. A representative species reflecting this pattern is *Plagiothecium denticulatum* (see Figure 16). None of these taxa represent disjuncts from the southern Hemisphere to the San Juan Islands, therefore this bipolar distribution pattern did not influence the moss flora of the islands.

Additional information on bipolar disjunct patterns can be found in the papers by Schofield (1969, 1974, 1980).

One of the more significant elements of the San Juan Islands moss flora is the Pacific North America - Mediterranean disjuncts. Fifteen species (6.69 %) show this disjunct pattern and all of them are drought tolerant species that occur within the southern portion of the Pacific North American Region. This disjunct element has been discussed in detail by Schofield (1969, 1980, 1984, 1988b, 1994), and when combined with the Western North American endemic species found in the islands, it comprises 26 % of the moss flora.

Although the origin of these disjunct species is not completely clear, two possible scenarios have been suggested by Schofield (1988a, 1994). The first idea is that the center of origin was located in the Mediterranean region of Europe and the taxa migrated to Pacific North America. The other scenario is just the opposite, i.e., the taxa originated in the Pacific North American area and migrated to the Mediterranean region. Both of these ideas suggest a migration route along the coastal shores of the Tethyan Sea during the late Tertiary. Therefore these disjunct species were probably well established in the Pacific Northwest prior to the last glacial episode, and survived glaciation south of the glacial boundary in the warmer and drier areas. It is probable that many migrated back into the region during the Hypsithermal Interval. Representative species of this element include *Antitrichia californica* (see Figure 17), *Dicranella howei*, *Orthotrichum lyellii*, and *Scleropodium cespitans*.

Since the San Juan Islands were heavily glaciated during the Pleistocene all of the vegetation that covers the islands today is composed of species that have vegetated the islands since deglaciation. The regional floristic patterns reflect those post Pleistocene migrations and they are important in interpreting the moss flora of the islands at the present time.

Figure 16. The Bipolar pattern of the world distribution of *Plagiothecium denticulatum*.
(based on Schofield 1974)

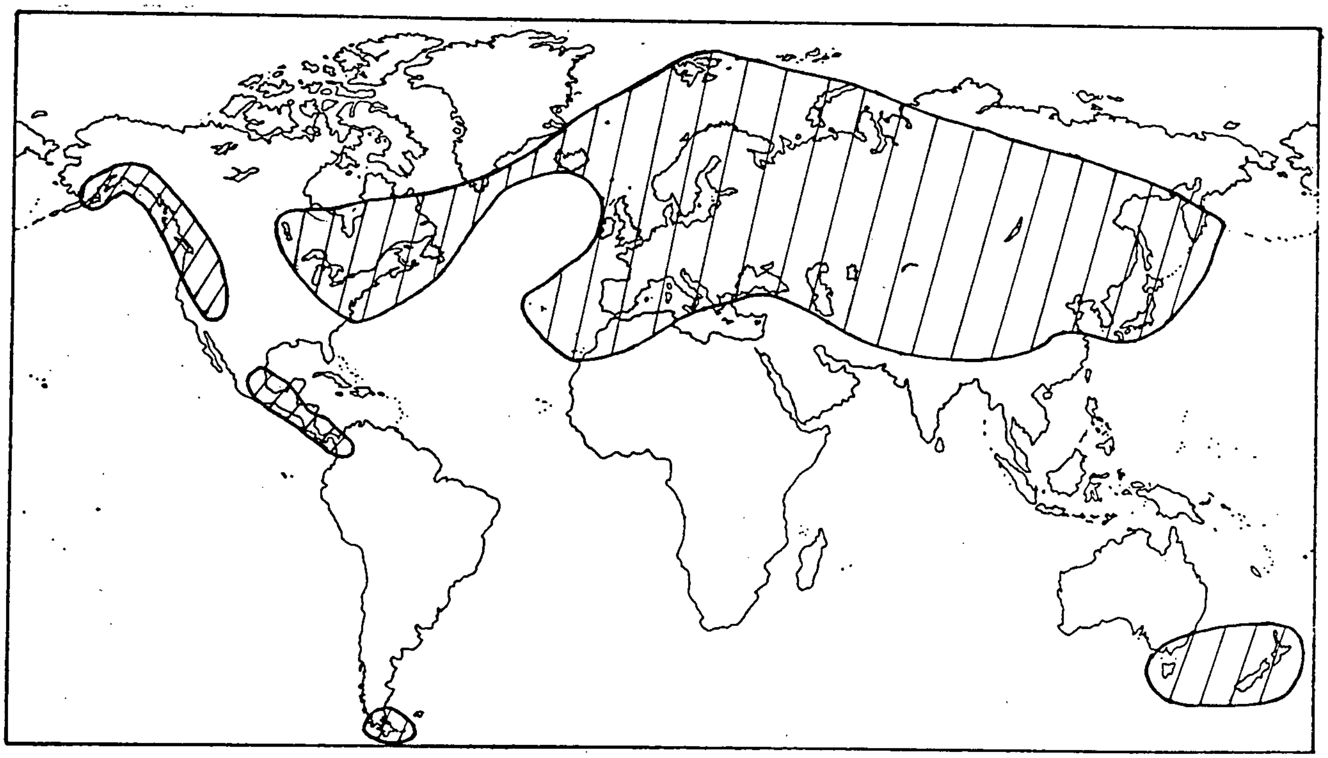
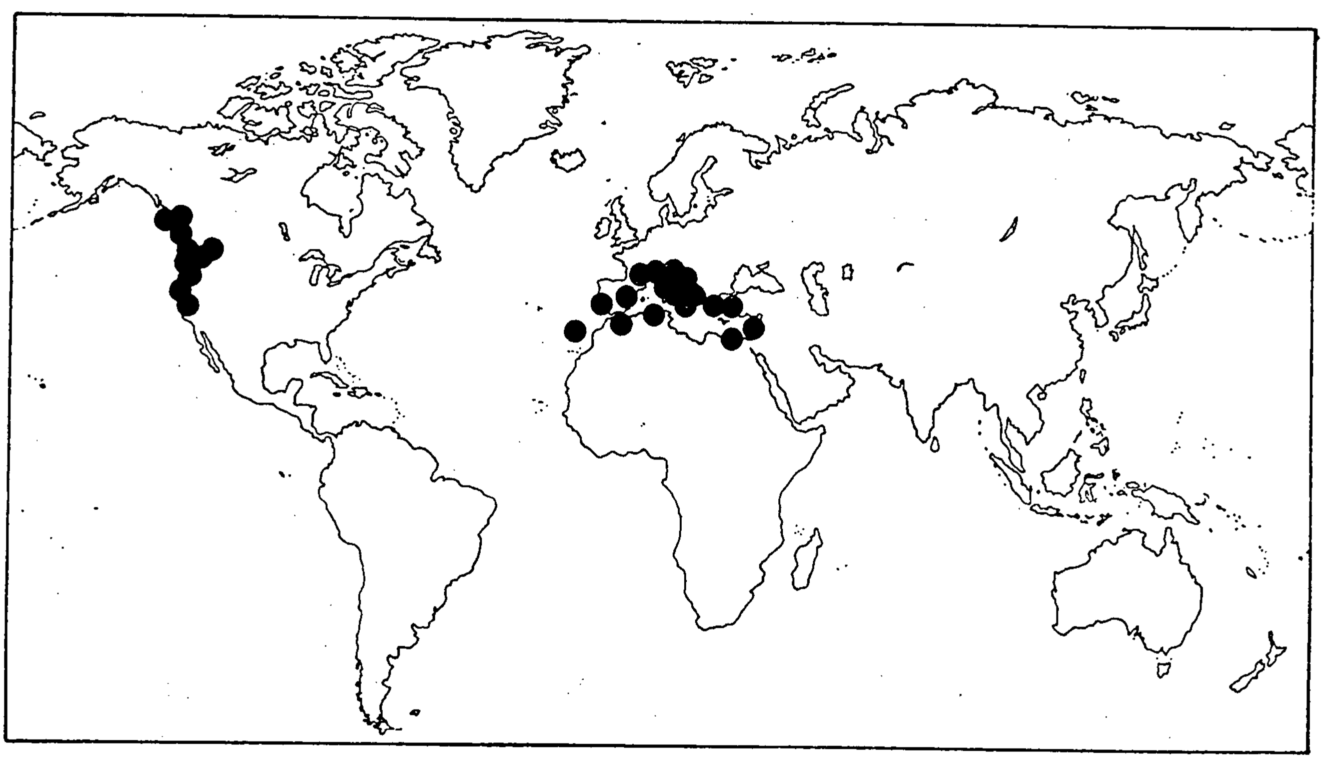


Figure 17. The Mediterranean pattern of the world distribution of *Antitrichia californica*.
(based on Schofield (1980)



Pacific Northwest Distributions

The bryophyte distribution patterns within the Pacific North American Region have been documented and discussed by Schofield (1969, 1976, 1988a). Using a slightly modified version of these geographic distributions the 224 species and varieties of moss found in the San Juan Islands were assigned to six Pacific Northwest distributional elements.

These elements include Coastal (species that occur on the west side of the Cascade and Coast Mountains), Coastal disjunct to the Humid Interior (species that are found in the Coastal area and then reappear in the humid areas east of the Cascade and Coast Mountains), Dry Interior disjunct Coastal (species that occur predominantly east of the Cascades and Coast Mountains and west of the Rocky Mountains), Rocky Mountain disjunct Coastal (species that have the bulk of their range in the Rocky Mountains but reappear in limited areas in the Coastal area), Mediterranean Climate (includes species that occur in the dry climatic areas west of the Cascade Mountains), and finally, Widespread (species that occur throughout the Pacific Northwest).

Each of these elements is discussed in detail below. For a complete list of species and their assigned geographic element, see Appendix H . Table 16. gives a summary of the number of species found in each element and the percent of the total flora they represent. A representative species was chosen from each element and a distribution map is provided to show each of the distributions.

Since the Widespread species form the foundation of most of the Pacific Northwest flora the large species diversity (114 species or 50.9 %), found in the San Juan Island flora was not unexpected, and it is consistent with the moss flora of British Columbia where just over 100 species belong to this element (Schofield 1976). Species in this element are usually tolerant of a wide variety of environment conditions and are capable of expanding their range rapidly. Representative species fall into two categories, those that occur on 25 % (or more) of the islands, e.g. *Ceratodon purpureus*, *Pleurozium schreberi* (see Figure 18a.), *Polytrichum juniperinum*, *P. piliferum* and *Rhytidiadelphus triquetrus*, and those that while widespread elsewhere but occur on only 3.5 % of the islands. Restricted species include *Blindia acuta*, *Polytrichum strictum*, *Sphagnum palustre* and *S. subsecundum*, and reflects the more scarce habitats within these islands.

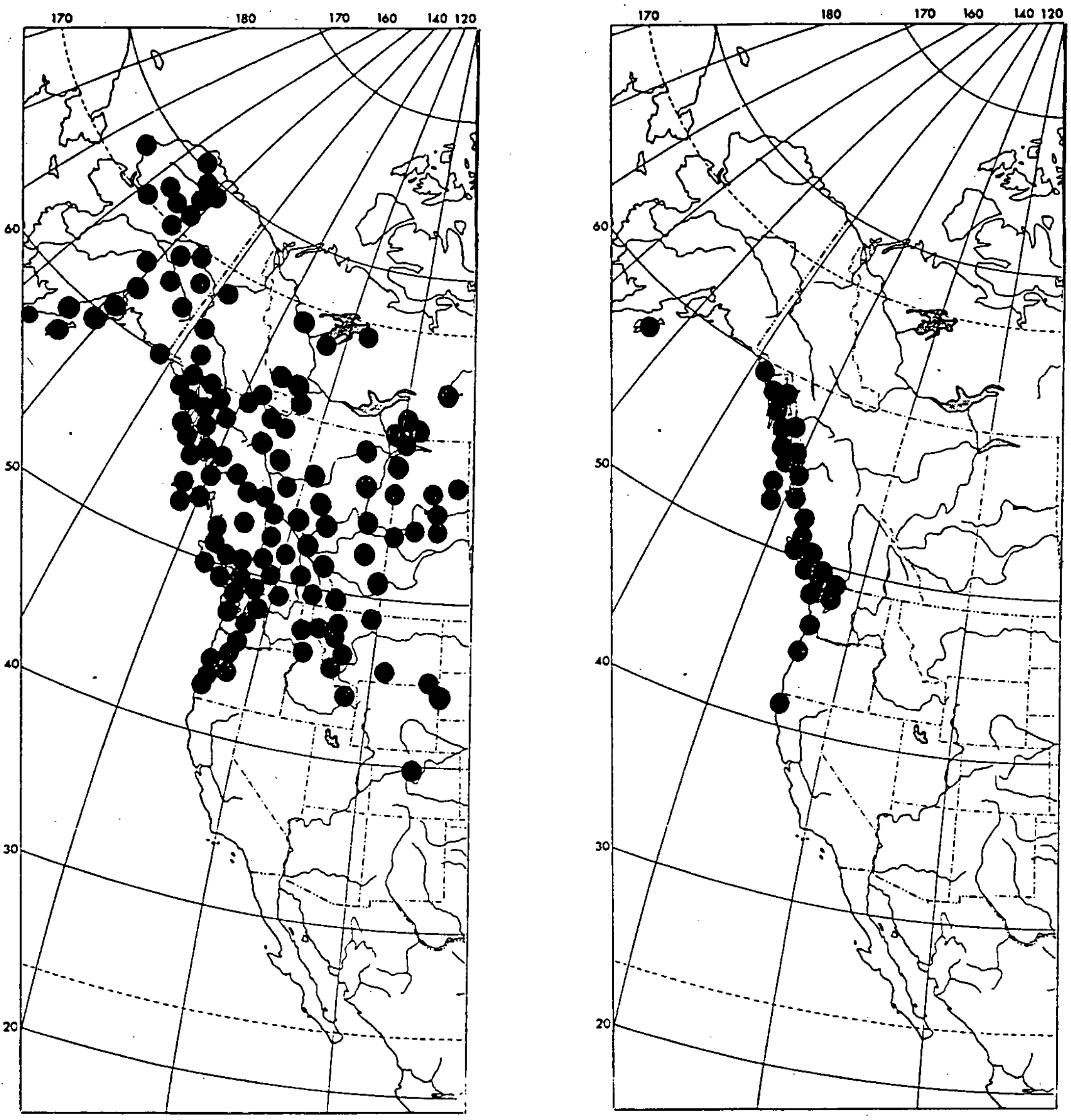
The Coastal element, consisting of the more humid sites west of the mountain crest, contains 27 species, or 12.0 % of the flora. Two species, *Schistidium maritimum* and *Ulota phyllantha*, obligate maritime shoreline species, are in this element. On the other hand, *Bryum amblydon*, a circumpolar species, is usually found in the sub-alpine to alpine areas in this element. On the basis of where the species may have survived during the Pleistocene glaciation, Schofield (1976) divides this element into the following three components, "species with a more northern distribution, species of general distribution and subalpine-alpine species".

Species of a more northern distribution, such as *Andreaea megistospora*, may have survived in such refugial sites as the Queen Charlotte Islands, and migrated southward after the glaciers retreated or they could have survived south of the glacial boundary and subsequently extended northward to sites that are climatically similar to the sites where they survived glaciation.

Work by Mathewes (1973) suggests that some of the species found in this element were present in the southern parts of British Columbia as early as 10,000 years ago, and these species may have survived in refugia south of the glacial boundary. Therefore the species of general distribution and the subalpine - alpine species most likely returned to the region from southern refugia. Representative species of the general distribution include *Claopodium crispifolium*, *Dicranoweisia cirrata*, *Schistidium maritimum*, and *Ulota phyllantha*. (see Figure 18b). True subalpine - alpine habitat does not occur within the San Juan Islands, therefore this component is not represented in the islands.

Forty-seven species (20.9 % of the flora) were found within the Coastal - disjunct to the Humid Interior element. The species in this distribution pattern are well represented in the coastal areas, yet reappear in isolated populations on the east side of the mountains in areas that are climatically and vegetationally similar to the west side. A substantial number of these species are Western North American endemics, including the following species: *Anacolia menziesii*,

Figure 18. The Pacific Northwest distribution of: A. *Pleurozium schreberi, a* widespread pattern. B. The Coastal distribution pattern of *Ulota phyllantha.*



A. (based on herbarium records at UBC)

B. (based on herbarium records at UBC)

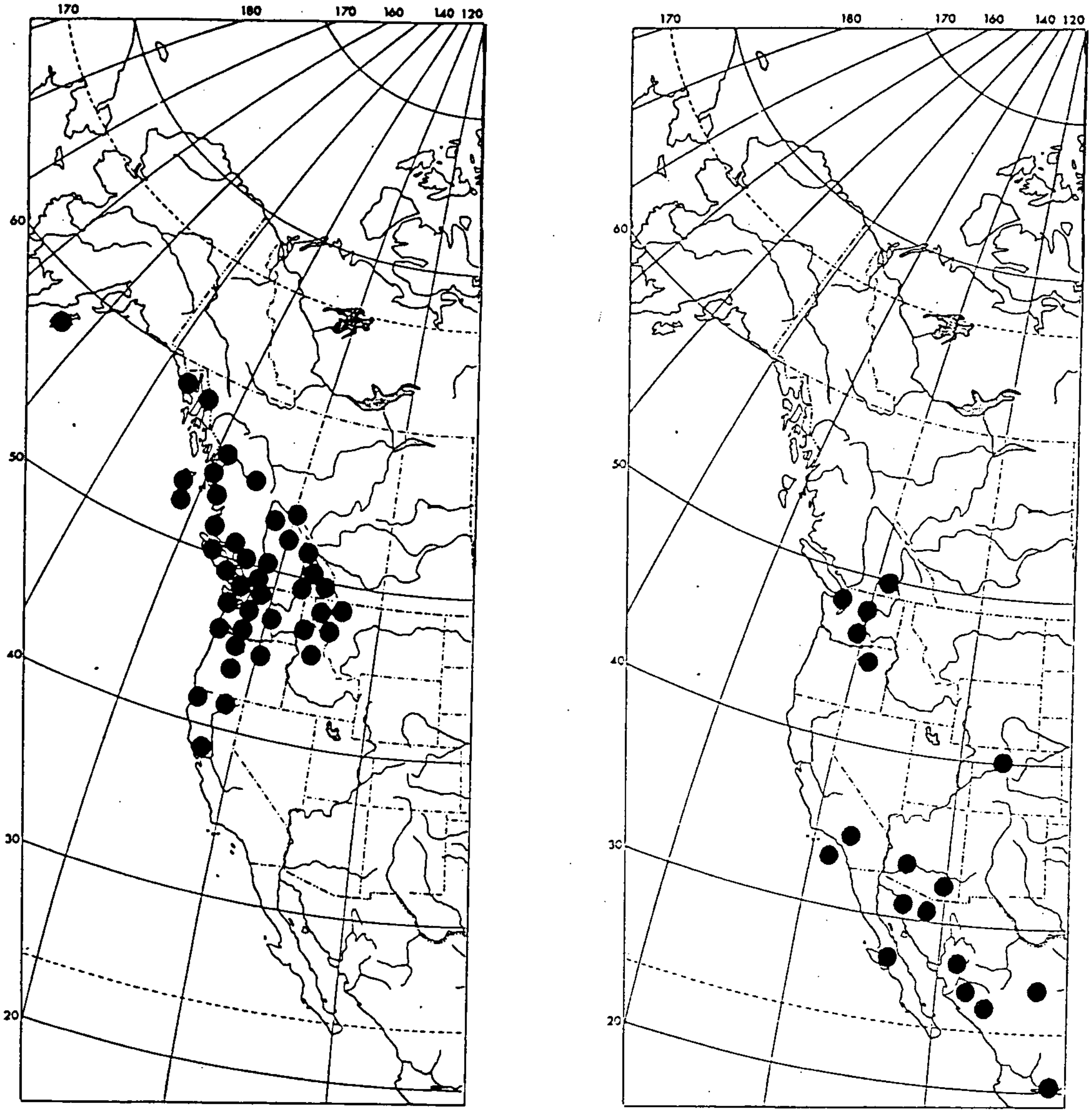
Atrichum selwynii, *Claopodium bolanderi* (see Figure 19a.), *Neckera douglasii*, and *Rhytidiopsis robusta*. Other species, such as *Bryum miniatum*, *Plagiothecium undulatum*, and *Pogonatum contortum*, are disjuntive from western Europe or eastern Asia.

Only nine species, or 4.0 % of the flora represent the Coastal - disjunct to the Dry Interior element. The species of this element usually occur on mineral soil or on rocks, and survive only in very dry areas; the low diversity in this element is not unexpected. Representative species include *Desmatodon obtusifolius*, *Funaria muhlenbergii*, *Grimmia laevigata*, and *Trichostomopsis australasiae* (see Figure 19b.). It is reasonable to speculate that these species survived in refugial sites well south of the glacial boundary and extended northward after the glaciers retreated, possibly as recently as the hypsithermal interval (Deevey and Flint 1957).

Atkinson and Sharpe (1985) found, in the vascular plant flora, that "a number of species that are more common east of the Cascades have been found in the San Juans". Representative species include *Juniperus scopulorum* (Rocky Mountain juniper), *Poa scabrella* (pine bluegrass), *Opuntia fragilis* (prickly pear cactus), and *Woodsia scopulina* (Rocky Mountain woodsia). This demonstrates a disjunct pattern that occurs between the Rocky Mountains and the San Juan Islands.

Two species of moss, *Drepanocladus crassicostatus* and *Orthotrichum hallii* seem to be best placed in the Rocky Mountain - disjunct Coastal element. These two species are very limited in distribution and occur on only two of the islands. *Drepanocladus crassicostatus* was described by Jannssens (1983a) from living populations and Pleistocene and Holocene age fossil material. He further comments that this new North American taxon is "clearly a western species with arctic-alpine aspect" (Janssens 1983b). The early fossil records and arctic-alpine aspect suggest that *D. crassicostatus* was part of the Arcto-Tertiary Geoflora that was widespread at one time. Living populations of this species have been recorded from Colorado, Wyoming, British Columbia and the Yukon Territory. The recent collection noted above was made during this study and represents the first record for Washington state.

Figure 19. The Pacific Northwest distribution of: A. *Claopodium bolanderi*, a Coastal disjunct to the Humid Interior pattern. B. *Trichostomopsis australasiae*, a Dry Interior disjunct pattern.



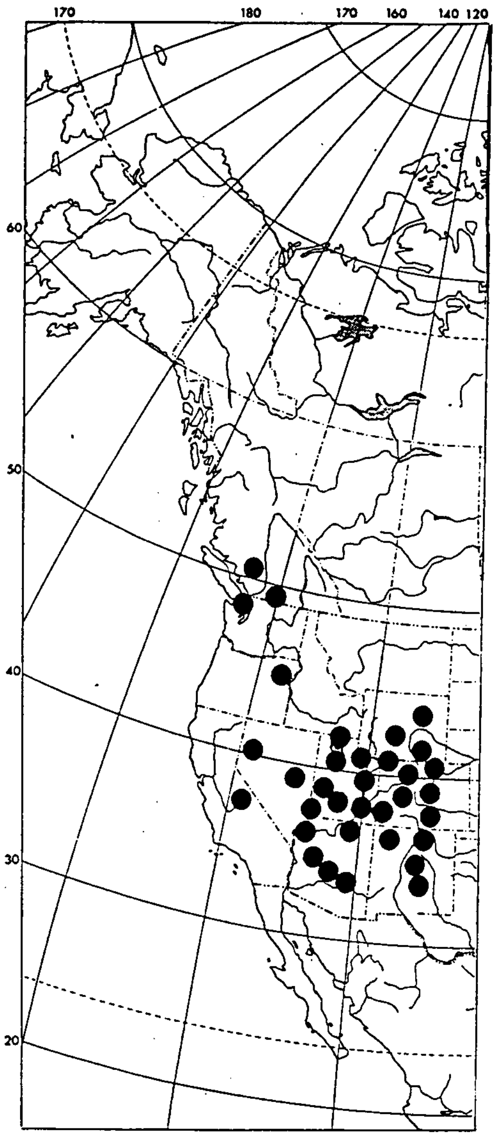
A. (based on herbarium records at UBC)

B. (based on Robinson 1970, McIntosh 1986, Zander 1981, Sharp et al. 1994)

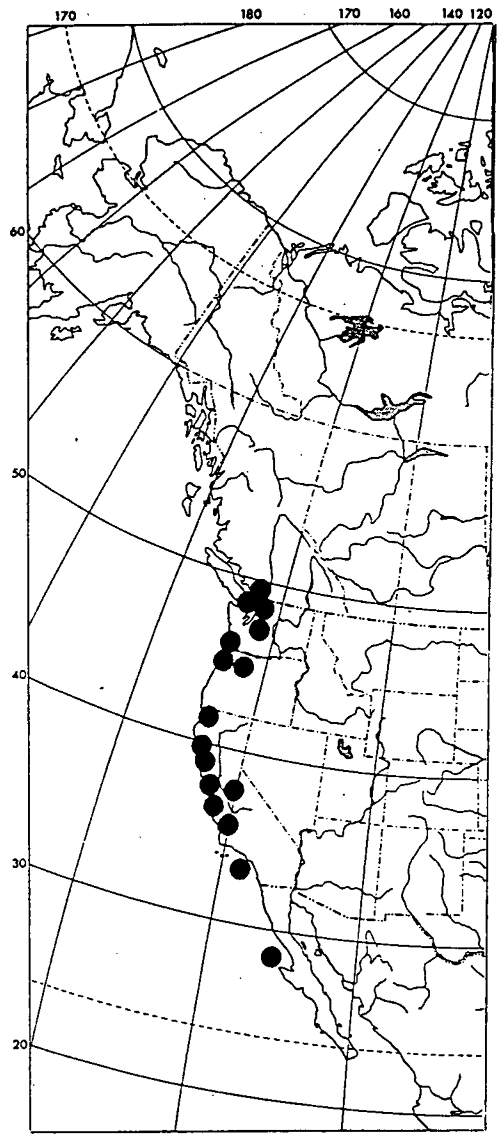
Orthotrichum hallii (see Figure 20a.) as previously noted was once thought to be a Western North American endemic species until it was collected from China by Tan (Lewinsky-Haapasaari and Tan 1995). Although originally considered to have "evolved relatively recently *in situ*" (Vitt 1971), it would appear that this species evolved much earlier and possibly was part of the Arcto-Tertiary Geoflora. This idea is supported by the China collection which places this species into the Western North American - disjunct Eurasia element. The San Juan Islands collection represents the first record for Washington state and suggests an interesting correlation between the disjunct vascular plant species found between the Rocky Mountains and the islands.

It is interesting to note that the North American distributions of *O. hallii* and *D. crassicostatus* (living populations only) closely follow the distribution pattern shown by *Juniperus scopulorum* (see Figure 21). The central portion of range for *J. scopulorum* is located in Colorado, Utah and Wyoming, disjunct populations occur in British Columbia and in the Puget Sound. Most likely the juniper reached its maximum distribution as part of the Madrean-Tethean Geoflora (Axelrod 1958). Adams (1983) using terpenoid variation in populations throughout the *J. scopulorum* range found that "the Manning Pass (BC) populations shows closest ties to the Puget Sound populations" and "the greatest differentiation is shown between the Puget Sound populations and the interior populations". Therefore it appears that *J. scopulorum* originally migrated northward with the Madrean-Tethean Geoflora and was isolated in the Puget Sound area before the Pliocene. During the Pleistocene glaciation these populations migrated southward (possibly into eastern Oregon) and moved northward during the hypsithermal interval. Since mosses usually move as part of a whole flora and not as individuals (Crum 1972) it would appear that *Orthotrichum hallii*, a species exhibiting arid evolutionary morphology (Vitt 1971), may have been well established throughout the region at the same time as the juniper. Therefore it most likely migrated into the San Juan Islands and British Columbia at the same time the junipers did. It must be noted that *O. hallii* is not an epiphytic species and its relationship to the junipers is purely on the basis of habitat similarities. At the present time the disjunct populations of both the juniper and *O. hallii* represent the northwestern edge of their ranges, and while the range of the

Figure 20. The Pacific Northwest distribution of: A. *Orthotrichum hallii*, a Rocky Mountain disjunct Coastal pattern. B. *Alsia californica*, a Mediterranean Climate pattern.

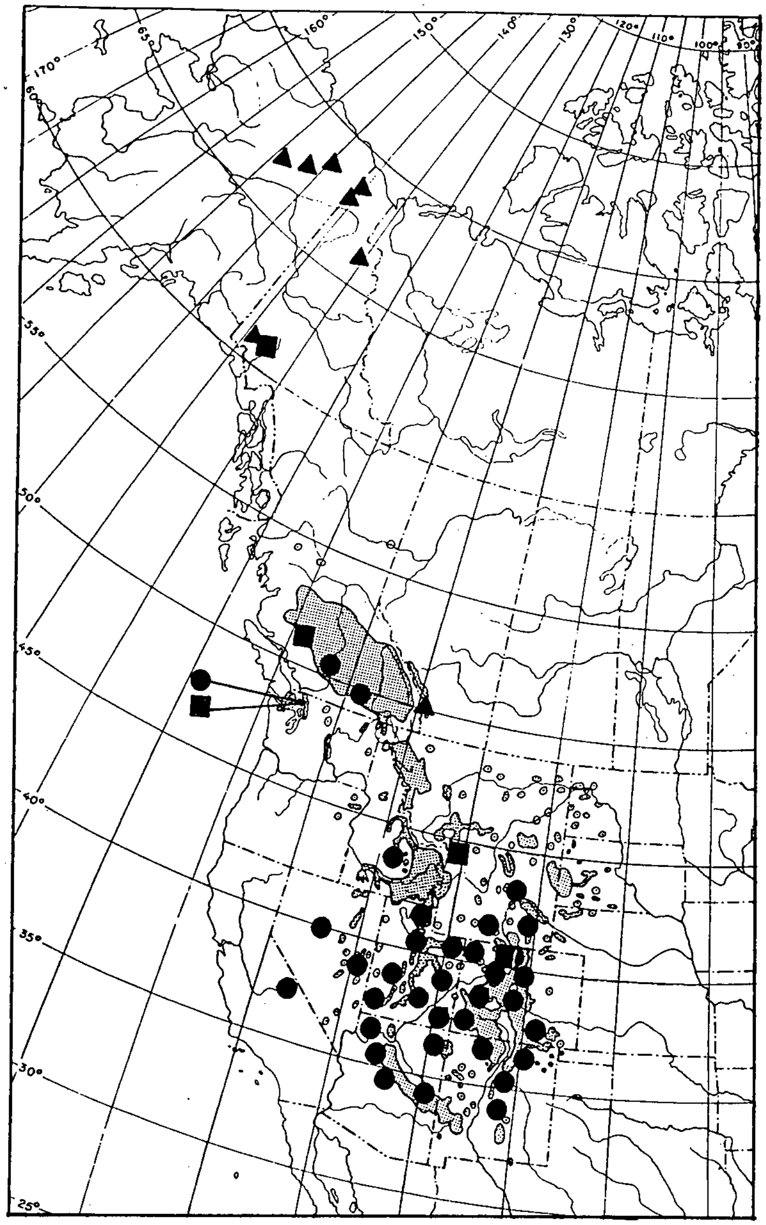


A. (based on Vitt 1973, McIntosh 1986)



B. (based on Manuel 1974)

Figure 21. The distribution of *Drepanocladus crassicostatus* and *Orthotrichum hallii* compared to the range of *Juniperus scopulorum*.
■ *Drepanocladus crassicostatus* (living populations), ▲ (fossil records)
● *Orthotrichum hallii* ◍ *Juniperus scopulorum*



Based on Little Jr. (1971), Vitt (1973) and Janssens (1983a) juniper is fairly well established, further fieldwork needs to be done to relate the Rocky Mountain populations with the coastal disjunct ones. It is interesting that the China location of *O. hallii* was also "found growing on logs and soil-covered rocks and boulders shaded by a *Juniperus* grove" (Lewinsky-Haapasaari and Tan (1995) therefore suggesting that there may be a correlation with the juniper migration path in that country as well.

Drepanocadus crassicostatus, on the other hand, may have extended its range southward during the cooler climatic periods and was driven northward during the hypsithermal interval. This appears to be the case, as the fossil records point to an arctic-alpine origin for this species. Therefore the southern populations found in Colorado, Wyoming and the San Juan Islands probably represent the southern edge of its range and are in or near refugial sites.

The Mediterranean Climate element contained 25 (11.16 %) species that represent a mixture of western North American endemic and Pacific North America - disjunct Mediterranean species. This element is found mainly along the coast in western North America extending from southwestern British Columbia to Baja California, and is most abundant in California (Schofield 1988b). Mathewes (1973) reports the presence of *Dendroalsia abietina* in lake bottom deposits immediately above the Mt. Mazama ash layer, therefore it existed in the region at about 6.600 yr. B.P.. This strongly suggests that the recolonization of the region by mediterraean climate type species could have occurred during the hypsithermal interval (Deevey and Flint 1957). Representative species include *Alsia californica* (See Figure 20b), *Dendroalsia abietina*, *Homalothecium arenarium*, *Isothecium cristatum* (endemics), *Dicranoweisia cirrata*, *Metaneckera menziesii*, *Pterogonium gracile*, and *Tortula laevipila* var. *meridionalis* (disjuncts). Species associated with this element reach their greatest numbers on well drained exposed rock outcrop knobs, but they are also well represented as epiphytes and on rock cliffs along stream sides in more open coniferous forests (Schofield 1994). This appears to be the case within the San Juan Islands as over 60 % of the species occurred in one or more of the five habitats found in the islands (see Table 19).

Table 19. The relationship between the number of mediterraean climate species found in climate found in each habitat.

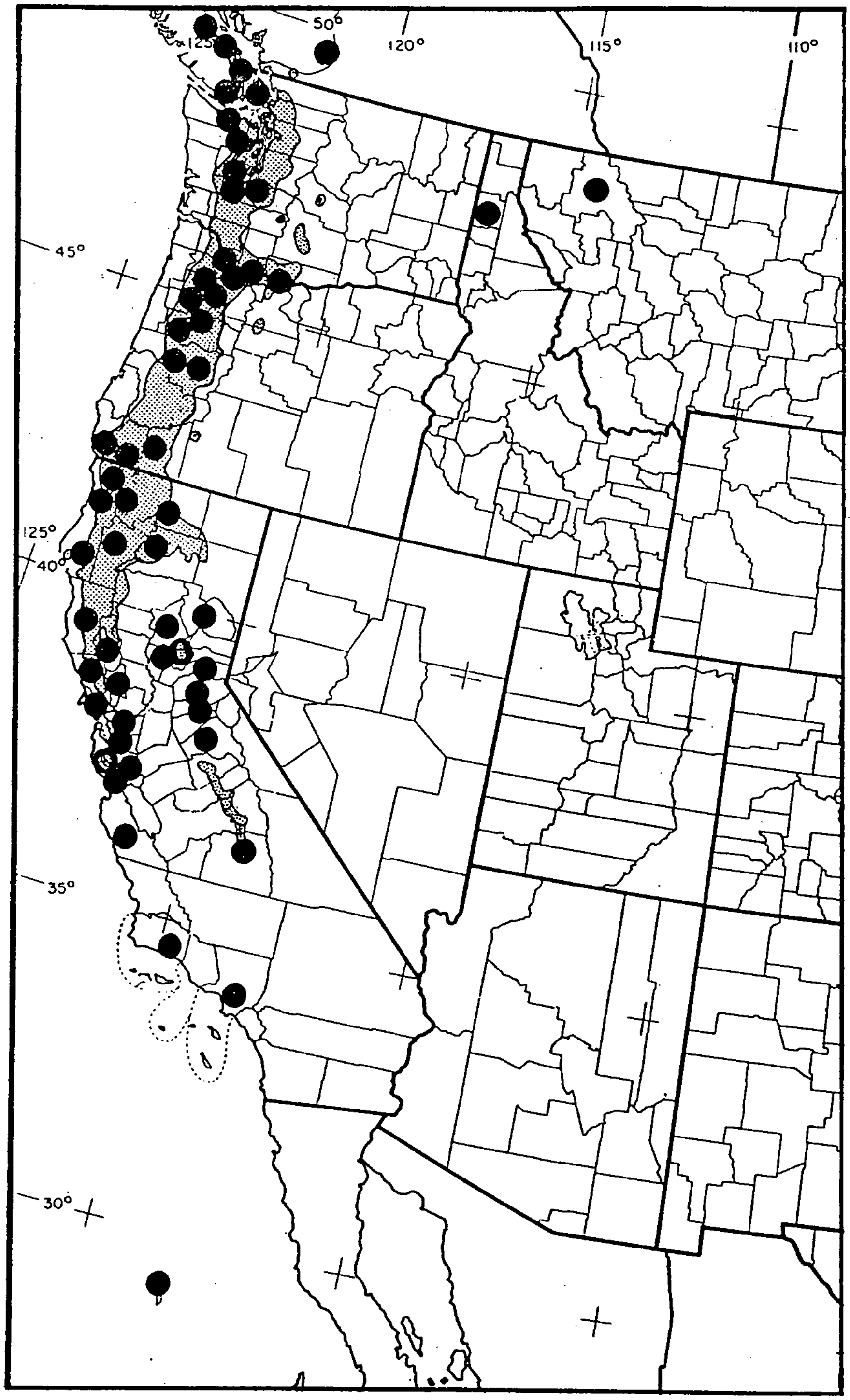
Habitat	Total No. of Species	% of Total No. of Species
Maritime	16	64.0
Meadows & Ridges	15	60.0
Wetland	15	60.0
Outcrops	16	64.0
Disturbed Sites	10	40.0
Woodlands	19	76.0

One species found in this element merits extra discussion. *Tortula laevipila* var. *meridionalis* (a disjunct species) was found on several of the islands and its collection represents a new record for the United States. Although there has been significant discussion in Europe over the validity of this variety, Anderson et al. (1990) have accepted it as a valid North American taxon. This species is epiphytic on *Acer macrophyllum* (bigleaf maple) and *Quercus garryana* (Garry oak) and two recent collections made on oak trees in the Tacoma, Washington and the Willamette Valley, Oregon areas strongly suggest that this species will ultimately be found throughout the entire Garry oak distribution. This pattern has already been demonstrated with *Dendroalsia abietina* (an epiphyte on both maple and oak) when the two distributions are compared (see Figure 22). Only additional field work throughout the region will clarify understanding of the distribution of *Tortula laevipila* var. *meridionalis*.

Although a number of different phytogeographical elements are represented within the islands, three points must be considered when interpreting these patterns. The first of these is that the entire flora of the islands represents the result of post Pleistocene migration and the islands presented no refugial sites during the glacial period. Second, when making comparisons between the moss flora of the San Juan Islands with the immediate adjacent areas it must be understood that a sound data base for most of the mainland and adjacent islands is lacking. Finally, the environmental destruction that has been ongoing from the time humans entered the region, continues to influence the number of species that occur in the area. These points are discussed in the following sections of this chapter.

Post glacial migration into the islands could have begun as early as 13,500 yr. B.P. (Deither et al. 1995). when the higher areas in the islands were exposed above the ice. These open treeless areas would have provided suitable habitat for moss spores or fragments to travel, settle and become established. Waitt et al. (1983) suggests that the alpine glaciers in the region were greatly diminished around 17000 -18000 yr. B.P. therefore it is possible that vegetation on these exposed higher areas on the mainland could have provided a source of moss spores and fragments to enter the islands. Wind dispersal of spores has been well established by Bergeron

Figure 22. The Distribution of *Dendroalsia abietina* ● compared to the range of *Quercus garryana*. ◌



Based on Manuel (1974) and Little Jr. (1971)

(1944), Crum (1972), Schofield and Crum (1972) and more recently by van Zanten et al. (1981). Miller et al. (1976) demonstrated that "some gametophyte fragments are able to function as propagules in nature and that wind dispersal and establishment of bryophytes by vegetative means may be routine in arctic latitudes". Since the climate in the region could have generated wind patterns that could have distributed spores and fragments from the mainland into the islands it is suggested that some of the more northern element species may have arrived in the islands sometime after 13,500 yr. B.P. The continued existence of these species, especially on the summit of Mt. Constitution is the result of the cooler, wetter climate that exists there now.

Since "...mosses have moved in the past as members of whole floras in migration, not as individuals and not aimlessly, but along natural migration routes..." (Crum 1972) it is safe to assume that the remainder of the flora migrated into the islands most likely from a southern refugial site, during the hypsithermal interval.

Lawton (1971) defines the Pacific Northwest as including Washington, Oregon, Idaho, western Montana, Wyoming and north to about the 52nd parallel, with a total moss flora of "598 species and varieties, attributed to 44 families and 156 genera". In order to present a comparison of the San Juan Island flora with the Pacific Northwest region defined by Lawton (1971) Table was developed. Checklists for each of the above states and province were available except for Washington considered as a separate unit, therefore Washington as an independent flora is not included in Table 20.

Considering the small area of the islands (172 km), they have a very diverse moss flora, consisting of 224 species and varieties. The islands possess 37. 4% of the species found throughout the Pacific Northwest and 20.3% of the North American flora. The low diversity of species found in relation to the British Columbia flora is the result of the greater habitat diversity that occurs throughout the province as well as its larger area. On a more local level the Gulf Islands of British Columbia, (located just north of the San Juan Islands in the southern portion of the Strait of Georgia), contain 114 species and varieties although additional field work will probably add species to the list. It is reasonably safe to assume that the two floras would be

Table 20. San Juan moss diversity comparisons to other areas.

Location	No. of Species	% of Flora
North America	1103	20.3
British Columbia	714	31.4
Pacific Northwest	598	37.4
California	495	45.2
Oregon	441	50.7
Montana	408	54.9
Wyoming	315	71.1
Idaho	257	87.1
San Juan Islands	224	100.0

Anderson et al. (1990), Schofield (1992b), Lawton (1971), Norris (unpublished), Christy et al. (1982), Elliott (unpublished), Eckel (1996), McCleary et al. (1971).

almost identical except for the *Sphagnum* bog species which do not occur in the Gulf Islands. In general the moss flora of the San Juan Islands is diverse but it is always possible to add additional species to a list when more field work is done.

In order to assess of the frequency for the species within the islands the data base was sorted to provide the total number of records and number of islands on which each species was found. Frequency was determined by dividing the number of islands where a species occurred by the total number of islands visited. The results are given in Appendix I . A species was considered to be common if it occurred on 50% or more of the islands, and six species were found on 90 % or more of the islands. Representative species in this group include *Dicranum scoparium*, *Polytrichum juniperinum*, and *Eurhynchium oreganum*, all of which are consistently widespread on the west side of the Cascade and Coast mountains, therefore it was not unexpected that they would appear as very common. Rare or infrequent species included any species that occurred on five or fewer of the islands. Species in this category include *Crumia latifolia*, *Fissidens grandifrons* and *Pseudoscleropodium purum*, and the *Sphagnum* species. It is important to caution that the "degree of rarity" reflected by some species in the islands may not be rare on the mainland or adjacent Vancouver Island. This is demonstrated with *P. purum* and the *Sphagnum*s which are restricted in the San Juan Islands but are more prevalent on the mainland. *Crumia latifolia* and *Fissidens grandifrons* (both obligate calcicoles) are restricted to a few sites in the islands and on the mainland. Therefore a knowledge of the floras throughout the region is important before a species can be listed as rare on a state or regional list.

Although the role of disturbance is discussed in previous chapters it can be segregated into human and non-human impacts, both play a role in determining where a species may occur. Human impacts are generally apparent and include agriculture, building, recreation, and timber harvest etc. Housing and the development that is associated with it poses the greatest current threat to most habitats on the islands. It is of significance that a number of property owners are becoming aware of the need to preserve their land and are acting to prevent future destruction by setting up conservation easements, etc.. Several organizations have been established in the islands to assist land owners with this process. Areas already under protection such as the United States Fish and Wildlife Refuges and The Nature Conservancy are certainly beneficial, provide habitat where public access is limited, and offer the best areas for survival for a number of the species found within the islands. Finally the State Parks and National Park while allowing public access have taken a greater interest in protecting from excess use any critical environments placed in their care.

Probably one of the best examples of human impact on the distribution of a species is demonstrated by *Dendroalsia abietina*, an epiphytic species usually found on *Acer macrophyllum* (bigleaf maple) or *Quercus garryana* (Garry Oak), and sometimes on rock. It is possible that the volume of trees cut down over the years to fuel the lime kilns, "feed" the steamers that moved about the islands and the clearing of land for agricultural purposes may have substantially reduced the available habitat for this species. At the present time *Dendroalsia* is found only on very old oak trees scattered on four islands but it may have been more widespread before people become well established in the islands and removed old oak trees during this settlement. Finally logging in the islands occurred extensively on Orcas and Waldron Islands; true old growth forest ecosystems are now absent in the islands. The loss of this type of habitat may explain why such dense woodland species as *Buxbaumia piperi* and *Tetraphis geniculata* were not found in the islands.

The role of non-human disturbance on the moss flora may be explained through in two scenarios. The first of these is related to the impact of birds nesting on some of the smaller islands. Goose Island demonstrates this well, with a flora of only 10 species. Human impact on this island is limited related to its inaccessibility and ownership, but it is a major nesting site for gulls. Therefore it is assumed that the concentration of bird droppings prevents the establishment of a large number of moss species or severely limits their distribution on the island. *Schistidium maritimum*, a common species of rock in the maritime sub-habitat throughout the islands was found in only one spot covering an area about 2 cm. in diameter. Additional field work on other islands used as nesting sites needs to be completed to further support this assumption, but at the present time it appears to be a reasonable explanation for the low number of species found on Goose Island.

Another non-human form of disturbance that occurs when a north-easterly storm brings very strong winds into the islands. These storms often result in a tremendous amount of blown down timber, this changes the light, temperature and humidity within the forest ecosystems affected. When these changes affect the coniferous woodlands, the mosses such as *Plagiothecium undulatum* and *Rhytidiadelphus loreus* usually cannot survive. This phenomenon was observed on Orcas Island in Moran State Park and on Jones Island where a recent north-easterly storm damaged a large volume of timber.

In conclusion, The bulk of the San Juan Islands moss flora is composed of circumboreal species that reflect a once more widespread Arcto-Tertiary flora. During the Pleistocene these islands were completely denuded several times. The flora and regional Pacific Northwest phytogeographical patterns that exist now are composed of species that have migrated back into the region, including the islands. This recolonization could have begun as early as 13,500 yr. B.P. (Deither et al. 1995) but the bulk of the flora probably returned during the hypsithermal interval described by Deevey and Flint (1957). During the Pleistocene glaciation, areas south of the glacial boundary possibly served as refugial sites, although some species might have survived in northern refugia.

A decrease in the amount of *Quercus* pollen in the Saanich Inlet (British Columbia) deposits occurred about 2000 years ago. At the same time an increase in the *Thuja-Chamaecyparis* pollen levels was noted (L. Heusser 1983). This implies that the climate in the region was changing from warm and dry into a cooler, wetter period. During this cooling trend the southern element appears to have retreated, with fragments remaining only in those areas where conditions were favorable. Thus the San Juan and adjacent islands represent a "modern" refugium for southern, mediterranean type climate species. It is hoped that the people who inhabit this unusual ecosystem will continue to become aware of its uniqueness and will support its preservation.

CHAPTER 7

Taxonomic Considerations

The known moss flora of the San Juan Islands is composed of 224 species and varieties representing 33 families and 97 genera. Complete lists of these species and varieties are provided in Appendix J and K . In addition to the 224 species and varieties collected during the present study, four historical taxa were found in various herbaria throughout the region. Identification keys were prepared to genera and species, and vouchers have been deposited in the University of British Columbia and University of Washington herbaria. A list of taxa not found during this study, but suspected to occur in the islands is provided in Appendix M . These taxa were chosen because they are found on the adjacent islands or are common in similar habitats on the mainland.

Distribution maps are provided for all species collected during this study in Appendix N.

Preparation of Keys

The dichotomous keys to genera and species were developed from personal observations made during the process of identification. In addition the following authors were consulted in order to clarify difficult taxa.

Buck and Norris (1996)	Lawton (1965, 1971)
Crum (1984)	Murray (1987)
Crum and Anderson (1981)	Noguchi (1987-1994)
Crundwell and Nyholm (1977)	Robinson (1970)
Flowers (1973)	Schofield (1969, 1970)
Frisvoll (1982, 1988)	Sharp et al. (1994)
Horton (1982, 1983)	Shaw (1982)
Hoisngton (1979)	Spence (1988)
Ireland (1969, 1970, 1971, 1982)	Vitt (1973)
Ireland and Spence (1987)	Vitt and Buck (1992)
Janssens (1983a, 1983b)	Welch (1960)
Koponen (1974)	Zander (1978)

These keys are designed to be used in conjunction with Lawton's *Moss Flora of the Pacific Northwest* (1973) and in most cases where measurements are provided in the keys they have been taken from her book. Because the species listed in the keys reflect the nomenclature of the current North American checklist (Anderson et al. 1990), a list of synonyms is provided for species that are different or missing from Lawton's text (Appendix L.). Whenever possible, the keys are based on gametophytic structures. Sporophytic characters are used when it is difficult to determine the species on gametophytic characters alone. Whenever ecological information is useful, it is provided.

Use of these keys requires the use of both dissecting and compound microscopes and it is important to have reliable ecological information available for each collection, because it is often needed in order to make a determination.

Problematic Taxa

Atrichum P. Beauv.

Both *Atrichum selwynii* and *A. undulatum* were collected from the islands with *A. selwynii* the more common species found. Distinguishing between these two species is strongly based on sexuality, therefore young material can be difficult to distinguish. Ireland (1969, 1971) separates sterile material on the basis of leaf shape and the position of the dorsal teeth on the surface of the lamina. In *A. selwynii* these teeth are distinct and in several diagonal rows. *A. undulatum*, on the other hand, had teeth that are few or lacking and do not form distinct rows. Unfortunately sexuality can often be a problem, while *A. selwynii* is always dioicous, *A. undulatum* is usually monoicous, but rarely dioicous, therefore the gametophytic characteristics become more important in identification.

Dicranella howei Ren. & Card.

Dicranella howei is distinguished from *D. varia* by Crundwell and Nyholm (1977) based on leaf and exothecium characters.

Brachythecium asperrimum (Mitt.) Sull.

This species is considered as distinct from *B. frigidum* by Hoisington (1979) and can be distinguished from *B. frigidum* on the following characteristics. *B. asperrimum* has a less defined alar cell region, the leaf tips are usually twisted and the species is always found in well drained habitats and forms loose open mats, it is commonly epiphytic or on logs. *B. frigidum* has a well defined alar region, often enlarged cells extending across the base of the leaf, is usually found in wet habitats, often submerged, and never forms loose open mats; it is commonly terrestrial on raw mineral soil.

Dicranum howellii Ren. & Card.

Lawton (1971) distinguishes *D. howellii* from *D. scoparium* on the basis of the inner perchaetial bracts being gradually acuminate, while they are abruptly acuminate in *D. scoparium*. Although this taxon is treated by Anderson et al. (1990) as a valid species, careful comparison of the perichaetial bracts in both species demonstrates that *D. howellii* should be treated within *D. scoparium.* It is therefore treated as *D. scoparium* here.

Fissidens bryoides Hedw. complex

Lawton (1971) combined *Fissidens limbatus* with *F. bryoides*, therefore placing all of the material through the Pacific Northwest under *F. bryoides*. Flowers (1973) recognizes *F. limbatus* as a distinct species but comments "The differences usually cited in *Fissidens bryoides, F. limbatus, F. sublimbatus* are so slight and intergrade so freely that it is difficult to admit them as full species". Pursell (who is working on *Fissidens* for the Flora North America project), after examining my material has assigned the following three names to the specimens; *F. bryoides* var. *bryoides*, *F. bryoides* var. *viridulus* and has placed *F. limbatus* into *F. crispus*. The two varieties of *Fissidens bryoides* have been included in this study, but the name *F. limbatus* has not been altered to *F. crispus*, since the substantiating data are unpublished.

Hedwigia stellata Hedenas

Recent studies by Buck and Norris (1996) have concluded that there are several species of *Hedwigia* in North America. Upon Buck's suggestion, reexamination of all of the San Juan material called *H. ciliata* was found to be *H. stellata. H. stellata* is distinguished from *H. ciliata* based on the number of papillae located on the upper laminal cells. *H. ciliata* has 2-4 papillae cells (rarely 1) on the upper laminal cells, while *H. stellata* has 1 or 2 papillae on the upper laminal cells.

Racomitrium heterostichum (Hedw.) Brid. Group

The Section *Laevifolia* (*heterostichum*) group is an extremely variable group of taxa, that are difficult to discriminate. Frisvoll (1988) revised this group using the following taxonomic characters that he felt were stable; alar cells and supra-alar marginal cells, costa structure, leaf margin and perichaetial leaf structure. Although he comments in his treatment that "It has proved difficult to make reliable keys for the taxa in the section, primarily because they are all easily modified by differences in environmental factors" (Frisvoll 1988). Using his treatment, three species were recognized, *R. lawtonae, R. pacificum* and *R. occidentale*.

R. pacificum has ovate-lanceolate leaves, unistratose margins, and lacks a hairpoint, the upper laminal cells are smooth and isodiametric. It could be confused with *R. aquaticum* and *R. varium* but both differ by having multipapillose leaf cells (Ireland and Spence 1987, Frisvoll 1988).

R. lawtonae has long lanceolate leaves with unistratose margins, the costa is deeply channeled and ends in a long clear hairpoint that is very decurrent extending down the margins of the leaf as a hyaline area. Leaf cells just below the apex are elongate, rather than isodiametric or mixed short and long (Ireland 1970, Frisvoll 1988).

R. occidentale has ovate-lanceolate leaves with bistratose margins. the hairpoint is either short or long. The most significant feature of this species is the bulging cells on the dorsal side of the costa (Frisvoll 1988). This species cannot be confused with *Dryptodon patens* which has well defined "wings" on the dorsal side of the costa.

Collections that did not fit into any of the above species were placed into *Racomitrium hetrostichum sensu lato*. The margins of the lamina were usually unistratose or occasionally had bistratose spots. The hairpoint often was decurrent but never formed the long narrow bands down the margin of the leaf, as in *R. lawtonae*. This group of highly variable of individuals may contain some material of true *R. heterostichum* but it was very difficult to sort these out.

Historical Taxa

Although search of herbarium records in the region resulted in a list of 45 species that represented the only available record for an island (see Appendix A.). Four of these species, *Distichium capillaceum, Hygrohypnum bestii, Roellia roellii* and *Tayloria serrata* were not relocated on any of the islands, therefore they represent the only records for these species. Although with the exception of *Roellia roellii* (a species usually found only at higher elevations on the mainland) these species may be revealed during future fieldwork, they have been excluded from the key until new populations can be located.

Taxa New To Washington State

During the present study, four taxa new to Washington State were found, one represents a new record for the United States and the second record for North America. A careful search throughout regional herbaria and the literature confirmed that these were obviously new records. Careful comparison to known vouchers assisted in verifying their identity and the *Drepanocladus crassicostatus* was determined by Janssens who originally described the species. The phytogeographic implications of these species are discussed in Chapter 6.

Drepanocladus crassicostatus Janssens

This species is distinguished by the very thick and wide costa at the base of the main stem leaves, and the leaf margins are lightly to sharply denticulate (Janssens 1983a).

Orthotrichum hallii Sull. and Lesq. in Sull.

This species is found on calcareous rock and has leaves that are bistratose in the upper half, sometimes with unistratose streaks. The sporophyte is immersed to 1/2 emergent and has immersed stomata. It can be distinguished from *O. anomalum*, which has an exserted sporophyte, and leaves that are unistratose. It is readily separated from *O. rupestre* by the superficial stomata found in the sporophyte. (Vitt 1973)

Tortula laevipila var. *meridionalis* (Schimp.) Wijk and Marg.

This species is identified on the basis of the costate leaf-like gemmae that are clustered at the top of the stem. It can be separated from *T. laevipila* var. *laevipila* by the gemmae and the costa which is excurrent as a short hairpoint or is absent (Barkman 1963, Smith 1978).

Tortula papillosa Wils. ex Spruce

This species has broadly obovate-spathulate leaves, with an excurrent costa that forms a smooth hairpoint. Multicellular, spherical or globose propagula are borne on the upper surface of the leaf. This species is easily distinguished from *T. latifolia* which has an obtuse apex, and lacks the hairpoint (Smith 1978, Crum and Anderson 1981).

KEY TO GENERA

1. Branches clustered in fascicles; leaf cells composed of a network of large hyaline cells and smaller green cells; found in bogs, fens, and along lake margins .... ***Sphagnum***

1. Branches not clustered in fascicles; leaf cells never having large hyaline or green cells; found on various substrata .... 2.

2. Leaves complanate .... 3.

2. Leaves not complanate, arranged in more than two rows .... 7.

3. Leaves undulate; stems with or without paraphyllia; plants never aquatic .... 4.

3. Leaves not undulate; stems without paraphyllia; plants usually aquatic or in damp areas .... 6.

4. Stems with abundant paraphyllia; leaf costa strong, to the middle .... ***Metaneckera***

4. Stems without paraphyllia; costa lacking or short .... 5.

5. Alar cells differentiated, forming several rows of decurrent rectangular cells ... ***Plagiothecium undulatum***

5. Alar cells not differentiated, irregular, quadrate .... 6.

6. Leaves with a vaginate lamina; median cells rounded-hexagonal; never undulate .... ***Fissidens***

6. Leaves never with a vaginate lamina; median cells elongate; undulate .... ***Neckera***

7. Plants acrocarpous, stems and branches erect; sporophytes develop terminally on the main....... stem .... 8.

7. Plants pleurocarpous, stems branched, creeping; sporophytes develop on the lateral .... 80.

8. Leaf cells smooth .... 9.

8. Leaf cells papillose .... 44.

9. Plants dendroid .... 10.

9. Plants never dendroid .... 11.

10. Paraphyllia abundant on stems .... ***Climacium***

10. Paraphyllia never found on the stems .... ***Leucolepis***

11. Leaves with lamellae on the upper surface ....12.

11. Leaves without lamellae...15.

12. Lamellae less than 20; leaves undulate, margins bordered ....***Atrichum***

12. Lamellae greater than 20; leaves never undulate, margins not bordered ....13.

13. Apical cells of lamellae smooth, sporophyte angular, never cylindrical...............***Polytrichum***

13. Apical cells of lamellae papillose or smooth, sporophyte cylindrical, rarely angular ....14.

14. Apical cells of lamellae not, papillose, if smooth then leaves are strongly contorted .... when dry .... ***Pogonatum***

14. Apical cells of lamellae pyriform, papillose, never smooth.........***Polytrichastrum alpinum***

15. Peristome composed of 4 teeth; disk-shaped, multicellular stalked gemmae in a cup-shaped apical rosette, on rotten logs ....***Tetraphis pellucida***

15. Peristome teeth more than 4, or absent ....16.

16. Leaves linear-setaceous; sporophyte elongate-pyriform and nodding, with a long slender neck ....***Leptobryum pyriforme***

16. Leaves not linear-setaceous..17.

17. Median leaf cells oblong-hexagonal or linear ....18.

17. Upper leaf cells isodiametric, rounded quadrate to quadrate (if elongate then the leaves are matted with rhizoids) ....27.

18. Leaf margins incurved...19.

18. Leaf margins plane, not incurved..23.

19. Alar cells inflated, forming distinct reddish-brown groups; sporophytes exserted...............20.

19. Alar cells not differentiated or inflated; sporophyte immersed or exserted, teeth present or absent, usually on dry soil...21.

20. Basal cells above inflated cells short, almost quadrate; usually on wet rock..***Blindia acuta***

20. Basal cells above inflated cells rectangular to linear; never on wet rock ....***Dicranum***

21. Sporophyte cleistocarpus, immersed on a very short seta.................***Pleuridium acuminatum***

21. Sporophyte cleistocarpus, exserted ....22.

22. Leaves erect, narrowly lanceolate, usually ending in a narrow awn; peristome teeth finely divided .... ***Ditrichum***

22. Leaves lanceolate-subulate, variable, spreading or squarrose; peristome teeth broad .... ***Dicranella***

23. Leaves narrowly lanceolate or lanceolate-subulate ....24.

23. Leaves broad, never lanceolate-subulate ....25.

24. Leaves erect, narrowly lanceolate, ending in a slender apex, peristome teeth narrow and finely divided .... ***Ditrichum***

24. Leaves spreading or squarrose, lanceolate-subulate, peristome teeth broad or absent .... ***Dicranella***

25. Leaf margin never bordered, median leaf cells long and linear; costa never excurrent..........26

25. Leaf margin bordered or not; median leaf cells rhomboidal to hexagonal; costa ± excurrent ....27.

26. Upper median cells long and linear .... ***Pohlia***

26. Upper median cells rhomboidal to hexagonal-oblong .... ***Bryum***

27. Leaves bordered with reddish linear cells; costa to just beyond the middle........ ***Epipterygium tozeri***

27. Leaves ± bordered, never with reddish linear cells; costa strong, percurrent to excurrent......... .... ***Bryum***

28. Leaves broad, oblong-lanceolate, oblong-elliptic to ovate-lanceolate ....29.

28. Leaves linear-lanceolate, never broad, oblong-lanceolate or elliptic ....33.

29. Leaf margins bordered and toothed with single or double teeth ....30.

29. Leaf margin ± bordered, never toothed ....31.

30. Leaf border unistratose; teeth single and to the base of the leaf; on soil, rotten logs or trees .... ***Plagiomnium***

30. Leaf border multistratose, teeth double and not extending to the base of the leaf, usually only on soil or soil over rock .... ***Mnium***

31. Leaves oblong-lanceolate, margins not bordered, slightly contorted when dry, on soil ....32.

31. Leaves broad, obovate ± orbicular, margins with a multistratose border, often strongly contorted when dry, on rotten logs or sometimes soil .... ***Rhizomnium***

32. Leaf margin entire, sporophyte immersed; peristome teeth absent.. .... ***Physcomitrium pyriforme***

32. Leaf margins entire in the lower half, ± serrulate in the upper half; sporophyte exserted, peristome teeth present .... ***Funaria***

33. Median leaf cells smooth or slightly papillose..34.

33. Upper cells smooth, never papillose ....37.

34. Median leaf cell walls sinuous; leaf apex ± a hairpoint..................................***Racomitrium***

34. Median leaf cell walls never sinuous; leaf apex without a hairpoint...............................35.

35. Leaves matted with reddish-brown rhizoids; sporophyte exserted .... ***Anacolia menziesii***

35. Leaves not matted with rhizoids, sporophyte exserted or immersed ....36.

36. Leaves linear-lanceolate, acute, entire or serrulate at apex; sporophyte exserted................. .... ***Cynodontium jenneri***

36. Leaves lanceolate to ovate-lanceolate, usually with a hairpoint; sporophyte immersed........ ....***Schistidium***

37. Leaves abruptly narrowed from an obovate base; sporophyte very strumose........ ***Oncophorus wahlenbergii***

37. Leaves never abruptly narrowed from an obovate base; sporophyte not strumose................38.

38. Plants on soil, usually in disturbed sites; leaves slightly twisted or contorted when dry,...... often reddish-purple; sporophyte strongly ribbed when dry .... ***Ceratodon purpureus***

38. Plants on rock or trees, not in disturbed sites; leaves strongly to slightly contorted when.... dry, green to blackish-green ....39.

39. Plants usually with gemmae; leaves strongly twisted and contorted when dry ....40.

39. Plants without gemmae; leaves not strongly twisted and contorted when dry; always............. on rock ....41.

40. Lower leaf cell walls thick, slightly sinuous; always on rock cliffs.......................***Grimmia torquata***

40. Lower leaf cell walls not thick, never sinuous; usually on coniferous trees or occasionally on rock .... ***Dicranoweisia cirrata***

41. Leaves with prominent dorsal wings on the outer surface of the costa......... ***Dryptodon patens***

41. Leaves without prominent dorsal wings on the costa ....42.

42. Leaf apex coarsely toothed; calyptra mitrate .... ***Ptychomitrium gardneri***

42. Leaf apex never coarsely toothed; calyptra not mitrate ....43.

43. Calyptra large, campanulate and persistent; lower leaf cell walls lightly sinuous and thick-walled.. ***Coscinodon calyptratus***

43. Calyptra smaller, not persistent; lower leaf cells sometimes sinuous and ± thick-walled..***Grimmia***

44. Leaf cells weakly papillose, usually appearing smooth ....45.

44. Leaf cells strongly papillose with superficial papillae or by projecting cell ends............46.

45. Leaves lanceolate-subulate, usually ending in a slender apex; sporophyte exserted, peristome teeth finely divided.. ***Ditrichum***

45. Leaves lanceolate, never subulate; sporophyte immersed, cleistocarpous..............***Pleuridium acuminatum***

46. Upper leaf cells papillose by projecting cell ends..47.

46. Upper leaf cells papillose with one or more papillae per cell, or cells mammillose.........49.

47. Alar cells inflated, often orange or brown; leaves sometimes with several dorsal ridges; on a wide variety of substrata...***Dicranum***

47. Alar cells not inflated or differentiated; leaves without several dorsal ridges.......................48.

48. Upper cells linear-oblong, margins recurved (occasionally plane), serrate ....***Philonotis***

48. Upper cells not linear-oblong, margins plane or incurved; papillose on a subulate awn....... .... ***Trichodon cylindricus***

49. Propagula usually present ....50.

49. Propagula, gemmae or brood bodies absent...57.

50. Propagula fusiform, on the tip of a pseudopodum, very common ....***Aulacomnium***

50. Propagula filamentous, multicellular and leaf shaped, or spherical................................51.

51. Propagula filamentous ....52.

51. Propagula multicellular, globose or leaf shaped ....55.

52. Filamentous propagula, branched and composed of papillose cells .... ***Encalypta procera***

52. Brown multicellular gemmae usually very common ....53.

53. Leaf apex covered with reddish-brown gemmae, or apex forming a rough knob if gemmae have been broken off; on rocks or trees along the coast .... ***Ulota phyllanta***

53. Abundant brown multicellular gemmae attached to the surface of the leaf..........................54.

54. Leaves strongly twisted and contorted when dry; peristome lacking; on trees or rocks ....***Zygodon viridisimus* var. *rupestris***

54. Leaves not contorted when dry, peristome always present ....***Orthotrichum***

55. Propagula leaf-shaped, in clusters in the leaf axils .... ***Totrula laevipila* v. *meridionalis***

55. Propagula multicellular, globose or spherical, on the upper surface of the leaf or in the leaf axils ....56.

56. Propagula globose or spherical, on the upper surface of the leaf; always found on trees...... .... ***Tortula***

56. Multicellular propagula on branched stalk-like structures in the axils of the leaves; always found on wet rock .... ***Dichodontium pellucidum***

57. Plants always found on wet calcareous rocks or soil ....58.

57. Plants not growing in wet calcareous sites..61.

58. Leaves oblong-spatulate, bordered by 4-7 rows of large orange cells .... ***Crumia latifolia***

58. Leaves linear-lanceolate, not bordered ....59.

59. Leaves with sharp marginal teeth, often recurved at the base; peristome teeth present............. .... ***Eucladium verticillatum***

59. Leaves without sharp marginal teeth at the base; peristome teeth absent.............................60.

60. Leaf margin plane, not recurved .... ***Gymnostomum aeruginosum***

60. Leaf margin recurved on one or both sides; operculum commonly attached to the columella .... ***Hymenostylium recurvirostre***

61. Leaf margin involute, never revolute .... 62.

61. Leaf margins plane or revolute .... 66.

62. Plants green to dark green; sporophyte cylindric, ± peristome teeth .... 63.

62. Plants reddish black to dark brown; very small, always on siliceous rock; sporophyte ellipsoid with 4 longitudinal slits, peristome lacking .... ***Andreaea***

63. Costa glossy, excurrent to a short point; leaves strongly crisped when dry .... ***Weissia controversa***

63. Costa not glossy, percurrent to excurrent, apex apiculate or piliferous; leaves moderately to strongly crisped when dry .... 64.

64. Calyptra large and persistent, covering half or all of the sporophyte; leaves ligulate-spatulate, with numerous papillae on the upper surface; moderately crisped when dry .... ***Encalypta***

64. Calyptra smaller, not persistent; leaves linear-lanceolate, median cells mammillose or with several small papillae; leaves strongly twisted and crisped when dry .... 65.

65. Median leaf cells strongly mammillose; costa broad, ending in or near the apex .... ***Timmiella crassinervis***

65. Median leaf cells with several small papillae per cell; costa strong, percurrent or excurrent; basal cells hyaline, extending "V" shaped up the margins .... ***Tortella***

66. Leaf margin or apex serrate or toothed .... 67.

66. Leaf margin or apex not serrate or toothed .... 70.

67. Upper cells mammillose .... 68.

67. Upper cells papillose, not mammillose .... 69.

68. Leaves ovate-lanceolate, apex finely or coarsely serrulate-denticulate, on wet soil or rocks .... ***Dichodontium pellucidum***

68. Leaves linear-lanceolate from an oblong, orange-brown expanded hyaline base; upper margins coarsely toothed with sharp teeth; on soil .... ***Timmia austriaca***

69. Plants always on siliceous rock; sporophyte ellipsoid with 4 slits, peristome lacking; reddish black and very small .... ***Andreaea***

69. Plants on rock, rock cliff faces or on trees .... 70.

70. Plants usually on rock, rock cliff faces or on trees .... 71.

70. Plants usually on soil, sometimes on rock or trees .... 74.

71. Plants on rock cliff faces, never found on trees; strongly crisped and contorted when dry .... 72.

71. Plants on rocks or trees; ± crisped and contorted when dry .... 73.

72. Plants matted with papillose reddish-brown rhizoids; sporophyte globose, zygomorphic exserted, peristome teeth present .... ***Bartramia pomiformis***

72. Plants not matted with rhizoids; sporophyte immersed, peristome teeth lacking .... ***Amphidium***

73. Plants strongly crisped and contorted when dry; sporophyte stomata superficial .... ***Ulota***

73. Plants never strongly crisped and contorted when dry; sporophyte stomata superficial or immersed .... ***Orthotrichum***

74. Leaf median cells densely papillose with C- or O-shaped papillae .... 75.

74. Leaf median cells papillose with several papillae, never C- or O-shaped .... 78.

75. Sporophyte immersed to emergent, peristome teeth absent; always on soil .... ***Phascum cuspidatum***

75. Sporophyte exserted, peristome teeth present; on soil or trees .... 76.

76. Leaves oblong to ligulate-spatulate, basal cells hyaline, smooth, extending almost to the middle or beyond; on trees and soil .... ***Tortula***

76. Leaves linear-lanceolate, oblong-ligulate, never spatulate, basal cells elongate, clear but not extending up the margins of the leaf; on soil .... 77.

77. Leaves linear-lanceolate, apex usually coarsely toothed, plants often brick red in color .... ***Bryoerythrophyllum recurvirostre***

77. Leaves oblong-ligulate, apex never toothed; plants dark green to nearly black, never red .... ***Didymodon***

78. Leaf margins always bistratose, lamina occasionally bistratose in spots; always on soil .... ***Trichostomopsis australasiae***

78. Leaf margins unistratose, rarely bistratose near apex; plants on rock or soil ....79.

79. Median leaf cells with several low papillae per cell or appearing smooth; peristome teeth long and twisted; on soil ....***Barbula unguiculata***

79. Median leaf cells with several simple papillae per cell; peristome teeth simple, slender, erect, not twisted; on soil or rock .... ***Didymodon***

80. Leaves complanate, arranged in two rows or appearing so..81.

80. Leaves erect, spreading, not complanate...83.

81. Costa strong, to the middle of the leaf or beyond; plants on wet rock or moist soil.................. .... ***Porotrichum***

81. Costa short, double or lacking; plants on soil or rotten logs...78.

82. Leaf margin serrate to serrulate in the upper half; numerous branch like Propagula occur in the leaf axils, abundant in the spring; alar cells not differentiated .... ***Pseudotaxiphyllum elegans***

82. Leaf margin entire; propagula lacking; alar cells inflated, auriculate and decurrent .... ***Plagiothecium***

83. Leaves keeled, conduplicate, median cells long and narrow; plants usually forming long "stringy" mats; always in wet places.. ***Fontinalis***

83. Leaves not keeled, conduplicate, median cells variable, never forming "stringy" mats; on rock, soil or trees, in wet or dry places ....84.

