English ivy in Stanley Park:

Effects of the invasion and implications for management

Hillary Quinn
Rebecca Best

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Abstract

This thesis aims to detail the effects, implications for management and environmental education, and control options for the invasion of English ivy in Stanley Park. As such, it incorporates a range of research techniques. Vegetation surveys were conducted to assess the effect of ivy on native vegetation in the Park. The observed decrease in native species diversity with increased density of ivy suggests that ivy may be negatively impacting native plant communities, which may also translate into impacts on Park wildlife. Park user surveys, as well as interviews with Park management and an environmental education co-ordinator, were designed to assess the implications of the ivy invasion for current management objectives and environmental education programs. As these implications were deemed to be significant, options for increasing control efforts in the Park were explored. GIS analysis was used to develop priority areas for control and to explore opportunities for prevention of spread. Methods for control and possibilities for volunteer control programs were also developed, and the feasibility of these assessed through the above interview process.

In its entirety, this thesis was designed to add to the very limited research currently available on ivy in natural systems, as well as to provide information useful to Park management, environmental educators in the Park, and any other groups that may be able to participate in raising awareness about ivy's effects, controlling its invasion, or carrying out additional research in the future.

1.0 INTRODUCTION

1.1 Introduction to the issue

The past decade has seen a growing awareness of the threats invasive plant species may pose to both individual native species and larger ecosystem functioning. Accordingly, scientists, managers and citizens' groups around the world have become increasingly concerned with the presence and spread of invasive plant species in their parks and nature reserves. Sometimes representing the last remnants of a local ecosystem, such areas often provide valuable opportunities to teach and learn about local ecology, as well as to protect it from further encroachment.

Studies of the invasion dynamics of invasive plants in protected areas continue to grow in number (Ogle *et al.* 2000, Heckman 1999, Kourtev *et al.* 1998, Drayton and Primack 1996, Robertson *et al.* 1994, Loeb 1992, Westman 1990), as do the volunteer efforts mobilised to remove invasive plants from these areas (Lovejoy 2002, Ivy Removal Project 2002a, Freshwater 1991). In some cases, extensive programs have been developed to co-ordinate the involvement of researchers, Park managers, and volunteers in a collaborative effort to better understand and control invasives. These types of programs seem to work especially well in urban parks, where a large population can provide a sufficient flow of volunteers, and where remnants of natural areas may be particularly valued for their accessibility. One example of such a program is the Ivy Removal Project headquartered in Forest Park, Oregon. This project co-ordinates research and control of invasive plant species in the largest urban forest in the United States (Ivy Removal Project 2002b).

Given the negative effects invasive plant species may have on forest ecosystems, and the possibilities for education about and control of invasives demonstrated elsewhere, this thesis seeks to examine the effects and management implications of one particular invasive plant species in Vancouver's Stanley Park. Though several invasive plants have been identified in the Park, including English holly (*Ilex aquifolium*), Himalayan blackberry (*Rubus discolor*), Canada thistle (*Cirsium arvense*), and English ivy (*Hedera helix*) (Beese 1989a), it is *Hedera helix* that covers the largest area of the Park's approximately 260 hectares of forest. Found in both numerous small patches and in three large infestations over 2.5 hectares in area (Pallochuck 1998), ivy has reached a density at which it may be having a significant effect on native plants and wildlife.

In order to retain both the aesthetic appeal and the educational value of the Park's forests, current management objectives for the forest are based on the idea of preserving a representative sample of a western hemlock forest ecosystem (Beese 1989a). Though control of invasive species may be necessary to meet these objectives, current control efforts are limited. With increased funding or use of volunteer labour, however, more comprehensive and long-term planning for invasive species management may be possible. In the hopes of providing information to aid such planning in the future, our research objectives were to measure the effects of the ivy invasion on native plants and wildlife, to investigate the implications these effects may have for management, and to develop possibilities for increased control.

1.2 Introduction to the project

The main objective of this thesis was to address the present lack of information regarding English ivy in Stanley Park and to produce some useful recommendations. Since scientific research on the ecological impacts of ivy is currently scarce, this project focussed on assessing some specific effects of this invasive plant on the forest of Stanley Park. Pairing this with the evaluation of implications for environmental education and management in Stanley Park makes the results relevant for future planning. By determining feasible control options and priority areas, this project also seeks to lay some of the groundwork for establishing a expanded control program in the Park.

In assessing the ecological impacts of English ivy, we focussed on changes in native plant composition and diversity and the associated wildlife effects. A vegetation survey was carried out in two sites; one containing ivy and one without. The sites were chosen for their comparability in terms of site association, stand composition and age, average height of stand and average diameter at breast height (DBH). Impacts on bird diversity were then assessed based on the observed changes in forest vegetation. Ivy potentially has many other ecological impacts on the forest in Stanley Park, but these were not within the scope of our investigation. For example, ivy may have detrimental impacts on trees as it is an aggressive climber.

Implications of English ivy for environmental education and Park management were explored using interviews with two individuals involved in these fields in Stanley Park. Since these interviews only encompass the opinion of two individuals, they are taken as a starting point in determining some of the potential implications of English ivy in Stanley Park. Emily Gonzales, prior Members and Public Programs Co-ordinator of the Stanley Park Ecology Society (SPES) was chosen for an interview because SPES organises extensive environmental education programs in the Park. An interview with Eric Meagher, supervisor of Park maintenance, illuminated the management perspective on English ivy in the Park. Eric discussed his opinion on the implications of ivy for Park management as well as the feasibility of various control options.

Another method by which we determined the implications of ivy in the Park was a user survey. Carried out in conjunction with a BCIT student, Tannis Nelson, and SPES, the survey was aimed at determining interest in environmental education, and the importance users place on Stanley Park's forest as a natural area. This data should help inform Park management as to the seriousness of ivy, if its invasion compromises the natural character of the forest.

A GIS analysis was carried out to meet several objectives. A map of ivy invasion produced in 1998 was digitised, providing a useful spatial display of the extent of ivy. Adding maps of trails gave an indication of sources of ivy, and influences on spread. A map of the six site associations allowed us to determine which site associations are at risk of being taken over by ivy. Priority areas for control were identified based on site association and the size, density, and number of ivy patches in each area.

Considerable literature review was undertaken to establish background information for this thesis. However, there is a lack of scientific research about English ivy, making our own research necessary. To determine the possible methods of control we consulted the literature, as there was adequate information available and carrying out a control assessment was not within the scope of this project.

This thesis continues with an introduction to the concept of exotic species. Next some useful background information about English ivy and Stanley Park is given. The remainder of the thesis is divided into three major parts. Part I investigates the impact of ivy invasion on the forested ecosystems of Stanley Park. Part II explores the importance of these impacts both for Park management and for the environmental education potential of the Park. Part III develops options for English ivy control programs in the Park. The thesis concludes with recommendations for management and suggestions for further research.

2.0 BACKGROUND

2.1 Exotic species background

In discussing complex ecological issues, an absence of clear definitions of key terms can lead to significant misunderstanding and inconsistency in their use. In many cases, with unresolved theoretical issues about these important terms, their meanings are the subject of much debate. Thus, in order to ensure clear use of key terms in this thesis, some important definitions will be discussed.

2.1.1 Definition of exotic species

Defining the term *exotic species* is far from trivial. Not only is it difficult to establish the specific details of what an exotic species actually is, but in developing the concept of exotic species, significant philosophical issues arise.

There is general scientific consensus that an exotic species is one that is “newly established at a significant distance from its former geographic range” (Westman 1990). However, many definitions include the requirement that the mode of introduction is by human influence (thus the commonly used synonym for exotic species, introduced species) (Coblentz 1990). This addition separates species that migrate by natural causes from those that are moved by humans, implying that species migrating due to natural causes could eventually be considered native.

Defining exotics as being introduced by humans raises some important questions. First of all, is there a line that can be drawn in time, before which human influence on species distribution is considered natural? Some would argue that in North America, the arrival of European settlers is the time after which human-assisted species transport became ‘unacceptable’

(Kendle and Rose 2000). In the UK, it has been suggested that plants are exotic if they arrived after Neolithic times due to human agency (Kendle and Rose 2000). Webb (1985) argues that it was during the Neolithic period that the technology of humans evolved to the point where humans "ceased to be in any ordinary sense a part of nature."

This discussion presents philosophical issues related to the place of humans within the 'natural' world and the significance of the effects of humans on the natural world. One viewpoint sees humans as being separate from the rest of nature, and in turn, sees all human impacts as inherently detrimental (Callicott et al 1999). Another view places humans as part of the natural world, and does not deem human influence to be necessarily harmful (Callicott et al 1999). These issues must be resolved in order to come to a consensus on when human impact on natural systems requires mitigation.

Another difficulty in defining exotic species as being dispersed by human actions is in drawing boundaries on what is considered human influence. It is known that species migrate in response to environmental change (Kendle and Rose 2000). It is also known that changes in ecological processes occur both naturally and due to human influence (Kendle and Rose 2000). The difficult part is separating environmental change that is induced by humans from that which is not. This has never been as clear as in the present climate change debate. Thus, human influence on species distribution is not simply humans taking a species from one location and releasing it elsewhere. The boundary between which species migrations are natural and which are human induced is very difficult to define. Some would go as far as to argue that human influence on natural systems is so pervasive that there can never be any new native species to an area (Kendle and Rose 2000). However, we know that organism invasions are an important and natural mechanism for speciation and biodiversity development so claims that all migrations are at least in part due to human influence is theoretically unrealistic (Kendle and Rose 2000). Practically, however, the scope of human influence on natural systems may prevent identification of completely natural migrations.

Defining exotic species as those which are introduced due to human actions immediately puts a different value on these species than on species that have migrated naturally. Exotic species may be seen as being out of place and thus in need of removal. This conjures up the hypothetical situation of two ecosystems being seriously altered by the invasion of species X. In one area, species X arrived due to natural occurrences while in the other area, humans introduced species X. In both areas species X is having the same, detrimental effect on the ecosystem. It seems illogical to put a different value on the species in the two areas, simply due to mode of transportation, if the effects are the same. Therefore, in order to rank species in terms of their ecological value, the effects of the species should be more important than how they migrated to an area. Thus, in theory, all exotic species are not inherently in need of removal from an area simply because they arrived due to human interference.

Attempting to establish criteria by which to judge whether an exotic species is in need of removal requires thought about what the goals of conservation efforts are. Some would claim that restoring “ecosystem integrity” is the most appropriate goal while others would advocate striving for “ecosystem health”. Callicott, Crowder and Mumford (1999) provide a useful explanation of these two concepts. They define ecosystem integrity as being from a compositionalist school of thought, which advocates the restoration of structure or composition of an ecosystem based on its historical elements. Ecosystem integrity is by definition threatened by exotic species, as they are not part of the historical composition of the ecosystem. However, it is difficult to identify a specific historical state to aim for along a continuum of escalating human influence on biotic dispersal (Westman 1990). Also, in attempting to mimic a historical state, species migrating due to natural events are eliminated.

Ecosystem health, on the other hand, is defined to be a functionalist concept, as it is focused on ecosystem processes or functioning (Callicott *et al.* 1999). This school of thought does not deem exotic species as necessarily bad, or out of place. It states that the elements of an ecosystem can be altered without necessarily adversely affecting ecosystem processes (Callicott *et al.* 1999). Thus, the concept of ecosystem health emphasises the effects of a species, not simply its origin and mode of dispersal.

Theoretically, the concept of ecosystem health is less problematic than that of ecosystem integrity, since the former does not require a historical reference point. In practical terms, however, it is difficult to implement, as often there is inadequate scientific information about complex ecosystem processes. For example, assessing the impact of a specific exotic species on ecosystem health requires substantial understanding of the biology and ecology of that species and its effects on native flora and fauna, soils, hydrology and nutrient levels, to name some of the most major system components. Most often, scientific study to explore these questions has not been carried out, leaving the impacts on ecosystem health a mystery.

Ideally, there would be adequate scientific information available to make an assessment of ecosystem health and thus a management decision based on the effects on ecosystem processes. However, since decision making must proceed in the face of scientific uncertainty, the compositionalist concept of ecosystem integrity is the next best option. Since we know that a historical species composition produced the necessary processes to create a healthy ecosystem, an imitation of this structure is our best chance for successful conservation. Thus, a historical structure is imitated not because it is theoretically the best state, but because it is our best chance to re-establish the processes that create a healthy ecosystem.

In practice, it is important that decisions about exotic species are made on a species by species basis. When there is substantial uncertainty about the impacts of an exotic species, but removal is costly and disruptive, the best option may be to put time and money into further scientific research. However, with other species, the removal process may be relatively quick and easy, and not significantly disruptive to the ecosystem. In these cases, it may not make sense to spend time and money on scientific research. This is especially true in cases where delaying removal during further study may allow a species to further establish itself. This may make control more difficult, and may increase the magnitude of any negative effects the species is having on its host ecosystem.

For the purposes of this project, exotic species will be defined as being species that are far from their geographic range and were introduced by humans. The ambiguities of this definition have been discussed and should be considered in thinking about exotic species. In terms of the exotic species in question, English ivy, there is significant scientific uncertainty about its impact on forest ecosystems. However, rather than assuming it is detrimental, we will attempt to assess its effects on native species.

2.1.2 Definition of invasive plant species

The term *invasive species* is often used in place of the term *exotic species*, but is actually more specific. There are three important features of invasive plant species distinguishing them from other exotic plants: they spread aggressively without human intervention, they have a negative impact on the ecosystem into which they are spreading, and they are invading natural or semi-natural areas (Cronk and Fuller 2001, Mooney and Hobbs 2000).

Firstly, aggressive spread must be quantified to some degree. One definition of invasion is the production of reproductive offspring in areas distant from sites of introduction. Approximate scales are >100m over < 50 years for taxa spreading by seed and other propagules and >6m/3 years for taxa spreading by roots, rhizomes, stolons, or creeping stems (Barbour *et al.* 2000). Other definitions deem invasive spread to be aggressive enough reproduction such that native components of the vegetative community are displaced (Haber *et al.* 1993).

Secondly, defining invasive plants requires stating potential impacts. These range from effects on structure and diversity to impacts on ecosystem processes. It is important to consider all possible impacts when assessing how invasive a plant species is. As will be discussed in the next section, the impacts of invasive species can be significant.

Thirdly, the distinction must be made between invasive plants and plants invading very disturbed, human-made, or agricultural habitats (i.e. weeds). Some species can be both invasive plants and weeds, as they spread aggressively in both highly disturbed and natural areas. However, in terms of conservation efforts, there is a significant difference between invasion of natural areas and the invasion of human dominated areas. Making this distinction brings up the difficulty of differentiating between natural and unnatural areas. Cronk and Fuller provide a useful definition of natural or semi-natural environments that we will adopt for the purposes of this project. These environments are defined as:

> *[c]ommunities of plants and animals with some conservation significance, either where direct human disturbance is minimal or where human disturbance serves to encourage communities of wild species (native species) of interest to conservation. (Cronk and Fuller 2001)*

Considering the three features above, for this thesis an invasive plant shall be defined as:

> *[a]n alien plant spreading naturally (without the direct assistance of people) in natural or semi-natural habitats, to produce a significant change in terms of composition, structure or ecosystem processes. (Cronk and Fuller 2001)*

Since the ivy invading Stanley Park appears to meet the criteria of the above definition, we refer to it as an invasive species throughout this thesis.

2.1.3 Effects of invasive plant species

Although highly underestimated, invasive species have the potential to cause environmental crises (Coblentz 1990). Unlike environments impacted by pollution or exploitation, for example, which may be able to recover following termination of the harmful activity, environments impacted by invasive species are permanently altered (Cronk and Fuller 2001). Once the introduction stops, the invasion persists. Perhaps for this reason, many experts around the world consider the impacts of invasive species to be the most significant threat to biodiversity, second only to habitat loss (Lee 1996). These species have also been seen to impact human health and economic productivity, particularly in agriculture and fisheries (McNeely 1996).

There are many potential impacts that invasive plants can have on natural ecosystems. It is important to have a clear idea of these effects not only to be aware of how severe they can be, but also to know what to study when assessing impacts.

