INITIATING RECOVERY STRATEGIES FOR THE GULF OF SAINT LAWRENCE ASTER (*Symphyotrichum laurentianum*) ON PRINCE EDWARD ISLAND AND ASSESSMENT OF ITS REPRODUCTIVE ABILITIES

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Abstract

The Gulf of St. Lawrence Aster (*Symphyotrichum laurentianum*) (SLA) is an annual plant species endemic to the Gulf of St. Lawrence region. Due to the dynamic nature of the environment that the Gulf of St. Lawrence Aster inhabits, severe and major threats to both the Aster and its habitat exist. The Committee on the Status of Endangered Wildlife in Canada listed the species as *Threatened* in Canada in 2004. This status was reached due to the species' limited distribution, fluctuating population size, and to continued pressures on its habitat. Surveys have revealed that both site and population numbers have been further and drastically reduced on Prince Edward Island. In 2007 only one populated site remained with a low number of 482 individuals. It is possible that this species is on the brink of extirpation from PEI.

Recovery of this species on Prince Edward Island is feasible. Promising results related to the transplantation of greenhouse grown seedlings at four *in-situ* sites demonstrated that SLA plantlets have the potential to serve as seed stock to re-establish populations. Over the two years of the transplantation experiment, the pooled overall survivorship was 52.8%. Specific site manipulations that were tested may also increase the potential survivorship of the transplants, and facilitate second-generation germination. Additionally, surveys and site assessments were conducted at 15 locations within the Prince Edward Island National Park. Although the search for new SLA populations was not successful, locations were identified in both historical and non-historical areas that yielded potential sites for future management actions to recover the species on Prince Edward Island. As well, analysis of the reproductive potential of SLA florets has revealed additional knowledge useful for future studies. Pollen exclusion experiments resulted in a significant difference in the median values of excluded versus unexcluded inflorescences. These results indicate that, as far as the production of viable seeds is concerned, SLA plants benefit more from geitonogamy and crosspollination than they do from selfing (cleistogamy).

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"There can be no purpose more enspiriting than to begin the age of restoration, reweaving the wondrous diversity of life that still surrounds us."

- from *The Diversity of Life* by E. O. Wilson

Chapter 1. General Introduction

General Biology:

The Gulf of St. Lawrence Aster (*Symphyotrichum laurentianum*) is an annual plant species endemic to the Magdalen Islands of Québec, New Brunswick and Prince Edward Island (PEI) (Houle and Haber 1990, Reynolds and Houle 2001). It belongs to the family Asteraceae and is found in disturbed sites within coastal ecosystems. It tends to grow within sandy, brackish, or muddy soils in areas that are infrequently flooded by salt water. As a result it grows within a dynamic and unpredictable intertidal habitat, mainly on the upper levels of salt marshes above the high water mark, but can be found along margins of ponds, lagoons, and coastal dunes as well (Houle and Haber 1990).

Plant emergence begins in mid-June and flowering occurs from late August to early September, with seed dispersal taking place in mid-October to early November (Stewart and Lacroix 2001). The plant is typically less than 30 cm tall, and can have either a branched or unbranched stem. Mature leaves are spatulate to linear-lanceolate with a smooth, fleshy surface and average 20-60 mm in length and 2-7 mm in width (Fernald 1914). Each individual plant has the ability to produce one to over 700 inflorescences (Houle and Haber 1990). These inflorescences have leafy bracts and individual flowers have a distinct white pappus (Houle 1988) (Figure 1.1). The white seed head is the showiest part of the plant and is fully expanded just before dispersal in mid-October, making it easy to identify in the field at this particular stage of development.

Figure 1.1: Photo of a mature Gulf of St. Lawrence Aster *in-situ*. Note the distinct white pappus on the florets within the inflorescences.

Although most Asteraceae outcross as the principal method of reproduction (Houle 1988), the Gulf of St. Lawrence Aster (SLA) is also self-compatible and may self-fertilize (Houle and Haber 1990). This species has two types of flowers; an outer zone of pistillate flowers as well as inner (central) bisexual disk flowers (Lacroix et al. 2007). The inner flowers have the ability to self-fertilize while remaining closed. The outer flowers of SLA (which are rayless) open earlier and can be fertilized by either pollen from another flower on the same plant, or another plant of the same species (Lord 1981).

The only form of natural regeneration for this species is through seed dispersal and germination (Lacroix et al. 2007, Kemp and Lacroix 2004). St. Lawrence Aster seeds can be dispersed through the air or water with the aid of a pappus. This structure helps to slow down the descent of the seeds in the wind, and provides buoyancy in the water (Gibson 2001). After dispersal, SLA seeds must overwinter before germinating under favorable conditions in following years. According to Baskin and Baskin (1998), seeds in general survive the harsh winter conditions by entering physiological dormancy. Although it is possible for the seeds of some species to enter a persistent seed bank (remain viable in the soil for at least two germination seasons), it is unknown how many years SLA seeds can remain viable in nature. Under laboratory conditions seeds of *Symphyotrichum laurentianum* have been shown to be viable after 3 years with an estimated viability of up to 10 years (Houle and Haber 1990).

When present, the St. Lawrence Aster tends to be the dominant species in clearly open and relatively small patches of coastal salt marshes. It requires full sunlight for optimal growth, and consequently minimal competition from surrounding vegetation for successful development (Houle 1988). Competition for light can have negative influences on this plant's development, especially during the adult stages of life both pre- and post-flowering (Houle et al. 2001). Species commonly found growing in SLA microhabitats include glasswort (*Salicornia europeae*), sea milkwort (*Glaux maritima*) and dense canopies of sedges (*Carex spp.*) (Houle and Valery 2003, Steeves 2005).

Field observations indicate that SLA seedlings can be found growing in and around pot-hole like depressions (C. Lacroix, University of Prince Edward Island, pers. comm.). These depressions may be created by ice rafting (the scouring of vegetation and substrate due to ice movement) and result in an overall decrease in vegetation density within the immediate area. Since the role of surrounding vegetation appears to have an effect on the establishment and seed dispersal of SLA, microhabitats such as the pot-hole depressions may be important for this species' germination and survival potential (Lacroix et al. 2007).

Status and Threats:

The national Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was formed in 1977 to meet the need to produce a single official, scientifically sound national list of wild species at risk in Canada. Presently, there are close to 200 vascular plant species at risk across Canada (Schwartz and Simberloff 2008). The listing and rating system that is used by the committee ranks the species into one of five categories.

- **Special Concern**: may become threatened or endangered because of a combination of biological characteristics and identified threats

- **Threatened**: likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction
- **Endangered**: facing imminent extirpation or extinction
- **Extirpated**: no longer exists in the wild in Canada, but exists elsewhere
- **Extinct**: no longer exists

In 1989, COSEWIC listed the Gulf of St. Lawrence Aster as Special Concern, and later re-evaluated its status to list it as Threatened in 2004. This status was assigned due to the plant's limited distribution, fluctuating population size, and continued pressures on its habitat (COSEWIC 2004). In addition, this species is listed as globally imperiled (N2 rating; see Table 1.1 for definitions of codes) by the Canadian Species of Global Conservation Concern (CSGCC 2005), and at the provincial level, the aster is considered rare throughout its range in Québec (S2 rating) and extremely rare throughout its range in New Brunswick and Prince Edward Island (S1 rating) by the Atlantic Canada Conservation Data Center (ACCDC 2004). The rankings provide a scientific consensus for the status of a species and may be used by appropriate jurisdictions to initiate conservation and recovery actions.

Due to the dynamic nature of the environment that the Gulf of St. Lawrence Aster inhabits, severe and major threats to both the Aster and its habitat include natural components of the ecosystem. Storm events, unusually high tides, overwash, and habitat modifications due to substrate and eelgrass deposition are examples of some incidents that may have both direct and indirect influences on this species' population (Reynolds

Table 1.1: National (N) and Subnational (S) conservation status ranks for wildlife species across Canada (modified from Natureserve 2010).

Status	Definition
NX SX	**Presumed Extirpated**—Species or community is believed to be extirpated from the nation or state/province. Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.
NH SH	**Possibly Extirpated** (Historical)—Species or community occurred historically in the nation or state/province, and there is some possibility that it may be rediscovered. Its presence may not have been verified in the past 20-40 years. A species or community could become NH or SH without such a 20-40 year delay if the only known occurrences in a nation or state/province were destroyed or if it had been extensively and unsuccessfully looked for. The NH or SH rank is reserved for species or communities for which some effort has been made to relocate occurrences, rather than simply using this status for all elements not known from verified extant occurrences.
N1 S1	**Critically Imperiled**—Critically imperiled in the nation or state/province because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state/province.
N2 S2	**Imperiled**—Imperiled in the nation or state/province because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the nation or state/province.
N3 S3	**Vulnerable**—Vulnerable in the nation or state/province due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation.
N4 S4	**Apparently Secure**—Uncommon but not rare; some cause for long-term concern due to declines or other factors.
N5 S5	**Secure**—Common, widespread, and abundant in the nation or state/province.
NNR SNR	**Unranked**—Nation or state/province conservation status not yet assessed.
NU SU	**Unrankable**—Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.
NNA SNA	**Not Applicable** —A conservation status rank is not applicable because the species is not a suitable target for conservation activities.
N#N# S#S#	**Range Rank** —A numeric range rank (e.g., S2S3) is used to indicate any range of uncertainty about the status of the species or community. Ranges cannot skip more than one rank (e.g., SU is used rather than S1S4).
Not Provided	Species is known to occur in this nation or state/province. Contact the relevant natural heritage program for assigned conservation status.

and Houle 2001). Events such as these may also positively influence populations. For instance, the removal of competing vegetation due to overwash may be a direct benefit to surviving SLA plants (C. Lacroix pers. comm.). However, there is also the potential that such events will not only completely eliminate SLA plants from a site, but also render the area unsuitable for recolonization.

Anthropogenic threats to this species exist as well. Recreational vehicle use and the development or infilling of marshes are events that alter or eliminate required habitat. On Prince Edward Island one historic SLA site in PEINP has already been lost due to development (Guignion et al. 1995). It is essential that incidents such as this do not occur in the future. Fortunately for the St. Lawrence Aster, protective measures such as those legislated by the Species at Risk Act (SARA 2008) afford protection to the species and any habitat that is public land, thus reducing the risk that future destruction of the known population sites will occur. Unfortunately, this type of legislation does not necessarily provide protection for additional and potential suitable habitat along the Gulf of St. Lawrence.

Global climate change (Hansen et al. 2000, Najjar et al. 2000, Root et al. 2003, Vitousek, 1994) is also expected to have important consequences for coastal ecosystems, with potential impact on the Gulf of St. Lawrence Aster and its habitat. For instance, it is highly likely that the rate of sea-level rise will increase greatly in the coming years, due to CO_2 induced warming, expansion of the ocean, and increased glacial melting (Najjar et al. 2000). As a result, long-term threats to coastal habitats such as inundation and increased coastal erosion may be detrimental to many species, including SLA.

History in Prince Edward Island National Park:

There are a number of sites on Prince Edward Island where the Gulf of St. Lawrence Aster is either currently growing, or have historically held populations. With the exception of one location in Tignish, each of the sites on PEI is situated within Prince Edward Island National Park (PEINP) (Houle and Haber 1990, Jacques Whitford 1994). PEINP was established in 1937 and is located along the northern shore of Prince Edward Island. The Park stretches along 40 kilometres of coastline, and is fragmented into three sections: Cavendish, Brackley/Dalvay and Greenwich. It is comprised mainly of coastal habitats including sandstone cliffs, barrier islands, submerged estuaries and long stretches of beaches and dunes. This park has a high level of human visitation due to the popularity of the beaches in the summertime (K. Tulk, Prince Edward Island National Park, pers. comm.).

National Parks are required to provide status reports to COSEWIC on vulnerable, threatened and endangered species located within their boundaries. As a result, in 1992/93 a consulting firm, Jacques Whitford Environment Limited, was hired by PEINP to conduct a thorough investigation of both historical and potential St. Lawrence Aster population sites within the Park. At the time, it was reported that this particular species was found at six sites. Two of these sites, both located on the Blooming Point peninsula, had relatively larger populations (up to 60,000 individuals) in comparison to other sites (Jacques Whitford 1994). These reports differ from the status of the plants in 1983-86, reported by Houle and Haber in 1990. When surveys were conducted by these researchers from 1983-1986, only 13 plants were counted at two sites within PEINP. Unfortunately, one of the sites reported by Houle and Haber (1990) was destroyed due to human development, and the other site is unidentifiable given their description. Therefore, long-term trends cannot be depicted for these two particular sites. Only the sites identified by Jacques Whitford (1994) will be used within this thesis to determine long-term population trends.

The survey methods used by Jacques Whitford varied from transects and actual counts and estimates depending on the areas surveyed. Where feasible, a complete census of potential areas was conducted on foot and counts of individual plants took place. As well, transects were established in areas of marginal habitat, and extrapolations were made at sites where the populations were too large to count individual stems. Their surveys were conducted during the fall, which would have provided estimates of the mature plants available to disperse seed for the next germination season. Houle and Haber (1990) did not mention when and where their surveys were conducted, or the methodology used to locate the plants.

The 2004 COSEWIC updated status report then indicated that since the 1992/93 surveys, two of the six populations within PEINP (Brackley Point and Long Pond) had disappeared. However, it was not determined whether or not viable seeds remained within the substrate. Since then, surveys conducted by individuals within the Lacroix laboratory of the University of Prince Edward Island (UPEI) (Steeves 2005, Allain 2007, Jenkins 2008) have concluded that both population sizes and number of sites with SLA present have been further and drastically reduced. As of 2007, only one natural site continued to support SLA, and it was located at the Blooming Point dune slack with only 482 individuals (Jenkins 2008).

Expected fluctuations exist in both the distribution and abundance of this species. Natural components of the ecosystem affect population size and numbers of sites on an annual basis. However, the overall decrease since 1992 of both SLA plant numbers and numbers of sites with SLA on Prince Edward Island alone indicate that the survival of this species may well depend on the development of recovery programs.

Reproduction and Habitat Requirements:

Given the dynamic nature of the coastal habitat that this species resides in, natural fluctuations in both site and population numbers are bound to exist. However, the Gulf of St. Lawrence Aster is an annual that relies heavily on seed-banking for recruitment. As population numbers continue to decrease in PEI, the average annual potential for replenishment of the potential seed bank will also diminish. It was previously estimated that the potential viability of natural seed banks for this species was up to 10 years or more (Gilbert et al. 1999, Houle and Haber 1990). However, recent work on the subject has shown that seed longevity could be shorter (Kemp and Lacroix 2004). In any case, both the habitat and environmental conditions need to be suitable in order for viable seeds to germinate and survive to maturity.

As a coastal species, it has been demonstrated that both the plants and the seed bank of SLA are tied to a variety of environmental factors that have effects on dispersal and germination (Houle and Belleau 2000, Reynolds and Houle 2001, Houle et al. 2001). Since suitable habitat for SLA includes salt marshes and narrow bands of habitat along the shoreline of coastal ponds and lagoons (Houle and Haber 1990), it is evident that the species' population numbers will be influenced by factors such as seasonal water level fluctuations, tidal action, wave exposure, storm events and siltation. Houle and Belleau (2000) found that if SLA plants experienced stress related to drought conditions at the time of floral bud differentiation, there was a reduction in overall flower-head production. It has been determined that high salinity levels (Houle et al. 2001, Reynolds and Houle 2001), as well as low soil temperatures (Heard and Ancheta 2010) can have negative implications on seed germination and plant development. As well, both siltation and wrack build up can suffocate plants and bury the seeds too deep for emergence (D. Mazerolle, Atlantic Canada Conservation Data Center, pers. comm.). Low light availability can also negatively influence plant performance (Reynolds and Houle 2001, Houle and Valéry 2003).

Although some environmental factors can be limiting to the growth and maturation of St. Lawrence Aster, others are also necessary for the creation of appropriate microhabitat. This species depends on fluctuating water levels to maintain periodic open habitat with reduced competition. During periods of low precipitation and low water levels, if climatic conditions are favorable, plants may germinate from newly exposed seed banks. In coastal habitats, wrack build up can also influence vegetation patterns by killing underlying vegetation and initiating succession (Pennings and Richards 1998). Microhabitat resulting from the removal of wrack build up from previous years may be the perfect location for SLA to prosper due to available sunlight and limited competition (Tulk, pers. comm.). However, it has been proposed that increased levels of eelgrass (*Zostera marina*) deposition within the historical SLA sites on PEI have affected the survival of this species (Lacroix pers. comm.). Essentially, the overabundance of washed up eelgrass debris has covered the Aster sites so extensively that SLA seedlings may have not been able to germinate or achieve full development, especially when burial happens at critical stages of flowering and seed production.

Rykeil (1985) describes disturbance as any event that can change community and ecosystem structure and composition. These events change the physical environment and/or resource availability, and usually remove biomass. Preliminary ecological observations indicate that disturbance is relevant to the establishment of Gulf of St. Lawrence Aster at the historical sites on Prince Edward Island (Lacroix, pers. comm.; Tulk, pers. comm.; Jacques-Whitford 1994).

Rare Plant Conservation and Recovery:

Given (1994) lists a number of reasons why the conservation of rare and threatened plants is important, including the scientific value of the species for future study, the role of plants in maintaining biological diversity, and the right of the species to exist. For years, efforts have been made across many regions, biomes and habitats to re-establish and protect various threatened species (Falk et al. 1996). Practices such as these have provided the basis for the development and testing of species and habitat restoration. No two recovery projects are exactly alike, as each species and habitat has its own unique set of factors to take into account. However, the key components of recovery or reintroduction studies are similar in their approach: preliminary biological and ecological research, recovery actions, monitoring and reporting (Falk et al. 1996).

A comprehensive investigation of biological information must be gathered prior to attempting the recovery of an endangered plant species. This information includes understanding specific genetic and ecological factors that may influence the species abundance and distributions. Examples of these factors include floral and seed development, seed dispersal, pollination potential, substrate components, spatial heterogeneity, and susceptibility to herbivory (Falk et al. 1996). Fortunately many of these factors have been documented for the Gulf of St. Lawrence Aster. The process of developing recovery guidelines for this species can therefore begin and build on this foundation of information.

Various approaches may be taken to conserve plant species. The preservation of natural habitats is the most effective action that can be taken (Given 1994). However, sometimes additional intervention, such as species introduction or reintroduction, may be necessary in order to assist in recovery and conservation efforts. There are a number of techniques used to incorporate recovery actions. Such methods include the translocation of whole plants from one natural site to another, or the transplantation of seedlings produced through *ex-situ* means to either historical sites (reintroduction) or non-historical, ideal locations (introduction) (Allen 1994). The *ex-situ* seedlings may be produced through the propagation of plants using seeds, cuttings, grafting or other methods.

Reintroduction may be used to either enhance a population that is close to disappearing, or to establish a population where one has already disappeared (Allen 1994). Many attempts at reintroduction have been made worldwide and for a variety of plant types. For example, attempts were made in 1985 in Texas to reintroduce the endangered Texas Snowbells (*Stryrax texana*), a deciduous shrub that reaches five feet in height. These reintroductions were accomplished by germinating collected seed and planting 1.5 year old seedlings to historical receptor sites. Success was determined five years later when ongoing monitoring reported that some of the shrubs had flowered for the first time, thus demonstrating potential to reproduce (Falk et al. 1996).

The success of recovery strategies depends on the objectives of the project. Typically, and especially in the case of endangered and rare species, success is achieved once the target species has become established and is able to reproductively sustain itself (Falk et al. 1996). However, it can take decades to determine a project's success or failure depending on the longevity of individual plants.

Introductions are more drastic methods that are often used to prevent a species from becoming extinct. Typically, introductions take place within the natural range of a species, although in an area where the plant is not known to have historically occurred (Allen 1994). Creating new populations can be very challenging; designing and managing the new populations requires preliminary experiments to determine important limiting factors (Heywood and Iriondo 2003). However, the benefit of successful introductions can surpass the negative aspects of testing introduction strategies (such as time and habitat consumption). Not only do successes reduce the risk of extinction, but they may also provide increased understanding of the target species (Falk et al. 1996). As well, knowledge of how to incorporate specific manipulations within natural populations may be derived from introductions and aid the target species as a whole.

Translocation, or relocation, is the most drastic and unpredictable technique (Allen 1994). The removal of mature plants from one site and their reestablishment in another site can be risky and detrimental to the plants. An example of a translocation success story was reported for Apalachicola rosemary (*Conradina glabra*), an endangered plant endemic to Florida (Falk et al. 1996). After the plant could no longer be found in the only known protected site, a project was initiated to reintroduce the species to sites within in its natural range. Fortunately, plants were available from the Center for Plant Conservation's collection located at Bok Tower Gardens in Florida. In 1991, the translocation of plants took place, and five years later seedling survival remained high at locations where additional management techniques (i.e. prescribed burning) had been implemented (Falk et al. 1996).

Regardless of the method used, if the goal of a rare plant reintroduction project is to conserve a species, the success of the project depends on the safekeeping of the habitat utilized. It is essential that the receptor locations be securely protected for the long-term (Falk et al. 1996). Therefore, land owners and/or land managers must be supportive of the study and committed to the permanent protection of the sites prior to management actions taking place.

In the case of the Gulf of St. Lawrence Aster, it is evident that although the conservation of appropriate habitat is essential, intervention is also necessary in order to sustain the species in PEI. *Ex-situ* conservation of wild plant species through seed banking is a method effectively used to conserve a species' genetic diversity (Allain 2007). These seeds can also be germinated to produce plantlets that have the potential to be transplanted in order to colonize an area, or supplement a population.

The Lacroix laboratory at UPEI has been successful in producing a seed bank for SLA. In 1999, batches of seeds were gathered from historical locations within PEINP (Blooming Point and Covehead Pond). These seeds have been used over the years to generate an extensive bank of viable seeds, by replenishing the stock each year by collecting seeds from greenhouse grown plants. The seed bank is currently stored at the University of Prince Edward Island (UPEI) using standard protocols (Allain 2007).

Promising preliminary results related to transplant experiments using this species supports the idea that SLA can be re-introduced to PEINP. Those data indicate that SLA plantlets, derived from the UPEI seed bank, have the potential to serve as seed stock to re-establish populations within PEI (Jenkins 2008). Therefore, experimental sites for testing reintroduction will be located within Prince Edward Island National Park, a tract of land that is permanently secured and within the natural range of the species. As well, specimens derived from this seed stock will be used to shed light on the pollination potential of the species.

The overall goals of this study are: (1) to determine means of establishing populations and promoting self-sustainability through management actions; (2) to thoroughly survey historical and potential sites within PEINP for SLA populations, as well as assess them for the implementation of future management actions; (3) to determine which reproductive strategy, self-pollination or outcrossing, is more beneficial to the overall sustainability of this species.

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Chapter 2.0 Population Recovery Experiment

2.1 Introduction:

The Gulf of St. Lawrence Aster (*Symphyotrichum laurentianum*) is an endemic plant species native to Prince Edward Island, New Brunswick and the Magdalene Islands of Québec (Houle and Haber 1990). This annual halophyte is a late summer flowering species that grows within dynamic habitats along the coastline. It is most commonly found within the upper levels of salt marshes, and along the edges of lagoons and outflows, all of which may periodically be subject to flooding (Houle 1988, Houle and Haber 1990, Gilbert et al. 1999). The plant is small to medium sized (up to 30 cm tall). Larger plants may be strongly branched and produce multiple inflorescences. The inflorescences have leafy bracts, and individual flowers display a distinct white pappus (Houle 1988).