84. Median leaf cells papillose with one or more papillae per cell or by projecting cell ends ....85.

84. Median leaf cells not papillose ....91.

85. Costa short, double, ending before the middle of the leaf or lacking ....86.

85. Costa double or single, extending to the mid-leaf or beyond ....88.

86. Leaves strongly julaceous; median leaf cells papillose by projecting cell ends; alar cells strongly differentiated, extending up the margins; peristome teeth present; on rocks and trees ....***Pterogonium gracile***

86. Leaves never strongly julaceous, lacking a costa; median leaf cells with one or more papillae per cell; alar cells not differentiated; peristome lacking; on rocks......................82.

87. Sporophyte immersed; perichaetial bracts with ciliate hairs on the margins; plants grayish-green...***Hedwigia stellata***

87. Sporophyte exserted; perichaetial bracts without ciliate hairs; plants reddish-brown............... ....***Pseudobraunia californica***

88. Stems without paraphyllia; leaves crisped and contorted when dry; on soil, rocks or trees.. ....***Claopodium***

88. Stems with paraphyllia; leaves never crisped and contorted when dry.............................89.

89. Plants dendroid or frondiform; branch leaves coarsely serrate at the apex; on trees or occasionally rock...***Dendroalsia abietina***

89. Plants never dendroid or frondiform; leaf margins plane or serrate, never coarsely serrate...... ....90.

90. Plants with regular pinnate branching (sometimes irregularly) forming large mats on soil or rotten logs; median leaf cells long and narrow...........................***Hylocomium splendens***

90. Plants branching ± pinnately; forming small mats on rock; median leaf cells shorter.......... ....***Heterocladium***

91. Plants dendroid; stems matted with paraphyllia; on soil or rotten logs in wet areas; (*Leucolepis* lacks paraphyllia)..***Climacium dendroides***

91. Plants not dendroid: stems with or without paraphyllia...92.

92. Costa short and double, never reaching beyond the middle of the leaf, or lacking..........93.

92. Costa long, extending to the middle of the leaf or beyond ....97.

93. Alar cells differentiated, inflated or quadrate ....94.

93. Alar cells scarcely differentiated..96.

94. Stems red; alar cells yellow-brown and thick-walled; on soil ....***Pleurozium schreberi***

94. Stems not red; alar cells hyaline, inflated or quadrate ....95.

95. Leaves straight, apex obtuse or rounded; on wet soil ....***Calliergonella cuspidata***

95. Leaves falcate to circinate, often ending in a filiform point; on wet or dry soil, rocks, trees and rotten logs .... ***Hypnum***

96. Costa wanting; plants filiform, forming thin mats on rock or soil in wet areas .... ***Platydictya jungermannioides***

96. Costa present; plants coarse, forming mats on soil, rotten logs or rocks .... ***Rhytidiadelphus***

97. Costa variable ± with supplementary costae or double .... 98.

97. Costa always single and well developed, never having supplemental costae .... 101.

98. Stems with numerous paraphyllia .... 99.

98. Stems without paraphyllia .... 100.

99. Alar cells differentiated, extending up the leaf margins; branch leaves costa short or lacking; stems sometimes flagelliform; on trees or rock .... ***Alsia californica***

99. Alar cells quadrate to rectangular, not extending up the margins; costa double, to the middle of the leaf; stems robust, never flagelliform; on soil .... ***Rhytidiopsis robusta***

100. Alar cells forming a large triangular group, oval to transversely elongate; median leaf cells elongate; costa ± supplemental costae; on trees or rocks .... ***Antitrichia***

100. Alar cells not forming a large triangular group, median leaf cells thick and pitted; costa without supplemental costae; on soil, rotten logs and rarely rock .... ***Rhytidiadelphus***

101. Leaves broadly ovate, suborbicular or broadly cordate-ovate .... 102.

101. Leaves ovate, ovate-lanceolate or lanceolate .... 107.

102. Stem and branch leaves julaceous .... 103.

102. Branch and stem leaves not julaceous .... 104.

103. Plants on rock in or near water; leaf apex obtuse .... ***Scleropodium obtusifolium***

103. Plants on soil in lawns or old fields; leaf apex apiculate .... ***Pseudoscleropodium purum***

104. Plants in wet locations; regularly or irregularly pinnate, branches spreading .... 105.

104. Plants always on dry soil; regularly pinnate, branches in one plane .... ***Trachybryum megaptilum***

105. Alar cells abruptly enlarged and inflated; usually found in bogs, swamps or along lake margins .... ***Calliergon giganteum***

105. Alar cells somewhat differentiated ± inflated, never abruptly enlarged .... 106.

106. Alar cells quadrate; stem leaves broadly cordate-ovate, decurrent; on wet soil or woody debris .... ***Eurhynchium praelongum***

106. Alar cells ± inflated, stem leaves ovate to suborbicular, on rock, submerged in water .... ***Platyhypnidium riparoides***

107. Leaves deeply plicate .... ***Homalothecium***

107. Leaves not deeply plicate, sometimes lightly plicate .... 108.

108. Leaves falcate-secund; usually in wet areas, often submerged .... 109.

108. Leaves not falcate-secund; plants in dry or wet area, usually never submerged .... 111.

109. Alar cells inflated and sharply defined; leaves straight or slightly falcate .... ***Cratoneuron filicinum***

109. Alar cells undifferentiated, or quadrate; leaves always falcate .... 110.

110. Leaves falcate to circinate, alar cells not extending to the costa .... ***Drepanocladus***

110. Leaves falcate-secund, alar cells quadrate often extending to the costa .... ***Sanionia uncinata***

111. Alar cells quadrate, sporophyte usually inclined to horizontal and arcuate, not shrunken under the mouth when dry .... 112.

111. Alar cells short rectangular to quadrate-rectangular, ± inflated; sporophyte inclined to horizontal, rarely upright, often shrunken under the mouth when dry .... 115.

112. Leaves broadly cordate-ovate, decurrent; margins serrate; stems branching irregularly to regularly pinnate; usually in dry places on soil, rotten logs and rocks .... ***Eurhynchium***

112. Leaves never broadly cordate-ovate; margins entire or serrate in upper half only .... 113.

113. Alar cells thick-walled, quadrate, forming well defined area; upper leaf margin coarsely serrate; on rocks, trees and soil, never in wet areas .... ***Isothecium***

113. Alar cells quadrate to rectangular, never forming distinct areas; leaf margin plane throughout, sometimes serrate at the apex .... 114.

114. Leaves often concave, never plicate; branches often julaceous; on the base of trees, soil or sometimes soil over rock .... ***Scleropodium***

114. Leaves never concave, ± plicate (never deeply); branches never julaceous; on soil, rocks or in streams .... ***Brachythecium***

115. Median cells long, 60-130 x 4-6 ; alar cells ± inflated; usually in wet areas often submerged .... 116.

115. Median cells short, 25-65 x 6-11 ; alar cells not inflated, in damp areas .... 117.

116. Leaves straight, margins and apex entire .... ***Leptodictyum riparium***

116. Leaves slightly curved, margins serrate at the apex .... ***Warnstorfia fluitans***

117. Basal leaf margins toothed with sharp often recurved teeth; (median cells never papillose); usually in wet calcareous areas .... ***Conardia compacta***

117. Basal leaf margins never toothed, never on calcareous rock or soil .... ***Amblystegium***

KEYS TO SPECIES

Amblystegium

1. Alar cells quadrate to transversely elongate, basal cells usually quadrate, leaves usually shorter, not wide-spreading .... ***A. serpens* var. *serpens***

1. Alar cells few, rectangular, basal cells rectangular; leaves large, wide-spreading ..... ***A. serpens* var. *juratzkanum***

Amphidium

1. Leaf cells smooth, margins not recurved; autoicous, often with sporophytes ..... ***A. lapponicum***

1. Leaf cells papillose with 8 or more papillae per cell; margins recurved; dioicous, sporophytes infrequent .... ***A. californicum***

Andreaea

1. Leaves ecostate .... ***A. rupestris***

1. Leaves costate .... ***A. megistospora***

Antitrichia

1. Costa single to the middle of the leaf, occasionally faint supplemental costae near the leaf base; branches with strong imbricate leaves when dry; cell walls not pitted .... ***A. californica***

1. Costa single with several distinct supplemental costae extending almost to the middle of the leaf; branches with leaves somewhat divergent dry or wet; cell walls pitted ..... ***A. curtipendula***

Atrichum

1. Leaves broad, apex obtuse; several diagonal rows of teeth on the dorsal surface; usually dioicous; common .... ***A. selwynii***

1. Leaves narrower, apex acute; teeth on dorsal surface few or lacking; monoicous; uncommon .... ***A. undulatum***

Aulacomnium

1. Alar cells inflated, sometimes brown, stems matted with rhizoids, gemmae leaf-like in irregular apical clusters on an attenuate shoot; on wet soil or in bogs........................ ***A. palustre***

1. Alar cells not inflated; rhizoids few; gemmae common, fusiform, clustered in a sphere at the apex of a leafless shoot; on rotten logs and soil..***A. androgynum***

Brachythecium

1. Plants large, (leafy shoots > 1 mm wide); leaves ovate-lanceolate, deltoid-ovate to ovate lanceolate, plicate..2.

   2. Plants light green to whitish -green; leaves ovate-lanceolate, apex long accuminate, lightly plicate; margins plane or slightly recurved at the base; alar cells quadrate; seta smooth; usually in dry open sites on soil .... ***B. albicans***

   2. Plants dark green to yellow green; leaves deltoid ovate, to broadly ovate, lightly plicate, margins usually recurved, alar cells rounded or inflated; seta rough throughout; habitat various..3.

3. Leaves scarcely plicate, deltoid-ovate, abruptly acute, alar cells rounded and inflated, often forming long decurrent auricles; usually in wet areas...***B. rivulare***

3. Leaves very plicate, broadly ovate to deltoid ovate, gradually acuminate; alar cells inflated forming a row across the bottom of the leaf; seta rough or smooth, occurring in wet or dry areas ....4.

   4. Plants often stoloniform, forming loose open mats; leaf apex not twisted at the tip; found on dry forested sites ....***B. asperrimum***

   4. Plants not stoloniform, occurring in dense or loose tufts; leaf apex often twisted at the tip; found in wet places, sometimes submerged in water.. ***B. frigidum***

1. Plants small (leafy shoots < 1 mm wide); autoicous; leaves ovate-lanceolate to lanceolate, weakly plicate at base..5.

   5. Seta rough throughout with large papillae ....***B. velutinum* var. *velutinum***

   5. Seta smooth or sometimes weakly papillose at base................. ***B. velutinum* var. *venustum***

Bryum

1. Plants grayish to whitish green, with clear to silver-white leaf tips........................***B. argenteum***

1. Plants green, greenish-brown to reddish-brown..2.

  2. Leaf shoots julaceous when dry, reddish-brown to purplish brown; leaf tip blunt.................
  ....***B. miniatum***

  2. Leaf shoots not julaceous when dry, green to brownish-green, sometimes tinged with red; leaf tip pointed ....3.

3. Autoicous; leaves ovate-lanceolate ± long accuminate; rhizoids few to numerous, leaf margins ± revolute ....4.

  4. Leaves long acuminate, slightly contorted when dry, margins revolute; stems matted with rhizoids; rarely synoicous; cilia appendiculate ....***B. pallescens***

  4. Leaves not long acuminate, margins occasionally lightly revolute; a few rhizoids at the base; cilia rudimentary or lacking ....***B. uliginosum***

3. Dioicous or sometimes synoicous; leaves ovate-lanceolate to oblong-ovate; rhizoids lacking to numerous; leaf margins ± revolute, entire or denticulate...5.

  5. Synoicous; costa excurrent as a ± toothed point, brood-bodies absent; leaf margins revolute almost to the apex ....6.

6. Stems matted with rhizoids; cilia lacking, rudimentary or present and appendiculate.............7.

  7. Cilia appendiculate; leaves ovate-lanceolate, acute........................ ***B. lisae* var. *cuspidatum***

  7. Cilia lacking or rudimentary; leaves ovate-lanceolate, long acuminate............***B. ambylodon***

5. Dioicous, occasionally synoicous; costa excurrent, percurrent or ending well below the apex, brood bodies present or absent, leaf margins ± revolute..8.

  8. Leaves oblong-ovate, widest above the middle; filamentous propagula or rhizoidal tubers sometimes present...9.

9. Leaves decurrent; filamentous propagula often found in the axils of the leaves.... ***B. flaccidum***

9. Leaves not decurrent; brown tubers occasionally found on rhizoids........................ ***B. capillare***

  8. Leaves ovate, ovate-oblong, never widest above the middle, or ovate-lanceolate; propagula may or may not be present ....10.

10. Propagula never found; stem matted at the base with rhizoids; leaves ovate-lanceolate, long accuminate, widest at the base, upper leaf cells long, 6-7:1 .... ***B. caespiticium***

10. Propagula often present; stems ± matted with rhizoids; leaves oblong-lanceolate to obovate-concave, concave, median leaf cells short, 2-3:1, rare 4:1 .... 11.

11. Propagula bulbiform; leaves ovate-oblong, ovate-lanceolate ± concave, obtuse or acute, margins entire .... 12.

12. Rhizoids few, not papillose, leaves obtuse or broadly acute, growing in calcareous sites .... ***B. gemmiparum***

12. Rhizoids few, usually papillose, leaves ovate-lanceolate, concave; not usually found in calcareous sites .... ***B. dichotomum***

11. Propagula filiform; or with tubers on rhizoids; leaves obovate-concave, ovate lanceolate... .... 13.

13. Filamentous propagula in leaf axils, leaves ovate-lanceolate, margin border unistratose or bistratose .... 14.

13. Rhizoids with brown tubers; leaves obovate-concave, acute, margin border unistratose.......... .... ***B. canariense***

14. Leaf border unistratose; stem matted with dense reddish-brown rhizoids; leaves twisted and contorted when dry .... ***B. pseudotriquetrum***

Claopodium

1. Plants branching irregularly; stem leaves without hyaline hairpoints; leaf cells with one large . papilla .... ***C. whippleanum***

1. Plants usually pinnate; stem leaves with hyaline hairpoints; leaf cells with one or several papillae per cell .... 2.

2. Leaf cells with a single large papilla per cell .... ***C. crispifolium***

2. Leaf cells with two or more papillae per cell .... ***C. bolanderi***

Dicranella

1. Leaves oblong or obovate, squarrose from a sheathing base, margins unistratose, (bistratose in part), plane to incurved on damp soil .... ***D. schreberiana***

1. Leaves lanceolate ± sheathing base, not squarrose, margins unistratose or bistratose, plane, incurved or recurved in part .... 2.

   2. Costa up to 1/3 width of leaf base; seta yellow or red, leaf margins unistratose or bistratose .... 3.

3. Seta yellow, darkening with age; leaf margins plane to incurved, unistratose; on road and trail soil banks .... ***D. heteromalla***

3. Seta red; leaf margins plane to lightly recurved and bistratose; on clay .... ***D. howei***

   2. Costa not up to 1/3 width of leaf base; seta red; leaf margins bistratose below the middle and recurved on one or both sides, on clay or wet soil .... ***D. pacifica***

Dicranum

1. Leaf tips usually broken off, plants forming short "stiff" tufts . 2 cm tall, leaves straight; median leaf cells not pitted, quadrate, rounded to shortly rectangular, on rotten logs and coniferous tree trunks .... ***D. tauricum***

1. Leaf tips intact, not broken off, plants forming tall "soft" tufts > 3 cm tall, leaves usually falcate; median cells ± pitted, lamina unistratose or bistratose found on a wide variety of substratum .... 2.

   2. Median leaf cells strongly pitted and thick-walled, lamina unistratose, costa with dorsal "wings"; papillae absent on leaf cells .... ***D. scoparium***

   2. Median leaf cells not pitted, thin or thick-walled, lamina often bistratose on upper margins, costa without dorsal "wings"; papillae common on leaf cells .... ***D. fuscescens***

Didymodon

1. Leaf apex obtuse to rounded, costa strong, ending before the apex; somewhat contorted when dry; peristome short and irregularly divided; often in wet calcareous areas .... ***D. tophaceous***

1. Leaf apex acute, costa ± strong, ending in or before the apex, lightly contorted to strongly crisped and contorted when dry; peristome teeth long or short and twisted; usually in dry calcareous sites .... 2.

   2. Peristome teeth short and twisted; leaf cells smooth or nearly so, margins recurved below the middle, plane above, slightly contorted when dry .... ***D. rigidulus* var. *gracilis***

2. Peristome teeth long and twisted; leaf cells papillose (rare smooth) with 1 or more papillae per cell ....3.

3. Costa ending in or just below the apex, wide at the base in x-section, guide cells 5-7 at the base, 3-4 in the middle .... ***D. fallax***

3. Costa ending in the apex, not wider at the base in x-section guide cells 4-5..............................4.

4. Leaves straight to curved, shorter (up to 2.5 mm long), margins recurved to above the middle .... ***D. vinealis* var. *vinealis***

4. Leaves flexuous, longer (up to 5 mm long), margins recurved only at the base.... ***D. vinealis* var. *flaccidus***

Ditrichum

1. Autoicous, leaves linear-lanceolate, bistratose, apex serrate; seta yellow .... ***D. montanum***

1. Dioicous, leaves lanceolate-subulate, unistratose, bistratose near apex, apex entire or serrate; seta red ....2.

2. Stems matted with rhizoids; costa excurrent .... ***D. flexicaule***

2. Stems not matted with rhizoids; costa percurrent to excurrent.................. ***D. heteromallum***

Drepanocladus

1. Costa extending beyond the middle, not excurrent, narrow at the base; leaf margins entire and plane ....***D. aduncus***

1. Costa excurrent, rarely percurrent, very thick and wide at the base; leaf margins lightly to sharply denticulate .... ***D. crassicostatus***

Eurhynchium

1. Plants with coarse side branches, simple pinnate, usually "flattened" in one plane; widespread on a variety of substrata, usually in dry mostly forested areas .... ***E. oreganum***

1. Plants with slender side branches, irregularly or often bipinnately branched; usually in wet locations on soil or woody material .... 2.

   2. Stem leaves ovate, never squarrose; stem and branch leaves obtuse to ± acute .... ***E. pulchellum***

   2. Stem leaves broadly cordate, squarrose; stem and branch leaves narrowly acute .... ***E. praelongum***

Fissidens

1. Laminal cells bulging, in x-section mostly twice as deep as wide, often arranged in rows; limbidium on all lamina of the leaf and usually ending a few cells below apex; usually fruiting in spring; on soil .... ***F. limbatus***

1. Laminal cells not bulging, not twice as deep as wide in x-section, not arranged in rows; limbidium ending in leaf apex; usually fruiting in fall; on rock .... 2.

   2. Plants synoicous or gonioautoicous .... ***F. bryoides* var. *bryoides***

   2. Plants rhizautoicous .... ***F. bryoides* var. *viridulus***

Fontinalis

1. Plants robust to very robust; stem leaves large, 4-8 mm long sometimes to 10 mm, 3 - 6.5 mm or occasionally to 8.5 mm wide .... ***F. antipyretica* var. *gigantea***

1. Plants medium in size, slender to slightly robust; stem leaves smaller , not longer than 6 mm, not wider than 4 mm .... 2.

   2. Plants medium to slightly robust; leaves somewhat divergent and swollen on branches; stem leaves 2 - 4 mm (rare 4.5 mm) wide .... ***F. antipyretica* var. *antipyretica***

   2. Plants slender to medium; leaves simply imbricated on branches; .75 - 2 mm wide, sometimes up to 3.5 mm. .... ***F. antipyretica* var. *oregonesis***

Funaria

1. Plants large (stems 1.6 - 6 cm tall) and branched; seta 1.6 - 6 cm long; annulus present and red; common and widespread, on soil .... ***F. hygrometrica***

1. Plants smaller (stems up to 0.6 cm tall), not branched; seta 0.4 - 1.5 cm long; annulus lacking. uncommon, on soil .... ***F. muhlenbergii***

Grimmia

1. Plants autoicous; seta curved to arcuate when moist; leaves unistratose, margins recurved below the middle, 2 - 3 stratose in the upper part, hairpoints long up to 1/2 the length of the leaf; on rock and cement in dry exposed sites .... ***G. pulvinata***

1. Plants dioicous; seta straight to ± arcuate; leaves unistratose or bistratose, margins plane or recurved, hairpoints short or long ....2.

   2. Shoots stiff, coarse and ± julaceous when dry; leaves not keeled, bistratose, margins plane to incurved, densely covered with spiny hairpoints .... ***G. laevigata***

   2. Shoots not stiff and coarse, never julaceous; leaves keeled, unistratose, margins plane or recurved, hairpoint muticous to long ....3.

3. Plants strongly twisted and contorted when dry; hairpoint muticous or forming a short hyaline point; multicellular filamentous gemmae sometimes on the back of the costa; leaf margins plane or recurved at the middle; on shaded rock outcrops and cliffs .... ***G. torquata***

3. Plants not strongly twisted and contorted when dry, often lightly twisted; hairpoints smooth or nearly so, length up to 1.2 mm; margins strongly recurved only on one side, occasionally multicellular brown gemmae present on the leaves; on rock in forested areas.... ***G. trichophylla***

Heterocladium

1. Leaf and stem cells smooth; leaves squarrose; psudoparaphyllia few to inconspicuous .... ***H. procurrens***

1. Leaf and stem cells papillose with 1 4 papillae per cell; leaves not squarrose; pseudoparaphyllia serrate and papillose .... ***H. macounii***

Homalothecium

1. Alar cells numerous, quadrate and clear; leaf margins entire; occurring on rock or soil over rock .... ***H. pinnatifidum***

1. Alar cells not numerous, short, irregularly quadrate to rounded; leaf margins entire or with sharp teeth; on soil, rocks or tree trunks .... 2.

   2. Plants found on trees, very rarely on rock .... 3.

3. Plants slender, pale yellow and shiny, often pinnate; basal marginal cells with numerous sharp recurved teeth; plants usually in tight stoloniferous mats .... ***H. nuttallii***

3. Plants robust, dark yellowish green and weakly glossy, rarely pinnate; basal marginal cells occasionally toothed with a few teeth, plants usually in loose mats .... ***H. fulgescens***

   2. Plants on soil, soil over rock or on rock, very rarely on trees .... 4.

4. Leaves ovate-lanceolate, acuminate with a broad often serrate apex, strongly plicate, not concave at the base; alar cells short, irregularly quadrate to rounded .... ***H. aeneum***

4. Leaves ovate-lanceolate, acute to acuminate, leaves plicate, very concave at the base; alar cells short, quadrate to rounded .... ***H. arenarium***

Hypnum

1. Cortical cells small, thick-walled .... 2.

   2. Plants forming small tightly appressed mats on logs and tree trunks; leaf base very rounded at the insertion .... ***H. circinale***

   2. Plants forming large loose mats on rocks and dry soil; leaf base not rounded at the insertion .... ***H. cupressiforme***

1. Cortical cells large and hyaline .... 3.

   3. Alar cells inflated, hyaline, strongly differentiated cells toward costa strongly pigmented; usually forming large mats in wetter habitats .... ***H. dieckii***

   3. Alar cells not inflated, not strongly differentiated; forming extensive mats on trees, cliffs in well-drained habitats .... ***H. subimponens***

Isothecium

1. Leaves oblong-lanceolate, widest at or just below the middle; branches julaceous when dry; alar cells numerous, strongly differentiated quadrate to transversely elongate......... ***I. cristatum***

1. Leaves ovate-lanceolate, widest just above the base; irregularly branching ± flagellate or julaceous; alar cells short and quadrate, not numerous or strongly differentiated.. ***I. myosuroides***

Mnium

1. Leaf border bistratose to multistratose without stereid cells, median cells with thickened corners; peristome teeth yellowish brown, seta single .... ***M. marginatum***

1. Leaf border multistratose with central streid cells, median cells without thickened corners; peristome teeth dark red, multiple seta ....***M. spinulosum***

Neckera

1. Leaf apex long acuminate with sharp often recurved teeth; dioicous, sporophyte exserted......... .... ***N. douglasii***

1. Leaf apex blunt or rounded, without sharp teeth, sometime apiculate, or serrate; autoicous, sporophyte immersed.. ***N. pennata***

Orthotrichum

1. Stomata superficial; dioicous or autoicous ....2.

    2. Always found on non-calcareous rock; autoicous; capsule immersed to emergent, occasionally slightly exserted .... ***O. rupestre***

    2. Found on trees, very rarely on rock, autoicous or dioicous, capsule immersed to exserted ....3.

3. Plants dioicous; brood bodies often abundant; capsule immersed to emergent, rarely exserted .. ..***O. lyellii***

3. Plants autoicous; brood bodies absent; capsule immersed to exserted ....4.

  4. Sporophytes exserted, lightly ribbed and not constricted under the mouth when dry; 1- 3 large conical or forked papillae per cell .... ***O. speciosum***

  4. Sporophyte immersed to 1/2, emergent or shortly exserted..5.

5. Sporophyte smooth when dry, immersed; endostome of 16 teeth, erose, stout and densely papillose .... ***O. striatum***

5. Sporophyte strongly 8 ribbed when dry, 1/2 emergent to shortly exserted, endostome 8 (rare 16) teeth, not erose or stout, reticulate-papillose .... ***O. affine***

1. Stomata immersed; always autoicous ....6.

  6. Plants growing on rock, often calcareous ....7.

7. Leaf lamina in upper 1/2 bistratose, (occasionally with unistrtose streaks), sporophyte immersed to 1/2 emergent, calyptra sparsely hairy .... ***O. hallii***

7. Leaf lamina unistratose, capsule exserted, calyptra hairy to nearly smooth .... ***O. anomalum***

  6. Plants growing on trees ....8.

8. Leaf apex obtuse to broadly acute, rarely apiclute or serrulate tip, sporophyte 2/3 emergent to shortly-exserted; calyptra sparsely hairy or naked .... ***O. tenellum***

8. Leaf apex acuminate to sharply acute, sporophyte exserted or 1/2 emergent; calyptra naked...9.

  9. Sporophyte long exserted; peristome teeth pale yellow.................................... ***O. consimile***

  9. Sporophyte exserted to 1/2 emergent, never long exserted; peristome teeth orange-red......... .... ***O. pulchellum***

Plagiothecium

1. Plants large, whitish-yellow-green, not glossy; leaves complantate, symmetric, very undulate; dioicous .... ***P. undulatum***

1. Plants smaller, various shades of green, always glossy; leaves complantate, symmetric or asymmetric, never undulate; autoicous, rarely dioicous ....2.

  2. Leaves symmetric, with a long filiform apex up to 1/3 the length of the leaf .....***P. piliferum***

2. Leaves asymmetric, apex not filiform .... 3.

3. Alar cells decurrent, composed of ± large bulging inflated cells; rarely dioicous .... ***P. denticulatum***

3. Alar cells decurrent, composed of a narrow band of rectangular cells; always autoicous .... ***P. laetum***

Pohlia

1. Leaves whitish-green to light green .... 2.

2. Leaves whitish-bluish green, opalescent or with a metallic luster; on rock cliffs in crevices and on ledges .... ***P. cruda***

2. Leaves without metallic luster and not opalescent; in wet seepy places on soil or rock .... ***P. wahlenbergii***

1. Leaves of various shades of green, never whitish .... 3.

3. Plants growing mixed in with *Sphagnum*, leaves small, acute and narrowly lanceolate .... ***P. sphagnicola***

3. Plants found in various habitats, wet or dry; leaves larger, ovate to ovate-lanceolate .... 4.

4. Leaves little decurrent, often twisted when dry; costa strong without spines on the back, antheridia in pairs at the base of the upper leaves; propagula sometimes present .... ***P. nutans***

4. Leaves decurrent, not twisted when dry, costa not as strong, with spines on the back near the apex; antheridia in large disk-like heads .... ***P. longibracteata***

Plagiomnium

1. Plants never having stoloniferous shoots; leaves obovate, slightly decurrent; marginal teeth sharp, extending almost to the base of the leaf; on trees, rotten logs and sometimes soil .... ***P. venustum***

1. Plants usually with stoloniferous shoots; leaves various ± decurrent; marginal teeth ± sharp; usually on soil .... 2.

2. Plants dioicous; leaves oblong to elliptic, acuminate, concave and strongly decurrent, marginal teeth sharp and to the base of the leaf; on soil .... ***P. insigne***

2. Plants synoicous; leaves variously shaped, $\pm$ decurrent, marginal teeth $\pm$ sharp, extending almost to the base of the leaf; on soil .... 3.

3. Leaves ovate to obovate or oblong, acute, strongly decurrent, marginal teeth sharp; on wet soil near water .... ***P. medium***

3. Leaves elliptic, rounded at the base and apex, sometimes apiculate, slightly deccurent; marginal teeth blunt (rarely sharp); on soil or soil over rock in dry areas .... ***P. rostratum***

Philonotis

1. Plants small; upper leaf cells papillose on the upper ends; rhizoids not abundant; on well-drained soil .... ***P. capillaris***

1. Plants robust; upper leaf cells papillose on the lower ends; stems with numerous brown rhizoids; on soil in wet areas .... ***P. fontana***

Pogonatum

1. Leaves strongly crisped and contorted when dry, leaf margins bistratose .... ***P. contortum***

1. Leaves not crisped and contorted when dry, leaf margins unistratose .... ***P. urnigerum***

Polytrichum

1. Leaves with incurved margins, forming "flaps" over the lamellae .... 2.

2. Costa excurrent as a long toothed hyaline awn .... ***P. piliferum***

2. Costa excurrent as a short toothed red awn or awn not conspicuous .... 3.

3. Leaves with a short toothed awn, rhizoids only on or near the base of the stem, usually in dry places on soil .... ***P. juniperinum***

3. Leaves without a conspicuous awn, stems matted with white rhizoids, only found in *Sphagnum* bogs .... ***P. strictum***

1. Leaves with plane margins, never incurved .... 4.

4. Lamellae 4- 8 cells tall, apical cell notched or dish shaped .... ***P. commune***

4. Lamellae 3 - 5 cells tall, apical cell not notched, slightly larger than the rest of the cells .... ***P. formosum***

Porotrichum

1. Leaf apex coarsely toothed; stems with paraphyllia or pseudoparaphyllia, usually in wet places .... ***P. bigelovii***

1. Leaf apex finely toothed, stems without paraphyllia; on the base of trees or rock .... ***P. vancouveriense***

Rhizomnium

1. Leaves elongate-ovate or elliptic; narrowed at the base; stems without rhizoids or rarely a few; on rotten logs or rock .... ***R. glabrescens***

1. Leaves obovate; stems matted with reddish-brown rhizoids the entire length of the stem; on wet soil .... ***R. magnifolium***

Rhytidiadelphus

1. Leaves without a costa or costa short and double, leaf cells smooth .... 2.

   2. Leaves squarrose recurved, not plicate, alar cells hardly differentiated .... ***R. squarrosus***

   2. Leaves plicate, not strongly squarrose recurved, alar cells somewhat enlarged and well defined .... ***R. loreus***

1. Leaves with a costa, double and strong to the middle, leaf cells papillose by projecting end walls .... ***R. triquetrus***

Racomitrium

1. Leaves with apparent hairpoints .... 2.

   2. Hairpoints hyaline, strongly papillose .... 3.

3. Papillae confined to hairpoint .... ***R. lanuginosum***

3. Papillae on most of leaf cells, including hairpoint .... 4.

4. Super-alar cells usually elongate, thin-walled, slightly papillose, hairpoint not strongly decurrent, lightly papillose in the upper part .... ***R. ericoides***

4. Super-alar cells mostly short, thick-walled, strongly sinuous, hairpoints very decurrent, papillose or denticulate throughout .... ***R. elongatum***

2. Hairpoints hyaline, smooth or denticulate .... 5.

5. Margins of lamina bistratose, dorsal side of costa with bulging cells, hairpoint long or short..... .... ***R. occidentale***

5. Margins of lamina unistratose, rarely with a few bistratose spots, hairpoint usually long and decurrent .... 6.

6. Upper lamina cells below the hairpoint small, short, not as long as wide, costa channeled, hairpoint bluntly decurrent, not usually forming long thin bands down the margins .... ***R. heterostichum***

6. Upper lamina cells below the hairpoint long, often 6 - 7 x as long as wide, costa deeply channeled, hairpoint very decurrent, forming thin lines down the margins......... ***R. lawtonae***

1. Leaves without hairpoints or hairpoints short, often muticous .... 7.

7. Leaf apex blunt, obtuse, lacking a hairpoint .... 8.

8. Apex broad, usually blunt-denticulate, leaf cells papillose, apical leaf cells short, less than 3 : 1 .... ***R. aciculare***

8. Apex blunt, not denticulate, leaf cells smooth, apical leaf cells elongate, greater than 3 : 1 .... ***R. fasciculare***

7. Apex blunt, acute, muticous or rarely with a very short hairpoint .... 9.

9. Leaf cells papillose, apex acuminate, muticous or with a short decurrent weakly denticulate hairpoint; alar cells somewhat differentiated .... ***R. varium***

9. Leaf cells smooth, acute to narrowly obtuse or muticous apex; alar cells not or scarcely differentiated .... ***R. pacificum***

Schistidium

1. On rock along the coast, often within the ocean spray zone, leaves stiff and slightly contorted when dry .... ***S. maritimum***

1. On rock, never in the ocean spray zone, leaves never contorted when dry .... 2.

   2. Leaf apex denticulate, mostly blunt or obtuse, usually on rock in or near fresh water .... ***S. rivulare***

   2. Leaf apex never denticulate, apex obtuse to acute, muticous ± a hairpoint, on rock in dry locations .... 3.

3. Leaves with hairpoints or muticous, margins recurved or revolute throughout, costa stout and channeled .... ***S. apocarpum***

3. Leaves without hairpoints, rarely muticous, margins ± recurved, costa stout, not channeled, sometimes denticulate on the dorsal surface .... ***S. agassizii***

Scleropodium

1. Plants strongly julaceous, tumid branches, occurring in or around streams, leaves broadly ovate and very concave .... ***S. obtusifolium***

1. Plants ± julaceous and tumid branches, occurring in well-drained sites, never in or near water, leaves various .... 2.

   2. Leaves ovate to ovate-lanceolate, apex acute without an apiculus; branches not julaceous, never tumid or turgid .... ***S. cespitans***

   2. Leaves ovate, oblong-ovate to broadly ovate-lanceolate, apex with a ± recurved apiculus, branches julaceous, often tumid or turgid .... 3.

3. Branches often flattened somewhat; leaf apex with the apiculus not or rarely recurved; on wood or rock .... ***S. tourettii* var. *colpophyllum***

3. Branches always terete; leaf apex with the apiculus never recurved; usually on mineral soil .... ***S. tourettii* var. *tourettii***

Sphagnum

1. Cortical cells of stem and branches with spiral fibrils, branch leaves broad, rough at the back of the apex .... 2.

   2. Plants pale red to purplish red, green cells central, not exposed on either surface .... ***S. magellanicum***

   2. Plants green, never showing red, green cells isosceles-triangular, exposed on the inner surface .... 3.

3. Branch cells with numerous large rounded pores; chlorophyll cells with ridges on outer face.. ***S. henryense***

3. Branch cells with fewer large elliptic pores; chlorophyll cells smooth on outer face.. ***S. palustre***

1. Cortical cells of stems and branches without spiral fibrils, branch leaves narrower, apex not rough at back .... 4.

   4. Branch leaves curved, stem and branch leaves with numerous commisural pores forming "bead like" rows, plants yellow-green to orange .... ***S. subsecundum***

   4. Branch leaves not curved, stem and branch leaves with few pores, never forming "bead like" rows, plants green, yellow-green to wine-red .... 5.

5. Green cells exposed on the inner surface, plants reddish or brownish .... 6.

   6. Capitulum flat on top, stem leaves oblong-lingulate, rounded at apex .... 7.

7. Plants and stems rusty brown, capitulum branches straight, with erect leaves............ ***S. fuscum***

7. Plants and stems reddish, capitulum branches upcurved, leaves subsecund .... ***S. rubellum***

   6. Capitulum "globose-rounded", stem leaves oblong to oblong-triangular, broadly acute .... ***S. capillifolium***

5. Green cells exposed on the outer surface, plants not red .... 8.

   8. Divergent branch leaves very squarrose-spreading throughout; capitulum terminal bud large, margins of branch leaves not wavy when dry .... ***S. squarrosum***

   8. Divergent branch leaves squarrose-spreading in capitulum only, capitulum terminal bud small, branch leaves with wavy margins when dry.. ***S. recurvum***

Tortella

1. Leaves soft and strongly twisted and contorted when dry, margins wavy, costa excurrent as a ± serrulate point .... ***T. tortuosa***

1. Leaves rigid and not strongly twisted or contorted when dry, margins not wavy, costa strong, leaf tips frequently broken off .... ***T. fragilis***

Tortula

1. Plants on trees, usually having numerous propagula, rarely without propagula .... 2.

    2. Propagula multicellular, spherical or globouse, borne on the upper surface of the leaf .... 3.

3. Leaves obovate-oblong to spathulate from a narrow base, apex obtuse, costa percurrent, never forming a hairpoint .... ***T. latifolia***

3. Leaves obovate-oblong, occasionally oblong-lanceolate, apex broadly rounded; costa excurrent forming a smooth hairpoint often yellow-brown at the base .... ***T. papillosa***

    2. Propagula leaf-like gemmae borne on the top of the stem amongst the leaves, or lacking .. 4.

4. Gemmae lacking; leaves with costa excurrent as a long smooth or lightly toothed hairpoint .... ***T. laevipila* var. *laevipila***

4. Gemmae leaf-like and costate, muticous or mucronate; leaves with costa excurrent as a short hairpoint or hairpoint absent .... ***T. laevipila* var. *meridionalis***

1. Plants on soil, rocks or sometimes on trees, without propagula .... 5.

    5. Leaf margins bordered by 1 -4 rows of smaller yellowish cells; without long hairpoints .... 6.

6. Plants autoicous; sporangia 4 - 6 mm long; leaves oblong-lanceolate to long-apatulate, costa excurrent as a short or long mucro; peristome teeth with a high basal membrane .... ***T. subulata***

6. Plants dioicous; sporangia 1.5 - 2 mm long; leaves oblong to ligulate, costa percurrent, apex with a mucronate tip; peristome teeth with a low basal membrane .... ***T. amplexa***

    5. Leaf margins not bordered; with long, smooth or denticulate hairpoints .... 7.

7. Plants autoicous; leaves oblong to spatulate, costa strong, excurrent as a long smooth hairpoint; on calcareous rock or cement .... ***T. muralis***

7. Plants dioicous or synoicous; leaves oblong-lingulate, costa excurrent as a long denticulate hairpoint; on soil, rocks or trees .... 8.

8. Plants synoicous, leaves recurved to just below the middle, costa strong, excurrent as a hyaline $\pm$ toothed awn, usually on soil or soil over rock, sometimes on trees...... ***T. princeps***

8. Plants dioicous, leaves recurved to the apex or just below it; costa strong, excurrent as a very toothed hairpoint usually red at the base..9.

9. Leaves densely papillose with one tall antleroid papilla per cell; on dry soil, never on trees ....***T. papillosissima***

9. Leaves densely papillose with several low C-shaped papillae per cell; on dry soil or trees ....***T. ruralis***

Ulota

1. Plants autoicous, often fruiting; gemmae lacking; on trees ....2.

2. Leaf apex bluntly acute, plants occurring as dense tufted cushions..............***U. obtusiuscula***

2. Leaf apex acute, filiform, ending in a row of several clear cells; plants prostrate, never forming dense cushions.. ***U. megalospora***

1. Plants dioicous, rarely fruiting; abundant brown gemmae occurring on the leaf tips, on rock or trees only along the coast...***U. phyllantha***

CHAPTER 8

Summary and Conclusions

The San Juan Islands contain a diverse moss flora within a small geographical area (445.5 square kilometers, 172 sq. miles) consisting of 224 species and varieties, comprising 33 families and 97 genera. Four species were found as new for the State of Washington with one of these new for the United States. This flora represents 37.4 % of what Lawton (1971) defined as the Pacific Northwest flora. Although 43 endemic Western North American taxa are present, none of these are endemic just to the San Juan Islands.

This flora is based on 6021 collections made over a four year period from 159 sites, and an extensive search of historical records from herbaria throughout the region. The collection provides documentation of the flora for future taxonomic studies, potential reevaluation, and is the foundation for a state wide moss checklist. A county distribution map for each of the species was made, and when combined with the vouchers, provides a substantial database to monitor the loss of species and habitat within the islands.

Keys to the genera and species were designed for future use by both amateurs and bryologists and their construction helped to clarify species concepts that were not clear. It is hoped that these keys ultimately will be expanded and refined to become useful for the entire state.

Detailed ecological observations were made for each collection and included information on habitat and substratum. Six general habitats and twenty-six sub-habitats were distinguished in order to determine their correlations to the mosses. Other than the habitat and substratum information provided in a paper by Schofield (1976) little has been published on this topic with reference to the Pacific Northwest. Therefore this study supplements the British Columbia information, and appears to represent the first such study for mosses in Washington State.

Habitats showing the highest diversity included woodlands (60.2%), outcrops (58.4%), and wetlands with 57.5% of the flora, with the majority of the species occurring on rock (72.7%) or soil (63.3%). Because freshwater sources are not abundant within the islands, the aquatic substratum showed lowest diversity with only 4.0% of the flora.

Each moss collection was correlated with the geological units presented by Brandon et al. (1988) and a database was established for comparing the relationship of the mosses to the geologic unit from which they were collected. The relationship between geological unit and species composition showed that the geological units with the greatest area in the islands correlated with the larger number of species. This higher species composition is a result of the greater variety of rock material found in the larger units and is reflected in the Constitution Formation (the largest formation covering 38.54% of the area) having 83.9% of the flora. One unit, the Nanaimo Group, covered only 4.84% of the area, yet harbored 43.7% of the moss flora. This probably is the result of the large quantity of conglomerate material that occurs in this formation which in turn, provides an excellent substratum for mosses to colonize.

This flora was completed as a qualitative study, therefore species diversity is presented from a floristic viewpoint. The relative high species diversity found in the islands is the result of a number of factors. First the large number of collections (6021) established a substantial database reflecting the six habitats and twenty six sub-habitats found within the islands. This database provided the information needed to interpret the geographical distributions and to compare the flora to the adjacent mainland and island floras. Although this database is quite large, additional species will certainly be added to it as more field work is completed. This is reflected in the number of species found on Henry Island. Only half a day was spent on this island, resulting in a species list composed of 28 species. Even with the addition of the five historical species the list still does not reflect what most likely will be found on the island when more field work is done. This same observation holds true for the islands that were not visited during the present study.

The size of the island also influences the number of species. This is a result of the number of habitats available; the larger the island, the greater the number of habitats available to species. Size alone is not the only limiting factor, the amount of rainfall available and the degree of disturbance (past or present) also influences species diversity. Orcas Island, the largest (14,761 hectares or 36,431 acres), clearly demonstrates this by harboring 85.7% of the flora. San Juan Island, the second largest (14,382 hectares, or 35,448 acres) contained only 67.8% of the flora. The higher percentage of species on Orcas Island demonstrates the increased number of niches found in the Mt. Constitution area resulting from the higher elevations, increased rainfall, and more freshwater sites. It also appears that less of Orcas Island has undergone disturbance, while San Juan Island has a considerable amount of agricultural land.

Non-human disturbance also plays a role in determining what species survive in or colonize, an area. This is clearly suggested by the influence of bird droppings on Goose Island and by the loss of species as a result of trees blown down by winter storms, with a consequent loss of habitat, on Orcas and Jones Islands.

The establishment of a complete inventory of a region's flora is necessary before any phytogeographical interpretations can be made. It appears that this study presents the first phytogeographical interpretation of past and present moss distribution patterns for Washington State.

The bulk of the flora is composed of circumboreal species that are derived from a once widespread Arcto-Tertiary flora. During the Pleistocene these islands were thoroughly glaciated and the present flora represents, therefore, species that have migrated back into the region predominantly from southern refugial sites, or less possibly from northern refugial areas. This recolonization in the islands may have begun as early as 13,500 yr. B.P. (Deither et al. 1995) but the bulk of the flora appears to have returned during the hypsithermal interval described by Deevey and Flint (1957). A cooling trend began about 2000 yr. B.P. that probably caused the southern element species to retreat southward, with fragments persisting only in those areas where favorable conditions also remained. The San Juan and adjacent islands can be interpreted as a "modern" refugium for southern mediterranean type climate species.

It is hoped that, through continued protection of these islands, this unique ecosystem will continue to remain in a relatively undisturbed state, and as additional field work is completed, the recorded diversity of the flora of the islands will be increased.

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Appendix A

Historical records that were not relocated.

HPSU = Portland State University, WWB = Western Washington University, WTU = University of Washington.

Genus & Species	Island	Collector	Date	Location of Record
Fontinalis antipyretica	Blakely	F.L. Spaulding	6 July 1919	WTU
Bryum argenteum	Flattop	T.C. Frye	10 July 1921	WTU
Alsia californica	Henry	A.S. Foster	11 July 1904	HPSU
Antitrichia californica	Henry	A.S. Foster	24 July 1904	WTU
Leptodictyum riparium	Henry	A.S. Foster	13 July 1904	HPSU
Neckera douglasii	Henry	T.C. Frye	3 July 1905	WTU
Orthotrichum lyellii	Henry	T.C. Frye	3 July 1905	WTU
Rhytidiopsis robutsta	Lopez	F. Richardson	April 1983	Per. comm.
Dendroalsia abietina	Matia	D. Durrwachter	18 Feb. 1962	WWB
Ceratodon purpureus	Matia	L. O'Flaherty	18 Feb. 1962	WWB
Polytrichum piliferum	Matia	D. Durrwachter	18 Feb. 1962	WWB
Porotrichum vancouveriense	Matia	D.Durrwachter	18 Feb. 1962	WWB
Racomitrium ericoides	Matia	D. Durwachter	18 Feb. 1962	WWB
Polytrichum piliferum	Matia	D. Durwachter	18 Feb. 1962	WWB
Hygrohypnum bestii	Orcas	C.M. Roberts	7 July 1925	WTU
Roellia roellii	Orcas	E. Peterson	?	WTU
Andreaea rupestris	San Juan	D. Mullen	23 July 1925	WWB
Bryum creberrimum	San Juan	D. Mullen	?	WWB
Climacium dendroides	San Juan	D. Mullen	29 June 1925	WWB
Distichium capillaceum	San Juan	T.C. Frye	1 July 1923	WWT
Encalypta vulgaris	San Juan	D. Mullen	21 July 1925	WWB
Fontinalis antipyretica	San Juan	D. Mullen	July 1908	WWB
F. antipyretica var. oregonensis	San Juan	D. Mullen	3 July 1925	WWB
Heterocladium macounii	San Juan	T.C. Frye	3 July 1921	WTU
Philonotis fontana	San Juan	J. Fritz	July 1908	FHL
Plagiomnium rostratum	San Juan	T.C. Frye	6 July 1930	WWB
Pohlia wahlenbergi	San Juan	?	25 June 1925	WWB
Polytrichastrum alpinum	San Juan	A. Daugherty	15 July 1923	WTU
Polytrichum commune	San Juan	D. Mullen	3 July 1925	WWB
Pseudotaxiphyllum elegans	San Juan	T.C. Frye	3 July 1923	WTU
Racomitrium affine	San Juan	T.C. Frye	?	WTU
Rhytidiopsis robusta	San Juan	T.C. Frye	31 July 1925	WTU
Sphagnum mendocinum	San Juan	T.C. Frye	10 July 1908	WTU
Tayloria serrata	San Juan	Mrs. Hartge	?	WTU
Distichium capillaceum	Spieden	C.M. Roberts	5 July 1925	WTU
Mnium spinulosum	Spieden	J.E. Kirkwood	17 July 1926	WTU
Timmia austrica	Spieden	J.E. Kirkwood	17 July 1926	WTU
Tortula subulata	Spieden	C.M. Roberts	5 July 1925	WTU
Polytrichastrum alpinum	Stuart	A.S. Foster	12 July 1904	WTU
Antitrichia curtipendula	Sucia	T.C. Frye	10 July 1907	WTU
Mnium spinulosum	Sucia	T.C. Frye	10 July 1907	WTU
Racomitrium varium	Sucia	A.M. Daugherty	1 July 1923	WTU
Timmia austrica	Sucia	A.M. Daugherty	1 July 1925	WTU
Brachythecium velutinum	Waldron	A.S. Foster	?	HPSU
Scleropodium touretii var. colophyllum	Waldron	A.S. Foster	12 July 1912	HPSU

Appendix B

Data on collecting bag.

DATE___________________ T____R____SEC____

LOC______________________________________

____

____

ELEVATION______________LAT______LONG_____

SITE forest meadow ridge valley

canyon beach lake pond river bog

swamp marsh trail roadside stream

PARTIAL SHADE______ FULL SHADE_____ FULL SUN____ EXPOSURE: N S E W

TREE trunk branch root leaf stump

LOG recent-fallen decaying rotten

SOIL gravel sand clay litter humus over rock

ROCK____________________ siliceous basic

cave ledge roof of overhang crevice

MESIC XERIC HYDRIC moist wet

spray waterfall seep submerged standing flowing

Appendix C

Species and habitat relationships.

Maritime | Meadows & Ridges | Disturbed Sites | Outcrops | Wetlands | Woodlands

G & S	M A R	M S E	M C S	O G S	O M P	O R S	C E M	D A I	D D E	O R Q	O O C	O O N	O S N	W B O	W L A	W P O	W S E	W S M	W S T	C W O	D W O	M W O	O A O
alca						X						X								X	X	X	
amju															X								
amse	X	X	X												X	X		X					
amca	X	X									X	X	X		X		X		X	X			
amla												X	X							X			
anme	X					X						X	X		X		X			X			
adme												X											
adru												X											
anca	X					X	X		X			X	X				X				X	X	X
ancu	X			X		X			X	X		X	X		X	X	X	X		X	X	X	X
atse						X			X			X	X	X		X			X	X	X	X	
atun																				X		X	
auan	X			X		X			X			X	X	X	X	X		X	X	X	X	X	
aupa													X	X	X								
baun		X								X													
bapo	X											X	X										
blac	X																						
bral	X			X	X	X		X	X			X								X			
bras									X				X									X	
brfr		X							X						X	X		X	X			X	
brri												X											
brve	X	X											X	X				X	X	X		X	
brvn																				X			
brre	X											X	X							X			
byam		X																					
byar	X									X		X											
byca	X					X		X	X			X	X		X	X	X			X	X		
bycn																				X			
bycp	X			X		X		X	X		X	X	X		X	X	X	X		X	X	X	
bydi	X																						
byfl																X							
byge		X	X																				
byli				X		X						X	X		X			X	X	X			
bymi		X	X									X			X	X	X						
bypa	X																						
bypl	X																			X		X	
byps	X			X	X	X		X	X	X		X	X	X	X	X	X	X		X	X	X	
byul														X									
cagi															X	X							
cacu												X		X	X	X							
cepu	X			X	X	X		X	X	X	X	X	X		X		X			X	X	X	

G & S	M A R	M S E	M C S	O G S	O M P	0 R S	C E M	D A I	D D E	O R Q	O O C	O O N	O S N	W B O	W L A	W P O	W S E	W S M	W S T	C W O	D W O	M W O	O A O
clbo						X						X	X				X		X	X			
clcr	X								X	X		X	X							X	X	X	
clwh												X	X							X		X	
clde															X								
coco												X											
coca												X											
crfi			X						X						X				X	X			
crla		X	X																X				
cyje												X	X							X			
deab													X								X	X	
deob												X											
dipe	X								X				X				X		X				
dihe	X	X										X	X	X		X	X		X	X	X	X	
diho	X	X																					
dipa	X	X																	X	X			
disc								X												X	X		
dici	X			X	X	X	X		X		X	X	X	X	X		X	X	X	X	X	X	X
dcfu	X					X						X	X	X	X	X		X	X	X	X	X	
dcsc	X				X	X		X	X			X	X	X	X		X	X	X	X	X	X	
dcta	X													X		X	X	X	X	X	X	X	
difa									X														
difl	X								X	X		X	X				X					X	
diri												X											
dito	X	X	X						X			X				X							
divi	X	X		X		X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	
dtfl												X	X										
dthe			X			X														X		X	
dtmo																				X		X	
drad														X	X			X					
drcr					X											X							
drpa												X	X							X			
enci												X	X							X			
enpr											X	X											
envu												X											
epto																			X				
euve	X		X																				
euor	X				X	X			X	X		X	X	X	X			X	X	X	X	X	
eupr	X	X			X			X	X	X	X	X	X	X	X	X	X	X	X	X		X	
eupu												X											
fiad																			X				
fibr		X											X							X		X	
fivi													X							X			
figr																			X				
fili	X	X	X										X				X			X		X	
five																	X		X				
foan																X			X	X			
fogi																				X			

G & S	MAR	MSE	MCS	OGS	OMP	ORS	CEM	DAI	DDE	ORQ	OOC	OON	OSN	WBO	WLA	WPO	WSE	WSM	WST	CWO	DWO	MWO	OAO
foor														X	X	X			X	X			
fuhy	X	X	X	X	X	X		X	X			X			X	X				X	X	X	
fumu						X																	
grla												X											
grpu	X			X		X	X		X	X	X	X	X			X		X		X	X	X	
grto	X											X	X							X			
grtr	X			X	X	X	X		X		X	X	X		X	X	X			X	X	X	
gyae		X										X					X		X				
hest	X			X	X	X			X			X	X		X					X	X	X	
hema												X											
hepr																				X		X	
hoae																				X	X		
hoar	X								X			X						X		X			
hofu							X		X	X		X	X					X		X	X	X	X
honu	X					X			X	X		X		X				X		X	X	X	X
hopi	X				X	X	X	X	X	X	X	X	X			X				X	X	X	X
hysp						X						X	X	X		X				X	X	X	
hyre		X	X														X						
hyci														X		X		X	X	X		X	
hycu																						X	
hydi									X	X		X	X		X		X	X		X		X	
hysu	X					X		X	X			X	X					X		X	X	X	
iscr	X			X		X			X		X	X	X		X				X	X	X	X	X
ismy	X				X	X			X	X		X	X		X		X	X	X	X	X	X	X
lepy									X							X	X			X		X	
leri					X			X	X					X	X	X		X		X		X	
leac									X	X		X	X			X		X	X	X	X		
meme	X					X			X	X		X	X							X	X	X	X
mnma												X							X				
mnsp												X	X			X			X	X	X	X	
nedo					X				X				X	X	X			X	X	X	X	X	
nepe																					X	X	
onwa																		X					
oraf															X						X	X	
oran									X														
orco							X		X	X		X		X	X			X	X	X	X	X	X
orha									X														
orly	X					X			X	X		X	X	X	X			X	X	X	X	X	X
orpu									X	X			X	X				X		X	X	X	
orru	X					X	X		X			X	X								X	X	
orsp																			X		X	X	
orst																					X	X	
orte																					X		
phcu				X																			
phca												X											
phfo														X	X		X						
phpy								X												X			

G&S	MAR	MSE	MCS	OGS	OMP	ORS	CEM	DAI	DDE	ORQ	OOC	OON	OSN	WBO	WLA	WPO	WSE	WSM	WST	CWO	DWO	MWO	OAO
plin	X				X	X							X				X	X	X	X	X	X	
plme																		X		X			
plro																				X			
plve									X			X	X				X			X	X	X	
plde												X	X					X	X	X	X	X	
plla		X											X					X	X	X	X	X	
plpi													X										
plun						X			X				X			X		X		X		X	
plju	X	X															X						
plri																			X				
plac	X			X				X				X											
plsc	X					X			X			X	X	X	X					X		X	
poco																				X			
pour												X	X							X			
pocr	X	X							X			X	X							X			
polo									X														
ponu	X					X			X			X		X						X			
posp														X									
powa		X														X	X						
pyal						X						X	X	X						X			
pyco																				X			
pofo						X						X				X				X			
pyju	X			X	X	X	X	X	X		X	X	X	X	X					X		X	
pypi	X			X		X			X			X	X							X	X	X	
pyst														X									
pobi	X											X	X				X		X	X		X	
pova												X											
psca						X						X			X								
pspu					X																		
psel									X			X	X				X			X		X	
ptgr												X											
ptga									X	X		X											
raac												X											
rael					X	X						X	X									X	
raer	X			X		X		X	X	X		X	X		X		X	X		X		X	
rahe	X				X	X		X	X	X	X	X	X	X	X	X	X			X		X	
rala						X						X	X										
ralw												X								X			
raoc	X											X								X			
rapa												X			X								
rava						X				X		X	X			X	X		X				
rhgl												X	X	X	X	X	X	X	X	X		X	
rhma														X									
rhlo						X				X		X	X	X		X	X	X	X	X	X	X	
rhsq					X																		
rhtr	X			X	X	X		X		X		X	X	X	X			X	X	X	X	X	
rhro																X				X		X	

G & S	M A R	M S E	M C S	O G S	O M P	O R S	C E M	D A I	D D E	O R Q	O O C	O O N	O S N	W B O	W L A	W P O	W S E	W S M	W S T	C W O	D W O	M W O	O A O
saun	X														X								
scag	X					X			X		X	X											
scap	X					X			X	X	X	X	X				X			X	X		
scma	X											X											
scri	X											X									X		
scce	X								X			X	X					X		X	X	X	
scco										X							X						
scob						X									X		X		X	X		X	
spto	X	X				X			X			X	X				X			X	X	X	
spca														X									
spfu														X									
sphe														X						X			
spma														X									
sppa														X									
spre														X									
spru														X									
spsq														X	X								
spsu														X	X								
tepe														X	X	X		X	X	X		X	
tiau	X					X				X		X	X						X	X		X	
ticr	X			X		X						X	X		X					X	X	X	
tofr						X																	
toto	X										X												
toam		X																					
tola						X															X		
tolt																					X		
tome						X															X	X	
tomu	X						X		X		X	X											
topa																					X		
topp				X							X	X											
topr	X			X		X	X		X	X	X	X	X		X		X	X	X	X	X	X	X
toru	X				X	X		X	X	X	X	X	X		X			X	X	X	X	X	X
tosu		X																		X			
trme	X			X	X	X						X	X		X					X		X	
trcy																				X			
trau	X												X							X			
ulme																	X			X	X	X	
ulob															X	X		X			X	X	
ulph	X																	X					
wafl					X													X	X				
weco	X	X		X		X		X				X				X				X		X	
zyvi	X								X			X	X							X	X	X	X

Appendix D

Acronyms for genus and species, arranged alphabetically by acronym.

Acronym	Genus and Species
adme	*Andreaea megistospora*
adru	*Andreaea rupestris*
alca	*Alsia californica*
amca	*Amphidium californicum*
amju	*Amblystegium serpens* var. *juratzkanum*
amla	*Amphidium lapponicum*
amse	*Amblystegium serpens* var. *serpens*
anca	*Antitrichia californica*
ancu	*Antitrichia curtipendula*
anme	*Anacolia menziesii*
atse	*Atrichum selwynii*
atun	*Atrichum undulatum*
auan	*Aulacomnium androgynum*
aupa	*Aulacomnium palustre*
bapo	*Bartramia pomiformis*
baun	*Barbula unguiculata*
blac	*Blindia acuta*
bral	*Brachythecium albicans*
bras	*Brachythecium asperrimum*
brfr	*Brachythecium frigidum*
brre	*Bryoerythrophyllum recurvirostre*
brri	*Brachythecium rivulare*
brve	*Brachythecium velutinum* var. *velutinum*
brvn	*Brachythecium velutinum* var. *venustum*
byam	*Bryum amblyodon*
byar	*Bryum argenteum*
bycp	*Bryum capillare*
bycn	*Bryum canariense*
byca	*Bryum caespiticium*
bydi	*Bryum dichotomum*
byfl	*Bryum flaccidum*
byge	*Bryum gemmiparum*
byli	*Bryum lisae* var. *cuspidatum*
bymi	*Bryum miniatum*
bypa	*Bryum pallens*
bypl	*Bryum pallescens*
byps	*Bryum pseudotriquetrum*
byul	*Bryum uliginosum*
cacu	*Calliergonella cuspidata*
cagi	*Calliergon giganteum*
cepu	*Ceratodon purpureus*
clbo	*Claopodium bolanderi*
clcr	*Claopodium crispifolium*
clde	*Climacium dendroides*
clwh	*Claopodium whippleanum*
coca	*Conscinodon calyptratus*
coco	*Conardia compacta*
crfi	*Cratoneuron filicinum*
crla	*Crumia latifolia*

cyje	*Cynodontium jenneri*
dcfu	*Dicranum fuscescens*
dcsc	*Dicranum scoparium*
dcta	*Dicranum tauricum*
deab	*Dendroalsia abietina*
deob	*Desmatodon obtusifolius*
dici	*Dicranoweisia cirrata*
difa	*Didymodon fallax*
difl	*Didymodon vinealis* var. *flaccidus*
dihe	*Dicranella heteromalla*
diho	*Dicranella howei*
dipa	*Dicranella pacifica*
dipe	*Dichodontium pellucidum*
diri	*Didymodon rigidulus* var. *gracilis*
disc	*Dicranella schreberiana*
dito	*Didymodon tophaceous*
divi	*Didymodon vinealis* var. *vinealis*
drad	*Drepanocladus aduncus*
drcr	*Drepanocladus crassicostatus*
drpa	*Dryptodon patens*
dtfl	*Ditrichum flexicaule*
dthe	*Ditrichum heteromalum*
dtmo	*Ditrichum montanum*
enci	*Encalypta ciliata*
enpr	*Encalypta procera*
envu	*Encalypta vulgaris*
epto	*Epipterygium tozeri*
euor	*Eurhynchium oreganum*
eupr	*Eurhynchium praelongum*
eupu	*Eurhynchium pulchellum*
euve	*Eucladium verticillatum*
fiad	*Fissidens adianthoides*
fibr	*Fissidens bryoides* var. *bryoides*
figr	*Fissidens grandifrons*
fili	*Fissidens limbatus*
five	*Fissidens ventricosus*
fivi	*Fissidens bryoides* var. *viridulus*
foan	*Fontinalis antipyretica* var. *antipyretica*
fogi	*Fontinalis antipytretica* var. *gigantea*
foor	*Fontinalis antipyretica* var. *oregonensis*
fuhy	*Funaria hygrometrica*
fumu	*Funaria muhlenbergii*
grla	*Grimmia laevigata*
grpu	*Grimmia pulvinata*
grto	*Grimmia torquata*
grtr	*Grimmia trichophylla*
gyae	*Gymnostomum aeruginosum*
hema	*Heterocladium macounii*
hepr	*Heterocladium procurrens*
hest	*Hedwigia stellata*
hoae	*Homalothecium aeneum*
hoar	*Homalothecium arenarium*
hofu	*Homalothecium fulgescens*
honu	*Homalothecium nuttallii*

hopi	*Homalothecium pinnatifidum*
hyci	*Hypnum circinale*
hycu	*Hypnum cupressiforme*
hydi	*Hypnum dieckii*
hyre	*Hymenostylium recurvirostre*
hysp	*Hylocomium splendens*
hysu	*Hypnum subimponens*
iscr	*Isothecium cristatum*
ismy	*Isothecium myosuroides*
leac	*Leucolepis acanthoneuron*
lepy	*Leptobryum pyriforme*
leri	*Leptodictyum riparium*
meme	*Metaneckera menziesii*
mnma	*Mnium marginatum*
mnsp	*Mnium spinulosum*
nedo	*Neckera douglasii*
nepe	*Neckera pennata*
onwa	*Onocophorus wahlenbergii*
oraf	*Orthotrichum affine*
oran	*Orthotrichum anomalum*
orco	*Orthotrichum consimile*
orha	*Orthotrichum hallii*
orly	*Orthotrichum lyellii*
orpu	*Orthotrichum pulchellum*
orru	*Orthotrichum rupestre*
orsp	*Orthotrichum speciosum*
orst	*Orthotrichum striatum*
orte	*Orthotrichum tenellum*
phca	*Philonotis capillaris*
phcu	*Phascum cuspidatum*
phfo	*Philonotis fontana*
phpy	*Physcomitrium pyriforme*
plac	*Pleuridium acuminatum*
plde	*Plagiothecium denticulatum*
plin	*Plagiomnium insigne*
plju	*Platydictya jungermannioides*
plla	*Plagiothecium laetum*
plme	*Plagiomnium medium*
plpi	*Plagiothecium piliferum*
plri	*Platyhypnidium riparioides*
plro	*Plagiomnium rostratum*
plsc	*Pleurozium schreberi*
plun	*Plagiothecium undulatum*
plve	*Plagiomnium venustum*
pobi	*Porotrichum bigelovii*
poco	*Pogonatum contortum*
pocr	*Pohlia cruda*
pofo	*Polytrichum formosum*
polo	*Pohlia longibracteata*
ponu	*Pholia nutans*
posp	*Pohlia sphagnicola*
pour	*Pogonatum urnigerum*
pova	*Porotrichum vancourveriense*
powa	*Pohlia wahlenbergii*

psca	*Pseudobraunia californica*
psel	*Pseudotaxiphyllum elegans*
pspu	*Pseudoscleropodium purum*
ptga	*Ptychomitrium gardneri*
ptgr	*Pterogonium gracile*
pyal	*Polytrichastrum alpinum*
pyco	*Polytrichum commune*
pyju	*Polytrichum juniperinum*
pypi	*Polytrichum piliferum*
pyst	*Polytrichum strictum*
raac	*Racomitrium aciculare*
rael	*Racomitrium elongatum*
raer	*Racomitrium ericoides*
rahe	*Racomitrium heterostichum*
rala	*Racomitrium lanuginosum*
ralw	*Racomitrium lawtonae*
raoc	*Racomitrium occidentale*
rapa	*Racomitrium pacificum*
rava	*Racomitrium varium*
rhgl	*Rhizomnium glabrescens*
rhlo	*Rhytidiadelphus loreus*
rhma	*Rhizomnium magnifolium*
rhro	*Rhytidiopsis robusta*
rhsq	*Rhytidiadelphus squarrosus*
rhtr	*Rhytidiadelphus triquetrus*
saun	*Sanionia uncinatus*
scag	*Schistidium agassizii*
scap	*Schistidium apocarpum*
scce	*Scleropodium cespitans*
scco	*Scleropodium touretii* var. *colpophyllum*
scma	*Schistidium maritimum*
scob	*Scleropodium obtusifolium*
scri	*Schistidium rivulare*
spca	*Sphagnum capillifolium*
spfu	*Sphagnum fuscum*
sphe	*Sphagnum henryense*
spma	*Sphagnum magellanicum*
sppa	*Sphagnum palustre*
spre	*Sphagnum recurvum*
spru	*Sphagnum rubellum*
spsq	*Sphagnum squarrosum*
spsu	*Sphagnum subsecundum*
spto	*Scleropodium touretii* var. *touretii*
tepe	*Tetraphis pellucida*
tiau	*Timmia austriaca*
ticr	*Timmiella crassinervis*
toam	*Tortula amplexa*
tofr	*Tortella fragilis*
toto	*Tortella tortuosa*
tola	*Tortula laevipila*
tolt	*Tortula latifolia*
tome	*Tortula laevipila* var. *meridionalis*
tomu	*Tortula muralis*
topa	*Tortula papillosa*

topp	*Tortula papillosissima*
topr	*Tortula princeps*
toru	*Tortula ruralis*
tosu	*Tortula subulata*
trau	*Trichostomopsis australasiae*
trcy	*Trichodon cylindricus*
trme	*Trachybryum megaptilum*
ulme	*Ulota megalospora*
ulob	*Ulota obusiuscula*
ulph	*Ulota phyllantha*
wafl	*Warnstorfia fluitans*
weco	*Weissia controversa*
zyvi	*Zygodon viridissimus* var. *rupestris*

Appendix E

Species relationships to substratum.

AQ = aquatic, BL = beach logs, DW = decayed wood, FL = floating logs, EP = epiphytic, FO = folicolous, HD = humus and duff, PE = peatlands, RA = slate, RB = basalt, RC = conglomerate, RG = granite or acidic rock, RL = calcareous rock, and cement, RO = unknown rock, RS = sandstone, SC = soil clay, SD = soil dry, SW = soil wet.