Firstly, invasive plants can create homogeneity in species composition (Soule 1990). They can displace native flora, and in turn extirpate other native species, such as birds, that use native flora as food or habitat (Cronk and Fuller 2001). However, it is important to note that, while many species of indigenous wildlife may suffer, others may thrive due to an ability to use the invasive flora (Cronk and Fuller 2001). This in turn may increase competitive interactions which might lead to further homogeneity of species, with few native plants surviving and fauna consisting mostly of animals that benefit from the invasive flora.

There are documented examples of invasive plants contributing to the extinction of native plant species (Cronk and Fuller 2001). In some cases, many factors have contributed to the extinction but on oceanic islands, some extinctions have been blamed almost entirely on invasive plants (Cronk and Fuller 2001).

Invasive plants can also have an indirect effect on diversity. They can alter soil characteristics, such as nutrient status, by processes such as nitrogen fixation (Cronk and Fuller 2001, Coblentz 1990). Geomorphological processes such as sedimentation or dune formation can be altered by invasive plants (Cronk and Fuller 2001). Invasive species that are fire-adapted can also alter both the frequency and intensity of fire regimes (Cronk and Fuller 2001). Finally, invasive plants can impact hydrology, for instance altering runoff simply by their structure (Cronk and Fuller 2001). Soil chemistry, fire, geomorphological processes, and hydrology are all crucial to the healthy functioning of ecosystems, so alterations to any of these can have serious and far-reaching implications. Changes in diversity and species extirpations are likely to accompany these major changes in ecosystems.

It is clear that invasive plants can potentially have devastating impacts on natural areas. Thus it is important that, when possible, the effects of particular invasive plants are studied in order to determine whether control is necessary. This process must be carried out in a timely fashion, as the longer invasive plants are left to spread, the greater impact they may have, and the harder they may be to control.

2.2 English ivy background

2.2.1 English ivy biology

English ivy (*Hedera helix*) belongs to the Araliaceae, or Ginseng, family (Mooney and Putz 1991). It is an evergreen vine native to European forests but now widely introduced into temperate parts of the world as a horticultural plant (Okerman 2001). However, *Hedera helix* has not remained only in the settings it was intended for. It has spread to many natural areas and is increasingly becoming recognised as a danger to natural ecosystems.

English ivy is desirable as a groundcover in landscaping and gardening due to the same biological features that make this vine a good invader. It is able to grow under harsh conditions, is evergreen, establishes rapidly and is persistent in temperate to subtropical zones. The fact that ivy is evergreen makes it particularly invasive in deciduous forests, where it can take advantage of the extra light in the winter (Okerman 2001).

English ivy has distinctive juvenile and adult phenotypic characteristics (Hackett and Wallerstein 1989). The most commonly recognised form is the juvenile, with its palmately lobed leaves (3-5 lobes) that are dark green and glossy and have whitish veins (Okerman 2001). The juvenile form cannot produce seeds, but it can reproduce vegetatively. While it often exists as a groundcover, juvenile ivy has a climbing growth habit, with adventitious roots allowing it to climb trees, walls and other vertical structures (Okerman 2001, Mooney and Putz 1991). These roots do not penetrate the bark of trees so ivy is not considered parasitic (Okerman 2001).

As an adult, English ivy can sexually reproduce by producing clusters of greenish-white flowers in the fall, and dark, purple fleshy berries the following spring (Okerman 2001). Adult leaves are thick, ovate to rhombic in shape, a lighter green than the juvenile leaves, and have less prominent whitish veins (Okerman 2001). As an adult, *Hedera helix* becomes arbourescent or tree-like and has woody, non-climbing stems that extend away from the juvenile support system, resulting in a shrub-like form (Okerman 2001, Mooney and Putz 1991, Elliott 1995). It is the adult form of English ivy that poses a serious threat to trees, as it can become very heavy, making trees susceptible to blowdown (Elliott 1995). This threat is most extreme for deciduous trees as ivy is able to climb not only the trunk, but also the branches due to the loss of leaves in the winter.

The juvenile form of *Hedera helix* is characterised by high endogenous gibberellin levels (Mooney and Putz 1991). Thus the transition to the adult stage may be due to reduced gibberellic acid (GA) levels in the absence of roots (Mooney and Putz 1991, Okerman 2001). Studies have shown the reversion of adult plants to juvenile-like plants with the application of GA_3 (Mooney and Putz 1991).

Studies exploring the dispersal of ivy have shown birds to be an important mode of seed transport (Clergeau 1992, Kalkhoven and van Ruremonde 1991). Kalkhoven and van Ruremonde (1991) classified bird species that eat ivy berries as being transversal dispersal agents, flying mainly across the landscape as opposed to birds that are longitudinal dispersal agents and prefer to stay within the woody vegetation of the forest (Kalkhoven and van Ruremonde 1991). This has implications for the spread of ivy to and from Stanley Park as, in the urban setting, seeds can be spread between fragmented natural areas by way of bird dispersal. Although some berries with fleshy fruit depend on ingestion by birds for their germination, ivy seeds germinate rapidly without the help of birds. Therefore, the main effect of birds on ivy is though dispersal of seeds (Clergeau 1992).

Ivy berries are mildly toxic to birds (Barnes *et al.* 1993). In their analysis of ivy and other plants with fleshy fruits, Barnes *et al.* (1993) found that the toxicity of berries is a method of discouraging birds and mammals from eating too many fruits at one time. This in turn prevents too many seeds from being deposited in one place (Barnea *et al.* 1993). They also suggested that the toxicity of berries regulates seed retention time in the birds. It is the diarrhoea-inducing saponins in ivy berries that carry out this function (Barnea *et al.* 1993). Decreasing the time seeds spend in the birds improves viability of seeds, as they are exposed to chemical activity in the birds for a shorter period (Barnea *et al.* 1993).

There is a considerable lack of research on the biology of ivy. In particular, little is known about its complex growth patterns and mechanisms of invasion. Thus, further research is needed in order to gain a more complete understanding of this invasive vine.

2.2.2 Effects of English ivy invasion

English ivy has long been a popular groundcover to use in landscaping projects. It is perhaps not surprising, then, that the body of research striving to develop new and better cultivars for the gardening trade is far greater than the body of research striving to understand the impacts of ivy on natural systems. The few studies that have been done, however, indicate that invasion of forest ecosystems by this ornamental can have serious consequences.

In Dandenong Ranges National Park, Australia, ivy has spread over several hectares of sclerophyll forest, forming a dense mat on the forest floor as well as climbing trees and shrubs (Freshwater 1991). According to the Friends of Sherbrooke Forest, as the area of the Park is called, the mats of ivy have smothered native grass species and reduced feeding areas for lyrebirds and wombats. Freshwater (1991) concludes her overview of control efforts in this forest by predicting that, in the absence of such efforts, ivy would “eventually dominate the indigenous vegetation, preventing natural regeneration and reducing floristic diversity.”

In Oregon, Portland Parks and Recreation directors estimate that ivy has invaded approximately 50% of the City's urban forest, parkland, and other undeveloped green space (Ivy Removal Project 2002c). The No Ivy League, an education and control organisation headquartered at Portland's Forest Park, attributes a number of negative effects to ivy's invasion of forest areas. These include the suppression of native plant species, interruption of succession, loss of habitat and food sources for native wildlife, and creation of "danger trees" susceptible to blowdown due to the added weight of mature ivy vines covering their trunks and branches (Ivy Removal Project 2002c,d,e). Field studies conducted by the No Ivy League have also shown that *Hedera helix* berries are consumed by English Sparrows and European Starlings, both introduced species, but are toxic to most native song birds (Ivy Removal Project 2002f). Ivy's suppression of native plant species may thus have serious consequences for higher trophic levels that depend on native seeds and berries for food.

Besides the community group observations detailed above, little is known about the mechanisms of ivy invasion or its specific effects on the different types of forests it invades. One of the very few scientific papers published on ivy in natural systems examined the effects of competition from *Hedera helix* on the development of the shade flora in secondary woodlands in the United Kingdom. Examining historical species lists to track the succession of these woodlands from abandoned farmland, Harmer *et al.* (2001) observed a marked reduction in the rate of colonisation by species from the adjacent meadow following colonisation by ivy. In one case the authors also observed the loss of already established species following colonisation by ivy. Harmer *et al.* concluded their 2001 study with a recommendation that thinning operations to break up ivy monocultures be incorporated into plans to develop new farm woodlands for nature conservation.

In a 1993 survey of invasive plants in Canada, English ivy was noted to have invaded open woods in southern British Columbia and south-western Ontario (Haber *et al.* 1993). It has also been reported as invading woodlands in 28 of the United States ("Invasive Plant Primer" 2002). Given the wide range of this invader, and the observations of its effects made thus far, further research on its effects and rate of spread seems to be long overdue.

2.3 Stanley Park background

2.3.1 Uses of the Park

Stanley Park is a 400 hectare expanse of public land located adjacent to downtown Vancouver, British Columbia. Coniferous, deciduous, and mixed forest stands cover approximately 65% of the Park (Beese 1989a) while the remaining 35% has been developed into recreation and entertainment facilities. These include the Vancouver Aquarium, the Children's Farmyard and Miniature Railway, a pitch and putt golf course, a water Park, tennis courts, an outdoor swimming pool, swimming beaches, flower gardens, restaurants and concessions, the seawall, and grassy picnic and play areas (Vancouver Parks and Recreation 2001a).

As this variety of natural areas and constructed facilities indicates, the estimated 8 million visitors the Park receives each year come to Stanley Park for a myriad of reasons. In order to obtain a profile of Park users and their priorities for Park management, the Stanley Park Task Force, a group of citizens selected in 1991 by Vancouver Parks and Recreation for this purpose, designed and carried out a number of public outreach events and survey activities. Among these was a survey of 1,157 Park visitors conducted at various locations in the Park from August to October of 1991 (Stanley Park Task Force 1992). When asked about the importance of various elements of the Park, the top three features were the seawall, wildlife, and the Park's forest, in that order. The percentage of respondents indicating each of these features is “very important” was 80.9% for the seawall, 70.4% for wildlife, and 69.2% for the forest (Stanley Park Task Force 1992). When added together, the “very important” and “important” responses were very high for these three features: 96.1%, 95.2%, and 94%, respectively. In addition, the most popular reasons for coming to the Park were hiking or walking (14.2%), the seawall (11.9%), sightseeing (8.2%), and cycling (6.7%), and the most popular locations in the Park were the seawall (18.5%), the beaches (11.3%), the zoo and aquarium (11.2%), Lost Lagoon (8.5%), and the forest trails (6.3%) (Belyea and St. Louis 1992). It is unclear from the published results of this survey why greater than 40% of the responses to the location question are not accounted for.

One interesting observation that can be made about the above results is that many more of the visitors surveyed valued the forest and the Park’s wildlife than actually spent time in the forest or at Lost Lagoon, the Parks’ primary bird watching location. This may simply mean that many of the Park’s visitors enjoying the seawall and beaches valued the aesthetics of the forest as a backdrop. It may also mean that there is, or was, potential for more nature education programs and awareness about the forest’s trail network to draw people into the forest for recreation and education. Indeed, 55.9% of survey respondents, 61% of which were residents of Greater Vancouver (Belyea and St. Louis 1992), were in favour of establishing a nature interpretation centre in order to provide opportunities for visitors to learn about the Park’s ecology (Stanley Park Task Force 1992). Following the surveys, the Stanley Park Ecology Society (SPES) opened a Nature House on Lost Lagoon. Since then, the Nature House has met the need for an interpretive centre in the Park by providing information about the ecology of Stanley Park to approximately 90,500 drop in visitors and program participants (SPES 2002).

The presence and spread of English ivy in Stanley Park may have some important implications for visitors' use and enjoyment of the Park's forested areas. First, ivy has a distinct aesthetic affect on the forest, and may be seen as enhancing or degrading its appearance by those frequenting the forest's trails. Second, ivy's potential impact on native plant and bird species may affect the ability of the forest to serve as a representative sample of coastal hemlock forest. This would in turn decrease the Park's potential as a classroom for educating visitors about local ecology. On the other hand, the presence and spread of ivy in the Park may provide an important opportunity to educate visitors about the mechanisms and effects of exotic species invasions.

2.3.2 Management objectives

Over the last ten years, the evolution of management plans for the forested area of Stanley Park has involved a substantial shift in approaches to management and conceptions of the 'natural' state of the forest. The management objective outlined in the 1989 Stanley Park Regeneration Program Forest Management Plan was "[t]o ensure that Stanley Park continues to provide an example of mature coniferous coastal forest, while maintaining or enhancing wildlife, interpretive and scenic values" (Beese and Paris 1989a). In order to achieve this, the Plan recommended a series of stand-by-stand treatments including planting, pruning, fertilisation, debris removal, thinning, and the conversion of deciduous stands to coniferous stands through clearing and planting (Beese and Paris 1989a).

This proposal for active management of the forest generated much controversy among Vancouverites concerned with the Park, and led Mark Wareing of the Western Canada Wilderness Committee to submit an alternative plan advocating what he termed "wholistic forestry." According to Wareing (1990), this means "looking after the forest, rather than managing or manipulating it," and avoiding active intervention such as planting and fertilisation as much as possible. Wareing went on to suggest that natural successional processes will arrive at the same endpoint, "mature coniferous coastal forest," but will do so in a more natural and educational manner. Thus Beese, Price, and Wareing seem to agree on the long-term purpose of the Park, but have divergent views on the type of management best suited to this purpose.

Given the public controversy generated by the Regeneration Plan, the Vancouver Board of Parks and Recreation produced a revised Forest Maintenance Plan in 1993. This most recent plan prescribed a lower intensity of silvicultural treatments, but retained some of the controversial prescriptions for the conversion of deciduous stands. This Plan also stated a modified management objective for the forest. This was "to retain a healthy, vibrant and diverse forest ecosystem in a condition safe for all users" (Vancouver Board of Parks and Recreation 1993).

Since 1993, Park managers have chosen not to implement any long term plan. Instead they have been operating on a site by site basis, managing only in areas where "natural openings" (Vancouver Board of Parks and Recreation 1993) have been created by insect infestation and windthrow. In the absence of both an overall plan to guide forest management and adequate funding, control efforts for English ivy are limited.

PART I – THE IMPACT OF IVY INVASION ON THE FOREST ECOSYSTEMS OF STANLEY PARK

Having described the scientific and management contexts for the study of *Hedera helix* in Stanley Park, we can now move on to the research we completed in each of these areas. Part I outlines our scientific research on the effects of ivy on the Park's native flora and fauna. Borrowing methodology from plant ecology, we completed vegetation surveys in areas of the Park that do and do not contain ivy. We also used our results from the vegetation surveys, along with literature review, to investigate the possible impacts ivy may be having on wildlife in the Park. This section details our research techniques, beginning with methodology and following through with the presentation and discussion of our results.

3.0 METHODOLOGY

3.1 Vegetation surveys

3.1.1 Survey rationale

The importance of biodiversity in ecosystem functioning is currently a topic of heated debate in plant ecology. For example, while Diaz and Cabido (2001) and Tilman (1999) assert that biodiversity increases community stability and productivity and decreases invasibility, Grime (1997) cites evidence that these and other ecosystem processes are instead governed by the characteristics of the dominant species. Where these opposing views tend to converge, though, is in the acknowledgement that diversity may be very important in ecosystems undergoing significant temporal fluctuation (Grime 1997). Known as the 'insurance hypothesis,' this is the idea that diversity may be most important in buffering and adapting to large-scale disturbances and environmental change over time (Diaz and Cabido 2001). In areas managed to preserve a representative sample of a local ecosystem (as is Stanley Park), the preservation of diversity should thus be an important long term objective. Measuring the effects of English ivy on vegetation diversity provides important information to guide such management.

In order to understand current debates on diversity, as well as to introduce the use of diversity as a variable in this study, it is crucial that the term be carefully defined. Diaz and Cabido (2001) distinguish species diversity, or species richness, (number of species present) from functional diversity, which refers to the range of functional traits (such as leaf size, reproductive phenology, seed dispersal, and nutrient requirements) that is present in a community. While they warn against using species richness as a measure of diversity in the short term, Diaz and Cabido (2001) find that it may be a reasonable diversity variable in the long term. With the possibility of large-scale disturbance or environmental change over time, the range of functional responses found in a range of species becomes important, even though such a range may be redundant under current conditions. Since this study focuses on diversity in the context of long term preservation strategies, rather than its immediate function in ecosystem processes, species richness is used as the diversity variable.