Although the St. Lawrence Aster (SLA) is currently listed as Threatened by COSEWIC (COSEWIC 2004), long-term population monitoring on Prince Edward Island indicates that the trend in both numbers of plants and sites are decreasing dramatically (Jenkins 2008, Tulk pers. comm.). Historically, eight sites were located on Prince Edward Island where this species was known to exist. With the exception of one site in Tignish, all of the sites were located within Prince Edward Island National Park (PEINP). Since 1992, intermittent population surveys have been conducted at the sites within PEINP by a number of researchers and organizations: individuals from the Lacroix laboratory at the University of Prince Edward Island (UPEI) (Kemp and Lacroix 2004, Allain 2007, Jenkins 2008), staff of PEINP (K. Tulk pers. comm.), and staff of the Atlantic Canada Conservation Data Center (ACCDC) (D. Mazerolle pers. comm.). Data from these surveys have been used to create a time series plot for these sites (Figure 2.1) (Jenkins 2008). The trends depicted from the recent surveys indicate that plant numbers have declined from a high of 160,000 in seven sites in 2000, to just a few plants in one site in 2007, suggesting that the species may soon become extirpated from PEI.

On PEI the Gulf of St. Lawrence Aster has been observed germinating in what has been termed "potholes" within the marsh (C. Lacroix pers. comm.). These potholes are created by ice rafting during the winter season. Essentially, large pieces of ice located within the marsh are moved around during the winter months due to tide and storm events. This ice movement serves as a mechanism to disturb the substrate by scraping and digging into the ground and displacing pieces of substrate along with the vegetation and roots embedded into the soil. This action creates patches of microhabitat by leaving behind divots and scrapes in the earth that exposes substrate for the establishment of opportunistic species (Figure 2.2). The creation of these pothole patches allow for increase in light availability, water, and access to substrate, all factors which benefit SLA establishment and development (Houle and Belleau 2000, Reynolds and Houle 2001, Houle and Valéry 2003).

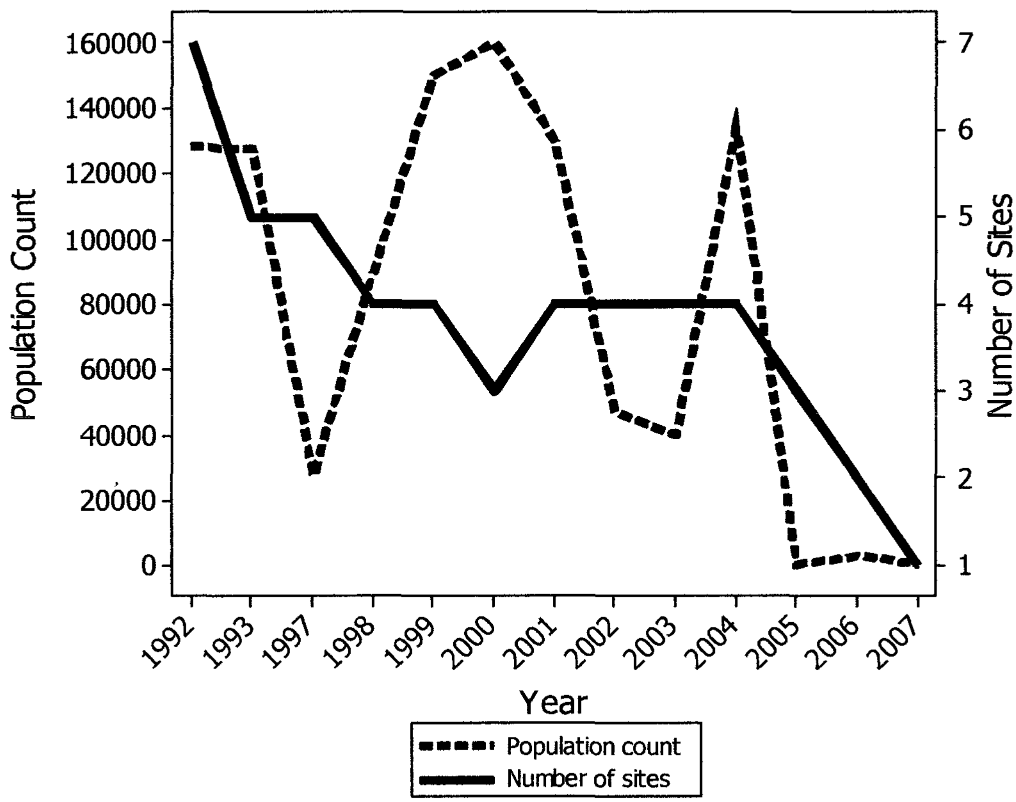

Figure 2.1: Total population estimates and number of sites for the SLA in Prince Edward Island National Park (adapted from Jenkins 2008).

Figure 2.2: Image of natural 'potholes' found within the substrate of the East Marsh on Blooming Point. Note the reduction of competing vegetation within the potholes.

When it comes to plant conservation, the preservation of natural habitats is the most effective action that can be taken (Given 1994). However, in the case of the Gulf of St. Lawrence Aster on Prince Edward Island it is evident that additional intervention may be necessary to sustain the species. The Lacroix laboratory has been successful in producing an extant seed bank for *Symphyotrichum laurentianum*. In 1999, batches of seeds were gathered from historical locations within PEINP (Blooming Point and Covehead Pond). These seeds have been used over the years to generate an extensive bank of viable seeds that is currently stored at the University of Prince Edward Island. Promising preliminary results demonstrated that SLA plantlets have the potential to serve as seed stock to re-establish populations (Jenkins 2008). This study used the seeds contained within the UPEI seed bank to determine whether or not the following methodology would in fact serve this purpose within PEINP.

Previous ecological observations made by past researchers from the Lacroix laboratory (Steeves 2005, Allain 2007, and Jenkins 2008) justified the proposal of a field experiment that would incorporate both transplant and seeding strategies. The primary objective of this project was to determine best methods for establishing self-sustaining populations of Gulf of St. Lawrence Aster. The hypothesis is that SLA will benefit from simulation of natural disturbance to the marsh substrate, such as the creation of potholes and the removal of competing vegetation. A secondary objective involved gaining a better understanding of the abiotic factors that may be influencing the species at the test sites on Prince Edward Island.

2.2 Materials and Methods:

In this study, achenes of *Symphyotrichum laurentianum* were used that were produced in the UPEI greenhouse in 2006, and which were two years old at the time of planting. This particular seed stock originated from a collection of inflorescences that was gathered in 1999 from the East Marsh of Blooming Point on Prince Edward Island. The seedlings were grown in a greenhouse setting under standard conditions as described in section 2.2.2 and were transplanted to four predetermined sites within PEINP. *Ex- situ* seed germination and plantlet production was synchronized with the phenology of plants in their natural setting.

2.2.1 Site selection and preparation:

Site selection for this project was based on historical records, as well as physical, biological and logistical suitability of candidate areas. In total, four sites, Blooming Point East Marsh A and B, Blooming Point Dune Slack, and Robinson's Island were selected to conduct the experiments. Three of the sites were historical (reintroduction) sites, while the fourth was a non-historical (introduction) site (Figure 2.3). At the end of July, the selected sites were manipulated to receive transplants. Two grids (1 x 3 m) were set up at each site in 2008 and 2009. A randomized block design was used to establish 4 plots within each grid for each of three transplanting strategies: undisturbed marsh vegetation (control), mowed marsh vegetation, and artificially-simulated potholes (Figure 2.4). By the end of the second field season there were 64 plots for each of the 3 treatment groups tested.

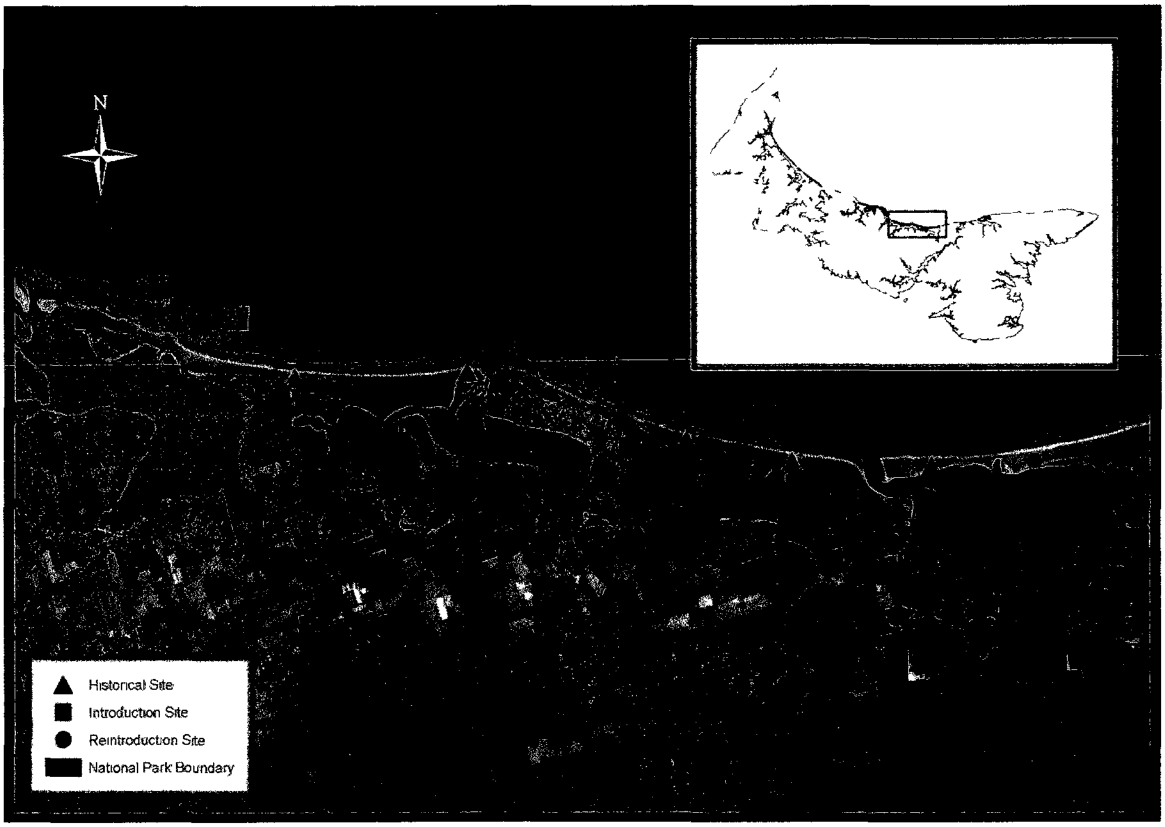

Figure 2.3: Site map for Gulf of St. Lawrence Aster in Prince Edward Island National Park. The four experimental sites, identified in green, from East to West include: Robinson's Island, the Blooming Point Dune Slack, Blooming Point East Marsh B, and Blooming Point East Marsh A.

Figure 2.4: Test plots within grid at Blooming Point. Top left: vegetation removed. Top right: untouched. Bottom two: potholes.

2.2.2 Seedling and transplant preparation:

Seedling production (*ex-situ*):

In 2008 several hundred seeds of SLA were germinated within a standard potting soil (PG Mix – professional growing mix) medium in a growth chamber. The chamber was set to a 14:10 (light:dark) hour photoperiod with a thermal regime of 25°C/15°C (day/night) and 80% humidity. After two weeks, seedlings of similar size (cotyledon stage) were transplanted into individual 25 cm^3 cells filled with the same mix of soil. These seedlings were moved to the greenhouse to continue their development for approximately 2 months (Figure 2.5). The greenhouse was set to maintain temperature levels between 20-30°C throughout the day, and 15-21°C throughout the night. The natural photoperiod of the season was used (approximately 14 hours of light). The plants were watered manually on a daily basis and monitored for any disruption (i.e. aphid infestation).

Hardening off:

Over the course of two weeks prior to transplantation, the SLA seedlings were slowly acclimated to natural weather conditions. This was accomplished by increasing the time, by approximately two hours, which the plantlets spent outside of the greenhouse each day. By the end of the hardening off period, the seedlings were acclimated to strong sunlight, cool nights and less-frequent watering.

Transplantation and monitoring:

At approximately 2 months post-germination, when SLA plants had achieved a vigorous growth, but had not yet initiated flowering, 10 plantlets were transplanted to

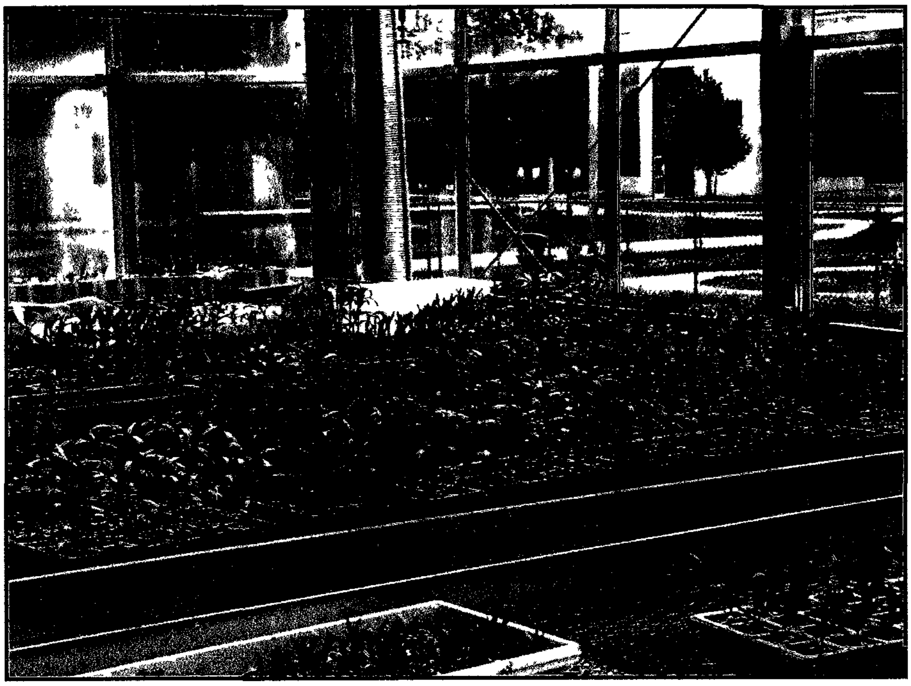

Figure 2.5: SLA plants in greenhouse, prior to transplantation (approximately 2 months of age).

Figure 2.6: Transplanting in the East Marsh of Blooming Point, PEINP, August 2009.

each of the established plots (Figure 2.6). These transplants took place in calm weather conditions during neap tides. These conditions were chosen in order to reduce the probability that bad weather or high tides would displace and/or disrupt the acclimation or transplant process. As well, each transplant was watered with fresh water immediately after planting in order to further assist with acclimation to higher *in-situ* salinity levels by making the transition more gradual.

Inflorescence planting:

Plots were created on the periphery of the 2008 transplant grids to test the success of germination from inflorescences planted at two different times of the year. 15 mature inflorescences were planted in 0.5 m^2 plots in the fall of 2008, and in the spring of 2009. The plots were manipulated slightly in order to facilitate the embedding of the seeds in the soil; as a result, approximately 50% of the existing vegetation was pulled out of the substrate prior to seeding.

The inflorescences used were collected from the 2008 greenhouse grown plants at the time of seedling maturity (at the beginning of dispersal) (Figure 2.7). The inflorescences used for the fall plots were planted immediately after they were collected. Inflorescences for the spring plots were stored in the UPEI seed bank over the 2008/09 winter months prior to planting at the end of May, 2009. These seeded plots were monitored to determine if successful germination and survival of plants took place during the 2009 season.

Figure 2.7: Mature SLA infloresence growing in the UPEI greenhouse, prior to collection and planting of the fall seeding plots, 2008.

2.2.3 Developmental variables monitored:

Survivorship to seed set:

Monitoring of seedling survival commenced one week post-transplantation, and continued bi-weekly until seed dispersal occurred (late October – early November). Survival was considered to be achieved if the plants remained green, intact and continued developing on site. As well, the average number of inflorescences per plant/treatment was also noted.

Seed production and potential:

Ten percent of the inflorescences were collected from each plot once the achenes had matured. In the laboratory, the total number of seeds produced within these inflorescences was recorded. Visual inspection was used to classify the achenes as being either filled or unfilled to determine percentage values for each category. Filled achenes contain an embryo and are noticeably wider and longer (2.5-3.5 mm) in length than unfilled achenes. As well, filled achenes are typically reddish to dark brown in colour while unfilled achenes are light-brown to tan coloured (Jenkins 2008) (Figure 2.8). Once counted, the seeds were returned (spread on) to their respective grids in the field to avoid reduction in the potential seed bank for the 2009 season. Although the viability of the seeds was not tested, the visual inspection of the achenes was used as a method of gaining quantitative estimates of potential viability.

Germination surveys:

In early June of 2009 surveys were conducted at the management sites to look for second generation plants. Each plot was thoroughly searched, as well as up to 1 meter around the perimeter of each grid.

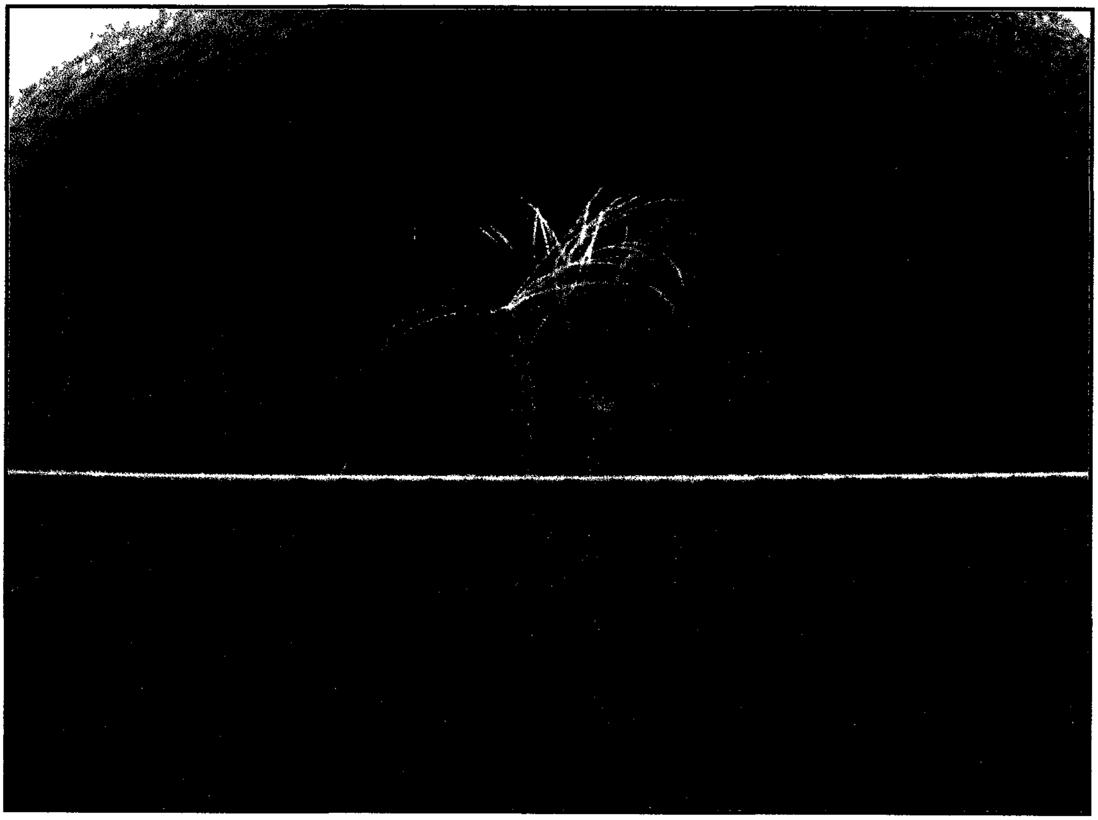

Figure 2.8: Image of filled SLA achene (left) and unfilled achene (right). For this study, counts of filled achenes were used to estimate potential viability.

2.2.4 Abiotic conditions monitored:

Weather conditions:

Data collected from a Vantage Pro 2 Weather Station (Davis Instruments, Haywood. Ca.) set up approximately one kilometer south of the Blooming Point re-introduction sites were used to monitor environmental conditions for the duration of the experiment. Air temperature, rainfall, wind speed and wind direction were recorded hourly between May and October for each study year.

Wrack and eelgrass monitoring and management:

The presence and/or absence of wrack build up both within and around the grids was noted on a biweekly basis. As well, one of the two grids at each of the experimental sites for each of the two years of study was managed for eelgrass/wrack build-up. This was accomplished by removing any buildup of wrack within the grid on a bi-weekly basis.

Ground temperature and moisture:

Temperature loggers (Hobo Tidbit v2 Temp Logger) were inserted 3 inches into the soil at each site at the beginning of the summer and remained in the soil for the duration of the plants' development. These loggers recorded ground temperature on a daily basis. A standard Westminster soil moisture meter, with a scale of 0-10 (0 representing dry and 10 representing wet), was also used biweekly to record relative moisture levels within the grids.

Soil salinity:

Throughout the germination season soil samples were collected during high-tide and in close proximity to each of the two grids in order to estimate soil salinity at each of the four management sites. The three collection dates corresponded to late-May/early-June, mid-June and end of June. Samples averaged 250 mL in volume, and were dried at 40°C for 48 hours. Samples were allowed to reach room temperature and were sifted through a 2 mm sieve. Soil salinity was determined by measuring the electrical conductivity (EC) of a mixture of 1 part soil to 5 parts distilled water (10 g:50 mL). The soil and water were continuously mixed on a mechanical rotary shaker at 80 osc/min for one hour before the electrical conductivity was tested. After allowing the solution to settle for a minute, a Thermo Fisher Scientific sympHony Conductivity Meter was used to gather an indirect measure of the total soluble salt concentration in the soil solution (measurements were taken above the settled soil). The unit of measurement was decisiemens per meter (dS/m), which was then converted to g/L given the soil solution ratio used. Three separate solutions were created for each of the two samples taken at each site. These results were then averaged to provide an estimated value for the site on each sample date. This methodology was provided by the P.E.I. Department of Agriculture, Fisheries and Aquaculture, and is their standard method for testing soil salinity.

2.2.5 Analysis:

After log transforming the survivorship data, the assumptions for parametric analysis of variance testing were met. For comparison of final survivorship among each year tested and the three treatment methods, a factorial analysis of variance (two-way ANOVA) testing was used. Post-hoc analysis (the Tukey test) was carried out for the three treatment methods to compare results for each year. As well, analysis of covariance (ANCOVA) was used to determine site effects on the treatment results. All of these analyses were conducted with 'Statistica' statistical software. Additional analysis consisted of conducting Mann Whitney U-tests to compare the average percent of filled seed for each treatment method in 2008.