GENUS AND SPECEIS	SUBSTRATUM																	
	AQ	BL	DW	EP	FL	FO	HD	PE	RA	RB	RC	RG	RL	RO	RS	SC	SD	SW
Alsia californica			X	X										X				
Amblystegium serpens var. serpens			X				X						X	X				X
A. serpens var. juratzkanum			X															X
Amphidium californicum									X	X	X		X	X			X	X
A. lapponicum														X				
Anacolia menziesii										X				X			X	
Andreaea megistospora														X				
A. rupestris														X				
Antitrichia californica			X	X								X	X	X	X		X	
A. curtipendula			X	X			X					X	X	X			X	
Atrichum selwynii			X				X					X		X		X	X	X
A. undulatum			X													X	X	
Aulacomnium androgynum			X	X			X	X				X		X			X	
A. palustre							X	X						X				X
Barbula unguiculata														X			X	
Bartramia pomiformis														X			X	
Blindia acuta														X				
Brachythecium albicans							X							X			X	
B. asperrimum			X										X	X				
B. frigidum	X		X		X		X						X	X				X
B. rivulare								X					X					
B. velutinum var. velutinum			X	X									X	X			X	
B. velutinum var. venustum																	X	
Bryoerythrophyllum recurvirostre														X			X	
Bryum amblyodon														X				
B. argenteum													X	X			X	
B. caespiticium			X				X						X	X			X	
B. canariense																	X	
B. capillare		X	X	X			X			X	X	X	X	X	X	X	X	X
B. dichotomum										X								
B. flaccidum			X															
B. gemmiparum													X	X		X		
B. lisae var. cuspidatum			X											X	X		X	X
B. miniatum					X						X		X	X				
B. pallens														X				
B. pallescens			X											X			X	
B. pseudotriquetrum			X	X	X		X				X		X	X		X	X	X
B. uliginosum								X										
Calliergon giganteum	X																	X
Calliergonella cuspidata	X							X					X					X

Genus & Species	A Q	B L	D W	E P	F L	F O	H D	P E	R A	R B	R C	R G	R L	R O	R S	S C	S D	S W
Ceratodon purpureus			X				X			X	X	X	X	X			X	X
Claopodium bolanderi				X							X				X			X
C. crispifolium			X	X			X				X	X	X	X	X		X	
C. whippleanum				X							X			X			X	
Climacium dendroides			X															
Conardia compacta														X				
Coscinodon calyptratus													X					
Cratoneuron filicinum	X				X								X			X		X
Crumia latifolia													X					
Cynodontium jenneri							X							X			X	
Dendroalsia abietina				X										X				
Desmatodon obtusifolius														X			X	
Dichodontium pellucidum	X												X	X				X
Dicranella heteromalla			X								X			X		X	X	X
D. howei																X		X
D. pacifica													X			X		X
D. schreberiana																X	X	X
Dicranoweisia cirrata			X	X			X					X	X	X	X		X	
Dicranum fuscescens			X	X			X	X						X			X	X
D. scoparium			X	X			X	X			X		X	X			X	X
D. tauricum			X	X								X					X	
Didymodon fallax													X					
D. rigidulus var. gracilis														X				
D. tophaceous													X	X		X		X
D. vinealis var. vinealis			X	X			X		X	X	X	X	X	X	X	X	X	X
D. vinealis var. flaccidus				X									X	X		X	X	
Ditrichum flexicaule														X				
D. heteromallum							X							X		X	X	X
D. montanum																	X	
Drepanocladus aduncus	X							X										X
D. crassicostatus																		X
Dryptodon patens														X				
Encalypta ciliata														X			X	
E. procera													X	X			X	
E. vulgaris														X				
Epipterygium tozeri																		X
Eucladium verticillatum													X					X
Eurhynchium oreganum			X	X			X	X			X			X	X		X	X
E. praelongum	X		X	X			X	X		X	X	X	X	X	X	X	X	X
E. pulchellum													X	X				
Fissidens adianthoides	X		X															
F. bryoides var. bryoides																X	X	X
F. bryoides var. viridulus											X					X	X	X
F. grandifrons	X												X					
F. limbatus									X					X		X	X	X
F. ventricosus	X													X				
Fontinalis antipyretica var. antipyretica	X		X															X
F. antipyretica var. gigantea																		X
F. antipyretica var. oregonensis	X		X					X										X

Genus & Species	AQ	BL	DW	EP	FL	FO	HD	PE	RA	RB	RC	RG	RL	RO	RS	SC	SD	SW
Funaria hygrometrica			X				X						X	X		X	X	X
F. muhlenbergii																	X	
Grimmia laevigata																	X	
G. pulvinata											X		X	X			X	
Grimmia torquata														X				
G. trichophylla			X	X			X				X		X	X			X	
Gymnostomum aeruginosum													X	X				
Hedwigia stellata							X				X			X			X	
Heterocladium macounii			X											X				
H. procurrens														X				
Homalothecium aeneum				X										X				
H. arenarium													X	X			X	
H. fulgescens			X	X									X	X			X	
H. nuttallii			X	X							X		X	X				
H. pinnatifidum				X			X				X		X	X			X	
Hylocomium splendens			X	X			X							X			X	X
Hymenostylium recurvirostre											X		X	X				X
Hypnum circinale			X	X													X	X
H. cupressiforme														X			X	
H. dieckii			X	X							X			X				X
H. subimponens			X	X			X				X		X	X			X	
Isothecium cristatum			X	X							X		X	X			X	
I. myosuroides			X	X			X				X		X	X			X	X
Leptobryum pyriforme							X						X			X	X	X
Leptodictyum riparium	X		X	X			X							X		X	X	X
Leucolepis acanthoneuron			X				X	X						X	X	X	X	X
Metaneckera menziesii			X	X							X		X	X				
Mnium marginatum														X				
M. spinulosum			X	X			X					X		X			X	X
Neckera douglasii			X	X								X		X			X	
N. pennata				X														
Oncophorus wahlenbergii																		X
Orthotrichum affine			X	X														
O. anomalum													X					
O. consimile			X	X		X						X	X	X				
O. hallii													X					
O. lyellii		X	X	X							X		X	X				
O. pulchellum			X	X										X				
O. rupestre				X							X	X	X	X	X		X	
O. speceiosum				X														
O. striatum				X														
O. tenellum				X														
Phascum cuspidatum																	X	
Philonotis capillaris														X				
P. fontana			X		X			X						X				X
Physcomitrium pyriforme																	X	X
Plagiomnium inigne			X	X			X							X		X	X	X
P. medium			X														X	
P. rostratum														X				

GENUS AND SPECIES	A Q	B L	D W	E P	F L	F O	H D	P E	R A	R B	R C	R G	R L	R O	R S	S C	S D	S W
Plagiomnium venustum				X			X						X	X			X	
Plagiothecium denticulatum			X	X			X				X	X		X			X	X
P. laetum			X	X			X							X			X	X
P. piliferum														X				
P. undulatum			X	X			X							X			X	X
Platydictya jungermannioides													X	X				
Platyhypnidium riparioides														X				
Pleuridium acuminatum																X	X	
Pleurozium schreberi							X	X						X			X	X
Pogoanatum contortum																	X	
Pogonatum urnigerum														X			X	
Pohlia cruda							X							X		X	X	X
P. longibracteata													X					
P. nutans								X						X			X	X
P. sphagnicola								X										
P. wahlenbergii														X		X		X
Polytrichastrum alpinum							X							X			X	
Polytrichum commune																		X
P. formosum			X				X							X				X
P. juniperinum			X				X	X		X	X	X		X		X	X	X
P. piliferum							X							X	X		X	
P. strictum								X										
Porotrichum bigelovii	X			X							X		X	X	X			X
P. vancouveriense														X				
Pseudobraunia californica										X	X			X			X	
Pseudoscleropodium purum																	X	
Pseudotaxiphyllum elegans			X	X							X			X			X	
Pterogonium gracile																	X	
Ptychomitrium gardneri												X	X	X				
Racomitrium aciculare														X				
R. elongatum							X				X	X		X	X		X	
R. ericoides							X			X	X	X	X	X	X		X	
R. heterostichum			X				X			X	X	X	X	X			X	
R. lanuginosum														X				
R. lawtonae														X				
R. occidentale														X				
R. pacificum										X	X			X				
R. varium													X	X			X	
Rhizomnium glabrescens			X	X			X							X			X	X
R. magnifolium																		X
Rhytidiadelphus loreus			X	X			X					X		X			X	X
R. squarrosus																	X	
R. triquetrus			X	X			X	X					X	X			X	X
Rhytidiopsis robusta							X							X			X	X
Sanionia uncinatus																		X
Schistidium agassizii													X	X				
S. apocarpum											X		X	X	X			
S. maritimum		X							X	X	X	X	X	X	X		X	
S. rivulare											X			X				

Genus & Species	AQ	BL	DW	EP	FL	FO	HD	PE	RA	RB	RC	RG	RL	RO	RS	SC	SD	SW
Scleropodium cespitans				X										X	X	X	X	
S. obtusifolium	X				X								X					X
S. touretii var. touretii			X				X			X	X		X	X			X	
S. touretii var. colpophyllum								X						X			X	
Sphagnum capillifolium								X										
S. fuscum								X										
S. henryense								X										X
S. magellanicum								X										X
S. palustre								X										
S. recurvum								X										
S. rubellum								X										
S. squarrosum								X										
S. subsecundum								X										
Tetraphis pellucida			X	X														
Timmia austriaca							X				X		X	X	X		X	
Timmia crassinervis			X	X									X	X	X	X	X	X
Tortella fragilis																	X	
T. tortuosa														X	X		X	
Tortula amplexa																X		
T. laevipila var. laevipila			X	X														
T. laevipila var. meridionalis			X	X														
T. latifolia				X														
T. muralis											X		X	X	X			
T. papillosa				X														
T. papillosissima							X						X	X				
T. princeps			X	X			X		X	X	X	X	X	X	X		X	
T. ruralis			X	X			X				X		X	X	X		X	X
T. subulata																X	X	
Trachybryum megaptilum			X				X			X				X			X	
Trichodon cylindricus																	X	X
Trichostomopsis australasiae														X		X	X	
Ulota megalospora			X	X														
U. obtusiuscula			X	X														
U. phyllantha		X		X						X	X	X	X	X	X			
Warnstorfia fluitans			X															X
Weissia controversa													X	X		X	X	X
Zygodon viridissimus var. rupestris			X	X								X	X	X	X			

Appendix F

Species relationships to geologic unit.

CF = Constitution Formation, CK = Chuckanut Formation, DB = Deadman Bay Volcanics, EG = East Sound Group, FC = Fidalgo Complex, LF = Lummi Formation, LS = Lopez Structural Complex, NG = Nanaimo Group, OC = Orcas Chert, QC = Quaternary Cover, SG = Speiden Group, TC = Turtleback Complex

GENUS & SPECIES	CF	CK	DB	EG	FC	LF	LS	NG	OC	QC	SG	TC
Alsia californica	X	X		X	X	X	X	X	X			
Amblystegium serpens var. serpens	X	X		X	X			X	X	X		X
A. serpens var. juratzkanum	X											
Amphidium californicum	X		X							X		X
A. lapponicum	X											X
Anacolia menziesii	X		X	X	X			X		X		X
Andreaea megistospora	X											
A. rupestris	X											
Antitrichia californica	X	X	X	X				X	X	X	X	X
A. curtipendula	X		X	X	X	X		X	X	X	X	X
Atrichum selwynii	X	X		X	X	X	X	X	X	X	X	X
A. undulatum	X	X							X	X		X
Aulacomnium androgynum	X	X		X	X				X	X	X	X
A. palustre	X											X
Barbula unguiculata												X
Bartramia pomiformis	X			X	X							X
Blindia acuta	X											
Brachythecium albicans	X					X	X	X	X		X	X
B. asperrimum	X	X		X								X
B. frigidum	X			X	X			X	X			X
B. rivulare				X								
B. velutinum var. velutinum	X			X			X	X	X	X	X	X
B. velutinum var. venustum												X
Bryoerythrophyllum recurvirostre	X							X				X
Bryum amblyodon					X							
B. argenteum	X			X				X	X			
B. caespiticium	X		X	X	X		X	X	X		X	X
B. canariense	X											
B. capillare	X	X	X	X	X	X	X	X	X	X	X	X
B. dichotomum	X											
B. flaccidum				X								
B. gemmiparum	X								X			
B. lisae var. cuspidatum	X			X	X	X		X			X	X
B. miniatum	X			X	X			X	X			X
B. pallens	X											
B. pallescens	X			X	X					X	X	X
B. pseudotriquetrum	X			X	X		X	X		X	X	X
B. uliginosum	X											
Calliergon giganteum	X											
Calliergonella cuspidata	X			X	X							X
Ceratodon purpureus	X	X	X	X	X	X	X	X	X	X	X	X
Claopodium bolanderi	X			X	X			X	X			X
C. crispifolium	X	X	X	X	X	X	X	X	X	X	X	X

Genus & Species	C F	C K	D B	E G	F C	L F	L S	N G	O C	Q C	S G	T C
Claopodium whippleanum	X	X			X	X		X				
Climacium dendroides				X								
Conardia compacta	X											
Coscinodon calyptratus				X								
Cratoneuron filicinum	X				X				X			X
Crumia latifolia			X						X			
Cynodontium jenneri	X			X								X
Dendroalsia abietina	X							X	X			X
Desmatodon obtusifolius	X											
Dichodontium pellucidum	X			X	X				X			X
Dicranella heteromalla	X	X		X	X	X	X	X	X	X	X	X
D. howei									X			X
D. pacifica	X											X
D. schreberiana	X									X		X
Dicranoweisia cirrata	X	X		X	X	X	X	X	X	X	X	X
Dicranum fuscescens	X	X		X	X	X	X	X	X	X	X	X
D. scoparium	X	X	X	X	X	X	X	X	X	X	X	X
D. tauricum	X	X		X	X	X	X	X	X	X	X	X
Didymodon fallax									X			
D. rigidulus var. gracilis	X											X
D. tophaceous	X		X	X			X	X	X		X	
D. vinealis var. vinealis	X	X	X	X	X	X	X	X	X	X	X	X
D. vinealis var. flaccidus	X			X	X	X		X	X			X
Ditrichum flexicaule	X			X								
D. heteromallum	X			X					X	X		X
D. montanum	X			X								X
Drepanocladus aduncus	X							X				
D. crassicostatus	X									X		
Dryptodon patens												X
Encalypta ciliata	X				X							
E. procera				X								X
E. vulgaris				X								
Epipterygium tozeri												X
Eucladium verticillatum	X			X					X			
Eurhynchium oreganum	X	X	X	X	X	X	X	X		X	X	X
E. praelongum	X	X	X	X	X	X	X	X	X	X		X
E. pulchellum	X			X								
Fissidens adianthoides												X
F. bryoides var. bryoides	X			X			X			X	X	X
F. bryoides var. viridulus	X				X			X		X		X
F. grandifrons	X								X			
F. limbatus	X	X	X	X	X		X	X	X	X	X	X
F. ventricosus	X			X								X
Fontinalis antipyretica var. antipyretica	X			X	X							
F. antipyretica var. gigantea	X											
F. antipyretica var. oregonensis	X							X				X
F. hygrometrica	X			X	X	X		X	X	X	X	X
F. muhlenbergii				X								
Grimmia laevigata								X				
G. pulvinata	X	X	X	X	X	X	X	X	X	X	X	X
G. torquata	X				X					X		X

Genus & Species	C F	C K	D B	E G	F C	L F	L S	N G	O C	Q C	S G	T C
Grimmia trichophylla	X	X	X	X	X	X	X	X	X	X	X	X
Gymnostomum aeruginosum	X				X				X			
Hedwigia stellata	X	X	X	X	X	X	X	X	X	X	X	X
Heterocladium macounii	X			X								X
H. procurrens												X
Homalothecium aeneum	X											X
H. arenarium	X		X					X		X		X
H. fulgescens	X	X	X	X	X	X		X	X	X	X	X
H. nuttallii	X	X		X	X			X	X	X	X	X
H. pinnatifidum	X	X	X	X	X	X	X	X	X	X	X	X
Hylocomium splendens	X	X	X	X	X	X	X	X	X	X	X	X
Hymenostylium recurvirostre		X	X	X	X	X			X			
Hypnum circinale	X	X		X	X	X	X	X	X	X		X
H. cupressiforme		X										
H. dieckii	X		X	X	X			X		X		X
H. subimponens	X		X	X	X		X	X	X	X	X	X
Isothecium cristatum	X	X	X	X	X	X	X	X	X		X	X
I. myosuroides	X	X	X	X	X	X		X	X	X	X	X
Leptobryum pyriforme	X		X	X	X				X			
Leptodictyum riparium	X			X	X			X		X		X
Leucolepis acanthoneuron	X	X		X	X	X	X	X	X	X	X	X
Metaneckera menziesii	X	X		X		X		X	X	X	X	X
Mnium marginatum	X			X								
M. spinulosum	X	X		X	X	X		X	X			X
Neckera douglasii	X	X	X	X	X	X	X	X	X	X		X
N. pennata				X				X				
Oncophorus wahlenbergii										X		
Orthotrichum affine	X		X							X		
O. anomalum												X
O. consimile	X	X	X	X	X			X	X	X	X	X
O. hallii	X											
O. lyellii	X	X	X	X	X	X	X	X	X	X	X	X
O. pulchellum	X	X	X	X	X	X	X	X	X	X	X	X
O. rupestre	X	X	X	X	X	X		X	X			X
O. speciosum	X		X							X		X
O. sriatum			X	X		X						
O. tenellum											X	
Phascum cuspidatum											X	
Philonotis capillaris												X
P. fontana	X			X	X							X
Physcomitrium pyriforme	X							X				
Plagiomnium inigne	X	X	X	X	X	X	X	X	X	X	X	X
P. medium												X
Plagiomnium rostratum												X
P. venustum	X		X	X	X			X	X		X	X
Plagiothecium denticulatum	X	X		X	X	X		X	X			X
P. laetum	X	X		X	X		X	X	X	X	X	X
P. piliferum												X
P. undulatum	X	X		X	X	X	X	X	X	X	X	X
Platydictya jungermannioides	X						X					
Platyhypnidium riparioides	X								X			X

Genus & Species	C F	C K	D B	E G	F C	L F	L S	N G	O C	Q C	S G	T C
Pleuridium acuminatum	X								X		X	
Pleurozium schreberi	X	X		X	X		X	X	X			X
Pogonatum contortum	X											
P. urnigerum	X			X								X
Pohlia curda	X	X		X	X			X	X			X
P. longibracteata												X
P. nutans	X			X	X	X						X
P. sphagnicola	X											
P. wahlenbergii	X						X		X			
Polytrichastrum alpinum		X		X								X
Polytrichum commune	X											
P. formosum	X	X		X	X							X
P. juniperinum	X	X	X	X	X	X	X	X	X	X	X	X
P. piliferum	X	X	X	X	X	X	X	X	X		X	X
P. strictum	X											X
Porotrichum bigelovii	X	X	X	X	X	X		X	X			X
P. vancouveriense									X			
Pseudobraunia californica	X			X	X			X				
Pseudoscleropodium purum	X											
Pseudotaxiphyllum elegans	X			X	X	X		X	X			X
Pterogonium gracile	X											
Ptychomitrium gardneri	X		X	X	X							X
Racomitrium aciculare	X											
R. elongatum	X	X	X	X	X	X		X	X		X	X
R. ericoides	X	X	X	X	X	X	X	X	X	X	X	X
R. heterostichum	X	X	X	X	X	X	X	X	X	X	X	X
R. lanuginosum	X				X				X			X
R. lawtonae	X				X							
R. occidentale	X		X		X							X
R. pacificum	X			X							X	
R. varium	X			X					X			X
Rhizomnium glabrescens	X	X		X	X	X	X	X	X		X	X
R. magnifolium	X											
Rhytidiadelphus loreus	X	X		X	X	X	X	X	X	X	X	X
R. squarrosus	X											
R. triquetrus	X	X	X	X	X	X	X	X	X	X	X	X
Rhytidiopsis robusta	X			X								X
Sanionia uncinatus	X											
Schistidium agassizii	X	X							X			X
S. apocarpum	X	X		X	X			X	X			
Schistidium maritimum	X	X	X	X	X	X	X	X	X	X	X	X
S. rivulare	X	X										X
Scleropodium cespitans	X	X		X				X	X	X		X
S. obtusifolium	X		X	X	X				X		X	X
S. touretii var. touretii	X											X
S. touretii var. colpophyllum	X	X	X	X			X	X	X			X
Sphagnum capillifolium	X											
S. fuscum	X											X
S. henryense	X											
S. magellanicum	X											
S. palustre	X											X

Genus and Species	CF	CK	DB	EG	FC	LF	LS	NG	OC	QC	SG	TC
Sphagnum recurvum	X											X
S. rubellum	X											X
S. squarrosum	X											X
S. subsecundum	X											X
Tetraphis pellucida	X			X	X		X	X	X	X	X	X
Timmia austriaca	X		X	X	X			X	X			X
Timmiella crassinervis	X	X	X	X	X	X		X	X	X	X	X
Tortella fragilis	X											
T. tortuosa	X	X										
Tortula amplexa							X	X				X
T. laevipila var. laevipila	X											X
T. laevipila var. meridionalis	X								X		X	
T. latifolia			X						X			
T. muralis	X	X	X			X		X	X	X	X	X
T. papillosa										X	X	
T. papillosissima	X										X	X
T. princeps	X	X	X	X	X	X	X	X	X	X	X	X
T. ruralis	X	X	X	X	X	X		X	X	X	X	X
T. subulata	X											X
Trachybryum megaptilum	X		X	X				X	X		X	X
Trichodon cylindricus	X											X
Trichostomopsis australasiae								X		X		
Ulota megalospora	X			X	X				X	X		X
U. obtusiuscula	X	X		X	X	X		X	X	X		X
U. phyllantha	X	X	X	X	X	X	X	X	X	X	X	X
Warnstorfia fluitans	X									X		
Weissia controversa	X	X	X	X				X	X		X	X
Zygodon viridissimus var. rupestris	X	X	X	X	X	X		X	X	X	X	X

Appendix G

Phytogeographic world distributions

Legend: WNA = Endemic Western North America, MED = Pacific North America - Mediterranean, CB = Circumboreal, CT = Circum-temperate, CP = Circumpolar, NP = North Pacific, BP = Bipolar, WWE = Western North America - Western Europe, WEN = Western North America - Eastern North America, WEA = Western North America - Eurasia, UNC = Unclassified, WD = Widespread, X = World Distribution, N = North America Distribution, A = Anthropogenic Introduction

GENUS & SPECIES	WNA	MED	CB	CT	CP	NP	BP	WWE	WEN	WEA	UNC	WD
Alsia californica	X											
Amblystegium serpens var. serpens					X		X					
A. serpens var. juratzkanum					X							
Amphidium californicum	X											
A. lapponicum					X							
Anacolia menziesii	X											
Andreaea megistospora								X				
A. rupestris					X		X					
Antitrichia californica		X										
A. curtipendula											X	
Atrichum selwynii	X											
A. undulatum			X									
Aulacomnium androgynum			X									
A. palustre					X		X					
Barbula unguiculata			X				X					
Bartramia pomiformis					X		X					
Blindia acuta					X							
Brachythecium albicans					X		X					
B. asperrimum	X											
B. frigidum	X											
B. rivulare			X									
B. velutinum var. velutinum			X				X					
B. velutinum var. venustum			X									
Bryoerythrophyllum recurvirostre					X		X					
Bryum amblyodon					X							
B. argenteum												X
B. caespiticium					X		X					
B. canariense		X										
B. capillare			X				X					
B. dichotomum			X									
B. flaccidum			X									
B. gemmiparum								X				
B. lisae var. cuspidatum					X		X					
B. miniatum								X	N			
B. pallens					X							
B. pallescens					X							
B. pseudotriquetrum					X		X					

GENUS & SPECIES	W N A	M E D	C B	C T	C P	N P	B P	W W E	W E N	W E A	U N C	W D
Barbula uliginosum			X									
Calliergon giganteum					X							
Calliergonella cuspidata			X				X					
Ceratodon purpureus												X
Claopodium bolanderi	X											
C. crispifolium						X						
C. whippleanum								X				
Climacium dendroides			X				X					
Conardia compacta			X									
Coscinodon calyptratus	X											
Cratoneuron filicinum			X				X					
Crumia latifolia											X	
Cynodontium jenneri								X				
Dendroalsia abietina	X											
Desmatodon obtusifolius			X									
Dichodontium pellucidum					X							
Dicranella heteromalla			X									
D. howei		X										
D. pacifica	X											
D. schreberiana			X									
Dicranoweisia cirrata		X										
Dicranum fuscescens			X									
D. scoparium			X				X					
D. tauricum		X										
Didymodon fallax				X								
D. rigidulus var. gracilis					X							
D. tophaceous					X							
D. vinealis var. vinealis										X		
D. vinealis var. flaccidus								X				
Ditrichum flexicaule			X				X					
D. heteromallum			X				X					
D. montanum	X											
Drepanocladus aduncus			X				X					
D. crassicostatus	X											
Dryptodon patens			X						N			
Encalypta ciliata			X									
E. procera			X									
E. vulgaris			X				X					
Epipterygium tozeri										X		
Eucladium verticillatum					X							
Eurhynchium oreganum	X											
E. praelongum			X				X					
E. pulchellum			X									
Fissidens adianthoides			X				X					
F. bryoides var. bryoides			X									
F. bryoides var. viridulus			X									
F. grandifrons			X									

GENUS & SPECIES	WNA	MED	CB	CT	CP	NP	BP	WWE	WEN	WEA	UNC	WD
F. limbatus											X	
F. ventricosus	X											
Fontinalis antipyretica var. antipyretica			X									
F. antipyretica var. gigantea			X									
F. antipyretica var. oregonensis	X											
Funaria hygrometrica												X
F. muhlenbergii			X									
Grimmia laevigata				X			X					
G. pulvinata				X			X					
G. torquata			X						N			
G. trichophylla							X			X		
Gymnostomum aeruginosum			X									
Hedwigia stellata								X				
Heterocladium macounii									X			
H. procurrens										X		
Homalothecium aeneum	X											
H. arenarium	X											
H. fulgescens	X											
H. nuttallii	X											
H. pinnatifidum	X											
Hylocomium splendens			X				X					
Hymenostylium recurvirostre			X									
Hypnum circinale	X											
H. cupressiforme			X				X					
H. dieckii						X						
H. subimponens						X						
Isothecium cristatum	X											
I. myosuroides											X	
Leptobryum pyriforme			X				X					
Leptodictyum riparium					X		X					
Leucolepis acanthoneuron	X											
Metaneckera menziesii		X										
Mnium marginatum			X									
M. spinulosum			X									
Neckera douglasii	X											
N. pennata			X				X		N			
Oncophorus wahlenbergii			X									
Orthotrichum affine	X											
O. anomalum					X							
O. consimile								X				
O. hallii										X		
O. lyellii		X										
O. pulchellum								X				
O. rupestre							X			X		
O. speciosum								X				
O. striatum								X				
O. tenellum								X				

GENUS & SPECIES	W N A	M E D	C B	C T	C P	N P	B P	W W E	W E N	W E A	U N C	W D
Phascum cuspidatum				X			X					
Philonotis capillaris			X									
P. fontana			X									
Physcomitrium pyriforme			X						N			
Plagiomnium insigne	X											
P. medium			X									
P. rostratum			X									
P. venustum	X											
Plagiothecium denticulatum			X				X					
P. laetum			X									
P. piliferum			X									
P. undulatum								X				
Platydictya jungermannioides			X									
Platyhypnidium riparioides			X									
Pleuridium acuminatum											X	
Pleurozium schreberi			X				X					
Pogonatum contortum						X						
P. urnigerum			X									
Pohlia cruda			X				X					
P. longibracteata	X											
P. nutans			X				X					
P. sphagnicola			X									
P. wahlenbergii			X				X					
Polytrichastrum alpinum			X				X					
Polytrichum commune			X				X					
P. formosum			X				X					
P. juniperinum			X				X					
P. piliferum			X				X					
P. strictum			X				X					
Porotrichum bigelovii	X											
P. vancouveriense	X											
Pseudobraunia californica	X											
Pseudoscleropodium purum												A
Pseudotaxiphyllum elegans					X		X		N			
Pterogonium gracile		X										
Ptychomitrium gardneri										X		
Racomitrium aciculare			X									
R. elongatum											X	
R. ericoides			X									
R. heterostichum			X									
R. lanuginosum			X				X					
R. lawtonae	X											
R. occidentale	X											
R. pacificum	X											
R. varium	X											
Rhizomnium glabrescens	X											
R. magnifolium			X									

GENUS & SPECIES	W N A	M E D	C B	C T	C P	N P	B P	W W E	W E N	W E A	U N C	W D
Rhytidiadelphus loreus			X						N			
R. squarrosus			X									
R. triquetrus			X									
Rhytidiopsis robusta	X											
Sanionia uncinata			X				X					
Schistidium agassizii			X				X					
S. apocarpum			X				X					
S. maritimum			X				X		N			
S. rivulare			X				X					
Scleropodium cespitans		X										
S. obtusifolium	X											
S. touretii var. touretii		X										
S. touretii var. colpophyllum	X											
Sphagnum capillifolium			X									
S. fuscum			X									
S. henryense					X							
S. magellanicum			X				X					
S. palustre					X		X					
Sphagnum recurvum											X	
S. rubellum					X							
S. squarrosum					X		X					
S. subsecundum					X		X					
Tetraphis pellucida			X									
Timmia austriaca			X				X					
Timmiella crassinervis	X											
Tortella fragilis			X				X					
T. tortuosa			X				X					
Tortula amplexa		X										
T. laevipila var. laevipila		X					X					
T. laevipila var. meridionalis		X										
T. latifolia								X				
T. muralis			X				X					
T. papillosa							X	X	N			
T. papillosissima			X									
T. princeps		X					X					
T. ruralis			X									
T. subulata		X										
Trachybryum megaptilum	X											
Trichodon cylindricus			X				X					
Trichostomopsis australasiae							X			X		
Ulota megalospora	X											
U. obtusiuscula	X											
U. phyllantha							X	X	N			
Warnstorfia fluitans					X		X					
Weissia controversa												X
Zygodon viridissimus var. rupestris			X						N			

Appendix H

Phytogeographic distributions in the Pacific Northwest

Legend: C = Coastal, CHI = Coastal - disjunct to Humid Interior, DIC = Dry Interior - disjunct Coastal, RMC = Rocky Mountains - disjunct Coastal, MC = Mediterranean Climate, SAA = Subalpine- alpine, W = Widespread, A = Anthropogenic Introduction. M = Occurs in mediterranean climate along coast but in a few cases is disjunct.

Genus & Species	C	CHI	DIC	RMC	MC	W	A
Alsia californica					X		
Amblystegium serpens var. serpens						X	
A. serpens var. juratzkanum						X	
Amphidium californicum					X		
A. lapponicum						X	
Anacolia menziesii		X					
Andreaea megistospora	X						
A. rupestris						X	
Antitrichia californica		M					
A. curtipendula		X					
Atrichum selwynii		X					
A. undulatum						X	
Aulacomnium androgynum						X	
A. palustre						X	
Barbula unguiculata						X	
Bartramia pomiformis						X	
Blindia acuta						X	
Brachythecium albicans						X	
B. asperrimum	X						
B. frigidum		X					
B. rivulare						X	
B. velutinum var. velutinum						X	
B. velutinum var. venustum						X	
Bryoerythrophyllum recurvirostre						X	
Bryum ambylodon	X						
B. argenteum						X	
B. caespiticium						X	
B. canariense					X		
B. capillare						X	
B. dichotomum						X	
B. flaccidum						X	
B. gemmiparum						X	
B. lisae var. cuspidatum						X	
B. miniatum		X					
B. pallens						X	
B. pallescens						X	
B. pseudotriquetrum						X	
B. uliginosum						X	
Calliergon giganteum						X	
Calliergonella cuspidata						X	
Ceratodon purpureus						X	
Claopodium bolanderi		X					
C. crispifolium	X						

Genus & Species	C	CHI	DIC	RMC	MC	W	A
Claopodium whippleanum					X		
Climacium dendroides						X	
Conardia compacta						X	
Coscinodon calyptratus			X				
Cratoneuron filicinum						X	
Crumia latifolia					X		
Cynodontium jenneri		X					
Dendroalsia abietina		M					
Desmatodon obtusifolius			X				
Dichodontium pellucidum						X	
Dicranella heteromalla						X	
D. howei					X		
D. pacifica		X					
D. schreberiana						X	
Dicranoweisia cirrata					X		
Dicranum fuscescens						X	
D. scoparium						X	
D. tauricum		M					
Didymodon fallax						X	
D. rigidulus var. gracilis						X	
D. tophaceous						X	
D. vinealis var. vinealis						X	
D. vinealis var. flaccidus						X	
Ditrichum flexicaule						X	
D. heteromallum		X					
D. montanum		X					
Drepanocladus aduncus						X	
D. crassicostatus				X			
Dryptodon patens		X					
Encalypta ciliata						X	
E. procera						X	
E. vulgaris						X	
Epipterygium tozeri					X		
Eucladium verticillatum						X	
Eurhynchium oreganum		X					
E. praelongum						X	
E. pulchellum						X	
Fissidens adianthoides						X	
F. bryoides var. bryoides						X	
F. bryoides var. viridulus						X	
F. grandifrons						X	
F. limbatus						X	
F. ventricosus					X		
Fontinalis antipyretica var. antipyretica						X	
F. antipyretica var. gigantea						X	
F. antipyretica var. oregonensis	X						
Funaria hygrometrica						X	
F. muhlenbergii			X				
Grimmia laevigata			X				
G. pulvinata			X				
G. torquata						X	
G. trichophylla						X	

Genus & Species	C	CHI	DCI	RMC	MC	W	A
Gymnostomum aeruginosum						X	
Hedwigia stellata	X						
Heterocladium macounii		X					
H. procurrens		X					
Homalothecium aeneum			X				
H. arenarium					X		
H. fulgescens		X					
H. nuttallii					M		
H. pinnatifidum					X		
Hylocomium splendens						X	
Hymenostylium recurvirostre						X	
Hypnum circinale		X					
H. cupressiforme		X					
H. dieckii		X					
H. subimponens		X					
Isothecium cristatum					X		
I. myosuroides		X					
Leptobryum pyriforme						X	
Leptodictyum riparium						X	
Leucolepis acanthoneuron		X					
Metaneckera menziesii		M					
Mnium marginatum						X	
M. spinulosum						X	
Neckera douglasii		M					
N. pennata	X						
Oncophorus wahlenbergii						X	
Orthotrichum affine						X	
O. anomalum						X	
O. consimile		M					
O. hallii				X			
O. lyellii		M					
O. pulchellum		X					
O. rupestre						X	
O. speciosum						X	
O. striatum		X					
O. tenellum	X						
Phascum cuspidatum			X				
Philonotis capillaris		X					
P. fontana						X	
Physcomitrium pyriforme					X		
Plagiomnium insigne		X					
P. medium						X	
P. rostratum						X	
P. venustum		X					
Plagiothecium denticulatum						X	
P. laetum						X	
P. piliferum						X	
Plagiothecium undulatum		X					
Platydictya jungermannioides						X	
Platyhypnidium riparioides		X					
Pleuridium acuminatum					X		
Pleurozium schreberi						X	

Genus & Species	C	CHI	DIC	RMC	MC	W	A
Pogonatum contortum		X					
P. urnigerum						X	
Pohlia cruda							
P. longibracteata	X					X	
P. nutans						X	
P. sphagnicola	X						
P. wahlenbergii						X	
Polytrichastrum alpinum						X	
Polytrichum commune						X	
P. formosum						X	
P. juniperinum						X	
P. piliferum						X	
P. strictum						X	
Porotrichum bigelovii		X					
P. vancouveriense	X						
Pseudobraunia californica					X		
Pseudoscleropodium purum	X						X
Pseudotaxiphyllum elegans		X					
Pterogonium gracile					X		
Ptychomitrium gardneri					X		
Racomitrium aciculare						X	
R. elongatum		X					
R. ericoides		X					
R. heterostichum						X	
R. lanuginosum						X	
R. lawtonae	X						
R. occidentale	X						
R. pacificum	X						
R. varium	X						
Rhizomnium glabrescens		X					
R. magnifolium						X	
Rhytidiadelphus loreus		X					
R. squarrosus		X					
R. triquetrus						X	
Rhytidiopsis robusta		X					
Sanionia uncinata						X	
Schistidium agassizii						X	
S. apocarpum						X	
S. maritimum	X						
S. rivulare						X	
Scleropodium cespitans		M					
S. obtusifolium		X					
S. touretii var. touretii					X		
Scleropodium touretii var. colpophyllum	X						
Spahgnum capillifolium						X	
S. fuscum						X	
S. henryense	X						
S. magellanicum						X	
S. palustre						X	
Sphagnum recurvum						X	
S. rubellum						X	
S. squarrosum						X	

Genus & Species	C	CHI	DIC	RMC	MC	W	A
Sphagnum subsecundum						X	
Tetraphis pellucida						X	
Timmia austriaca						X	
Timmiella crassinervis					X		
Tortella fragilis						X	
T. tortuosa						X	
Tortula amplexa					X		
T. laevipila var. laevipila					X		
T. laevipila var. meridionalis					X		
T. latifolia					X		
T. muralis	X						
T. papillosa	X						
T. papillosissima			X				
T. princeps					X		
T. ruralis						X	
T. subulata					X		
Trachybryum megaptilum					X		
Trichodon cylindricus	X						
Trichostomopsis australasiae			X				
Ulota megalospora	X						
U. obtusiuscula	X						
U. phyllantha	X						
Warnstorfia fluitans						X	
Weissia controversa						X	
Zygodon viridissimus var. rupestris		X					

Appendix I

Number of records and frequency of species on islands.

Genus & Species	No. of Records	No. of Islands	% of Islands
Dicranum scoparium	140	27	96.4
Polytrichum juniperinum	139	27	96.4
Dicranoweisia cirrata	131	26	92.8
Eurhynchium oreganum	106	26	92.8
Grimmia trichophylla	197	26	92.8
Rhytidiadelphus triquetrus	119	26	92.8
Bryum capillare	39	23	82.1
Isothecium myosuroides	143	23	82.1
Polytrichum piliferum	70	23	82.1
Schistidium maritimum	66	23	82.1
Didymodon vinealis var. vinealis	206	22	78.5
Ceratodon purpureus	117	21	75.0
Tortula princeps	30	21	75.0
Claopodium crispifolium	119	20	71.4
Dicranum fuscescens	85	20	71.4
Racomitrium ericoides	61	19	67.8
Rhytidiadelphus loreus	65	19	67.8
Dicranum tauricum	72	18	64.2
Hedwigia stellata	93	18	64.2
Homalothecium pinnatifidum	80	18	64.2
Hylocomium splendens	73	18	64.2
Plagiothecium undulatum	65	18	64.2
Dicranella heteromalla	50	17	60.7
Eurhynchium praelongum	118	17	60.7
Isothecium cristatum	73	17	60.7
Orthotrichum lyellii	173	17	60.7
Timmiella crassinervis	39	17	60.7
Ulota phyllantha	38	17	60.7
Atrichum selwynii	80	16	57.1
Leucolepis acanthoneuron	76	16	57.1
Racomitrium elongatum	42	16	57.1
Racomitrium heterostichum	154	16	57.1
Zygodon viridissimus var. rupestris	71	16	57.0
Homalothecium fulgescens	85	15	53.5
Rhizomnium glabrescens	56	15	53.5
Tortula ruralis	90	15	53.5
Antitrichia curtipendula	78	14	50.0
Funaria hygrometrica	36	14	50.0
Grimmia pulvinata	71	14	50.0
Hypnum circinale	56	14	50.0
Homalothecium nuttallii	53	13	46.4
Metaneckera menziesii	49	13	46.4
Orthotrichum pulchellum	47	13	46.4
Plagiomnium insigne	55	13	46.4
Plagiothecium laetum	50	13	46.4
Aulacomnium androgynum	53	12	42.8
Antitrichia californica	61	11	39.2

Genus & Species	No. of Records	No. of Islands	% of Islands
Fissidens limbatus	35	11	39.2
Hypnum subimponens	57	11	39.2
Mnium spinulosum	36	11	39.2
Orthotrichum consimile	67	11	39.2
Anacolia menziesii	48	10	35.7
Bryum pseudotriquetrum	44	10	35.7
Neckera douglasii	55	10	35.7
Schistidium apocarpum	53	10	35.7
Ulota obtusiuscula	24	10	35.7
Amphidium californicum	75	9	32.1
Brachythecium albicans	17	9	32.1
Bryum caespiticium	34	9	32.1
Plagiothecium denticulatum	35	9	32.1
Scleropodium touretii var. touretii	26	9	32.1
Timmia austriaca	42	9	32.1
Tortula muralis	26	9	32.1
Bryum lisae var. cuspidatum	15	8	28.5
Claopodium bolanderi	44	8	28.5
Didymodon vinealis var. flaccidus	17	8	28.5
Leptodictyum riparium	37	8	28.5
Plagiomnium venustum	36	8	28.5
Orthotrichum rupestre	35	7	25.0
Pleurozium schreberi	28	7	25.0
Pohlia cruda	18	7	25.0
Porotrichum bigelovii	33	7	25.0
Pseudotaxiphyllum elegans	25	7	25.0
Trachybryum megaptilum	24	7	25.0
Bartramia pomiformis	34	6	21.4
Brachythecium velutinum var. velutinum	16	6	21.4
Claopodium whippleanum	11	6	21.4
Fissidens bryoides var. viridulus	6	6	21.4
Hypnum dieckii	26	6	21.4
Racomitrium lanuginosum	14	6	21.4
Scleropodium cespitans	10	6	21.4
Weissia controversa	16	6	21.4
Alsia californica	14	5	17.8
Amblystegium serpens var. serpens	10	5	17.8
Calliergonella cuspidata	15	5	17.8
Didymodon tophaceous	15	5	17.8
Homalothecium arenarium	5	5	17.8
Leptobryum pyriforme	9	5	17.8
Pseudobraunia californica	8	5	17.8
Tetraphis pellucida	25	5	17.8
Bryum miniatum	9	4	14.5
Brachythecium frigidum	23	4	14.2
Bryum argenteum	6	4	14.2
Dendroalsia abietina	12	4	14.2
Homalothecium aeneum	11	4	14.2
Hymenostylium recurvirostre	10	4	14.2
Polytrichastrum alpinum	22	4	14.2
Polytrichum formosum	5	4	14.2
Schistidium agassizii	6	4	14 .2

Genus & Species	No. of Records	No. of Islands	% of Islands
Scleropodium obtusifolium	15	4	14.2
Atrichum undulatum	7	3	10.7
Brachythecium asperrimum	4	3	10.7
Bryoerythrophyllum recurvirostre	6	3	10.7
Bryum gemmiparum	3	3	10.7
Bryum pallescens	7	3	10.7
Cratoneuron filicinum	11	3	10.7
Dichodontium pellucidum	11	3	10.7
Dicranella schreberiana	4	3	10.7
Ditrichum heteromallum	11	3	10.7
Drepanocladus aduncus	3	3	10.7
Encalypta ciliata	5	3	10.7
Fissidens bryoides var. bryoides	11	3	10.7
Grimmia torquata	11	3	10.7
Gymnostomum aeruginosum	5	3	10.7
Orthotrichum speciosum	6	3	10.7
Orthotrichum striatum	3	3	10.7
Pohlia nutans	14	3	10.7
Ptychomitrium gardneri	8	3	10.7
Racomitrium lawtonae	4	3	10.7
Racomitrium occidentale	7	3	10.7
Racomitrium pacificum	4	3	10.7
Tortula amplexa	3	3	10.7
Tortula laevipila var. meridionalis	8	3	10.7
Tortula papillosissima	4	3	10.7
Amblystegium serpens var. juratzkanum	3	2	7.1
Aamphidium lapponicum	3	2	7.1
Aulacomnium palustre	16	2	7.1
Barbula unguiculata	2	2	7.1
Crumia latifolia	7	2	7.1
Dicranella howei	2	2	7.1
Dicranella pacifica	4	2	7.1
Didymodon rigidulus var. gracilis	3	2	7.1
Encalypta procera	3	2	7.1
Eucladium verticillatum	6	2	7.1
Fissidens ventricosus	5	2	7.1
Fontinalis antipyretica var. antipyretica	7	2	7.1
Fontinalis antipyretica var. oregonensis	9	2	7.1
Neckera pennata	2	2	7.1
Orthotrichum affine	3	2	7.1
Philonotis fontana	6	2	7.1
Physcomitrium pyriforme	2	2	7.1
Platydictya jungermannioides	3	2	7.1
Pleuridium acuminatum	4	2	7.1
Pohlia wahlenbergii	4	2	7.1
Racomitrium varium	14	2	7.1
Schistidium rivulare	4	2	7.1
Scleropodium touretii var. colpophyllum	2	2	7.1
Sphagnum capillifolium	3	2	7.1
Sphagnum henryense	12	2	7.1
Sphagnum recurvum	10	2	7.1
Sphagnum squarrosum	9	2	7.1

Genus & Species	No. of Records	No. of Islands	% of Islands
Tortella tortuosa	3	2	7.1
Tortula laevipila var. laevipila	6	2	7.1
Tortula papillosa	4	2	7.1
Tortula subulata	2	2	7.1
Trichodon cylindricus	2	2	7.1
Trichostomopsis australasiae	3	2	7.1
Ulota megalospora	14	2	7.1
Warnstorfia fluitans	3	2	7.1
Andreaea megistospora	4	1	3.5
Andreaea rupestris	12	1	3.5
Blindia acuta	1	1	3.5
Brachythecium rivulare	1	1	3.5
Brachythecium velutinum var. venustum	2	1	3.5
Bryum amblyodon	1	1	3.5
Bryum canariense	1	1	3.5
Bryum dichotomum	1	1	3.5
Bryum flaccidum	1	1	3.5
Bryum pallens	1	1	3.5
Bryum uliginosum	1	1	3.5
Calliergon giganteum	2	1	3.5
Climacium dendroides	1	1	3.5
Conardia compacta	1	1	3.5
Coscinodon calyptratus	1	1	3.5
Cynodontium jenneri	8	1	3.5
Desmatodon obtusifolius	2	1	3.5
Didymodon fallax	1	1	3.5
Ditrichum flexicaule	2	1	3.5
Ditrichum montanum	5	1	3.5
Drepanocladus crassicostatus	4	1	3.5
Dryptodon patens	4	1	3.5
Encalypta vulgaris	1	1	3.5
Epipterygium tozeri	1	1	3.5
Eurhynchium pulchellum	2	1	3.5
Fissidens adianthoides	2	1	3.5
Fissidens grandifrons	4	1	3.5
Fontinalis antipyretica var. gigantea	1	1	3.5
Funaria muhlenbergii	1	1	3.5
Grimmia laevigata	1	1	3.5
Heterocladium macounii	3	1	3.5
Heterocladium procurrens	3	1	3.5
Hypnum cupressiforme	2	1	3.5
Mnium marginatum	3	1	3.5
Oncophorus wahlenbergii	1	1	3.5
Orthotrichum anomalum	3	1	3.5
Orthotrichum hallii	2	1	3.5
Orthotrichum tenellum	1	1	3.5
Phascum cuspidatum	1	1	3.5
Philonotis capillaris	1	1	3.5
Plagiothecium medium	2	1	3.5
Plagiothecium rostratum	1	1	3.5
Plagiothecium piliferum	1	1	3.5
Platyhypnidium riparioides	3	1	3.5

Genus & Species	No. of Record	No. of Islands	% of Islands
Pogonatum contortum	1.	1	3.5
Pogonatum unigerum	7	1	3.5
Pohlia longibracteata	1	1	3.5
Pohlia sphagnicola	1	1	3.5
Polytrichum commune	1	1	3.5
Polytrichum strictum	3	1	3.5
Porotrichum vancouveriense	1	1	3.5
Pseudoscleropodium purum	1	1	3.5
Pterogonium gracile	1	1	3.5
Racomitrium aciculare	1	1	3.5
Rhizomnium magnifolium	2	1	3.5
Rhytidiadelphus squarrosus	1	1	3.5
Rhytidiopsis robusta	12	1	3.5
Sanionia uncinata	1	1	3.5
Sphagnum fuscum	5	1	3.5
Sphagnum magellanicum	1	1	3.5
Sphagnum palustre	3	1	3.5
Sphagnum rubellum	2	1	3.5
Sphagnum subsecundum	3	1	3.5
Tortella fragilis	1	1	3.5
Tortula latifolia	2	1	3.5

Appendix J

Species list arranged systematically.

Sphagnaceae

Sphagnum capillifolium (Ehrh.) Hedw.
S. fuscum (Schimp.) Klinggr.
S. henryense Warnst.
S. magellanicum Brid.
S. palustre L.
s. recurvum P. Beauv.
S. rubellum Wils.
S. squarrosum Crome
S. subsecundum Nees in Sturm

Andreaeaceae

Andreaea megistospora B. Murr.
A. rupestris Hedw.

Ditrichaceae

Pleuridium acuminatum Lindb.
Ditrichum flexicaule (Schwaegr.) Hamp.
D. heteromallum (Hedw.) Britt.
D. montanum Leib.
Trichodon cylindricus (Hedw.) Schimp.
Ceratodon purpureus (Hedw.) Brid.

Dicranaceae

Dicranella heteromalla (Hedw.) Schimp.
D. howei Ren. & Card.
D. pacifica Schof.
D. schreberiana (Hedw.) Hilf. ex Crum & Anderson
Oncophorus wahlenbergii Brid.
Cynodontium jenneri (Schimp. in Howie) Stirt.
Dichodontium pellucidum (Hedw.) Schimp.
Dicranoweisia cirrata (Hedw.) Lindb. ex Milde
Dicranum fuscescens Turn.
D. scoparium Hedw.
D. tauricum Sapeh.

Fissidentaceae

Fissidens adianthoides Hedw.
F. bryoides Hedw. var. *bryoides*
F. bryoides Hedw. var. *viridulus* (Sw.) Broth.
F. grandifrons Brid.
F. limbatus Sull.
F. ventricosus Lesq.

Seligeriaceae

Blindia acuta (Hedw.) Bruch & Schimp. in B.S.G.

Encalyptaceae

Encalypta ciliata Hedw.
E. procera Bruch
E. vulgaris Hedw.

Pottiaceae

Weissia controversa Hedw.
Gymnostomum aeruginosum Sm.
Hymenostylium recurvirostre (Hedw.) Dix.
Eucladium verticillatum (Brid.) Bruch & Schimp. in B.S.G.
Timmiella crassinervis (Hampe) L. Koch
Tortella fragilis (Hook. & Wils in Drumm.) Limpr.
T. tortuosa (Hedw.) Limpr.
Trichostomopsis australasiae (Grev. & Hook.) Robins.
Didymodon fallax (Hedw.) Zand.
D. tophaceous (Brid.) Lisa
D. vinealis (Brid.) Zand. var. *vinealis*
D. vinealis (Brid.) Zand. var. *flaccidus* (Bruch & Schimp. in Schimp.) Zand.
Bryoerythrophyllum recurvirsotre (Hedw.) Chen.
Barbula unguiculata Hedw.
Crumia latifolia (Kindb. in Mac.) Schof.
Phascum cuspidatum Hedw.
Desmatodon obtusifolius (Schwaegr.) Schimp.
Tortula amplexa (Lesq.) Steere
T. laevipila (Brid.) Schwaegr. var. *laevipila*
T. laevipila (Brid.) Schwaegr. var. *meridionalis* (Schimp.) Wijk & Marg.
T. latifolia Bruch ex Hartm.
T. muralis Hedw.
T. papillosa Wils in Spruce
T. papillosissima (Copp.) Broth.
T. princeps De Not.
T. ruralis (Hedw.) Gaertn. et al.
T. subulata Hedw.

Grimmiaceae

Coscinodon calyptratus (Hook. in Drumm.) C. Jens. ex Kindb.
Dryptodon patens (Hedw.) Brid.
Grimmia laevigata (Brid.) Brid.
G. pulvinata (Hedw.) Sm.
G. torquata Hornsch. in Grev.
G. trichophylla Grev.

Ptychomitriaceae

Ptycomitrium gardneri Lesq.

Funariaceae

Physcomitrium pyriforme (Hedw.) Hampe
Funaria hygrometrica Hedw.
F. muhlenbergii Turn.

Bryaceae

Pohlia cruda (Hedw.) Lindb.
P. longibracteata Broth. in Roll.

P. nutans (Hedw.) Lindb.
P. sphagnicola (Bruch & Schimp.) Lindb. & Arnell
P. wahlenbergii (Web. & Mohr) Andrews
Epipterygium tozeri (Grev.) Lindb.
Leptobryum pyriforme (Hedw.) Wils.
Bryum ambylodon C. Mull.
B. argenteum Hedw.
B. caespiticium Hedw.
B. canariense Brid.
B. capillare Hedw.
B. dichotomum Hedw.
B. flaccidum Brid.
B. gemmiparum De Not.
B. lisae De Not. var. *cuspidatum* (Bruch & Schimp. in B.S.G. Marg.
B. miniatum Lesq.
B. pallens (Brid.) Sw. in Rohl.
B. pallescens Schleich. ex Schwaegr.
B. pseudotriquetrum (Hedw.) Gaertn. et al.
B. uliginosum (Brid.) Bruch & Schimp. in B.S.G.

Mniaceae

Mnium marginatum (With.) Brid. ex P. Beauv.
M. spinulosum Bruch & Schimp. in B.S.G.
Leucolepis acanthoneuron (Schwaegr.) Lindb.
Rhizomnium glabrescens (Kindb.) T. Kop.
R. magnifolium (Horik.) T. Kop.
Plagiomnium insigne (Mitt.) T. Kop.
P. medium (Bruch & Schimp. in B.S.G.) T. Kop.
P. rostratum (Schrad.) T. Kop.
P. venustum (Mitt.) T.Kop.

Aulacomniaceae

Aulacomnium androgynum (Hedw.) Schwaegr.
A. palustre (Hedw.) Schwaegr.

Bartramiaceae

Anacolia mensiesii (Turn.) Par.
Bartramia pomiformis Hedw.
Philonotis capillaris Lindb. in Hartm.
P. fontana (Hedw.) Brid.

Timmiaceae

Timmia austriaca Hedw.

Orthotrichaceae

Zygodon viridissimus (Dicks.) Brid. var. *rupestris* Lindb. ex Hartm.
Amphidium californicum (Hampe ex C. Mull.) Broth.
A. lapponicum (Hedw.) Schimp.
Orthotrichum affine Brid.
O. anomalum Hedw.
O. consimile Mitt.
O. hallii Sull. & Lesq. in Sull.
O. lyellii Hook. & Tayl.

O. pulchellum Brunt. in Winch. & Gateh.
O. rupestre Schleich. ex Schwaegr.
O. speciosum Nees in Sturm
O. striatum Hedw.
O. tenellum Bruch ex Brid.
Ulota megalospora Vent. in Roll.
U. obtusiuscula C. Mull. & Kindb. in Mac. & Kindb.
U. phyllantha Brid.

Fontinalaceae

Foninalis antipyretica var. *antipyretica* Hedw.
F. antipyretica Hedw. var. *gigantea* (Sull.) Sull.
F. antipyretica Hedw. var. *oregonensis* Ren. & Card.

Climaciaceae

Climacium dendroides (Hedw.) Web. & Mohr.

Anomodontaceae

Pterogonium gracile (Hedw.) Sm.

Hedwigiaceae

Hedwigia stellata Hedenas
Pseudobraunia californica (Lesq.) Broth.

Leucodontaceae

Alsia californica (Hook. & Arnott) Sull.
Dendroalsia abietina (Hook.) Britt.
Antitrichia californica Sull. in Lesq.
A. curtipendula (Hedw.) Brid.

Neckeraceae

Neckera douglasii Hook.
N. pennata Hedw.
Metaneckera menziesii (Hook. in Drumm.) Steere

Leskeaceae

Claopodium bolanderi Best.
C. crispifolium (Hook.) Ren. & Card.
C. whippleanum (Sull. in Whipple & Ives) Ren. & Card.

Pterigynandraceae

Heterocladium macounii Best.
H. procurrens (Mitt.) Jaeg.

Thamnobryaceae

Porotrichum bigelovii (Sull.) Kindb.
P. vancouveriense (Kindb. in Mac.) Crum

Amblystegiaceae

Cratoneuron filicinum (Hedw.) Spruce
Amblystegium serpens (Hedw.) Schimp. in B.S.G. var. *serpens*
A. serpens (Hedw.) Schimp. in B.S.G. var. *juratzkanum* (Schimp.) Rau & Herv.
Leptodictyum riparium (Hedw.) Warnst.
Conardia compacta (C. Mull.) Robins.
Sanionia uncinata (Hedw.) Loeske
Drepanocladus aduncus (Hedw.) Warnst
D. crassicostatus Janssens
Warnstorfia fluitans (Hedw.) Loeske

Calliergon giganteum (Schimp.) Kindb.
Calliergonella cuspidata (Hedw.) Loeske

Brachytheciaceae

Homalothecium aeneum (Mitt.) Lawt.
H. arenarium (Lesq.) Lawt.
H. fulgescens (Mitt. ex C. Mull.) Lawt.
H. nuttallii (Wils.) Jaeg.
H. pinnatifidum (Sull. & Lesq.) Lawt.
Trachybryum megaptilum (Sull.) Schof.
Isothecium cristatum (Hampe) Robins.
I. myosuroides Brid.
Brachythecium albicans (Hedw.) Schimp. in B.S.G.
B. asperrimum (Mitt.) Sull.
B. frigidum (C.Mull.) Besch.
B. rivulare Schimp in B.S.G.
B. velutinum (Hedw.) Schimp. in B.S.G. var. *velutinum*
B. velutinum (Hedw.) Schimp. in B.S.G. var. *venustum* (De Not.) Arc.
Scleropodium cespitans (C. Mull.) L. Koch
S. obtusifolium (Jaeg.) Kindb. in Mac. & Kindb.
S. touretii (Brid.) L. Koch var. *touretii*
S. touretii (Brid.) L. Koch var. *colpophyllum* (Sull.) Lawt. ex Crum
Eurhynchium oreganum (Sull.) Jaeg.
E. praelongum (Hedw.) Schimp. in B.S.G.
E. pulchellum (Hedw.) Jenn.
Platyhypnidium riparioides (Hedw.) Dix.
Pseudoscleropodium purum (Hedw.) Fleisch. in Broth.

Plagiotheciaceae

Plagiothecium denticulatum (Hedw.) Schimp. in B.S.G.
P. laetum Schimp. in B.S.G.
P. piliferum (Sw. ex Hartm.) Schimp. in B.S.G.
P. undulatum (Hedw.) Schimp. in B.S.G.

Hypnaceae

Platydictya jungermannioides (Brid.) Crum
Hypnum circinale Hook.
H. cupressiforme Hedw.
H. dieckii Ren. & Card. in Roll
H. subimponens Lesq.
Pseudotaxiphyllum elegans (Brid.) Iwats.

Hylocomiaceae

Hylocomnium splendens (Hedw.) Schimp. in B.S.G.
Rhytidiadelphus loreus (Hedw.) Warnst.
R. squarrosus (Hedw.) Warnst.
R. triquetrus (Hedw.) Warnst.
Pleurozium schreberi (Brid.) Mitt.
Rhytidiopsis robusta (Hook.) Broth.

Tetraphidaceae

Tetraphis pellucida Hedw.

Polytrichaceae

Atrichum selwynii Aust.
A. undulatum (Hedw.) P. Beauv.
Pogonatum contortum (Brid.) Lesq.
P. urnigerum (Hedw.) P. Beauv.
Polytrichastrum alpinum (Hedw.) G. L. Sm.
Polytrichum commune Hedw.
P. formosum Hedw.
P. juniperinum Hedw.
P. piliferum Hedw.
P. strictum Brid.

Appendix K

Alphabetic list of Species, * = historical collection not relocated.

Alsia californica (Hook. & Arnott) Sull.
Amblystegium serpens (Hedw.) Schimp. in B.S.G. var. *serpens*
A. serpens (Hedw.) Schimp. in B.S.G. var. *juratzkanum* (Schimp.) Rau & Herv.
Amphidium californicum (Hampe ex C. Mull.) Broth.
A. lapponicum (Hedw.) Schimp.
Anacolia menziesii (Turn.) Par.
Andreaea megistospora B. Murr.
A. rupestris Hedw.
Antitrichia californica Sull. in Lesq.
A. curtipendula (Hedw.) Brid.
Atrichum selwynii Aust.
A. undulatum (Hedw.) P. Beauv.
Aulacomnium androgynum (Hedw.) Schwaegr.
A. palustre (Hedw.) Schwaegr.
Barbula unguiculata Hedw.
Bartramia pomiformis Hedw.
Blindia acuta (Hedw.) Bruch & Schimp. in B.S.G.
Brachythecium albicans (Hedw.) Schimp. in B.S.G.
B. asperrimum (Mitt.) Sull.
B. frigidum (C. Mull.) Besch.
B. rivulare Schimp. in B.S.G.
B. velutinum (Hedw.) Schimp. in B.S.G. var. velutinum
B. velutinum (Hedw.) Schimp. in B.S.G. var. venustum (De Not.) Arc.
Bryoerythrophyllum recurvirostre (Hedw.) Chen.
Bryum ambylodon C. Mull.
B. argenteum Hedw.
B. caespiticium Hedw.
B. canariense Brid.
B. capillare Hedw.
B. dichotomum Hedw.
B. flaccidum Brid.
B. gemmiparum De Not.
B. lisae De Not. var. *cuspidatum* (Bruch & Schimp. in B.S.G.) Marg.
B. miniatum Lesq.
B. pallens (Brid.) Sw. in Rohl.
B. pallescens Schleich. ex Schwaegr.
B. pseudotriquetrum (Hedw.) Gaertn. et al.
B. uliginosum (Brid.) Bruch & Schimp. in B.S.G.
Calliergon giganteum (Schimp.) Kindb.
Calliergonella cuspidata (Hedw.) Loeske
Ceratodon purpureus (Hedw.) Brid.
Claopodium bolanderi Best.
C. crispifolium (Hook.) Ren. & Card.
C. whippleanum (Sull. in Whipple & Ives) Ren. & Card.

Climacium dendroides (Hedw.) Web. & Mohr.
Conardia compacta (C. Mull.) Robins.
Coscinodon calyptratus (Hook. in Drumm.) C. Jens. ex Kindb.
Cratoneuron filicinum (Hedw.) Spruce
Crumia latifolia (Kindb. in Mac.) Schof.
Cynodontium jenneri (Schimp. in Howie) Stirt.
Dendroalsia abietina (Hook.) Britt.
Desmatodon obtusifolius (Schwaegr.) Schimp.
Dichodontium pellucidum (Hedw.) Schimp.
Dicranella heteromalla (Hedw.) Schimp.
D. howei Ren. & Card.
D. pacifica Schof.
D. schreberiana (Hedw.) Hilf. ex Crum & Anderson
Dicranoweisia cirrata (Hedw.) Lindb. ex Milde
Dicranum fuscescens Turn.
D. scoparium Hedw.
D. tauricum Sapeh.
Didymodon fallax (Hedw.) Zand.
D. rigidulus Hedw. var. *gracilis* (Schleich. ex Hook. & Grev.) Zand.
D. tophaceous (Brid.) Lisa
D. vinealis (Brid.) Zand. var. *vinealis*
D. vinealis (Brid.) Zand. var. *flaccidus* (Bruch & Schimp. in Schimp.) Zand.
Distichium capillaceum (Hedw.) Bruch & Schimp. in B.S.G. *
Ditrichum flexicaule (Schwaegr.) Hamp.
D. heteromallum (Hedw.) Britt.
D. montanum Leib.
Drepanocladus aduncus (Hedw.) Warnst.
D. crassicostatus Janssens
Dryptodon patens (Hedw.) Brid.
Encalypta ciliata Hedw.
E. procera Bruch
E. vulgaris Hedw.
Epipterygium tozeri (Grev.) Lindb.
Eucladium verticillatum (Brid.) Bruch & Schimp. in B.S.G.
Eurhynchium oreganum (Sull.) Jaeg.
E. praelongum (Hedw.) Schimp. in B.S.G.
E. pulchellum (Hedw.) Jenn.
Fissidens adianthoides Hedw.
F. bryoides Hedw. var. *bryoides*
F. bryoides Hedw. var. *viridulus* (Sw.) Wahlenb. Purs.
F. grandifrons Brid.
F. limbatus Sull.
F. ventricosus Lesq.
Fontinalis antipyretica Hedw. var. *antipyretica*
F. antipyretica Hedw. var. *gigantea* (Sull.) Sull.
F. antipyretica Hedw. var. *oregonensis* Ren. & Card.
Funaria hygrometrica Hedw.
F. muhlenbergii Turn.

Grimmia laevigata (Brid.) Brid.
G. pulvinata (Hedw.) Sm.
G. torquata Hornsch. in Grev.
G. trichophylla Grev.
Gymnostomum aeruginosum Sm.
Hedwigia stellata Hedenas
Heterocladium macounii Best.
H. procurrens (Mitt.) Jaeg.
Homalothecium aeneum (Mitt.) Lawt.
H. arenarium (Lesq.) Lawt.
H. fulgescens (Mitt. ex C. Mull.) Lawt.
H. nuttallii (Wils.) Jaeg.
H. pinnatifidum (Sull. & Lesq.) Lawt.
Hygrohypnum bestii (Ren. & Bryhn in Ren.) Broth. *
Hylocomium splendens (Hedw.) Schimp. in B.S.G.
Hymenostylium recurvirostre (Hedw.) Dix.
Hypnum circinale Hook.
H. cupressiforme Hedw.
H. dieckii Ren. & Card. in Roll.
H. subimponens Lesq.
Isothecium cristatum (Hampe) Robins.
I. myosuroides Brid.
Leptobryum pyriforme (Hedw.) Wils.
Leptodictyum riparium (Hedw.) Warnst.
Leucolepis acanthoneuron (Schwaegr.) Lindb.
Metaneckera menziesii (Hook. in Drumm.) Steere
Mnium marginatum (With.) Brid. ex P. Beauv.
M. spinulosum Bruch & Schimp. in B.S.G.
Neckera douglasii Hook.
N. pennata Hedw.
Oncophorus wahlenbergii Brid.
Orthotrichum affine Brid.
O. anomalum Hedw.
O. consimile Mitt.
O. hallii Sull. & Lesq. in Sull.
O. lyellii Hook. & Tayl.
O. pulchellum Brunt. in Winch. & Gateh.
O. rupestre Schleich. ex Schwaegr.
O. speciosum Nees in Sturm
O. striatum Hedw.
O. tenellum Bruch ex Brid.
Phascum cuspidatum Hedw.
Philonotis capillaris Lindb. in Hartm.
P. fontana (Hedw.) Brid.
Physcomitrium pyriforme (Hedw.) Hampe
Plagiomnium insigne (Mitt.) T. Kop.
P. medium (Bruch & Schimp. in B.S.G.) T. Kop.
P. rostratum (Schrad.) T. Kop.

P. venustum (Mitt.) T. Kop.
Plagiothecium denticulatum (Hedw.) Schimp. in B.S.G.
P. laetum Schimp. in B.S.G.
P. piliferum (Sw. ex Hartm.) Schimp. in B.S.G.
Plagiothecium undulatum (Hedw.) Schimp. in B.S.G.
Platydictya jungermannioides (Brid.) Crum
Platyhypnidium riparioides (Hedw.) Dix.
Pleuridium acuminatum Lindb.
Pleurozium schreberi (Brid.) Mitt.
Pogonatum contortum (Brid.) Lesq.
P. urnigerum (Hedw.) P. Beauv.
Pohlia cruda (Hedw.) Lindb.
P. longibracteata Broth. in Roll.
P. nutans (Hedw.) Lindb.
P. sphagnicola (Bruch & Schimp.) Lindb. & Arnell
P. wahlenbergii (Web. & Morh) Andrews
Polytrichastrum alpinum (Hedw.) G.L. Sm.
Polytrichum commune Hedw.
P. formosum Hedw.
P. juniperinum Hedw.
P. piliferum Hedw.
P. strictum Brid.
Porotrichum bigelovii (Sull.) Kindb.
P. vancouveriense (Kindb. in Mac.) Crum
Pseudobraunia californica (Lesq.) Broth.
Pseudoscleropodium purum (Hedw.) Fleisch. in Broth.
Pseudotaxiphyllum elegans (Brid.) Iwats.
Pterogonium gracile (Hedw.) Sm.
Ptychomitrium gardneri Lesq.
Racomitrium aciculare (Hedw.) Brid.
R. elongatum Ehrh. ex Frisv.
R. ericoides (Web. ex Brid.) Brid.
R. heterostichum (Hedw.) Brid.
R. lanuginosum (Hedw.) Brid.
R. lawtonae Irel.
R. occidentale (Ren. & Card.) Ren. & Card.
R. pacificum Irel. & Spence
R. varium (Mitt.) Jaeg.
Rhizomnium glabrescens (Kindb.) T. Kop.
R. magnifolium (Horik.) T. Kop.
Rhytidiadelphus loreus (Hedw.) Warnst.
R. squarrosus (Hedw.) Warnst.
R. triquetrus (Hedw.) Warnst.
Rhytidiopsis robusta (Hook.) Broth.
Roellia roellii (Broth. in Roll) Andrews ex Crum *
Sanionia uncinata (Hedw.) Loeske
Schistidium agassizii Sull. & Lesq. in Sull.
S. apocarpum (Hedw.) Bruch & Schimp. in B.S.G.

S. maritimum (Turn.) Bruch & Schimp. in B.S.G.
S. rivulare (Brid.) Podp.
Scleropodium cespitans (C. Mull.) L. Koch
S. obtusifolium (Jaeg.) Kindb. in Mac. & Kindb.
S. touretii (Brid.) L. Koch var. *touretii*
Scleropodium touretii (Brid.) L. Koch var. *colpophyllum* (Sull.) Lawt. ex Crum
Spahgnum capillifolium (Ehrh.) Hedw.
S. fuscum (Schimp.) Klinggr.
S. henryense Warnst.
S. magellanicum Brid.
S. palustre L.
Sphagnum recurvum P. Beauv.
S. rubellum Wils.
S. squarrosum Crome
S. subsecundum Nees in Sturm
Tayloria serrata (Hedw.) Bruch & Schimp. in B.S.G. *
Tetraphis pellucida Hedw.
Timmia austriaca Hedw.
Timmiella crassinervis (Hampe) L. Koch
Tortella fragilis (Hook. & Wils in Drumm.) Limpr.
T. tortuosa (Hedw.) Limpr.
Tortula amplexa (Lesq.) Steere
T. laevipila (Brid.) Schwaegr. var. *laevipila*
T. laevipila (Brid.) Schwaegr. var. *meridionalis* (Schimp.) Wijk & Marg.
T. latifolia Bruch ex Hartm.
T. muralis Hedw.
T. papillosa Wils. in Spruce
T. papillosissima (Copp.) Broth.
T. princeps De Not.
T. ruralis (Hedw.) Gaertn. et al.
T. subulata Hedw.
Trachybryum megaptilum (Sull.) Schof.
Trichodon cylindricus (Hedw.) Schimp.
Trichostomopsis australasiae (Grev. & Hook.) Robins.
Ulota megalospora Vent. in Roll.
U. obtusiuscula C. Mull. & Kindb. in Mac. & Kindb.
U. phyllantha Brid.
Warnstorfia fluitans (Hedw.) Loeske
Weissia controversa Hedw.
Zygodon viridissimus (Dicks.) Brid. var. *rupestris* Lindb. ex Hartm.

Appendix L

Names of taxa that differ from those in Lawton (1971) or are not treated in that publication are given below. The name on the left is that used in the thesis.