In addition to the measurement of species richness, our study also involves the measurement and comparison of vegetation composition. Vegetation composition is the combination of the assemblage of species present in a community and their relative abundances. Unlike diversity, composition refers to the particular combinations of species present rather than simply the number present. Since Diaz and Cabido (2001), Loreau (2000), and Tilman (1999) have identified vegetation composition as a second crucial variable in the determination of ecosystem function, it serves as an important indicator of the effects ivy may be having on such function.

3.1.2 Study area

Under British Columbia's biogeoclimatic ecosystem classification system, the forests of Stanley Park are classified as the Pacific Ranges variant of the Drier Maritime Coastal Western Hemlock subzone (Beese 1988a). Within this subzone, the understory vegetation in the Park is classified into six different site associations.

Though a complete study of the effects of ivy on the ecology of Stanley Park would require sampling sites with and without ivy in all forest types in the Park, time limitations led us to locate our sites in the type of forest that is most common. Forest dominated by mature western hemlock is widespread throughout the Park, and also represents the climax stage for much of the Park's immature forest. Furthermore, it is primarily this type of forest that current management activities are designed to preserve (Beese and Paris 1989a, Vancouver Board of Parks and Recreation 1993).

In choosing our site with ivy, we looked for an area of dense ivy infestation. As time limitations again prevented us from sampling sites with a range of ivy densities, we chose to sample an area with dense ivy as an indicator of the potential effects of ivy in areas where it is allowed to grow unchecked over a long period of time. Given the number of smaller infestations scattered through the forest (Pallochuck 1998), and the density of the plant where it has long been established, the dense stands represents what a larger area of the Park may look like in the future if ivy is not controlled.

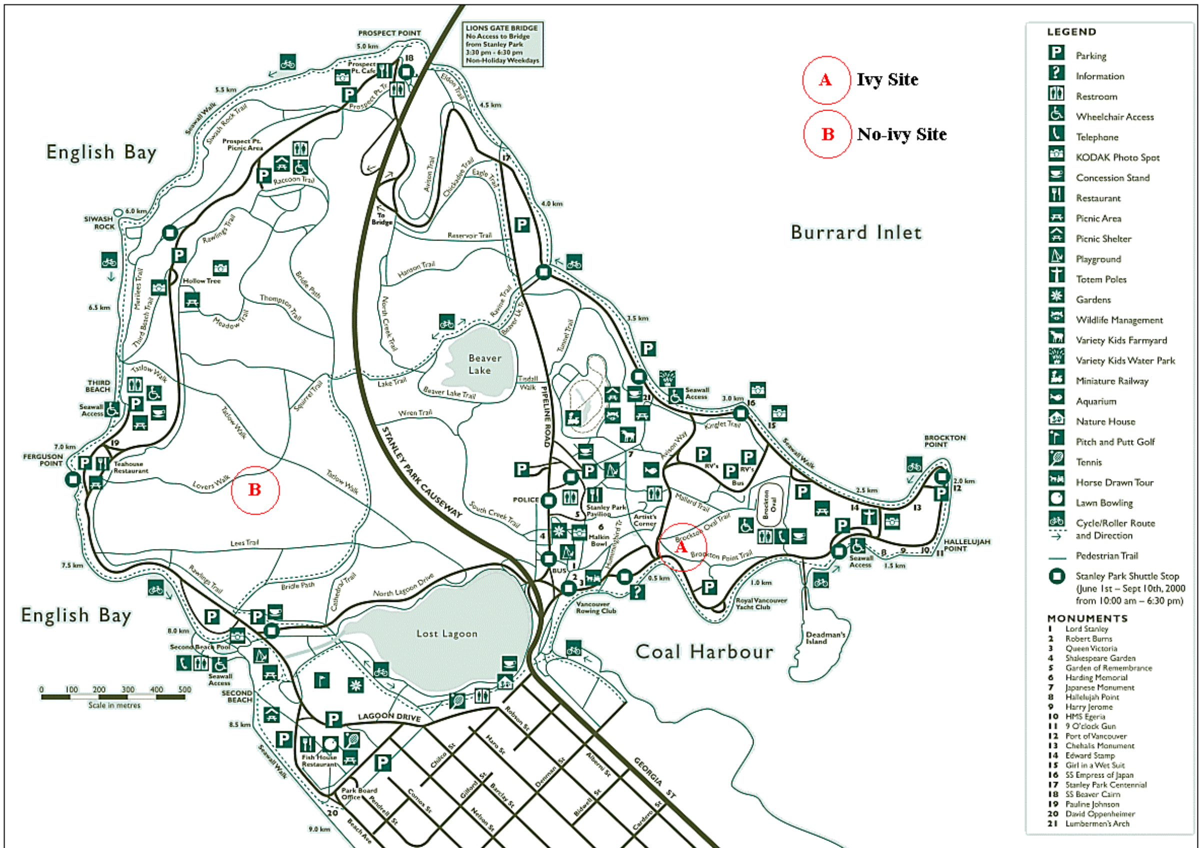


Figure 3.1 - Location of sample sites in Stanley Park
Base map source: Vancouver Parks and Recreation 2001b.

Of the three largest and densest ivy infestations identified in the Park by Pallochuck (1998), the one in the south-east corner occurs in a mature, hemlock-dominated stand. The understory vegetation in this stand also falls into the most widespread of the site associations, the ladyfern-foamflower-swordfern association. For these reasons, we chose the area just south of Brockton Point Trail as our Ivy sampling site (see Figure 3.1). This is stand number 6035 on the stand map generated as part of the 1989 ecosystem classification (Beese and Paris 1989a).

Given the site characteristics summarised in Table 3.1, we then looked for an ivy-free site with similar characteristics. Of the several stands we explored, stand number 6025 was the best match based on these characteristics and on our field observations. Several of the candidate sites

	Stand 6035 **Ivy Site**	Stand 6025 **No-ivy site**
site association	ladyfern-foamflower-swordfern	ladyfern-foamflower-swordfern
stand age	225 years	300 years
stand composition	80% hemlock, 10% cedar, 10% Douglas-fir	60% hemlock, 20% cedar, 10% big leaf maple
average height	43m	43m
average DBH	59cm	65cm

Table 3.1 – Comparison of characteristics of the two study sites.

we examined were significantly affected by windthrow and subsequent replanting, or had stands of deciduous trees not found in the Ivy site. Stand 6025 was free of these complications, and so was selected to minimise between-site variation in vegetation and environmental conditions.

3.1.3 Sampling methods

3.1.3.1 Plot location

In order to sample vegetation composition and diversity at the bryophyte, herb, and shrub layers at each site, we surveyed 10 plots at the Ivy site and 10 plots at the No-ivy site. In order to minimise the effects of differences in canopy and soil dynamics under different tree species, each plot was centred on a tree of the dominant species, western hemlock. To locate our plots, we first marked off points every 10m along the trail edge. We then followed a compass bearing perpendicular to the trail for a randomly generated distance into the forest, and picked the nearest hemlock tree to that point. In the No-ivy site, we choose the nearest hemlock in the same size range as we had sampled in the previously completed Ivy site. By recording the diameter at breast height (DBH) of our centre trees and incorporating size into our random selection process, we were able to ensure we were comparing understory vegetation between trees of approximately the same ages. The average DBH in the Ivy site was 73.9 cm, with a standard deviation of 25.7 cm. In the No-ivy site, the average was 76.2 cm and the standard deviation was 22.7 cm.

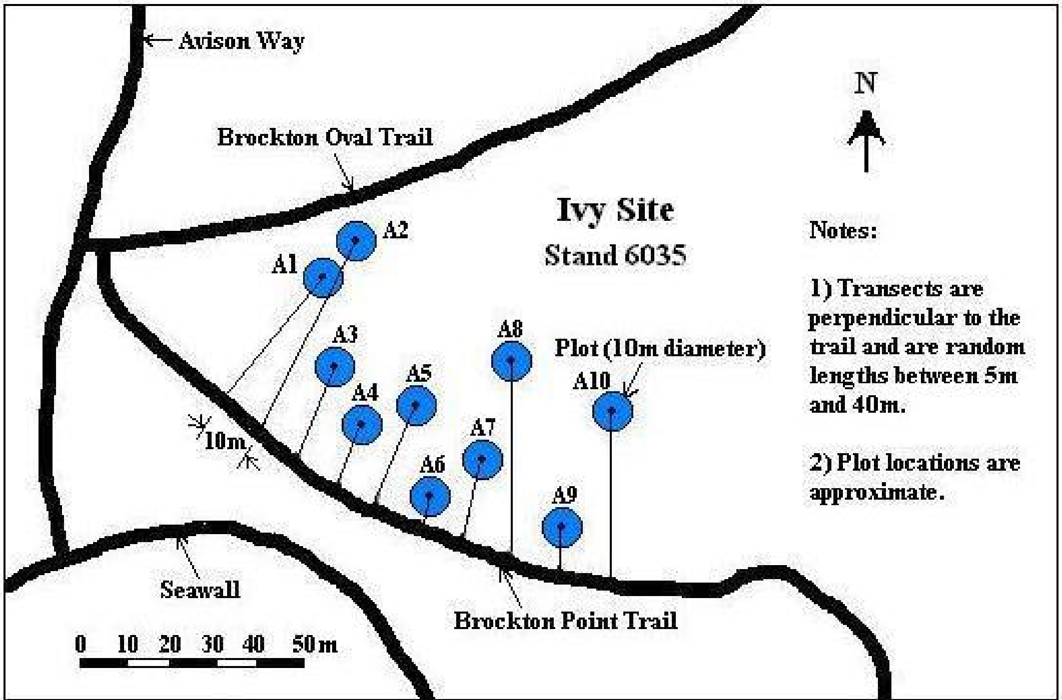


Figure 3.2 - Location of sample plots in the Ivy site.

In order to sample a range of distances in from the trail, we used random numbers between 5 and 50m in from the trail, generated with a random number spreadsheet function. At each site, we used two random numbers in each of the following ranges: 5 to 10m, 10 to 20m, 20 to 30m, 30 to 40m, and 40 to 50m. The lower limit of 5m was chosen to avoid including trails in the plots, while the 50m upper limit was chosen to avoid entering a different stand of trees. See Figures 3.2 and 3.3 for approximate plot locations.

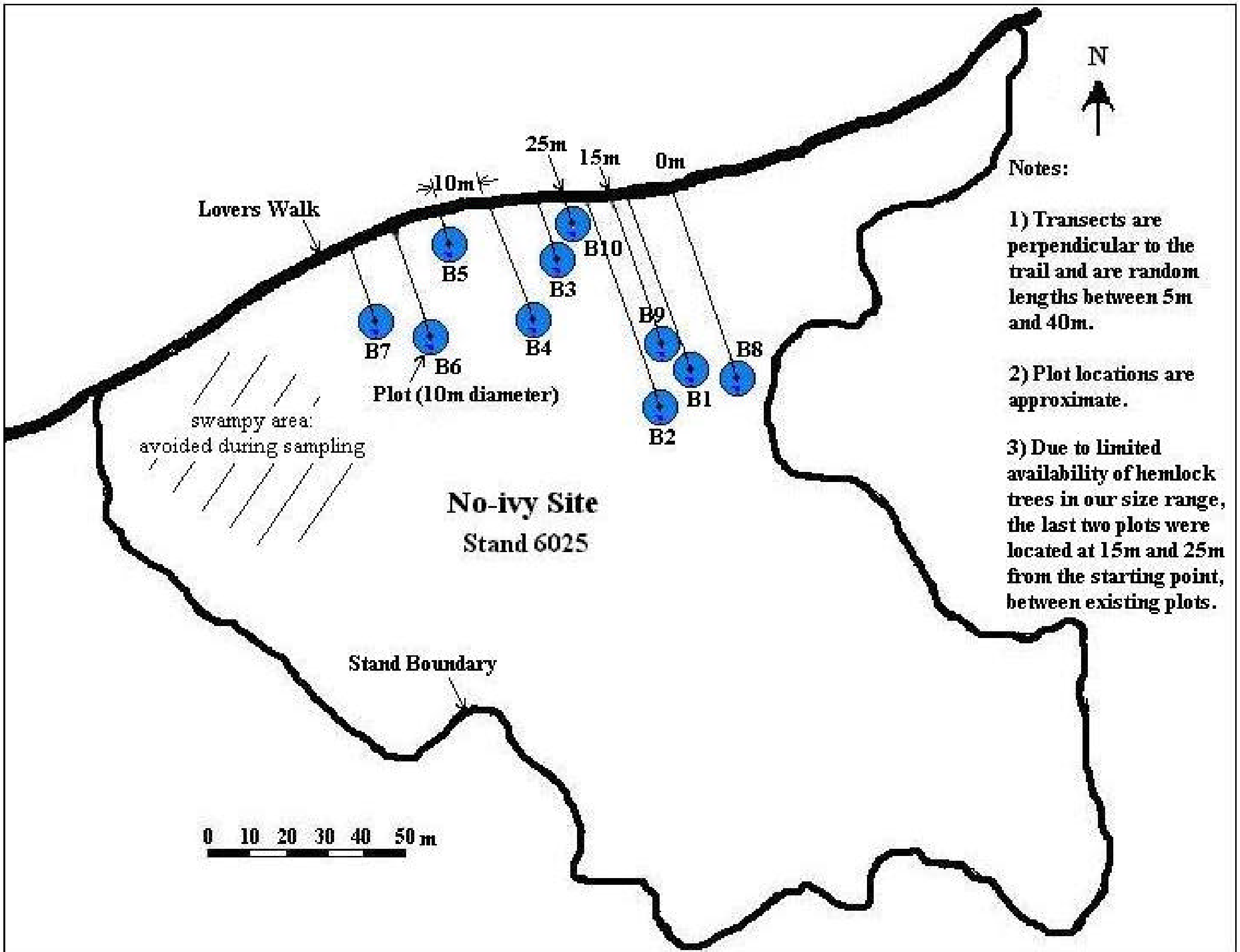


Figure 3.3 - Location of sample plots in the No-ivy site.

3.1.3.2 Plot design

Each plot consisted of a circle with a 5m radius, divided into 3 sectors of equal area by transects heading out from the centre tree at 0^{o}, 120^{o}, and 240^{o}. Two 1m x 1m x 1m quadrats, one between 1m and 2m from the tree and one between 4m and 5m from the tree, were placed along each transect. This gave a total of 6 quadrats per plot (see Figure 3.4 for plot layout). In each of the quadrats, percent cover was estimated for all species present, including trees. To minimise individual bias, cover estimates were agreed upon by both samplers at every quadrat sampled.

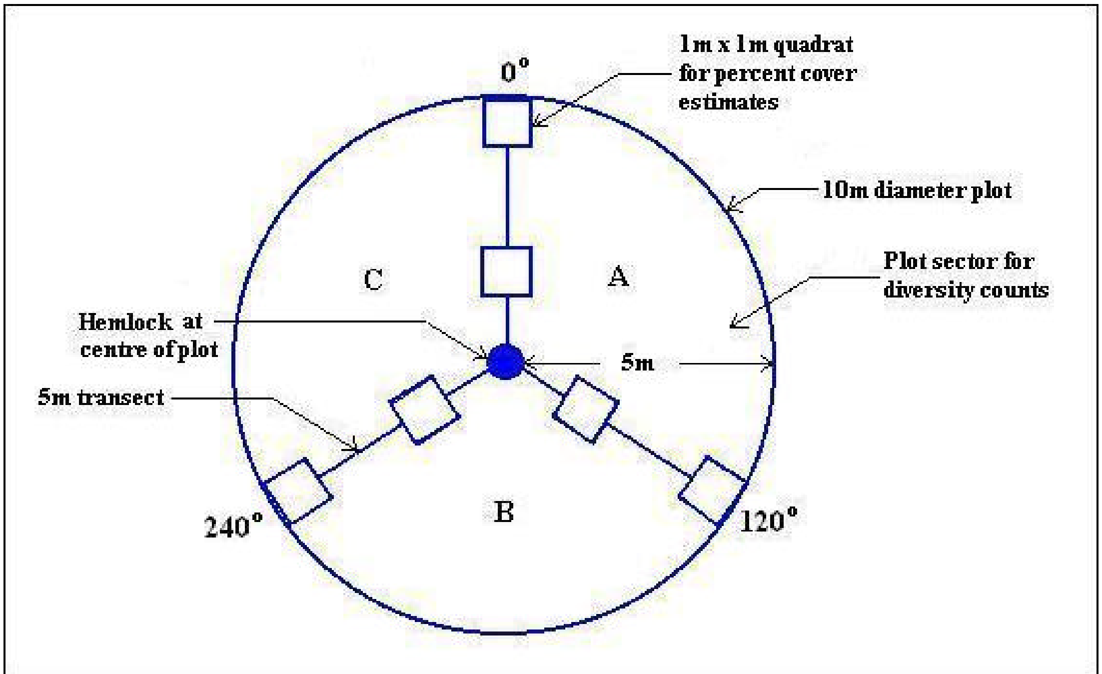


Figure 3.4 - Plot layout.