2.3: Results:

Final survivorship to seed set:

Site had no significant effect on the treatment results (ANCOVA; $p = 0.06$). Therefore, all of the sites were pooled for further analysis. Year did have a significant effect (two-way ANOVA; $p = 0.0004$) on the survivorship of the plants across the three treatment methods. Due to this outcome, each year was analyzed separately. Interestingly, for each year the only significant differences were between the pothole and vegetation removed groups [Tukey; $p = 0.00002$ (2008), and $p = 0.00002$ (2009)], and the pothole and untouched groups [Tukey; $p = 0.00002$ (2008), and $p = 0.00002$ (2009)]. These differences were more prominent in 2009 than in 2008 (Figures 2.9 and 2.10). The overall survivorship of the transplants was 63% in 2008 and 47.7% in 2009. Over the two years of the experiment, the pooled overall survivorship was 52.8%.

Average number of inflorescences per plant, per treatment:

Throughout the month of October, transplants were monitored for survivorship and seed dispersal. There was a reduction in the average number of inflorescences on the plants in the pothole treatment compared to the other two treatments. The pothole

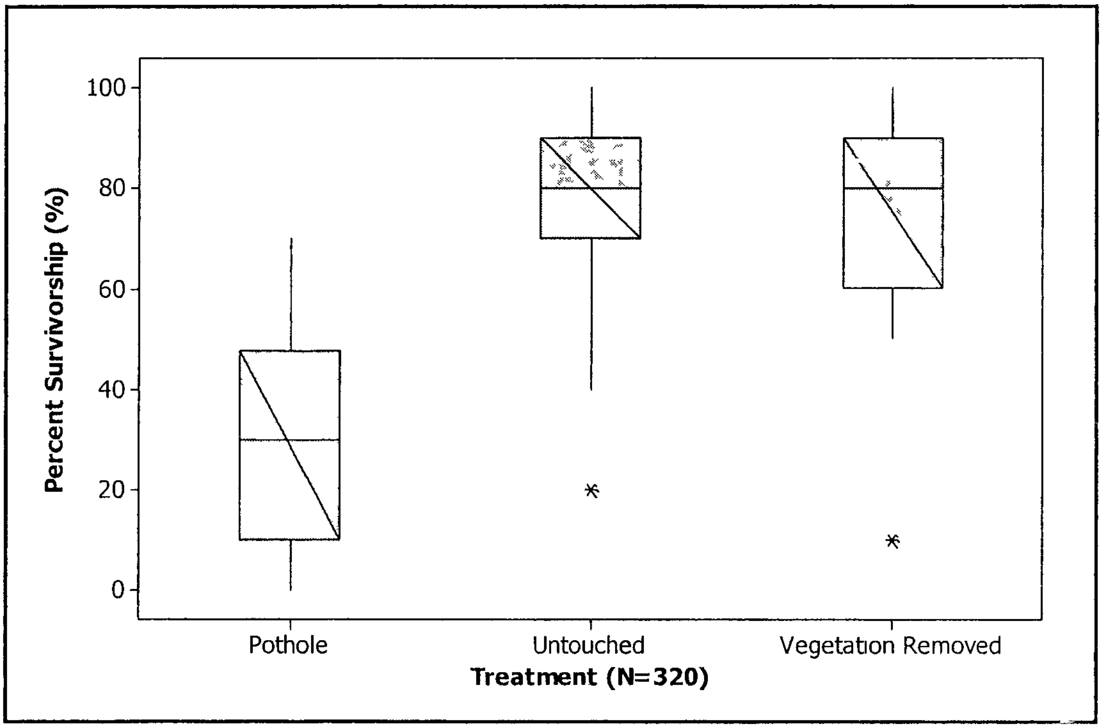

Figure 2.9: Median (center lıne) and range of survivorship for the transplants of each treatment group durıng 2008.

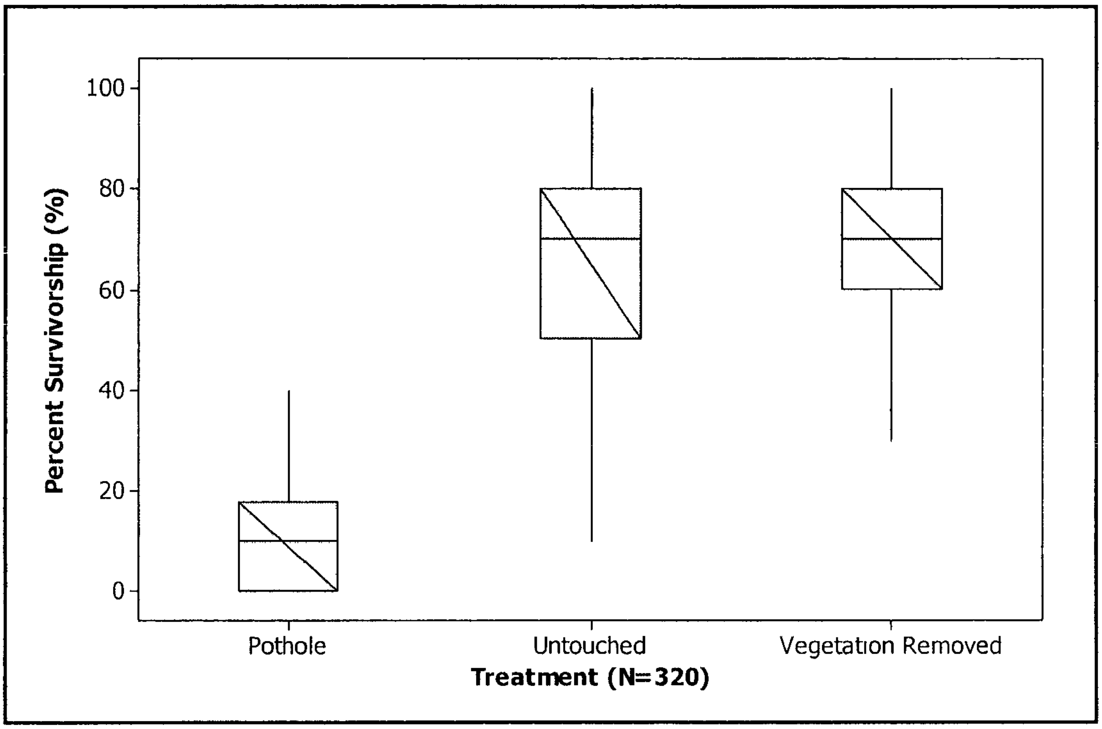

Figure 2.10: Median (center line) and range of survivorship for the transplants of each treatment group during 2009.

plants averaged 3.6 ± 2.3 inflorescences per plant, while the vegetation removed plants averaged 6.1 ± 4.1, and the control or untouched plants averaged 6.8 ± 4.5 (means ± standard deviations).

Seed production and potential:

In October of 2008, a total of 271 inflorescences were collected from the grids. These represented approximately 10% of the total number of inflorescences located in each plot at the time of plant maturity. There were no significant differences between the treatment groups tested (Mann Whitney U-tests; $p > 0.05$ for all three treatment comparisons). 25 inflorescences were examined from the pothole treatment group, with an average of 70.19% ± 18% filled seeds. For the untouched and vegetation removed treatment groups 122 and 124 inflorescences were examined respectively. The plants in the vegetation removed treatment group had an average of 70.23% ± 21% filled seeds in their inflorescences, and an average of 67.18% ± 19% of the seeds were filled for the untouched treatment (means ± standard deviations). It was also noted that the majority of the dispersed seeds seemed to remain within the immediate area surrounding the maternal plants, a phenomenon known as ``seed shadowing`` (Lacroix et al. 2007). This spatial distribution was useful in detecting second generation SLA`s derived from the transplants.

Germination surveys:

These surveys lead to the positive identification of over 500 SLA seedlings found within and around the 2008 management grids. Regrettably, due to an oversight in data collection, these data were unable to be statistically analyzed. However, it was noted that at each site the seedlings were found growing within areas that vegetation reduction had

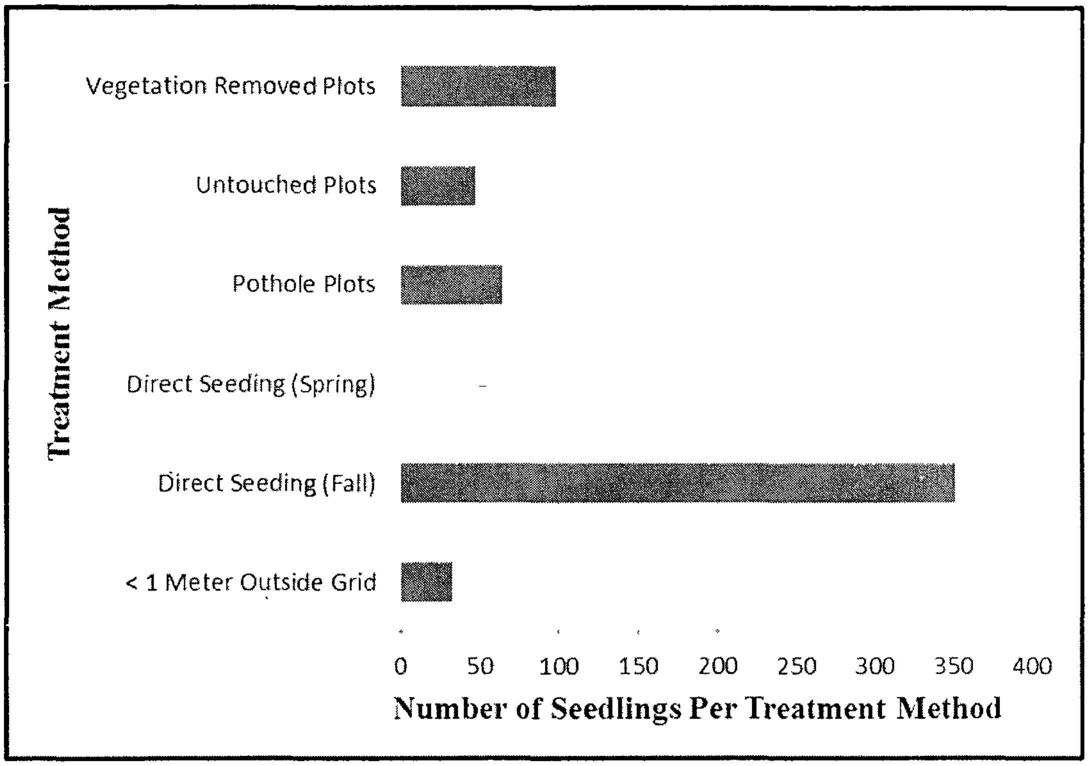

Figure 2.11: SLA second generation germination counts for each treatment method tested. Germination surveys took place in June of 2009.

taken place, including the edges of the potholes and where the substrate had been manipulated in the 'untouched' and 'vegetation removed' plots in order to insert the transplants. On a treatment level, the majority of the seedlings were found growing in clusters in the fall seeding plots (Figure 2.10). Unfortunately, the seedlings died one week later due to extreme weather conditions.

Weather conditions:

Over the course of the 2008 and 2009 seasons, the experimental plants were exposed to some extreme weather conditions. In 2008, transplanting at the Dune Slack site was delayed due to heavy flooding of the marsh. Both the East Marsh A and B sites, located adjacent to the Dune Slack site, dried up much faster throughout this study than the Dune Slack site which retained water for up to 4 weeks longer. The flooding is believed to be the result of heavy rainfall that took place throughout the month of August. According to the weather office located at the Charlottetown Airport, August 2008 was the wettest month ever recorded on Prince Edward Island. The month's total precipitation recorded at the Blooming Point weather station was 191.6 mm.

Within one week of transplantation (which took place in August), all of the 2008 experimental plots were inundated by flooding due to the high precipitation levels. Despite these hardships, the plants were able to survive even though many of them, especially plants in the pothole treatment, were completely submerged for several days. The SLA plants apparently aborted the development of submerged buds, but were able to maintain the development of the terminal and lateral buds that were above the water and were exposed to air and sunlight.

Another major rain event occurred during the germination period in June 2009, when 97.2 mm of rain fell within 24 hours. This rainfall event may have been responsible for the loss of germinating SLA seedlings resulting from the 2008 SLA transplants.

Weather also affected the transplanting in 2009. Within two weeks of planting, the 2009 transplants were exposed to high winds and rains from the remnants of two Atlantic hurricanes, Hurricane Bill and Hurricane Danny. The first storm, on August 23, had winds up to 64.4 km/hour and total precipitation of 18.2 mm at Blooming Point. One week later, the second storm had wind speeds up to 51.5 km/hour and 108.4 mm of rainfall. The majority of the transplants survived these storms; only two plants were uprooted and displaced from their plots.

Wrack and eelgrass monitoring and management:

Throughout the development of the SLA transplants, little to no eelgrass removal was necessary at any site. Although eelgrass would build up along the beach in thick mats (Figure 2.11), very little washed up into the sites and created issues for the transplants prior to seed dispersal. Therefore, no conclusions could be drawn from the eelgrass management efforts on the survivorship of the relatively mature transplanted SLA's. However, at the time of germination in 2009, there were plots within some grids that were buried under mats of dead eelgrass up to 4 inches thick. Despite management actions to remove the built up eelgrass, grid comparisons were not possible due to the death of all of the germinating seedlings.

Figure 2.12: Mats of dead eelgrass washed-up along the beach in front of the Dune Slack site, October 2009. Note knee-high level of accumulation.

Ground temperature and moisture:

The average ground temperature at the time of transplantation in 2008 was 18.9°C ± 1.4, while 2009 temperatures were higher at 23.3°C ± 5.2. The average ground temperature during SLA germination in 2009 was 15.29°C ± 4.0 (means ± standard deviations). Although some sites were visibly wetter or drier than others at times, each moisture measurement taken indicated that the substrate was wet and always rated 10 on the meter's scale.

Soil salinity:

In all samples and at all sites, the soil salinity never rose above 8g/L. The historic sites displayed rather low levels of soil salinity each time they were tested with the highest levels being 1.08g/L at the East Marsh A site. On the other hand, Robinson's Island, the only non-historic site tested, did reach higher salinity levels. The maximum for that site was 7.7 g/L while the minimum was 6.4g/L.

2.4: Discussion:

Although it was hypothesized that removing vegetation and simulating natural potholes would aid in population establishment, survival results indicate otherwise. The survivorship results indicate that transplants did not benefit from the removal of vegetation in order to lower competition levels, and that simulating potholes had a detrimental effect on populations. This may be in large part due to the frequent flooding and consistent waterlogging of the pothole plots.

Seed dispersal is the ability to spread through space and time within occupied sites or to unoccupied sites (Raven et al. 1999). The dispersal methodology of a plant can affect both the regional and local distribution of that species. Seeds of the Gulf of St.

Lawrence Aster possess a pappus, or plume-like structure, that slows the descent of the achene and may aid in transporting it further away from the mother plant. Lacroix et al. (2007) assessed SLA dispersal potential and found that *in-situ* achenes travelled a maximum of 23 cm from their point of release. Travel was impeded when the seeds came into contact with the surrounding vegetation. They also noted that seedlings were generally found in the immediate area surrounding the previous year's plants. Based on the seed shadow of the plants studied, most achenes travelled a range of 0.15-0.20m

The seed shadow phenomenon was also witnessed during both seasons of this study. The dispersal trends observed were very similar to those highlighted in Lacroix et al's. (2007) research, with the spatial distribution of the majority of the seeds remaining close to the source. For this reason, positive identification of second generation SLA plantlets within and around the experimental plots was assumed to have derived from the adjoining treatment plots themselves. The majority of the seedlings located during the germination surveys were found growing in clusters in the fall seeding plots.

These results indicate that the seeding methodology that was utilized in the fall serves the purpose of initiating SLA plant populations *in-situ*. Although the survivorship data indicate that there was not a significant difference in untouched and vegetation removed treatments, higher germination was noted to take place in the areas where vegetation underwent some form of removal, including the edges of the potholes and the areas within the plots where vegetation was disturbed to facilitate the insertion of the transplants the previous year. This suggests that these manipulations may affect the overall reproductive potential of the transplants and/or seeds by facilitating second generation plant establishment. This is probably due to the reduction in competition from other plants, since this species tends to colonize reasonably bare substrates and requires disturbance to offset competition (Gilbert et al. 1999, Houle et al. 2001, Houle and Valéry 2003).

Throughout both field seasons, plants in the pothole treatment remained underwater and waterlogged longer than plants in the other treatments. These pothole plants produced the lowest output in survival rates. Houle and Haber (1990) suggested that intra- and inter-annual water level fluctuations affect the annual variations in population density of this species. In 1999, Houle and Belleau (2000) studied the effects of drought and waterlogging on the development and performance of the SLA. They found that drought stress can negatively affect flower-head production, but that waterlogging had no effect on plant growth or biomass allocation. Although our study was unable to provide additional *in-situ* knowledge on drought stress, due to the high amounts of precipitation, extreme waterlogging and prolonged flooding was a common factor experienced by the transplants, and may have contributed to the low survivorship rates of plants in the potholes.

There was no difference when comparing the estimated germination potential of filled and unfilled achenes across the three treatment groups. All groups produced relatively equal average percentages of filled achenes (approximately 70%). These averages are consistent with the data collected by Lacroix et al. (2007). They found that inflorescences collected from the Dune Slack and East Marsh B sites (n = 47) in 2002 produced 64.9% filled achenes. There are however, acknowledged limitations to the collection of data for the 2008/09 study. The data that were collected could not be considered to be completely unbiased. Due to the need to collect inflorescences that looked as though they had not lost many seeds to dispersal, and achenes that were mature, it is possible that the inflorescences chosen represented a biased sample of productive inflorescences. In essence, the collection of the seed production data would have had confounding variables. For this reason inflorescences were only inspected after the 2008 season.

Unfortunately this study was not able to determine whether eelgrass wrack deposition had any effect on germination or survivorship of SLA. However, it is still possible that eelgrass deposition is a predominant factor that negatively affected the SLA seed bank and germination success at certain sites. Since eelgrass only seemed to cover the plant habitat during germination in the 2008 and 2009 seasons, eelgrass removal would be most beneficial if conducted prior to and throughout the germination season and only washed into the sites over the winter and spring months. This may be because eelgrass leaves die back during the winter months (Hemminga and Duarte 2000). These accumulations of wrack have the ability to bury the seeds in the seedbank and inhibit their germination. It is also possible for mats of eelgrass located within the marsh at the time of SLA germination to be moved by spring floods and winds, and consequently have the same effect. As Reynolds and Houle (2001) suggest, the relative importance of this structuring variable changes with the physical characteristics of the site. Ongoing monitoring and experimental management of this factor may be worthwhile.

According to Houle et al. (2001), SLA plants are more susceptible to high salinity during germination and early seedling growth than in later stages of development. They demonstrated that germination is reduced once salt concentrations reach 10g/L and are completely inhibited once they reach 20g/L. The levels detected in the soil salinity tests conducted throughout the germination season in 2009 were lower than the cautionary or limiting levels listed by Houle et al. (2001). Although there is no conclusive or quantitative evidence to prove that the seedbank at these sites was affected by salinity levels, the 2009 germination counts suggest that levels were at least within an acceptable range to produce seedlings.

Recent research conducted by Heard et al. (2010) proposed that the effect of temperature on SLA germination is more limiting than the effect of salinity. They state that delays in germination resulting from exposure to low soil temperatures could set up strong size asymmetries between SLA seedlings and surrounding vegetation, resulting in a suppression of SLA population growth due to shading. Interestingly, the majority of the temperatures that they tested (16, 23, and 30°C) were above the average ground temperature recorded *in-situ* for this experiment (15.29°C ± 4.0). They found that after 16 days, germination was greatest at their highest temperature tested. Therefore, the results from the 2008/09 study suggest that ground temperature may not be optimal for SLA establishment throughout the germination season at the sites tested within PEINP.

Although there are many factors to consider when attempting the establishment of populations of Gulf of St. Lawrence Aster, this research concludes that recovery efforts based on the methodologies listed may be possible. Discerning which methods would be most successful at each recovery site would be practical. Therefore, adequate information gathered on the potential sites that will be used for future recovery purposes would be beneficial.

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Chapter 3.0. Population Surveys and Site Assessments

3.1 Introduction:

First discovered by John Macoun in 1888, the Gulf of St. Lawrence Aster (*Symphyotrichum laurentianum*) (SLA) is an annual pioneer species found inhabiting saline and brackish areas such as dune slacks and sheltered salt marshes (Houle and Haber 1990, Gilbert et al. 1999). This very rare endemic of the Gulf of St. Lawrence, only known to exist in the Magdalen Islands of Québec, and coastal regions of New Brunswick and Prince Edward Island, is presently regarded by the Committee on the Status of Endangered Wildlife in Canada as being threatened (COSEWIC 2004).

This species has been the object of increased research and monitoring efforts across the Atlantic region. In Prince Edward Island, staff of the National Park have attempted to conduct annual surveys in the majority of the historic locations within the Park. As well, researchers from the University of Prince Edward Island and the University of New Brunswick have been working to establish additional information related to the development of the species (C. Lacroix, pers. comm.). In 2000, a joint project between Kouchibouguac National Park and the Irving Eco-center was initiated. As a result various populations of the species in New Brunswick were monitored and new populations were searched for, especially along the Northumberland Coast (D. Mazerolle, Atlantic Canada Conservation Data Centre, pers. comm.). In Québec, a number of organizations and University researchers have been monitoring populations in the

Magdalen Islands and conducting ecological studies to add to the research base (D. Mazerolle, and K. Tulk, pers. comm.)

Symphyotrichum laurentianum is a halophytic colonial species that generally grows on gently sloping ground above the high water line and below the dense upper marsh vegetation (Houle 1988, Gilbert et al. 1999, Houle and Valéry 2003). It has been determined that high salinity levels (Houle et al. 2001, Reynolds and Houle 2001), as well as low soil temperatures (Heard et al. 2010) can have negative implications on seed germination. As well, plant performance can be negatively affected by low light availability (Reynolds and Houle 2001, Houle and Valéry 2003), high salinity (Reynolds and Houle 2001) and drought conditions (Houle and Belleau 2000).

Since the plants usually colonize reasonably bare substrates, the general conclusion is that SLA requires disturbance to offset competition, (Gilbert et al. 1999, Houle et al. 2001, Houle and Valéry 2003). Various dynamic processes that contribute to the opening of vegetation cover in coastal environments are therefore necessary elements of this species habitat. The somewhat cyclical yet variable process by which habitat is modified through disturbance causing exposed substrate, and then the recolonization of that substrate may in large part explain significant interannual variations in population sizes (Houle 1988, Houle and Belleau 2000).

In Prince Edward Island, eight sites containing SLA have been identified, seven of which are located within Prince Edward Island National Park (PEINP). One National Park site reported by Houle and Haber (1990) (Brackley) was destroyed due to land development prior to surveys conducted in 1992. Distribution of the species within the Park is illustrated in Figure 3.1.

The majority of these sites have been reported to be inactive over the last 10 years, and the active sites have had significant reduction in population numbers (Guignion et al. 1995, Stewart and Lacroix 2001, Kemp and Lacroix 2004). Although a number of population surveys have been conducted at these sites over the last two decades by different researchers and organizations, they used a variety of survey methods and timing. These variations may have affected the reported population densities for the species. At the outset of this study in spring 2008, only one site was reported to be active with a total of 482 plants (Jenkins 2008).