Amblstegium serpens var. *juratzkanum*	=	*Amblystegium juratzkanum*
Andreaea megistospora	=	not treated in Lawton, see Murray (1987)
Bryoerythrophyllum recurvirostre	=	*Didymodon recurvirostris*
Bryum ambylodon	=	*Bryum stenotrichum*
Bryum dichotomum	=	*Bryum bicolor*
Bryum flaccidum	=	*Bryum capillare* var. *flaccidum*
Coscinodon calyptratus	=	*Grimmia calyptrata*
Crumia latifolia	=	*Scopelophila latifolia*
Didymodon fallax	=	*Barbula fallax*
Didymodon rigidulus var. *gracilis*	=	*Barbula acuta*
Drepanocladus crassicostatus	=	not treated in Lawton, see Janssens (1983a)
Dryptodon patens	=	*Rhacomitrium patens*
Fissidens limbatus	=	*Fissidens bryoides*
Hedwigia stellata	=	*Hedwigia ciliata*
Hymenostylium recurvirostre	=	*Gymnostomum recurvirostre*
Isothecium myosuroides	=	*Isothecium stoloniferum*
Leptodictyum riparium	=	*Amblystegium riparium*
Leucolepis acanthoneuron	=	*Leucolepis menziesii*
Metaneckera menziesii	=	*Neckera menziesii*
Phytscomitrium pyriforme	=	*Physcomitrium kellermanii* & *P. megalocarpum*
Platyhpnidium riparioides	=	*Eurhynchium riparioides*
Pleuridium acuminatum	=	*Pleuridium subulatum*
Pohlia sphagnicola	=	not treated in Lawton, see Shaw (1982)
Polytrichastrum alpinum	=	*Polytrichum alpinum*
Porotrichum bigelovii	=	*Porothamnium bigelovii*
Porotrichum vancouveriense	=	*Bestia vancouveriensis*
Pseudotaxiphyllum elegans	=	*Isopterygium elegans*
Racomitrium	=	*Rhacomitrium*
Racomitrium lawtonae	=	not treated in Lawton, see Ireland (1970) or Frisvoll (1988)
Racomitrium occidentale	=	*Rhacomitrium heterostichum* var. *occidentale*
Racomitrium pacificum	=	not treated in Lawton, see Ireland & Spence (1987) or Frisvoll (1988)
Roellia roellii	=	*Bryum sandbergii*
Sanionia uncinata	=	*Drepanocladus uncinatus*
Schistidium agassizii	=	*Grimmia alpicola*
Schistidium apocarpum	=	*Grimmia apocarpa*
Schistidium maritimum	=	*Grimmia maritima*
Schistidium rivulare	=	*Grimmia alpicola* var. *rivularis*
Sphagnum	=	not treated in Lawton, see Crum (1984)
Trachybryum megaptilum	=	*Homalothecium megaptilum*
Trichodon cylindricus	=	*Ditrichum cylindricum*
Ulota obtusiuscula	=	*Ulota crispa* var. *alaskana*
Warnstorfia fluitans	=	*Drepanocladus fluitans*
Zygodon viridissimus var. *rupestris*	=	*Zygodon vulgaris*

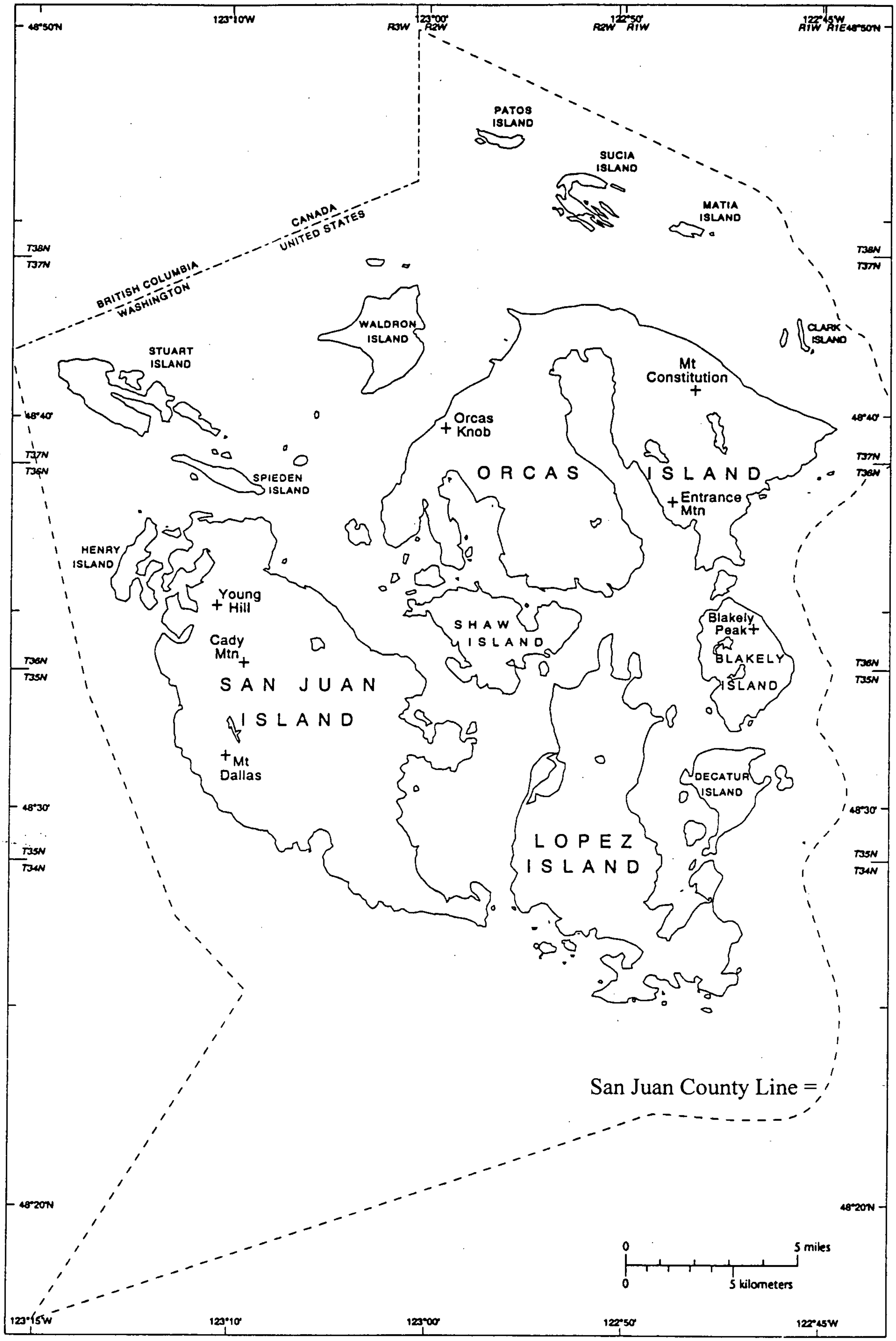
Appendix M

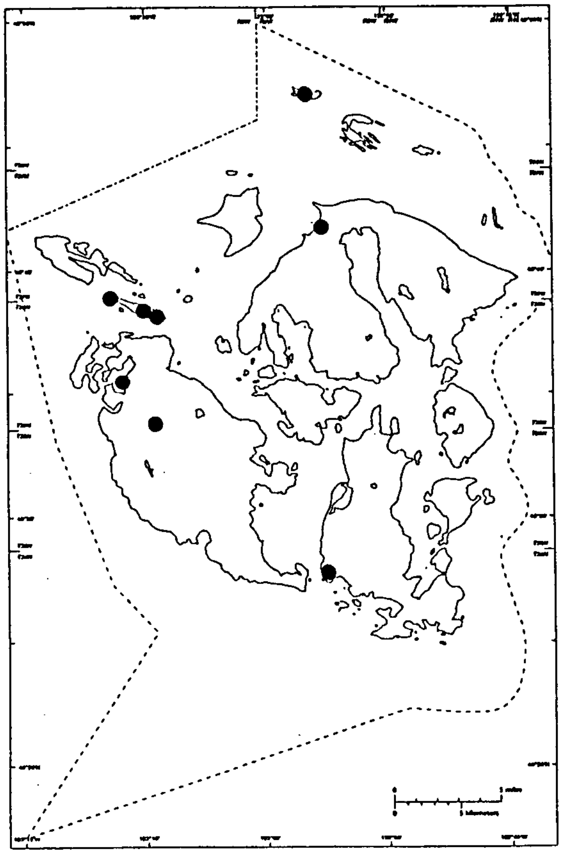
Species that could be expected to be in the San Juan Islands but were not found.

Barbula convoluta Hedw.
Bartramia stricta Brid.
Calliergon stramineum (Brid.) Kindb.
Campylopus fragilis (Brid.) Bruch & Schimp. in B.S.G.
C. subulatus Schimp in Rabenh.
Dicranella rufescens (With.) Schimp.
D. cerviculata (Hedw.) Schimp.
Ditrichum ambiguum Best.
Encalypta rhaptocarpa Schwaerg.
Entosthodon fascicularis (Hedw.) C. Mull.
Hygrohypnum ochraceum (Turn. ex Wils.) Loeske
Oligotrichum aligerum Mitt.
Plagiothecium cavifolium (Brid.) Iwats.
Pohlia proligera (Kindb. ex Breidl.) Lindb. ex Arnell
Pottia truncata (Hedw.) Furnr. ex B.S.G.
Racomitrium obesum Frisv.
Sphagnum mendocinum Sull. & Lesq. in Sull.

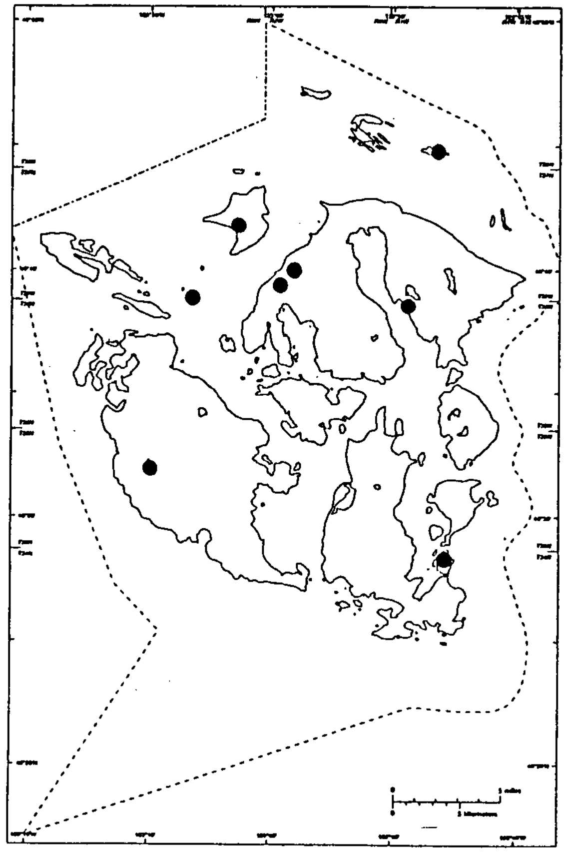
Appendix N

County reference map and distribution maps for all of the species.

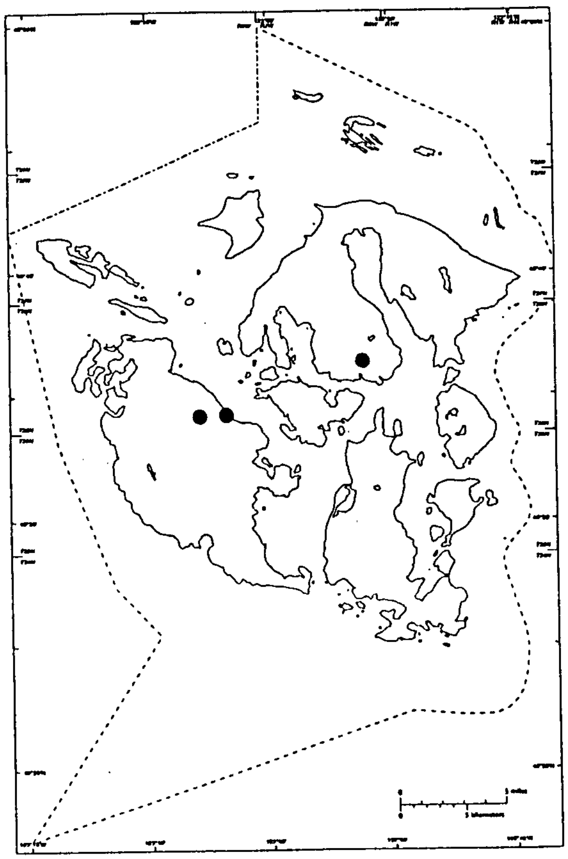

48°50'N
123°10'W
R3W R2W
123°00'
122°50'
R2W R1W
122°45'W
R1W R1E
PATOS ISLAND
SUCIA ISLAND
MATIA ISLAND
CANADA
UNITED STATES
BRITISH COLUMBIA
WASHINGTON
T38N
T37N
WALDRON ISLAND
CLARK ISLAND
STUART ISLAND
Mt Constitution
48°40'
Orcas Knob
SPIEDEN ISLAND
ORCAS ISLAND
Entrance Mtn
T36N
HENRY ISLAND
Young Hill
SHAW ISLAND
Blakely Peak
Cady Mtn
BLAKELY ISLAND
T35N
SAN JUAN ISLAND
Mt Dallas
DECATUR ISLAND
48°30'
LOPEZ ISLAND
T34N
San Juan County Line =
48°20'N
0
5 miles
5 kilometers
123°15'W
123°10'
123°00'
122°50'
122°45'W



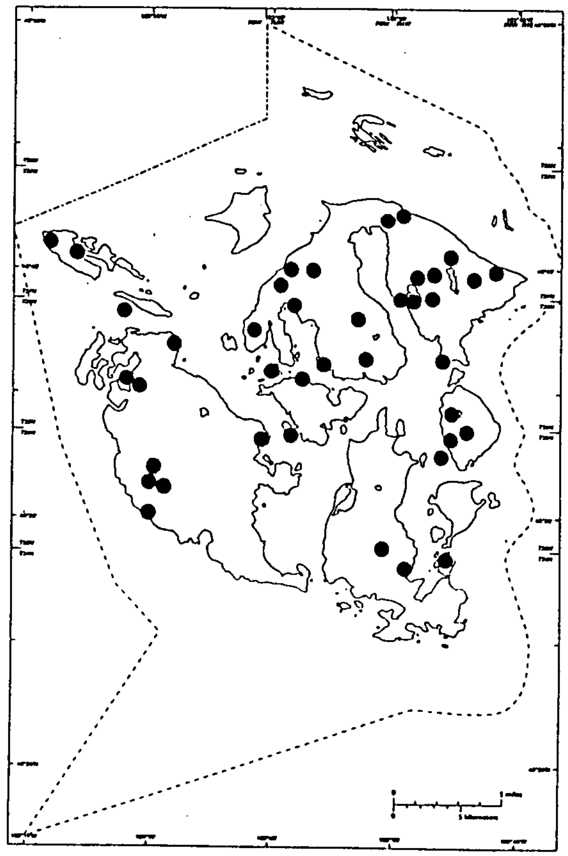
Alsia californica



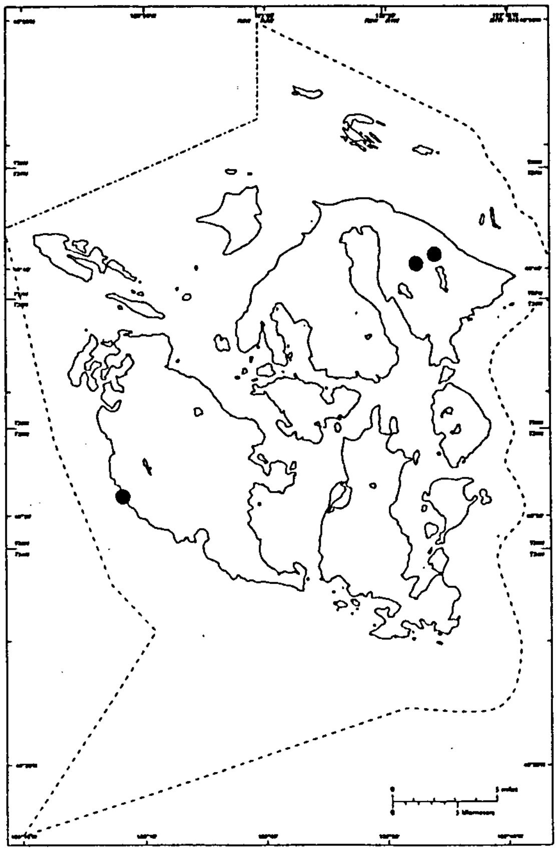
Amblystegium serpens var. *serpens*



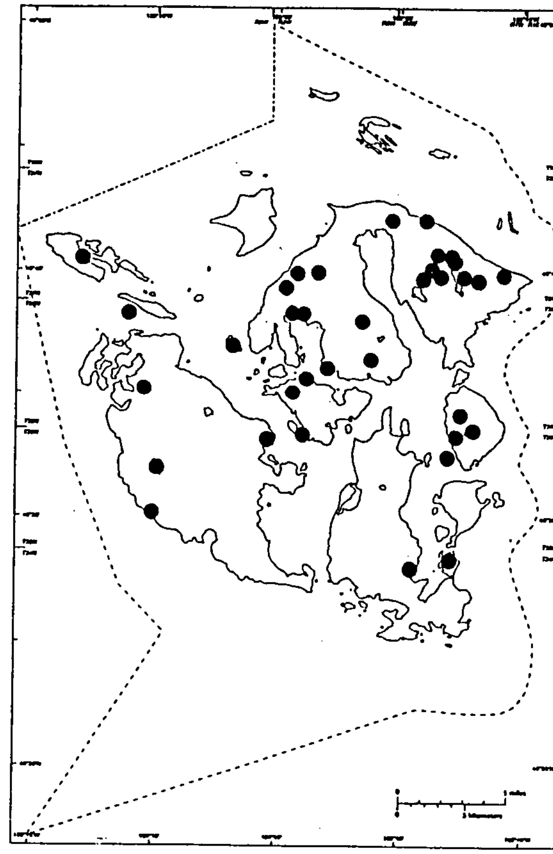
Amblystegium serpens var. *juratzkanum*



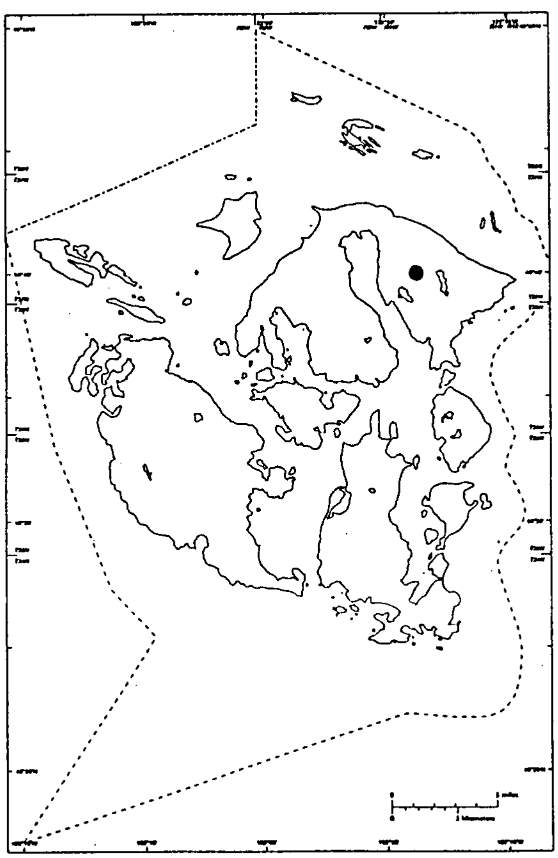
Amphidium californicum



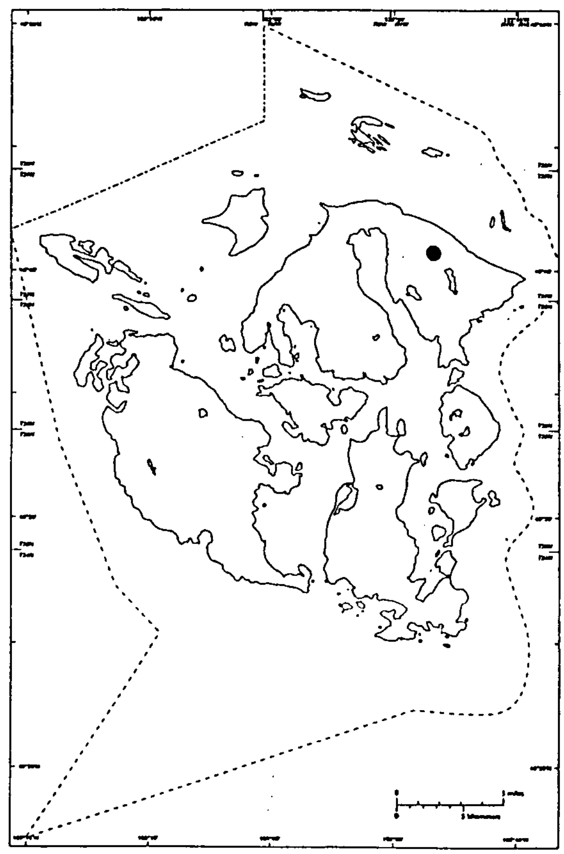
Amphidium lapponicum



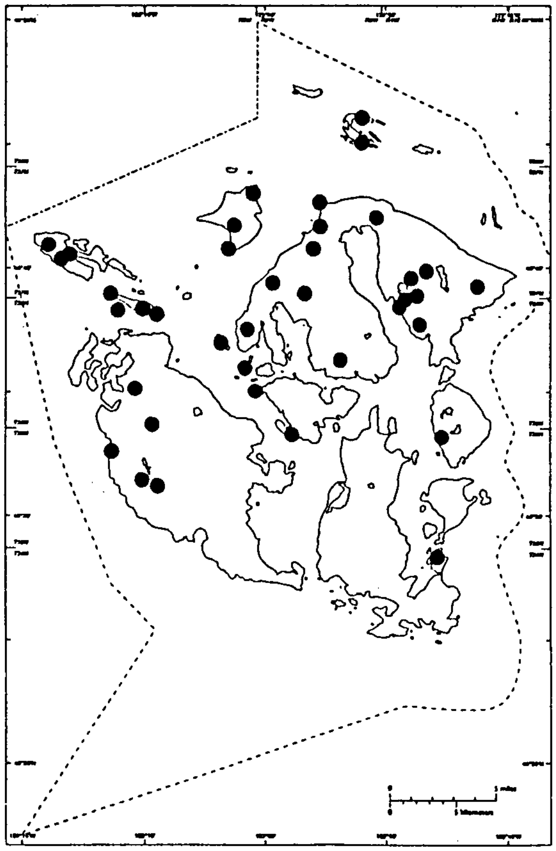
Anacolia menziesii



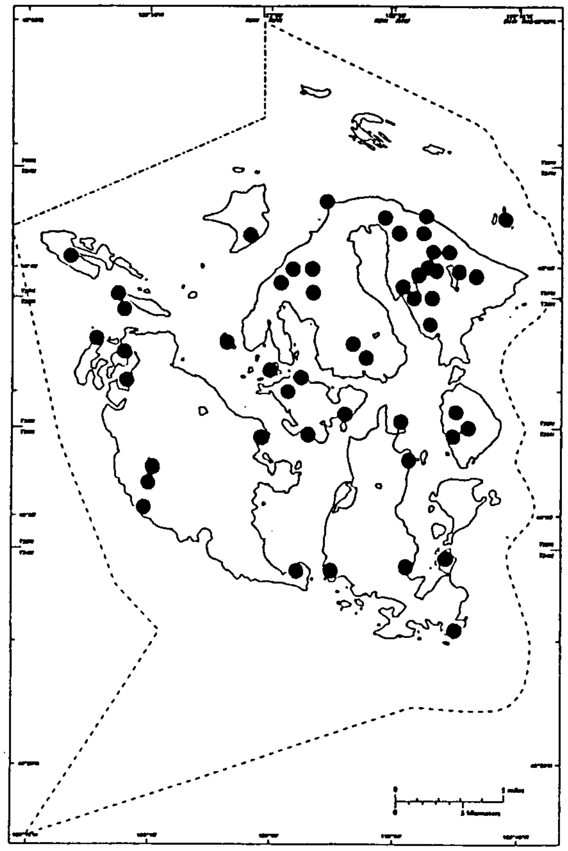
Andreaea megistospora



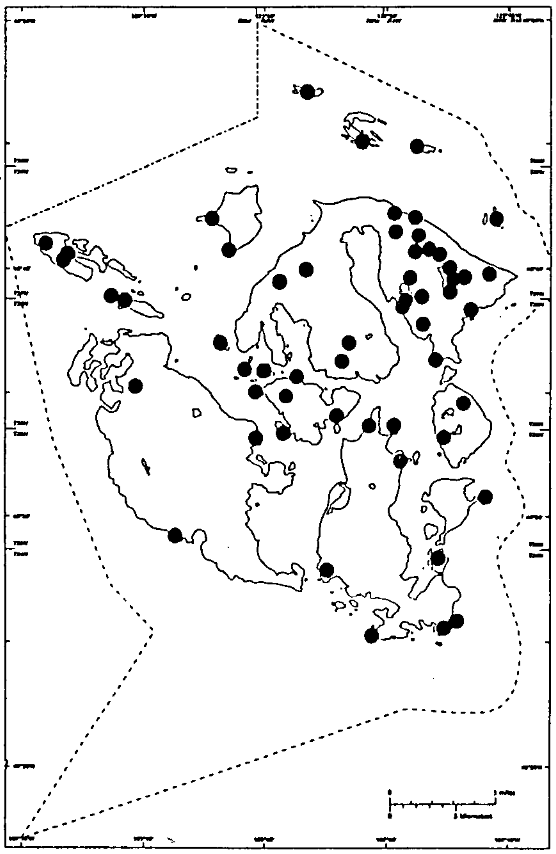
Andreaea rupestris



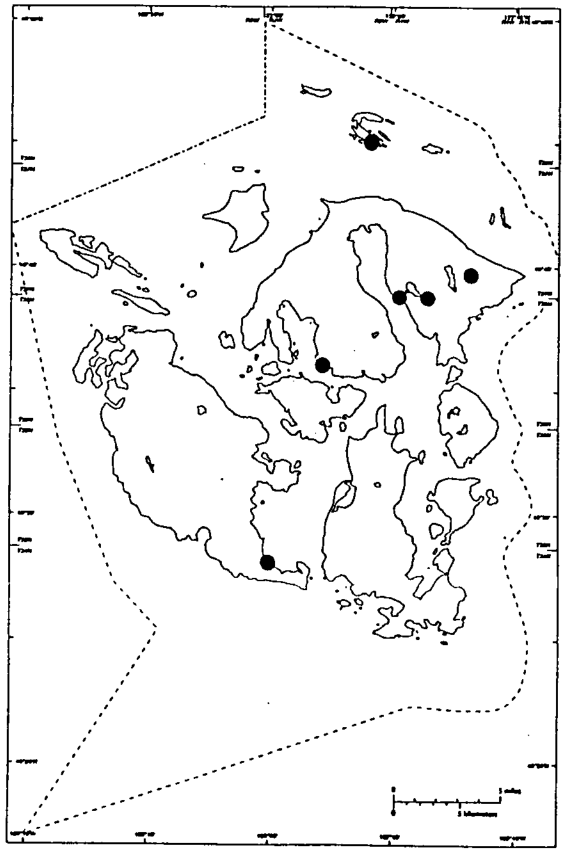
Antitrichia californica



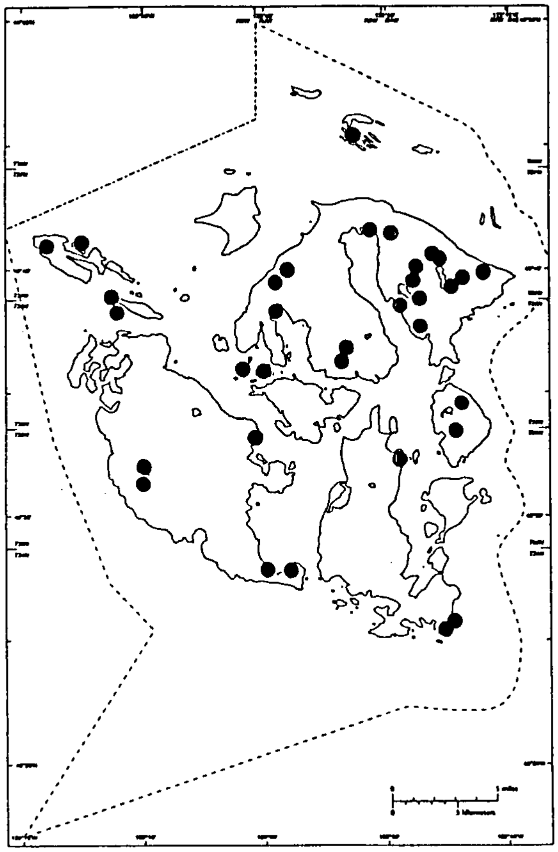
Antitrichia curtipendula



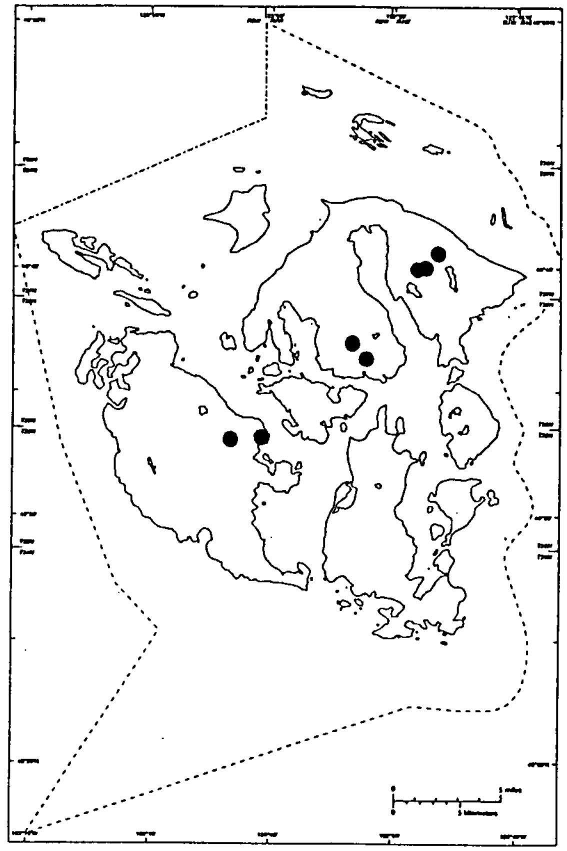
Atrichum selwynii



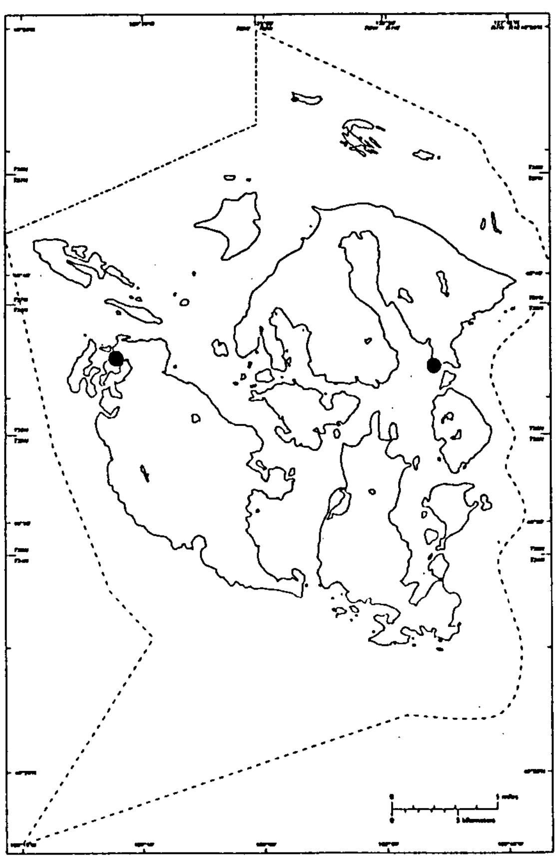
Atrichum undulatum



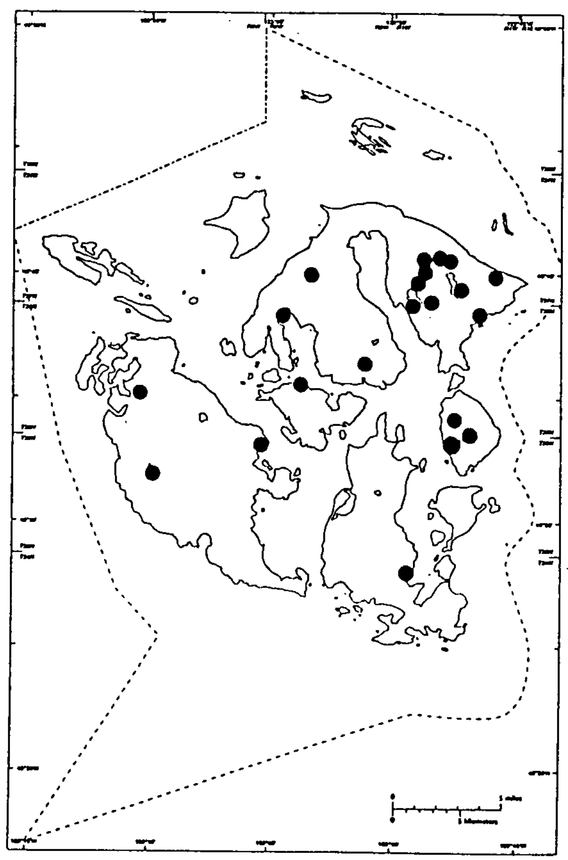
Aulacomnium androgynum



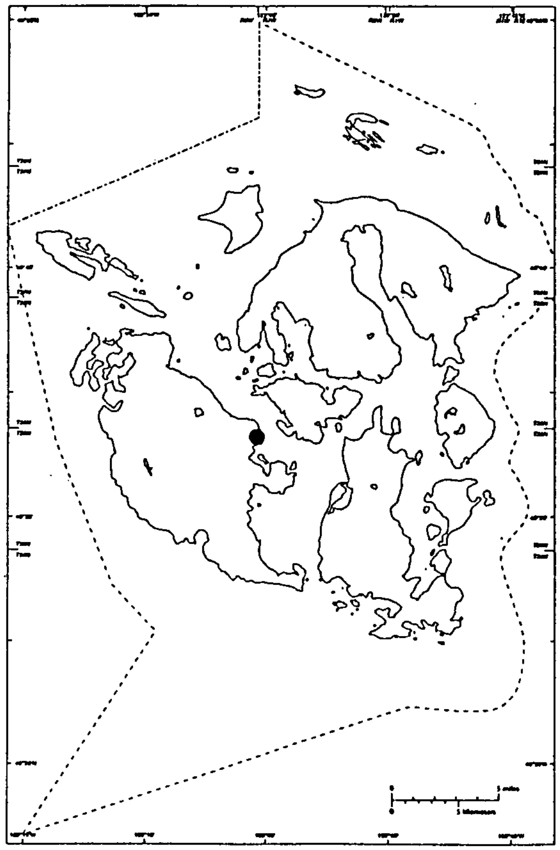
Aulacomnium palustre



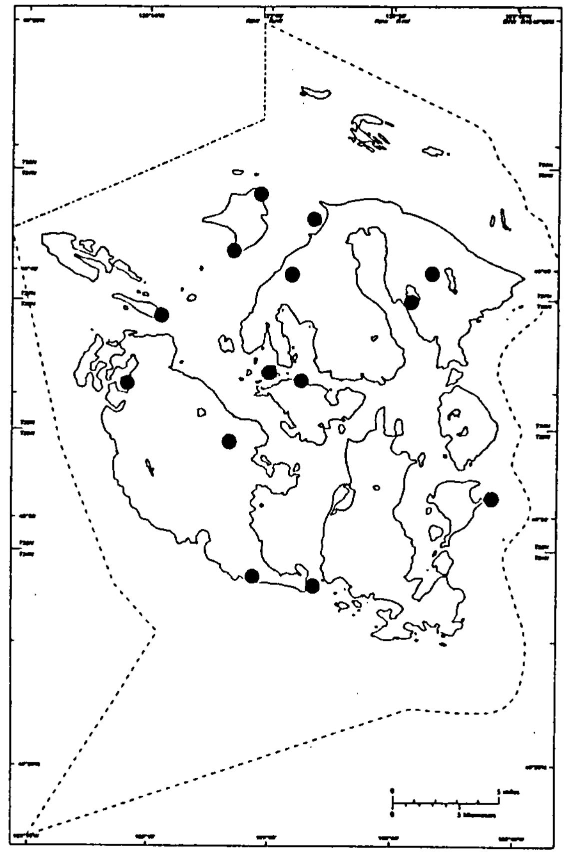
Barbula unguiculata



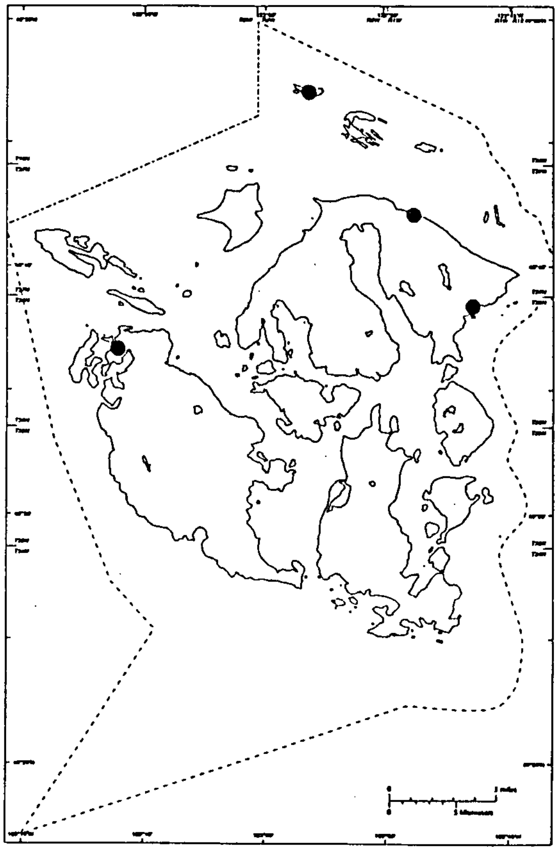
Bartramia pomiformis



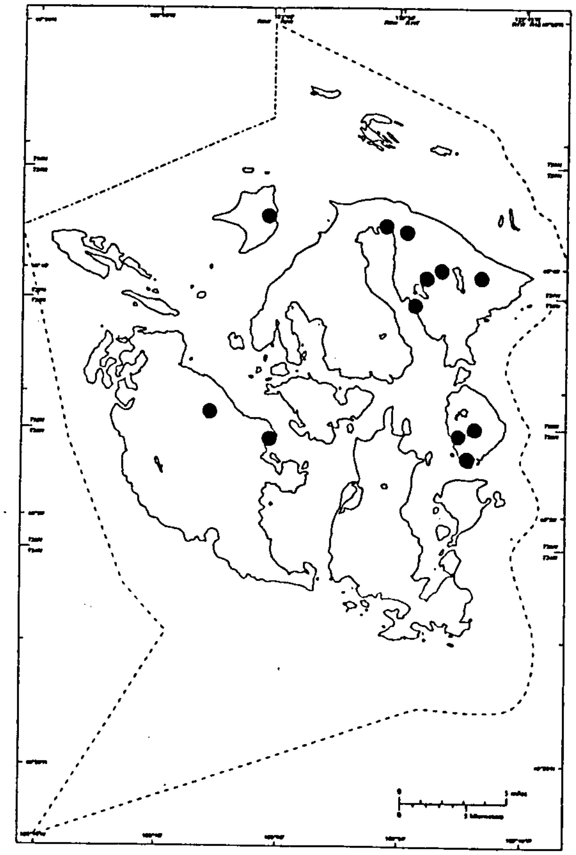
Blindia acuta



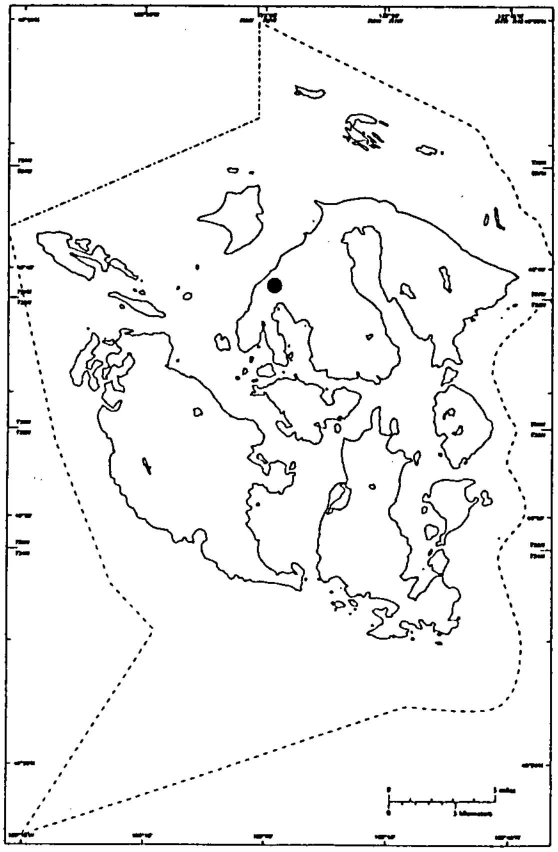
Brachythecium albicans



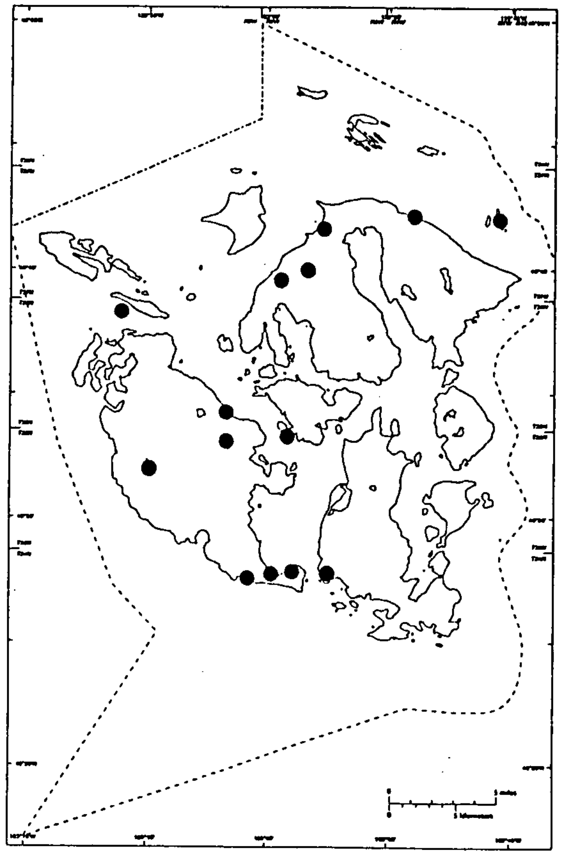
Brachythecium asperrimum



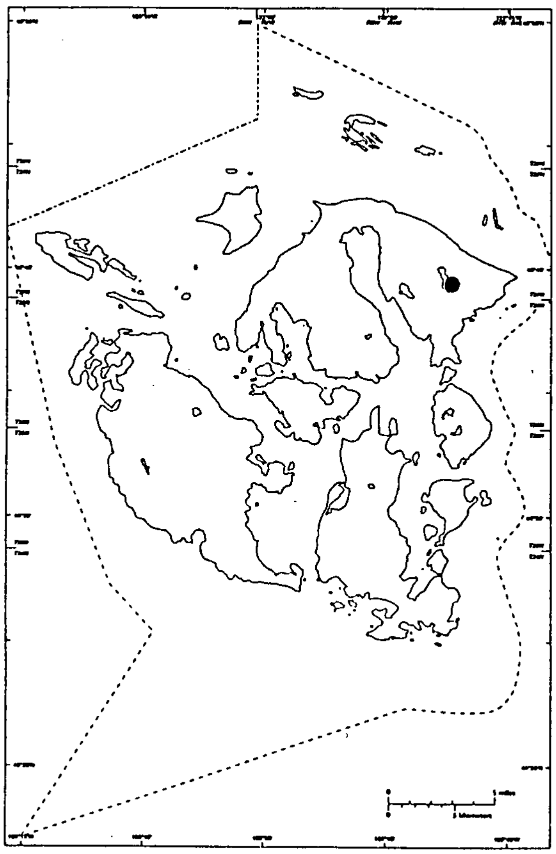
Brachythecium frigidum



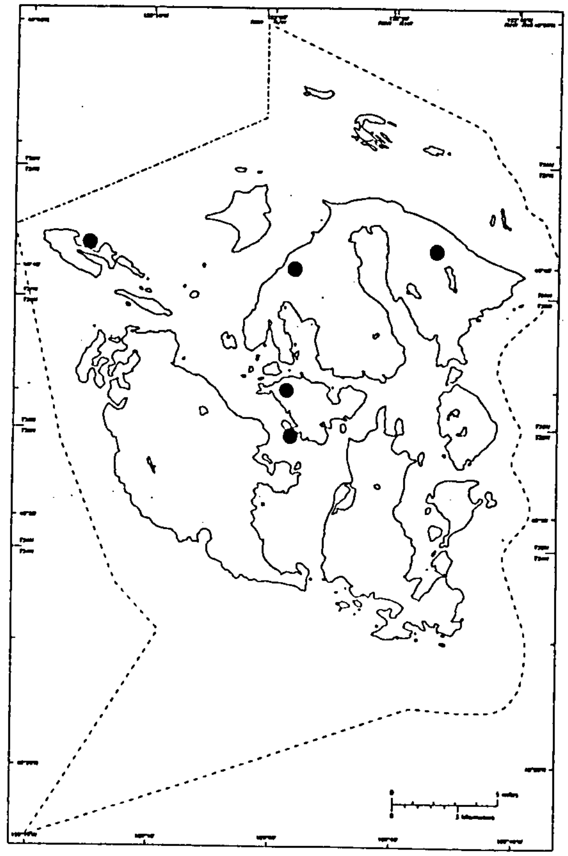
Brachythecium rivulare



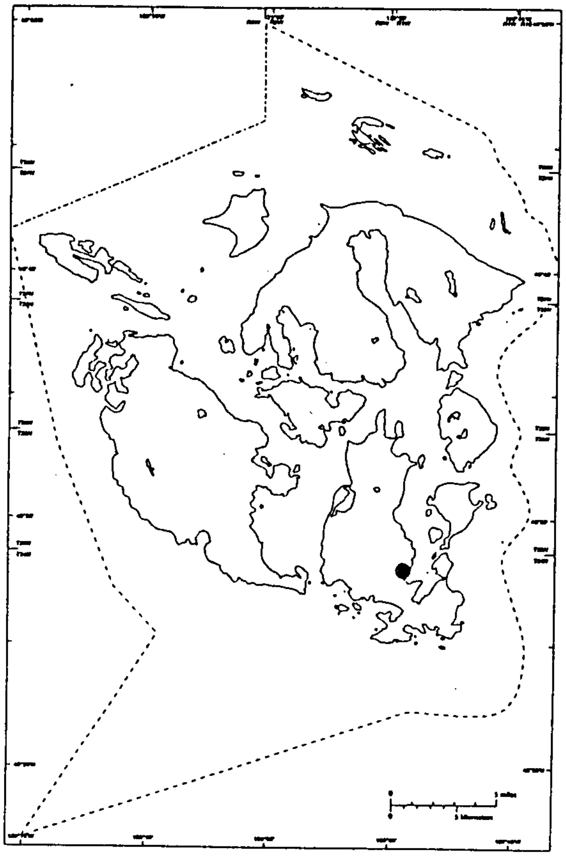
Brachythecium velutinum var. *velutinum*