In the 3 sectors of the circle, all species present were listed along with a broad cover class for that sector (>0-2%, 5-25%, 25-50%, or 50-75%). While the quadrat data were collected in order to compare vegetation composition between the two sites, the sector data were collected to allow comparison of species diversity.

3.1.4 Data analysis

The data collected in the vegetation surveys were analysed in two separate ways. First, vegetation composition and species richness observed in plots in the Ivy site were compared to those observed in the No-ivy site. We termed this *between-site analysis*. Second, the quadrats and sectors in the Ivy site were compared in order to detect any relationship between species richness and the density of ivy within the Ivy site. We termed this *within-site analysis*.

For much of the analysis of our quadrat data, we used the plant ecology software PC ORD. This program is capable of performing outlier analysis, data adjustment, ordination by several methods, and of generating species area curves and jackknife estimates (please see Appendix A for explanation of these standard plant ecology methods). As such, PC ORD was used for both between-site and within-site analysis.

3.1.4.1 Between-site analysis

Between-site analysis for the data was comprised of two major components. The vegetation composition data collected from the 120 quadrats (6 per plot x 20 plots) were analysed using Bray-Curtis ordination, while the species richness data collected from the plot sectors were analysed using simple graphic comparisons. Species richness was also compared using jackknife estimates from the vegetation composition data.

To analyse the vegetation composition data, the 6 quadrats in each plot were averaged, so that our main species-quadrat matrix was condensed to 20 plot rows. We also removed ivy from the matrix to keep the simple presence or absence of ivy from dominating the ordination. We then entered the site, Ivy or No-ivy, into the second matrix for overlay on the ordination.

Since we do not assume that our Ivy and No-ivy sites are contiguous communities joined by linear species-species and species-environment relationships, we chose Bray-Curtis over PCA as the best ordination method. Bray-Curtis is a polar ordination method, choosing the most dissimilar pair of plots as endpoints for its axes (Bradfield 2001). In order to avoid the use of outliers as endpoints and the consequent artificial stretching of the point cloud, it is very important to perform an outlier analysis on any matrix prior to ordination (Bradfield 2001). Before each of our ordinations, we used PC ORD to identify outliers, defining these as plots that fall outside two standard deviations (2 SD) of the average Euclidean distance between plots.

Outliers were then removed. Bray-Curtis ordinations were carried out on the unmodified data, as well as after Beals Smoothing (to reduce the prevalence of zero values in our matrix) and after relativisation by species' maximum cover to increase the weight of rare species in the quadrats. Bray-Curtis ordinations were also carried out separately for shrub, fern, and moss data. This gives some indication of the role of different vegetation layers in shaping the overall ordination.

The primary tool for analysing the plot sector (species richness) data was graphical comparison of increasing diversity with area between the Ivy and No-ivy site. The average number of species in any one sector (A, B, or C), the average number of species in any two combined sectors (A+B, B+C, or A+C), and the average number of species found in the plot (A+B+C) was be plotted for both sectors. Averaging species number over all possible combinations serves to increase sample size and decrease error. More importantly, it allows us to avoid the assumption of radial symmetry or homogeneity that must be made in single start point sampling methods for diversity, such as nested plot sampling.

Our second method for comparing species diversity between the Ivy and No-ivy sites was a simple comparison of species-area curves and the jackknife estimates they produce. Jackknife estimates are estimates of the number of species actually present in a sampling site, based on the frequency of rare species found in the quadrats of that site.

3.1.4.2 Within-site analysis

In order to discern relationships between species richness and ivy density in the Ivy site, we used three separate methods. First, species richness was compared at the quadrat level. We divided all 60 quadrats in the Ivy site (6 per plot x 10 plots) into 17 classes, based on the percent cover of ivy in the quadrats. We then graphed the average number of species present in the quadrats of each class against the percent cover of ivy for that class. Second, species richness was compared at the sector level. We separated all 30 sectors in the Ivy site (3 per plot) into three groups based on the percent cover class of ivy recorded for that sector, 2-25%, 25-50%, or 50-75%. We then averaged the number of species present in the sectors of each group. The correlation coefficient and an associated t-test were used to assess the strength of the relationship in these first two methods.

The third method we used in the within-site analysis was ordination of the quadrat data (averaged by plot) for the plots in the Ivy site. This allowed us to investigate the possible effects of different densities of ivy on vegetation composition, rather than diversity. For this ordination the average percent cover of ivy in each plot was entered as a quantitative variable in a second ordination matrix. These values were then used to overlay a percent cover of ivy gradient on the ordination. This provides a visual indication of the degree to which variation in vegetation composition between plots corresponds with changes in ivy density, measured as percent cover.

4.0 RESULTS

4.1 Vegetation surveys

Please Note: All species identified during the surveys are listed in Appendix A. Numbers of occurrences in each site are also given.

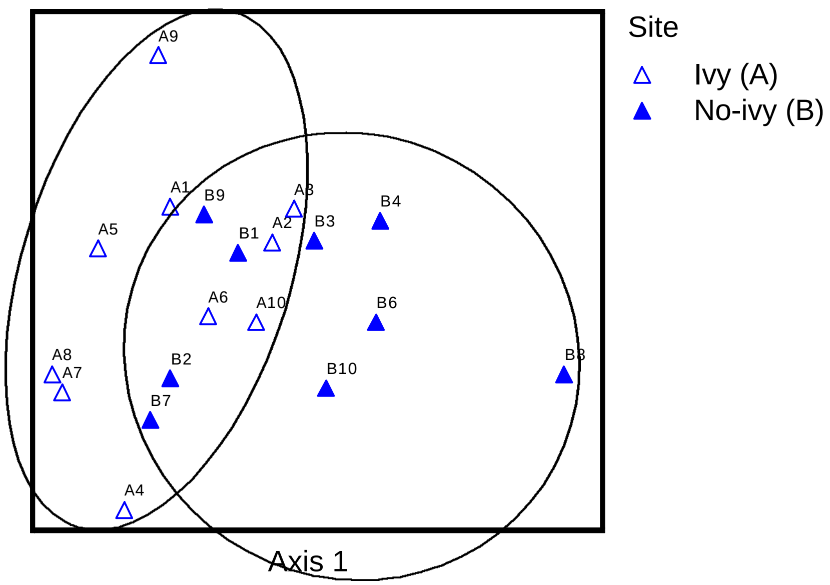
4.1.1 Between-site analysis

4.1.1.1 Vegetation composition

Our initial ordination of the unmodified plot data (averaged from quadrat data) for all plots from both sites, is shown in Figure 4.1. This ordination was carried out after one outlier plot (B5) had been identified and removed. The first two ordination axes capture approximately

43% of the original distance matrix, which seems to be a reasonable amount when compared to other examples (Kent and Coker 1992). See Appendix A for ordination output.

Figure 4.1 – Bray-Curtis ordination of quadrat data averaged by plot. Cumulative variation extracted by first two axes is 43.41%. One outlier (Plot B5) has been removed from the matrix.



As emphasised by the ellipses drawn over Figure 4.1, there does seem to be some separation of plots according to their site. There is a good deal of overlap between the clumps of plots from the two sites, but towards the two poles of the first ordination axis there is some distinct separation.

As discussed in the Data Analysis section, ordinations were also carried out following Beals Smoothing and following relativisation by species maximums. These ordinations are shown in Figures 4.2 and 4.3, respectively. For each data adjustment technique, we began with the entire plot-species matrix, performed the adjustment, checked for and removed any outliers,

Figure 4.2 – Bray-Curtis ordination on the plot-species matrix adjusted with Beals Smoothing. Following Beals Smoothing, one outlier (Plot A9) was removed from the matrix. Cumulative variation extracted by the first two axes is 75.86%.

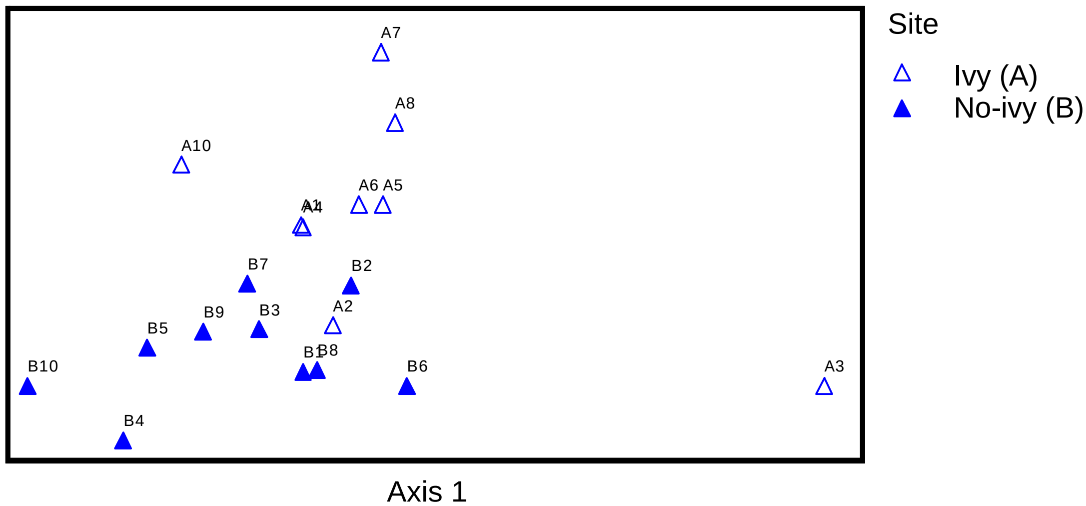
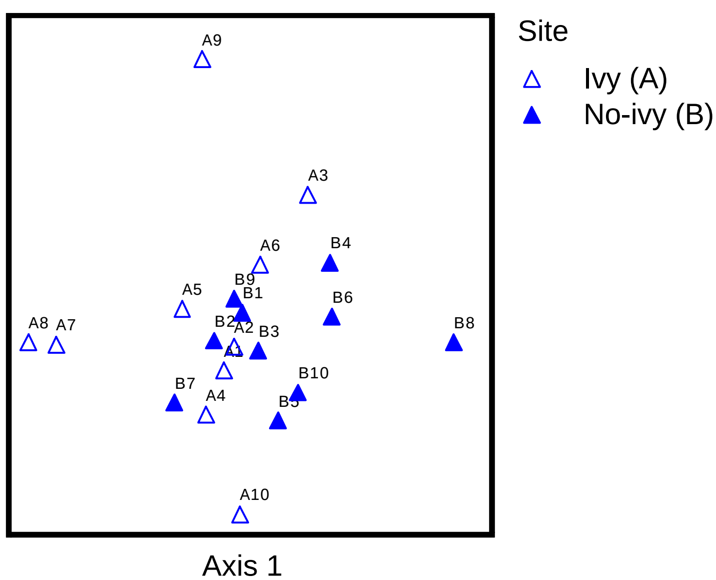


Figure 4.3 – Bray-Curtis ordination of plot-species matrix adjusted with relativisation by species. Following relativisation, no outliers were found. Cumulative variation extracted by the first two axes is 32.70%

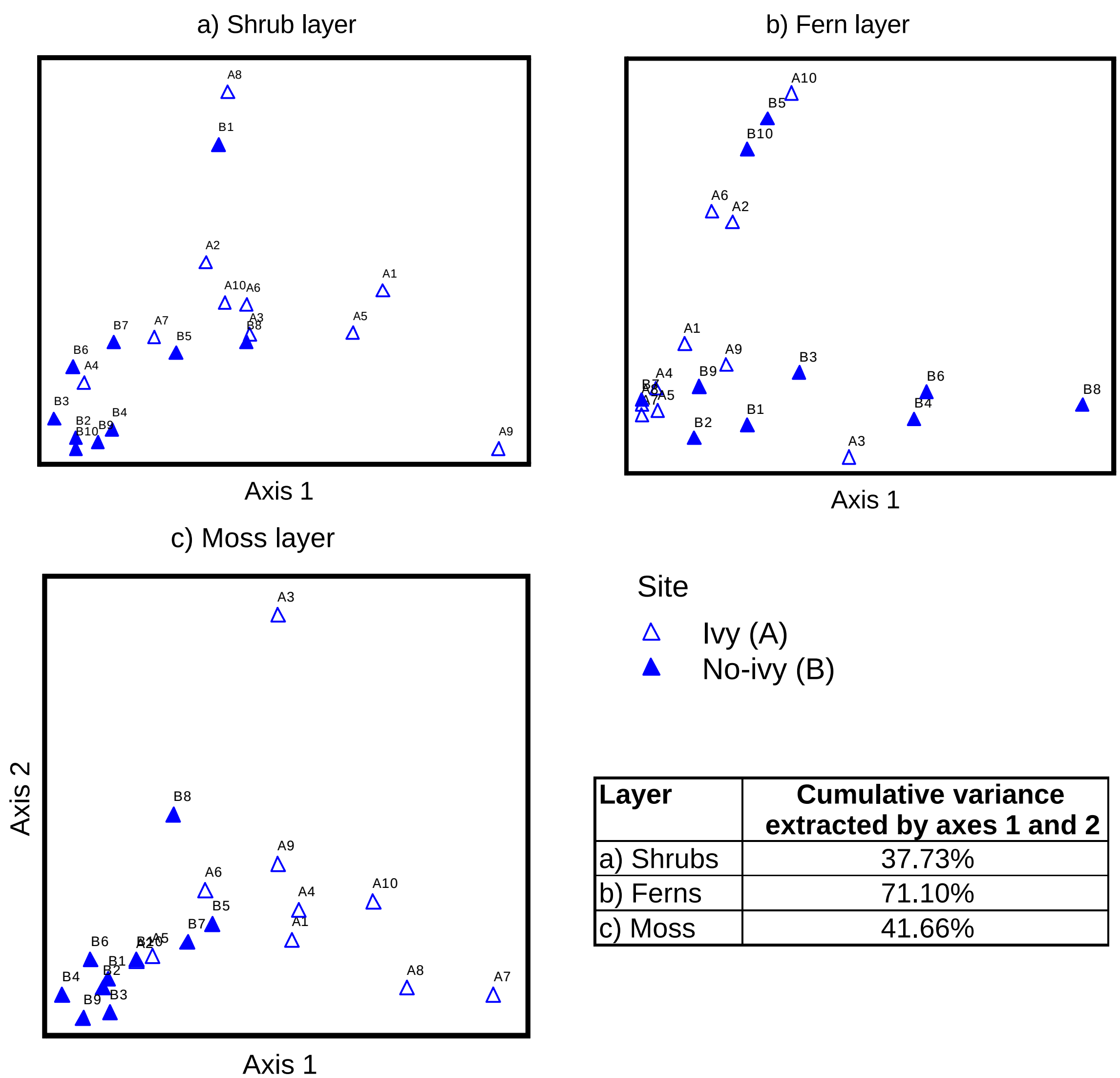


and then carried out the ordination. Following Beals Smoothing, we found Plot A9 to be an outlier (based on the $\pm$ 2 SD cut-off) and removed it prior to ordination. Following relativisation by species maximums we did not have any outliers, and so the ordination was carried out on all 20 plots.

As Figures 4.2 and 4.3 show, both the data adjustment techniques resulted in ordinations with a similar grouping pattern to that found in the original ordination. The plots seem to be separated by site as we move away from the overlap at the centre of the graph. The ordination following Beals Smoothing appears to have the least overlap between sites, as well as the highest measure of significance of the ordination axes, with axes 1 and 3 capturing approximately 76% of the total variation in the plot-species matrix.