Since the ultimate goal of the transplant experiments reported in Chapter 2 was to explore methods to increase the abundance of SLA on PEI, current information on what the species populations levels are, and what the population trends have been, is required in order to accurately report on recovery successes. As well, assessments of historic and potential sites will be useful for implementing future recovery strategies in Prince Edward Island National Park.

There is a lack of knowledge concerning the natural seed bank and viability limitations of this species (Allain 2007, Kemp and Lacroix 2004). Due to this insufficient information, it is critical to monitor the potential for natural recovery of the species in the sites that are not managed, in addition to monitoring effectiveness of the recovery efforts. It is possible that sites currently believed to be unpopulated could successfully re-establish populations through germination of viable seeds within a persistent seed bank, or through seed dispersal and migration from other sites. As a result, population surveys were conducted in 2008 and 2009 at all known historical SLA sites within PEINP, regardless of whether or not they had been reported to support

Figure 3.1: Map of historic SLA locations within PEINP. The blue outline indicates the Prince Edward Island National Park boundary, and the red symbols indicate the historic SLA sites. Sites from West to East: Brackley, Covehead Pond, Long Pond, Campbell's Pond, Blooming Point Western Wetland, Blooming Point Dune Slack, Blooming Point East Marsh.

populations over the last decade. A systematic approach to surveying each of the sites was implemented each season. As well, site assessments were conducted at these historical locations, as well as in other potential locations during the summer of 2009. In total, 16 sites were surveyed for plants, and assessed for habitat suitability. The central objectives of this study were:

- to assess the current status of *Symphyotrichum laurentianum* in Prince Edward Island National Park
- to survey potential habitats in the search for unknown populations
- to detect the possibility of reporting population discrepancies based on the timing of the surveys conducted
- to identify sites with the highest potential for successful recovery implementation.

3.2 Methodology:

Historical data were compiled from a number of sources including population reports found in journal articles, surveys conducted by UPEI researchers, as well as surveys conducted by staff of the Atlantic Canada Conservation Data Center (ACCDC) and Prince Edward Island National Park. Tables were created to present the range of population numbers that have been reported for each site to date.

Current population patterns were assessed through surveys in 2008 and 2009, which took place twice per field season at each of the historical sites within PEINP. The first survey was conducted in early to mid-June in order to determine the number of plants germinating. The second survey was conducted at the time of flowering/seed production (mid-September to early October) in order to determine the number of plants that survived to maturity. Prior to conducting the surveys, key indicator species were identified through a review of the available literature to help locate areas with the highest potential of having SLA populations. Six species were confirmed as being the most common associated indicator plants for St. Lawrence Aster populations on Prince Edward Island (Jacques Whitford ,1994): sea-milkwort (*Glaux maritime* (L.)), glasswort (*Salicornia europaea* (L.)), seashore buttercup (*Ranunculus cymbalaria*), toad rush (*Juncus bufonius* (L.)), three-square bulrush (*Scirpus americanus*), and orach (*Atriplex patula* var. *littoralis* (L.)).

Sites were surveyed using a line transect methodology. Salt marshes were surveyed by walking transects approximately five meters apart. The substrate to the left and right of the transect (2.5 meters on either side) was checked for St. Lawrence Aster plants and/or potential microhabitat. Microhabitat was defined by patches of available substrate with little vegetative competition. When a microhabitat was located it was surveyed thoroughly for the plants.

Sites around the perimeter of a pond or along the edges of outflows often required only one transect on each side of the outflow or around the perimeter. When SLA plants were detected, the plants were counted individually to report exact counts for the entire population.

The methodology used in this study to conduct the site assessments was based on the work conducted by Jacques Whitford in 1992-93. It involved rating all of the historic sites, as well as 8 potential sites suggested in the research conducted by Houle and Haber (1990), and Jacques Whitford (1994). Figure 3.2 shows the historic and potential sites that were assessed.

The methodology used to assess the sites was based on the physical parameters identified by Jacques Whitford (1994) as being important to note during initial inspections in 1992-93. These parameters are still relevant today based on the literature review that was conducted for this thesis. The ratings for each parameter were subjective, and consistency was maintained by having the same individual conduct each assessment. The parameters and range of possible ratings include:

- **Moisture Availability** – an indication of how wet or how well drained the soil at the site is. Potential sources of moisture include rain or tides

  0 = relatively dry site

  2 = ample moisture available

- **Substrate** – an indication of the available exposed substrate and its suitability for aster development

  0 = very little substrate exposed

  2 = sparse ground cover resulting in exposed substrate

- **Competition** – an indication of plant density or crowding at the site

  0 = very crowded or densely vegetated site

  2 = sparsely vegetated site

- **Sunlight** – an indication of overshadowing vegetation density

  0 = very dense canopy resulting in little or no sunlight reaching substrate

  2 = no canopy allowing full sunlight

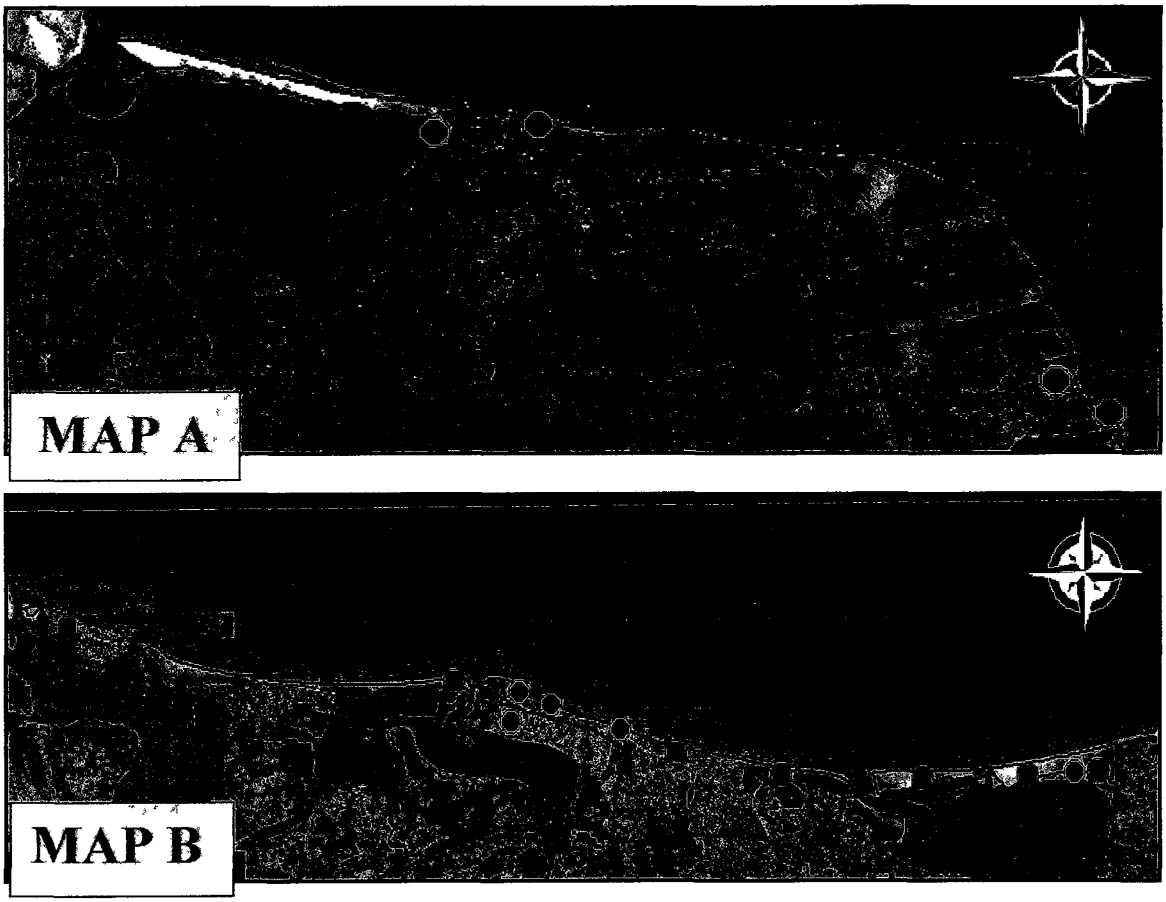

Figure 3.2: Maps of all sites surveyed and assessed for SLA populations and potential. The blue outline indicates the Prince Edward Island National Park boundary, and the green symbols indicate the site locations. MAP A: from Cavendish Sandspit to North Rustico dune slacks. Locations from West to East: Cavendish Marsh, Clarke's Pond, Rolling's Pond, and North Rustico Dune Slacks. MAP B: from Robinson's Island to Blooming Point. Locations from West to East: Robinson's Island, Covehead Pond, Covehead North Marsh, Covehead South Marsh, John Archie's Pond, Bell's Pond, Long Pond, Campbell's Pond, Blooming Point Western Wetland, Blooming Point Dune Slack, Blooming Point East Mash 'B', Blooming Point East Marsh 'A'.

• **Physical Stress** – an indication of site stability

0 = unstable site due to susceptibility to erosion or other physical damage causing destruction of site and elimination of seed stock

2 = stable site providing relatively exposed substrate through events of nature

Each parameter could receive a maximum value of two points – two points given for a positive influence on the aster and zero given for a negative influence. Using these five parameters each site was rated for its ability to support transplanted and/or seeded stock, with a total possible maximum habitat score of 10.

3.3 Results:

Tables 3.1 and 3.2 illustrate the compiled data for reported SLA population numbers in PEINP sites.

Table 3.1: Reported SLA population estimates/counts for PEINP sites, 1992-1999.

	1992	1993	1994	1995	1996	1997	1998	1999
Long Pond	1 [a]	1 [a]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]
Campbell's Pond	30 [a]	3 [a]	N/A	N/A	N/A	4 [b]	0 [b]	0 [b]
Cove Head	164 [a]	214 [a]	N/A	N/A	N/A	763 [b]	412 [b]	243 [c]
Dune Slack	~15,000 – 20,000 [a]	~15,000 – 20,000 [a]	N/A	N/A	N/A	13,569 [b]	12,600 [b]	~65,250- 117,600 [b c]
East Marsh	~48,000 - 60,000 [a]	~48,000 - 60,000 [a]	N/A	N/A	N/A	1,890 [b]	38,700 [b]	~17,010 - 60,000 [b c]
Western Wetland	425 [a]	0 [a]	N/A	N/A	N/A	N/A	0 [b]	0 [b c]

Data Sources for Table 3.1:
[a] Guignion et al 1995 [b] Data table provided by ACCDC [c] Stewart & Lacroix 2001 [d] Kemp & Lacroix 2004 [e]Jenkins 2008 N/A = Data not available

Table 3.2: Reported SLA population estimates/counts for PEINP sites, 2000-2008.

	2000	2001	2002	2003	2004	2005	2006	2007
Long Pond	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]
Campbell's Pond	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]	0 [b]
Cove Head	N/A	123 - 243 [e]	10 [d]	1 - 15 [b]	0 - 15 [e]	0 -5 [b]	0 [e]	0 [e]
Dune Slack	~52,000 [b]	~65,000 [e]	~2,200 [d]	1,000 - 5,000 [b]	~20,000 - 25,000 [e]	100 - 500 [b]	~3,000 [e]	482 [e]
East Marsh A	2,000 [b]	25,000- 60,000 [e]	133 [d]	~1,000 [b]	~400 - 500 [b]	0 [b]	0 [b]	0 [b]
East Marsh B	106,000 [b]	25,000– 60,000 [e]	~44,100 [d]	25,000 - 50,000 [b]	100,000- 115,000 [b]	<50 [b]	0 [b]	0 [b]
Western Wetland	N/A	0 [e]	0 [e]	0 [b]	N/A	N/A	0 [b]	0 [b]

Data Sources for Table 3.2:
[a] Guignion et al.1995 [b] Data table provided by ACCDC [c] Stewart & Lacroix 2001 [d] Kemp & Lacroix 2004 [e] Jenkins 2008
N/A = Data not available

3.3.1 Historic Sites:

3.3.1.1 Covehead Pond:

Macrosite Description

This pond is located behind a line of well-established dunes along the Gulf of St. Lawrence coastline. The Gulfshore Highway, PEINP's main highway, runs along the southern side of the pond. The majority of the perimeter of the pond consists of dense populations of graminoids, cattails and rushes, transitioning into thick bayberry and rose shrubs.

Microsite Description

A narrow strip along the northern edge of the pond (indicated by arrows in Figure 3.3 and Figure 3.4) was identified as potential habitat. This band is approximately 5 meters in length and 1-1.5 meters in width. Here, the surrounding vegetation is less dense and the exposed substrate is quite moist. Indicator species dominating within this area include three-square rush, milkwort and orach. Within 2 meters of this microhabitat however, the elevation is higher and the vegetation transitions into species indicative of high marsh (i.e., seashore goldenrod (*Solidago sempervirens*), marram grass (*Ammophila arenaria*) and bayberry (*Myrica pensylvanica*)).

Population Surveys

A full survey of the perimeter of the pond was conducted in both July and October of 2008 and 2009. No SLA plants were located during the surveys. The overall rating for this site was 7.0 (Table 3.3).

Figure 3.3: Picture of Covehead Pond taken from the Gulfshore parkway in PEINP, 2008. Sites of interest indicated with arrows.

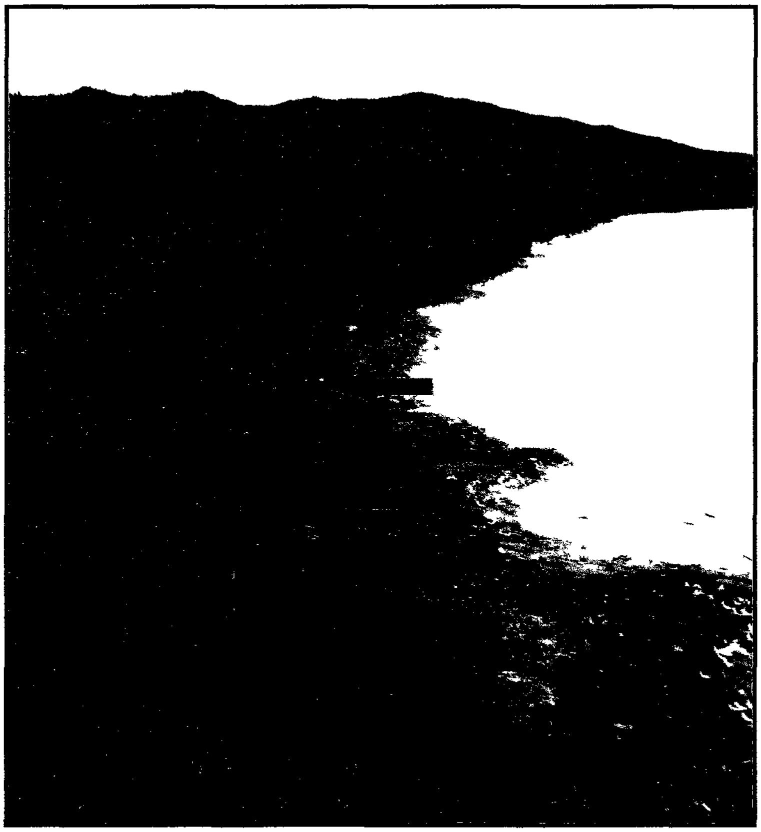

Figure 3.4: Picture of potential microhabitat located along the northern edge of Covehead Pond, 2009.

Table 3.3: Assessment ratings for historical sites within PEINP.

	Covehead Pond	Long Pond	Campbell's Pond	Blooming Point West	Blooming Point Dune Slack	East Marsh A	East Marsh B
Moisture Availability	1.5	2	2	1	2	1	1
Substrate	1	2	2	1	0	0	0
Competition	1	1	1.5	1	1	1	1
Sunlight	2	1	2	2	2	1	1
Physical Stress	1.5	0	0	1.5	1	1	1
Total	7.0	6.0	7.5	6.5	6	4	4

3.3.1.2 Long Pond

Macrosite Description

Long Pond (Figures 3.5 and 3.6) is a freshwater pond with an outflow to the Gulf of St. Lawrence. The perimeter of the pond is thickly vegetated and provides no habitat for SLA. The outflow is divided by a culvert due to the Gulfshore Parkway running above it. The northern side of the outflow is comprised of high banks, up to 10 feet tall, that are thickly vegetated at the top. The lower half, and sides of the banks do not support much vegetation.

Microsite Description

There are pockets of potential habitat along both sides of the outflow, and on either side of the culvert. These pockets contain two of the indicator species, orach and toad rush. There is water in the outflow and the microhabitat could be flooded during storm surges and spring floods. Tidal influence at these times would also affect salinity levels. The banks are tall and relatively stable, however erosion from the sides could bury plants during heavy disturbances. The overhanging cliff and vegetation may inhibit sunlight.

Population Surveys

There were no SLA plants detected during the surveys.

Assessment Rating

The overall rating for this site was 6.0 (Table 3.3).

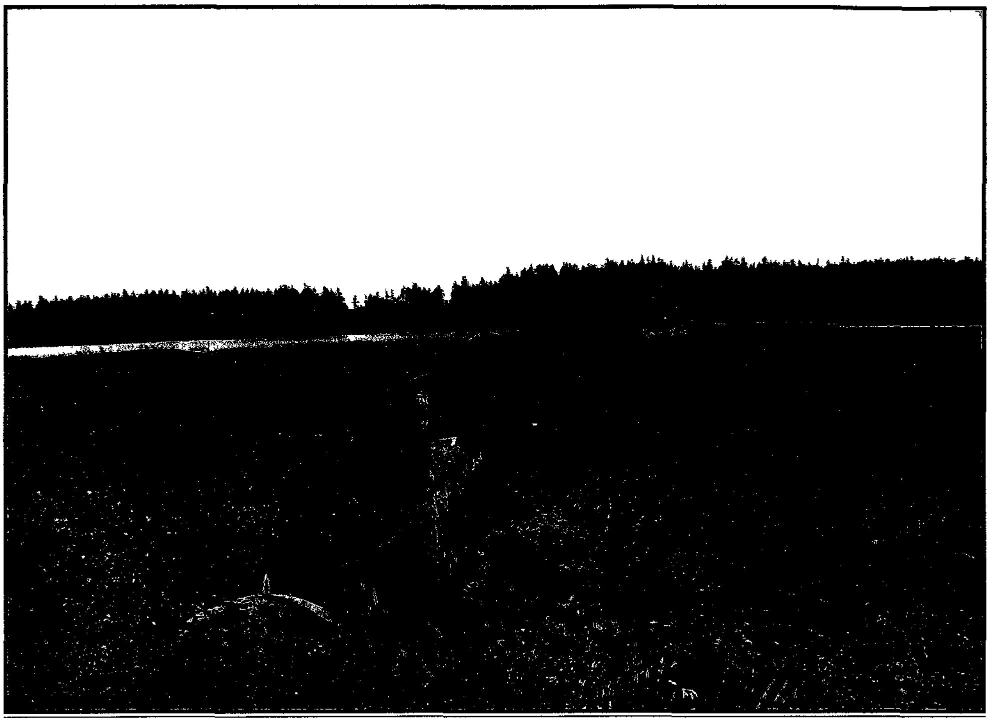

Figure 3.5: Picture of Long Pond and southern half of outflow, taken from the Gulfshore Parkway in 2009.

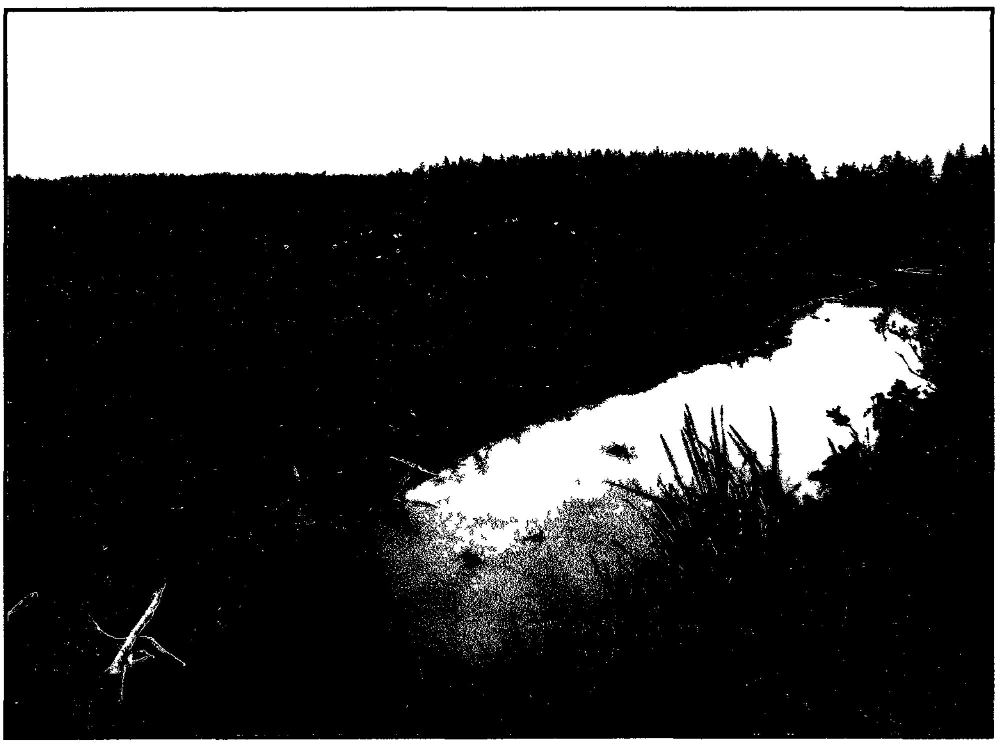

Figure 3.6: Arrows indicating potential microhabitat located along the southeast side of the Long Pond outflow, 2009.

3.3.1.3 Campbell's Pond

Macrosite Description

Campbell's Pond (Figures 3.7 and 3.8) is a freshwater pond with an outflow to the Gulf of St. Lawrence. The perimeter of the pond itself is thickly vegetated and provides no habitat for SLA. The upper banks of the outflow are thickly vegetated with graminoids, transitioning into rose and bayberry shrubs. Sparse vegetation exists along the lower edges of the outflow.

Microsite Description

The lower edges of the outflow provide the only potential habitat for SLA. Patches of habitat exist approximately halfway from the beginning of the outlet on the Gulf, up to the opening of the pond. The outflow is wide, with little overhanging vegetation allowing for adequate sunlight. Moisture availability is also adequate due to the water in the outflow. However, influences of extremely high tides, weather and ice conditions could cause flooding and erosion disrupting the available habitat. Few indicator plants were located in patches along the outflow, although orach and seashore buttercup were identified in low abundance.