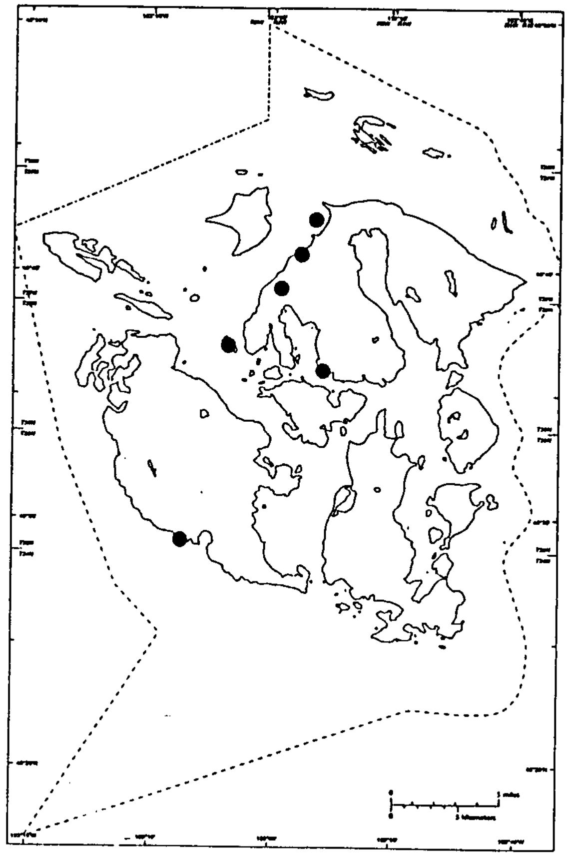
Brachythecium velutinum var. *venustum*



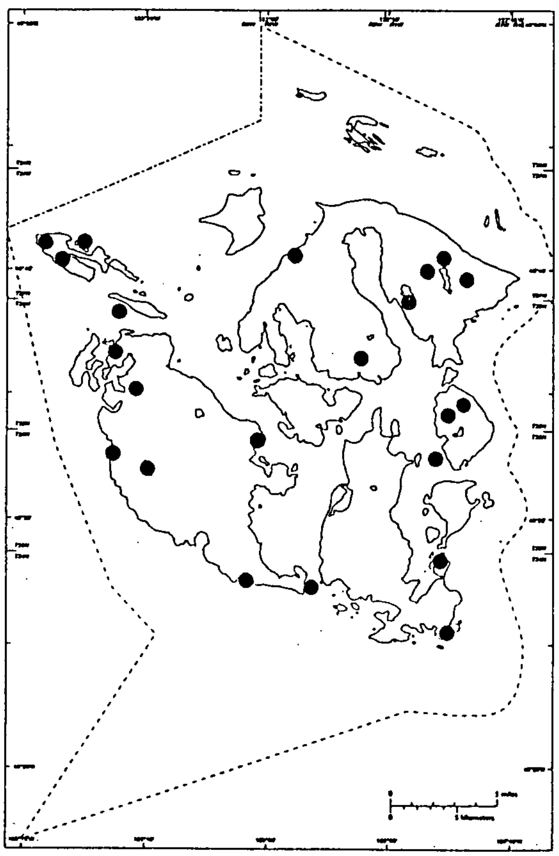
Bryoerythrophyllum recurvirostre



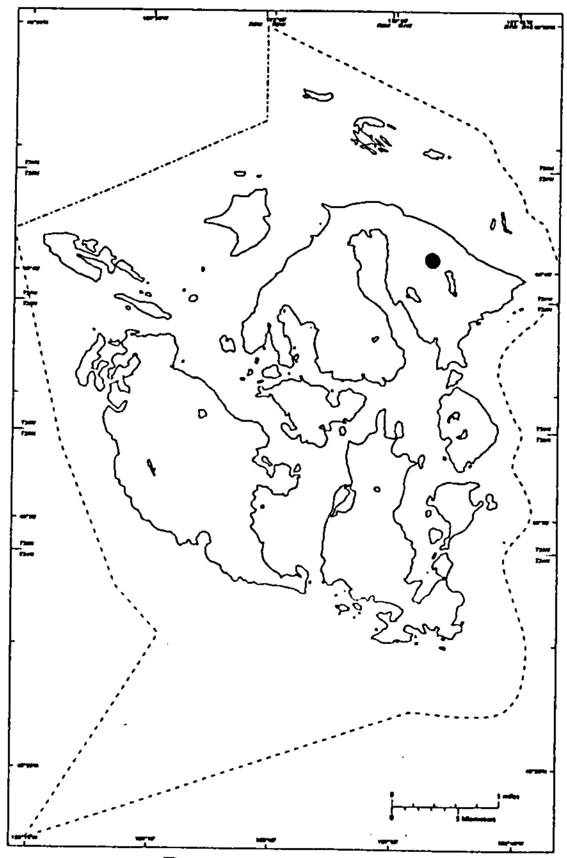
Bryum amblyodon



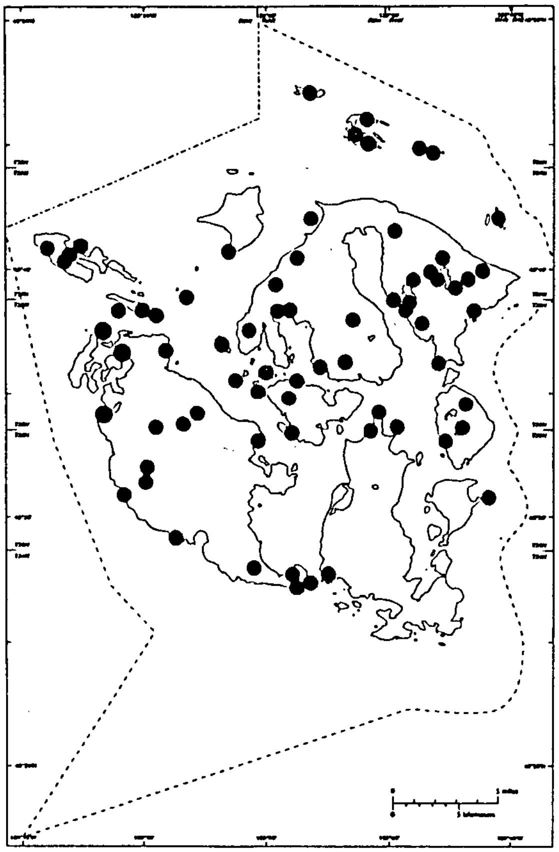
Bryum argenteum



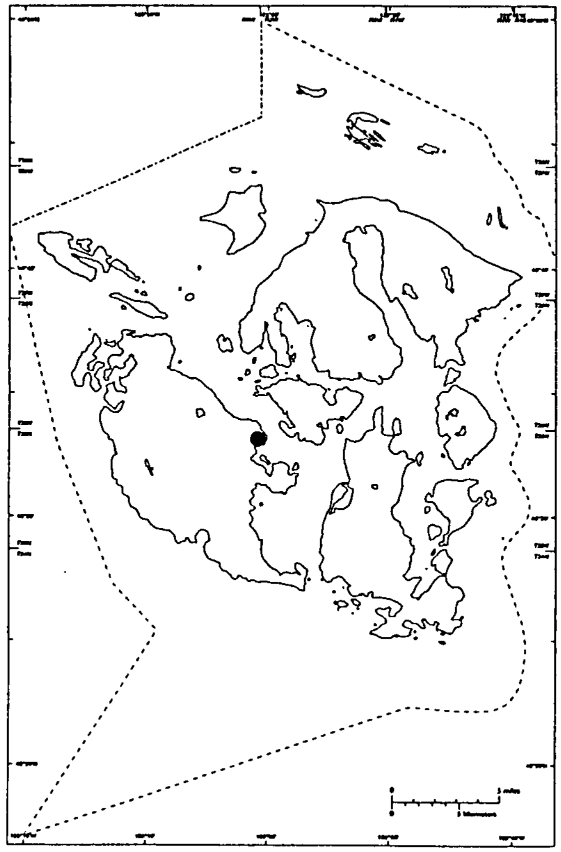
Bryum caespiticium



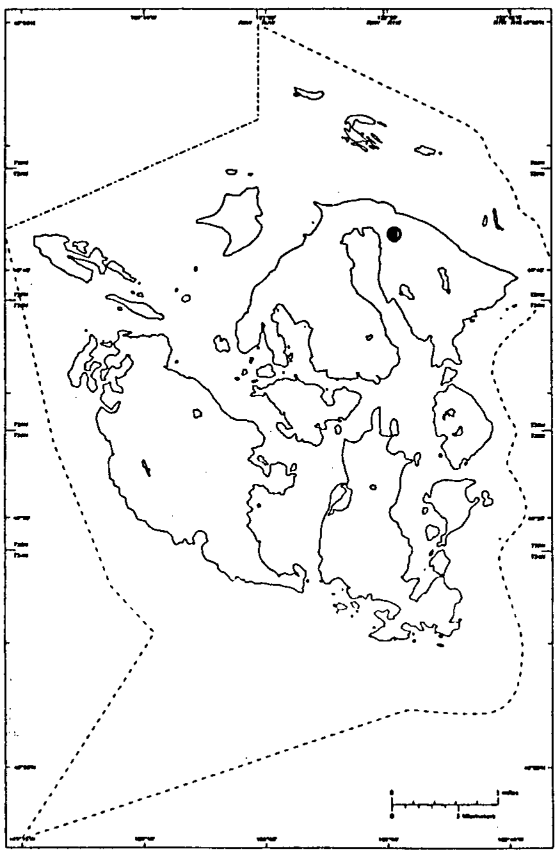
Bryum canariense



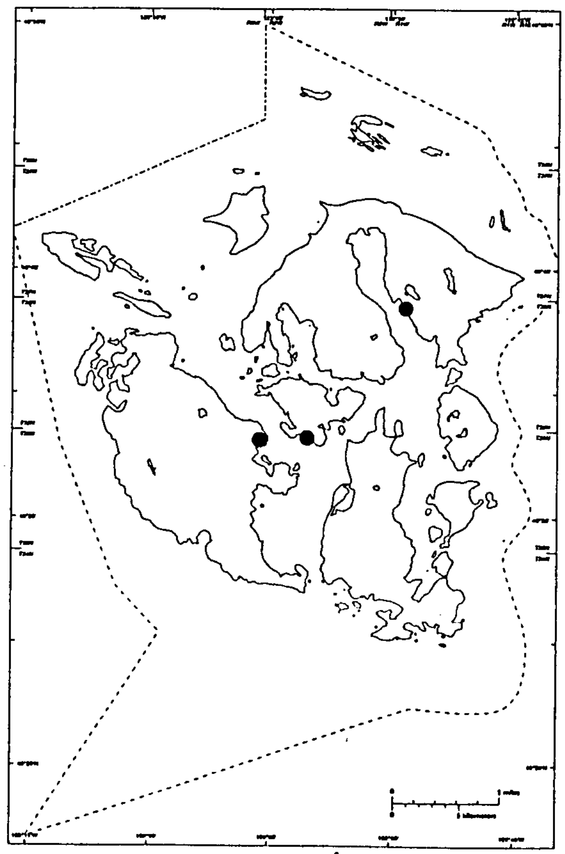
Bryum capillare



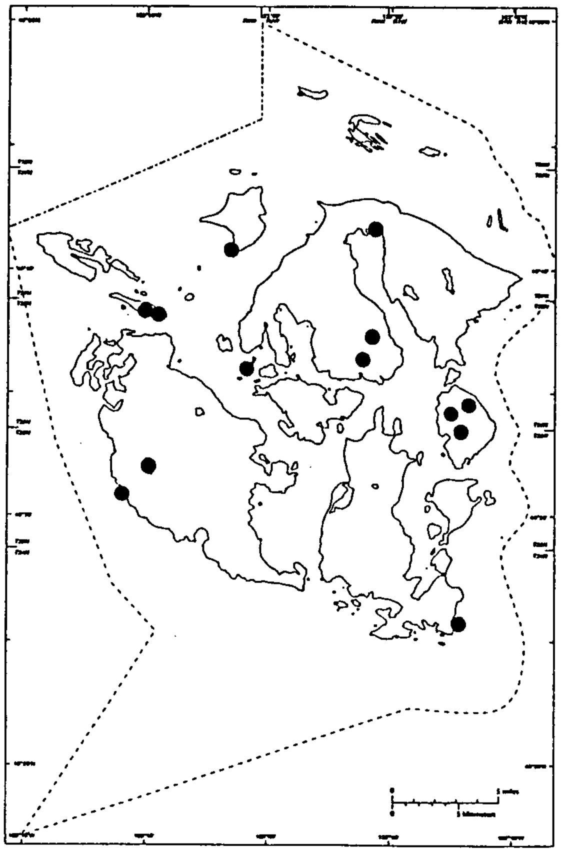
Bryum dichotomum



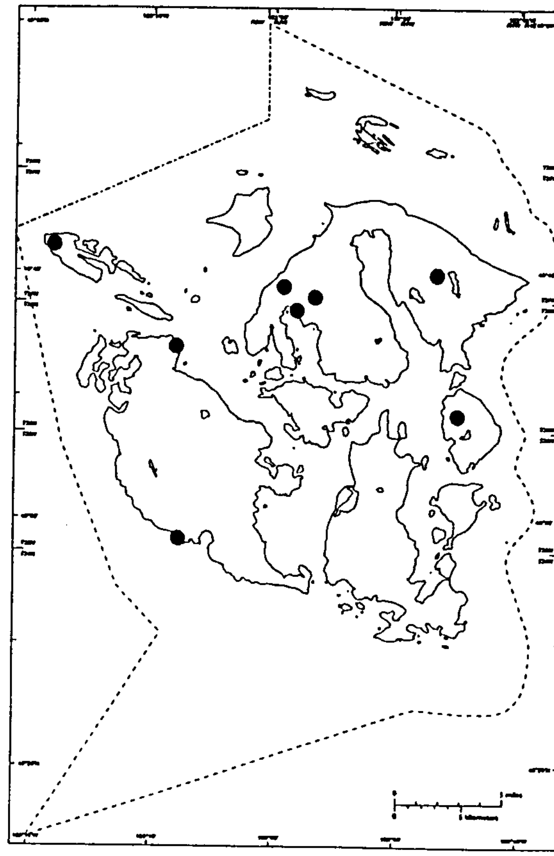
Bryum flaccidum



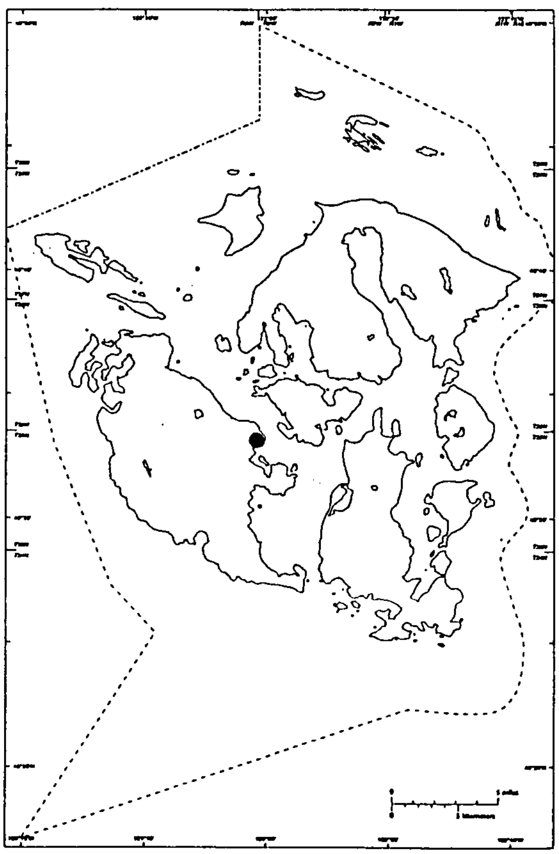
Bryum gemmiparum



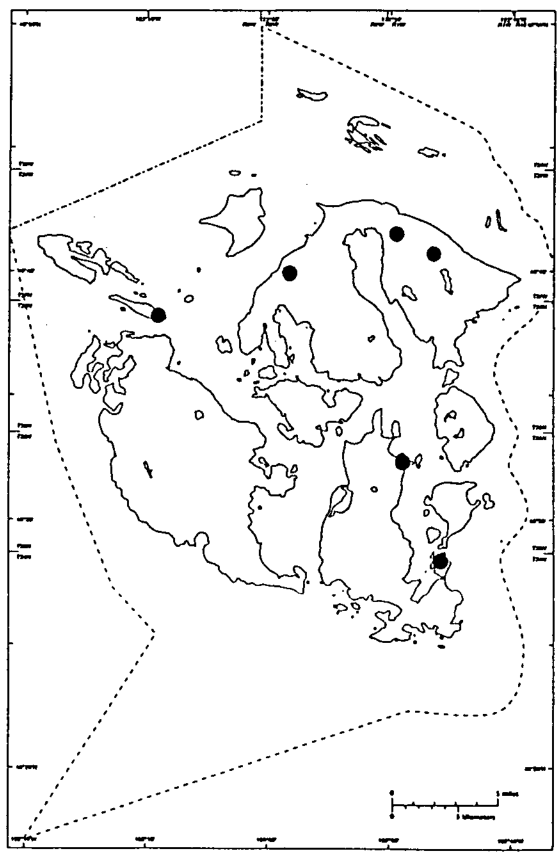
Bryum lisae* var. *cuspidatum



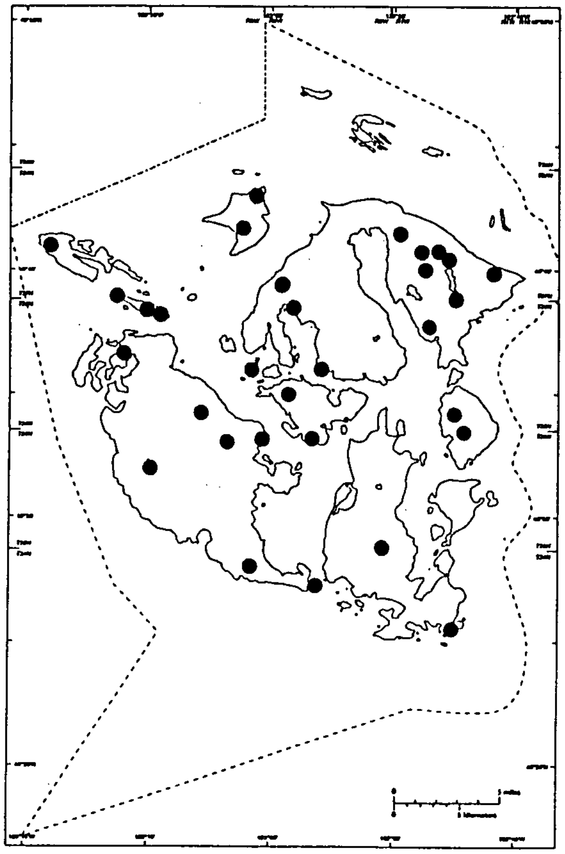
Bryum miniatum



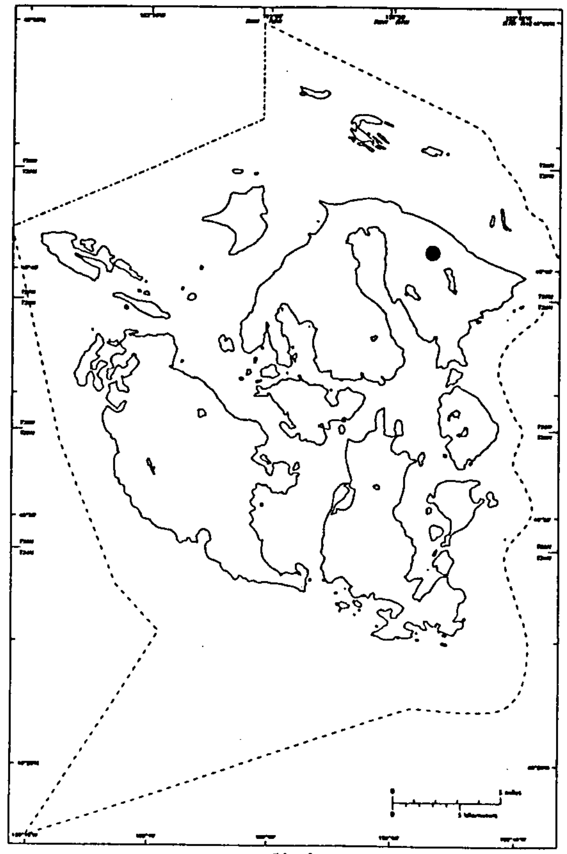
Bryum pallens



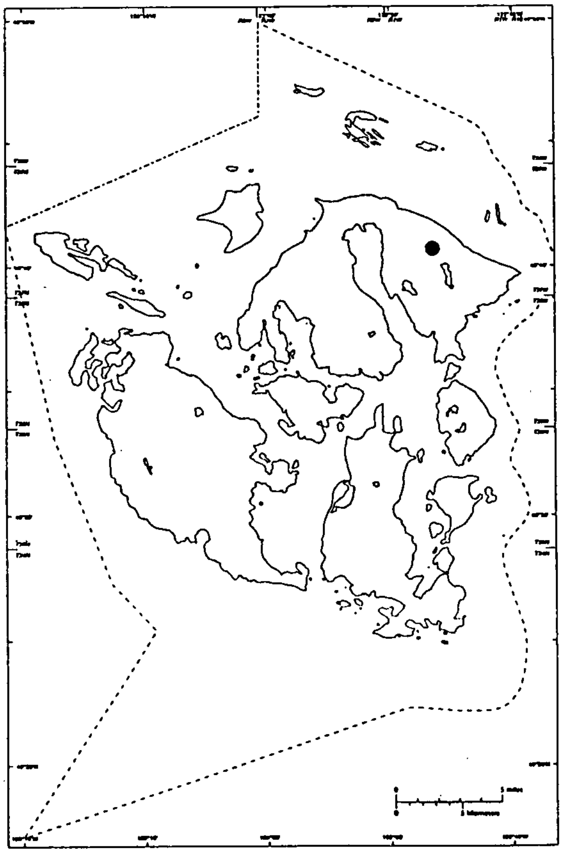
Bryum pallescens



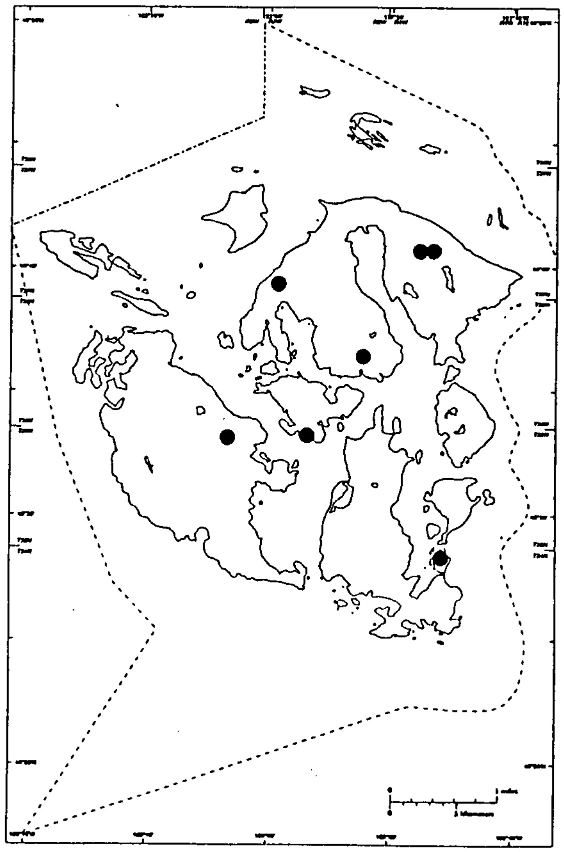
Bryum pseudotriquetrum



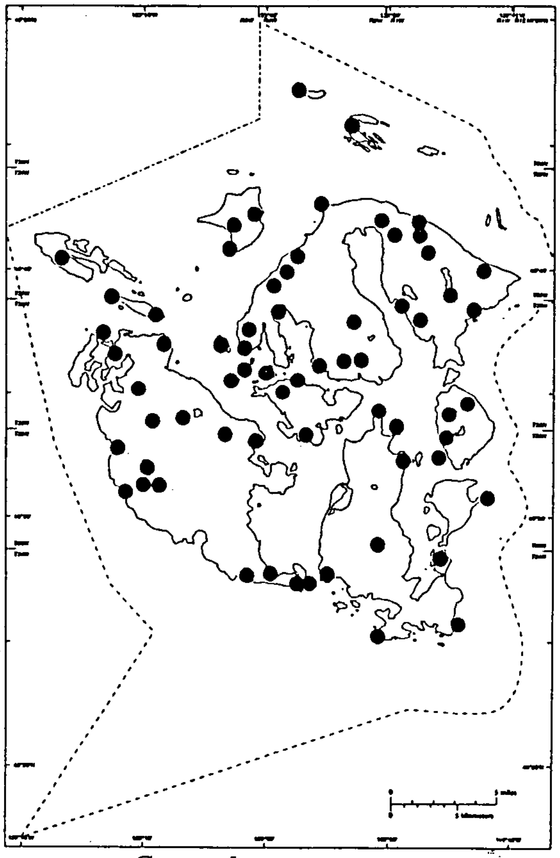
Bryum uliginosum



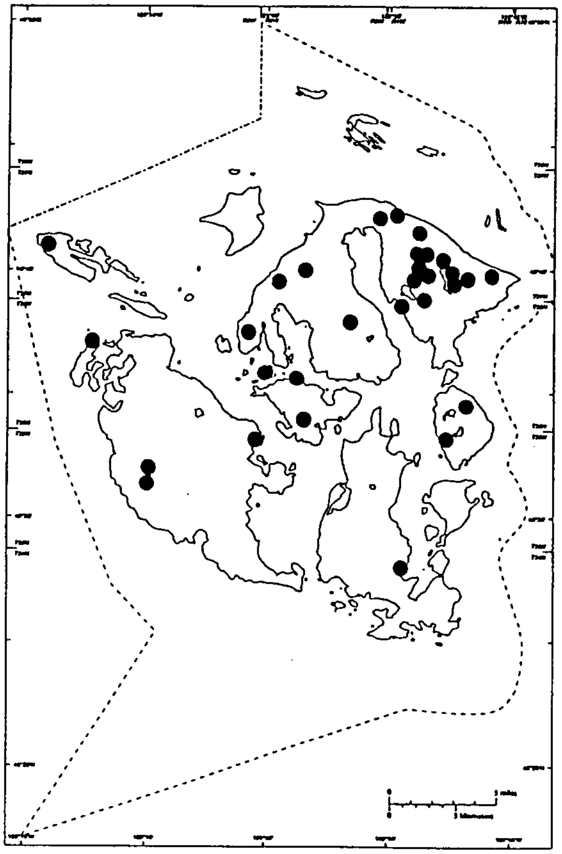
Calliergon giganteum



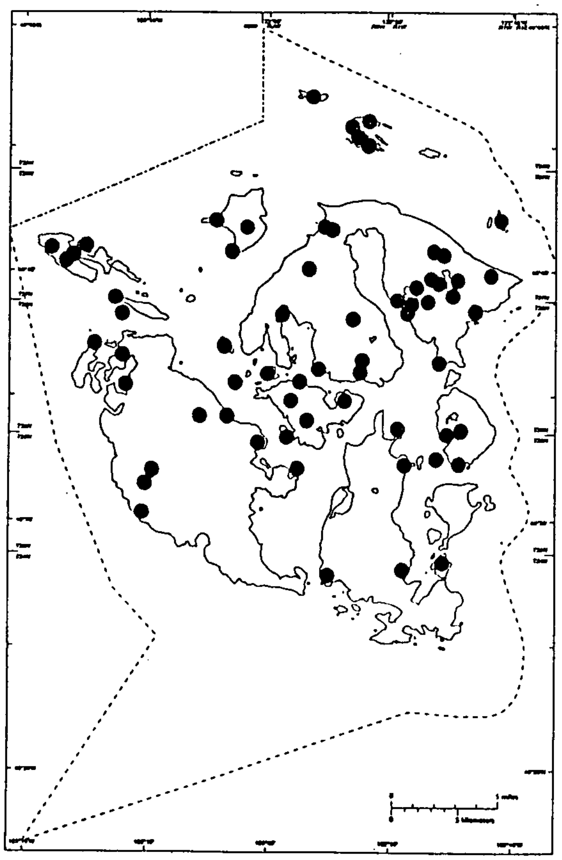
Calliergonella cuspidata



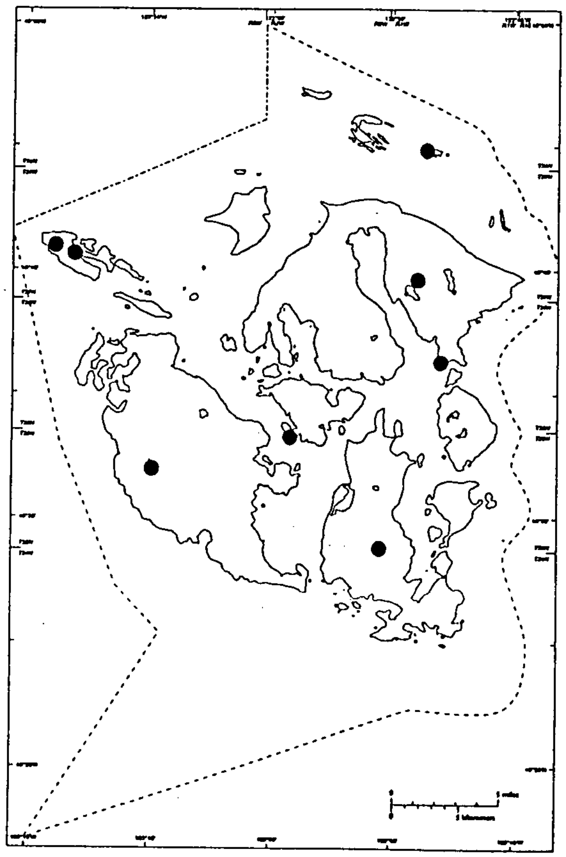
Ceratodon purpureus



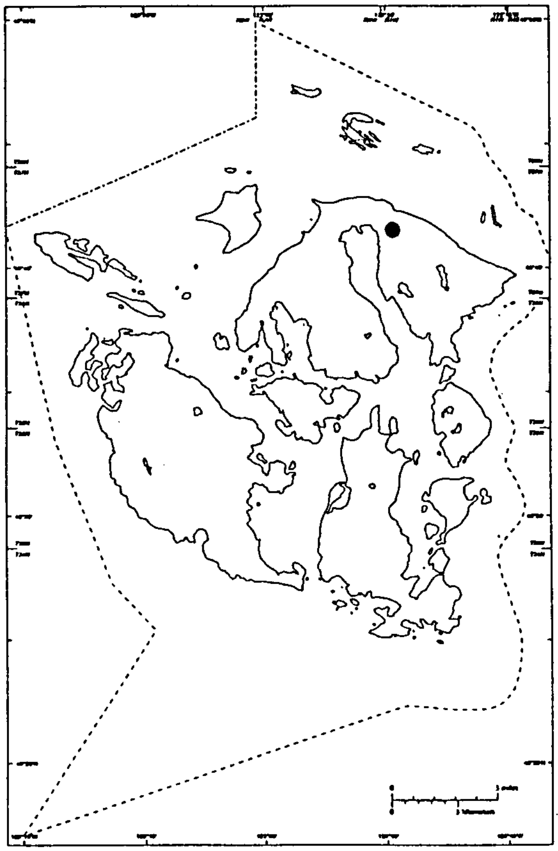
Claopodium bolanderi



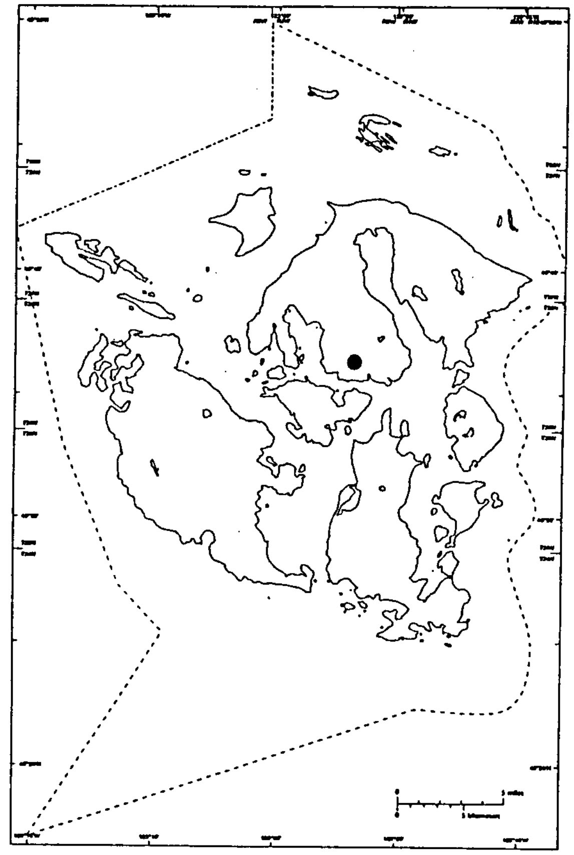
Claopodium crispifolium



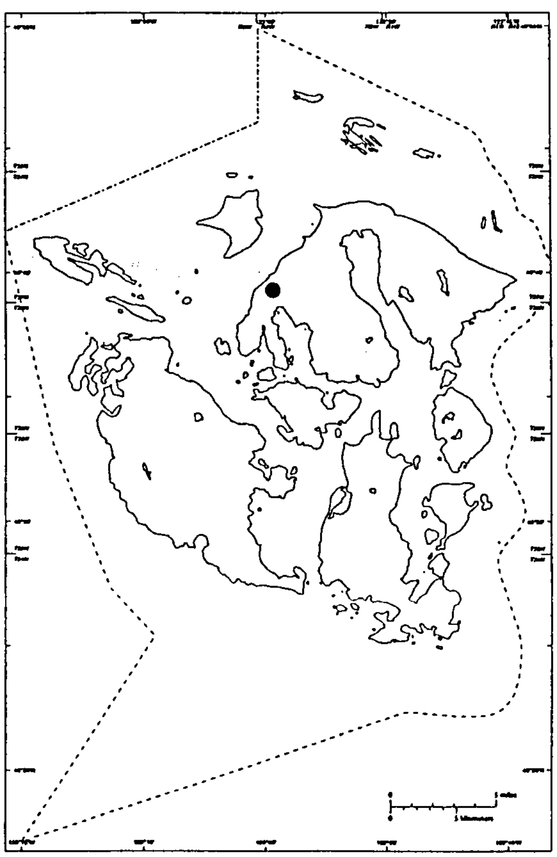
Claopodium whippleanum



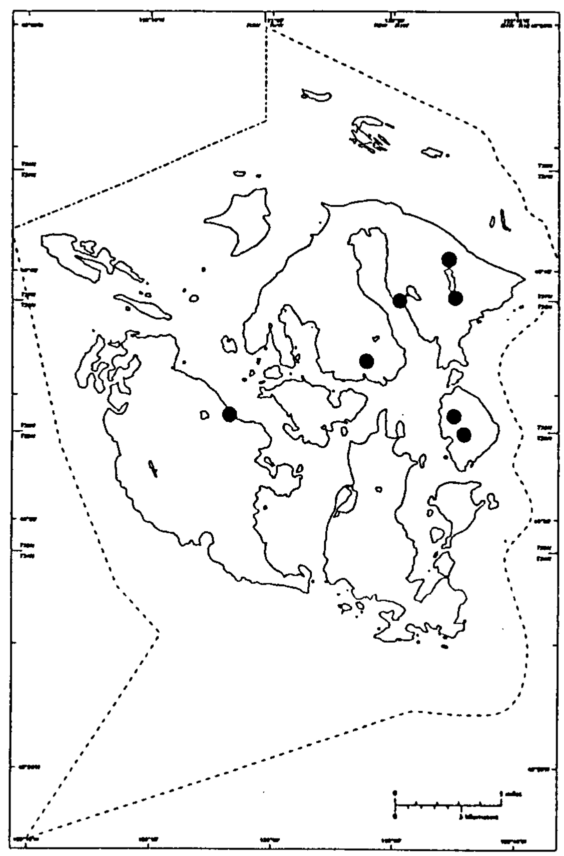
Climacium dendroides



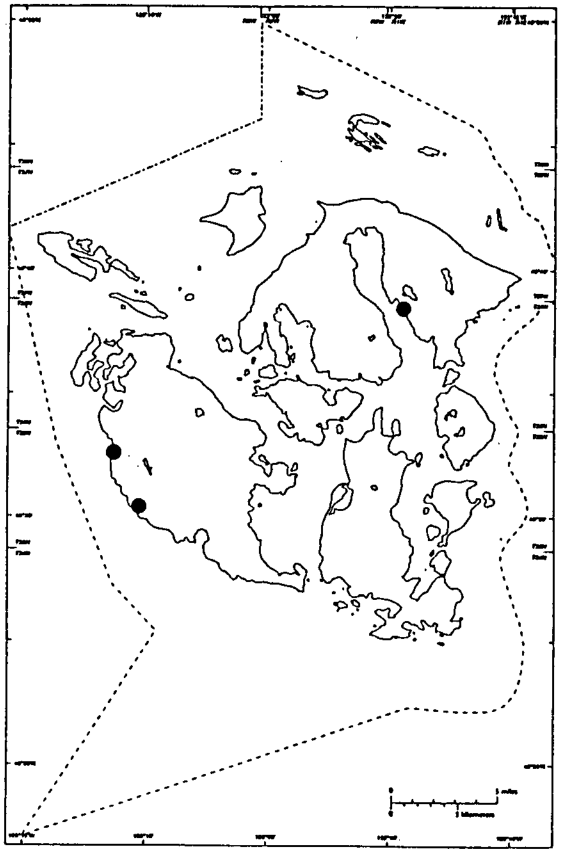
Conardia compacta



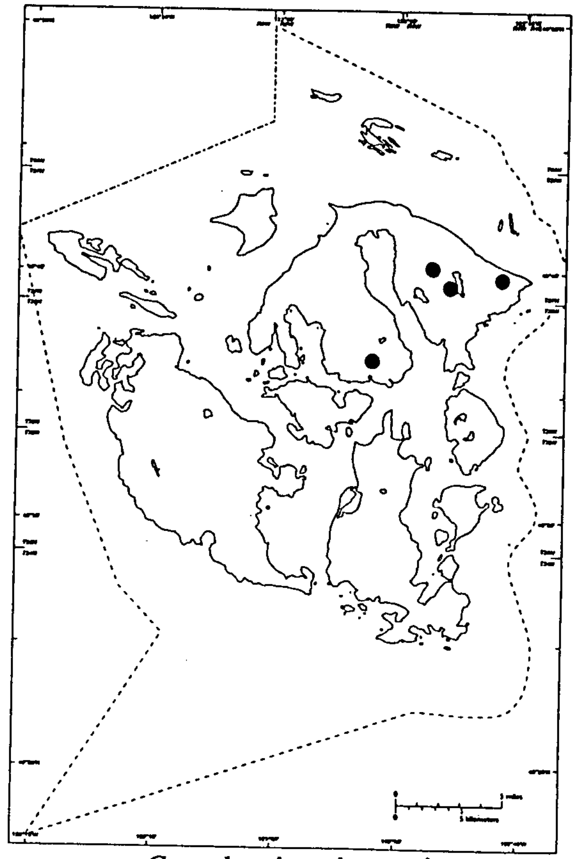
Coscinodon calyptratus



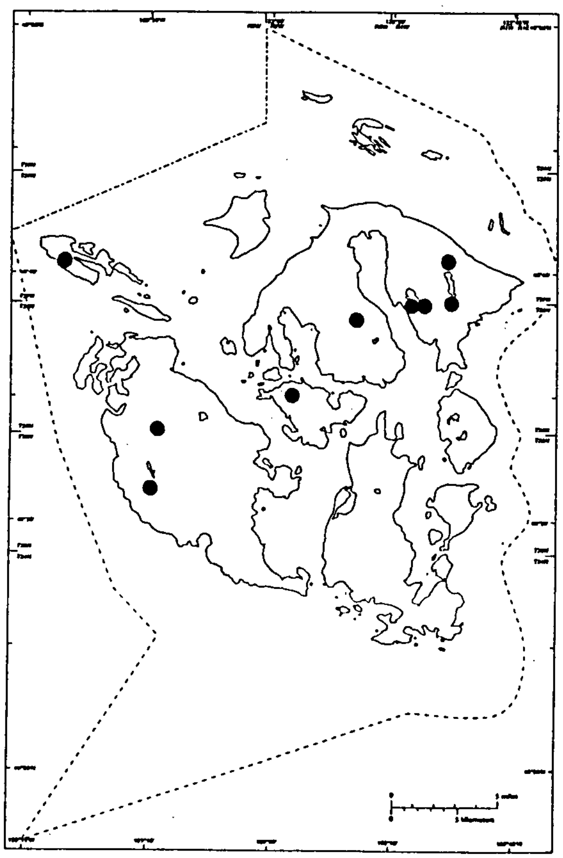
Cratoneuron filicinum



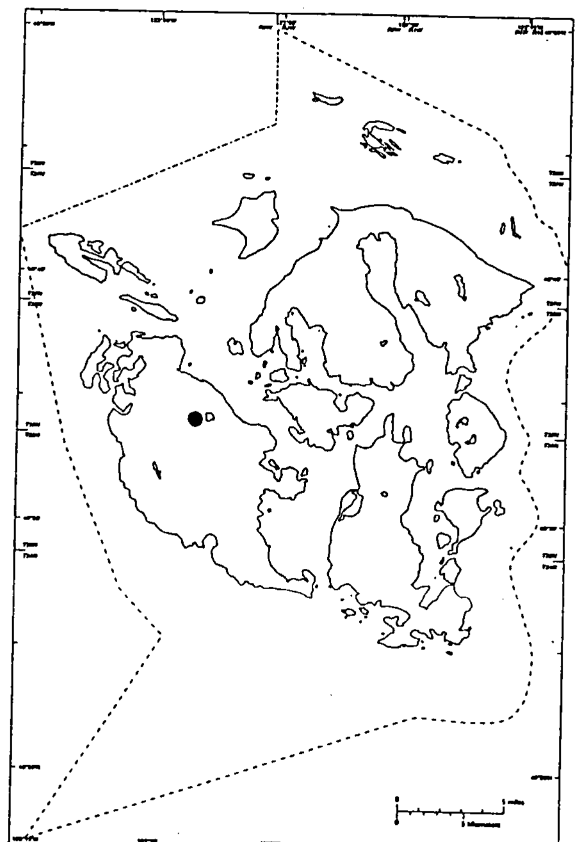
Crumia latifolia



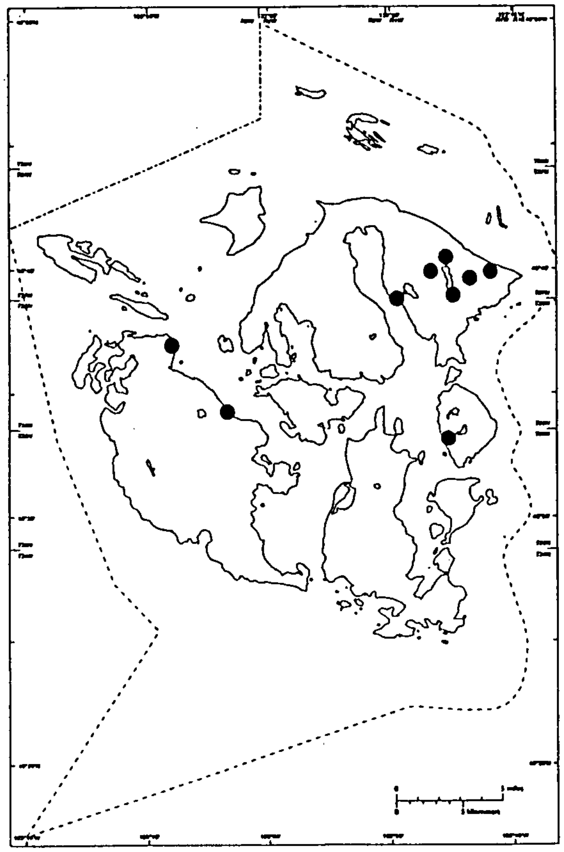
Cynodontium jenneri



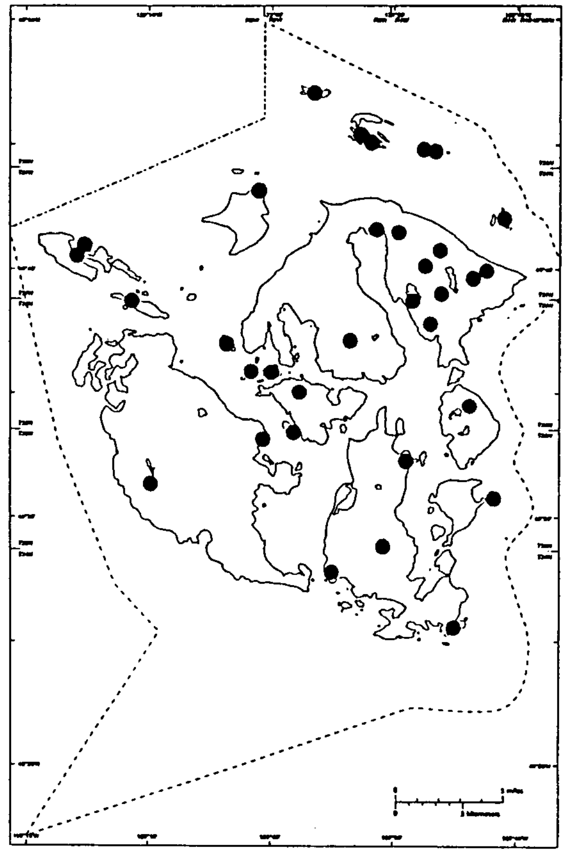
Dendroalsia abietina



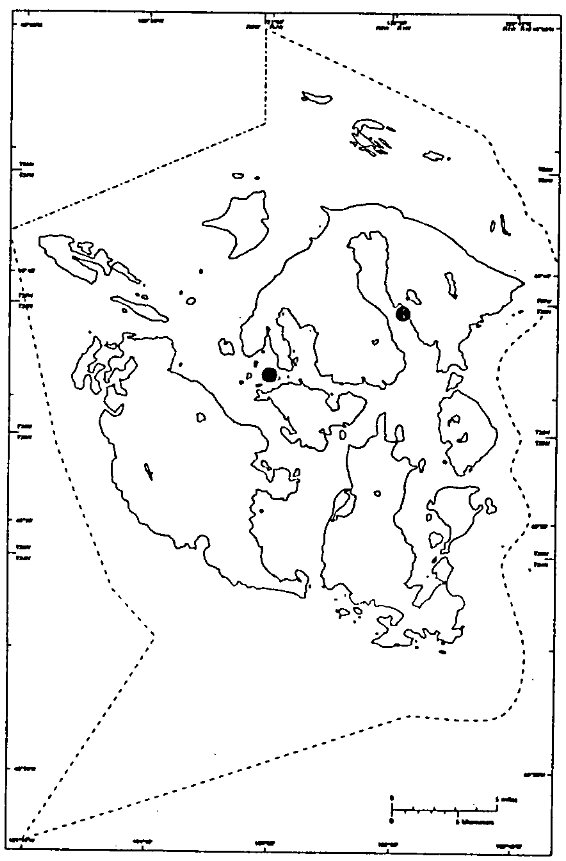
Desmatodon obtusifolius



Dichodontium pellucidum



Dicranella heteromalla



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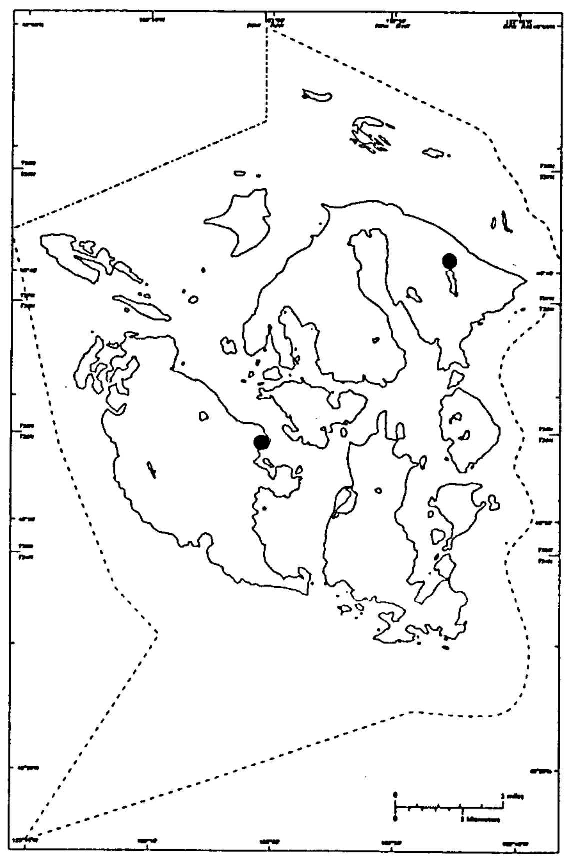

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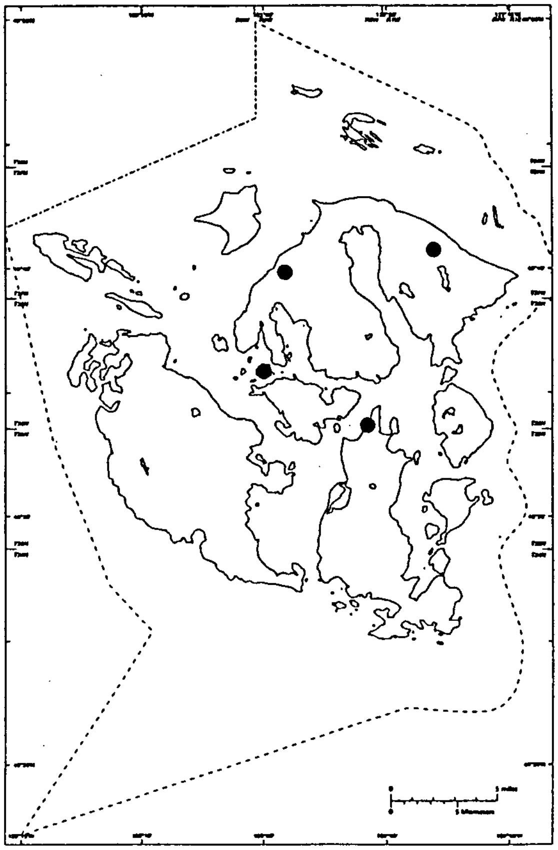

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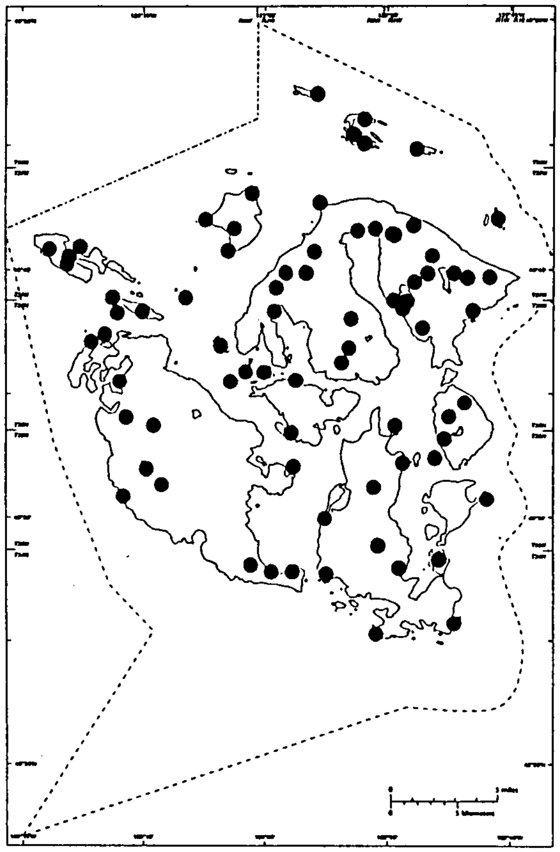

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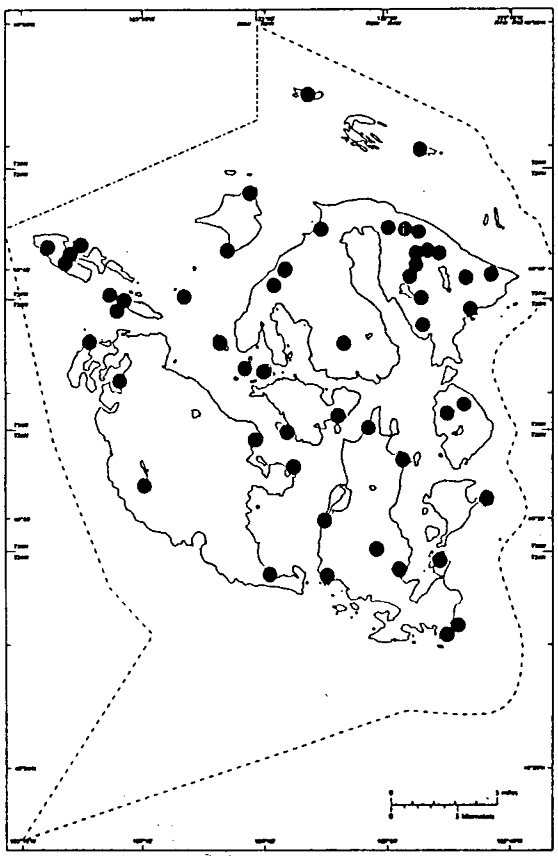

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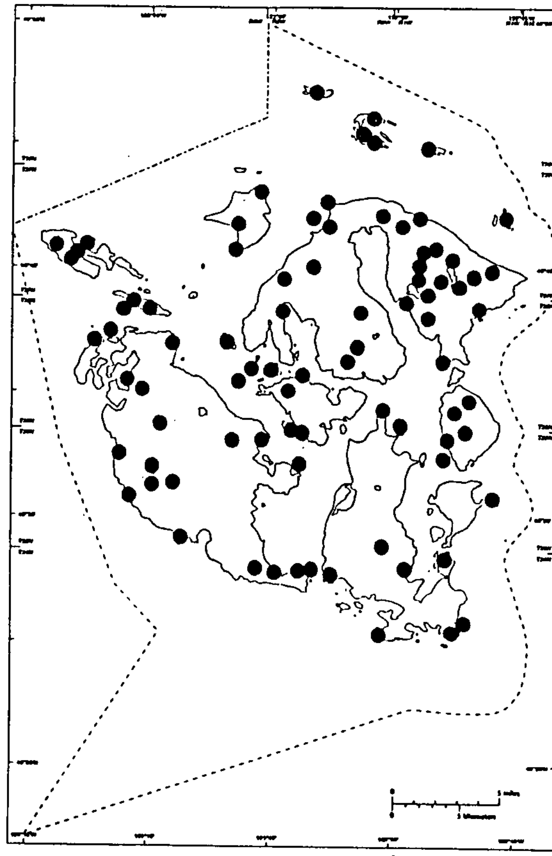

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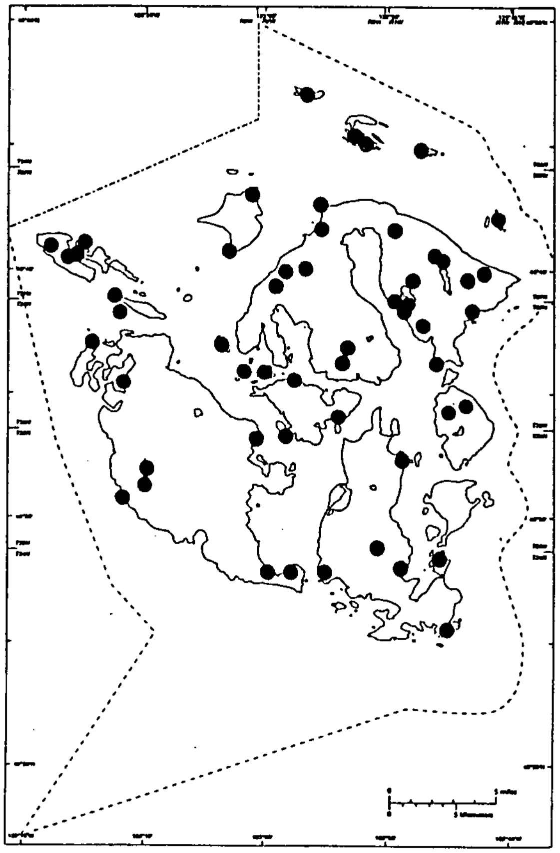

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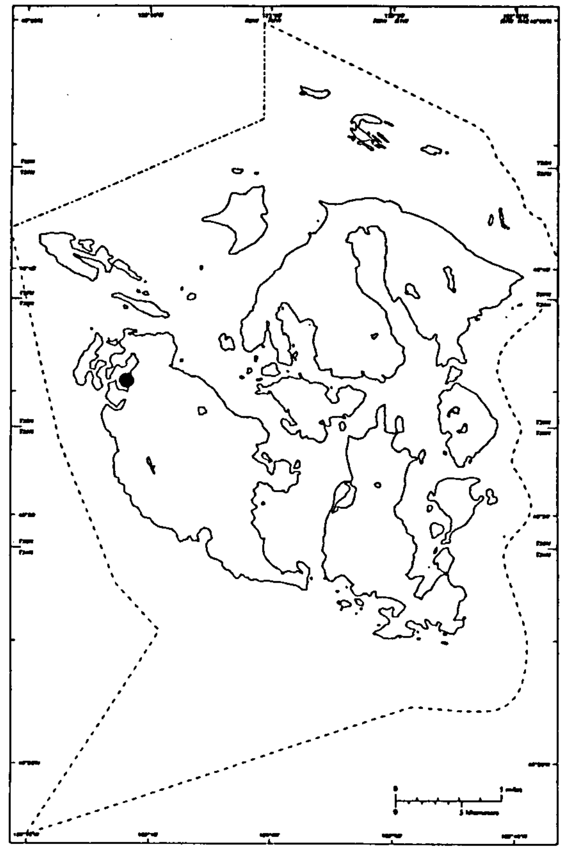
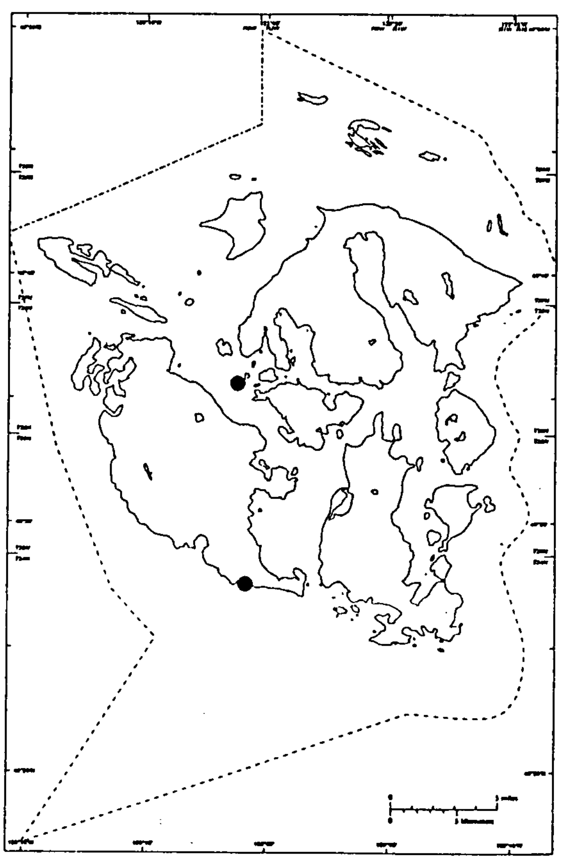
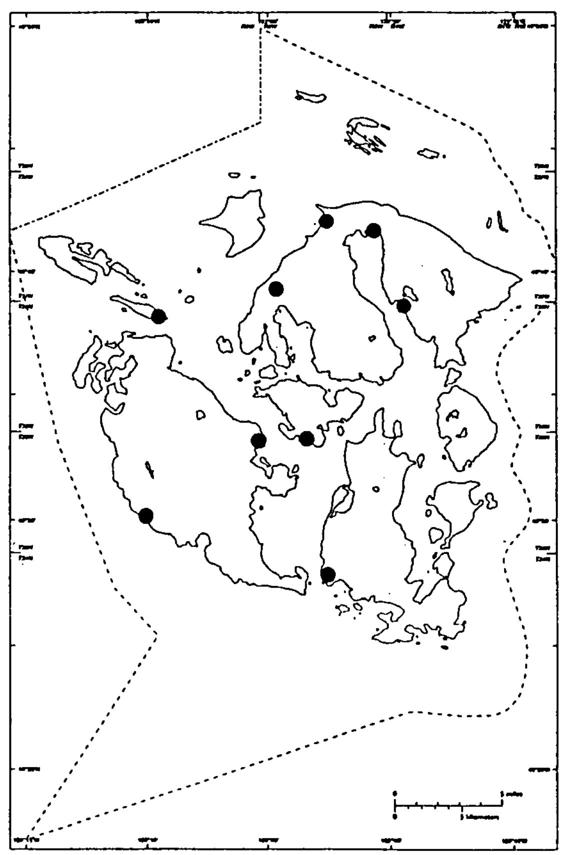


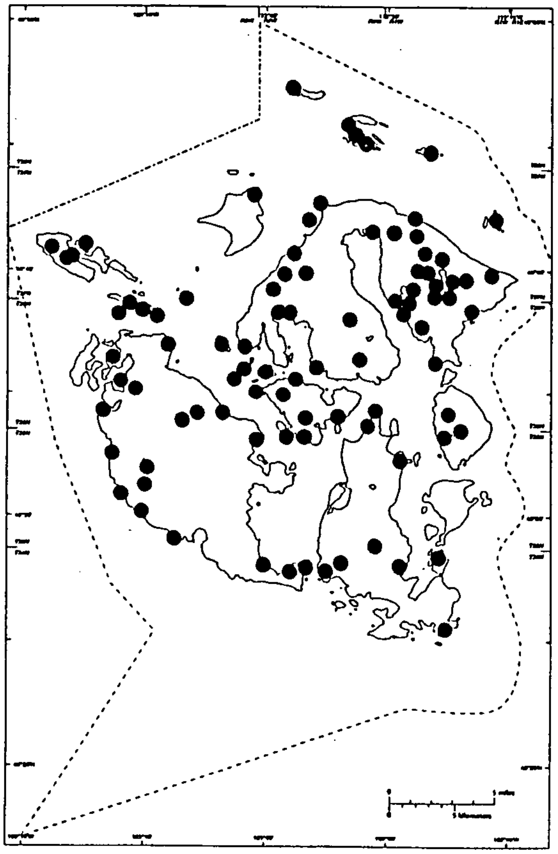
Didymodon fallax



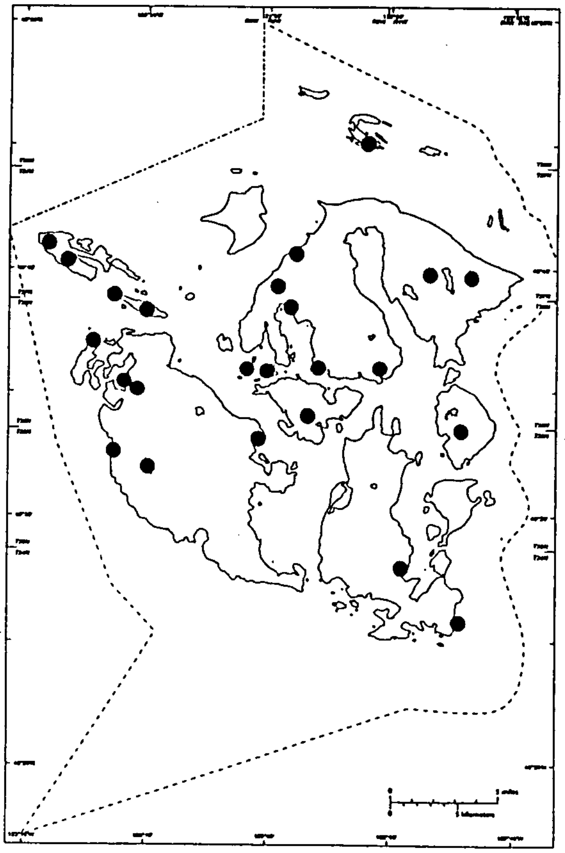
Didymodon rigidulus* var. *gracilis



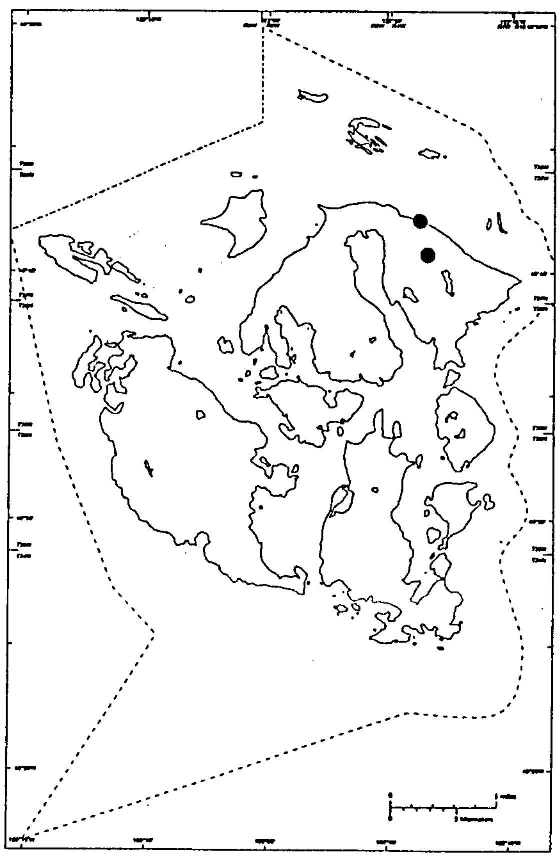
Didymodon tophaceus



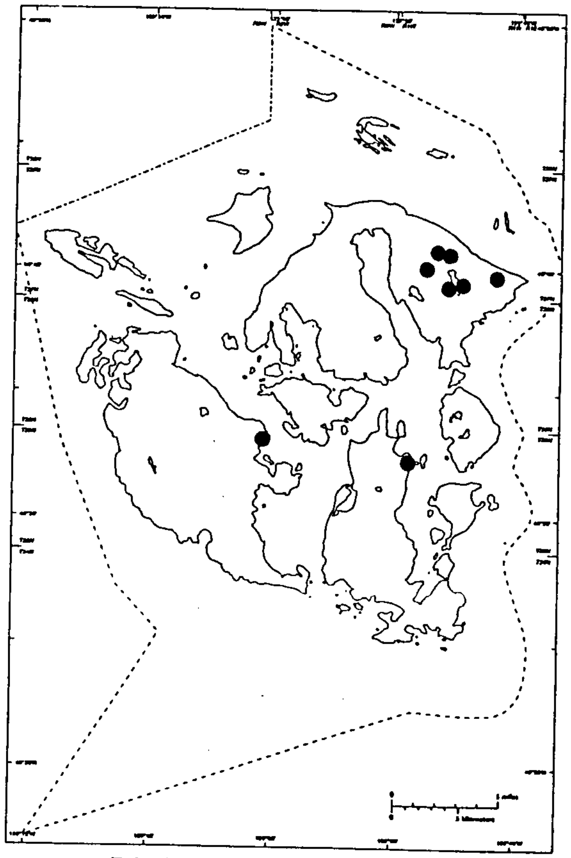
Didymodon vinealis var. *vinealis*



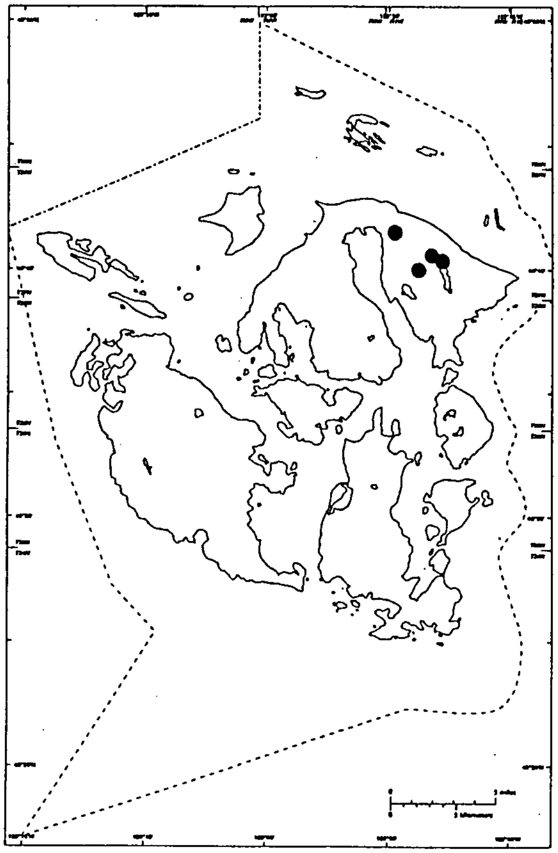
Didymodon vinealis var. *flaccidus*



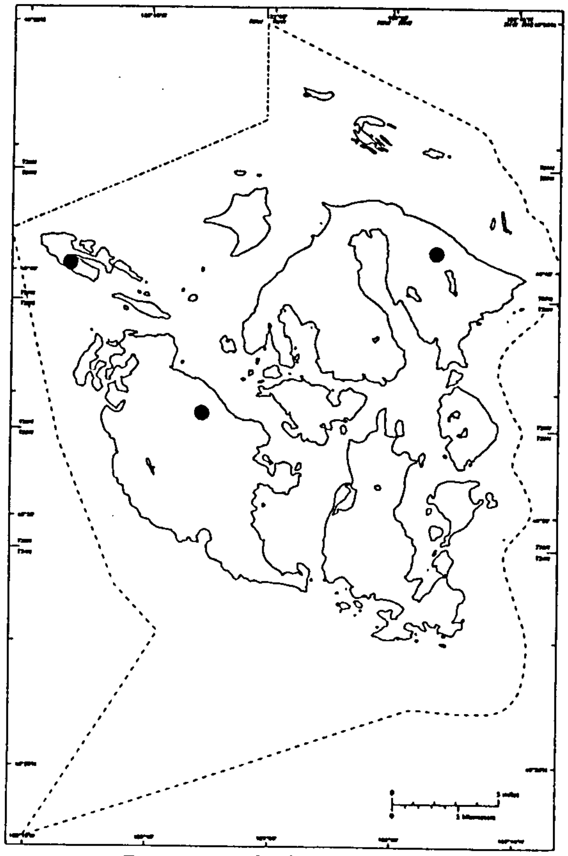
Ditrichum flexicaule



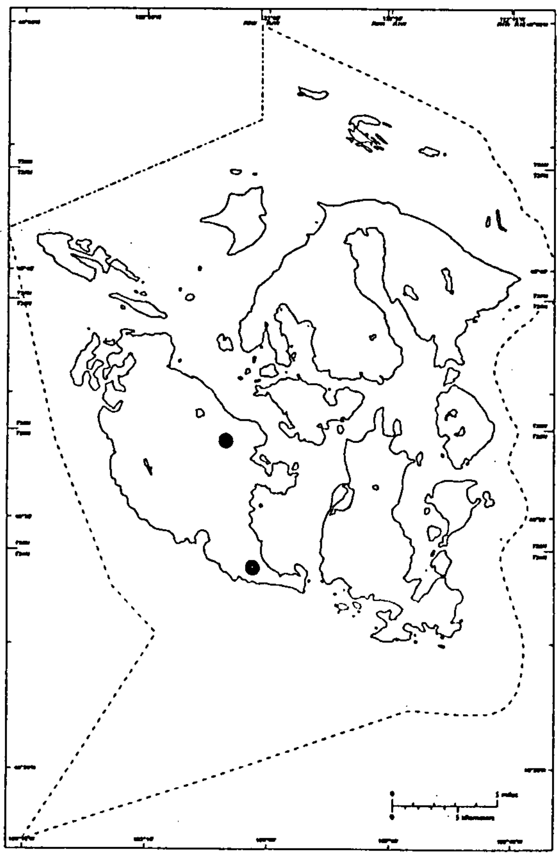
Ditrichum heteromallum



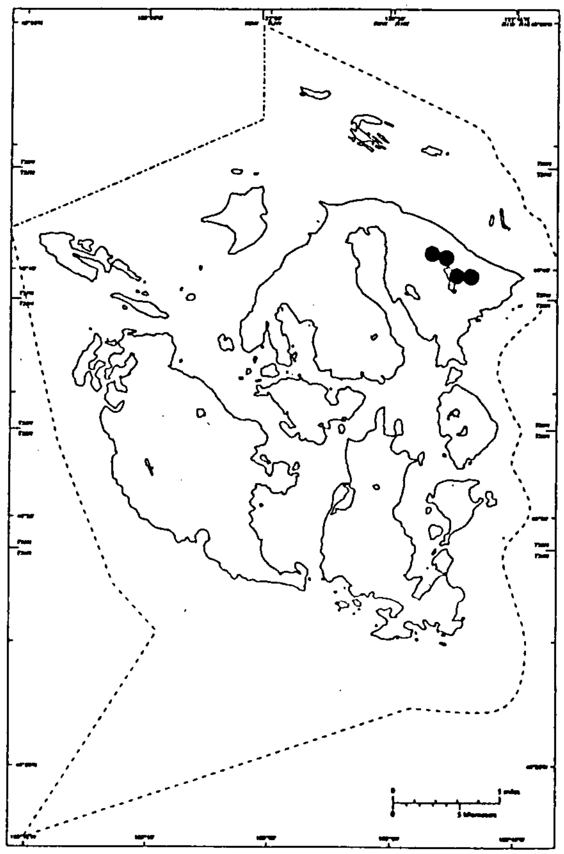
Ditrichum montanum



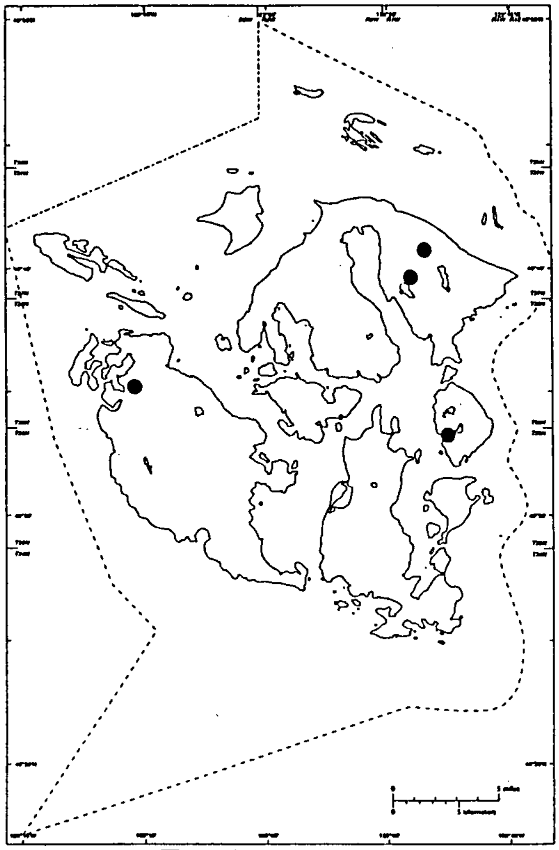
Drepanocladus aduncus



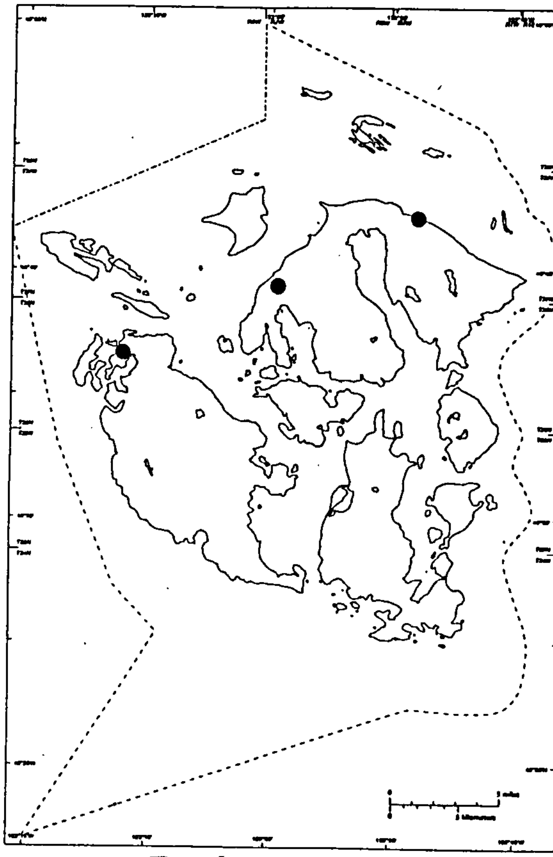
Drepanocladus crassicostatus



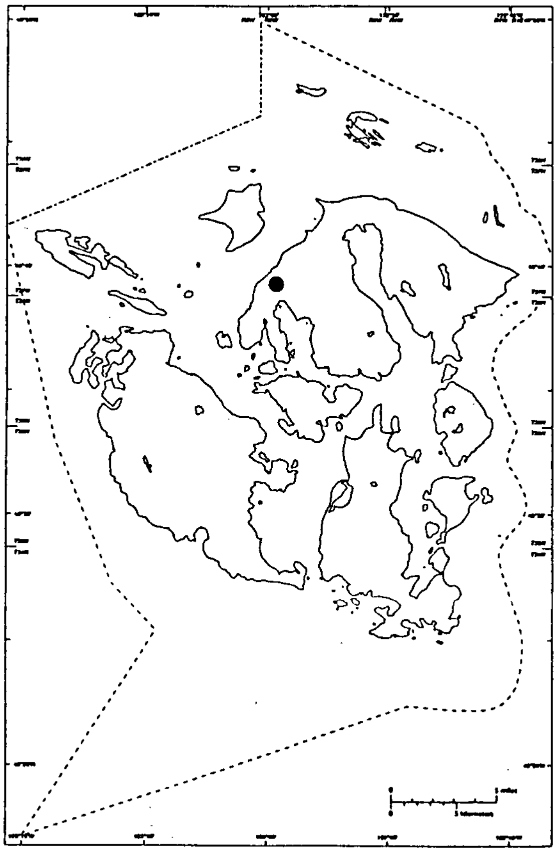
Dryptodon patens



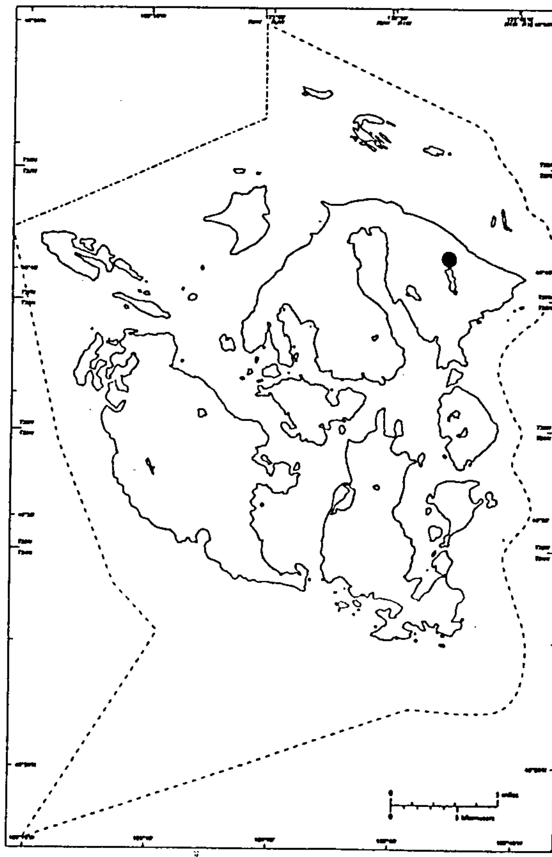
Encalypta ciliata



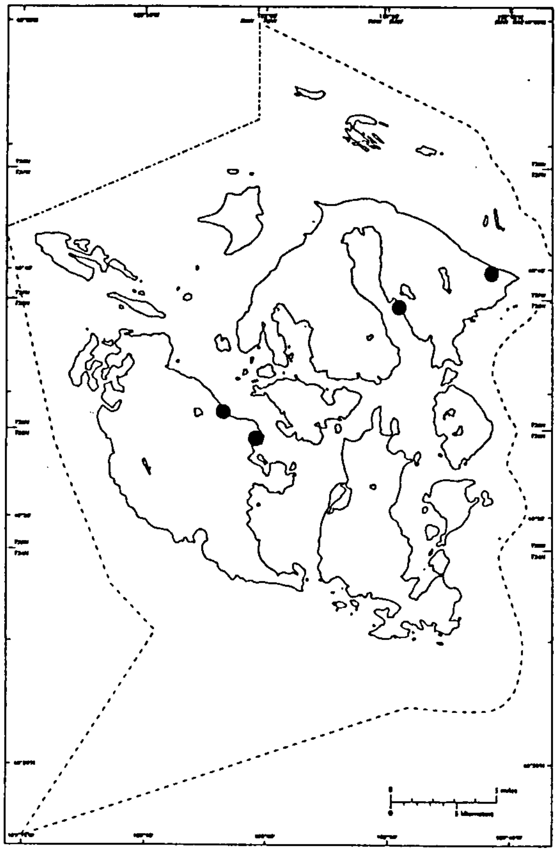
Encalypta procera



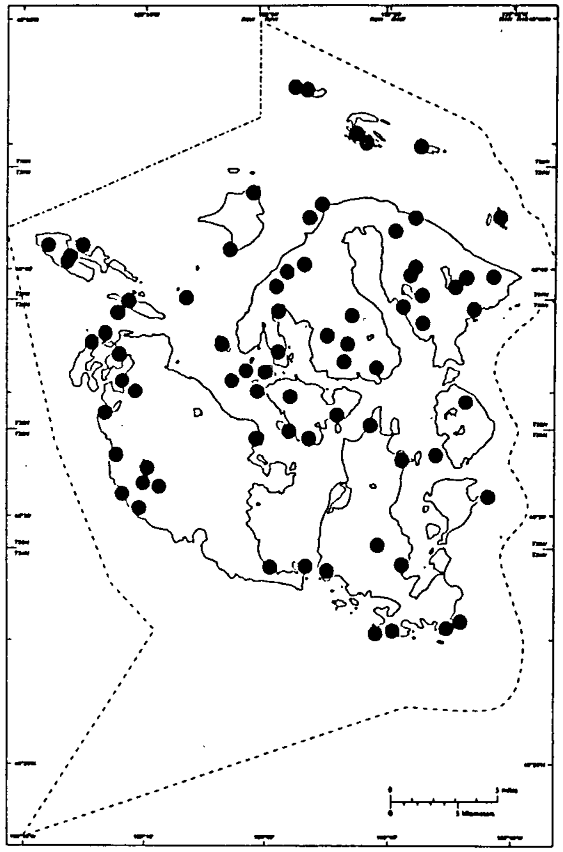
Encalypta vulgaris



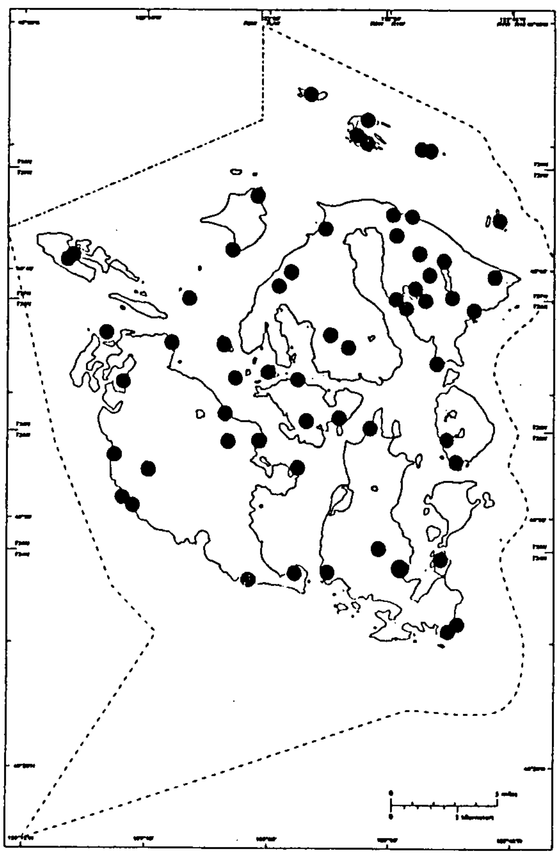
Epipterygium tozeri



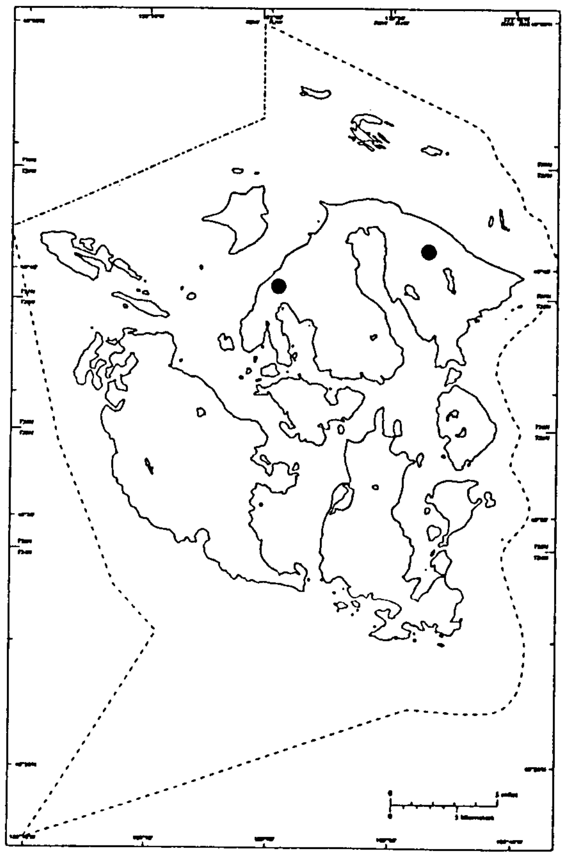
Eucladium verticillatum



Eurhynchium oreganum



Eurhynchium praelongum



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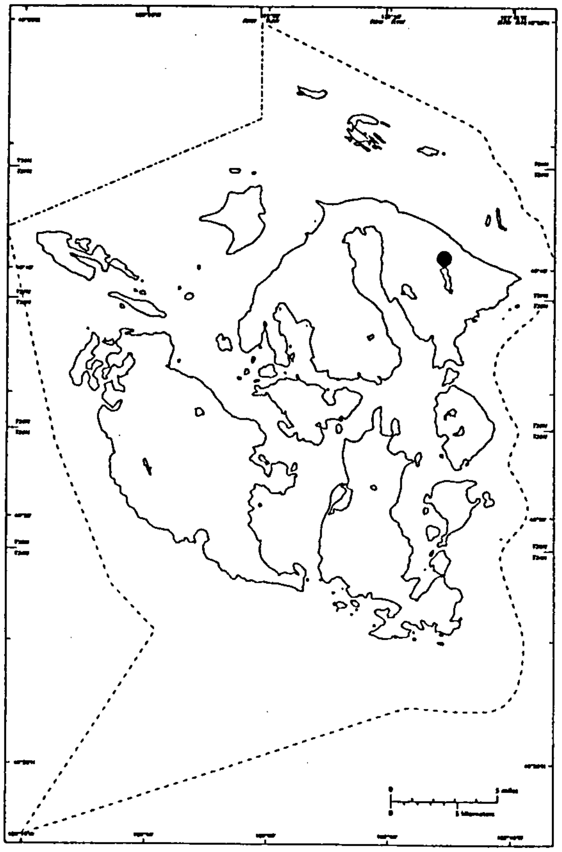
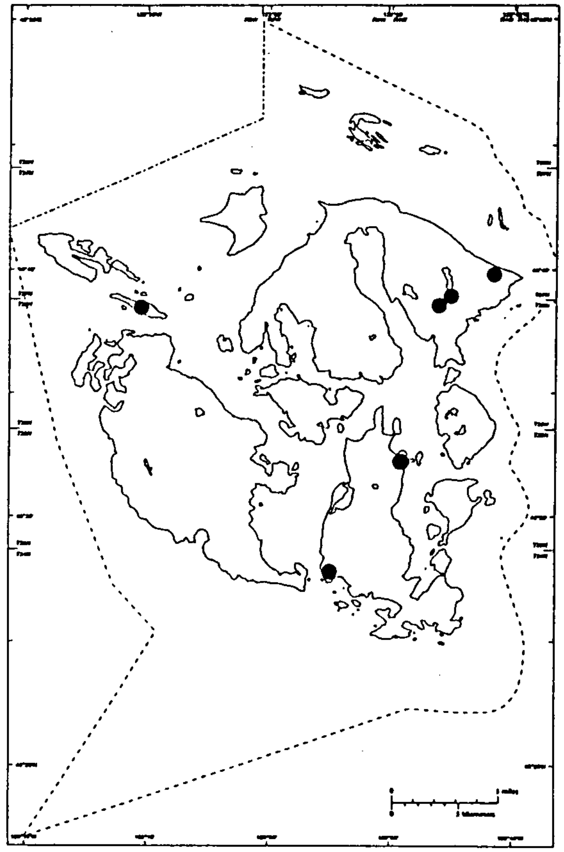
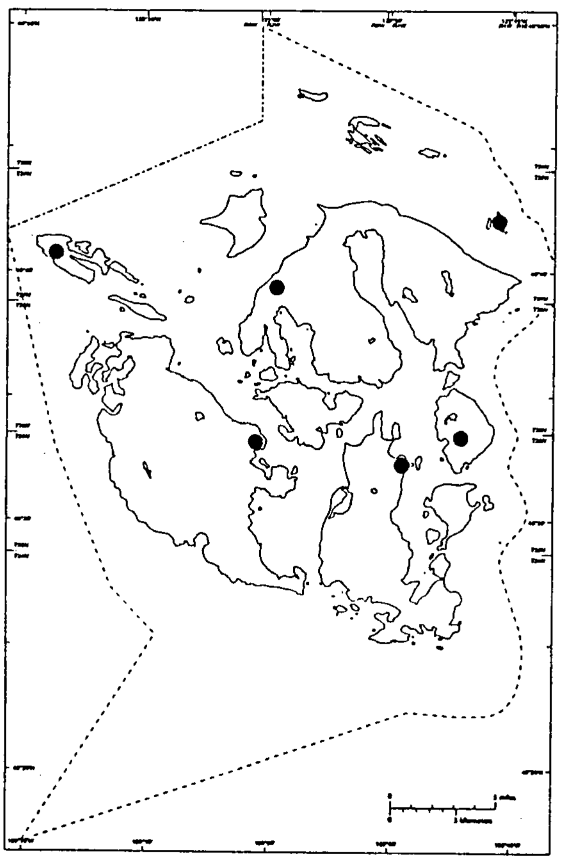


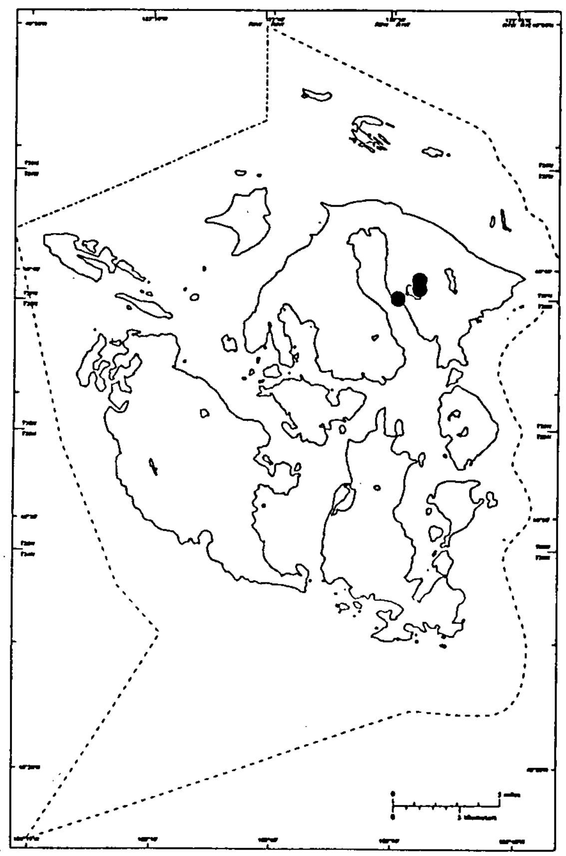
Fissidens adianthoides



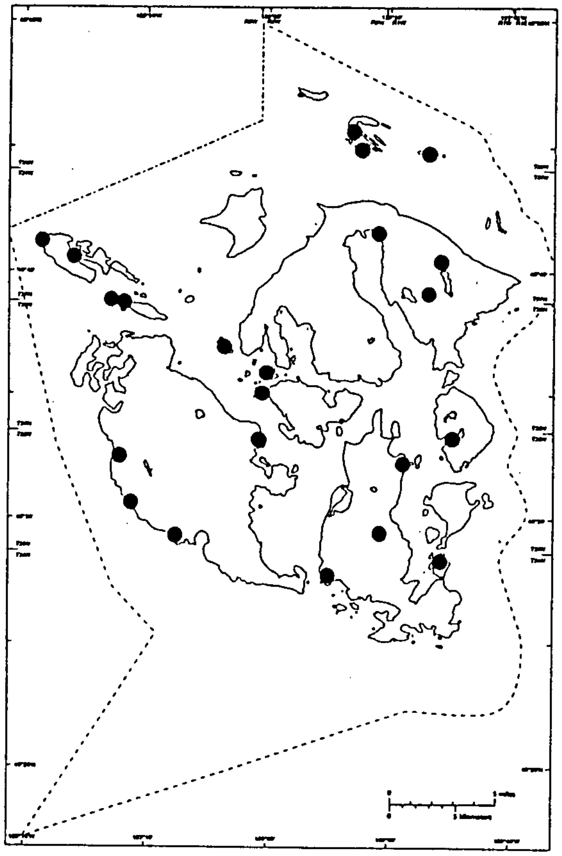
Fissidens bryoides var. *bryoides*



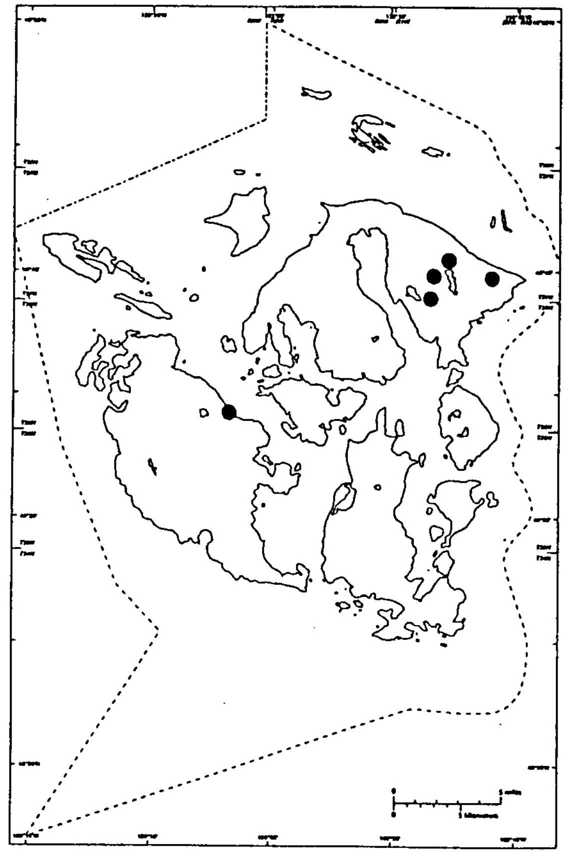
Fissidens bryoides var. *viridulus*



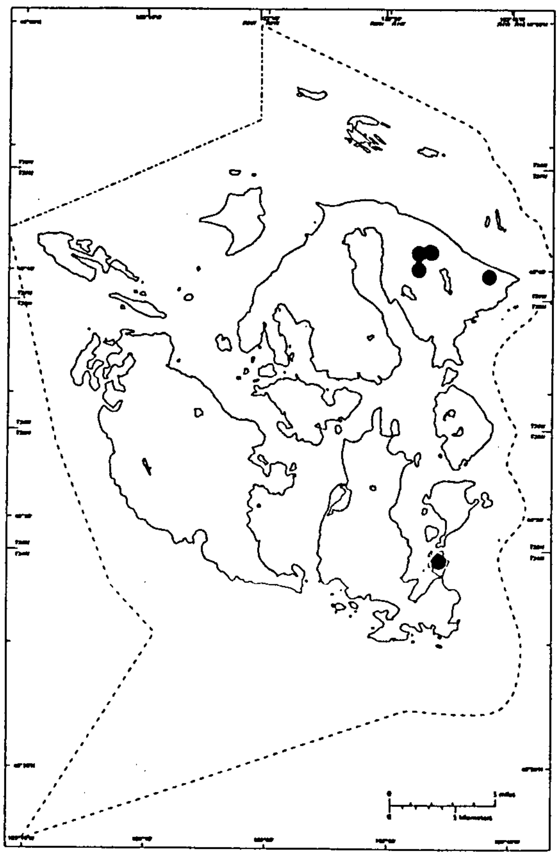
Fissidens grandifrons



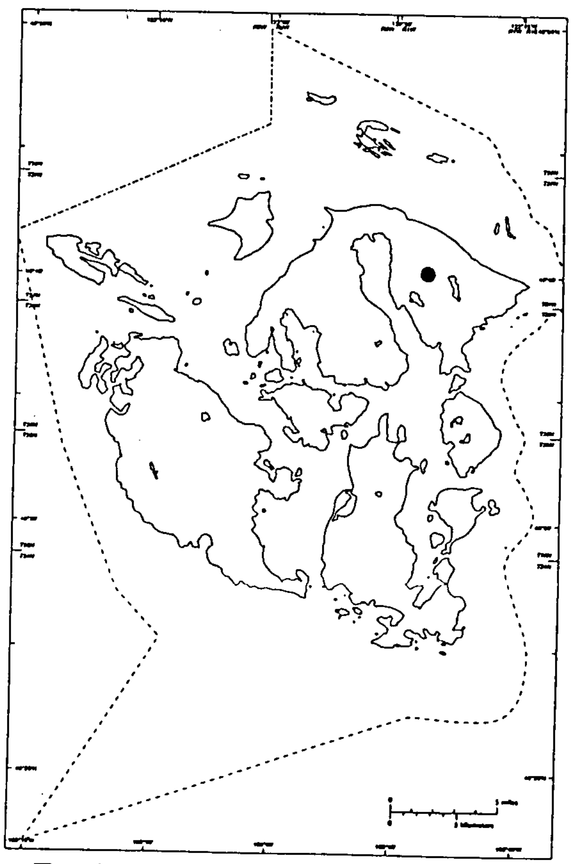
Fissidens limbatus



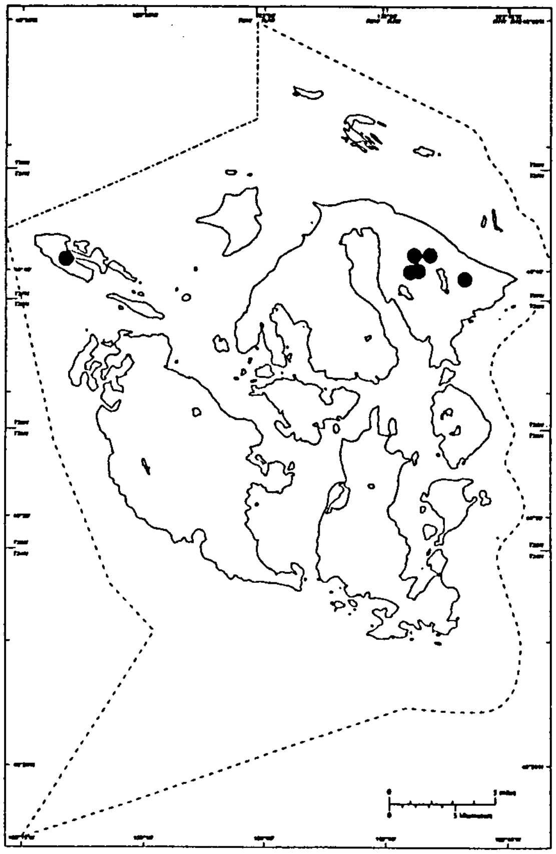
Fissidens ventricosus



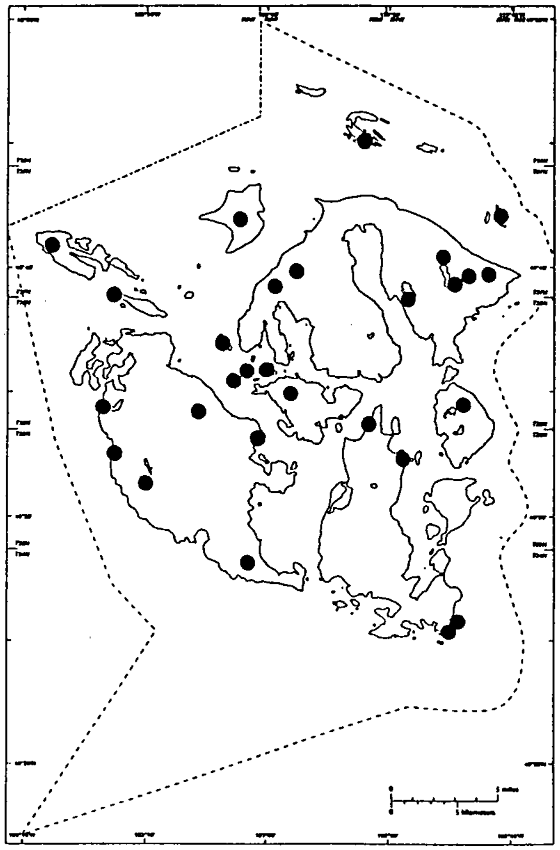
Fontinalis antipyretica* var. *antipyretica