The final Bray-Curtis ordinations carried out for the between-site analysis were layer-specific ordinations based only on the data from a particular vegetation layer. No data adjustment techniques were used. Figure 4.4 shows the ordinations for shrub, fern, and moss layers, chosen because they contained the majority of species found in the plots. The total numbers of shrubs, ferns, and mosses identified in the quadrats were 6, 4, and 10, respectively. In Figure 4.4, the shrub and moss ordinations show some separation of the plots by site, while the fern ordination does not.

Figure 4.4 – Bray-Curtis ordinations of individual vegetation layers. No outliers were removed.

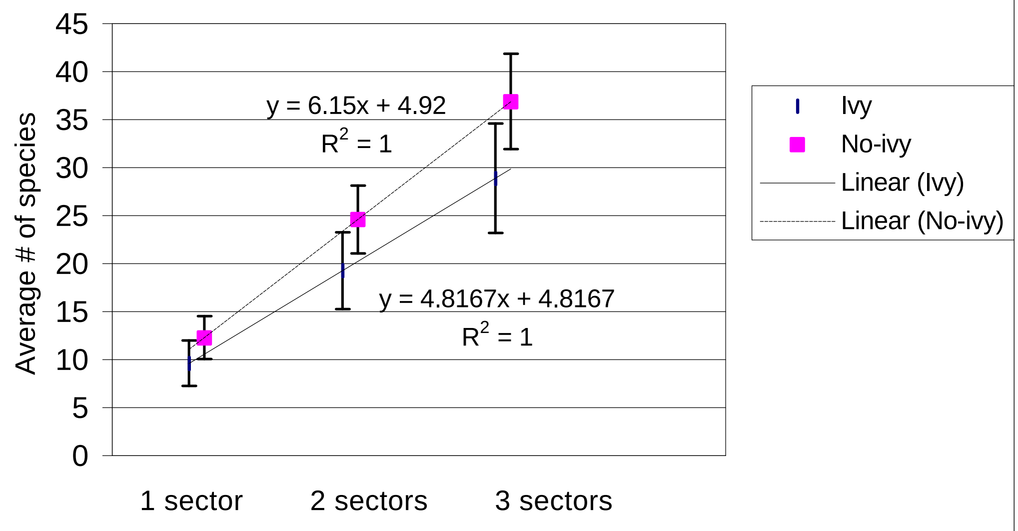


Layer	Cumulative variance extracted by axes 1 and 2
a) Shrubs	37.73%
b) Ferns	71.10%
c) Moss	41.66%

4.1.1.2 Vegetation diversity

As noted in the Data Analysis section, the primary method for comparing diversity between the Ivy and No-ivy sites was graphical comparison of increasing species richness with area. Figure 4.5 shows the increase in the average number of species in any 1, any 2, and all 3 sectors of each plot, for both sites. Judging by the overlap of the ± 1 standard deviation error bars, the higher diversity in the No-ivy site does not seem to be significant.

Figure 4.5 - Increasing species richness with area for the Ivy and No-ivy sites. Error bars are +/- 1 SD.



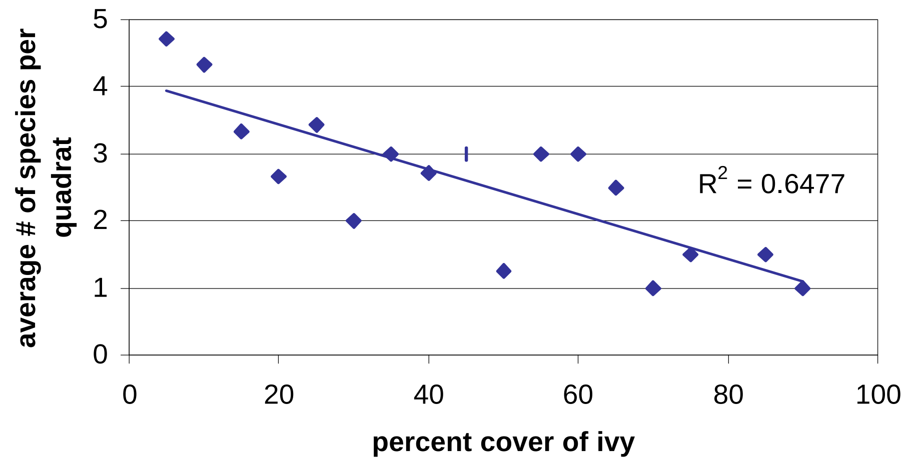
The jackknife estimates for the two sites also suggest that if there is a difference in species richness, it is not very large. We found a total of 18 species in the Ivy site, and the species area curve for that site generated a first-order jackknife estimate of 19.8 species. In the No-ivy site we identified 21 species and the jackknife estimate was 22.8 species, just 3 more than in the Ivy site. The estimates are the total number of species suspected to be in the site based on the frequency of rare species in the site. That is, given the species we encountered and their frequencies, there will be a certain number of additional rare species that could be present in the site but missed in the sampling. The small difference between the jackknife estimate and number of species observed indicates that we used adequate sampling replicates to capture nearly all of the species present.

4.1.2 Within-site analysis

4.1.2.1 Vegetation diversity

Figure 4.6 shows the number of species present in the quadrats in the Ivy site plotted against the percent cover of ivy in the quadrats. The percent cover of ivy values were grouped into cover classes, shown on the x-axis, and the average number of species present in the quadrats with that cover class of ivy was plotted on the y-axis. Since we had more quadrats with low percent covers of ivy than we did with high percent covers, this grouping and averaging was carried out to remove bias towards quadrats with less ivy. Figure 4.6 shows the correlation between species richness and percent cover of ivy. We used a t-test to determine that this correlation is statistically significant with 95% confidence.

Figure 4.6 - Variation of species richness with percent cover of ivy. Data are from the individual quadrats of the Ivy site.



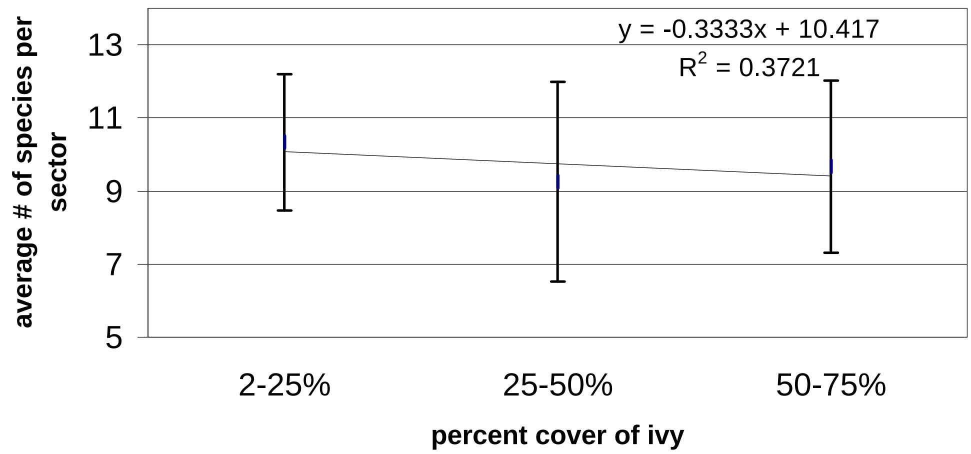


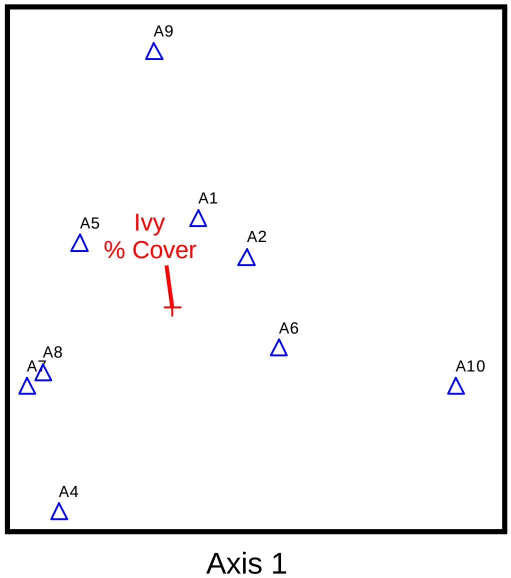
Figure 4.7 - Variation of species richness with percent cover of ivy. Data are from the sectors of the Ivy site.

When we use the sector data to examine relationships between ivy density and species richness, as shown in Figure 4.7, we see no relationship at all. The ± 1 SD error bars all overlap, and the mean number of species actually increases from the 25-50% ivy sectors to the 50-75% ivy sectors.

4.1.2.2 Vegetation composition

In order to assess the impact of different ivy densities on vegetation composition, we carried out a Bray-Curtis ordination of the quadrat data from the Ivy site. Again, the data was averaged by plot. The ordination is shown in Figure 4.8, with the percent cover of ivy gradient overlaid. This vector is based on the average cover of ivy in each plot (averaged from the quadrats), with cover increasing away from the central crosshairs. Overlaying this data gives an indication of the amount of variation in vegetation composition that is correlated with changing ivy density. The shortness of the vector and its low R^2 value means that very little, if any, of the variation in composition between plots in the Ivy site can be explained by changes in ivy density.

Figure 4.8 – Bray-Curtis ordination of plots in the Ivy site. One outlier (Plot A3) has been removed from the Matrix. Cumulative variance extracted by the first two axes is 66.42%. The percent cover of ivy in the quadrats has been overlaid as a gradient from the second matrix. The R^2 value for the % Ivy gradient is between 0.1 and 0.2.



5.0 DISCUSSION OF RESULTS

5.1 Effects of ivy invasion

5.1.1 Effects on vegetation

Examining only the results from our between-site analysis, there appears to be some difference in vegetation composition correlated with the presence or absence of ivy. Ordinations of the unmodified and the adjusted data (see Figures 4.1 to 4.3) produce some separation of the two sample sites, using relatively significant axes. Furthermore, this difference appears to occur in the shrub and moss layers (see Figure 4.4). This is not surprising, since woody species like salal (*Gaultheria shallon*) may play similar functional roles to that of *Hedera helix*, a woody vine in its juvenile stage and a woody shrub in its mature stage.

Such speculation, however, points out a crucial gap in the current understanding of ivy's behaviour in natural systems. Very little is known of the mechanisms of ivy invasion. In their study of the effects of *Lonicera maackii* on native annuals, Gould and Gorchov (2000) suggest two basic mechanisms by which this exotic shrub may out-compete native plants in an Ohio forest. First, the long leaf phenology of the shrub may give it an advantage in competition for light, and allow it to shade out herbs early in the growing season. Second, the shallow rooting system of the shrub may allow it to out-compete native plants for water and nutrients (Gould and Gorchov 2000). Both of these are also possibilities for *Hedera helix,* since ivy is evergreen and has shallow roots (Ivy Removal Project 2002h).

In terms of effects on plant diversity, Figure 4.5 shows no significant difference in species richness between the two sites. Our within-site analysis, however does show a significant relationship between species diversity and ivy density. Decreasing diversity with increasing ivy density is observed at the quadrat level (Figure 4.6) but not the sector level (Figure 4.7). In interpreting this inconsistency, it is important to remember that that the Ivy site is located in one of the Park's densest ivy infestations, and to again acknowledge our lack of information on the mechanisms of invasion. Though there was variation in the percent cover of ivy in our sectors, the sectors with little ivy were not far removed from dense patches. If ivy out-competes native species for nutrients and/or water, or otherwise alters soil properties in some way, its presence in patches may also affect the dynamics of adjacent areas where it is more sparse.

Though the relationship shown in Figure 4.6 is statistically significant with 95% confidence, there is a good deal of uncertainty about what this relationship means. In particular, observational studies of diversity within well established ivy infestations, such as ours, do not allow the separation of “(1) the effect of the invasive species in suppressing native species from (2) the occupation by invasives of sites from which native species are absent” (Gould and Gorchov 2000). We attempted to use our No-ivy site, selected to be as similar as possible, to provide a reference point for the “natural” abundance of native species in this particular kind of forest. Comparing the two sites, we did observe a slightly higher overall species richness (three more native species) in the No-ivy site than the Ivy site, as well as differences in vegetation composition, as outlined above. The problem with this type of comparison is that environmental conditions in the two sites will inevitably act as confounding variables, making a true “control” site impossible. This type of uncertainty, due to the complexity of natural systems, is typically not resolvable.

Fortunately, some of the other sources of uncertainty outlined above can be addressed. Further study on the mechanisms and time series dynamics of invasion would be very useful. Uncertainty about the effects of dense patches on sparse areas within an infestation could be resolved with a time series study of native species richness in a patch of ivy starting out at low densities and growing to greater densities over a larger area. Data from the beginning of the study would capture the species richness associated with low densities without the influence of dense patches. Long-term monitoring would also give the best possible indication of ivy’s rate of spread. Since the growth patterns of ivy are extremely complex, it is currently not possible to model spread over time with any accuracy. Time series data would greatly increase current knowledge about growth rates.

A very important element of experimental design for studies of ivy impacts is the choice of indicators. We attempted to capture the effects of ivy on both vegetation composition and species richness. There are, however, other possibilities. Depending on the management objectives for the study area, effects of ivy invasion on particular species of plants may be the most important variable to measure. Plant species valued for their rarity, their importance to wildlife, or for aesthetic or cultural reasons, should be monitored specifically, since studies of overall composition and diversity may not detect impacts on particular species.

Finally, though the forest type we studied is the most common in the Park (see Appendix D, Figure 1, site association 4.0), a more comprehensive analysis of ivy's effects would require research on the ivy infestations in different site associations in the Park. In particular, the dense ivy patches at the northern tip of the Park, east of the Causeway (see Appendix D, Figure 2), are invading deciduous forest. In this type of forest, ivy tends to grow up and into the canopy, making the rate of spread and potentially the effects on vegetation quite different.

Despite the uncertainly inherent in our results, they do show 1) a significant difference in vegetation composition between the Ivy site and the No-ivy site, 2) a higher number of native plant species in the No-ivy site, and 3) a significant decrease in native species diversity with increased ivy density within the Ivy site. All three of these lead us to conclude that English ivy seems to be having a significant effect on native plant composition and diversity in Stanley Park.

5.1.2 Effects on wildlife

In analysing impacts of ivy on wildlife, we have chosen to focus on birds, as they are a significant part of the ecosystem of Stanley Park. With over 230 species of birds (Kautesk and Weber, 1988), it is clear that the forest of Stanley Park is important urban bird habitat and is highly valued by birders. Also, there is a clear connection between our study of vegetation effects and the associated impact on birds.

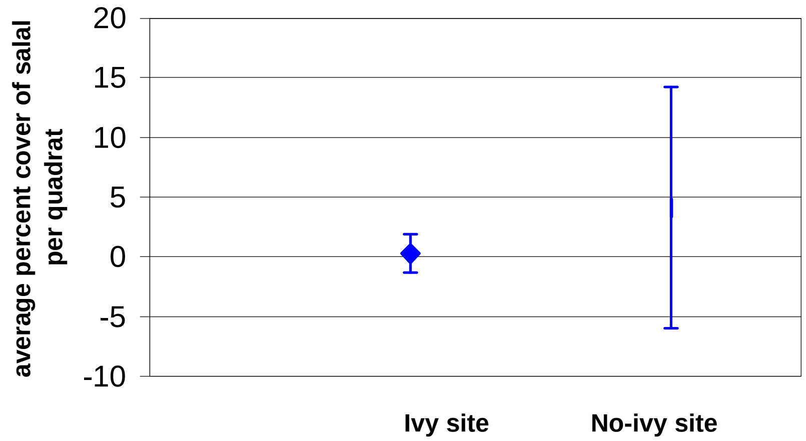
Due to the considerable lack of previous studies on the relationship between ivy and birds, it is difficult to establish a clear picture of the complete interactions. Thus, we will discuss various factors that warrant further investigation.

Firstly, being such a prolific groundcover and tree climber, ivy influences the structure of both the herbaceous understory and trees. It is unlikely that structural changes of groundcover due to ivy will have a significant impact on birds, as this layer is not as important habitat as the shrub and canopy layers (Er 2002). However, in climbing trees and becoming arbourescent, ivy can significantly alter the structure of trees. This is particularly clear for deciduous trees, where ivy establishes itself over the entire tree, including the branches. The implications of this structural change for birds are unclear and would be interesting to explore further.