Population Surveys

During the second survey in 2008, 18 mature plants were located along the outflow. A distinct patch on the West side of the outlet near the opening to the pond contained the 18 plants, all with at least one inflorescence. The plants were located in an area approximately 3m x 1m. These plants were initially found during a survey conducted by David Mazerolle, a botanist from the Atlantic Canada Conservation Data

Figure 3.7: Campbell's Pond, view from opening of outflow looking south, 2009

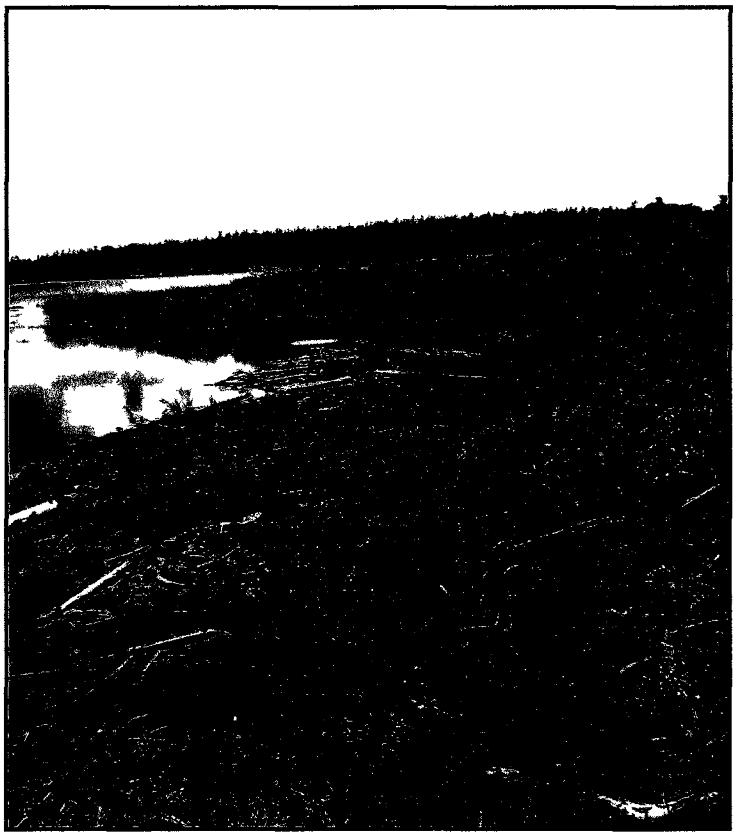

Figure 3.8: Potential SLA habitat (arrows) bordering Campbell's Pond along southwest edge of outflow, 2009.

Centre, and were identified again within one week of his survey. The surveys conducted in 2009 revealed no SLA growing at this site, despite intense searches.

Assessment Rating

The overall rating for this site was 7.5 (Table 3.3).

3.3.1.4 Blooming Point - Western Wetland

Macrosite Description

This site contains a well-protected shallow water pond within the dune slacks (Figures 3.9 and 3.10). There is currently not a permanent outflow located along the perimeter of the pond. The water would be acquired mainly through ground water and precipitation. The dunes surrounding the pond are well established and secured with typical dune vegetation (white spruce, bayberry, and sweet gale). The majority of the pond is surrounded by dense vegetation with little potential for SLA habitat.

Microsite Description

The northern edge of the pond has the most potential in terms of being suitable SLA habitat. There are a few strips, approximately 1 meter wide, wherein small pockets of available substrate containing indicator species are located. Milkwort, glasswort and toad rush were identified; however there were also some substantial patches of graminoid species within these communities. Although the substrate was not flooded at the time of the assessment in late summer, it is possible that these areas would be inundated with water earlier in the summer season.

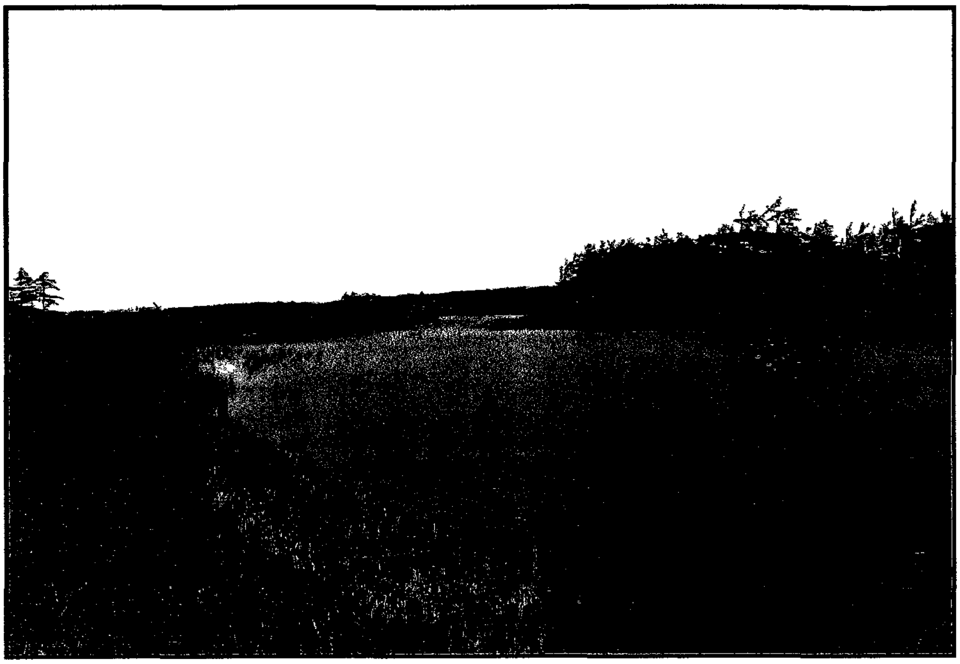

Figure 3.9: View of Western Wetland, looking northeast, 2009.

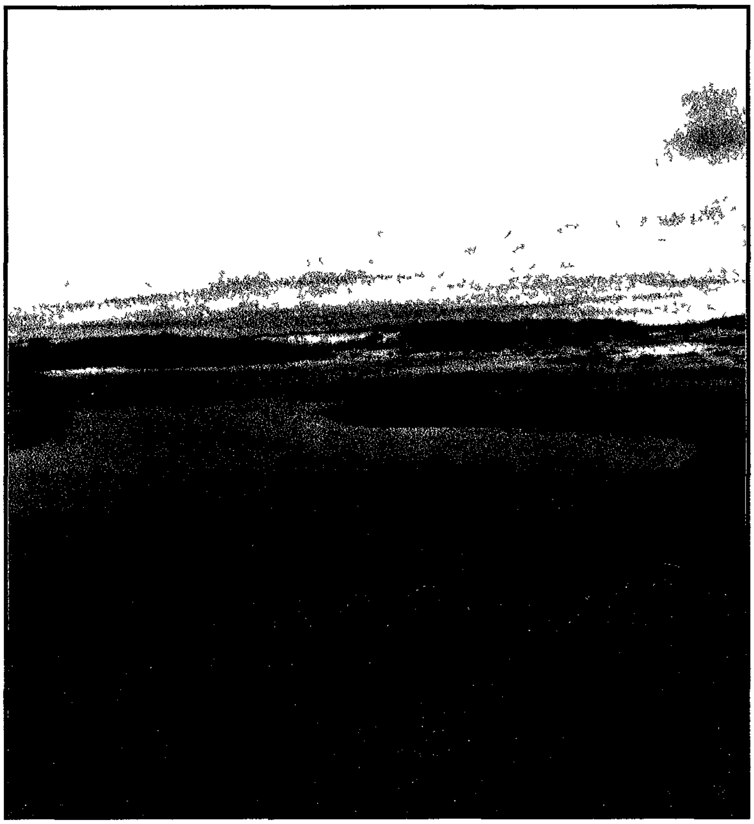

Figure 3.10: View of northeast edge of Western Wetland, very small patches of potential habitat (arrows), 2009.

Population Surveys

There were no SLA plants detected during the surveys.

Assessment Rating

The overall rating for this site was 6.5 (Table 3.3).

3.3.1.5 Blooming Point – Dune Slack

Macrosite Description

This site (Figures 3.11 and 3.12) is bordered by dunes on three sides and by Tracadie Bay on the south side. The habitat and vegetation is indicative of a salt marsh, bordered by typical dune vegetation. Although this site historically supported a large population of SLA, there is now little exposed substrate where the species could establish itself. The majority of the marsh is dominated by milkwort, lending the appearance of a flat level marsh.

Microsite Description

Random pockets of exposed substrate are available throughout the site. These pockets are essentially 'potholes' created by ice rafting. They are divots within the substrate where previously established vegetation has been uprooted. These areas are prone to collecting washed up eelgrass and flooding, which would unfortunately reduce the potential for SLA to become established. Within and immediately surrounding some of the potholes, indicator species are present, mainly milkwort and toad rush.

Population Surveys

There were no naturally growing SLA plants found during the 2008 surveys. Since this was a management site for the previously discussed transplant experiments, the

Figure 3.11: Blooming Point Dune Slack.

Figure 3.12: Germinating SLA plants, June 2009 Blooming Point Dune Slack.

2009 surveys reported data from both natural and experimental plants. During the early summer survey, conducted in June, there were 413 plants found germinating in and around the 2008 transplant and seeding plots. However, by the time the second survey was conducted in late September, no SLA plants were detected.

Assessment Rating

The overall rating for this site was 6.0 (Table 3.3).

3.3.1.6 Blooming Point – East Marsh A and B

Macrosite Description

This site (Figures 3.13 and 3.14) contains an extensive salt marsh sheltered by a system of stabilized dunes along the northern border. The southern side of the marsh is bordered by the Tracadie Bay. Due to a change in vegetation patterns the East Marsh site was divided into two sites, East Marsh A and East Marsh B in 2002 (Mazerolle pers. comm.). At that time a definite separation existed between the existing SLA populations. Together, the sites average approximately 100 meters in width and 1 km in length. There are a number of channels that remain open across the southern border, allowing an input of salt water and subjecting the site to tidal influence. Vegetation is very dense across the marsh and is dominated by salt-meadow cord grass (*Spartina patens*), followed by milkwort.

Microsite Description

Behind and around the channels open to tidal influence is where patches of potential microhabitat exist. Disturbances such as flooding and ice rafting in the winter have allowed for available substrate within these areas. Unfortunately, these areas have

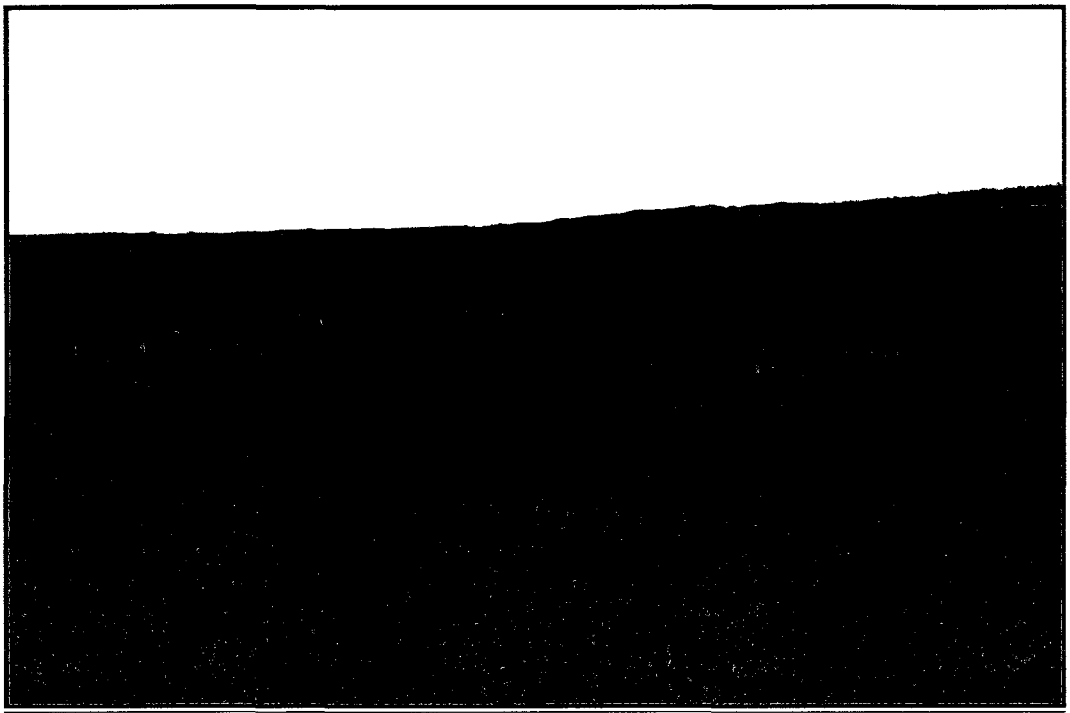

Figure 3.13: View of Blooming Point East Marsh with experimental grids, looking east, 2009.

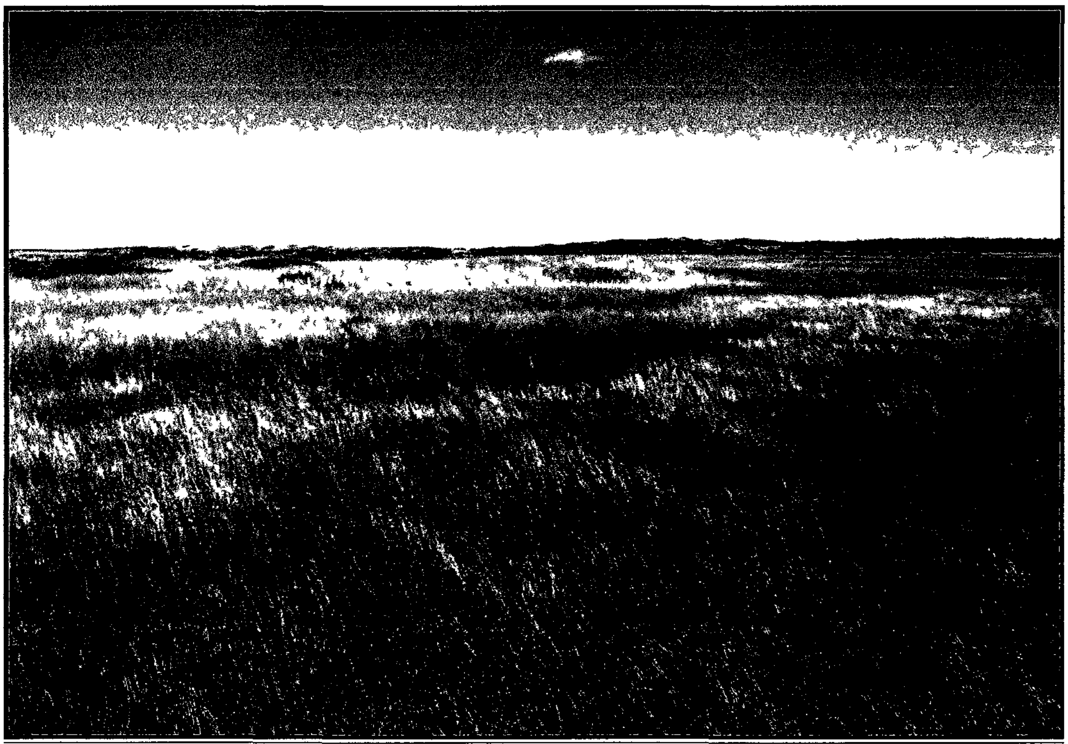

Figure 3.14: View of Blooming Point East Marsh, looking east, 2009.

also been noted to be inundated with washed up eelgrass. Any potholes or scrapes within the marsh that may have provided microhabitat tended to be either dense with milkwort, or buried under dead eelgrass. Indicator species detected included milkwort and glasswort, however where milkwort existed it was dense leaving little room for other species to establish themselves.

Population Surveys

No natural SLA plants were detected at these sites in either year. In 2009, 128 plants were found to be germinating within and around the 2008 experimental plots. Their location supports the fact that they resulted from successful transplants and seeding that took place the year before.

Assessment Rating

The assessment and rating for each of these sites were the same. The overall rating was 4.0 (Table 3.3).

3.3.2 Potential Sites:

3.3.2.1 Bell's Pond

Site Description and Assessment

Vegetation along the perimeter of the pond consists of thick populations of cattails, rose bushes and bayberry shrubs allowing for very little to no available substrate. There is no outflow running from this pond to the Gulf of St. Lawrence, reducing the potential for SLA microhabitat. The overall assessment rating for this site was 0 (Table 3.4), with negative implications allotted for each parameter measured. No SLA plants were found at this site during the surveys.

Table 3.4: Assessment ratings for potential sites within PEINP.

	Bell's Pond	John Archie's Pond	Clarke's Pond	Covehead Harbor North Marsh	Covehead Harbor South Marsh	Cavendish Marsh	Rolling's Pond	North Rustico Dune Slacks	Robinson's Island
Moisture Availability	0	1	0.0	2	2	2	0	0	1
Substrate	0	2	1.0	0	0	2	0	1.0	0
Competition	0	2	1.0	0	0	1.5	0	0	0
Sunlight	0	1.5	1.0	0	0	2	0	0	2
Physical Stress	0	0.5	1.0	0	0	1	1.0	0	1
Total	0	7.0	4.0	2.0	2.0	8.5	1.0	1.0	4

3.3.2.2 John Archie's Pond

Macrosite Description

This pond is located behind a wall of low, stable dunes (Figures 3.15 and 3.16). The perimeter of the pond is thickly vegetated, much like the dominant riparian area around Bell's Pond. There is an intermittent outlet located on the northeastern side of the pond, running into the Gulf of St. Lawrence. Although there was no potential microhabitat located along the perimeter of the pond itself, patches of the outflow provided potential areas for SLA plants to become established.

Microsite Description

The edges of the outflow average approximately 3 feet in height in relation to the water and are densely vegetated at the top. Along the bottom and side edges of the outflow, numerous pockets of available substrate containing indicator species are located. Milkwort, glasswort, orach, toad rush and three-square rush were all identified at this location. These areas of microhabitat receive much sunlight due to little overhanging vegetation and low outflow edges. Moisture availability would be fairly good due to the influence of high tides. Shallow water was present in areas of the outflow, despite little to no rain in the days prior to the assessment.

Population Surveys

Despite the potential suitability of this site, no SLA plants were located during the surveys.

Assessment Rating

The overall rating for this site is 7.0 (Table 3.4).

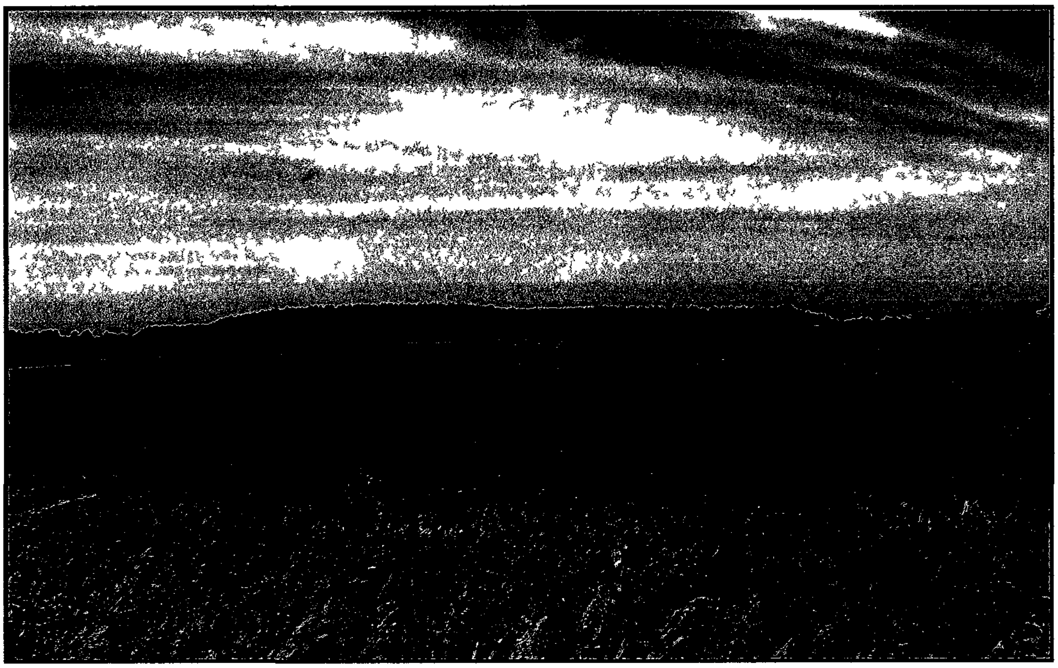

Figure 3.15: View of John Archie's Pond, looking west, 2009.

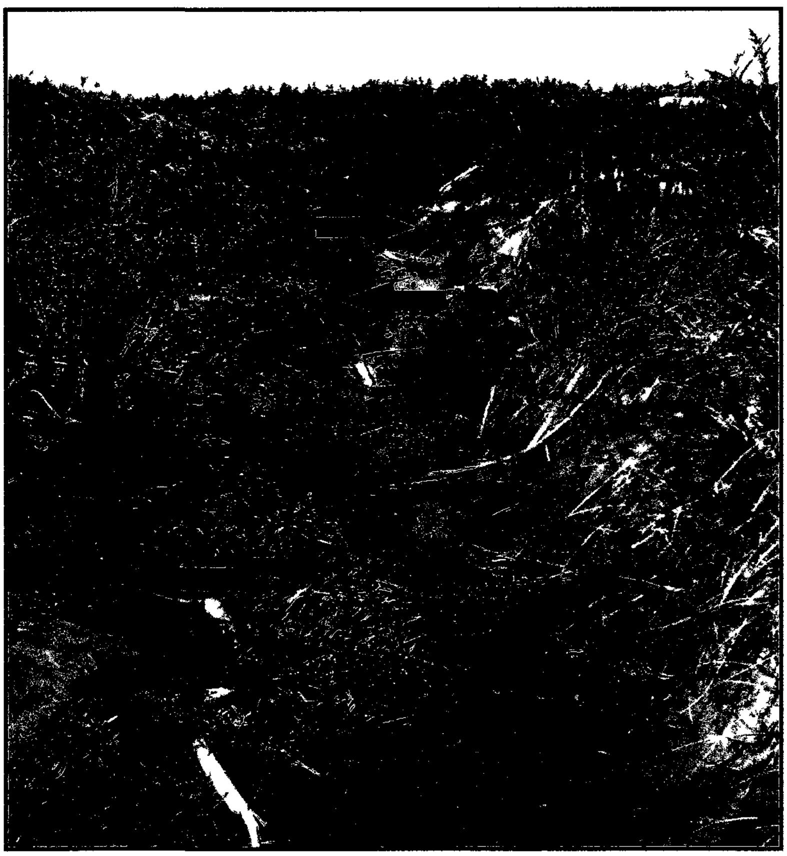

Figure 3.16: Potential microhabitat (arrows) located along John Archie's outflow, 2009.

3.3.2.3 Clarke's Pond

Macrosite Description

This pond (Figure 3.17) is located behind a sheltering dune system, and contains a very large and active outflow to the Gulf. Despite its close proximity to the Gulf and the active influence of tidal disturbance along the outflow, the site yielded little to no potential microhabitat. Thick vegetation along the perimeter of the pond dominates the substrate. Potential habitat that might exist at the mouth of the outflow is routinely disrupted and is not conducive to the establishment of any vegetation. The only indicator species identified within the area was three-square rush in small quantity. There were no SLA plants located during the surveys, and the assessment rating for this site was 4 (Table 3.4).