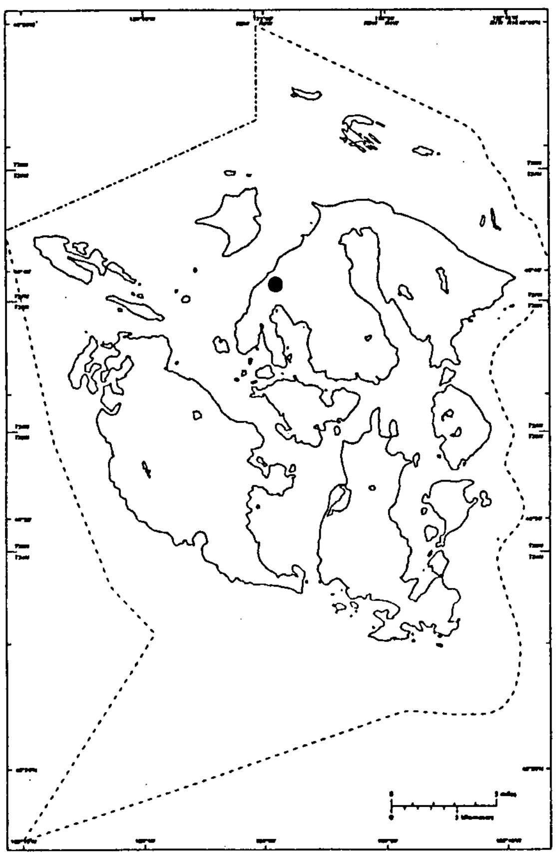
Fontinalis antipyretica* var. *gigantea



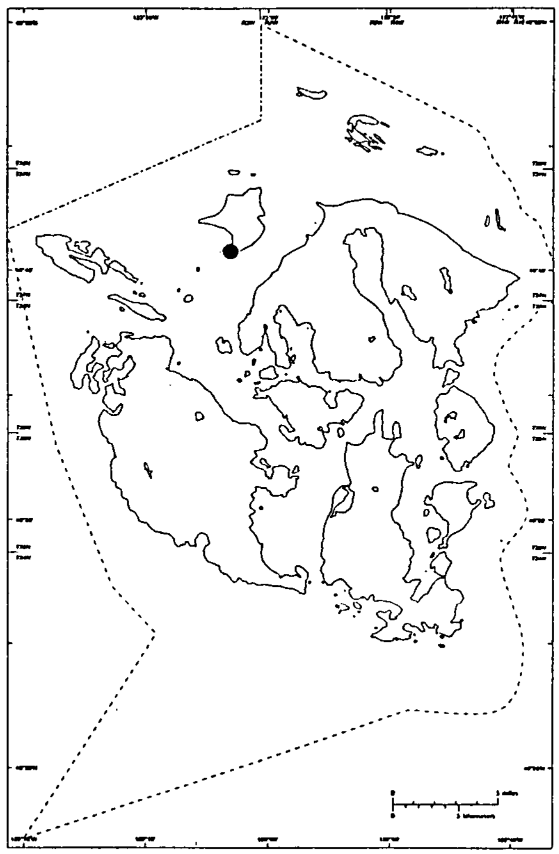
Fontinalis antipyretica var. *oregonensis*



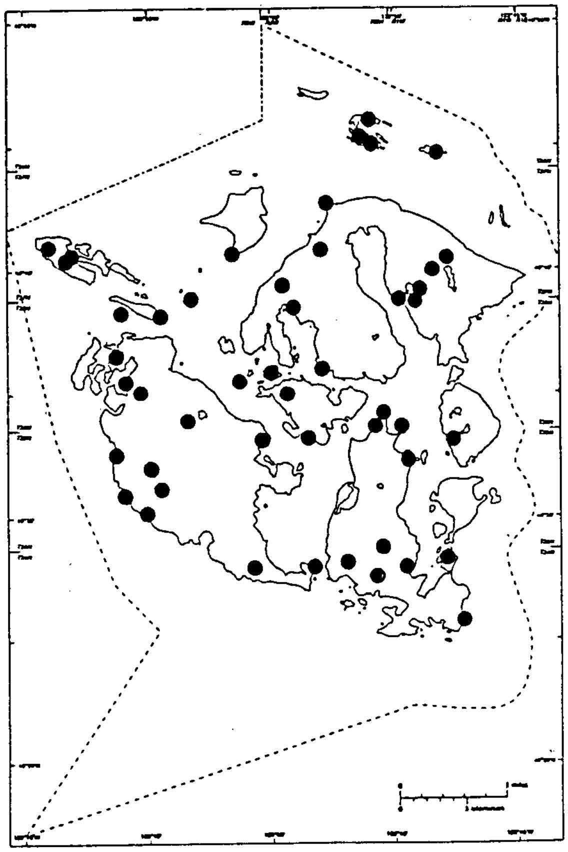
Funaria hygrometrica



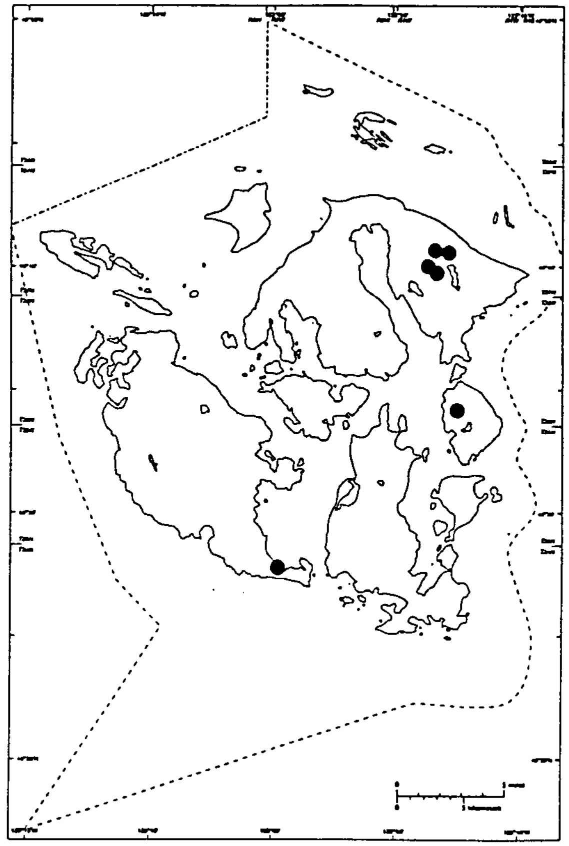
Funaria muhlenbergii



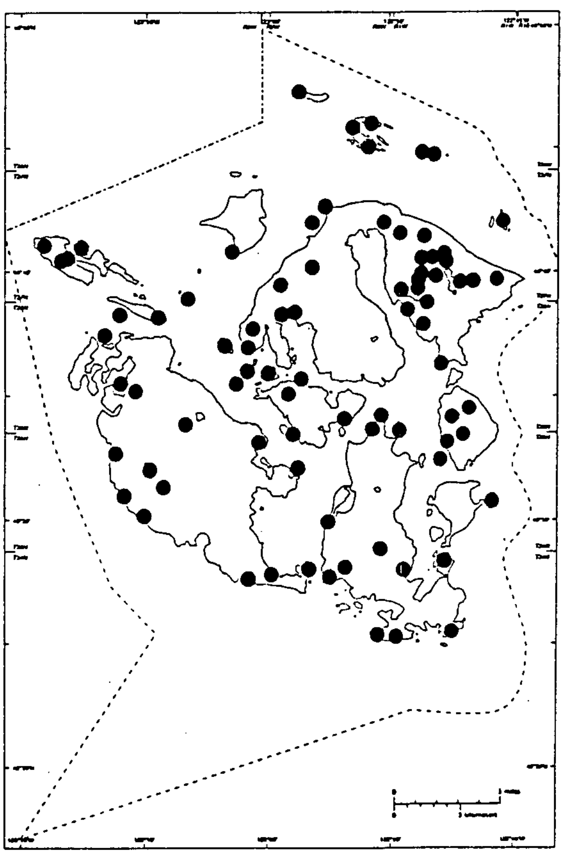
Grimmia laevigata



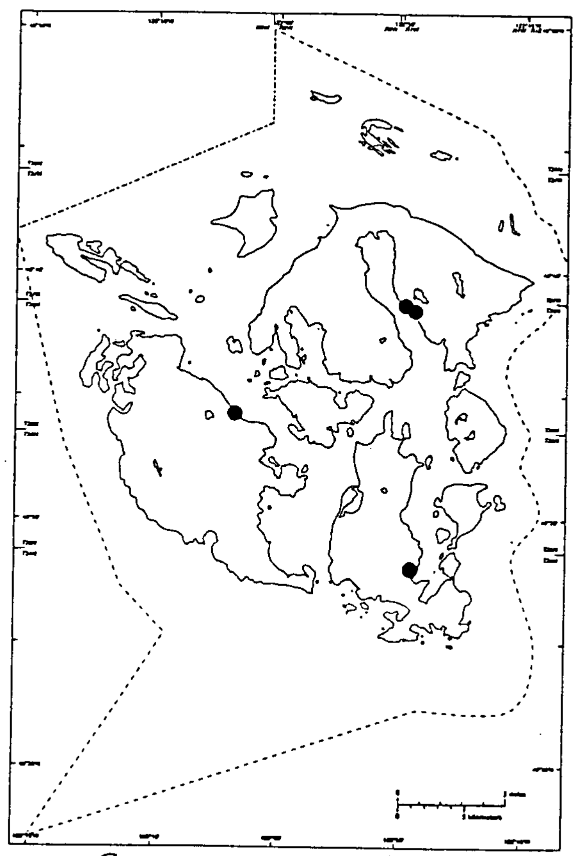
Grimmia pulvinata



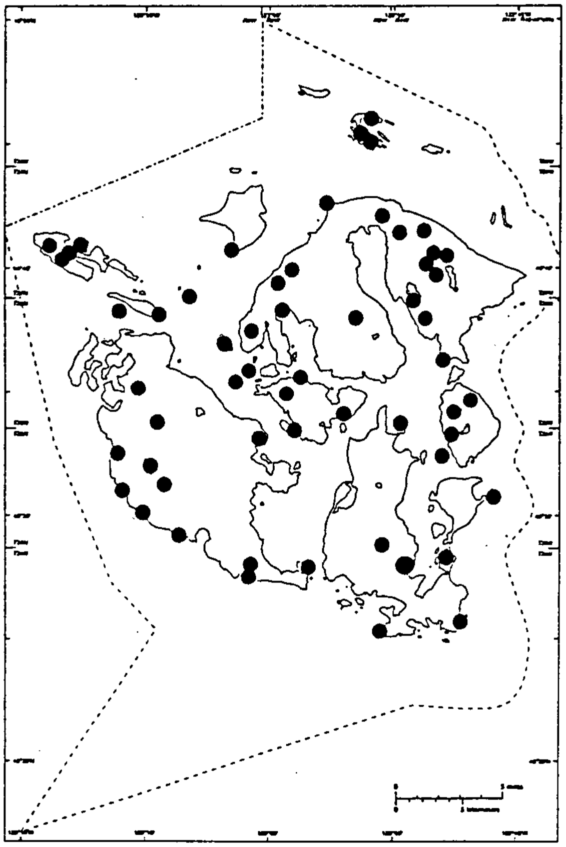
Grimmia torquata



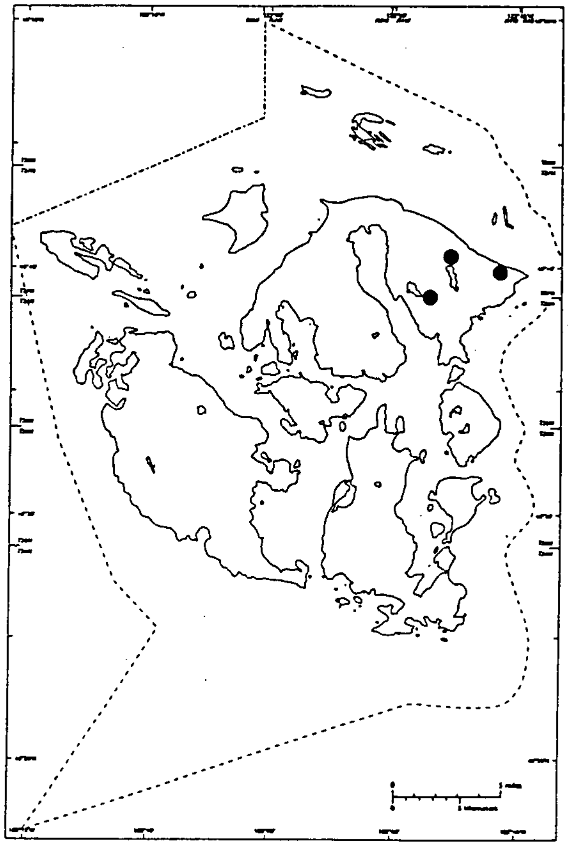
Grimmia trichophylla



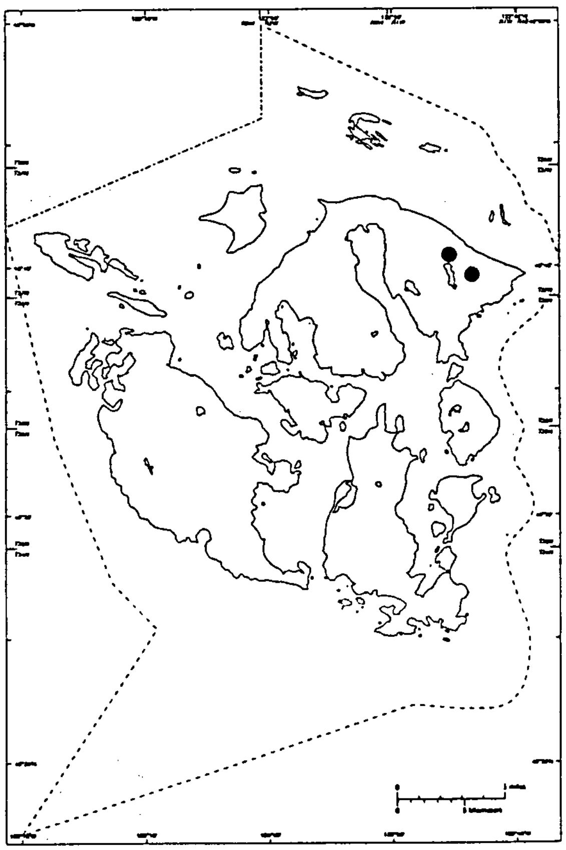
Gymnostomum aeruginosum



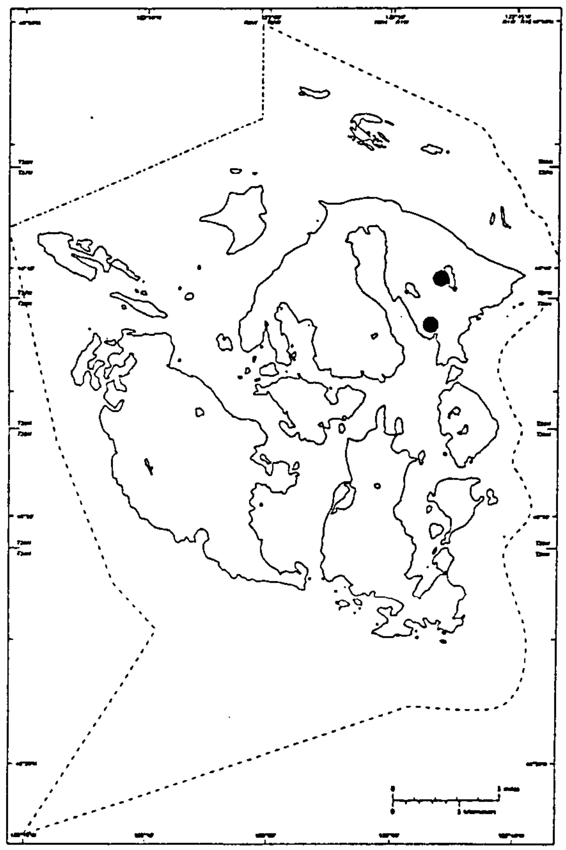
Hedwigia stellata



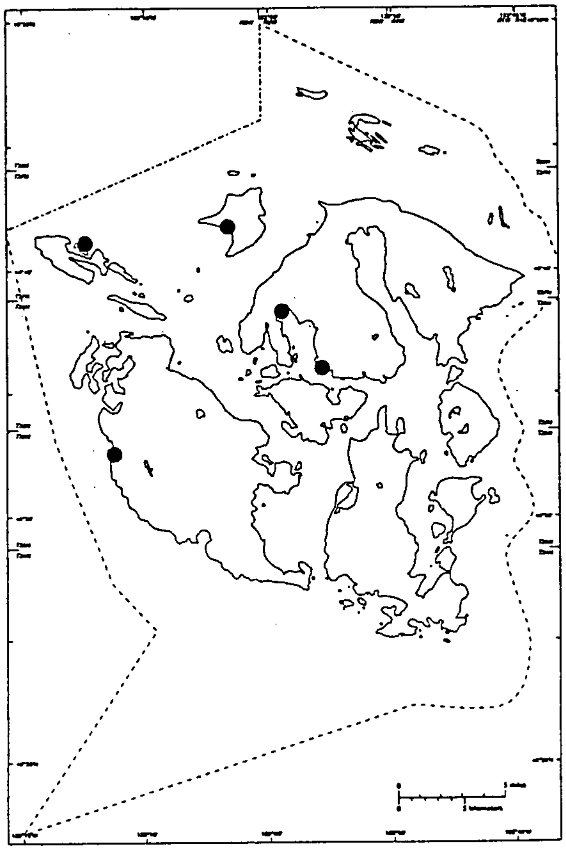
Heterocladium macounii



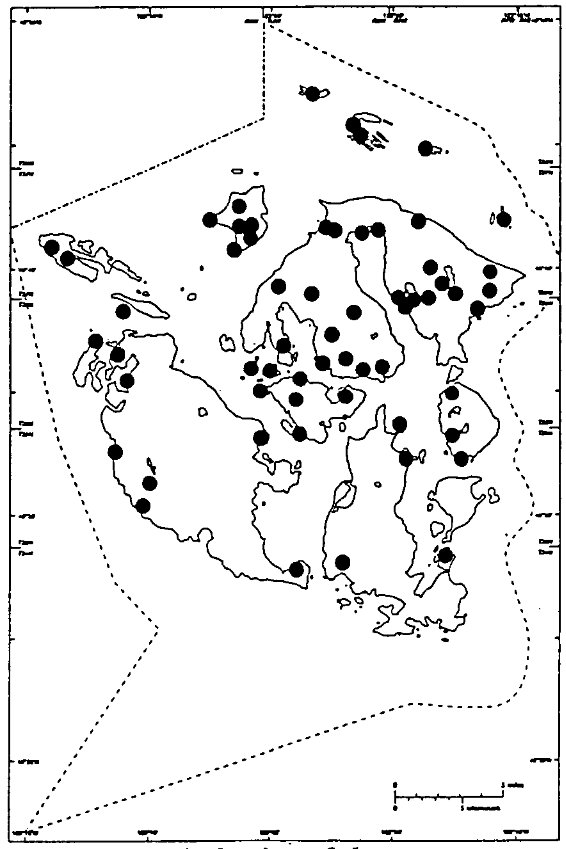
Heterocladium procurrens



Homalothecium aeneum



Homalothecium arenarium



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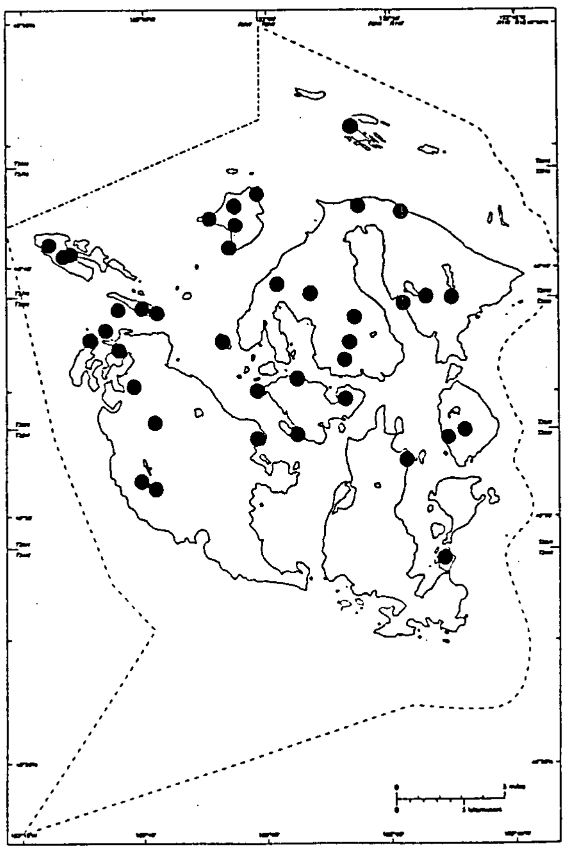
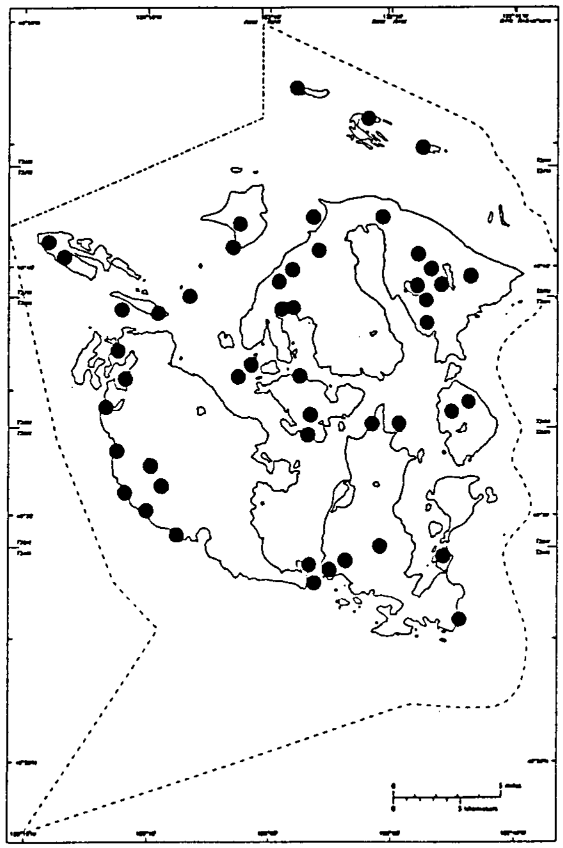
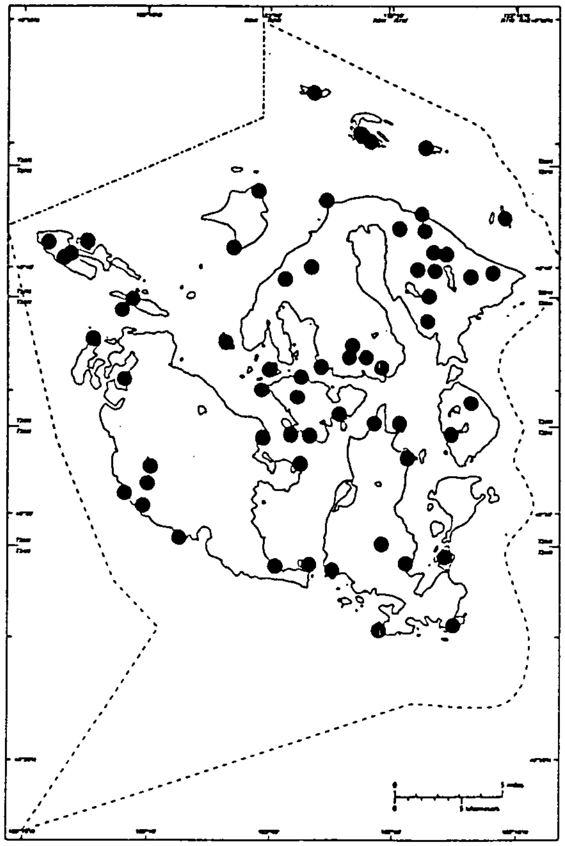


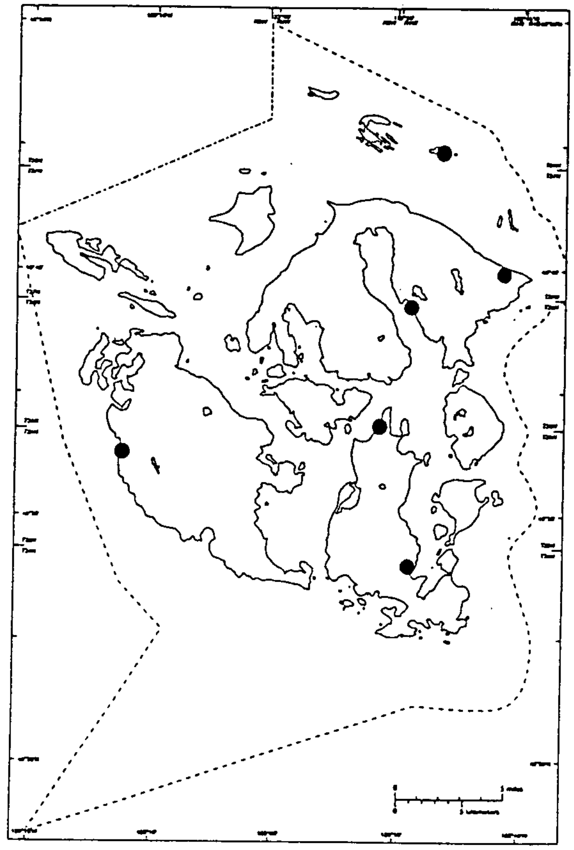
Homalothecium nuttallii



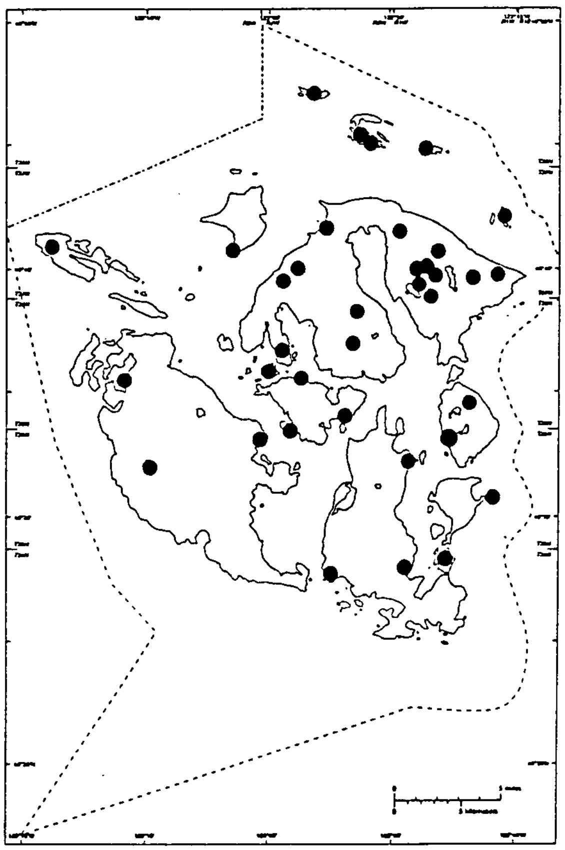
Homalothecium pinnatifidum



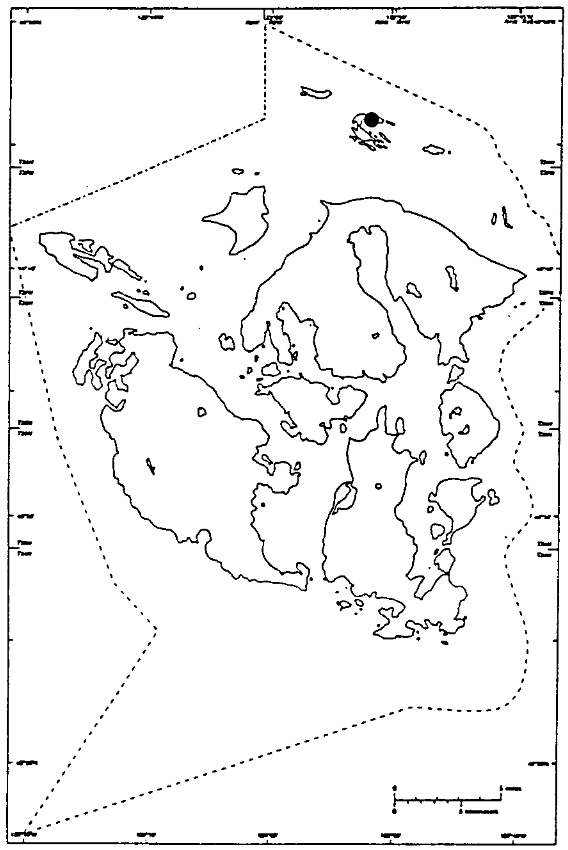
Hylocomium splendens



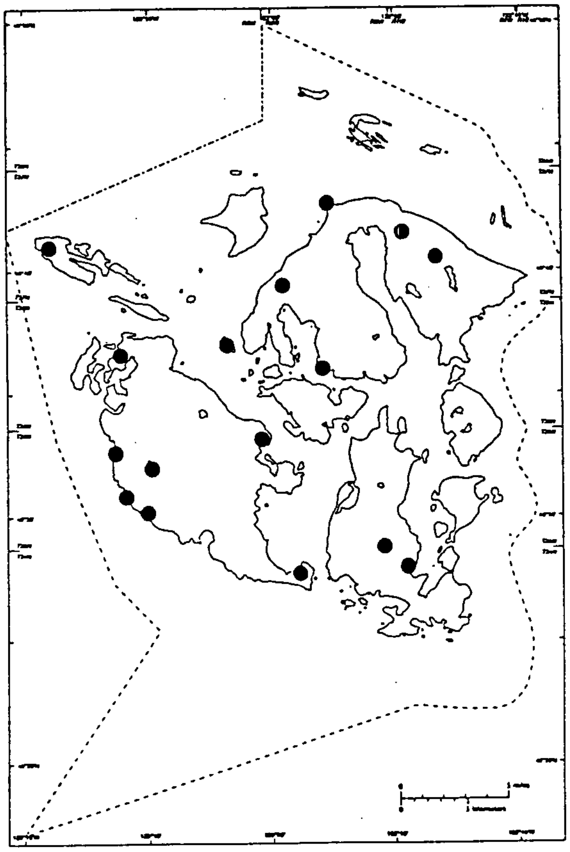
Hymenostylium recurvirostre



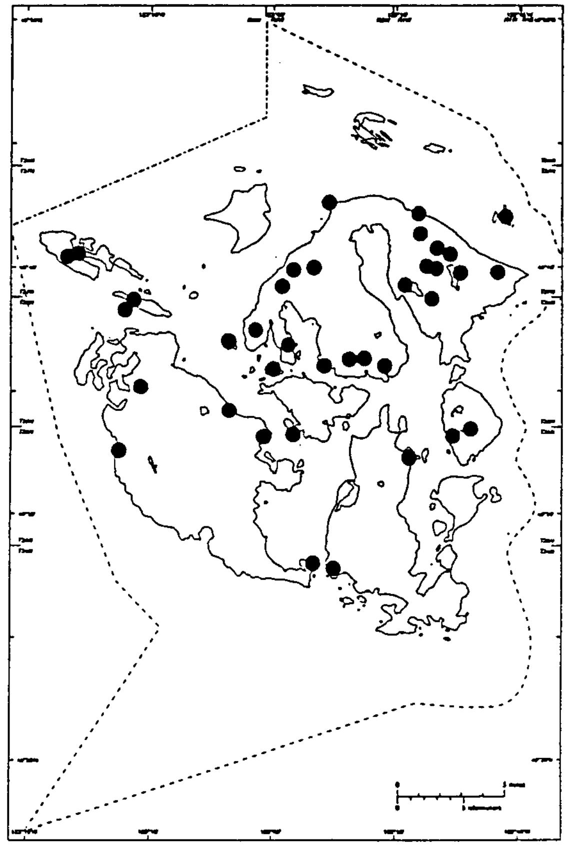
Hypnum circinale



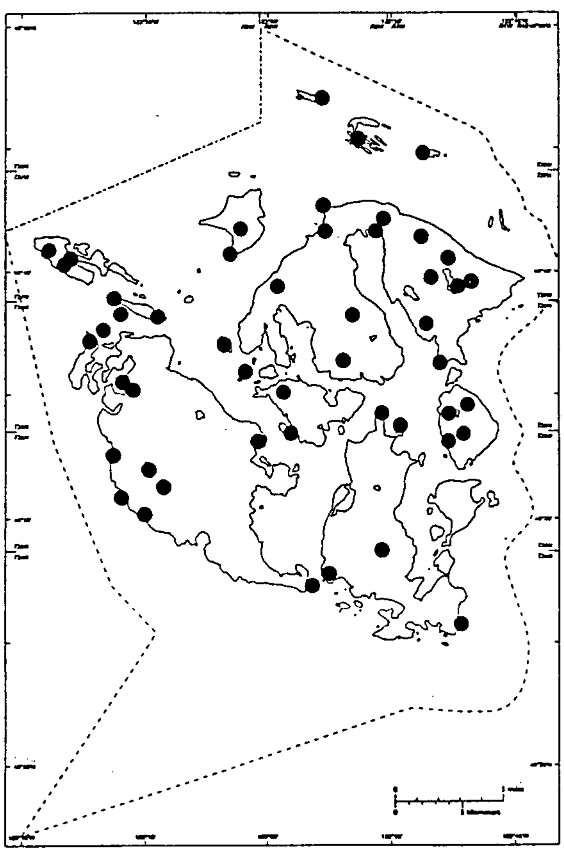
Hypnum cupressiforme



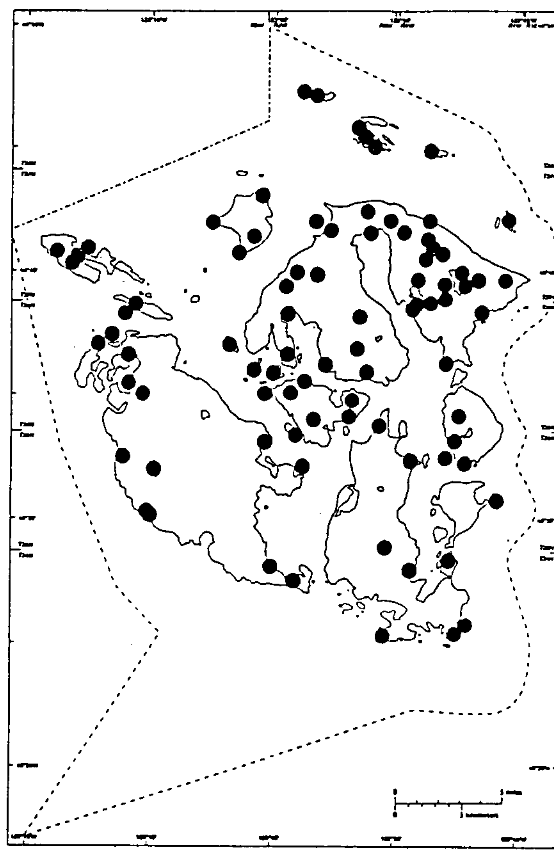
Hypnum dieckii



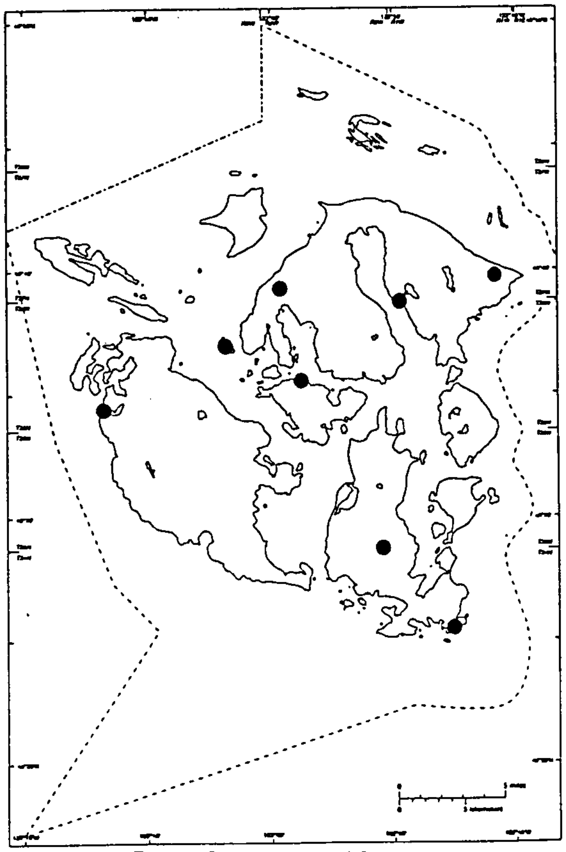
Hypnum subimponens



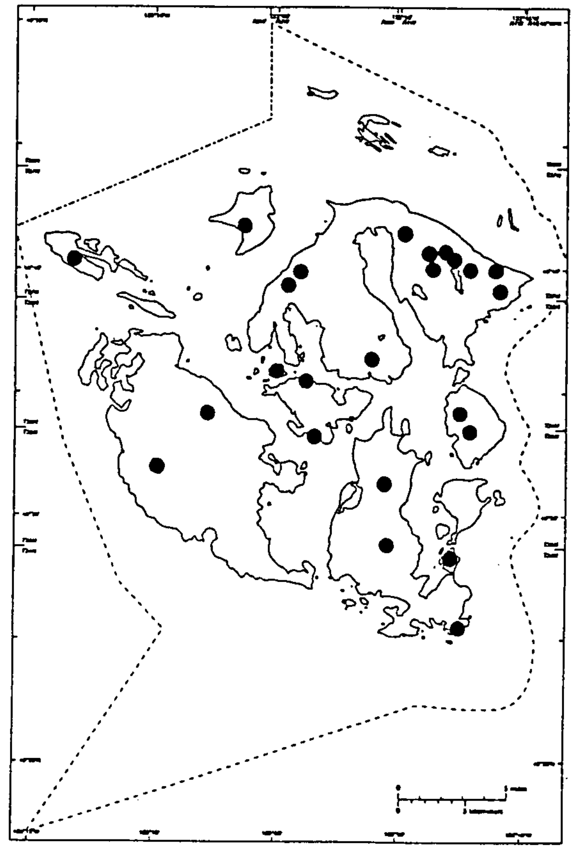
Isothecium cristatum



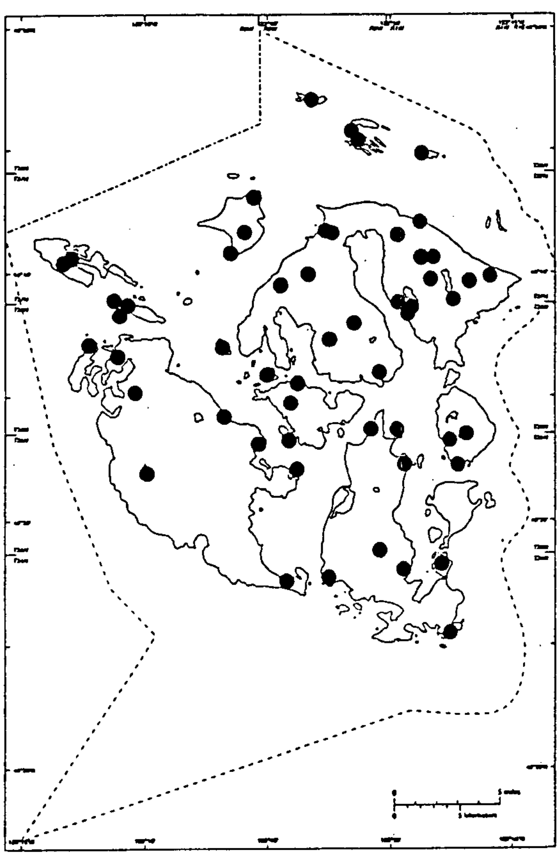
Isothecium myosuroides



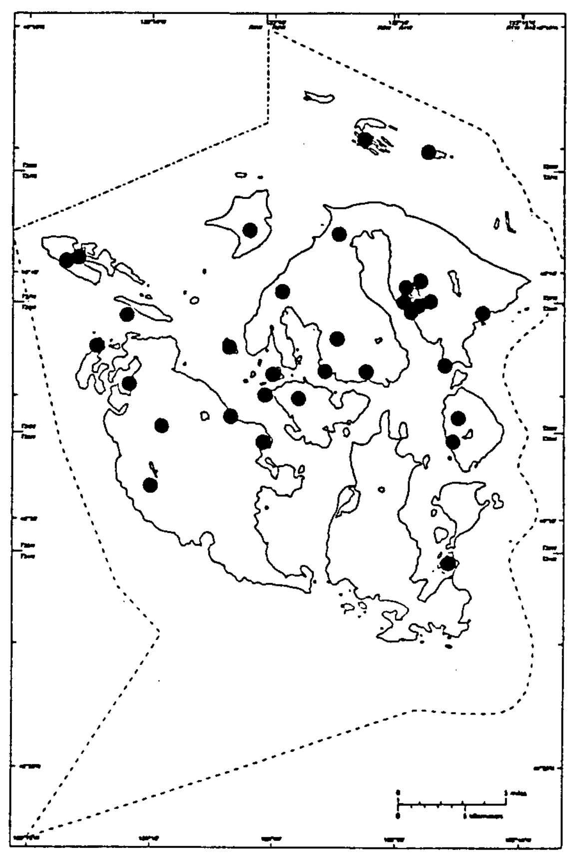
Leptobryum pyriforme



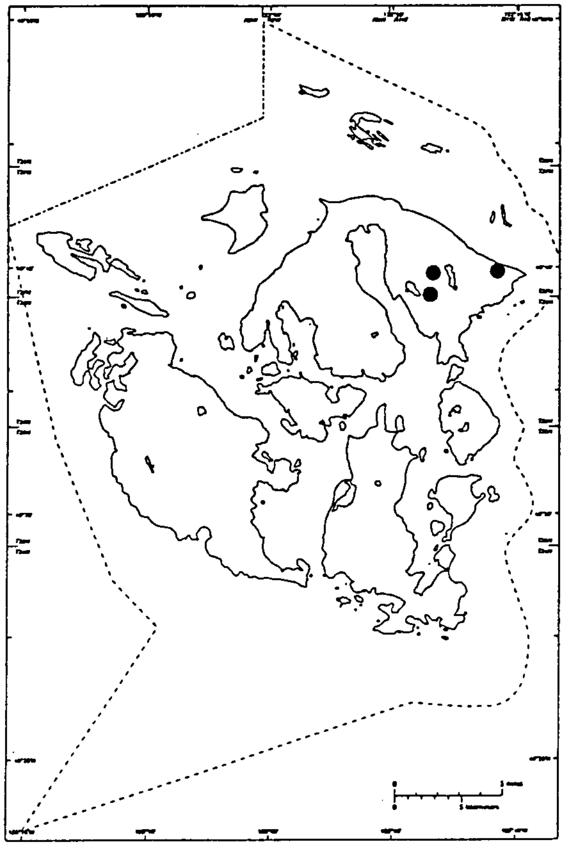
Leptodictyum riparium



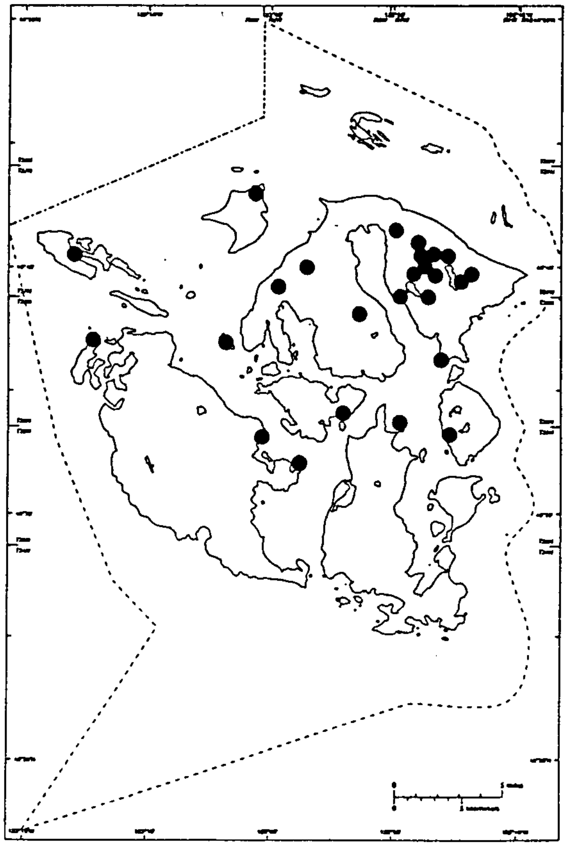
Leucolepis acanthoneuron



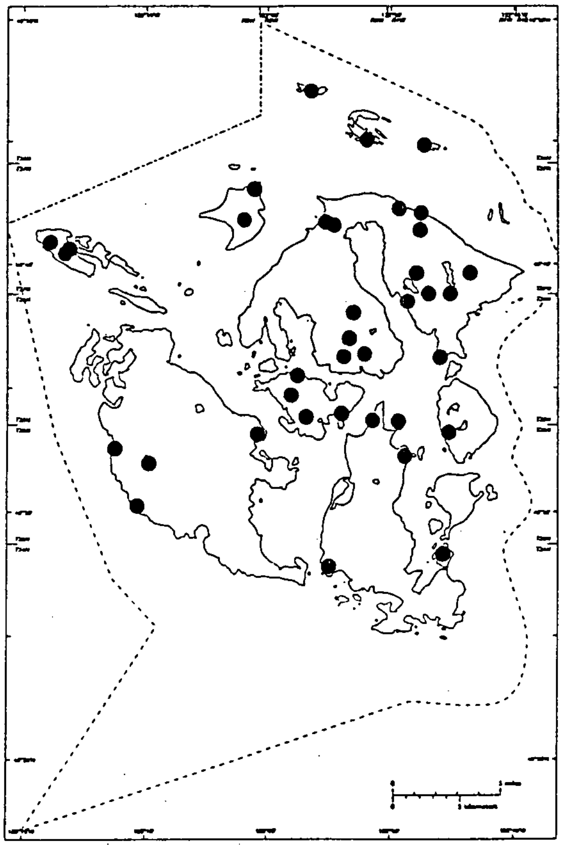
Metaneckera menziesii



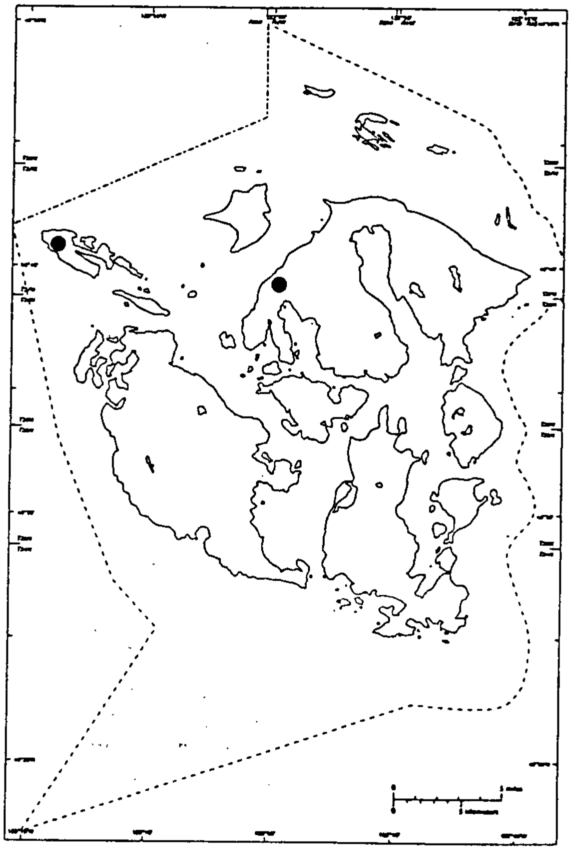
Mnium marginatum



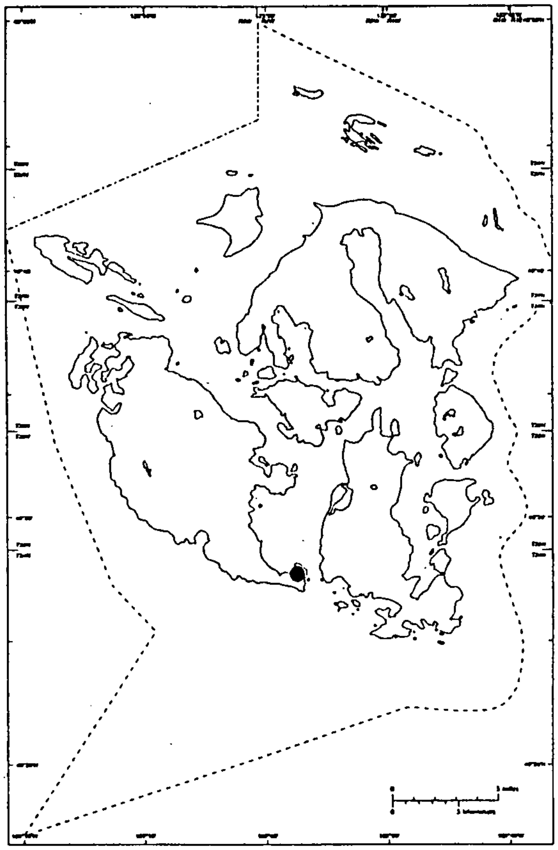
Mnium spinulosum



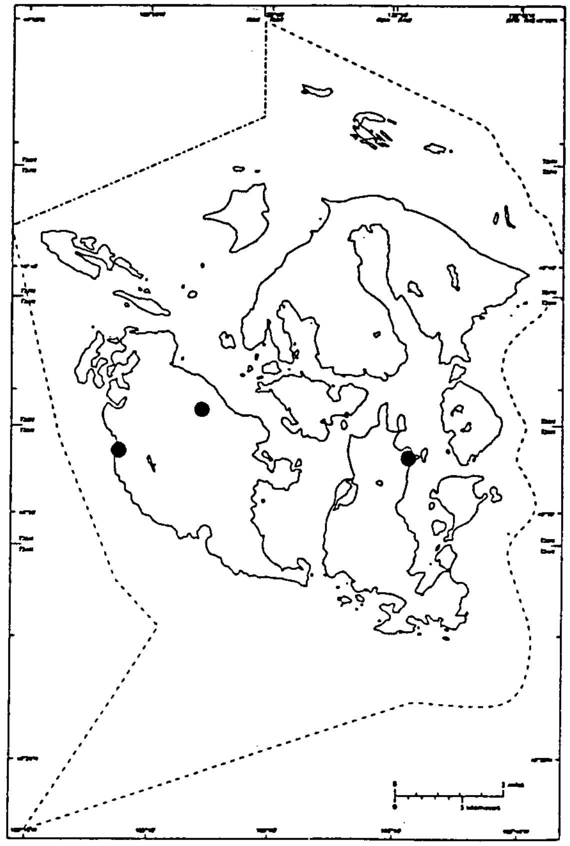
Neckera douglasii



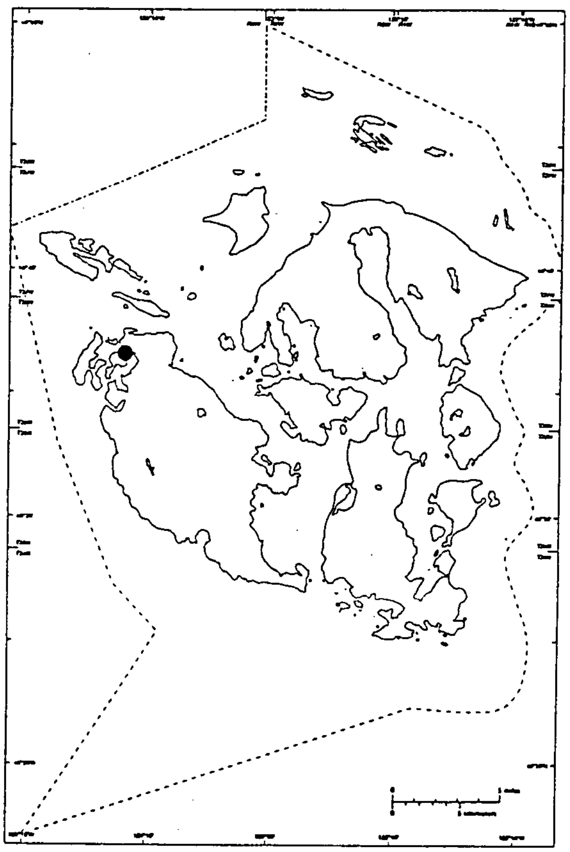
Neckera pennata



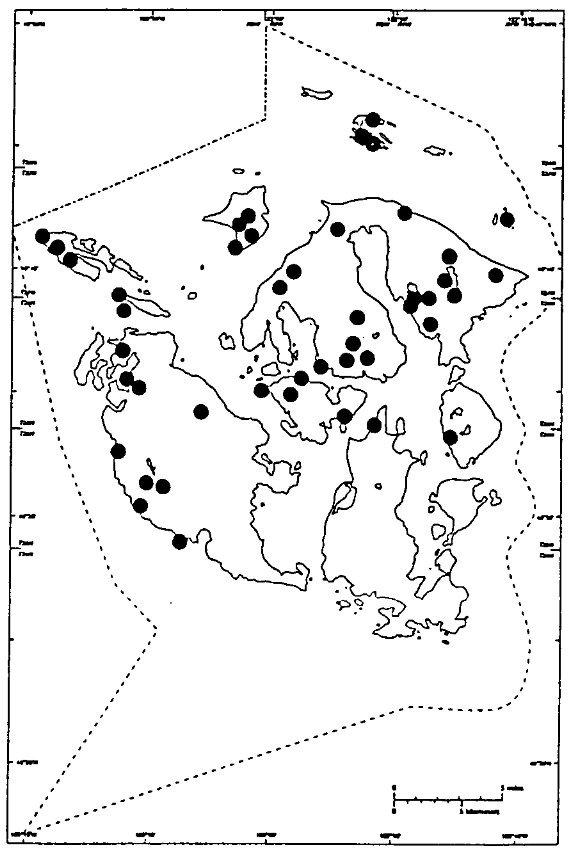
Oncophorus wahlenbergii



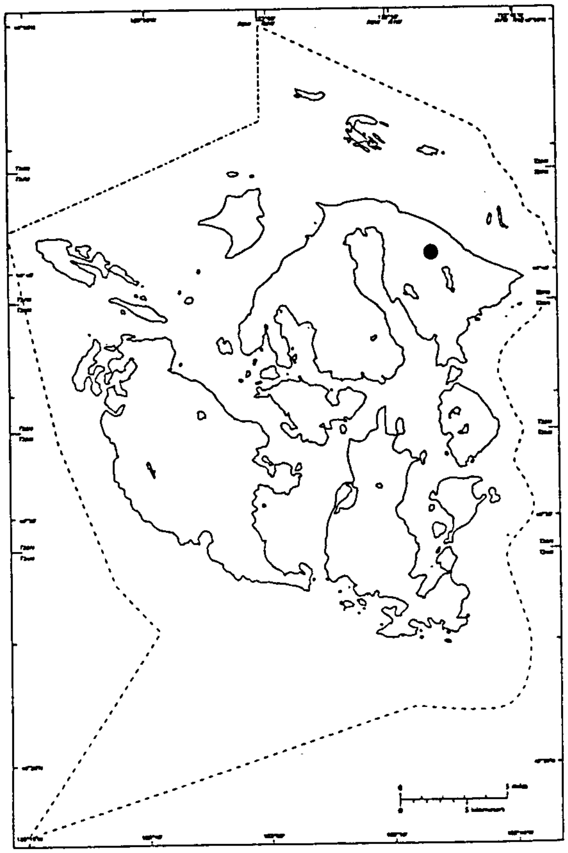
Orthotrichum affine



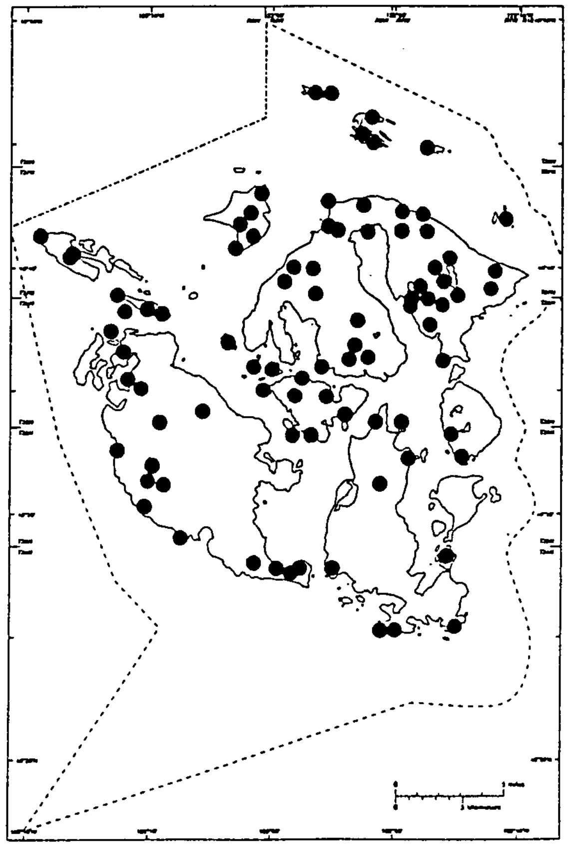
Orthotrichum anomalum



Orthotrichum consimile



Orthotrichum hallii



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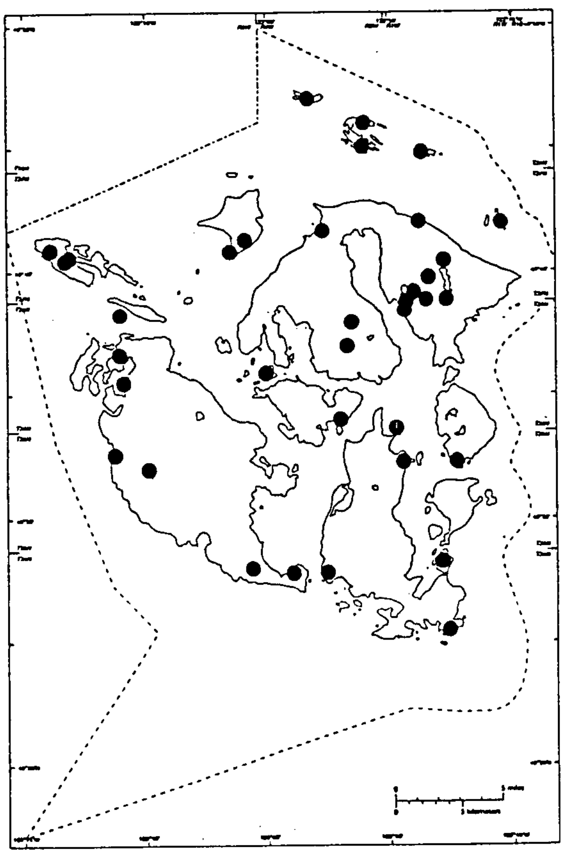

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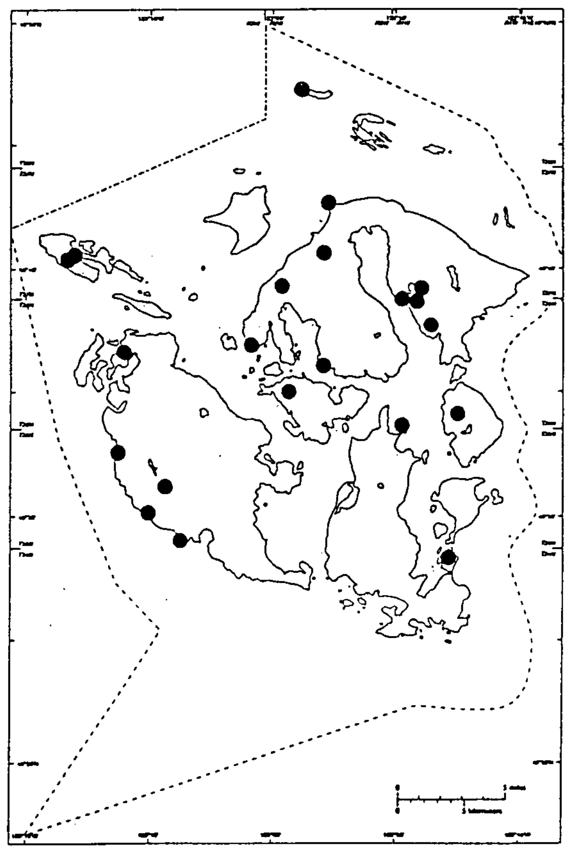

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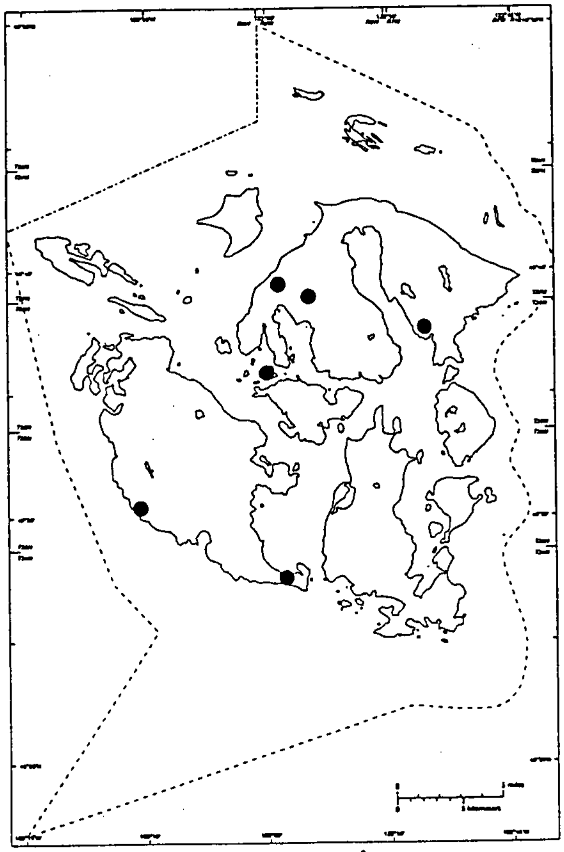

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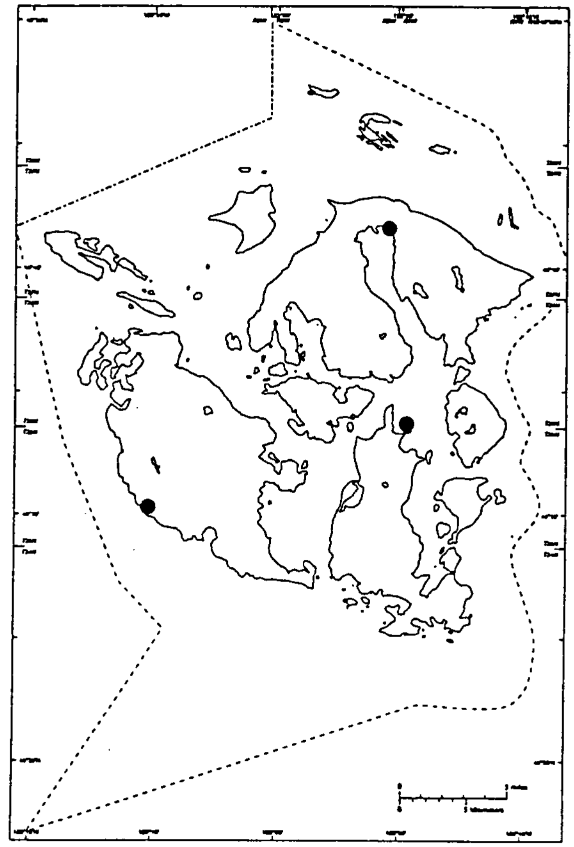
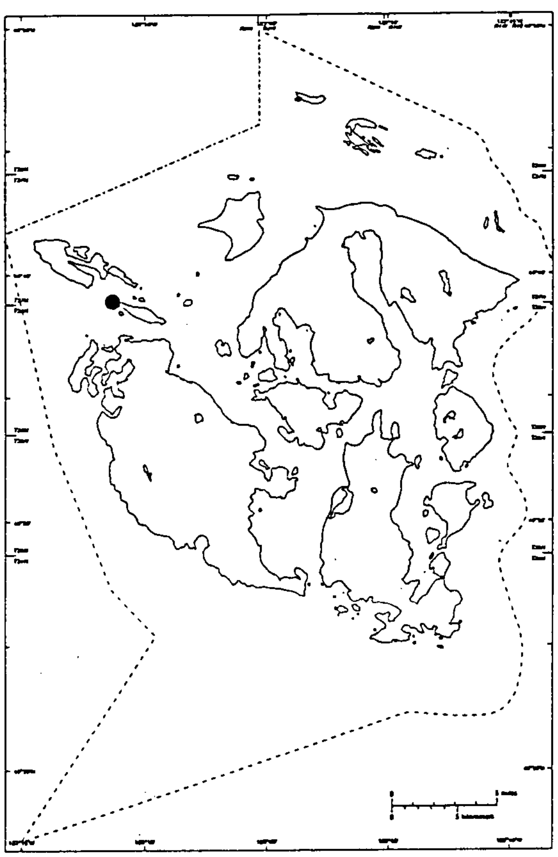