The second potential impact of ivy invasion on birds is through competition with native plant species. As we showed with our vegetation analysis, ivy seems to be having an impact on native plant diversity. This could affect birds through the availability of desirable food sources. It has been discovered that in some areas, native birds are very selective about the plant species they use for food (Catterall *et al.* 1989). This would make birds very sensitive to changes in vegetation composition.

Salal is a native plant readily used by birds, such as the Swainson's Thrush, as a source of berries (Er 2002). Thus, we were interested in whether there is a competitive interaction between ivy and salal. Upon analysis of the amount of salal in the Ivy and No-ivy sites, we did not find a statistically significant difference between the two (see Figure 5.1). Although there

Figure 5.1 - Average percent cover of salal in the quadrats of the Ivy and No-ivy sites.



did appear to be more salal in the No-ivy site, there was significant variance (as seen by the large 1 standard deviation error bars) in the quadrats, from no salal at all, to a large percent cover. However, in the Ivy site, salal was never present at a high percent cover. Also, in the No-ivy site, salal was present in 58% of the quadrats, while in the Ivy site it was present in only 5% of the quadrats. Thus our results suggest some kind of competitive interaction may exist between ivy and salal. In order to better understand the implications of this possible interaction for birds, further study would be valuable. It may also be useful to analyse the relationship between ivy and other plant species known to be important to birds as food sources.

Thirdly, since ivy produces berries, it is possible that it is utilised as a food source by birds in Stanley Park. Studies by Green (1984, 1986) showed that native birds used native plants more than exotic plants and that the total density and number of species of native birds was higher in areas containing more native plants. However, Catterall, Green and Jones (1989) found that the very selective diet of native birds in the area they studied did include exotic plants.

There are many birds in Stanley Park that make use of berries as a major food source, including many species of thrushes, American robins and cedar waxwings (Er 2002). It is unknown whether any of these native birds make use of ivy berries. One bird that is known to consume ivy berries is the starling, which is an exotic species as well (Snow and Snow, 1988). Since birds that consume its berries are important in ivy dispersal, this is an interesting connection, with one exotic species aiding in the spread of another.

Little is known on the suitability of ivy berries as a food source for native birds. The toxicity of *Hedera helix* has been studied and it has been discovered that the berries are mildly toxic to birds (Barnea *et al.* 1993). Barnea, Harborne and Pannell (1993) determined that it is the pulp and not the seeds of the ivy berries that are toxic. The berry pulp, as well as other parts of the plant, contain saponins, which are present in many plant species (Barnea *et al.* 1993). The bitter taste of saponins often deters animals from feeding on plants where it is present (Barnea *et al.* 1993). Ivy berries also contain cyanogenic glycosides, which are toxic through their release of hydrocyanic acid (HCN) (Barnea *et al.* 1993). HCN is poisonous and can affect a wide range of organisms (Barnea *et al.* 1993). The leaves of ivy also contain cyanogenic glycosides, which may be significant for wildlife grazing on the ivy leaves (Barnea *et al.* 1993).

There have been several studies exploring the dispersal of ivy seeds by birds, illustrating that in some ecosystems ivy is consumed by birds (Clergeau 1992, Kalkhoven and van Ruremonde 1991). Apart from these studies and the limited information about the toxins in ivy berries, no detailed studies exist on ivy as a food source for birds. It would be useful to determine whether or not ivy is an important food source for birds and whether they use it preferentially to other native plants. It is also important to examine the physiological impact of ivy berry toxicity on birds.

The results of our vegetation studies, along with other scientific literature, are inadequate to determine the full implications of ivy in Stanley Park for birds. Priority issues for further study are vegetation effects influencing desirable food sources for birds, and the suitability of ivy berries as a food source for native birds.

PART II – IMPLICATIONS FOR MANAGEMENT AND ENVIRONMENTAL EDUCATION

Given the results of the research presented in Part I, the next step was to determine what they mean for decision makers in the Park. Stanley Park is managed by the City of Vancouver Board of Parks and Recreation, which has extensive horticulture and maintenance departments located in the Park. The Board of Parks and Recreation also provides some funding for the Stanley Park Ecology Society, which runs the Stanley Park Nature House and a wide range of educational and stewardship programs. In order to determine the implications of *Hedera helix* for the City's management of the Park and for environmental education in the Park, we interviewed individuals working in these two fields. We also surveyed Park users to determine their priorities for management and interest in environmental education. Methodology for both of these research techniques begins this section of the thesis.

6.0 METHODOLOGY

6.1 User Surveys

In order to assess current use of Stanley Park's forest, and visitor interest in environmental education opportunities in the Park, we surveyed 133 visitors to the Park during the winter of 2001-2002. The survey questions were developed in conjunction with Tannis Nelson, a BCIT student in the Fish, Wildlife, and Recreation Program, and can be found in Appendix B, along with the tabulated results. The questions were designed to meet the research objectives of this thesis as well as those of a BCIT final project, and thus span a range of issues. The questions relevant to our research are those regarding time spent in the natural areas of the

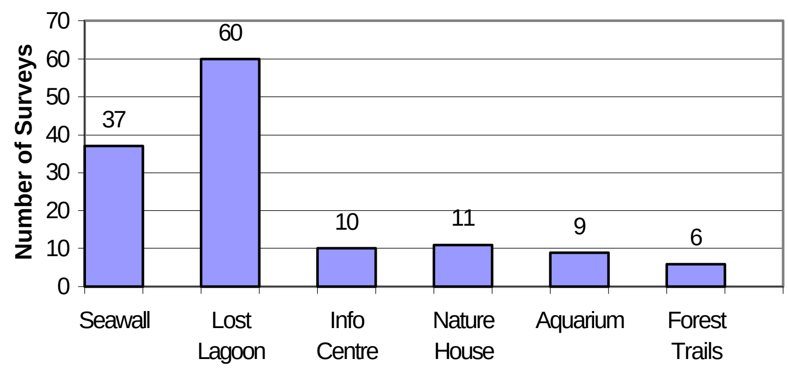
Park, purpose of visits to the natural areas, and interest in educational programs run by the Stanley Park Ecology Society.

The 133 surveys were collected over three months, with 53 collected in November of 2001, 11 collected in December of 2001, and 69 collected in January of 2002. All of the surveys were collected on the weekend, with a roughly even distribution between Saturdays and Sundays. Survey respondents were mostly (80%) residents of Greater Vancouver, with 2% from elsewhere in BC, 9% from elsewhere in Canada, and 8% from countries other than Canada. In regards to the age of the respondents, 9% were between 18 and 25, 57% were between 26 and 50, and 31% were over 50. The remaining 3% of respondents did not record their age.

Along with Tannis Nelson and a second BCIT student, we collected the survey responses by standing at various locations in the Park and asking those walking by to fill out the two page survey. If participants requested help with reading the questions or writing their answers, we offered to read the survey and mark in responses for them.

Two very important sources of bias emerge from this survey method. First, because we were asking people to stop for approximately five minutes to fill out the survey, we did not approach runners; people with large, energetic dogs; or people with several small children. We also noticed that when we approached people not completely comfortable with speaking in English, they were often reluctant to complete the survey. There is therefore a substantial bias toward English speaking, unencumbered walkers who were relaxed and good humoured enough to stop for five minutes in very cold weather.

Figure 6.1 - Survey locations in the Park, with number of surveys collected at each. Total number of surveys = 133.



Second, the locations we chose to survey played a large part in determining the types of responses we received. We attempted to survey a range of locations in both the natural and developed parts of the Park. In order to collect the maximum number of surveys in limited time, however, we focused on the seawall and Lost Lagoon (see Figure 6.1). The Stanley Park Task Force's 1992 survey indicated that hiking or walking and the seawall were the two top reasons for coming for the Park, and that the most popular locations in the Park were the seawall, the beaches, the zoo and aquarium, Lost Lagoon, and the forest trails, in that order (Belyea and St. Louis 1992). Since that survey was conducted in summer and ours was carried out in the winter, we found the beaches and the aquarium to be far less busy than the seawall and the walking trails in the forest and around Lost Lagoon. Our focus on the latter areas does, however, further bias the survey toward walkers rather than those visiting the Park for its developed facilities.

6.2 Interviews

Interviews were carried out with two individuals involved with Stanley Park to obtain expert opinions about the implications of English ivy for the Park. Although the individuals were chosen due to their extensive experience, their responses represent personal opinions, not the consensus of all individuals involved in their fields. Thus, their opinions were taken as a starting point to determine some of the major implications of English ivy.

Information was needed on the impacts of ivy invasion on environmental education in Stanley Park. For this we looked to the Stanley Park Ecology Society (SPES), as environmental education in the Park is their focus. A management perspective on the implications of ivy for current management objectives and the feasibility of various control options was also required. For this we interviewed an individual working in Stanley Park management.

6.2.1 Stanley Park Ecology Society

The individual chosen as an expert on environmental education in Stanley Park was Emily Gonzales, as she was the Members and Public Programs Co-ordinator of SPES until December 2001. Gonzales was asked what she thinks the implications of invasive plants such as ivy are for environmental education in Stanley Park. She was also asked whether she thought volunteer control programs are feasible and within the mandate of SPES. The particular questions asked are contained in Appendix B.

6.2.2 Park Management

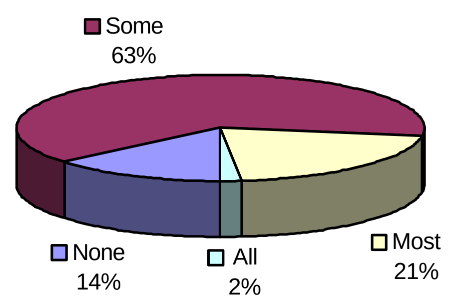
Eric Meagher, Supervisor of Maintenance for Stanley Park , was chosen to represent a management perspective on the implications and control of English ivy in Stanley Park. Meagher is a key decision-maker in Park management, thus his responses represent what is likely to happen in response to English ivy.

The two main questions of this interview addressed 1) the implications of English ivy for management objectives and 2) the most feasible control options for English ivy from a management perspective. Meagher was also asked if he thinks the problem of English ivy is significant enough that it warrants increased control efforts and what resources are available for this. The specific questions are contained in Appendix B.

7.0 IMPLICATIONS FOR FOREST MANAGEMENT

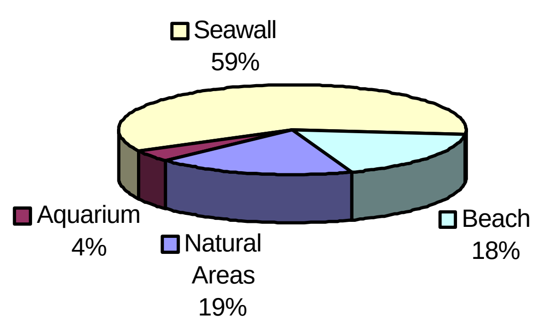
As outlined in the introductory sections of this thesis, visitors to Stanley Park value a wide range of Park facilities and features. According to the results of the Stanley Park Task Force's 1992 survey, the Park's forest and wildlife are considered important or very important by the vast majority of those surveyed (Stanley Park Task Force 1992). We conducted an additional survey (described in the preceding methodology section) in order to further investigate Park visitors' use of the forest. Together with the objectives of current forest maintenance activities, information on user activities is essential to understanding the implications English ivy may have for management of the Park.

Figure 7.1 - Amount of visitors' time in the Park spent in natural areas (i.e. forest trails).



As shown in Figure 7.1, of the survey respondents who answered this question, 86% spend at least some time in the Park's forest. During the period of our survey (November to January), this is the Park's second most popular location after the Seawall (see Figure 7.2). This differs from the results of the 1992 survey (conducted August to October), which show natural areas last in popularity after the seawall, the beach, and the zoo and aquarium (Belyea and St. Louis 1992). The results of our survey thus add a valuable picture of changed user activities in the winter months.

Figure 7.2 - Percentage of visitors spending "most" or "all" of their time in the Park in each area.



If we are to assess the implications that ivy has for forest management in the Park, we must understand not only the frequency of forest use, but also the reasons for forest use. In response to our question about visitors' reasons for spending time in the Park's forest, 81% of those surveyed indicated that their reason is “sometimes” or “often” to get exercise, 83% indicated that it is “sometimes” or “often” to spend time in a natural setting, and 41% indicated that it is “sometimes” or “often” to learn about the natural environment.

In light of the results presented in Part I of this thesis, the significant proportion of Park users who claim the latter two reasons may be seriously impacted by the invasion of English ivy. In particular, they may be affected by the dramatic impact ivy has on the appearance of the forest, and by the negative effects that ivy seems to be having on native plants and wildlife. Visitors to the Park may not be able to enjoy being in a natural setting if the forest around them is dominated by an exotic species. Nor will they be able to study coastal forest ecology if the elements and interactions of the forest ecosystems are altered by ivy invasion.

Following completion of our surveys, designed to collect user perspectives, we were able to obtain an interview with Eric Meagher, Supervisor of Maintenance for Stanley Park. This allowed us to consider a management perspective on the implications of ivy for the Park's forest, as well as on current control efforts in the forest.

According to Meagher, the major objective for the forest is to manage it sustainably, so that visitors to the Park in the future may enjoy the same experience they currently enjoy (Meagher 2002). Though there is currently no master plan for management of Stanley Park, the general objectives outlined in the 1989 Regeneration Plan (Beese and Paris 1989a) remain the basis of management activities in the Park's forest. At present, reforestation efforts are applied in a site by site manner, following blowdown events or in areas severely affected by parasitisation of hemlock trees by dwarf mistletoe. Follow-through on more structured management plans, such as the Regeneration Plan, is made difficult by fluctuations in capital funding for management activities (Meagher 2002).

Currently, control of English ivy in the Park is also limited by funding constraints. Two Park Maintenance employees, hired to conduct hazard tree assessments, are also cutting ivy vines as the base of trees it has invaded (Meagher 2002). This form of manual control kills the ivy that has spread up the tree, but does not remove ivy from the ground, where it may be affecting native understory species. In managing Stanley Park to sustain a representative sample of coastal forest for the future, it is entire plant communities, and not just trees, that must be preserved. As such, the unchecked spread of ivy on the ground has serious implications for current management objectives. In order to retain the aesthetic and educational value of native forest communities, the effect of ivy on these communities must be minimised.

Longevity of the forest in its semi-natural state is something the Park's Supervisor of Maintenance takes very seriously (Meagher 2002). When funding allocation and management directives are being considered by the Board of Parks and Recreation, Meagher stresses the importance of careful management of the forest's natural features. In terms of ivy control, this translates into a general goal to keep the ivy invasion where it is, and to prevent large amounts of future spread (Meagher 2002). If given the funding and resources, however, consideration of expanded control efforts to preserve native vegetation might be possible. Given both user and management perspectives on the value of the forest's natural state, such efforts would seem to fall within stated objectives of sustainable management, and to be beneficial to a great number of Park users, both now and in the future.

8.0 IMPLICATIONS FOR ENVIRONMENTAL EDUCATION

8.1 Potential for environmental education in Stanley Park

8.1.1 Importance of environmental education in urban areas

Upon recognising the enormous impacts that humans have on the natural world, it has become clear that environmental awareness in all people is essential in enacting the social change required to sustain both ourselves and the world around us. Environmental education seeks to fulfil this need through formal and informal programs for all ages. Although the goals of environmental education vary from program to program, UNESCO (1977) devised three major objectives that offer a useful starting point. These are:

1) *to foster a clear awareness of and concern about economic, social, political and ecological interdependence in urban and rural areas;*
2) *to provide every person with opportunities to acquire the knowledge, values, attitudes, commitment and skills needed to protect and improve the environment;*
3) *to create new patterns of behaviour of individuals, groups and society as a whole towards the environment.*

Personal contact with nature is important in the development of respect for the environment (Hale 1993, Harvey 1993). In fact, one study showed that for 90% of respondents, outdoors experiences were particularly instrumental in the development of positive attitudes towards the environment (Palmer 1993). Second to outdoors experiences were education courses, with 59% naming them as being key in the development of their appreciation for nature (Palmer 1993). These findings illustrate the need for environmental education to entail direct interaction with nature.