3.3.2.4 Covehead Harbor; North and South Marsh

Macrosite Description

These sites (Figures 3.18 and 3.19) represent saltmarsh habitat located along the southern side of an established dune system. The marsh is divided into two sections due to the Gulfshore Parkway running through the center. The northern section is composed of dense marsh vegetation with no disturbed areas or indicator species. The southern section contains deep pools of water throughout the area. Despite the presence of these lagoons, there were no potential microhabitat sites identified and no indicator species present. PEINP owns approximately half of the habitat located on the southern side of the highway; however surveys revealed no potential SLA plants at either site, or within the habitat located on the outskirts of the Park boundary. These sites were rated as 2 (Table 3.4), with maximum points being given for moisture availability.

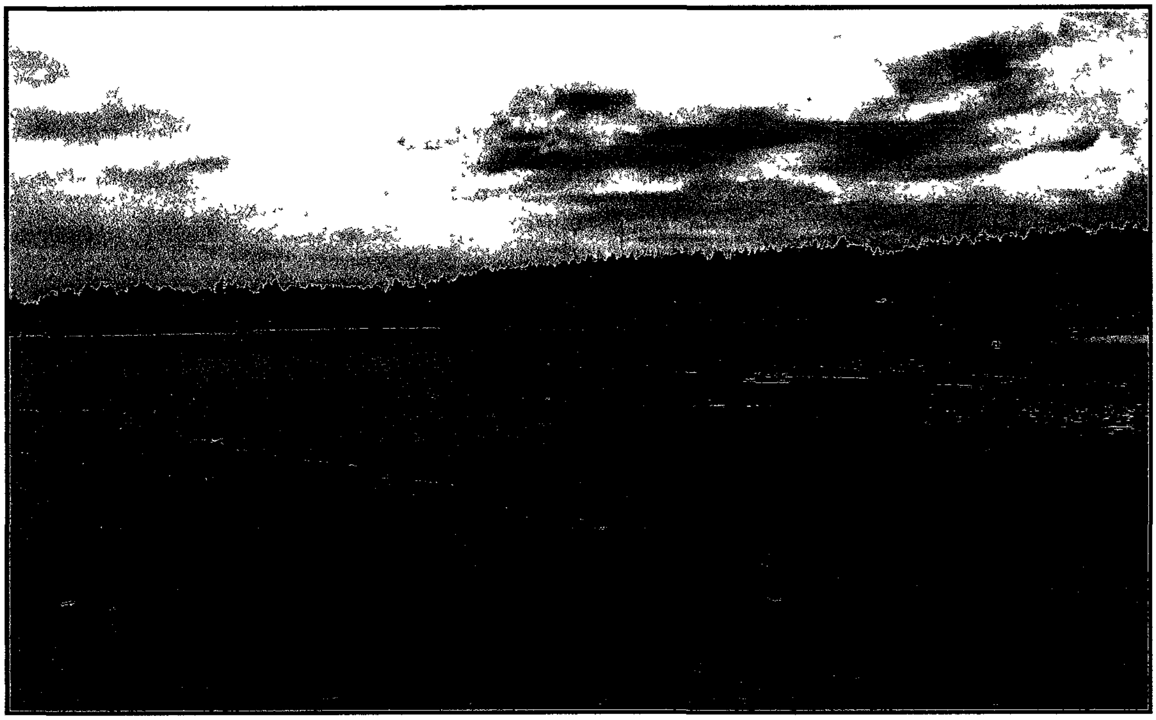

Figure 3.17: Clarke's Pond and opening to outflow, 2009.

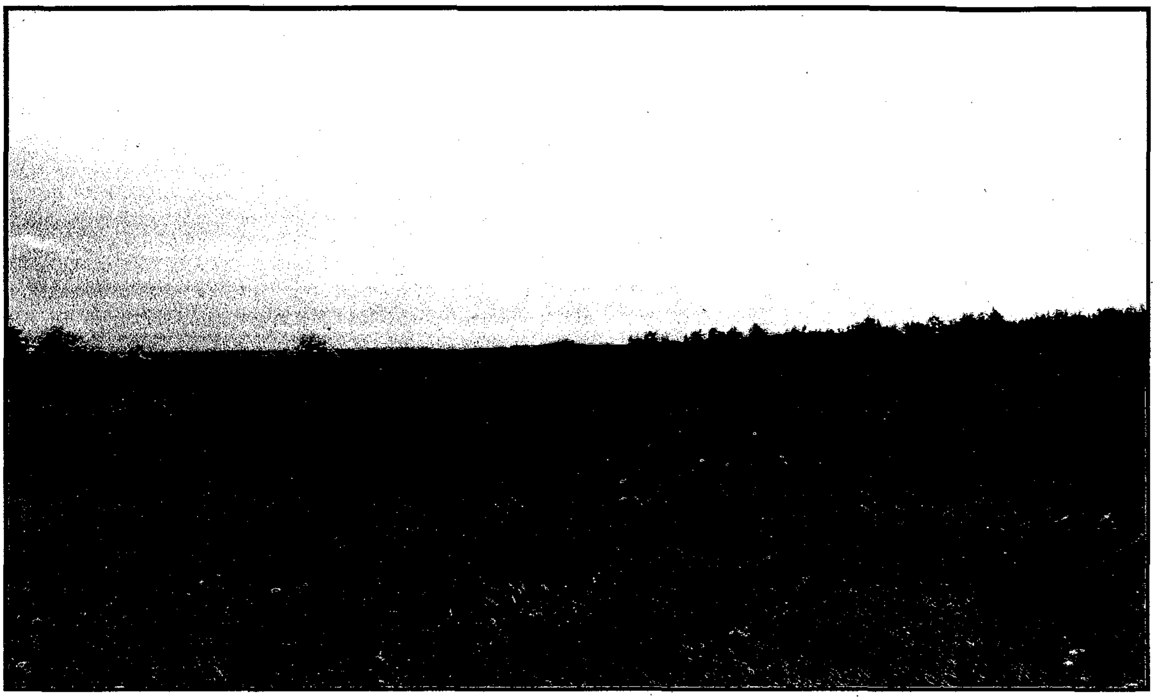

Figure 3.18: View of Covehead Harbor North Marsh, 2009.

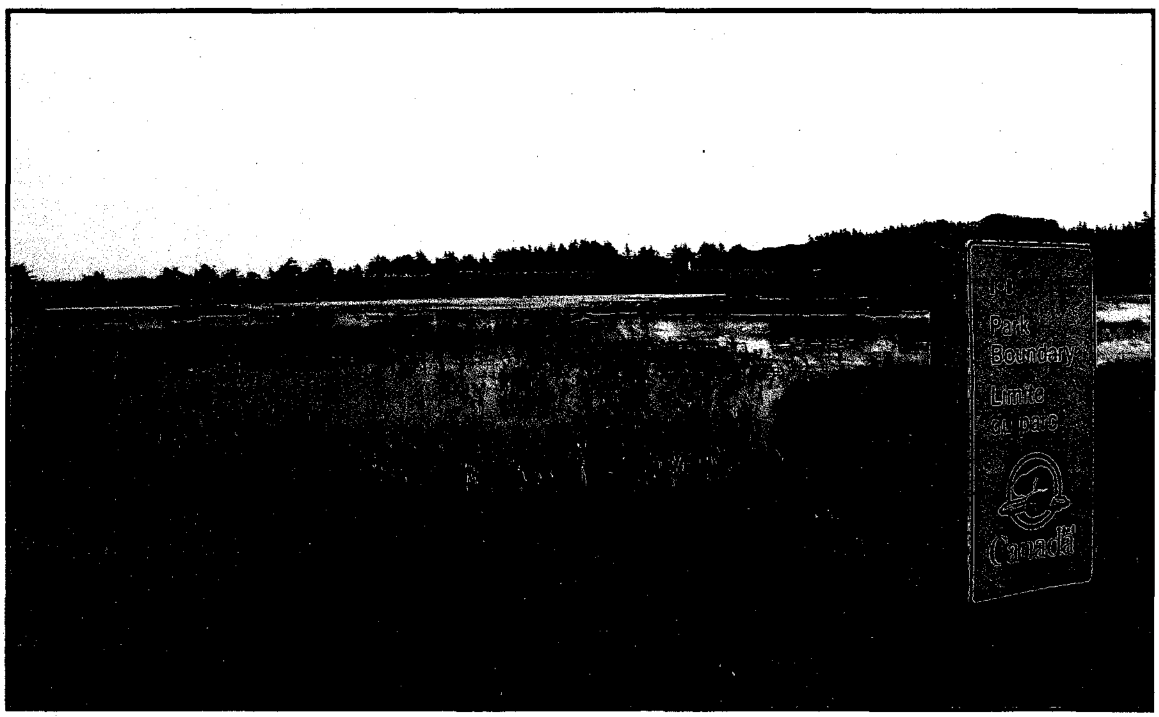

Figure 3.19: View of Covehead Harbor South Marsh, looking towards the Gulfshore Parkway, 2009.

3.3.2.5 Cavendish Marsh

Macrosite Description

This site (Figure 3.20) contains an extensive saltmarsh located behind the large, well established Cavendish Sandspit. The large dune system along the northern border of the marsh, combined with forest along the eastern and southeast borders enclose the marsh and provide adequate shelter. Throughout the marsh there are many lagoons and channels that are constantly filled with water due to tidal influence.

Microsite Description

Around the perimeters of many of the pockets of water and influxes there are expanses of available substrate that are inhabited by many of the SLA indicator species (Figure 3.21). Specifically, glasswort, orach, and milkwort have established themselves well within these areas. Substrate is readily available, with little to no competition for sunlight. Eelgrass is not considered to be an inhibitor due to the limited amount of buildup observed over the two monitoring seasons. Any amounts that were found within the marsh were situated within random pockets of marsh vegetation and have served as a positive disturbance to create available substrate (Figure 3.22).

Population Surveys

Despite available microhabitat, no SLA plants were detected throughout any of the population surveys.

Assessment Rating

This site received the highest assessment rating of 8.5 (Table 3.4).

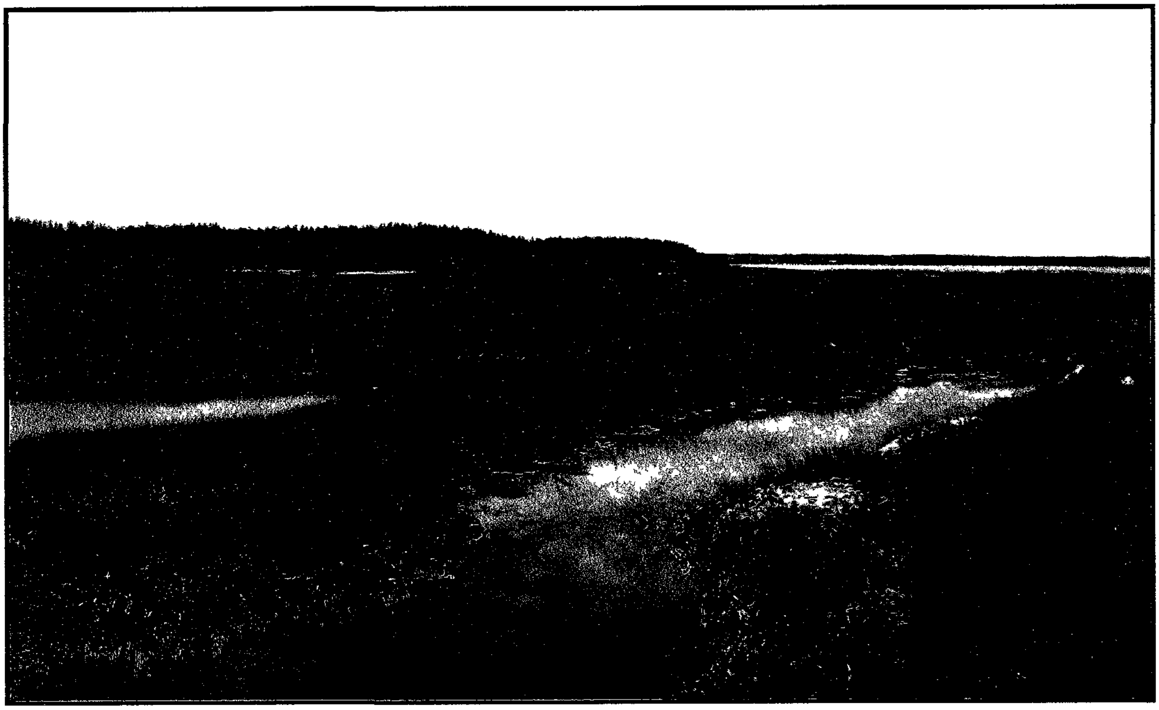

Figure 3.20: Cavendish Marsh, 2009.

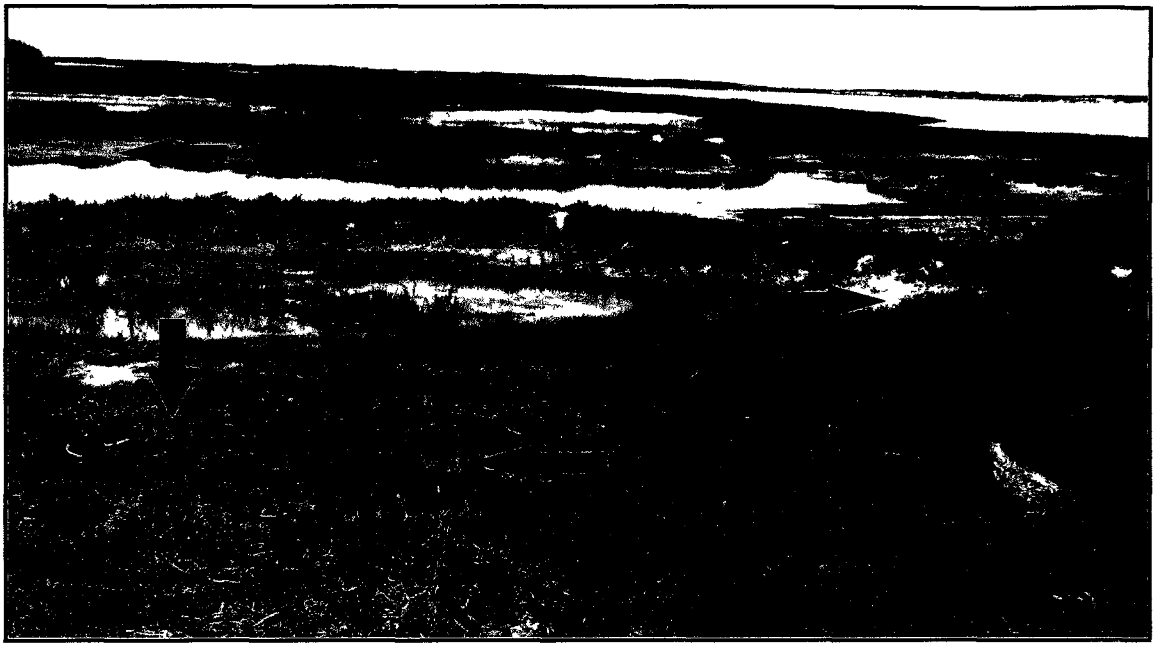

Figure 3.21: Cavendish Marsh, potential SLA habitat (arrows) located adjacent to water pockets, 2009.

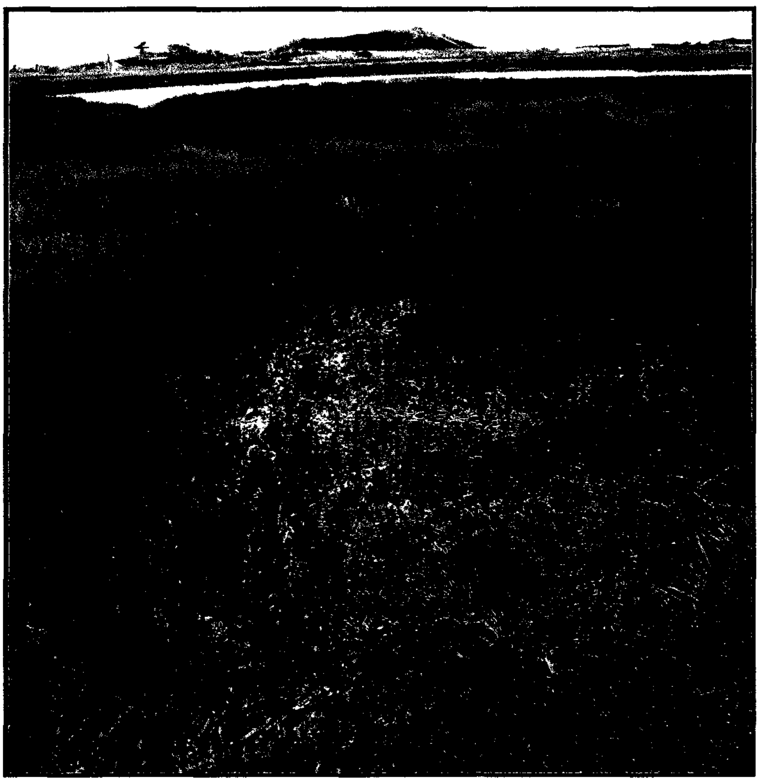

Figure 3.22: Cavendish Marsh, patch of potential SLA habitat located in a random pocket of disturbed substrate, 2009.

3.3.2.6 Rolling's Pond and North Rustico Beach Dune Slacks

Macrosite Description

The pond and dune slacks are situated near the Rustico entrance to PEINP. The habitat around Rolling's Pond is very densely vegetated and provides no potential habitat for SLA (Figure 3.23). There is an outflow running from this pond, through culverts under two roadways, to the Rustico beach (Figure 3.24). As a result of the outflow, there is a patch of habitat that is indicative of freshwater marsh along the southeast side of the entrance roadway. This area is small and densely vegetated with no available substrate. At the beach end of the culvert, the habitat is sandy and rocky with little vegetation. All areas were heavily vegetated with mature dune vegetation (marram grass, bayberry, rose bushes), and consequently no microhabitat or indicator species were identified at this particular site. The overall ratings for both of these sites were 1 (Table 3.4).

3.3.2.7 Robinson's Island (formerly named Rustico Island Wetlands)

Macrosite Description

This site is located on the southern side of Robinson's Island and contains a well-developed salt marsh (Figure 3.25). The marsh is densely vegetated with salt-meadow cord grass and graminoid species. There were some patches that contained milkwort, however they were densely populated and did not reveal available substrate. This was the only introduction site chosen for the populating experiments discussed in Chapter 2.

Microsite Description

The areas containing the indicator species were identified as the only potentially suitable microhabitats, and were limited in number and size. Any scrapes and/or potholes

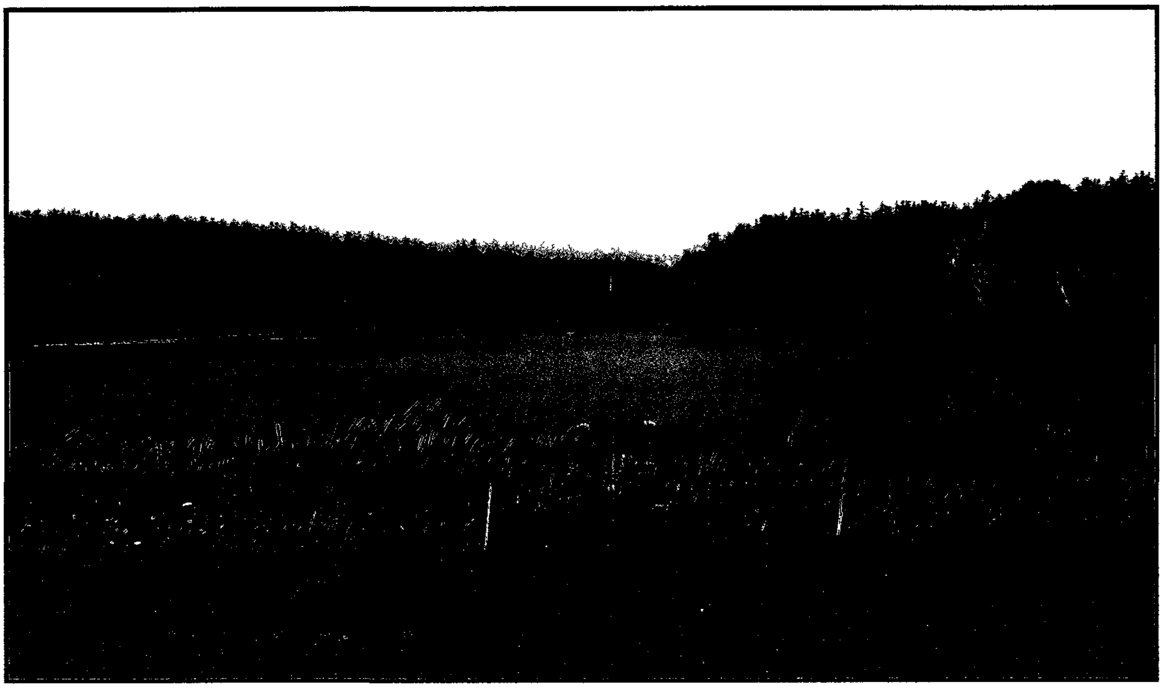

Figure 3.23: Rolling's Pond, 2009.

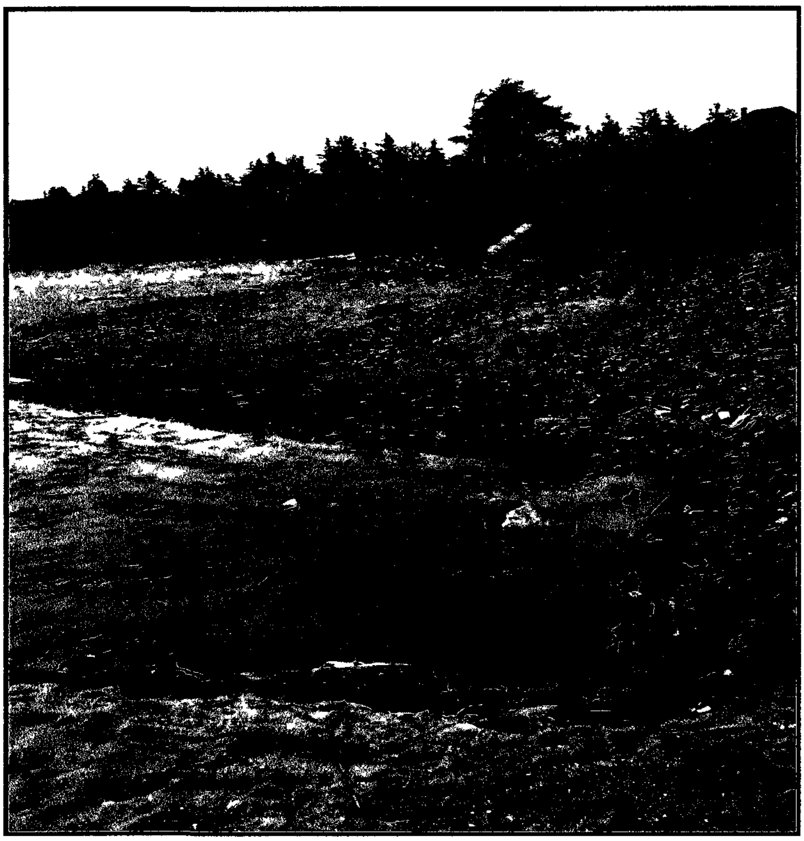

Figure 3.24: Beach side of Rolling's Pond outflow, looking towards dunes, 2009.