Orthotrichum striatum



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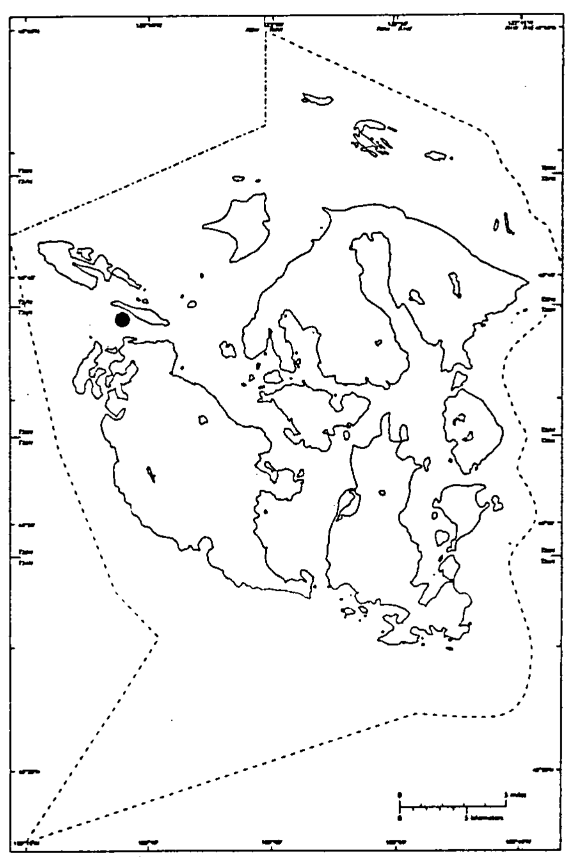
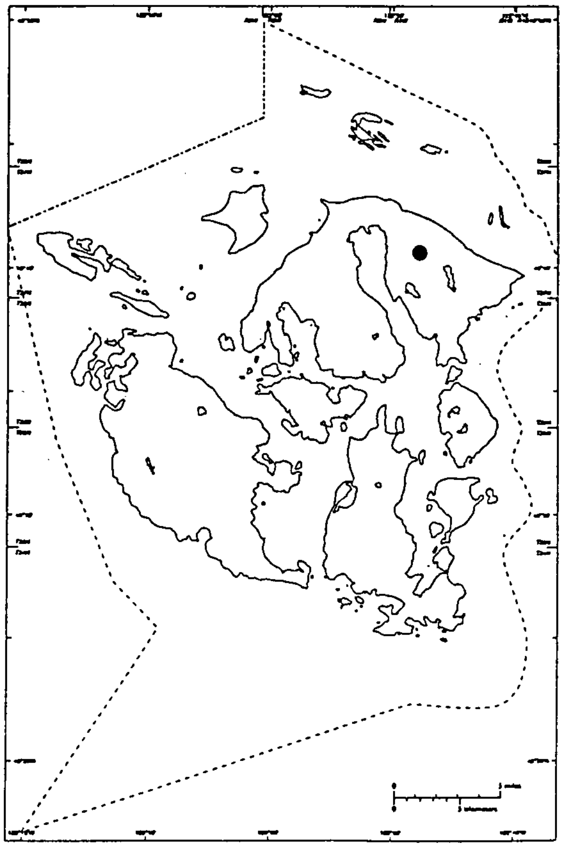
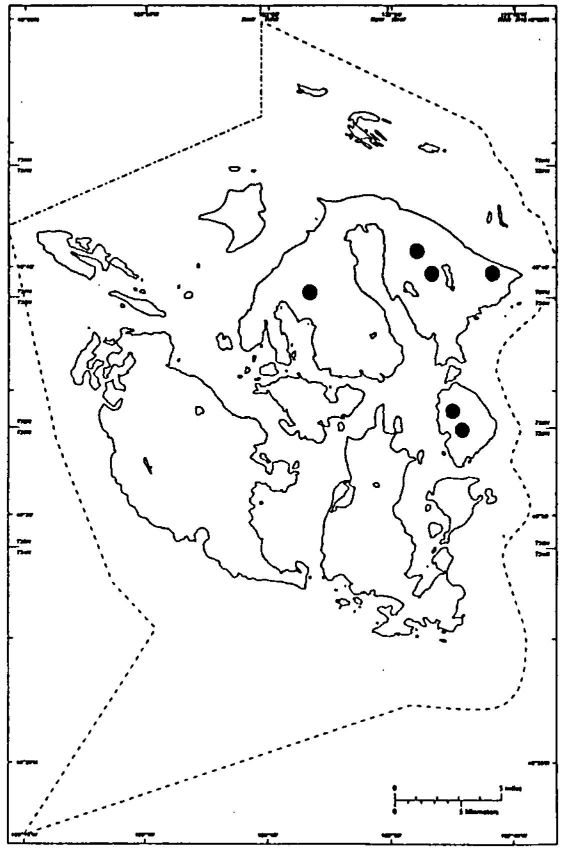


Phascum cuspidatum



Philonotis capillaris



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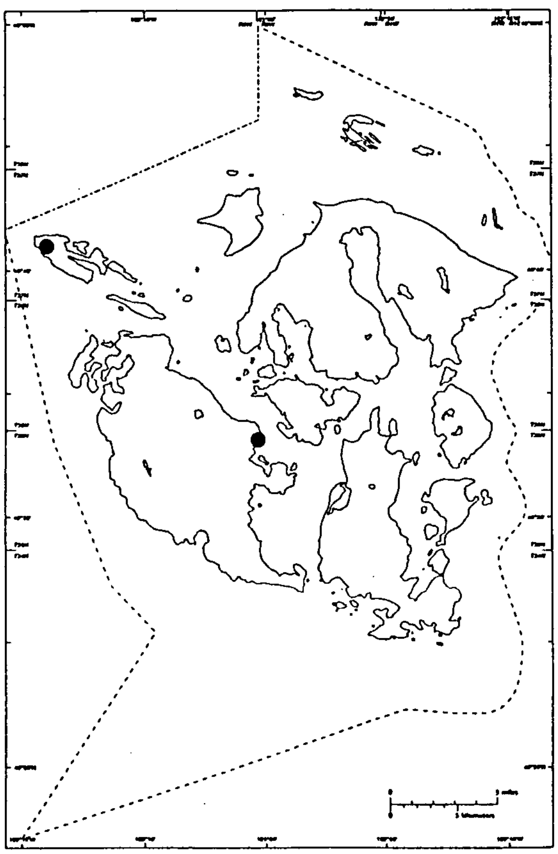
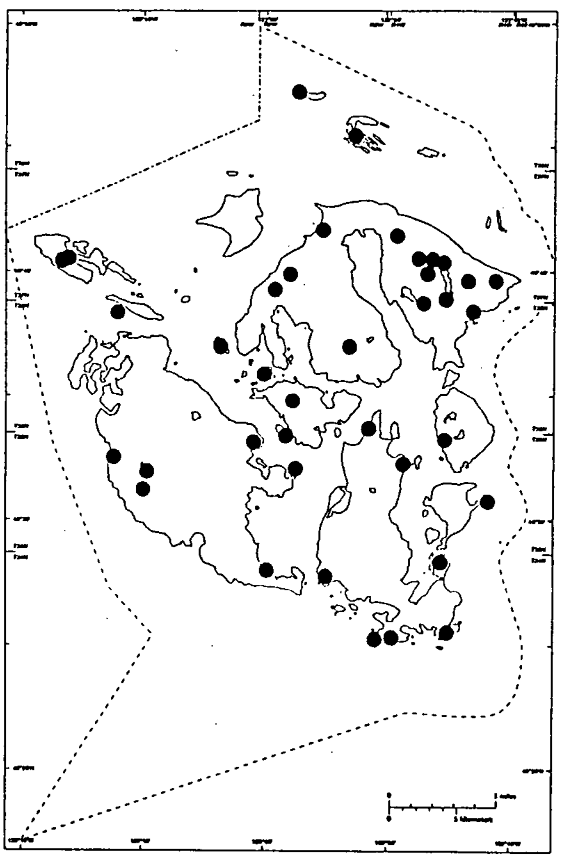
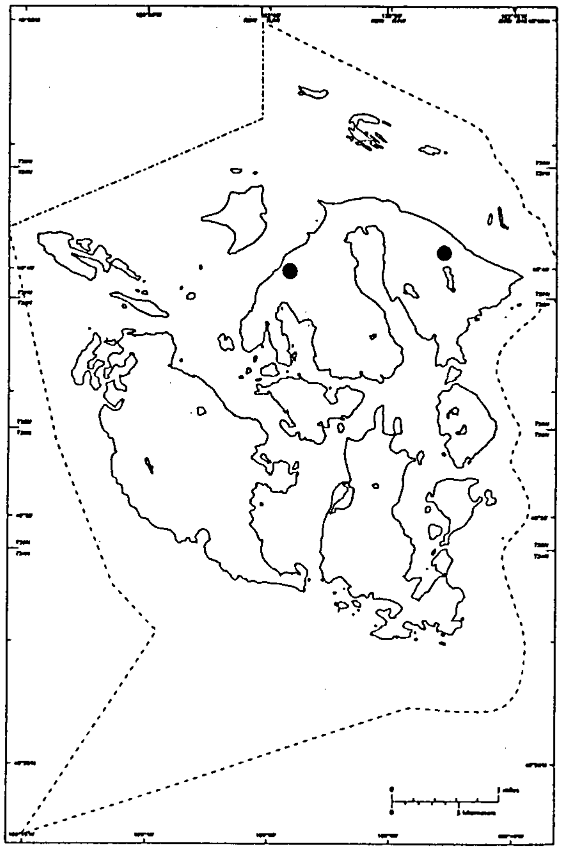


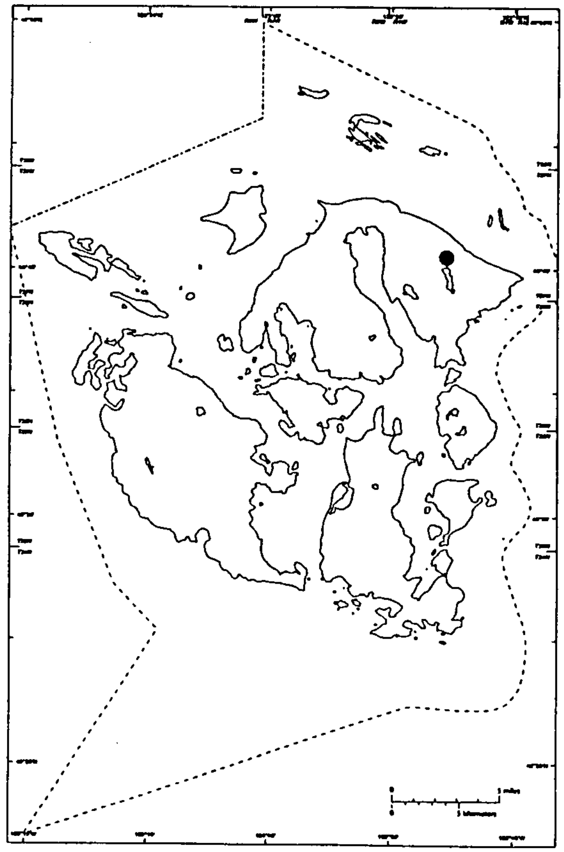
Physcomitrium pyriforme



Plagiomnium insigne



Plagiomnium medium



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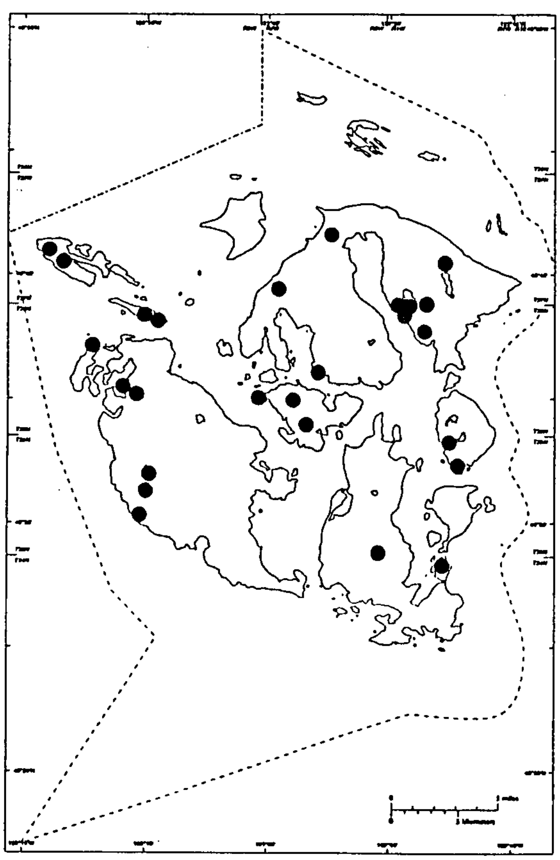

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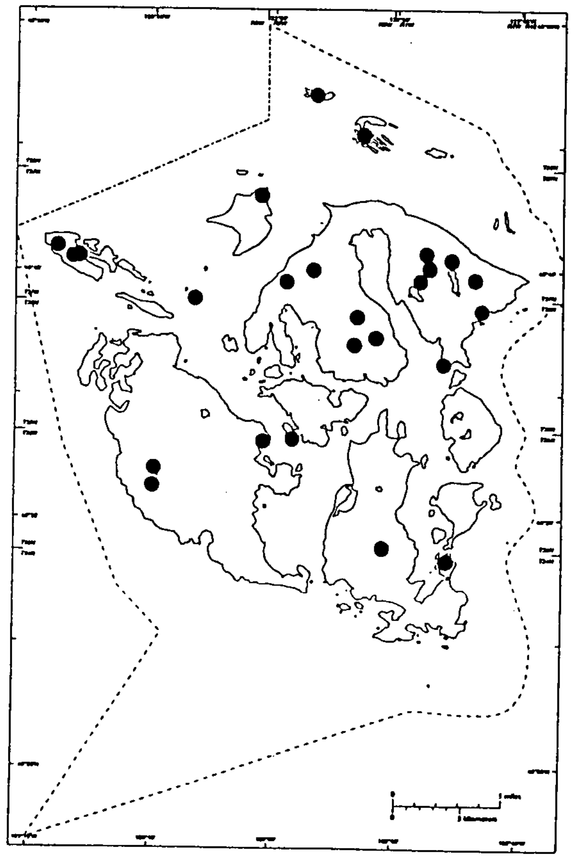
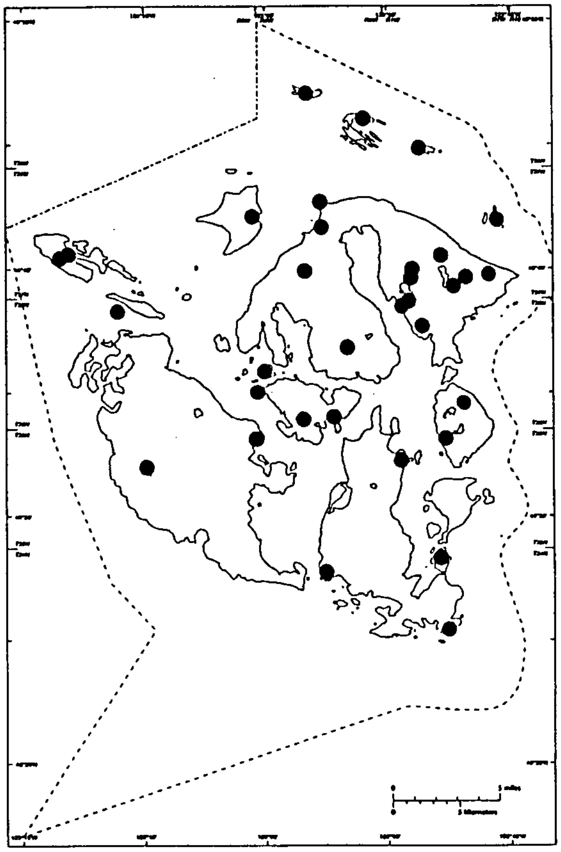


Plagiothecium denticulatum



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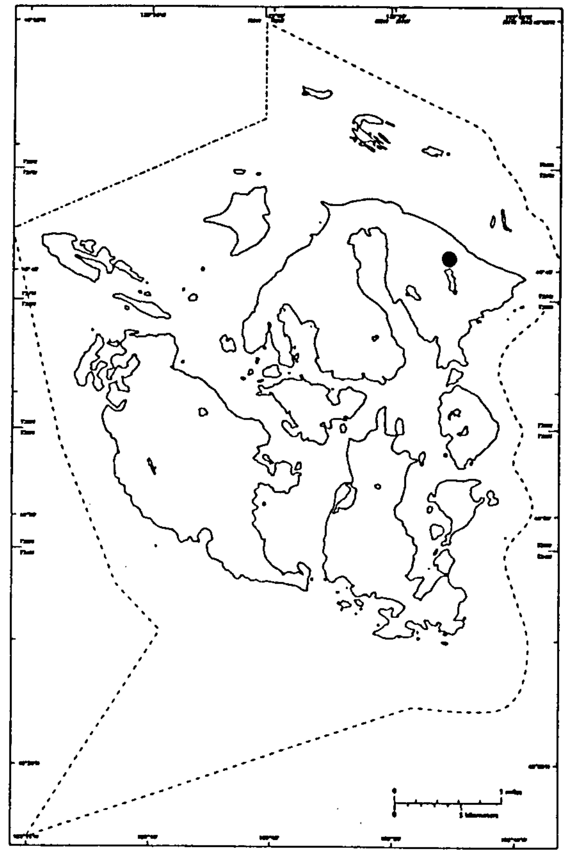
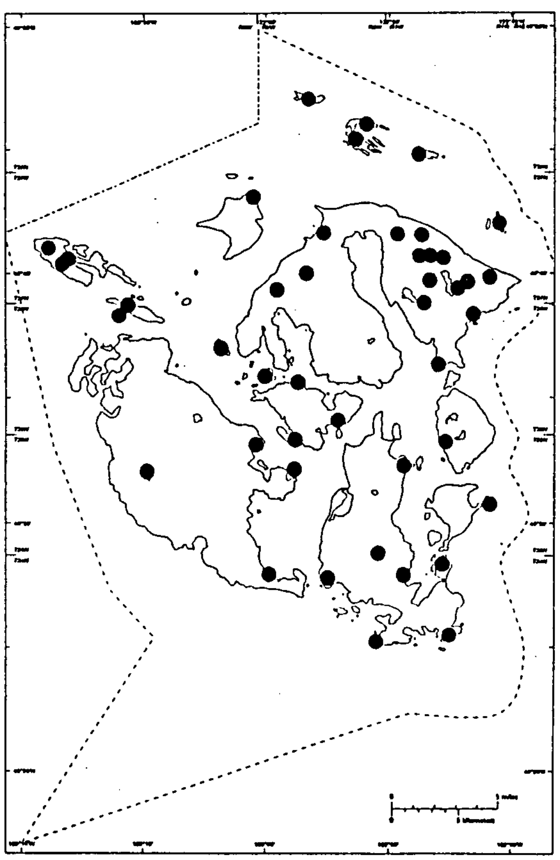
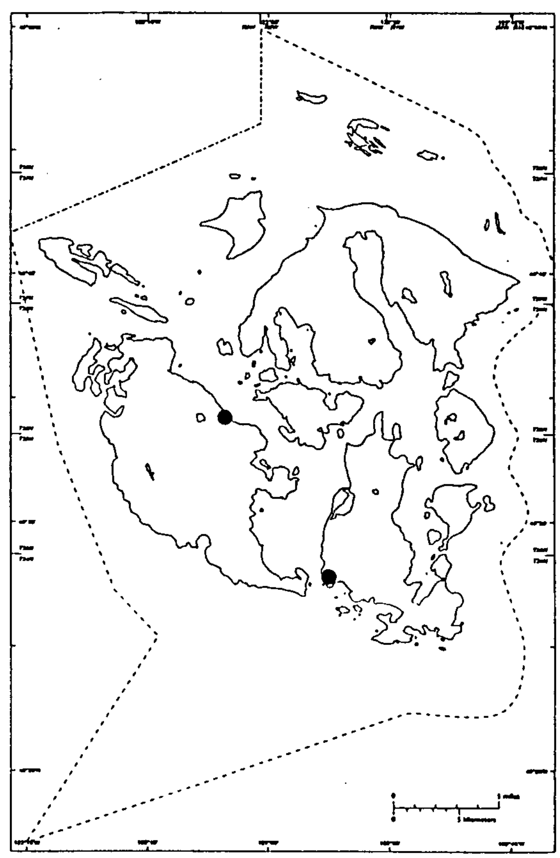


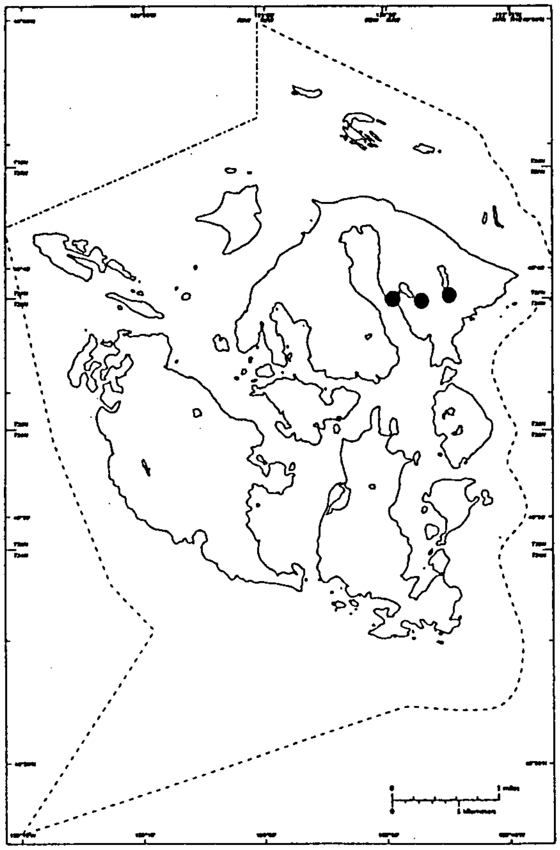
Plagiothecium piliferum



Plagiothecium undulatum



Platydictya jungermannioides



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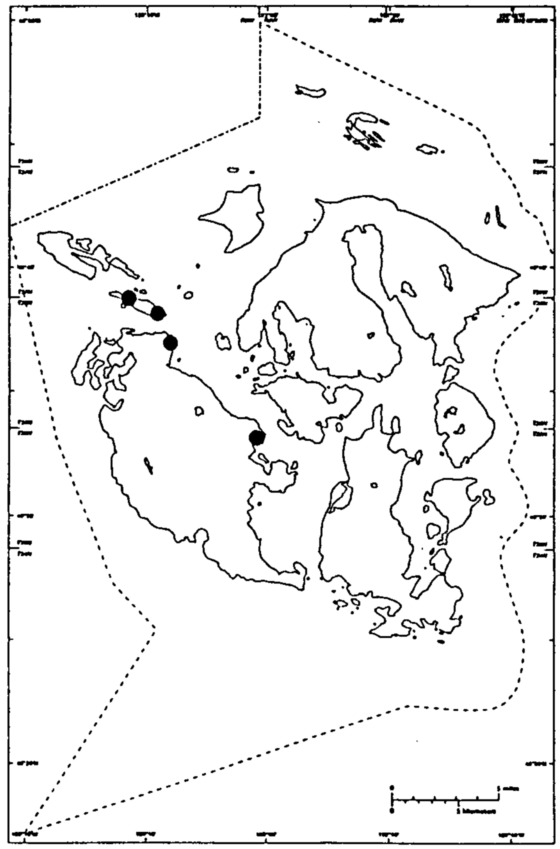
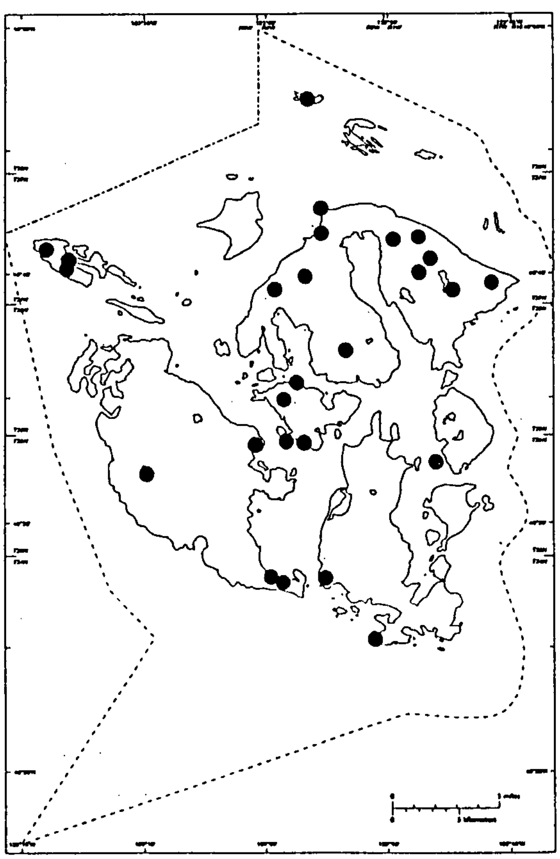


Pleuridium acuminatum



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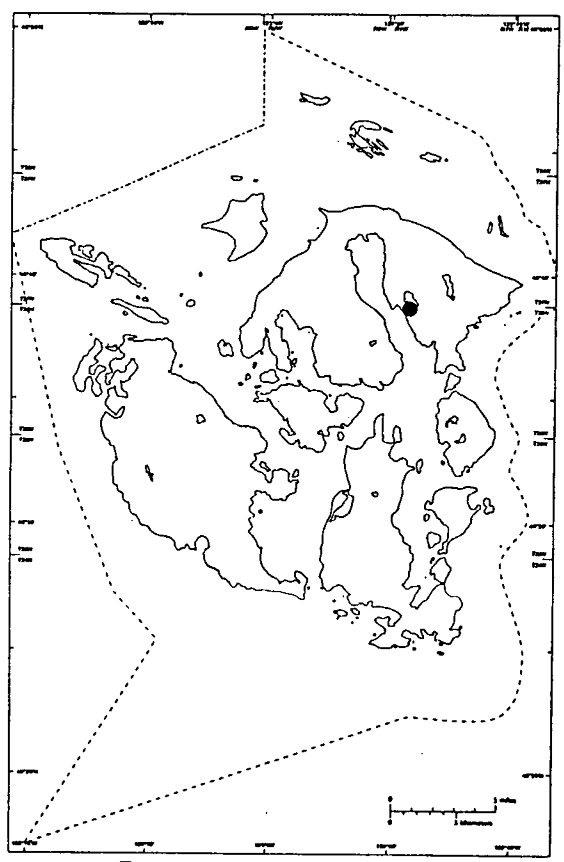
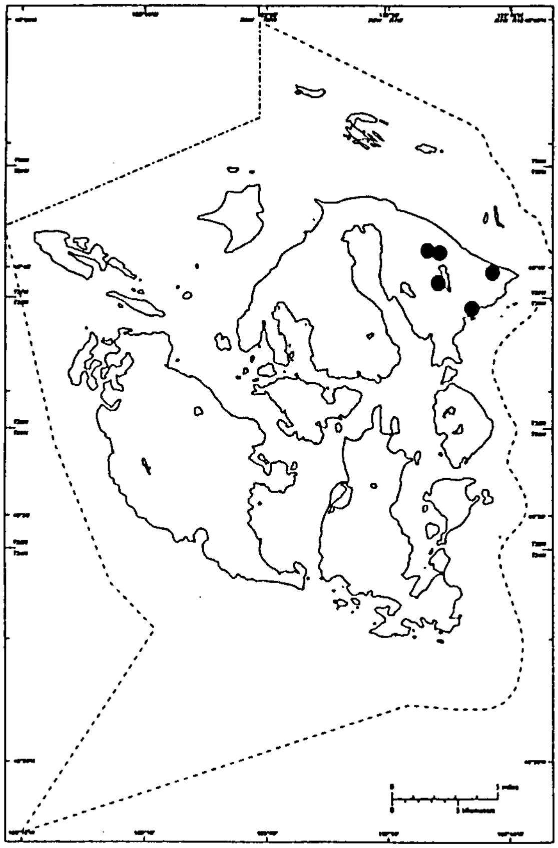


Pogonatum contortum



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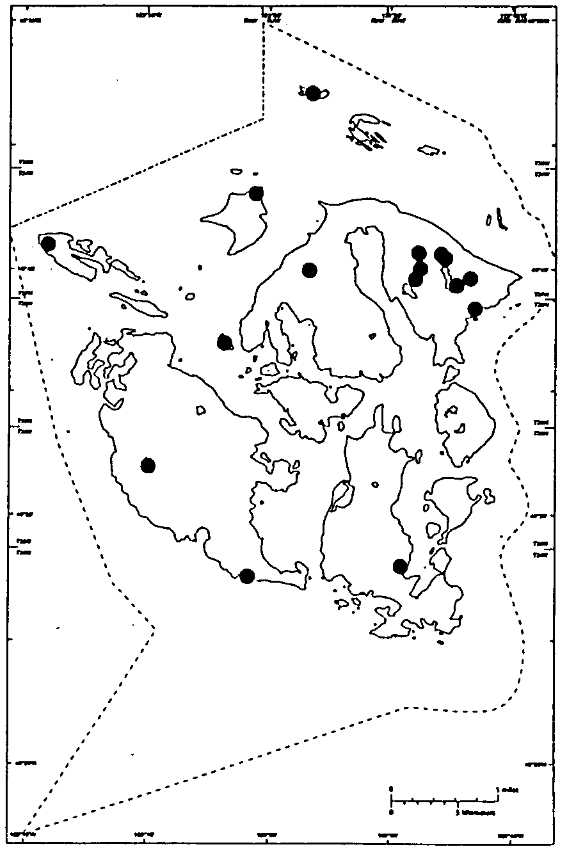
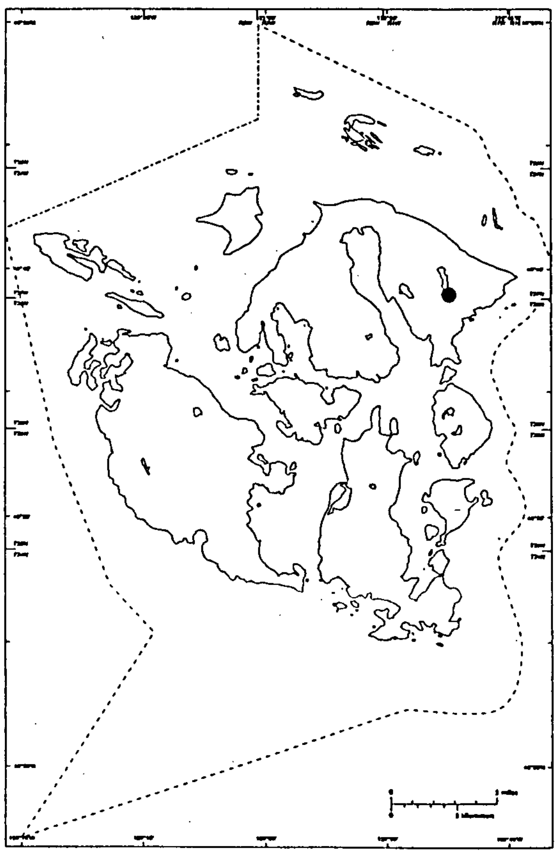


Pohlia cruda



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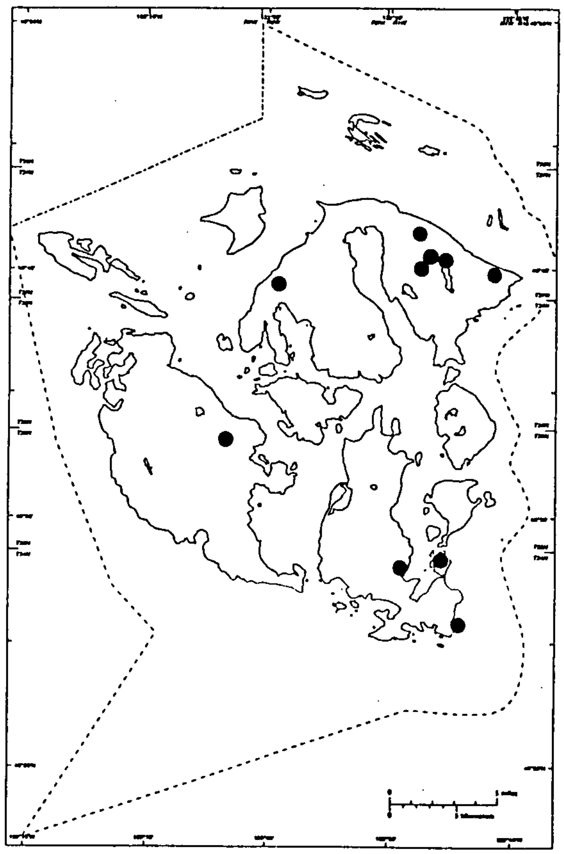
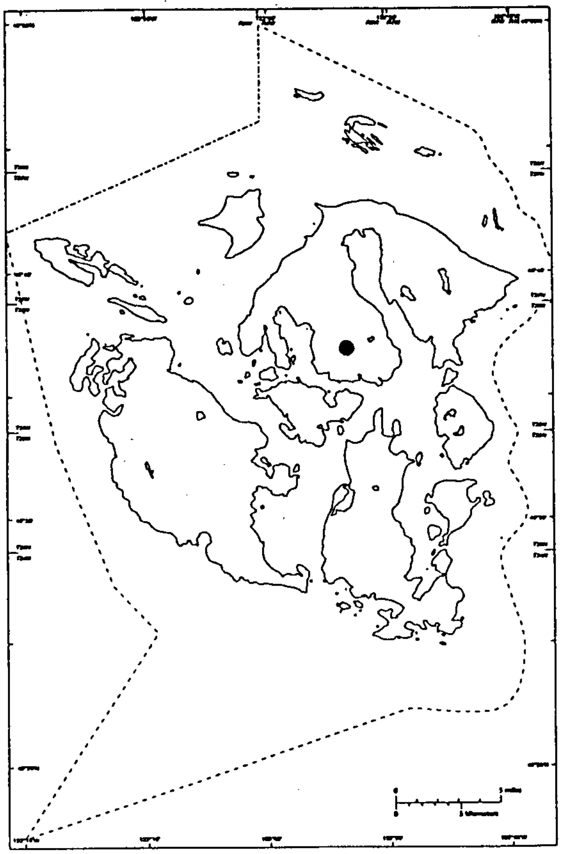
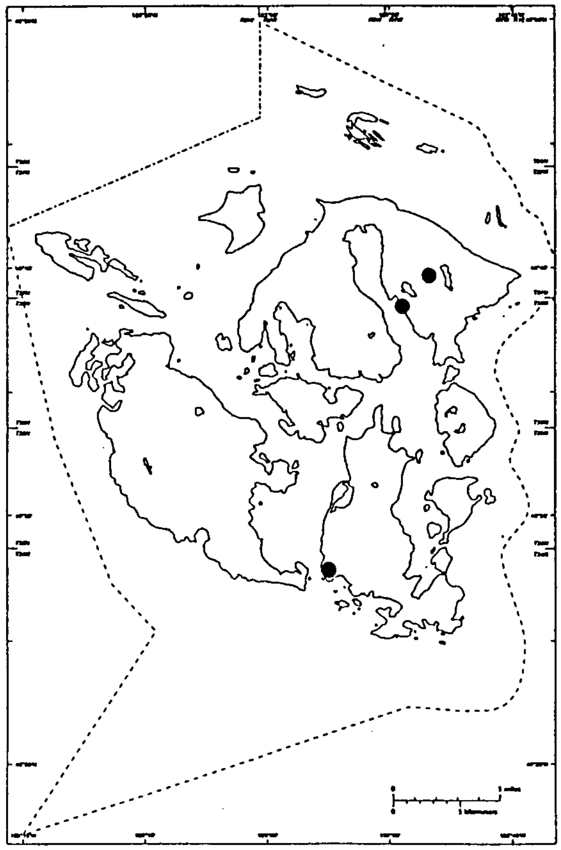


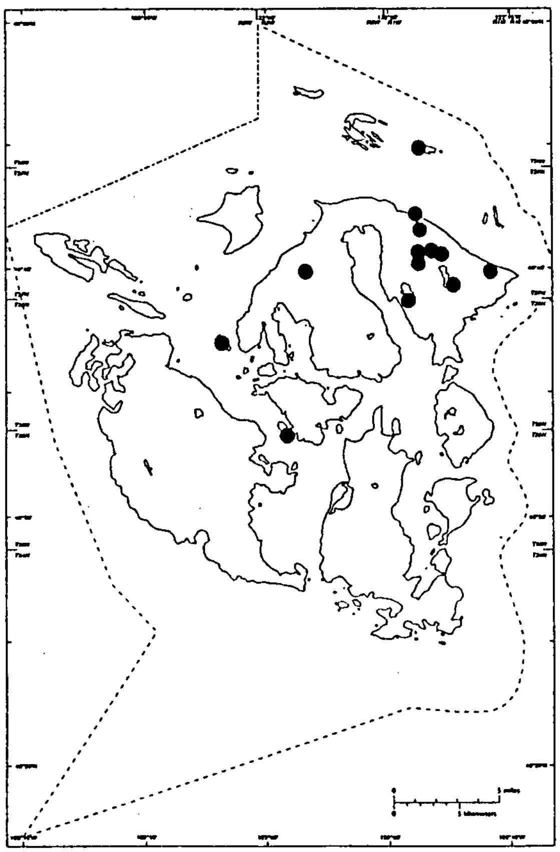
Pohlia nutans



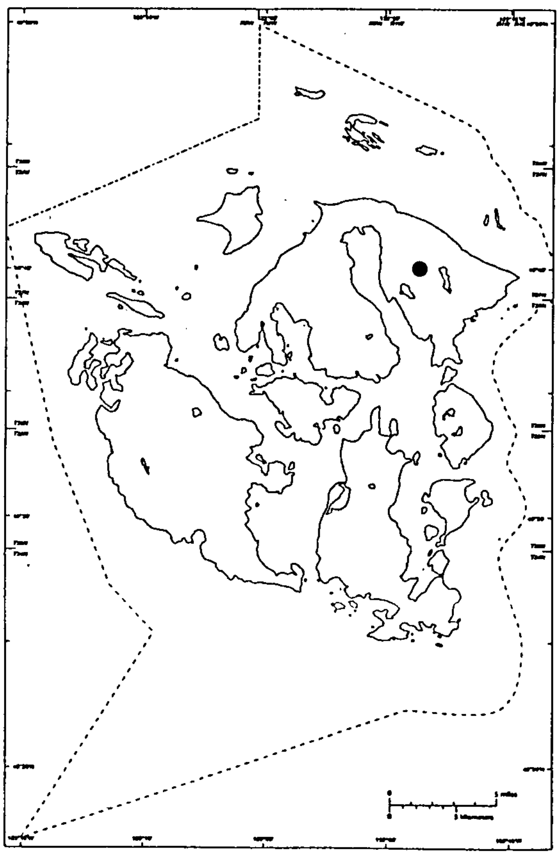
Pohlia sphagnicola



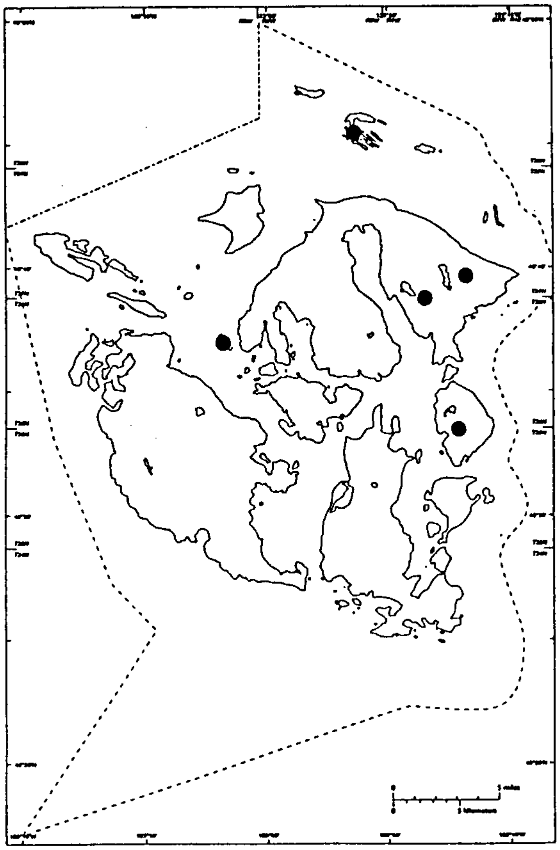
Pohlia wahlenbergii



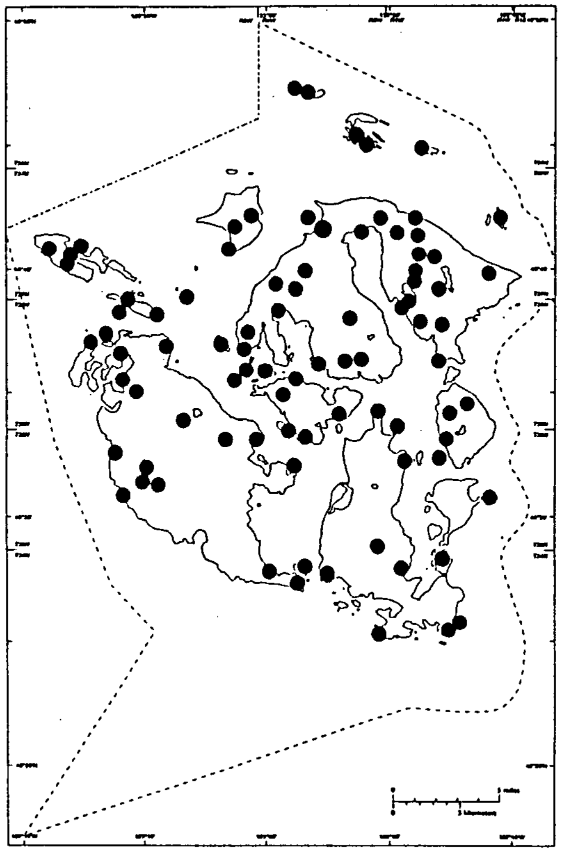
Polytrichastrum alpinum



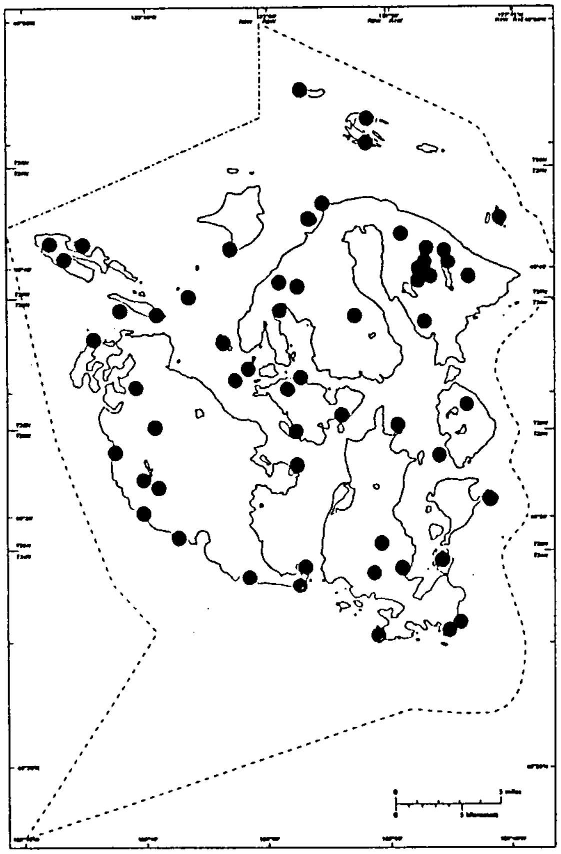
Polytrichum commune



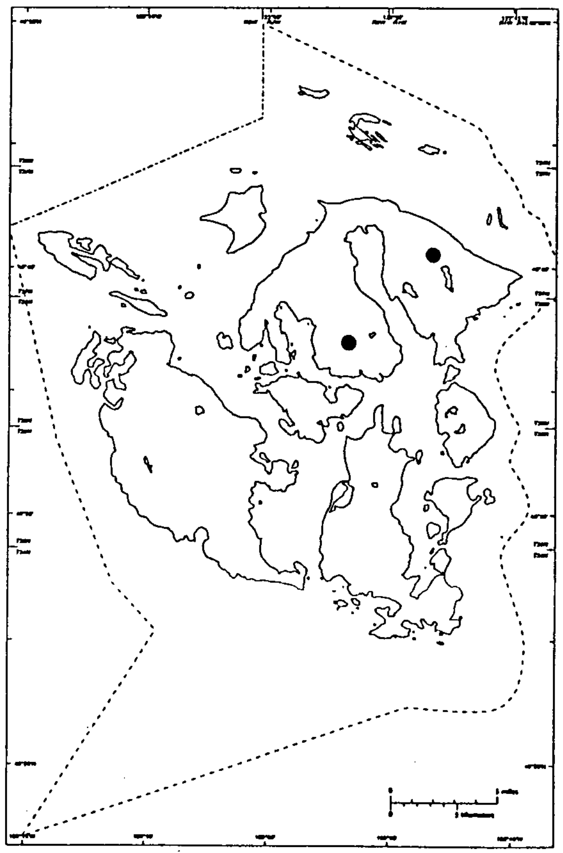
Polytrichum formosum



Polytrichum juniperinum



Polytrichum piliferum



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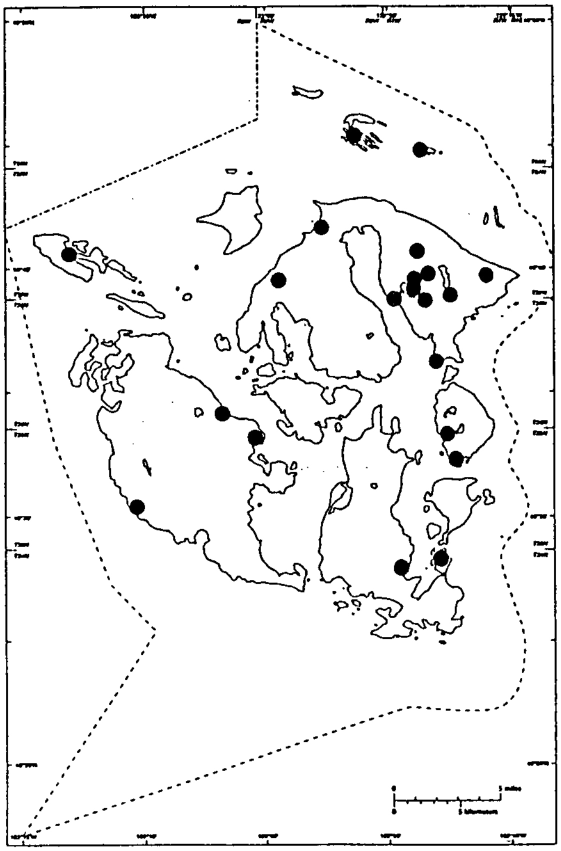

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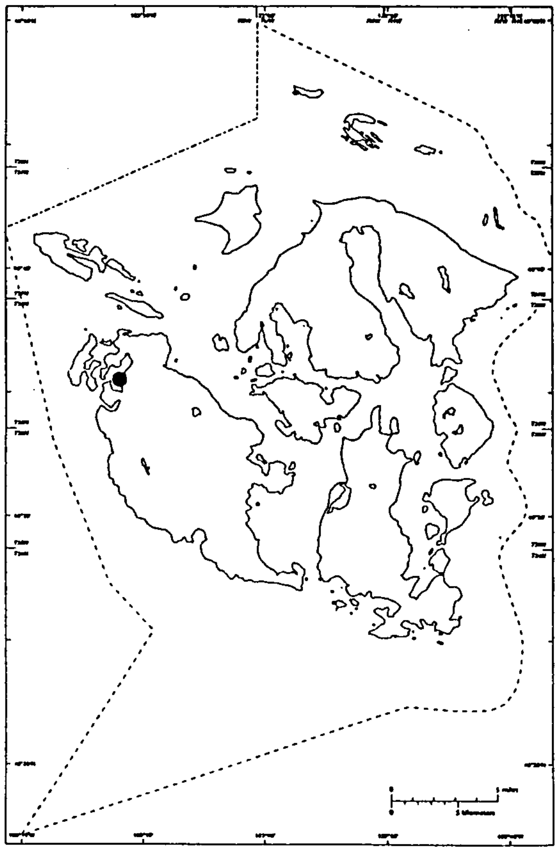

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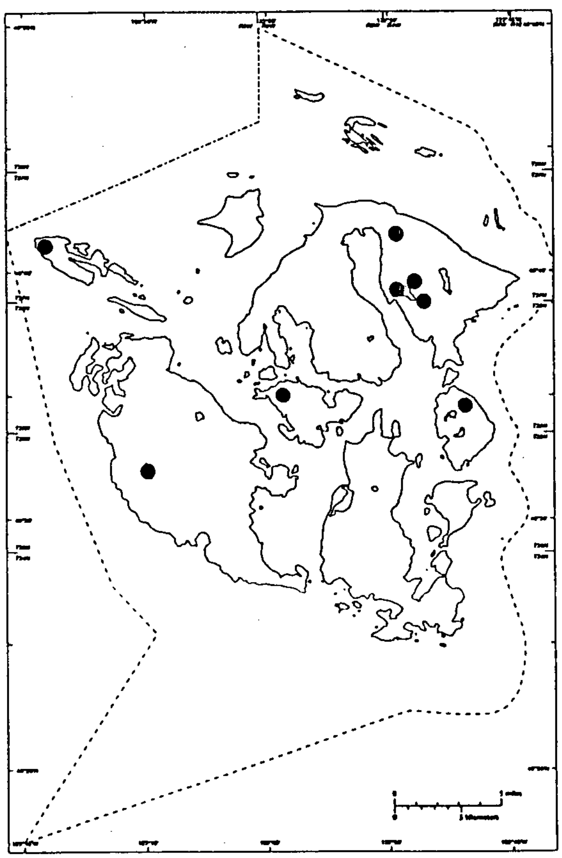
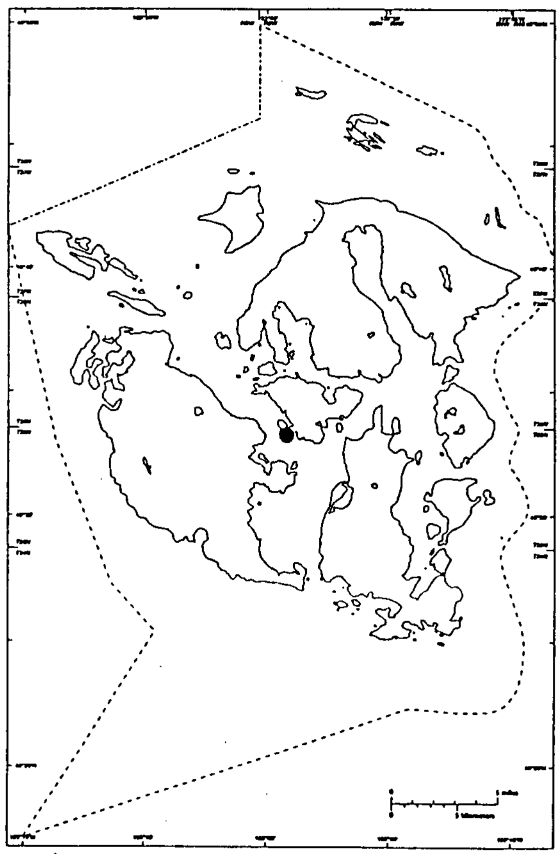
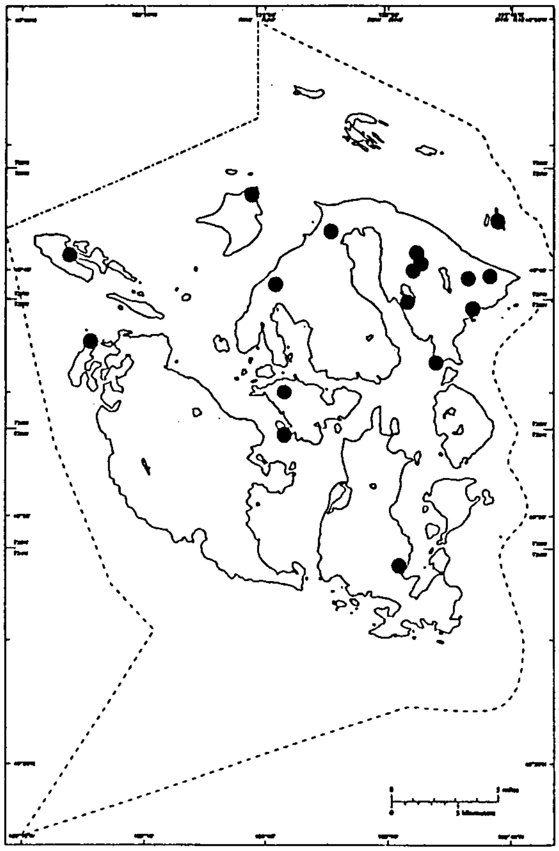


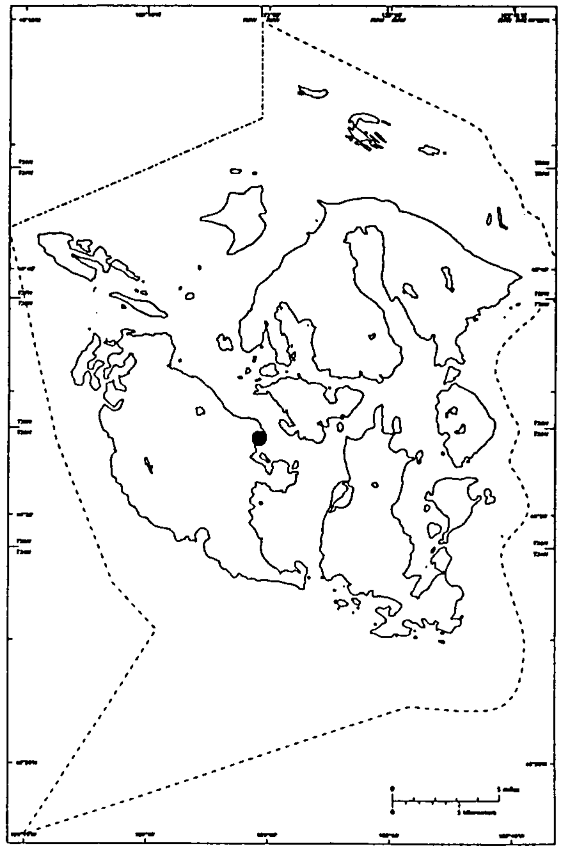
Pseudobraunia californica



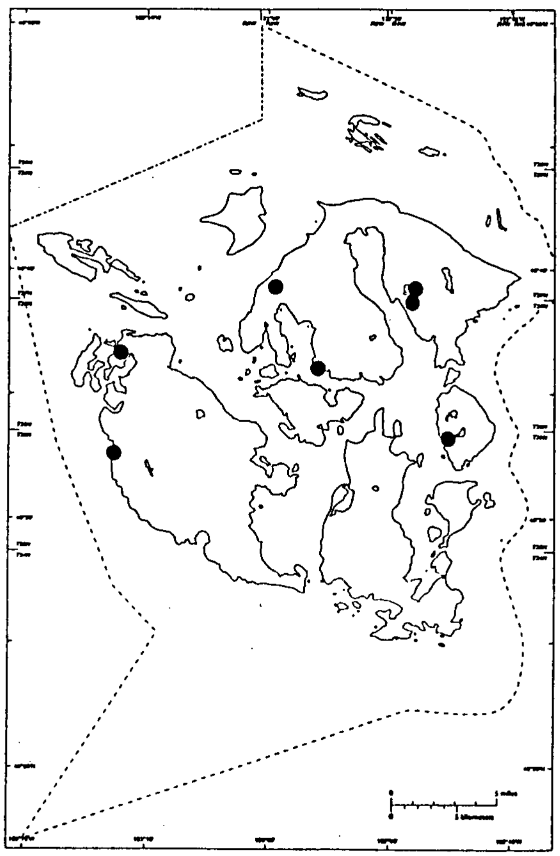
Pseudoscleropodium purum



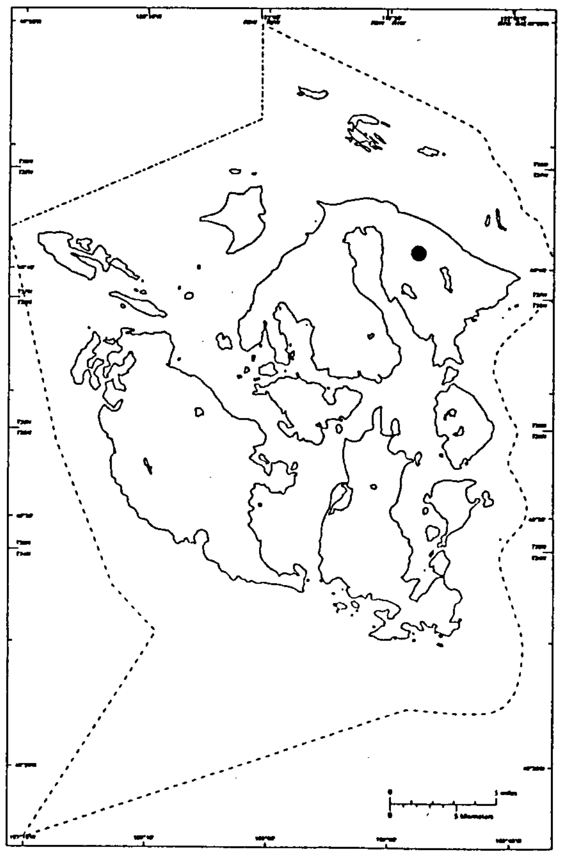
Pseudotaxiphyllum elegans



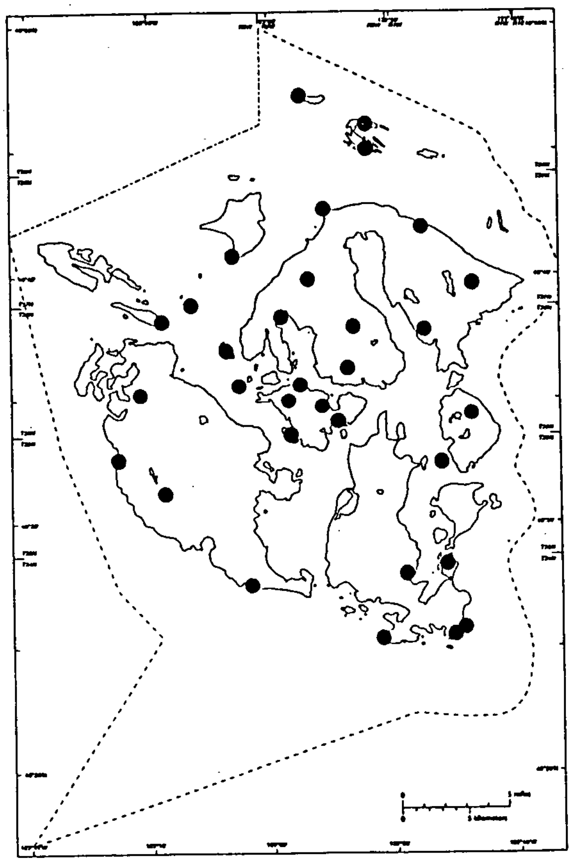
Pterogonium gracile



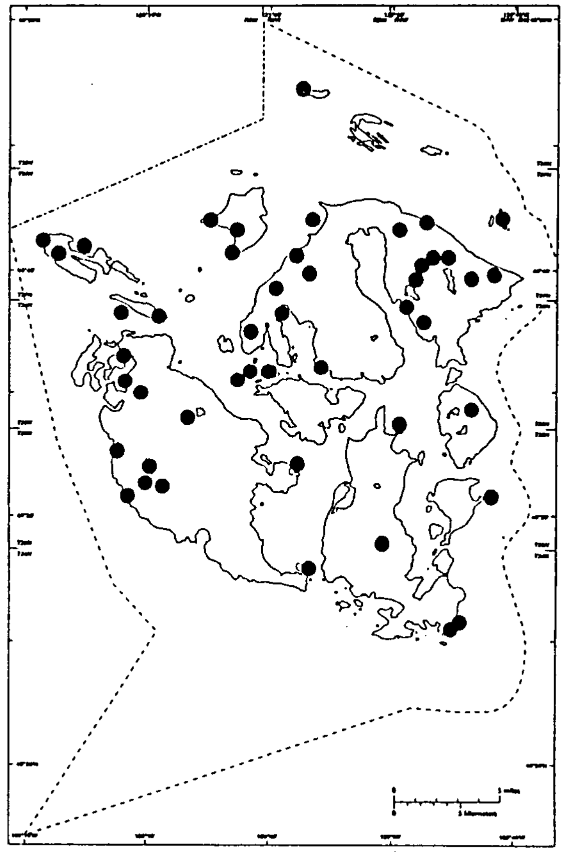
Ptychomitrium gardneri



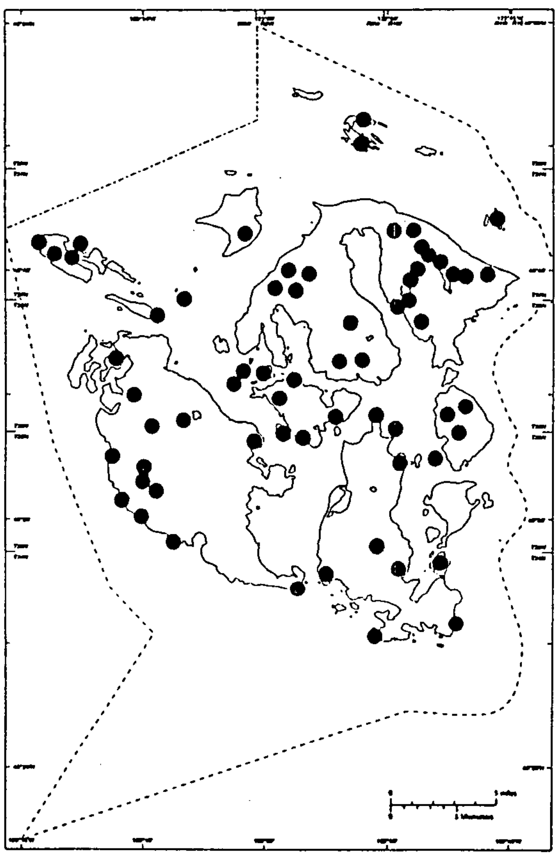
Racomitrium aciculare



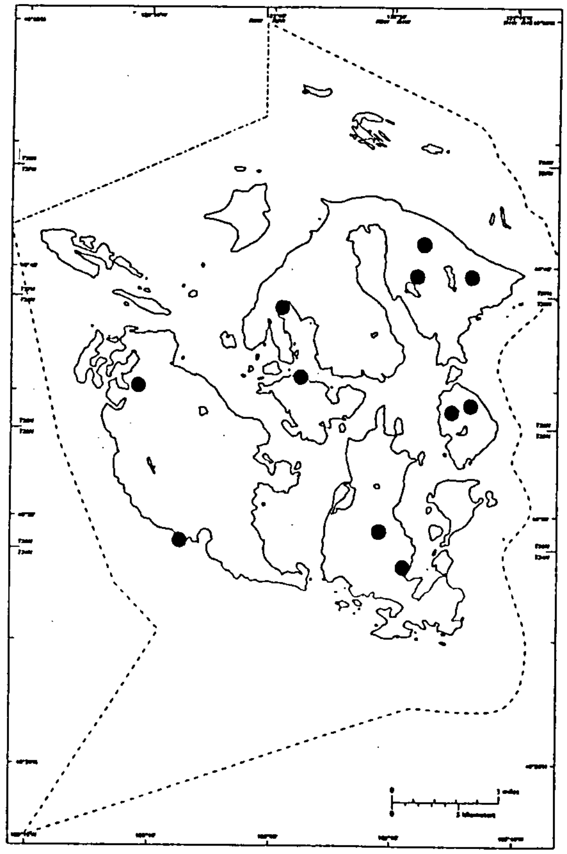
Racomitrium elongatum



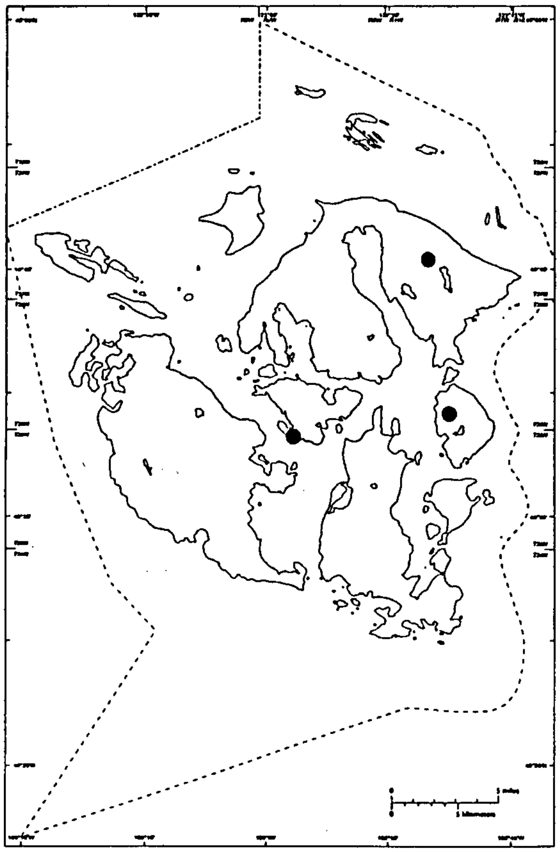
Racomitrium ericoides



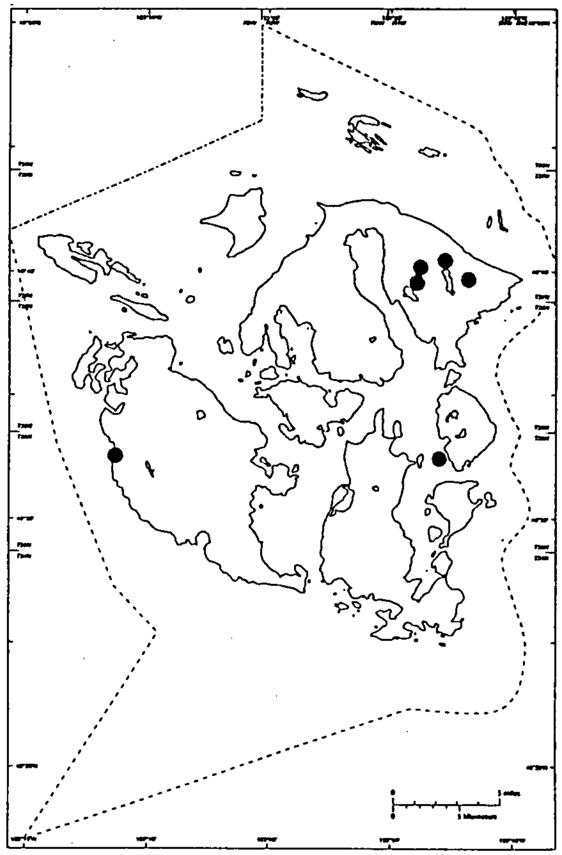
Racomitrium heterostichum



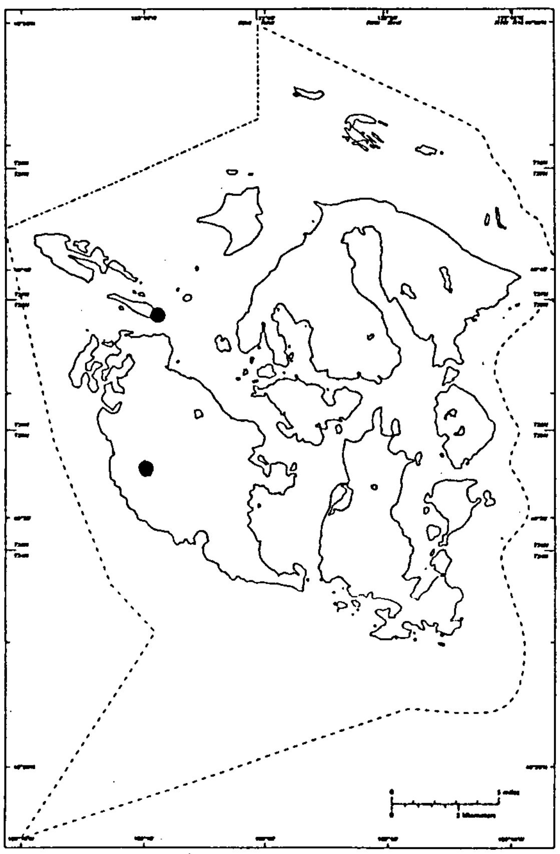
Racomitrium lanuginosum



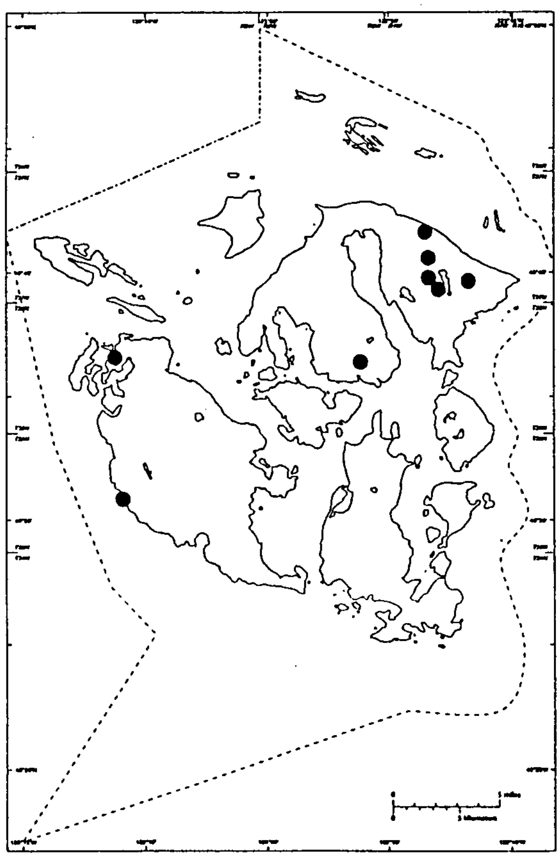
Racomitrium lawtonae



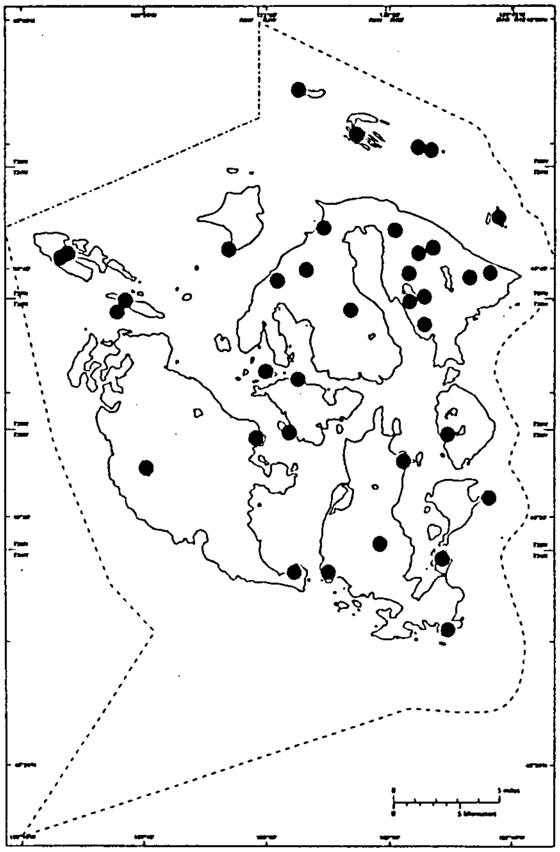
Racomitrium occidentale



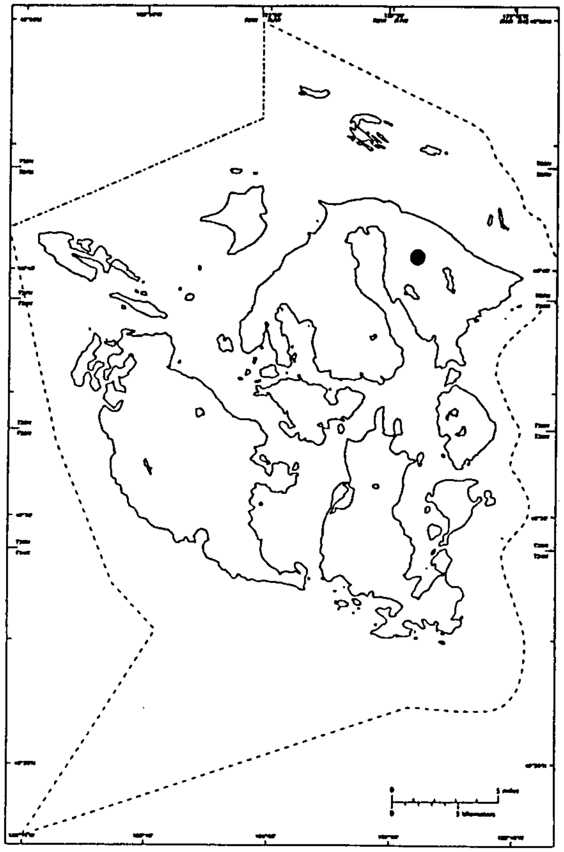
Racomitrium pacificum



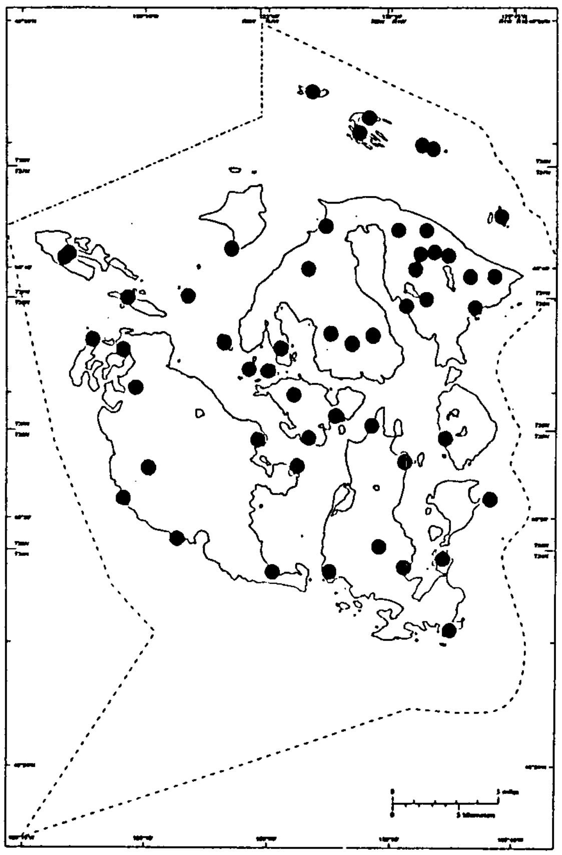
Racomitrium varium



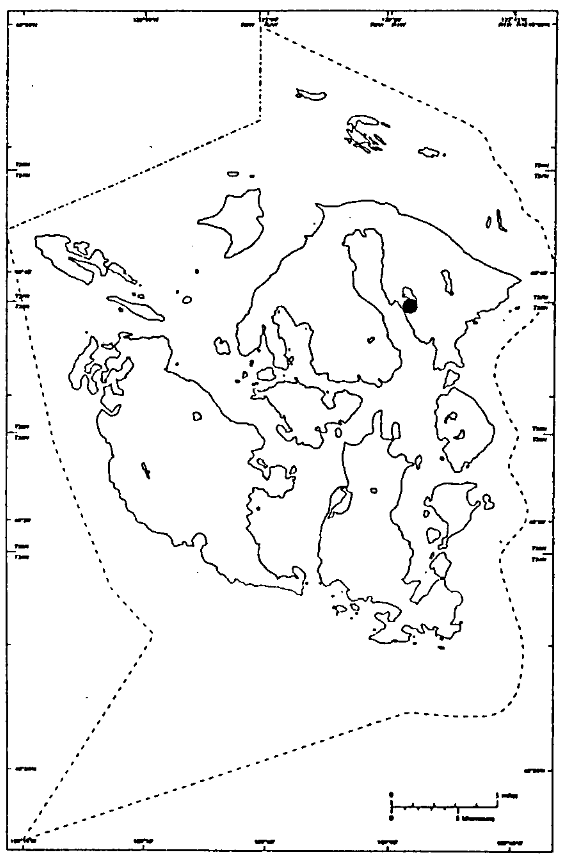
Rhizomnium glabrescens



Rhizomnium magnifolium



Rhytidiadelphus loreus



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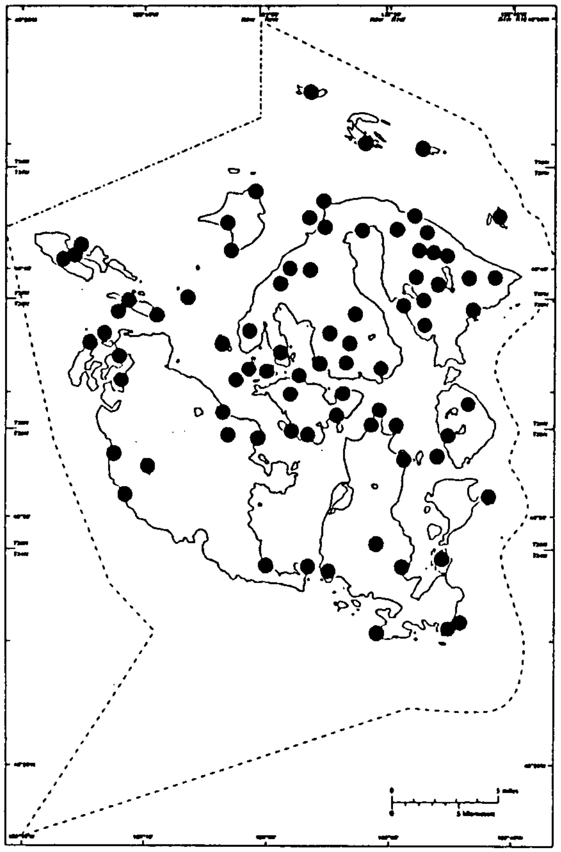