It is often assumed that nature is absent from the city and that in order to experience nature one must travel to the wider environment (Bridge 2001). In fact, nature exists throughout the city and offers unique habitat for many species. Although it is important to celebrate and value ‘wilderness,’ ecosystems within the city must not be overlooked (Bridge 2001). Because urban ecology is heavily influenced by humans (unlike ‘wilderness,’ by definition), nature in urban settings provides the opportunity to raise awareness about the impacts humans have on the environment. Although urban ecosystems are generally disturbed, they retain the potential to teach people the principles of ecology (Hale 1993).

The accessibility of urban nature makes it an important educational tool. Many people in urban settings do not, and perhaps should not, have the opportunity to experience untouched wilderness. If everyone did have access to wilderness, there would be very little wilderness left.

Having natural areas in cities allows a large proportion of people to have first-hand experience with nature and thus gain an appreciation for its value and beauty without putting pressure on wilderness areas.

A major benefit of placing value on urban ecosystems is that the importance of environmentally responsible urban decisions becomes clear (Bridge 2001). By abolishing the notion that only untouched nature is valuable, decision makers are forced to be aware of the local environmental impacts of urban development.

Since cities are home to both the majority of people and the most influential decision making bodies, building an environmental ethic in urban populations is crucial to the protection of our environment. Although natural areas in cities are heavily influenced by human activity, they still provide an important opportunity to learn about natural systems and the impact of humans on the environment.

8.1.2 The Stanley Park Ecology Society

Stanley Park is a prime example of urban nature. Its extensive forest of 250 hectares (Beese and Paris 1989a) provides an ideal setting for environmental education in the city. Parts of the forest provide a representative sample of relatively undisturbed west coast forest, while others illustrate the effects of various harvesting, silvicultural and management practices. The forest contains many native plants organised into six site associations (Beese 1988a,b). In terms of wildlife, Stanley Park is home to 7 amphibian, 5 reptile (Grass 1988), at least 230 bird species (Kautesk and Weber 1988), and over 30 species of mammals (Merilees 1988). Some of these species of wildlife, along with many plant species in the Park, are not native to the area. Although the forest ecosystem is far from untouched, with all of the life in Stanley Park, it offers many possibilities to learn about nature. Also, the fact that many human influences are evident in the forest offers the potential to learn about human impacts on the environment.

The Stanley Park Ecology Society (SPES) is a community-based non-profit organisation whose mandate is to "encourag[e] stewardship of our natural world through environmental education and action" (Stanley Park Ecology Society 2001). They seek to encourage care for the natural world not only by exposing people to it and teaching them about its wonders, but also by raising awareness about the relationship between people and nature in urban areas (Stanley Park Ecology Society 2001). Although they do carry out stewardship and outreach activities, the main focus of SPES is environmental education for all ages. They have a variety of programs including:

- Environmental education for school children both in the Park and in the classroom
- Family Workshops
- Sunday Discovery Walks for adults
- Natural history displays at the Lost Lagoon Nature House
- The Urban Camping program
- Stewardship projects

(Stanley Park Ecology Society 2001)

A list of specific topics for some of these programs is given in Appendix C. Topics range from an individual species focus to an ecosystem focus to human and natural history.

The Stanley Park Ecology Society is an asset to the city. It provides a great opportunity to build knowledge and awareness of the environment in a natural area that is beautiful, complex and most importantly, very accessible. Also, programs are reasonably inexpensive, ranging from $2 - $8, which makes them available to a large sector of the population.

8.2 Importance of environmental education about invasive plants

8.2.1 The need for education about invasive plants

The problem of invasive plant species is perpetuated by an extreme lack of public awareness of the issue. Unlike most major environmental crises, the introduction of invasive plants can be carried out by an innocent gardener choosing the wrong ground cover, or a traveller accidentally bringing home seeds of a non-native plant (Alpert and Colton 1989). Thus educating the public about how they can prevent introductions and control invasive plants on their own land is crucial (Cronk and Fuller 2001).

In order to create support and funding for control programs, the public must understand the serious problems that some invasive plants pose (Dextrase 1996). In the case of invasive plants that have economic or aesthetic value for certain groups, significant education efforts are required to convince the public that the problems posed by these plants are greater than the benefits they provide (Alpert and Colton 1989).

At present, knowledge in the general public about the invasive plants is minimal (Alpert and Colton 1998). Not only are people generally unaware of the impacts of these plants, but are also unclear as to exactly what they are. An interesting study carried out in California by Alpert and Colton (1998) was aimed at determining whether the public perceives biological invasions by exotic plants to be a serious problem. It was determined that among relatively well educated people, only a minority supported greater control of invasive plants (Alpert and Colton 1998). However, almost 30% of the respondents had no opinion. The respondents also showed a very limited familiarity with the concepts of biological invasion and biodiversity (Alpert and Colton 1998). Many people were familiar with the term *weed*, but identified these as being a nuisance in gardens or a human health problem, not a serious environmental problem (Alpert and Colton

1998). This obvious lack of knowledge about invasive plants may be a major reason why greater control efforts were not supported (Alpert and Colton 1998).

This same study determined three potential reasons why people are not more aware of the major economic and ecological impacts of invasive plants (Alpert and Colton 1989). These explanations are indicated by the study's survey results (Alpert and Colton 1989). Firstly, people do not directly feel the effects of invasive plants. When respondents discussed the problems associated with "weeds" they cited impacts that they personally felt, such as allergies (Alpert and Colton 1989). Secondly, people have not been told about the impacts of invasive plants (Alpert and Colton 1989). Thirdly, people may not think of the ecological impacts as undesirable (Alpert and Colton 1989). With most people not understanding the concept of biodiversity, it may be difficult for them to understand the far-reaching impacts of invasive plants (Alpert and Colton 1989). All of these reasons for lack of public awareness about invasive plants and the associated lack of support for control programs suggest a need for environmental education on the topic.

Upon determining that public awareness about invasive plants needs to be increased, questions arise of how this information is best communicated and what exactly should be taught. Alpert and Colton (1989), like Cronk and Fuller (2001), suggest the following concepts: 1) the difference between native and invasive plants; 2) the ecological impacts of invasive plants, including the displacement of native species; and 3) seemingly innocent activities that can lead to the introduction of invasive species. Other suggested topics include the importance of native plants (Cronk and Fuller 2001) and the economic threats of invasive plants (Alpert and Colton 1989). It is very important that, when available, solid scientific evidence is presented in a way that is accessible to everyone (Lee 1996). When this scientific evidence about invasive plants is lacking, as it often is, this should also be explained. This explanation could include discussion of scientific uncertainty and taking a precautionary approach to the issue. This may help to justify removal programs and gain public support for them.

Environmental education can take many forms, such as school curriculum, interpretive walks, media, brochures and posters (Lee 1996). The survey by Alpert and Colton (1989) suggests that presenting concepts at a personal level is most effective. Thus, programs based on local, individual cases may prove to be most effective (Alpert and Colton 1989). They also suggest that this approach lends itself to individual control efforts (Alpert and Colton 1989). This 'hands on' approach allows people not only to learn about an invasive plant, but also to take part in a meaningful stewardship activity. As will be discussed below, this approach to environmental education about English ivy may be a feasible option for Stanley Park.

8.2.2 Case studies

In many other cases where invasive plant species have been found to be affecting natural areas, education about these species has lead to increased support for control and restoration efforts. The following case studies provide useful insight into the value of such education and suggest a possible framework for raising awareness about ivy.

8.2.2.1 Tallow tree replacement program in Florida

Tallow trees are invading natural areas throughout the south-eastern United States (Holdnak *et al.* 1999). Like English ivy, these trees are seen as horticulturally desirable by the public (Holdnak *et al.* 1999). Thus, education about the impacts of these trees is required to create public support for removal programs.

This case study illustrates the potential for successful education about invasive plants at a local level. In Gainesville, Florida, a multifaceted environmental education campaign was carried out aimed at tallow eradication. Firstly, the City's Tree Advisory Board solicited support for the campaign from many different groups (Holdnak *et al.* 1999). A partnership was formed with the nursery industry, which offered discounts on native trees purchased as replacements for tallow trees (Holdnak *et al.* 1999). A brochure was designed with information about tallow trees and was distributed by the regional electric utility's line clearance co-ordinators during their annual visits to private homes (Holdnak *et al.* 1999). A Gainesville Arbor Week celebration included a series of events such as native tree plantings at elementary schools, public lectures about the threat of tallow trees, and various media events on the issue.

Although the Gainesville Tree Advisory Board was generally pleased with the results of the campaign, it did have its setbacks (Holdnak *et al.* 1999). It was discovered that the message of 'not all trees are good' is hard to communicate to the public, and there was considerable backlash to the tree removals (Holdnak *et al.* 1999). Thus, it is clear that significant effort needs to be put into education about these projects in order to gain public support.

8.2.2.2 Purple loosestrife in Canada

Purple loosestrife (*Lythrum salacaria*) is an attractive purple plant that is extremely invasive and exists in all 10 provinces of Canada (Lee 1996). In the 1980's, various observers recognised that this plant was a serious problem, but it wasn't until the early 1990's that enough awareness was raised for action to be taken (Lee 1996).

The fight against purple loosestrife involved local and regional initiatives as well as national action. It took many forms, from school and community projects to television documentaries (Lee 1996). Partnerships were established with Ducks Unlimited and the horticultural industry in some areas (Lee 1996). In 1994 a Manitoba horticultural outlet, convinced by research results about the damage purple loosestrife can do, ran a Lythrum trade-in program (Lee 1996). This sparked the City of Winnipeg to provide a greenhouse for the Manitoba Loosestrife Committee to rear biological control insects on the traded-in plants (Lee 1996). Furthermore, several educational brochures were produced and distributed throughout the country (Lee 1996).

From all of this action came some important lessons. First, communicating the message is of greatest importance. Before the loosestrife campaign it would have been hard to find someone who knew what loosestrife was, let alone what its effects are (Lee 1996). The first educational brochure about loosestrife was entitled “The Beautiful Killer” and was quite extreme about the effects of the plant (Lee 1996). Although this made some people uncomfortable, it was extremely successful at catalysing public interest. This shows that the first information document needs to be dramatic, yet hopeful and informative at the same time (Lee 1996). Following information needs to be increasingly positive and constructive. It is important to supply the public with factual information, but it must be expressed in a way that everyone can understand (Lee 1996). In the case of purple loosestrife, it was difficult to convince people of the “beast behind the beauty,” but without public understanding, there is no public support (Lee 1996).

Another lesson that came from the loosestrife campaign was the importance of seeking out and educating those groups and individuals that could potentially be affected by control or eradication efforts. These people are likely to resist such efforts, particularly without adequate information as to their purpose. The two groups targeted in the purple loosestrife campaign were the horticultural industry, which sells the plant, and bee keepers, as loosestrife is known to be a good nectar source (Lee 1996). These groups, along with other interest groups, took part in a national workshop that discussed the economic costs and benefits of a national anti-loosestrife campaign (Lee 1996). This well-targeted educational campaign made supporters out of potential resistors.

The purple loosestrife case study illustrates how important informative, accessible, and interest group specific education about invasive species is in creating public support. It also shows the range of possible methods of education about invasive plants.

8.3 Implications for environmental education

As was discussed earlier, Stanley Park is an ideal setting for environmental education, and the Stanley Park Ecology Society fulfils that role with a variety of interesting programs for all ages. The question arises of whether Park users take advantage of this opportunity. The proportion of users who are interested in environmental education helps to determine the significance of this Park use to management. Thus, before the implications of English ivy for environmental education are discussed, the results of our user survey to determine interest in environmental education will be presented.

Our survey focussed on determining how much time Park visitors spend in natural areas (forested trails), their interest in environmental education, and their potential involvement with SPES. As has already been discussed, the majority of Park users spend at least some time in the Park's forest. When asked why they seek out the natural areas, most users stated that usually it was to get exercise or be in a natural area. For 40% of respondents, however, it was "sometimes" or "often" to learn about the natural environment. The survey did not differentiate between learning independently and taking part in educational programs. This would have been an interesting distinction because, as will be discussed below, these two types of education may be affected differently by the presence of English ivy.

In order to assess interest in environmental education, users were asked whether they were familiar with SPES and whether they had taken part in programming. We found 46% of respondents were familiar with SPES and knew about their educational programs. Of this 46%, 23% had actually taken part in programming. Of all respondents who had not taken part in SPES programs, only 14% stated that it was because they were not interested. A much larger percentage (35% of those who had not participated) stated it was because they didn't know about them Now that they are aware of SPES programs, roughly one third of those previously unaware are now "likely" to take part. As more than half of our respondents had not heard about SPES programs, and as many of these expressed interest upon learning of them, more publicity may be the key to increasing the number of people taking part in environmental education programs in the Park.

These results show that environmental education is an activity in which many Park users are interested. Thus the implications of ivy for environmental education influence a large number of Park visitors.

There are two major consequences of having English ivy in Stanley Park in terms of environmental education. First, a loss in the diversity of native flora and fauna could hinder programming about natural west coast forest ecosystems, and could affect what people consider as natural. Second, having invasive plants, such as English ivy, provides the opportunity to teach people about exotic species and the influence of humans on natural systems.

The results of our vegetation survey revealed that ivy seems to be affecting the diversity of native flora and fauna in the areas of Stanley Park which it has invaded. Environmental education strives to teach people about natural ecosystems and thus hinges on the presence of native species. Although at present there are still many regions of the Park that contain native species, further invasion by ivy and the associated loss of plant diversity may have serious ramifications for environmental education.

At present, educational programming in the Park can be structured so as to provide people with a reasonable understanding of a natural west coast forest by emphasising native species. However, Park users who choose to learn about nature independently, simply by spending time in the forest, may develop an unrealistic perception of nature. If these individuals are not aware of the exotic nature of plants such as ivy, these species may be included in their vision of what a natural west coast forest looks like. It should also be noted that, due to the disturbed nature of the forest in Stanley Park, these independent learners may develop an unrealistic perception of nature even without the presence of invasive plants.

Emily Gonzales, former Members and Public Programs Co-ordinator of SPES, did not mention either of these possible effects when asked what she saw as the implications of ivy for environmental education. Although she did not state that the presence of ivy is necessarily beneficial for the Park in general, she did mention the opportunity it provides to teach people about exotic species (Gonzales, 2002). She also pointed out that Stanley Park has a unique capacity to show people the connection between human actions and natural areas (Gonzales, 2002). While most people see intensely managed areas, such as gardens, and natural areas, such as wilderness, as being completely separate, Stanley Park represents a combination of these two areas. As such, the potential impact that humans can have on natural areas is evident.

SPES presently runs programs about exotic species for both children and adults (Gonzales, 2002). One example of this is their school programming for Grade 5 students. This programming includes the topic of non-native species in order to coincide with BC curriculum (IRP) requirements (Gonzales 2002). These programs are usually focussed on exotic wildlife, as it is easier to interest children in squirrels than plants (Gonzales, 2002). Adult programs are usually in the form of invasive species walks and include comparisons of native and exotic plant species as well as possible implications of exotic species (Gonzales 2002).

Despite the opportunity that invasive plants provide for environmental education, Gonzales did not see this as a reason to stop the expansion of control efforts. She pointed out that, in reality, there will never be enough control carried out to completely eradicate all invasive plants from Stanley Park. Thus, there is no risk of losing the opportunity to teach people about invasive plants.

As will be discussed in greater detail later, control programs may be a valuable component of education about invasive plants. By including environmental education in stewardship activities, such as pulling invasive plants, the stewardship experience is much more meaningful (Gonzales, 2002). Gonzales also stated that it would be important to keep the goals of control projects positive. This could be accomplished by striving for restoration rather than focussing solely on the plant to be removed (Gonzales, 2002). For example, re-vegetation efforts could be combined with control.

Although Gonzales focussed on the educational potential provided by ivy, the negative impacts we hypothesised may become more relevant in the future. It may be that the invasion of English ivy has not reached a level where it is having a dramatic enough impact to seriously hinder environmental education. With further invasion, however, the effects of ivy may become significant, and by that stage it could be too late to carry out successful restoration. Although control of ivy would limit the areas in which to teach people about invasive plants, it would ensure that the Park also has some areas of native vegetation available for educational opportunities in the future.