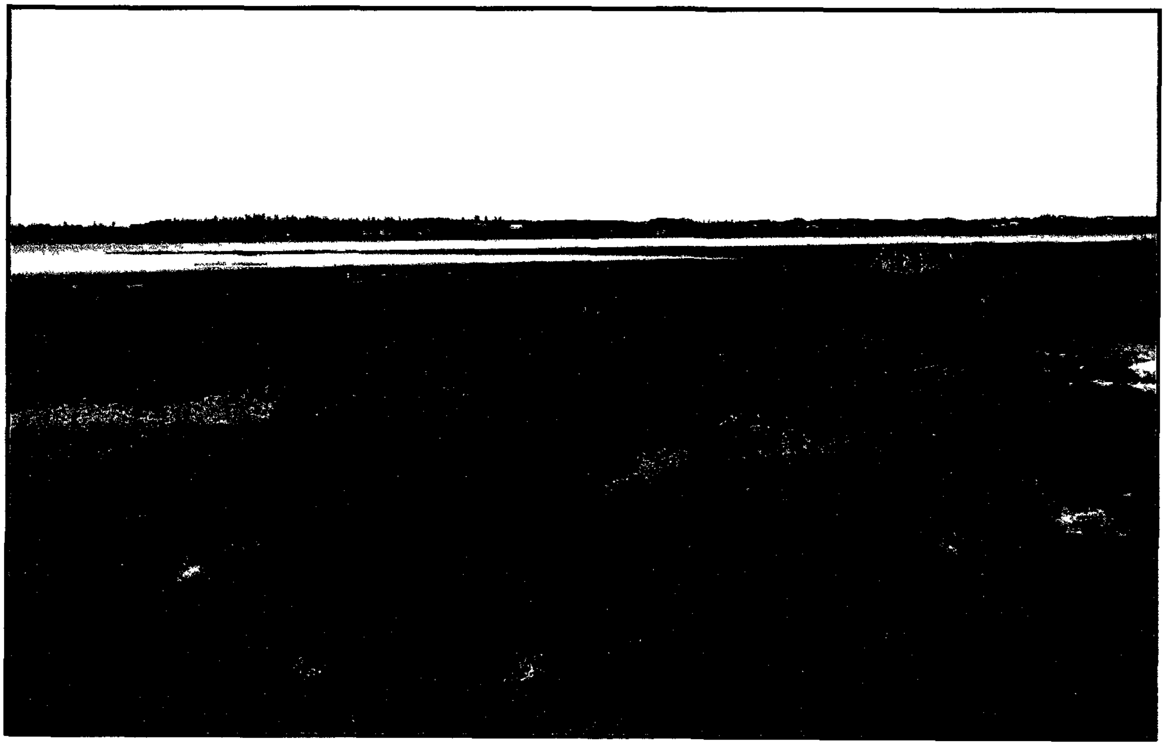

Figure 3.25: Robinson's Island salt marsh and experimental plots, 2009.

located within the marsh had abundances of washed up eelgrass that were too thick to allow for the successful germination and establishment of any SLA plants.

Population Surveys

There were 24 plantlets found germinating within the experimental grids in 2009. These plants did not survive for more than a couple of weeks. No natural SLA plants were detected throughout the surveys.

Assessment Rating

The overall rating for this site was 4 (Table 3.4).

3.4 Discussion:

Although population trends for the Gulf of St. Lawrence Aster have fluctuated greatly over the last two decades, recent surveys have indicated that this species has been extremely rare within Prince Edward Island National Park over the last three years. Throughout this interval, only one site has been active with low numbers of naturally occurring individuals, and 2009 yielded no active natural sites. The complete loss of SLA at each of the historically heavily populated sites located on Blooming Point is definitely noteworthy. It is also interesting to note that although 18 plants were identified at Campbell's Pond in 2008, it was reported that no SLA plants had been identified at this location since 1997, when four individuals were confirmed by a surveyor from the Atlantic Canada Conservation Data Center (D. Mazerolle, pers. comm.).

Three possibilities exist that may explain the phenomenon of the recurrence of the species at Campbell's Pond. It is possible that plants at this site have in fact existed and went without recognition over the years. Another less likely possibility may be that seeds migrated to this location from other sites and established themselves. However, it is also possible that a seed bank dating back to 1997 still existed at the site, and recent disturbances rendered the area suitable for germination of those seeds. This last explanation is of interest due to the limited knowledge we have of the germination potential for seeds older than three years, and the extent of the persistent seed bank. Kemp and Lacroix (2004) found that the majority of viable seeds germinate within one year of being produced. Their research indicates that the percentage of viable seed in the persistent seed bank is very low (2%). In theory, it is possible, although unlikely, that even low percentages of viable seeds in the persistent seed bank would have the ability to reestablish populations given the appropriate conditions. Additional seed bank studies would benefit conservationists in their effort to recover and/or sustain this species.

Historical population numbers indicate that surveyors have reported diverse numbers for SLA populations at the different sites. Through conducting two separate population surveys at different stages of plant development, this study suggests that the timing of surveys may in fact affect population size reports. For example, the Dune Slack site contained over 400 plants in June of 2009. However, within one week of that survey, those plants had all been destroyed due to heavy rains and flooding. Basically, the plants which were at cotyledon stage at the time of the survey were drowned, uprooted or buried by overwash. Continued surveys of this site yielded no other SLA plants; therefore, no plants achieved full development and contributed to the seed bank. It would be beneficial to standardize the timing of surveys and the techniques of estimating population sizes in order to more efficiently report on the reproductive population size.

Houle and Belleau (2000) reported that waterlogging had no significant impact on SLA development, although the monitored loss of over 500 germinating plants in PEINP (Chapter 2) may contradict this point. The seedlings were identified, counted and photographed on June 6, 2009. Heavy rainfall resulted in flooding of the marsh on June 12, and by June 15 the plants were found to be uprooted, buried or no longer turgid. It's likely that these forms of mortality were related to the inundation that took place. Houle and Belleau (2000) conducted their treatments on seedlings that were three weeks old. The seedlings identified within the PEINP site were most likely around the same age, based on comparisons of cotyledon stage and size of plants growing in the UPEI greenhouse. Therefore, either flooding in the natural habitat, hardships endured as a result of rainfall, or a combination of both factors had detrimental effects on this species. Even though inundation may not have caused significant effects on plants in the *ex-situ* study, it is possible that this factor can impact overall population development in a natural setting.

Although the search for new SLA populations was not successful, new locations were identified as potential areas for introduction. Based on the assessment ratings, two historical sites were rated as equal to or above 7.0 out of 10. These sites have been recognized as having the highest potential for successful recovery strategies. Transplanting, seeding or a combination of these two recovery methods would be most beneficial at the Covehead Pond and Campbell's Pond historic sites.

There were also two non-historical sites that received ratings equal to or higher than 7.0; the Cavendish Marsh and John Archie's Outflow. The Cavendish Marsh location provides not only the highest potential for naturally sustained microhabitat, but also the majority of microhabitat within the Park. It is possible that transplanting and direct seeding at this site may initiate an introduced population of Gulf of St. Lawrence Aster that is able to naturally sustain itself. On the other hand, John Archie's outflow did score high on the assessment rating used, however there is admittedly limited area available within this locality to incorporate management actions.

Overall, the methodology to rate the sites is a comparative way of ranking the best possible locations to implement SLA recovery strategies, and was based on past practice. However, given recent research results, including those of Chapter 2 in this thesis, there are a number of variables that can also be added to this methodology to achieve more appropriate assessments of potential management sites. For example, the total area of potential microhabitat within a locality is important. Several of the sites, including some with high scores (ex. John Archie`s Pond) had small overall areas of potential habitat compared to others. Including a means of measuring this variable would be beneficial. In addition, an indication of potential for flooding at each site would also be useful, as well as measurements of soil salinity levels throughout the germination season. Incorporating these variables into the assessment methodology would strengthen the reliability of choosing appropriate sites for future management purposes. Based on the ratings that were applied, it would be interesting to conduct studies of recovery management actions at different sites within the Park, and monitor their success over the long term.

The assessment methodology would also benefit from a comparison of site descriptions from the early 1990s to present. As a result, knowledge of how the sites have transitioned over the years could be acquired. For example, in the 1990s the

Blooming Point Dune Slack, a prominent location for SLA, was considered to be ephemeral -- a pond that dries up as the summer progresses. This site is now better described as a well-developed salt marsh. The dominant vegetation is quite homogenous and consists mainly of milkwort and secondarily of salt-meadow cord grass. The site supports little exposed substrate across the expanse of the marsh. The comparisons indicate that the site has matured over the years allowing for a decrease in potential SLA habitat.

Density of vegetation cover and interspecific competition play a major role in limiting SLA establishment and development (Houle 1988). Given the results of the germination data discussed in Chapter 2, the sites with high ratings for all parameters except vegetative competition levels may require further investigation. This is because the reduction of competing vegetation is one of the limiting factors that can be efficiently managed and may be useful for germination of seeds (Chapter 2). If necessary, this action can be initiated prior to germination, maintained throughout the development season, and may in fact sustain a recovering population of SLA. Some of the sites that would benefit from this management include the Western Wetland, Covehead Pond and the Blooming Point Dune Slack.

A review of rare plant recovery literature conducted by Falk et al. (1996) identified four classes of selection criteria to consider when determining what constitutes suitable habitat in the site selection process for the introduction of rare plants. Each of the categories (physical, biological, logistical and historical) are acknowledged in the methodology used for this study. The main consideration for the physical category is that the landscape-specific selection be of similar geomorphic setting (i.e. similar landscapes should be chosen as have been historically proven for the species to subsist in).

The biological selection category (Falk et al. 1996) is based on factors related to the autecology (biological relationships between an individual species and its environment) and synecology (structure and development of entire ecological communities and the interrelationships within them) of the rare plant species. These factors were accounted for in this study by recording floristic composition and structure (i.e. the identification and presence of indicator species), as well as the assessments of the habitat functions (i.e. ratings of competition levels, and susceptibility to flooding and physical stress).

The third category in Falk et al.'s (1996) selection criteria, logistical criteria, deals with the degree of site protection and human access, as well as the responsibility of monitoring and remediation. The first factor is covered since all of the assessed sites are located within the federally protected PEINP. As well, based on the interest that PEINP resource conservation staff has in this particular project, long-term monitoring and site accessibility should not be an issue if recovery actions move forward in the proposed sites.

The final category, historical criteria, involves assessing both historical as well as potential habitat locations (Falk et al. 1996). This is important for the persistence and adaptation of the species. Falk et al. (1996) states that, "it is possible, and in some cases probable, that the greatest potential for persistence and evolutionary change is found in the never occupied but apparently suitable habitat." The historical criteria were addressed with the assessments of both historical and potential sites located within PEINP.

Overall, this study should be of key interest and use to ecologists interested in conducting recovery efforts of SLA within PEINP. As well, biologists in other regions who are attempting to identify and assess potential habitat within their area could easily adapt the methodologies used here for their own needs.

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Chapter 4. Pollination Experiment

4.1 Introduction:

The annual coastal plant Gulf of St. Lawrence Aster (*Symphyotrichum laurentianum*) is listed as Threatened in Canada (COSEWIC 2004). Recovery to the level of a non-risk category is particularly desirable given its endemic nature. The species is known only to exist in Prince Edward Island, the Magdalene Islands of Québec, and New Brunswick. Population trends within these three provinces indicate a reduction in both numbers of plants and sites (Tulk, pers. comm.). Specifically, in Prince Edward Island, comparison of recent and older surveys indicates a lack of growth and spread of this species within Prince Edward Island National Park (PEINP) – the area where the majority of historical sites exist within the province (Houle and Haber 1990, Guignion et al. 1995, Stewart and Lacroix 2001, Kemp and Lacroix 2004).

Suitable habitat for SLA includes intertidal habitat, mainly on the upper levels of salt marshes above mean high tide. However, the species can be found along the margins of ponds, lagoons, and coastal dunes as well (Houle and Haber 1990). These areas are influenced by seasonal water variation and wave action, and may periodically be subject to tidal flooding resulting in increased levels of soil salinity. As an annual species, the Gulf of St. Lawrence Aster is mainly dependent upon its seed bank for recruitment (Allain 2007, Kemp and Lacroix 2004). The plants and the seed bank are tied to many dynamics, including tidal action that removes organic build up and disperses seeds, high water levels that control encroachment by other vegetative species, and wrack deposition.

Ecological observations indicate that the species is largely dependent upon disturbance events to create appropriate microhabitat that can be colonized by the plant.

Flowering of St. Lawrence Aster occurs from late August to mid-September with fruits appearing in late September and dispersal occurring in October (Houle 1988, Houle and Haber 1990). Each individual plant has the ability to produce 1 > 700 inflorescences (Houle and Haber 1990). Although an inflorescence on the SLA plant may initially look like a single flower, it is in fact comprised of many individual florets that make up a capitulum or 'head' (Bell 1991). The Gulf of St. Lawrence Aster's inflorescences have leafy bracts at their base and individual florets, once they set fruit, have a distinct white pappus (Houle 1988) (Figure 4.1).

Symphyotrichum laurentianum belongs to a section of the family Asteraceae known as *Conyzopsis* (Nesom 1994). This section is described as having inflorescences with two types of florets (Houle 1988, Nesom 1994). Lacroix et al. (2007) found that within SLA the central disk florets are larger and fewer in number than the peripheral pistillate florets (Figure 4.2). As well, the disk florets appear to be hermaphroditic from both an anatomical and morphological point of view, even though there is no visible confirmation of a style and/or stigmas prior to the corolla tube enclosing the inner floral organs completely. This may indicate that the disc florets are cleistogamous. Cleistogamous flowers have the ability to self-fertilize while remaining closed (Lord 1981). This adaptation is viewed as a way to ensure the production of offspring. In contrast, the corolla does not completely enclose the floral bud of the outer pistillate florets. As well, stamens are not initiated and pollen is not produced in pistillate florets, therefore they are essentially considered "female". These flowers would be

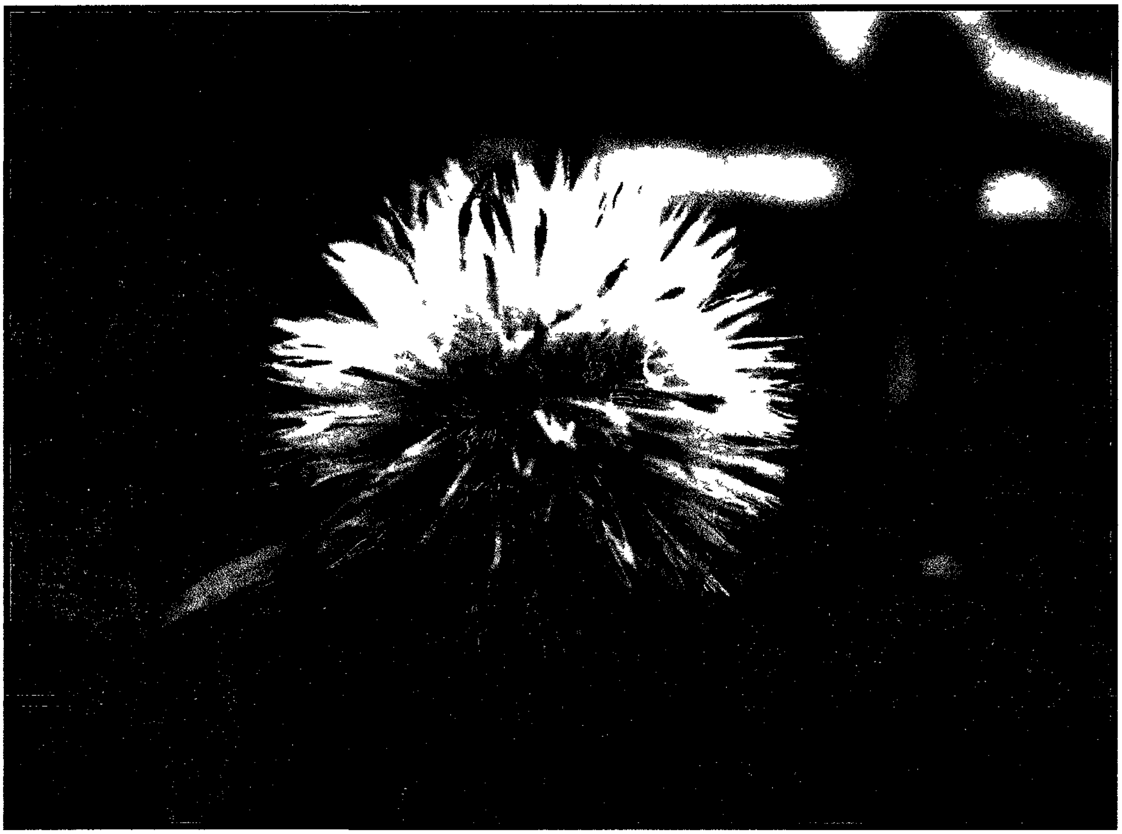

Figure 4.1: Photo depicting an individual SLA inflorescence at maturity.

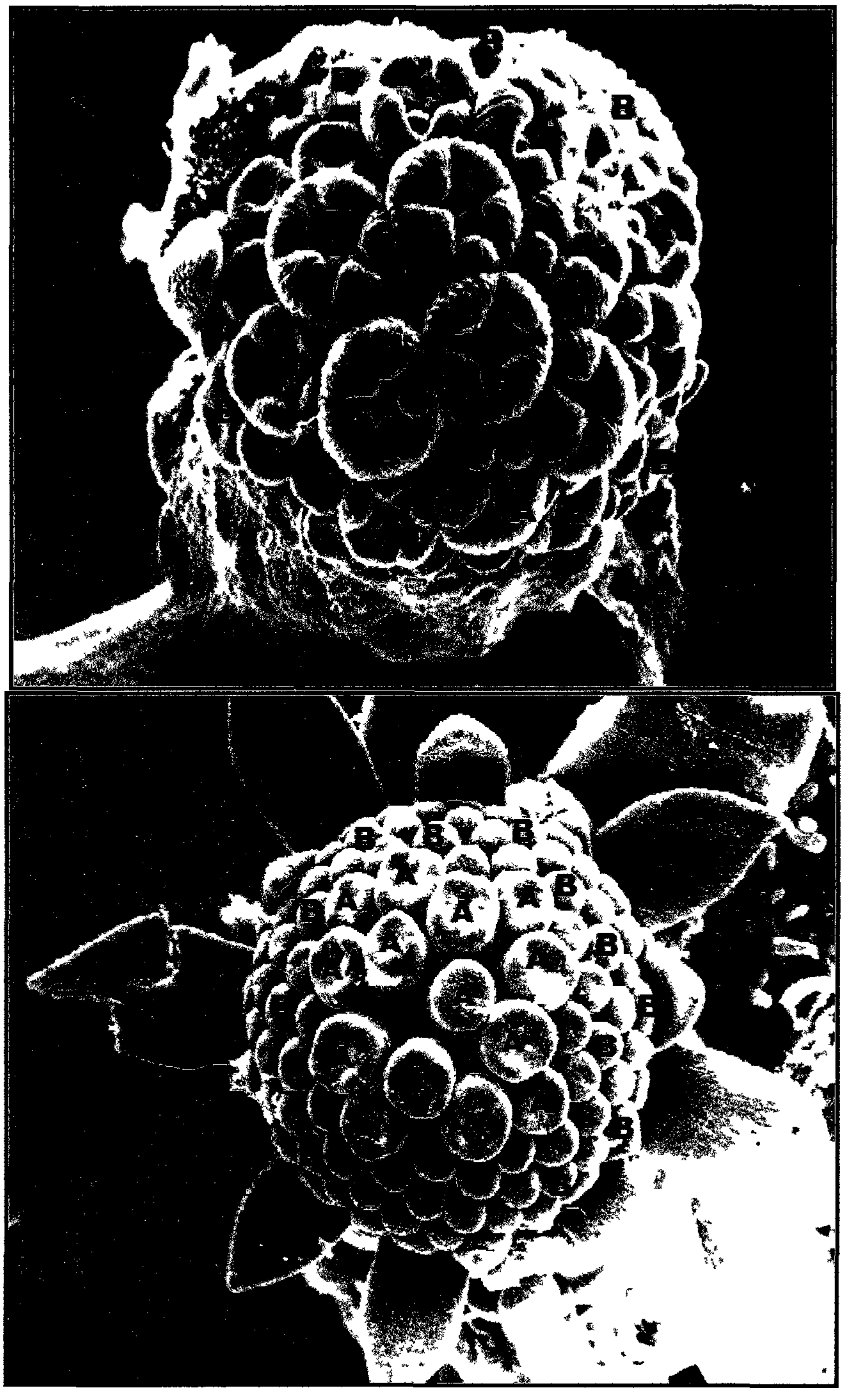

Figure 4.2: Scanning electron images of SLA during early stages of development. Note the number and size of disk (**A**) and pistillate (**B**) florets.

chasmogamous – they open up in order to receive pollen and have the potential to be cross-pollinated by another individual (Lord 1981).

Understanding the mating system of a rare species is important because variation in the pattern of mating can have significant ecological and evolutionary consequences on the survival of the species. While studying the fruit set of SLA, Lacroix et al. (2007) found that the central disk florets produced higher percentages of filled achenes than the outer pistillate florets. However, the pistillate florets produced a larger number of filled achenes overall, something that can be explained by the greater abundance of pistillate florets within the inflorescences. Additional research on the reproductive biology of this species may be useful in determining limiting factors. Although the SLA is believed to be capable of self-fertilization (Houle and Haber 1990, Jenkins 2008), and Heard et al. found small but non-zero genetic estimates of outcrossing, it is unknown whether or not this is the most beneficial strategy for production of viable seeds. To test this, an *ex-situ* experiment was conducted using the University of Prince Edward Island's (UPEI) greenhouse facilities. The goals of the study were to: 1) compare samples of pollen-excluded inflorescences and unexcluded inflorescences to determine the influence of self-pollination on the species; and 2) determine if terminal and lateral buds differed in their overall reproductive output.

4.2 Methodology:

Seedlings produced from seeds from the UPEI seed bank were grown under greenhouse conditions. The plants were randomly subjected to the following pollination treatments: (1) controls -- inflorescences were left untouched to allow florets to either cross or self-pollinate (referred to as "unexcluded" in subsequent sections); and (2) selfing – terminal and lateral inflorescences were bagged separately with nylon pollen exclusion bags prior to anthesis in order to determine potential seed production through selfing (referred to as "excluded" treatments in subsequent sections). Trials commenced in the summer of 2009, with a replicate conducted in 2010. Each treatment was applied to 30-50 different plants.

The pollen exclusion bags were placed over entire inflorescences on either a terminal or lateral bud of a randomly chosen plant. The bags were propped up with wooden skewers in order to allow air circulation and reduce the risk of buds becoming moldy (an issue that was observed in a pilot study). As well, the bags were secured at the top and bottom with twist ties (Figure 4.3).