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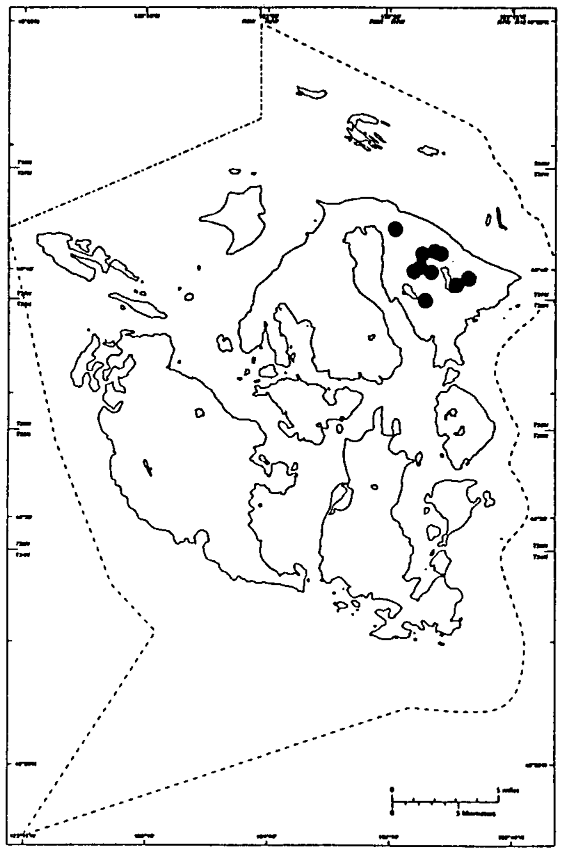
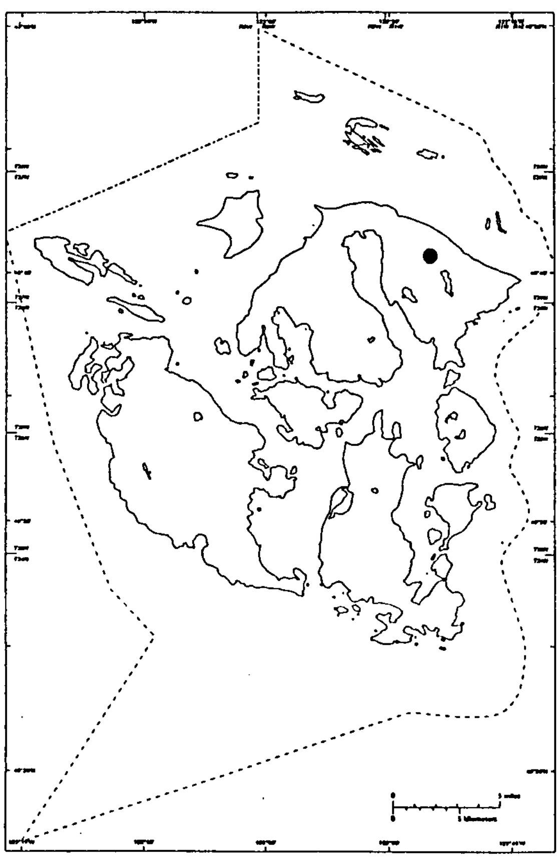
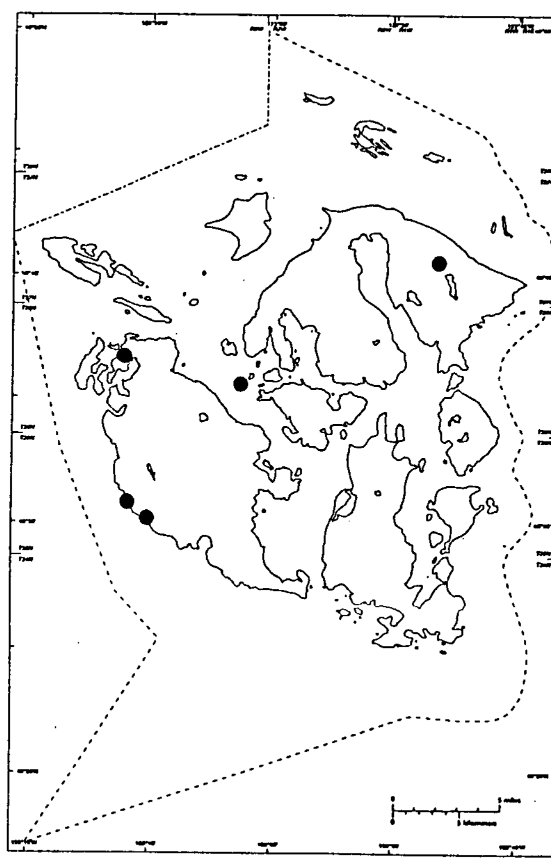


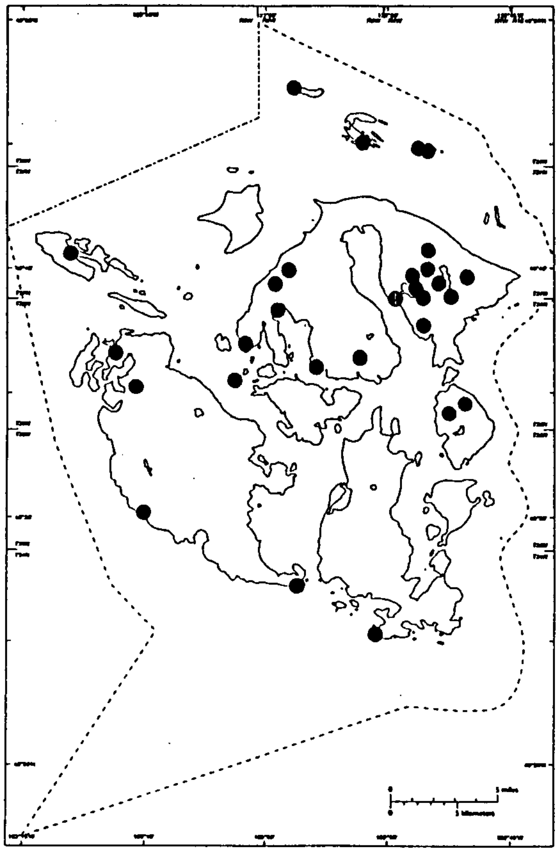
Rhytidiopsis robusta



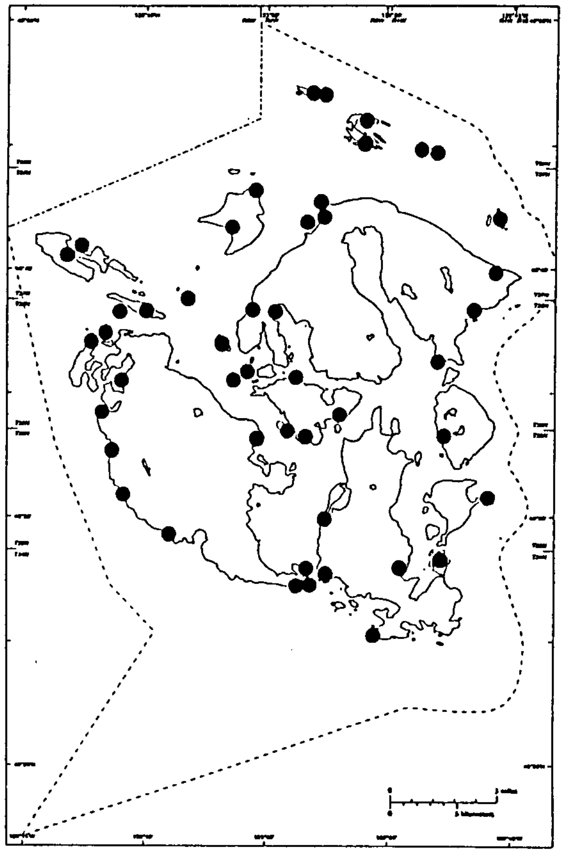
Sanionia uncinata



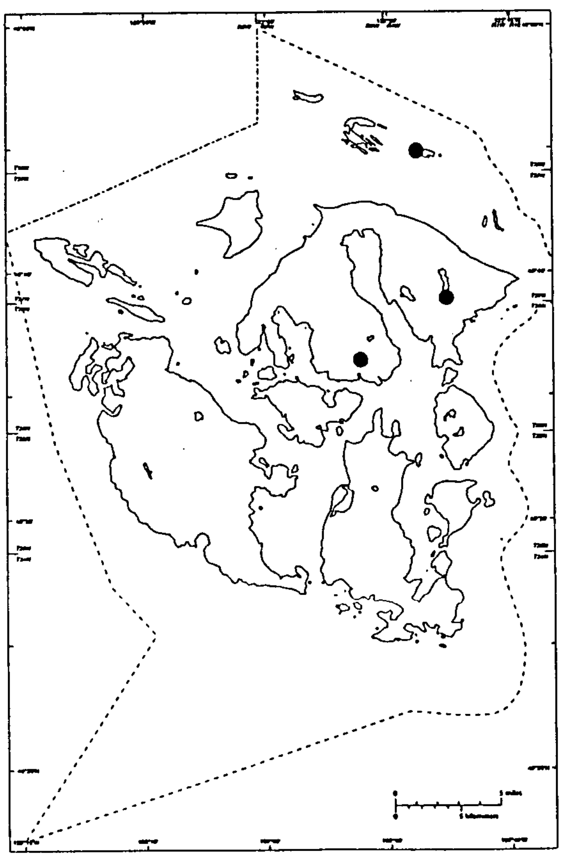
Schistidium agassizii



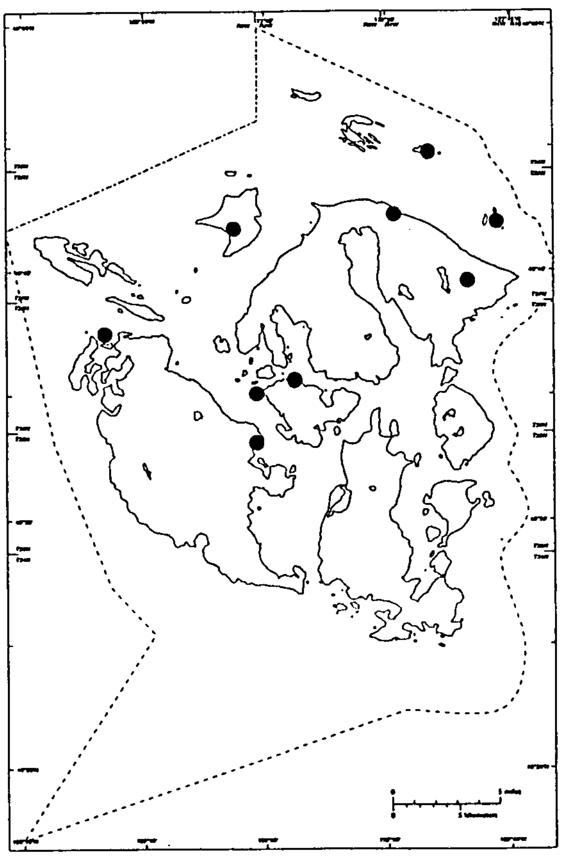
Schistidium apocarpum



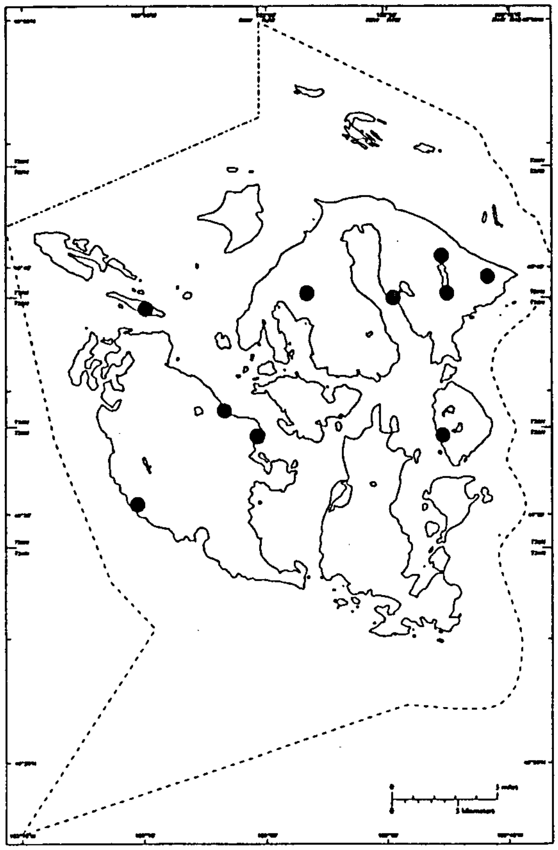
Schistidium maritimum



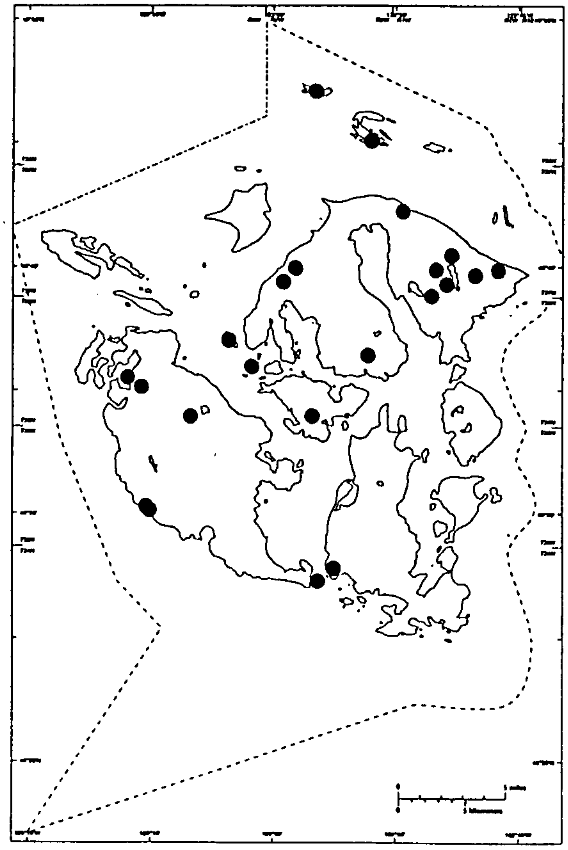
Schistidium rivulare



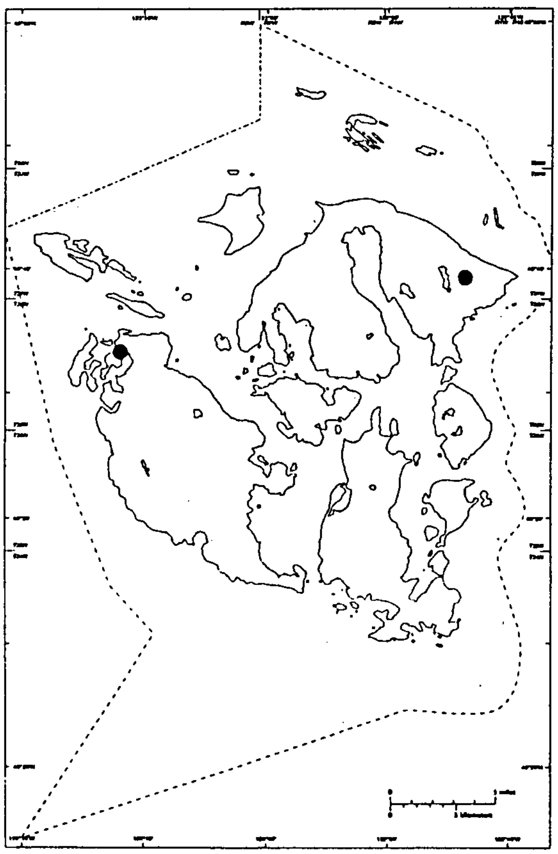
Scleropodium cespitans



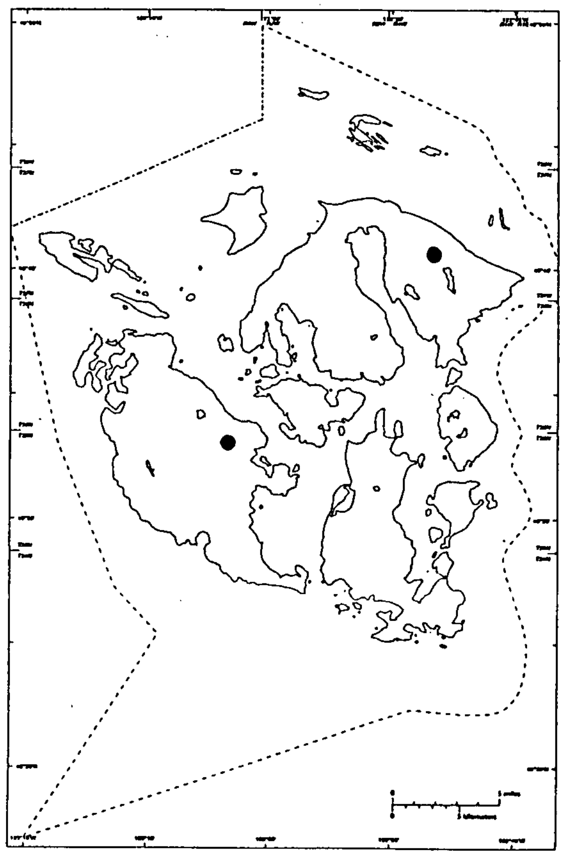
Scleropodium obtusifolium



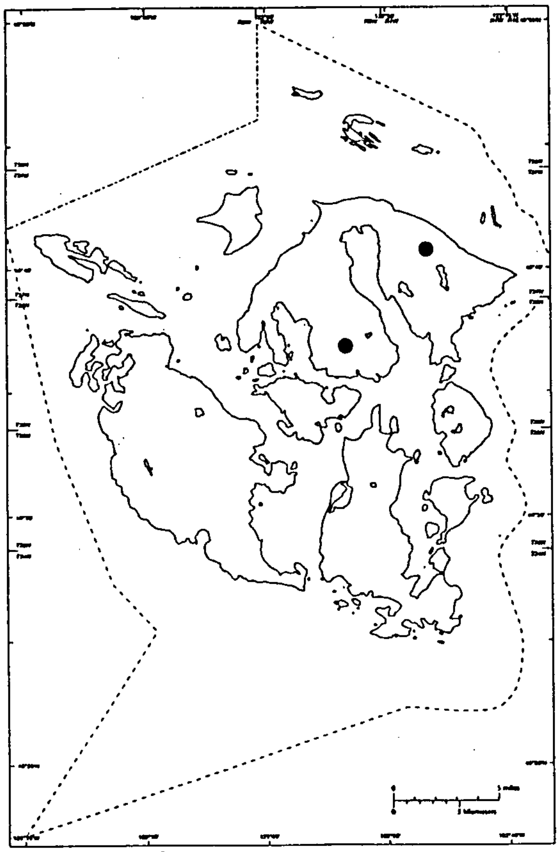
Scleropodium touretii var. *touretii*



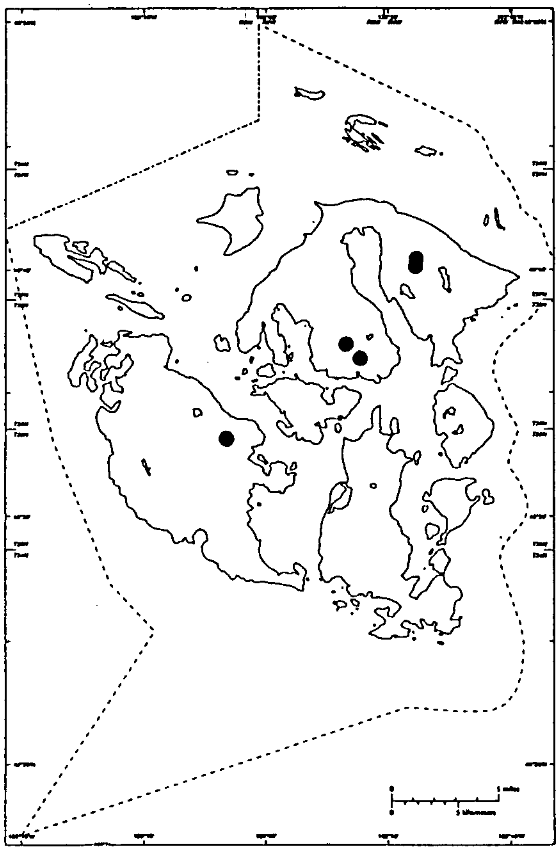
Scleropodium touretii var. *colpophyllum*



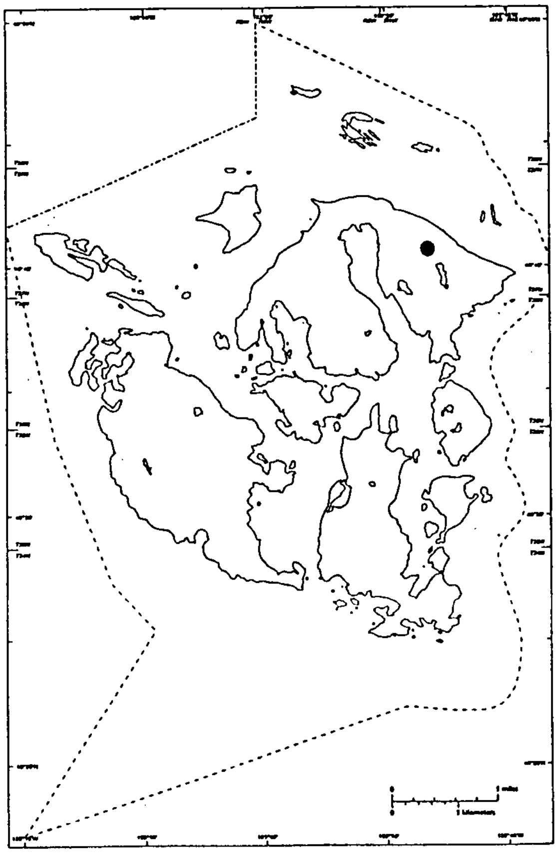
Sphagnum capillifolium



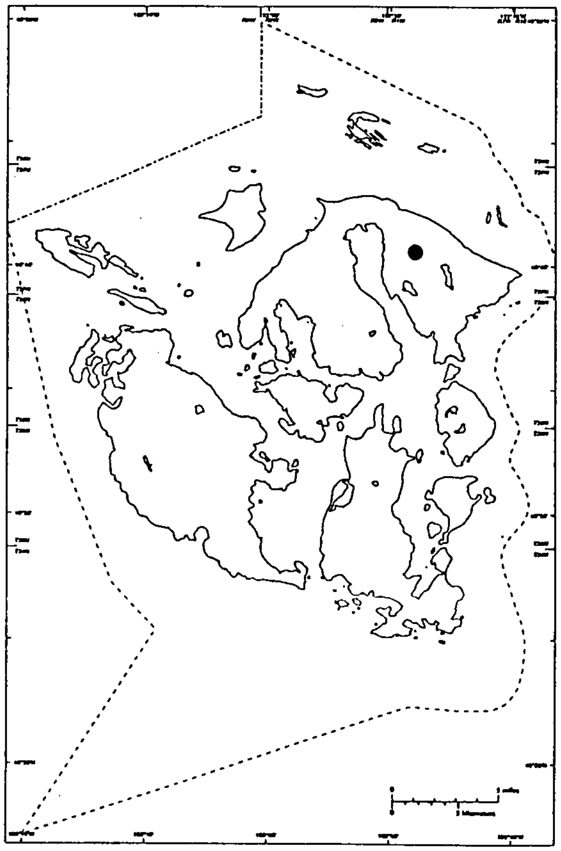
Sphagnum fuscum



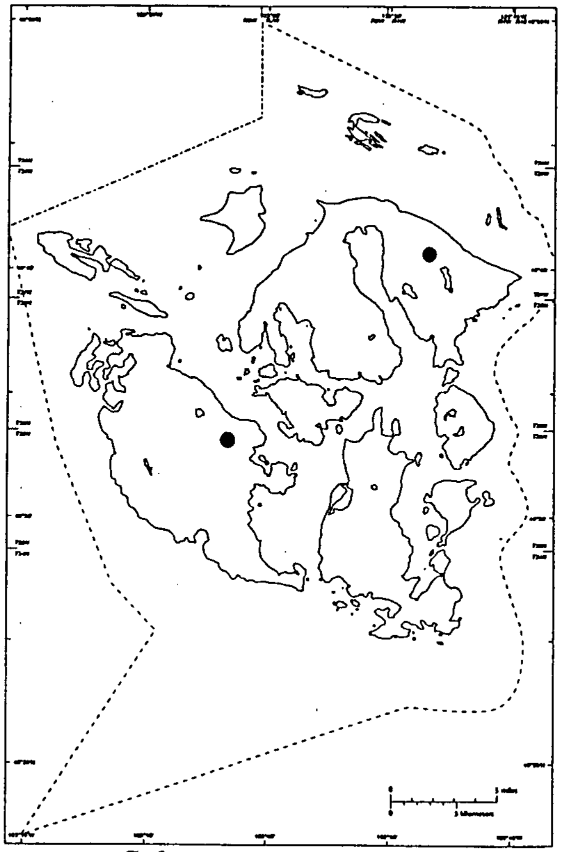
Sphagnum henryense



Sphagnum magellanicum



Sphagnum palustre



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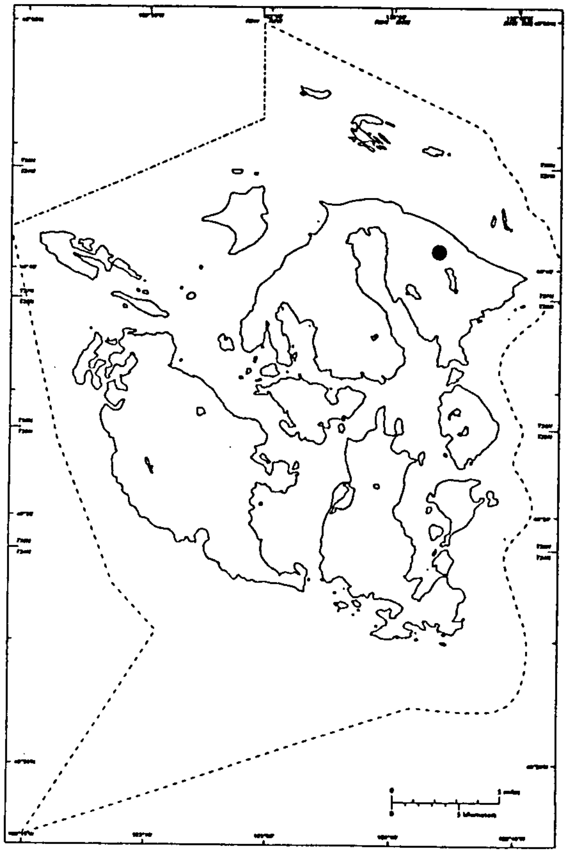

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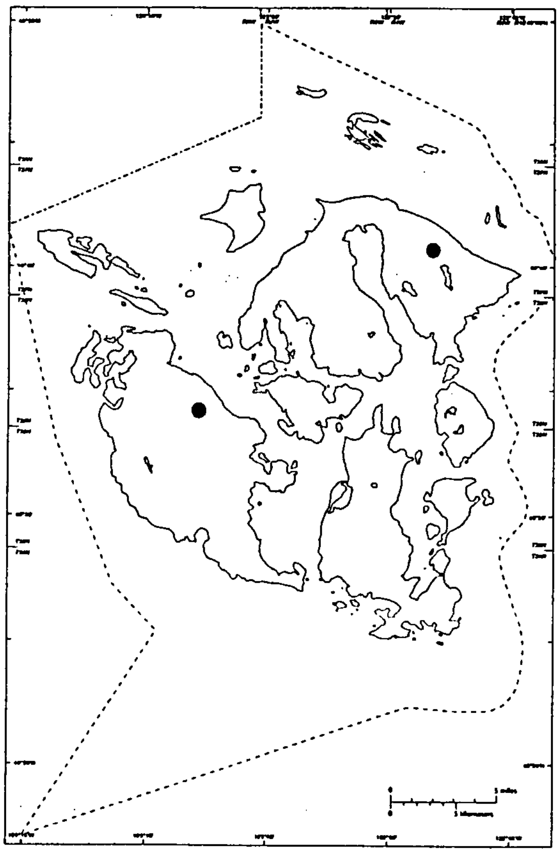

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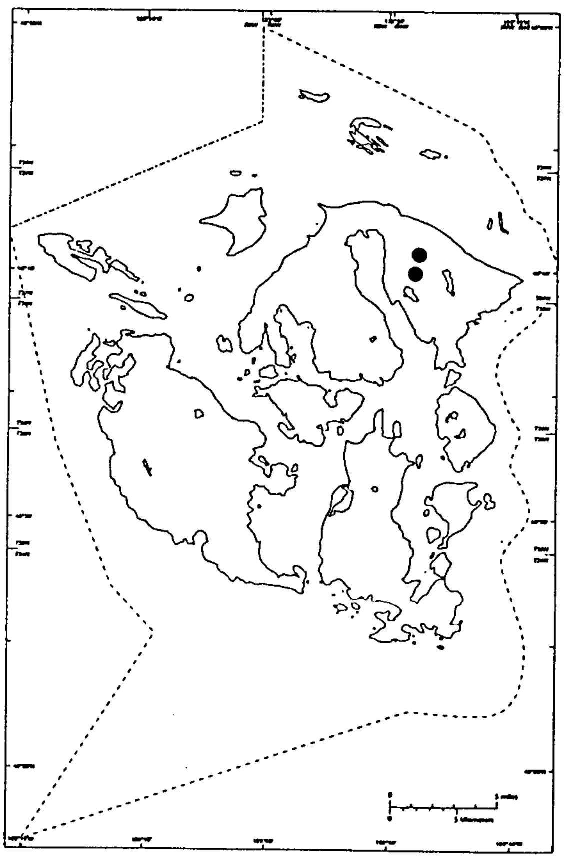
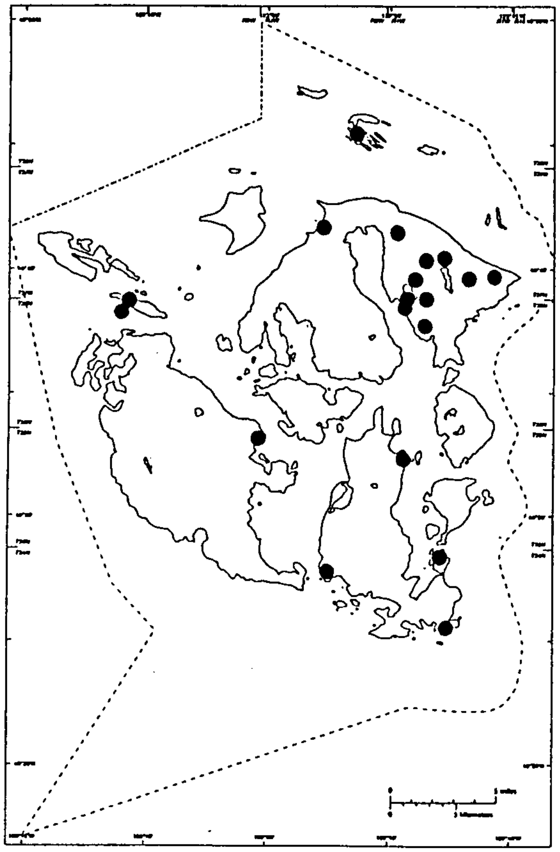
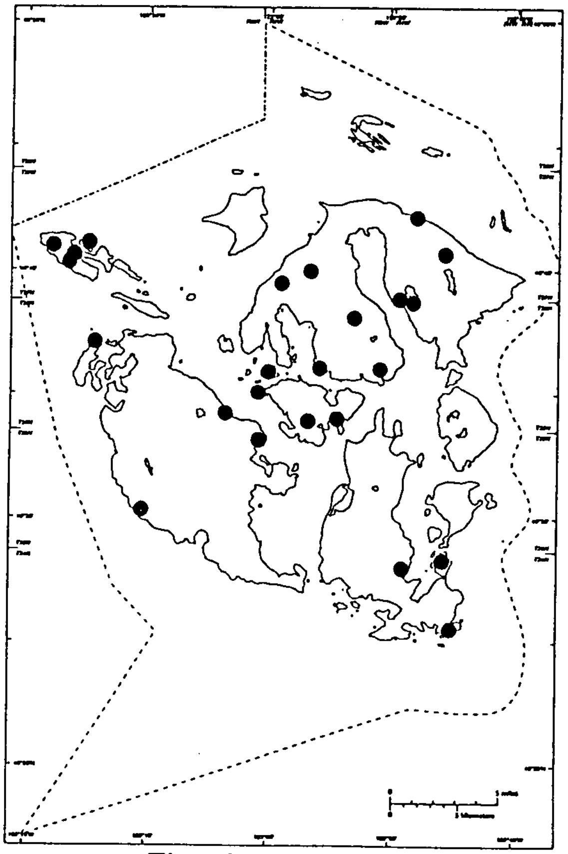


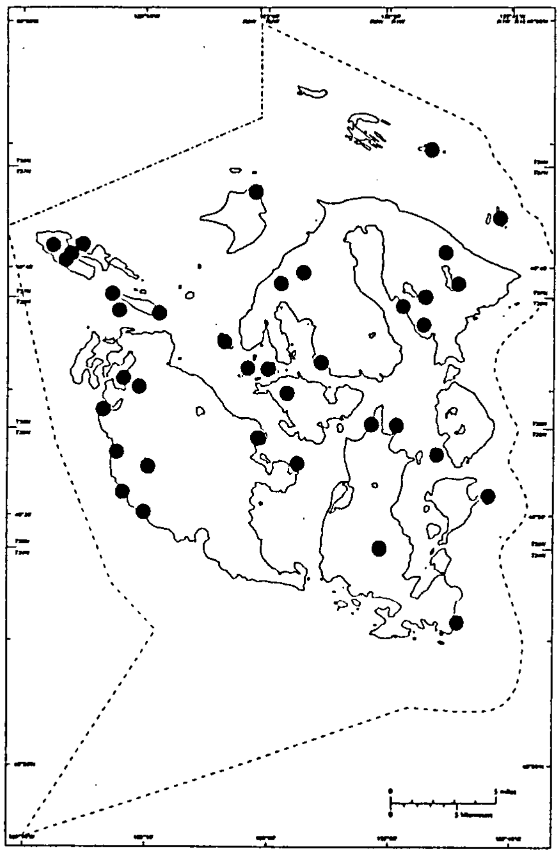
Sphagnum subsecundum



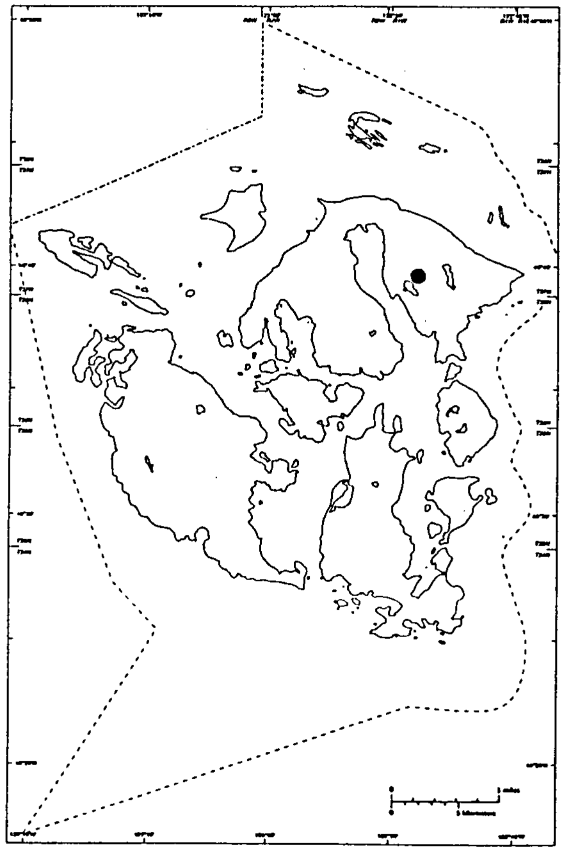
Tetraphis pellucida



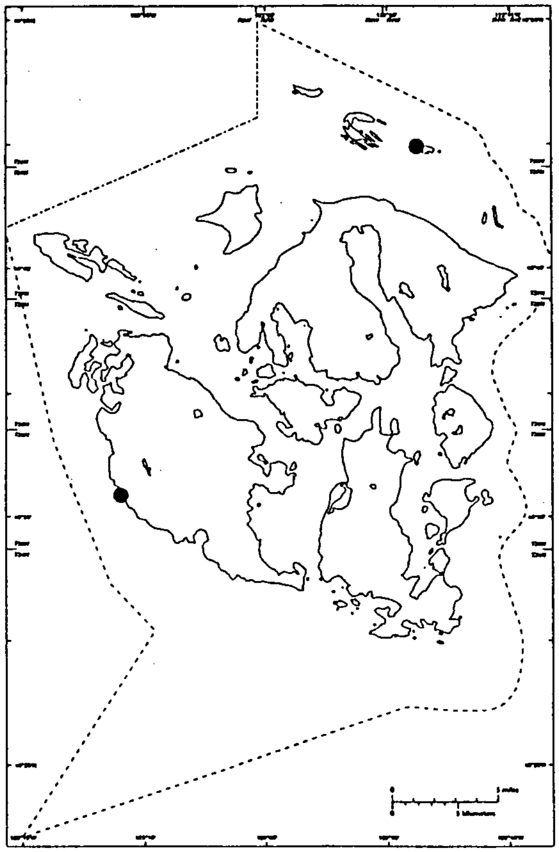
Timmia austriaca



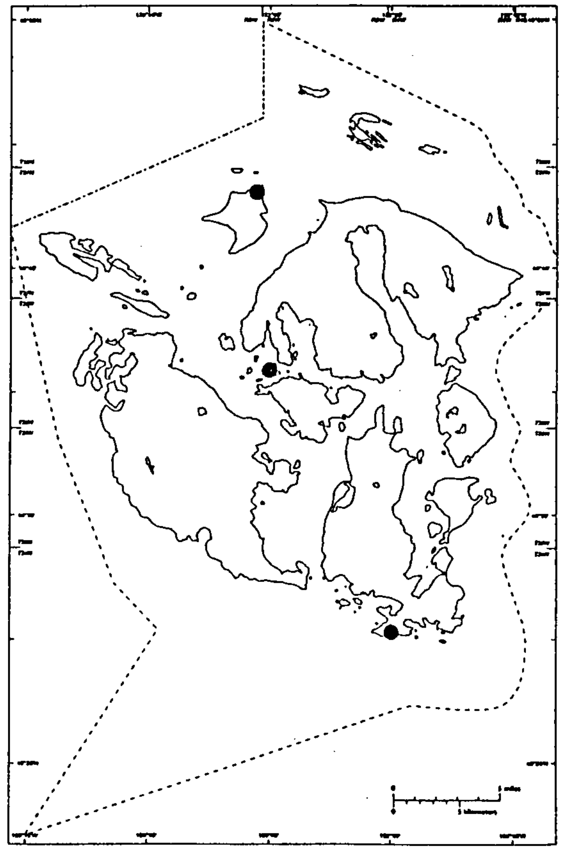
Timmiella crassinervis



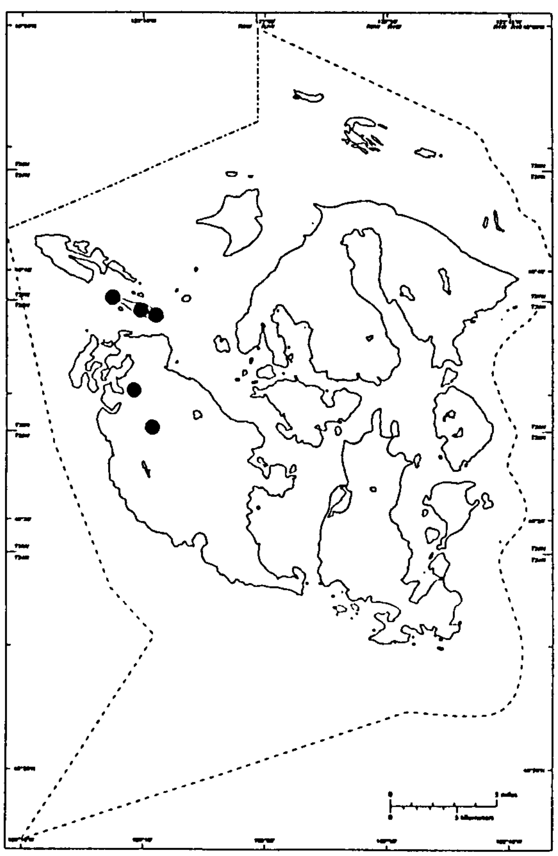
Tortella fragilis



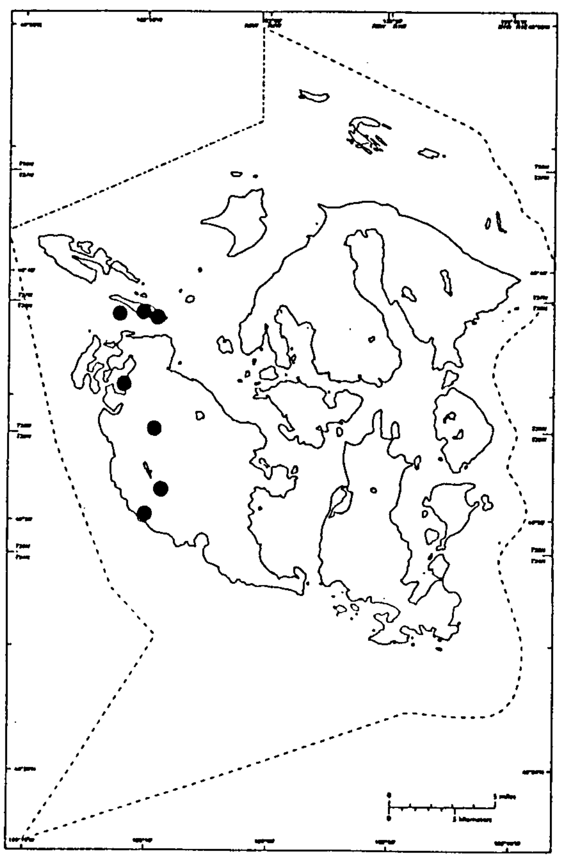
Tortella tortuosa



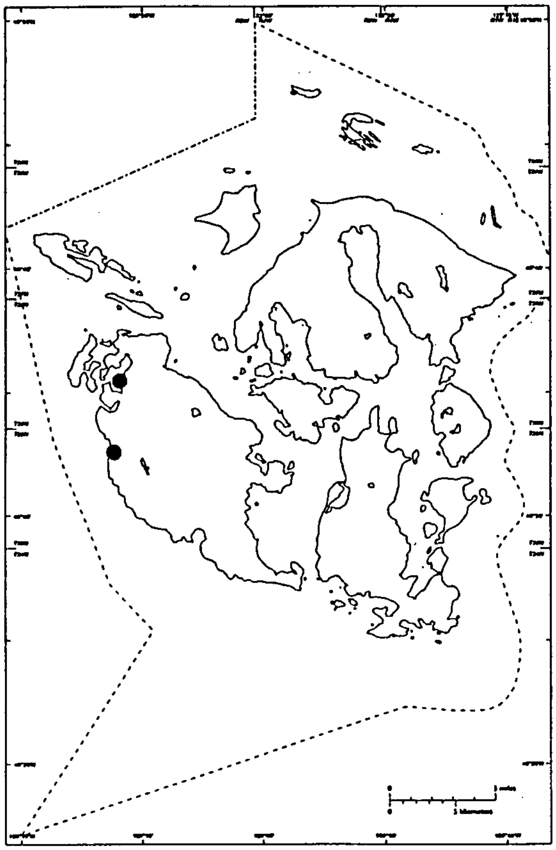
Tortula amplexa



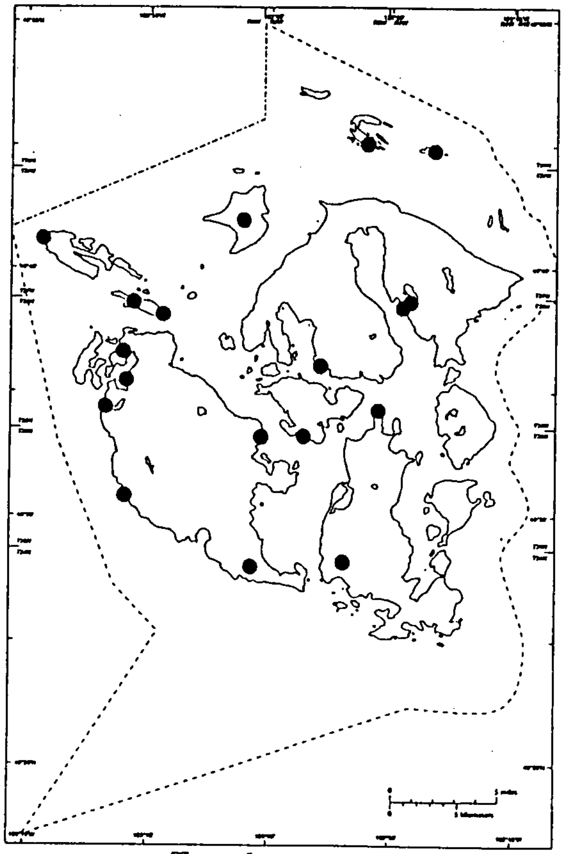
Tortula laevipila var. *laevipila*



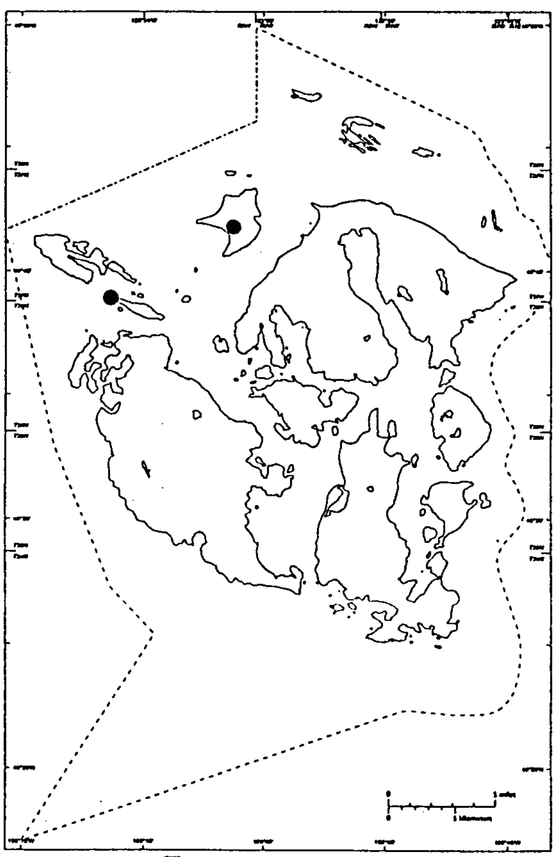
Tortula laevipila var. *meridionalis*



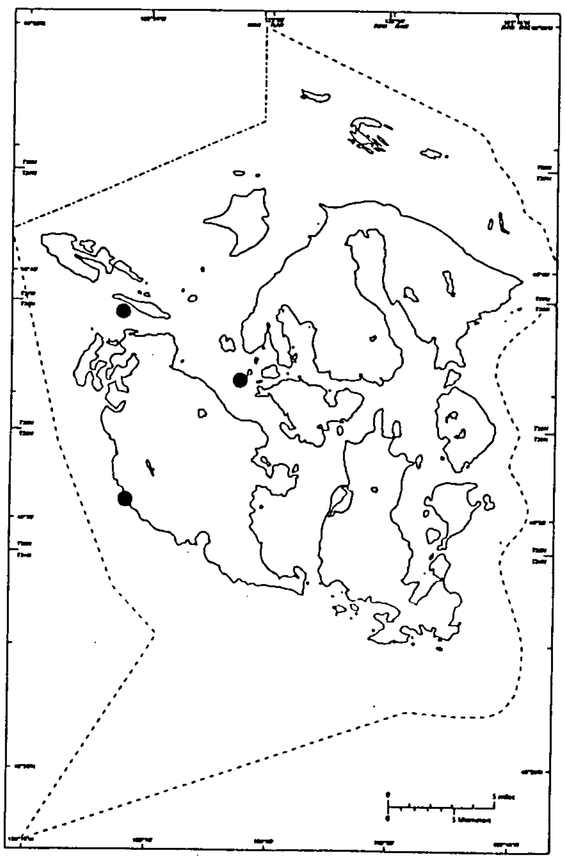
Tortula latifolia



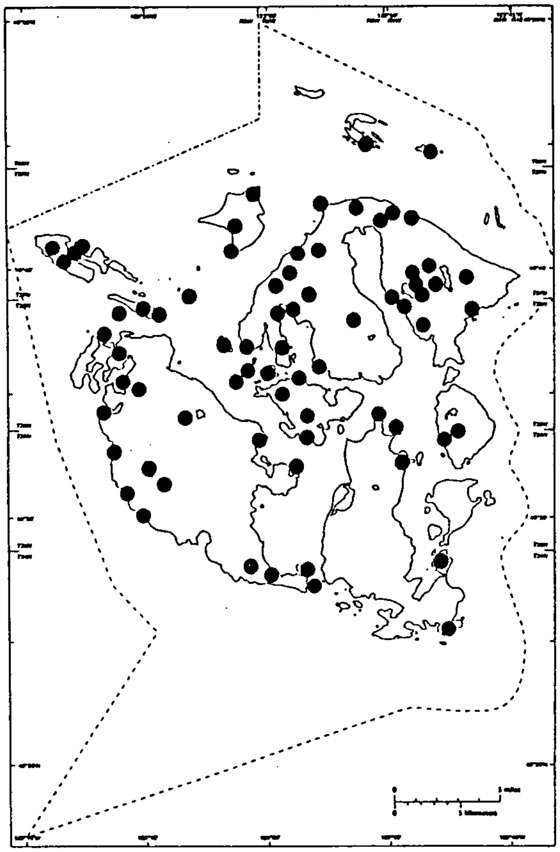
Tortula muralis



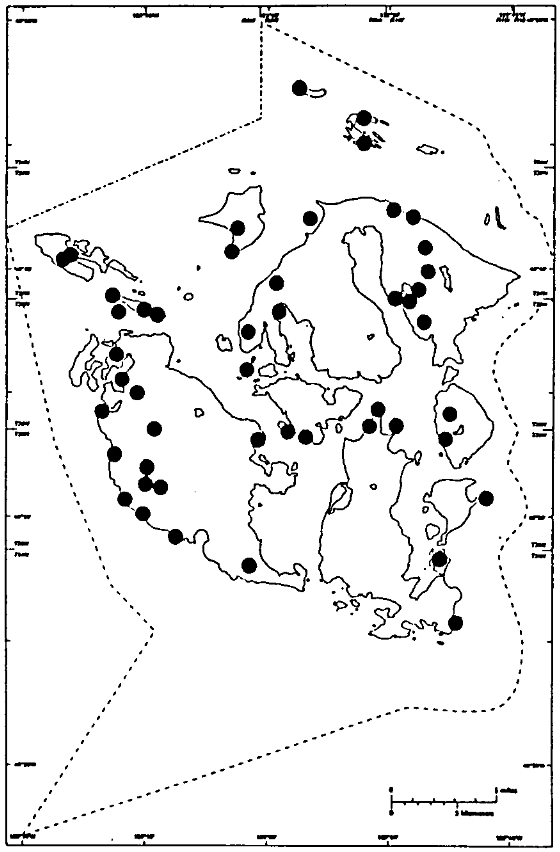
Tortula papillosa



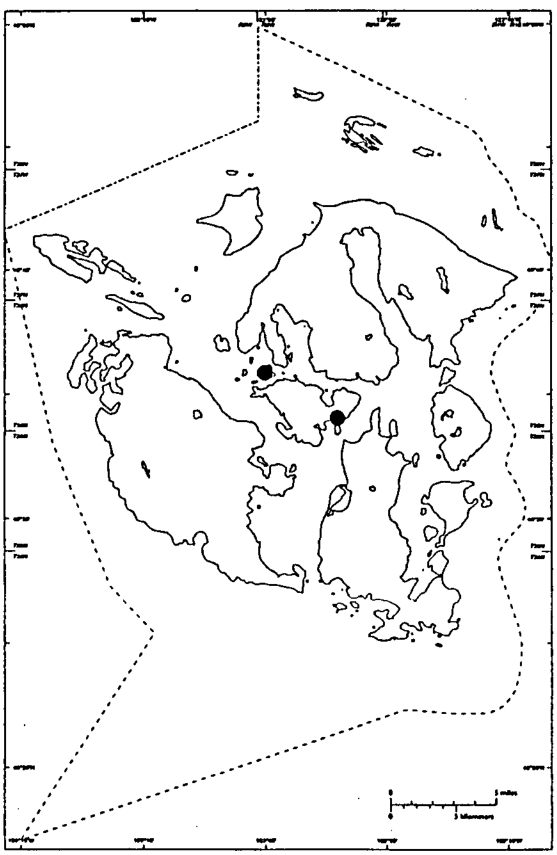
Tortula papillosissima



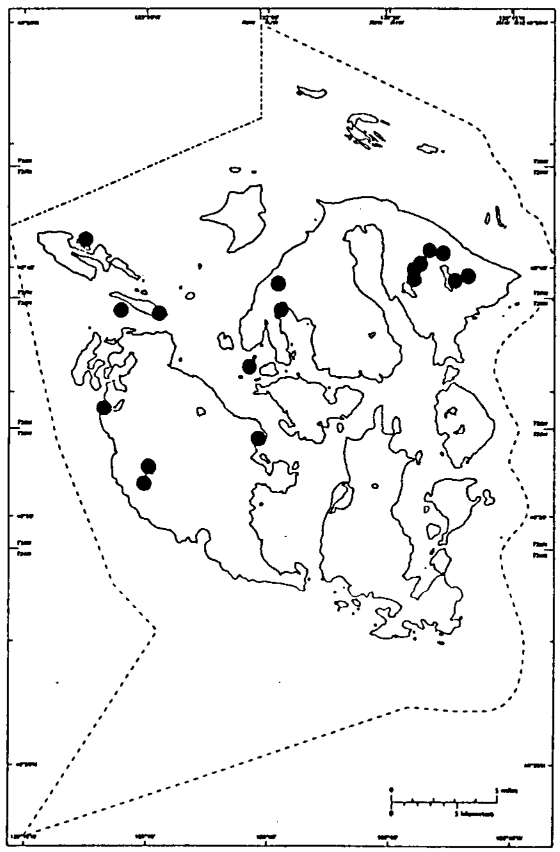
Tortula princeps



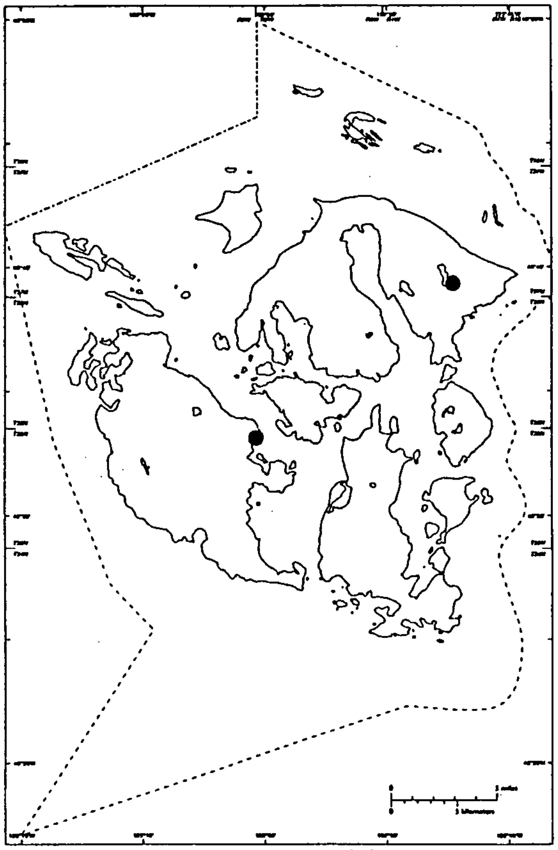
Tortula ruralis



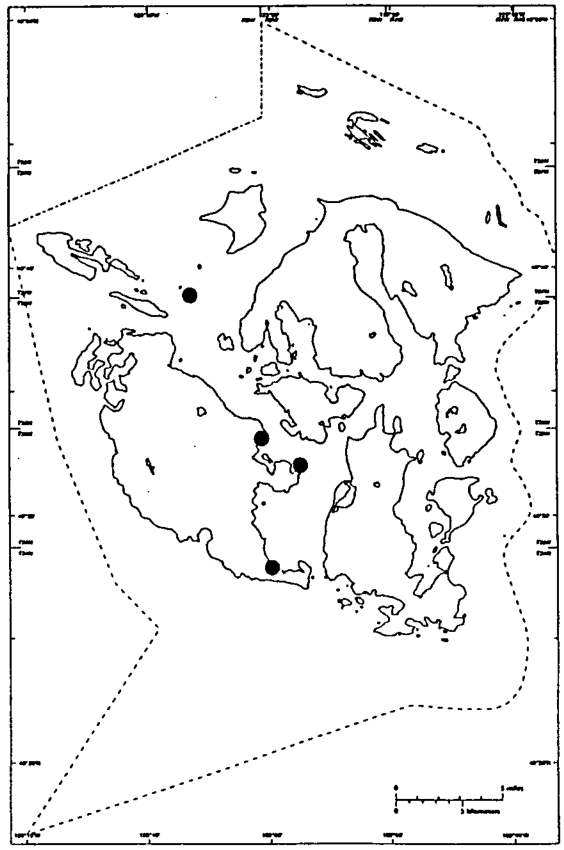
Tortula subulata



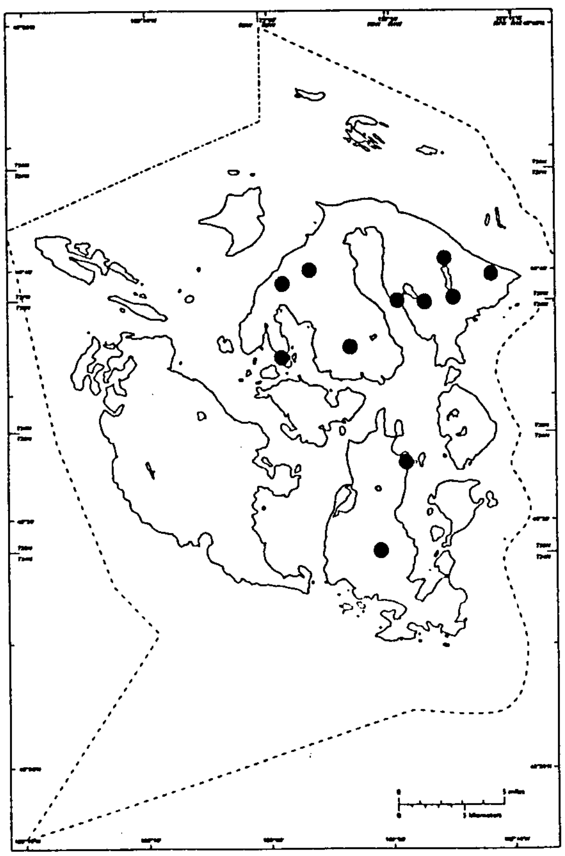
Trachybryum megaptilum



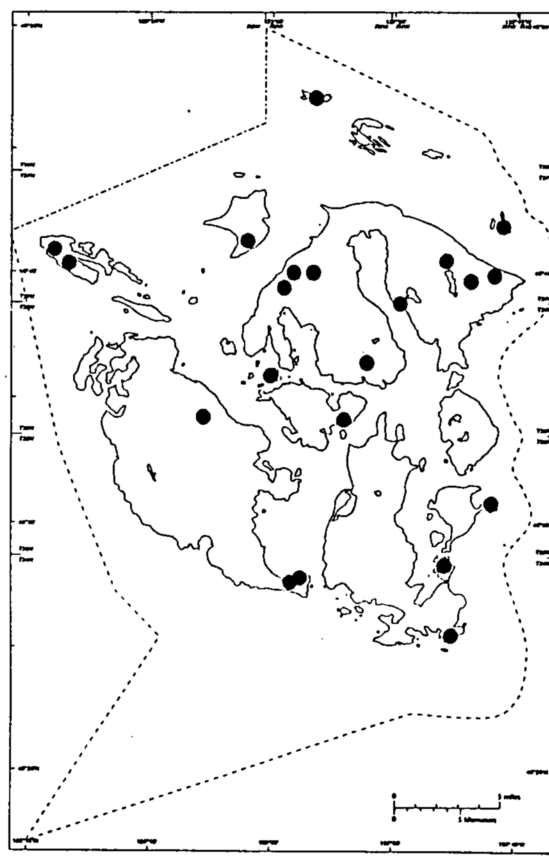
Trichodon cylindricus



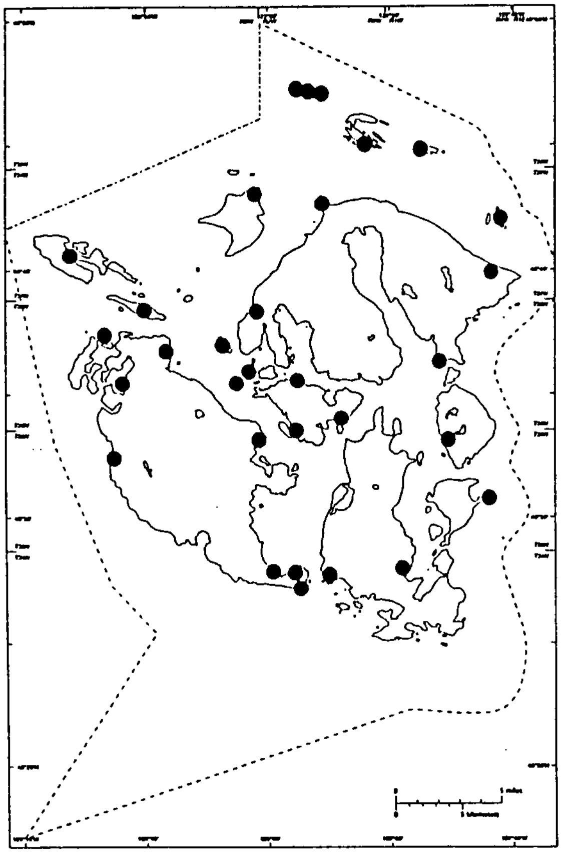
Trichostomopsis australasiae



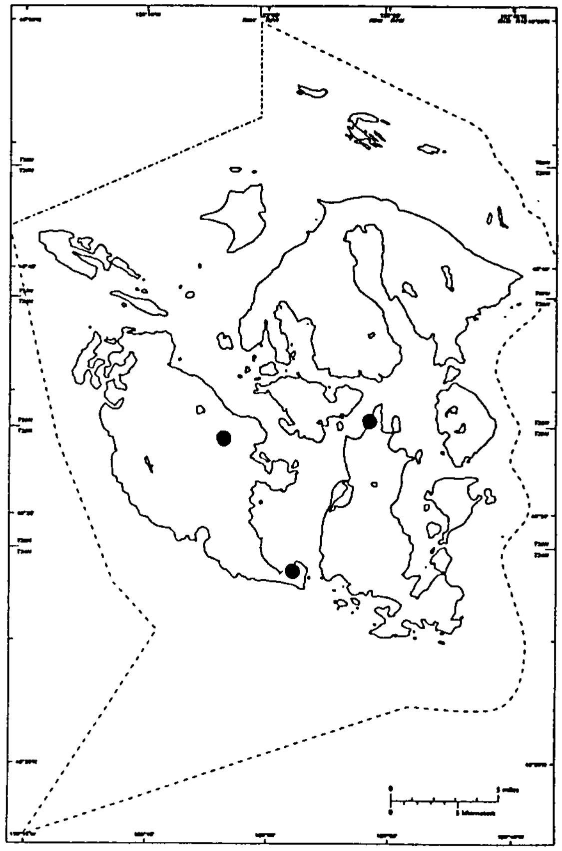
Ulota megalospora



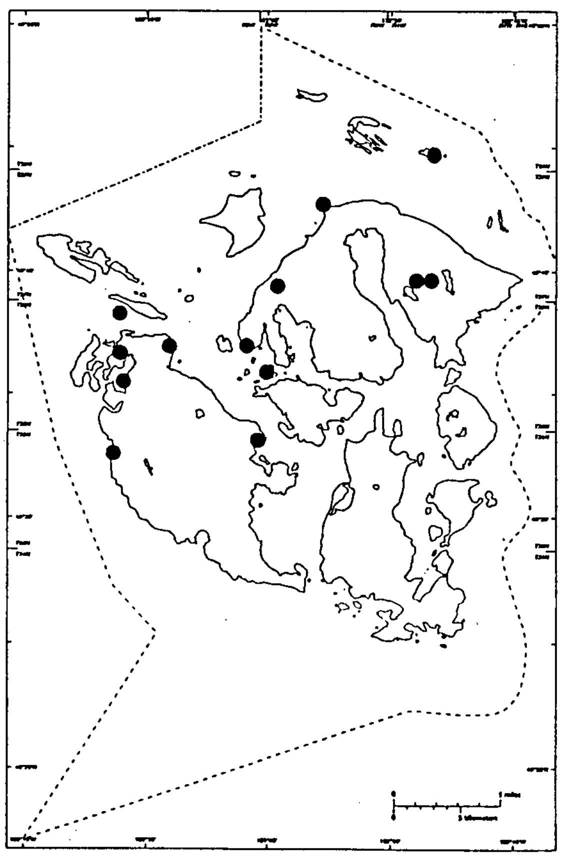
Ulota obtusiuscula



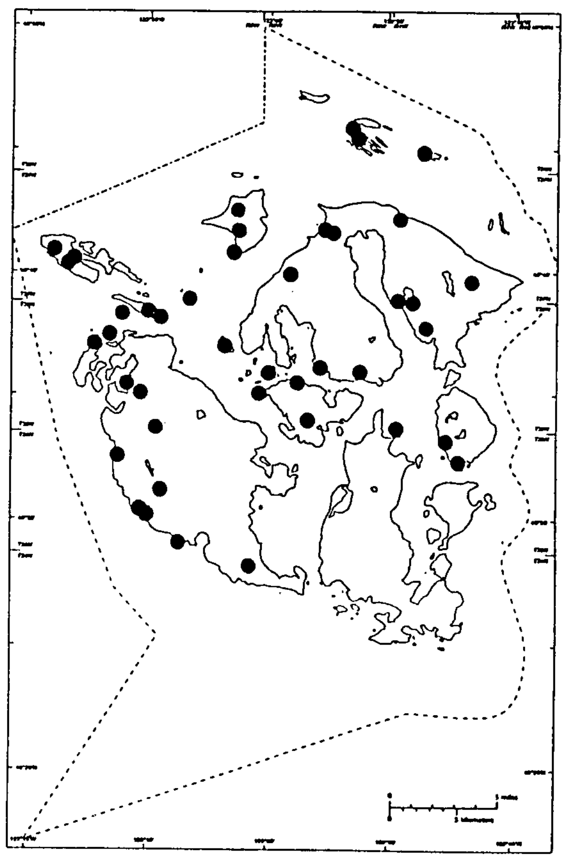
Ulota phyllantha



Warnstorfia fluitans



Weissia controversa



Zygodon viridissimus var. *rupestris*