Semi-natural environmental conditions were simulated within the greenhouse in order to facilitate pollen movement. Fans were turned on at different times and in random locations -- wind speeds were varied and fell within the parameters measured within Lacroix et al.'s (2007) *in-situ* dispersal study. As well, open doorways and greenhouse venting panels allowed airflow to generate pollen movement. The plants were monitored daily. Once flowering terminated and mature achenes were visible on the inflorescences, the exclusion bags were removed. Each inflorescence tested was collected at maturity. The seeds were manually removed and visual identification was used to discriminate between filled and empty achenes. Filled achenes were considered as representing potentially viable embryos (see Chapter 2). The total number of both filled and unfilled seeds per inflorescence was recorded and used to calculate the

Figure 4.3: SLA plants in the UPEI greenhouse. Randomly selected plants have pollen exclusion bags covering the terminal buds.

percentage of filled achenes per inflorescence (number of filled achenes/total number of achenes).

Analysis:

Data were evaluated for normality using the Anderson-Darling normality test, and found to be non-normal ($p<0.05$), so all analysis were carried out using non-parametric tests. A Mann-Whitney U-test was used to determine the difference in filled seeds between excluded terminal inflorescences (N = 54) and unexcluded terminal inflorescences (N = 50) of different plants. The test determined whether or not there was a significant difference in the distribution of the median number of filled seeds in each of the groups. The total number of seeds produced by terminal inflorescences (N = 50) and lateral inflorescences (N = 38) was also compared using a Mann-Whitney U-test. The main assumption for these data was that one fruit, filled or not, is equal to one floret. All of the analyses were conducted with Minitab 16 statistical software.

4.3 Results:

There was a significant difference in the distributions of filled seeds for each of the excluded (selfing) and unexcluded (control) terminal inflorescence groups (U-test $p < 0.01$). The excluded inflorescences had a significantly lower median number of filled achenes (26.0) than the unexcluded inflorescences (46.0) (Figure 4.4). In addition, terminal inflorescences produced significantly more seeds overall (Figure 4.5; U-test $p < 0.001$) than the lateral inflorescences.

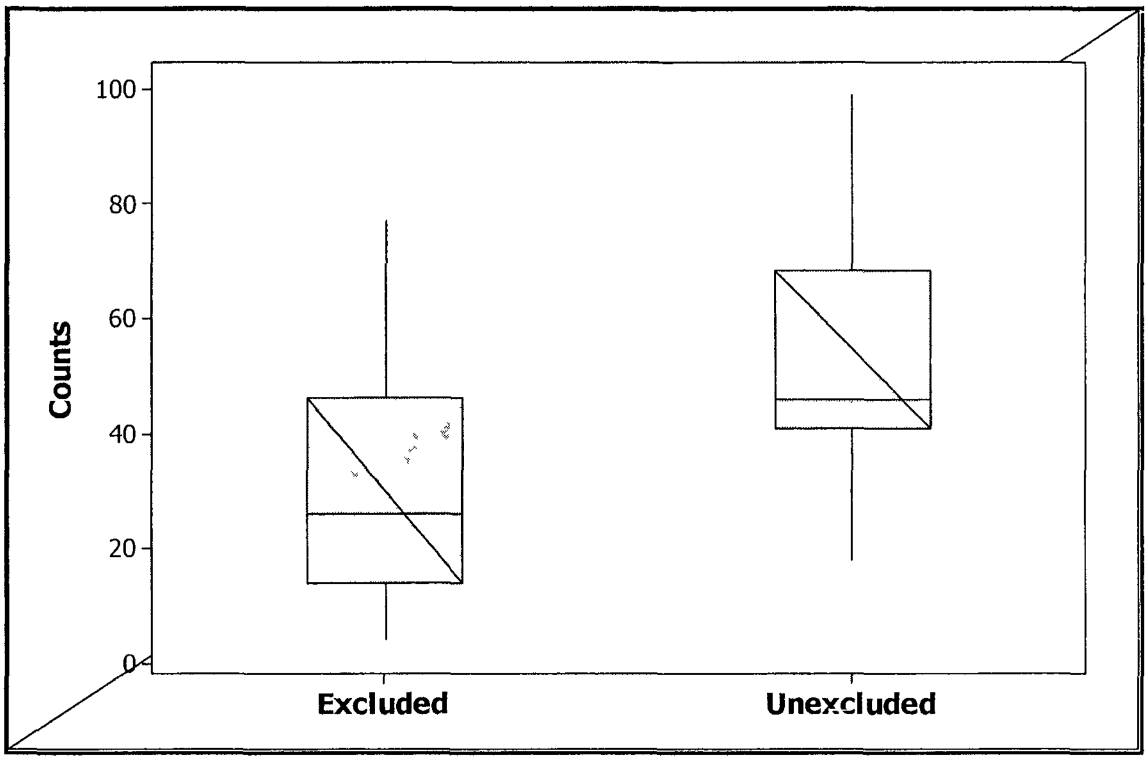

Figure 4.4: The distribution of filled achenes for each of the excluded and unexcluded (control) terminal inflorescences sampled.

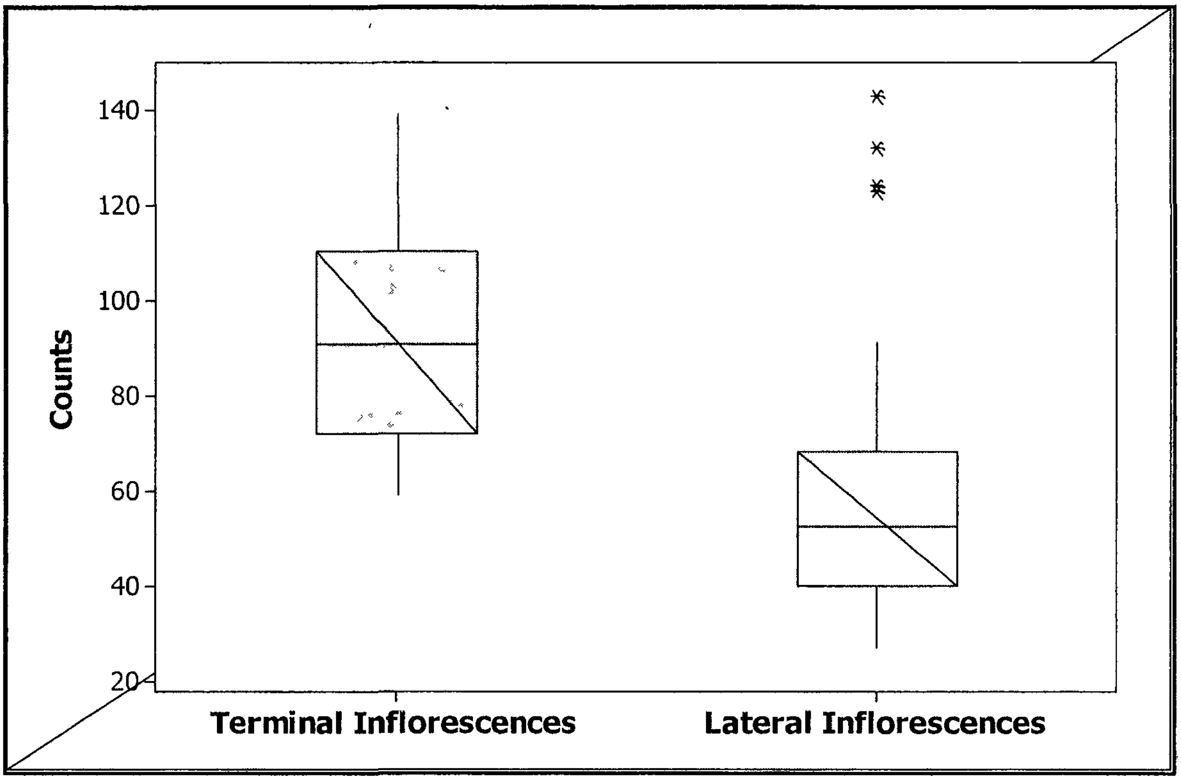

Figure 4.5: The total seeds produced, both filled and unfilled, by terminal and lateral inflorescences.

4.4 Discussion:

Results from the greenhouse pollination trials support the hypothesis that *Symphyotrichum laurentianum* is in part self-compatible (Houle 1988, Lacroix 2007). The viable seed sets from the *ex-situ* pollen exclusion tests were much lower than in controls. The controls indicate that the addition of cross-pollination produced the highest viable seed set. These results imply that although self-fertilization is beneficial to the species reproductive output, outcrossing is the complementary mechanism for producing higher seed output.

Houle (1988) hypothesized that although this species could be cross-pollinated in the lab, it was compelled to selfing in the field due to its floral anatomy. As well, recent research conducted on the genetic structure of the species resulted in substantial estimates of selfing within natural populations (Heard et al. 2009). For obvious reasons, further research in this area would be beneficial including *in-situ* analysis incorporating emasculation experiments if ever possible. Heard et al. (2009) also demonstrated that populations of SLA show modest levels of genetic variation, with the current study's population having the lowest genetic diversity tested. However, it is possible that the plants tested were from a limited original population.

Given the dynamic nature of this species habitat, populations can vary considerably in size from one year to the next. This variation is expected to result in corresponding variation in the proportion of viable seed output. It is likely that population fluctuations, combined with seasonal environmental factors, correspond to lower levels of cross-pollination. Due to the morphology of SLA disk florets (i.e. presence of 'cleistogamous' florets), large variation in levels of selfing are unlikely to occur. There are advantages to selfing over cross-pollination such as the assurance of seed production when a population lacks mates or pollinators; this advantage is termed "reproductive assurance" (Herlihy and Eckert 2005). However, although self-compatibility can be an efficient means of ensuring reproductive output, it can also lead to a reduction in seed output if inbreeding depression results (i.e., the decrease of vigor and fertility of self-fertilized offspring) (Giblin and Hamilton 1999). Theoretically, ongoing selfing in a population may cause a reduction in the fitness value that cross-pollination offers. This can in turn alter aspects of population demography (Charlesworth and Charlesworth 1987).

Given the ecological observations that were noted in Chapters 2 and 3, certain environmental factors occurring within a SLA population can be indicators that the reproductive output of the population may be affected. For example, consistent flooding was shown to result in a reduction of overall survivorship as well as the development of fewer lateral inflorescences. Logically, these reductions resulted in lower numbers of total seed produced and dispersed. As a result, the population dwindled and the area between plants expanded. It is possible that factors such as this will have an effect on the cross-pollination abilities of the populations – that could in turn produce a population bottleneck within the area. A population bottleneck is a significant reduction in the size of a population that causes the extinction of many genetic lineages within that population, thus decreasing genetic diversity (Grant 1975).

There were some observations that are noteworthy to report. For example, it was observed while counting achenes on the unexcluded inflorescences that the majority of the unfilled seeds were located at the periphery of the inflorescence. This observation is consistent with Lacroix et al.'s 2007 research which noted that the pistillate florets had a higher proportion of unfilled achenes than the disc florets. Observations from the current study suggest that it is possible that pollen grains liberated from anthers did not come into contact with the stigmatic surface of the furthermost peripheral florets. This lack of pollen exposure may be due to the leafy bracts of the inflorescence acting as a barrier – they seemed to be covering the peripheral florets at the time of counting and may therefore have possibly interfered with pollen reception during anthesis.

Given that SLA was assumed to have 'cleistogamous' hermaphroditic florets as well as non-pollen producing pistillate florets, where exactly does the pollen that fertilizes the pistillate florets come from? Is 'cleistogamy' in fact the proper designation for this particular species? A review of literature related to cleistogamous breeding systems resulted in the identification of three major types of cleistogamy, each varying in terms of their developmental pathways. The three types are dimorphic, complete and induced cleistogamy (Cully and Klooster 2007). In dimorphic cleistogamy, there is a prominent difference in the development of the cleistogamous and chasmogamous flowers. The cleistogamous flowers are characterized by a reduction in corolla size and stamen size and/or stamen number relative to chasmogamous flowers. Either both types of flower can appear on a given plant at the same time and be spatially separated, or they can be temporally separated. The second category, complete cleistogamy, includes species where there is production of only cleistogamous flowers on an individual. The third category is called induced cleistogamy. In this situation the chasmogamous flowers actually stop developing prior to anthesis taking place. This results in a mechanical failure of the flower to open, resulting in the production of fully cleistogamous flowers (Culley and Klooster, 2007).

Given what we know of the development of SLA to date, the species cannot be categorized in any of these three major categories. However, another reported type of cleistogamy is termed 'preanthesis cleistogamy' (Culley and Klooster, 2007) Here, self-pollination occurs first in the bud, followed by anthesis and opportunities for outcrossing. Because these flowers do not remain closed, some researchers feel that they cannot be considered cleistogamous, but are rather self-pollinating chasmogamous flowers Additional research on the development of SLA floret morphology would be useful in appropriately categorizing the species.

Another noteworthy observation that was made throughout both the transplant study (Chapter 2) as well as the reproductive study may provide more insight on the pollination biology of this species. The terminal buds were noted to develop much faster than the lateral buds. In some cases the terminal inflorescences dispersed mature achenes up to a month prior to lateral inflorescences. As well, many plants had dispersed matured achenes from the terminal inflorescence while the lateral buds had not yet reached anthesis. This temporal variation may have significant ecological and evolutionary consequences. Given the dynamic nature of this species' habitat, patterns of successive inflorescence emission may be a beneficial strategy ensuring seed set and dispersal.

Determining the nature of a species breeding system is an important step in designing rare plant management strategies. The increased understanding of factors influencing seed output in the Gulf of St. Lawrence Aster may be useful to managers responsible for the conservation and/or reintroduction of this rare species. Although these experiments have shed some light on the reproductive biology of *Symphyotrichum laurentianum*, further research is necessary. The viable seed sets produced *in-situ* may differ from *ex-situ* experiments, due to the natural environmental variables. For instance, the presence of increased cross winds and certain pollinators may influence the overall reproductive output. Another interesting question to investigate would be whether or not pollination between patches (i.e. spatially separated populations) produce significantly more filled seed than pollinations within patches. Answering these questions should provide further insight into the relationship between the rarity of SLA and its reproductive biology.

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Chapter 5. Conclusions and Recommendations

The research presented in this thesis is directly beneficial to the process of developing recovery guidelines for the Gulf of St. Lawrence Aster (*Symphyotrichum laurentianum*) within its range. Although Chapter Three is specifically related to identifying potential sites within Prince Edward Island National Park, the local historic records and ecological observations in combination with the habitat assessment methodology may also be employed by ecologists in other areas of the range as well. Overall, the knowledge assembled from the transplanting and seeding methodology, the habitat assessment methodologies, as well as the reproductive output experiments should be considered and integrated into future recovery actions.

The data derived from the two-year population recovery experiments indicate that both transplant and seeding activities serve as a potential method to either re-establish or introduce populations of SLA, as was observed through the germination of second generation plants. It is possible that the reduction of competing vegetation within the microhabitat was most beneficial to second generation SLA seedlings when the competing vegetation was pulled out of the ground, leaving behind relatively level substrate for planting. When the vegetation was dug out of the ground, resulting in a divot within the substrate, transplant survivorship, inflorescence development, and germination was reduced. This reduction occurred when the divots retained water due to intense precipitation and/or tidal action. The plants were then waterlogged and/or flooded for a longer period of time and suffered negative consequences. However, ecologists within the region who attempt the recovery of this species in areas where low water availability may be a factor might want to consider the benefits that 'potholes' may offer as a water supply source.

The trend in Figures 2.9 and 2.10, displaying a lower survivorship for pothole transplants and relatively equal survivorship for both vegetation removed and untouched transplants, may be due to levels of flooding and waterlogging experienced by the plants. These factors both had an effect on second generation SLA as well, although further research should be conducted to test and compare these theories. Observations and germination counts conducted in the test plots in 2009 indicated that the majority of seedlings germinated directly in the areas where some form of vegetation reduction had taken place, and substrate was exposed. As long as the plantlets are not uprooted and displaced by heavy rains or flooding, they have the potential to reach maturity.

We found that flooding most likely has an effect on plant survivorship and reproductive output. Intense flooding *in-situ* was followed by low survivorship and reproduction, as well as the mortality of second generation plants at cotelydon stage. This knowledge is consistent with Houle and Haber's (1990) research indicating that water is a very important factor in population variations. It is also possible that the methods by which the plants become flooded is the main detriment to this species at cotelydon stage. Heavy rainfalls, which were witnessed in this *ex-situ* study, may have been the overall cause of the plants mortality in the very early stages of deveopment.

The recovery of endangered and threatened plants often requires the creation of new populations in order to decrease the risk of extinction (Falk et al. 1996). The results from Chapter Three's habitat assessments can be used to guide conservation managers on Prince Edward Island to locations in Prince Edward Island National Park that have the most potential to support sustainable populations of SLA. Based on the results, there are both historical and non-historical sites within the National Park that have this potential.

If these potential areas are to be used for active management purposes, any past knowledge of the trends in seasonal flooding of the habitats would be very beneficial. For example, it is possible that the microhabitat located at both Long Pond and John Archie's outflow may be out of the question for seeding or transplants due to high water levels at the time of germination (mid-May to mid-June), even though these sites ranked highly based on the habitat assessments. Personal observations have indicated that water levels at that time of the year can be much higher in the area, due to snow melting and spring rainfall levels. Since the potential microhabitat at these particular sites border on the perimeter of the ponds, waterlogging and flooding may be a concern for the seedlings at the cotelydon stage, as this is a particularily sensitive point in development.

Based on the results of the soil salinity tests that were conducted, it can be concluded that salinity is not a limiting factor in the four historical sites where recovery actions were tested. However, salinity could be a limiting factor in the potential sites that were listed. Therefore, prior to conducting recovery actions at any other location, soil samples should be gathered at the time of germination (mid-May to mid-June) and analyzed in order to rule out this factor as a negative variable on recovery success.

Important factors such as water availability, salinity levels, as well as vegetative competition can all be addressed when conducting future recovery actions using the discussed methodologies. Based on personal experience and observations, both water level alterations, as well as encroaching and increased density of competing vegetation within the historical sites on Prince Edward Island may have altered the persistence or emergence of seeds from the seed bank, as well as limited any subsequent recruitment. These factors, combined with the limited available habitat within the area, are suspected to be the main contributors to the decline and loss of populations on Prince Edward Island.

Since the objective of this thesis is to intiate recovery strategies for self-sustaining populations of SLA, including variables such as 'susceptibility to flooding', 'soil salinity levels throughout germination season', and 'total area of potential microhabitat' within the assessment methodology is reccommended for future site assessments. Although these variables were not included in the initial methodology used in this thesis, the results suggest that the addition of these parameters to future assessments will improve the overall rating of the sites, and further assist in the overall goal of recovery.

Testing for soil salinity, as described in Chapter Two, could be incorporated into the assessment and conducted throughout the germination season. Susceptibility to flooding would be a little more difficult to establish, but nonetheless feasible. Plants are more susceptible to flooding conditions during the earlier stages of development, measuring this parameter throughout the germination season would also be useful to evaluate the overall growth of the seedlings. Total area of microhabitat can be simply measured by estimating the area for each potential microhabitat within a site, and adding them together for each site assessed.

In Prince Edward Island, significant fluctuations in population sizes, as well as loss of populations observed in recent years have underlined the importance of continued monitoring. However, it would be beneficial to standardize the timing of surveys and techniques used in order to accurately prepare and report population trends. For example, conducting surveys early in the summer could yield higher population counts than in the fall. As observed in this study, many of the plantlets die before seed production and dispersal is accomplished. On the other hand, surveying at this time of the year could also yield significantly lower population estimates because seedlings could easily be missed due to their small size and inconspicuous identifying features.

For these reasons, conducting surveys near the end of the developmental season (in early to mid-October) is recommended. Surveying during the fall makes it easy to positively identify the species in the field, and also provides the ability to gather information on the reproductive potential of the population. This can be accomplished by determining the estimated percentage of plants in flower within each site, as well as the average number of inflorescences per plant. This will result in more accurate estimates of the reproductive population size (i.e. the number of plants that have the potential for reproductive output). Surveying at this time of the season will also help to assess what the habitat conditions are at the critical time of seed production.

Chapter four provided additional knowledge on this species' reproductive potential. The results indicated that, as far as the production of viable seeds is concerned, SLA plants benefit more from geitonogamy and crosspollination than they do from selfing (cleistogamy). Although the genetic implications of these strategies were not investigated in this study, it can be assumed that when the species has to rely on selfing for successful reproduction, there is little potential for the diversification of the gene pool. Since the transplants and seeds used for the recovery experiments all derived from the same seed stock originating from Blooming Point, the research conducted in Chapter two tested establishment methods without the introduction of new genetic variables. It is possible that when the seeds were collected in the early 2000s, a genetic bottleneck was created for the current UPEI seed stock. Although, Heard et al's. (2009) genetic results state that the greenhouse population actually had higher genetic variation than the one natural PEI population that was tested.

If this seed stock is the only source utilized for future recovery actions on PEI, the lack of genetic diversity may have negative implications on the survival abilities of the species in specific sites. Due to lack of immigration and/or migration from other sites, this situation can become worse if there is no new gene flow taking place. As previously discussed, recent research conducted by Heard et al. (2009) showed that populations of SLA have modest levels of genetic variation. Since the Prince Edward Island populations displayed the lowest genetic variation compared to all that were tested, it may be beneficial to introduce plants and seeds originating from other areas. Specifically, stock from the Magdalen Islands may be useful in assisting the recovery strategies by introducing new genetic variations. These introductions may increase genetic variability among future generations and benefit PEI populations.

In conclusion, not only has this research been conducted at a critical time in the evolutionary history of the Gulf of St. Lawrence Aster, but it has also been conducted while this species may in fact be near extirpation from Prince Edward Island. Based on the present research, recovery for this species is biologically and technically feasible. There are currently enough seed bank resources to improve the size and number of populations of SLA. Suitable habitat has been identified on PEI to support the species, and other habitats may be made available through habitat management strategies such as those tested in Chapter 2. Significant threats to the species or its habitat may be avoided or mitigated through the recovery actions that were discussed.

If a management plan were to be implemented within PEINP in the near future, the following recommendations should be considered:

(1) Seeding and/or transplant strategies should be initiated within the identified habitat at Covehead Pond, Campbell's Pond, Blooming Point Western Wetland, and Cavendish Marsh. These sites scored the highest in the assessment categories, and also offer enough potential habitat to conduct further analysis.

(2) Site assessments, including the addition of the recommended three variables, should be conducted annually to gain adequate knowledge of site characteristics at both the managed sites, and any other potential locations for future use.

(3) The removal of vegetation by "pulling out" the surrounding competition in order to facilitate germination and seedling establishment is a treatment that should be tested further.

(4) The addition of genetic variation to these management areas, using populations from the Magdalen Islands, should be considered and incorporated into future recovery efforts.

Conservation managers can build on the foundation of information that has been accumulated for this species. Largely, the goal of this study was to facilitate the recovery of the Gulf of St. Lawrence Aster on Prince Edward Island, and to contribute to a regional recovery strategy. The knowledge and actions that have derived from this research have, and will hopefully continue to, assist in the endeavours to move the Gulf of St. Lawrence Aster from the Threatened risk category to a category of lower concern.

This can be achieved by increasing the abundance of this species. This increase will take place through re-establishing the species in appropriate habitat within its historic range, with consideration given to genetic characteristics.

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