PART III – POSSIBILITIES FOR CONTROL

Given that ivy seems to be having a significant effect on native plant diversity, and that this has serious implications for long-term management and for the educational potential of the forest, the next step was to examine possibilities for control. As discussed in the Implications for Management section, control of ivy is currently limited. In the hopes of aiding planning for expanded control efforts in the future, we investigated priority areas for control, possible prevention of the spread of ivy, methods of control, sources of labour for control programs, and the feasibility of each of these options for implementation in Stanley Park.

First, since funding for control efforts is limited (Meagher 2002) and since ivy has already spread over much of the Park, it is important to focus control efforts in those areas of the Park where they are most needed. Thus, we used a GIS analysis to determine priority control areas. This was based on the location, size, and density of ivy patches in the forest, and the abundance of the various vegetation site associations found in the Park.

Second, we investigated one possibility for the prevention of spread. Since little is known about ivy's mechanisms of invasion, it is difficult to identify and protect susceptible sites. One possibility is that roads and trails facilitate ivy colonisation in the forest. This might occur due to increased light levels at the forest edge; soil disturbance, which is commonly associated with plant invasion (Crawley 1986); or the dumping of garden clippings along roadsides and at pullouts (Meagher 2002). For this reason, we again used GIS analysis to determine if there is a correlation between the location of ivy in the forest and proximity to roads and trails.

Third, we explored a range of control methods used for invasive plant species, and selected those effective at controlling ivy and appropriate for use in Stanley Park. Fourth, we examined existing control programs elsewhere for the advantages and disadvantages of paid labour versus volunteer programs.

Finally, we used the interviews with Eric Meagher, Supervisor of Maintenance for Stanley Park, and Emily Gonzales, former Members and Public Programs Co-ordinator of the Stanley Park Ecology Society, to assess feasibility of control options for Stanley Park. Methodology and results for each of these sections are presented below.

9.0 METHODOLOGY

9.1 GIS analyses – priority areas and prevention

GIS is a useful tool not only for representing information spatially, but also for carrying out unique analyses. It is not presently used by management in Stanley Park despite being helpful in urban forest management (Idziak and Kenney, 2000). In particular, inventories of the forest resource, an essential indicator of forest sustainability, are optimally carried out using GIS (Idziak and Kenney, 2000). The digitised maps of the Park, which we created during our GIS analysis, will make it easier for management to adopt this useful technology if they so desire.

There are several major stages in carrying out a GIS analysis. First, the required data must be gathered and converted into the appropriate digital form in order to be used in the analysis. Second, the actual analysis is carried out. Finally, to represent the results of the analysis, outputs, which are usually in the form of maps, are produced.

9.1.1 Data acquisition and input

Stanley Park is managed by the City of Vancouver Board of Parks and Recreation, which holds several paper maps but no digital maps of the Park’s features. As a result, all of the data used in this analysis was digitised from paper maps. We used a digitising table and ArcView software to do this. In order to register our paper maps, we used BC TRIM (Terrain Resource Information Management) data, which includes a rough coastline and road network for the Park. BC TRIM data is in Albers projection, which means that each of our digitised themes also use this projection.

We first digitised trails, including the seawall; roads; a more detailed coastline; water features, namely Beaver Lake and Lost Lagoon; and site associations from a 1988 map of the Park produced by W.J. Beese. The map was produced as part of an ecosystem classification accompanying the 1988-89 Forest Regeneration Program planning (Beese and Paris 1989a, Beese 1988b). We then digitised ivy patches from a map produced in 1998 by R. Pallochuck, an employee of Vancouver Parks and Recreation. Pallochuck's map was produced by walking a grid of the forest and 'eye-balling' the size and location of ivy patches based on their proximity to trails. Although this is not a rigorous method, the map provides an approximate representation of ivy location and abundance, sufficient for this GIS analysis. This map depicts two different densities of ivy patches, with the high density defined as "ivy as the sole ground cover" and the low density defined as "ivy in competition with other groundcover species" (Pallochuck 2001).

The spatial accuracy of all themes but the ivy theme is approximately ± 10 meters relative to the BC TRIM data. Since the accuracy of the TRIM data is also approximately ± 10 meters, this gives an additive error of approximately ± 20 meters. The spatial accuracy of the ivy theme is slightly lower, approximately ± 11 meters relative to the TRIM data or ± 21 metres additive error. This error is relative to the ground locations designated by the two paper map sources referenced above, each entailing an unknown degree of accuracy.

Following our digitising, we had six new themes to work with in our analysis. These are summarised in Table 9.1. Maps showing the site association and ivy themes are found in Appendix D (Figures 1 and 2, respectively). A table of the plant species used to characterise each site association is also given in Appendix D. Since we used ArcView to digitise these themes,

Theme	Type	Fields
roads	linear	name
trails	linear	name
coastline	linear	n/a
water features	polygon	name
site associations	polygon	ID, site association, area
ivy	polygon	ID, ivy density, area

Table 9.1 - Themes created for our analysis.

were able to begin our analysis immediately following data entry and correction. No conversion of our digital data was required.

9.1.2 Analysis – priority areas

To maximise the practical efficiency of control efforts, we chose to provide priority areas for control rather than assigning priority to single patches of ivy. We used the site association polygons (see Figure 1, Appendix D) as our possible control areas, and assessed and ranked the priority of each. Determination of priority for control was based on three major factors: the risk of ivy completely covering the site association to which the polygon belongs, size of ivy patches within the polygon, and density of ivy within the polygon. Each polygon was ranked according to each of these three factors with the highest ranking corresponding to the highest priority in terms of that factor. The rankings for each factor were then weighted based on their relative importance, and summed for each polygon. This final number corresponded to the priority of the polygon with the largest number being the highest priority.

The first factor assessed was the risk of losing an entire site association to ivy invasion. Site associations are classifications of plant communities and show the diversity of native flora present in Stanley Park. Since we have shown that ivy may be negatively impacting native vegetation, it is important to consider which plant communities ivy is invading, and to give top priority to site associations most at risk of complete invasion. This is the most important factor to consider in the design of a control program for Stanley Park.

Risk of certain site associations being taken over by ivy was assessed based on both the percentage of that entire site association covered with ivy, and the area of that site association not invaded by ivy. It was important to consider both of these factors as individually they are inadequate. Using only percentage covered with ivy is insufficient, as a large site association with a high percentage covered would receive a higher ranking than a small site association with a small percentage covered. Since the large site association has so much area, there is much of the site association that is unaffected. The small site association, meanwhile, has very little unaffected area, making it at risk of disappearing completely. On the other hand, simply using the area unaffected by ivy would automatically make small site associations high priority, even if they have very little ivy present. Thus, site associations were ranked based on both area unaffected and percentage covered with ivy. These rankings were added together and multiplied by 10. This was the highest weighting assigned, because the possible loss of an entire vegetation type is more important than the loss of any one polygon. Most site associations in Stanley Park consist of several polygons although there are a few with just one polygon. Each polygon was given the value assigned to the site association to which it belongs.

The next factor we considered for control priority was the size of patches in each polygon. Both theoretical models and practical experience have shown that clearing less established, small patches of invasive plants first is the most efficient and cost effective method (Higgins *et al*. 2000). This is because it is much easier and quicker to pull small patches, and makes a greater difference than spending that same amount of time pulling a small part of a well established large patch. Also, large patches are likely to have had a more severe impact on native vegetation than newly established patches. Thus, it seems logical to control ivy before it takes hold and begins to seriously affect the area.

We split up the polygons into small, medium, and large patches using orders of magnitude as our size boundaries. Small patches were those between 0 and 500 m^2, medium patches were 500-5000 m^2, and large patches were >5000 m^2. Because many polygons had the same number of patches of a particular size, ranking them based on patch numbers was problematic. Instead, we used the numbers of patches directly, and multiplied these by weightings based on size. Since small patches are most important to pull, the number of small patches in each polygon was multiplied by 6. The number of medium patches are the next most important to pull, so they were multiplied by 3. As was discussed above, it is important not to spend time pulling small parts of large patches as the effect will be minimal. In order to ensure that polygons with large patches were not given a high priority, the number of these patches was multiplied by –2.

The third factor assessed was the percent of each polygon covered in high density ivy. Ivy at high density, although more difficult to control, may spread faster than low density patches so should be cleared first. This factor is, however, most critical when dealing with small patches of ivy. Once the invaded area gets large enough, density becomes insignificant compared to the effect of patch size. Thus, density is considered secondary to size of patch and risk to site association. Polygons were ranked according to the percentage of their area covered with high density ivy. These values were given a weighting of one, as density is less significant than the other two factors

The following is the priority calculation. The higher the number the higher priority the polygon. For a detailed description of the actual procedures used to calculate values for A, S, M, D, and L, including a flow chart of processes, see Appendix D.

$$\text{Priority} = 10A + 6S + 3M + D - 2L$$

where A = site association rank
S = # of small patches
M = # of medium patches
D = rank of polygon based on percentage covered with high density ivy
L = # of large patches

Once A, S, M, D, and L had been determined for each polygon, we removed four polygons from the analysis before continuing. Three of these polygons are located in the south-east corner of the Park, where they are isolated between highly developed areas. These polygons contain large, dense infestations of ivy that would not be easily controlled, and are not likely to spread to natural areas. The fourth polygon we removed is at the northern tip of the Park, to the east of the Causeway. This polygon also contains a very large, dense ivy infestation which would not be easily controlled. Due to their isolation and the difficulty of restoring these four areas, we removed them from the analysis and assigned them zero priority.

By inspecting the site associations containing ivy, it was determined that site association 4.1 was most likely to be lost completely. Due to the nature of our GIS procedure to determine priority, however, it may not have been given top priority. This is a very small site association (0.81 ha in area), with only a small amount of ivy. There is potential, though, for ivy invasion from adjoining site associations, putting its small and unique vegetation communities at risk. For simplicity, our analysis did not include adjacency to highly affected polygons, but we wanted to ensure that 4.1 was given top priority. We therefore removed site association 4.1 from the rest of the analysis, and placed it first on the list of priority areas.

The priority for each of the remaining polygons was determined using the priority calculation. They were then organised into five levels of priority (low, medium low, medium, medium high, and high), dividing the numerical priority values into these classes using equal interval classification. Site association 4.1, which we removed from the analysis at the outset, was deemed highest priority.

9.1.3 Analysis – prevention

As was mentioned above, a GIS analysis was carried out to assess the effect of trails and roads on the amount of ivy present. This is a first step in determining appropriate preventative measures to control the introduction and spread of ivy.

To explore the relationship between trails and roads and ivy, we calculated the area of ivy present in 5 meter intervals from all major trails and roads. These areas were collected for intervals 0-5 meters to 100-105 meters from roads and trails. We chose 105 meters as the end point of the analysis, as all ivy in the Park is within 105 meters of roads and trails. Thus, after 105 meters, the area of ivy present in each new interval is zero. Since the input map of ivy differentiated high and low density ivy, we were able to explore the potential correlation for high density ivy, low density ivy, and total ivy. For a detailed description of the actual procedures used to carry out this analysis, including a flow chart of processes, see Appendix D.

Once the data was collected for all 5 meter intervals, it was represented graphically. The area of ivy in each 5 meter interval was plotted against distance of that interval from roads and trails.

9.2 Methods of control

Testing various control methods for the removal of ivy in Stanley Park was not within the scope of this project. However, there is a sufficient body of knowledge on the subject of ivy control both in the scientific literature, and from the experiences of individual and groups involved in ivy control. Thus, in order to determine the potential methods of ivy control and to assess which methods may be possible in Stanley Park, we carried out a literature review.

9.3 Paid versus volunteer labour

Issues related to who should carry out control, if a program is established, were explored through a literature review. The two possibilities considered were volunteers and paid labourers. The analysis focussed mainly on the use of volunteers and reviewed volunteer programs established for ivy control in other places.

9.4 Feasibility of control options for Stanley Park

To determine the feasibility of methods for control and the types of labour used, we asked related questions in the interviews with Eric Meagher, of Park Maintenance, and Emily Gonzales, of SPES. The methodology for these interviews has been discussed and the questions are contained in Appendix B. However, the responses to these questions were treated differently than the responses about the implications of ivy. Information gained from the interviews about the feasibility of control is less opinion-based and more factual. Therefore, the answers provided by these two individuals were taken to reflect what might realistically be possible for control in Stanley Park.

10.0 PRIORITY AREAS

10.1 Results

The results of the priority analysis are represented in map form using a graduated colour scheme to illustrate urgency of control. This map (Figure 4) is included in Appendix D.

10.2 Discussion

After site association 4.1, which was removed at the beginning of the analysis, the two highest priority polygons are in site association 4. Though this site association is very common in the Park, the two polygons identified are high priority because they have high numbers of small patches with the potential to spread. The polygons of site association 1, on the other hand, are all ranked medium priority, even though this site association is over 20% covered by ivy. This is because almost all of the ivy in this site association is in one very large patch along Pipeline Road. These examples demonstrate the effects of weighting the various factors we considered in this analysis.

Though our priority calculations are based on the best information we have about efficient control strategizing, they are somewhat subjective. With many factors influencing ivy spread and risk of invasion, ranking priority areas requires a great number of decisions about the most important factors and their quantified importance relative to other factors. From Figure 4 (see Appendix D) and from Figures 10.1 and 10.2 (below) it appears that our priority ranking does, however, reflect the criteria we intended it to reflect. In Figure 10.1, site association

Figure 10.1 - Percentage of each site association covered by ivy, unaffected area remaining, and the resulting relative priority.

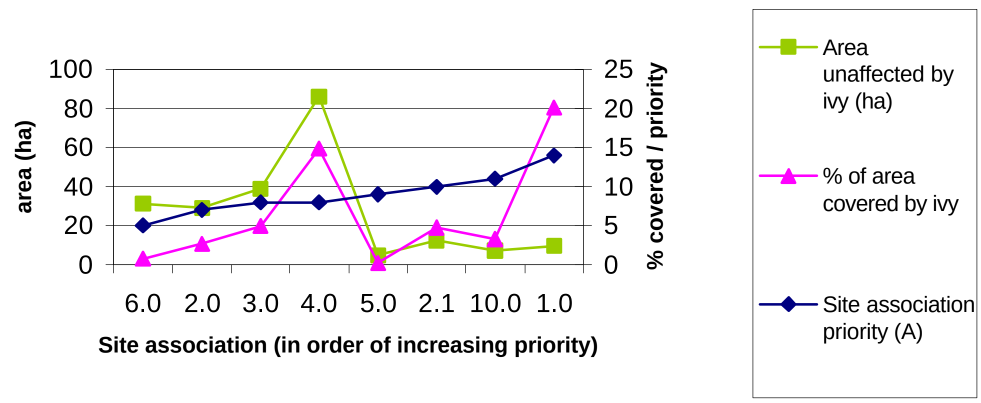
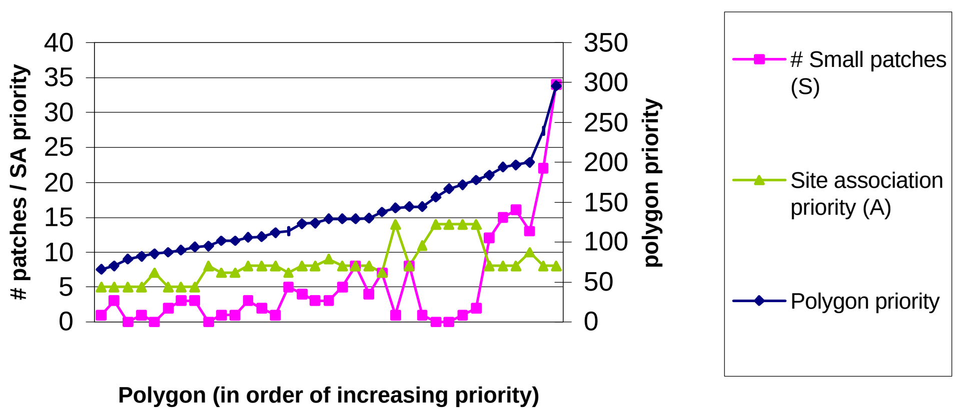


Figure 10.2 - Number of small patches in each polygon (S), site association priority (A), and the resulting polygon priority.



priority increases with increasing percentage of area covered by ivy and decreasing area unaffected. In Figure 10.2, polygon priority increases with increasing site association priority (A) and number of small patches (S). Though our priority ranking seems to be appropriate, with more time and information it could be improved. It is also important to remember that this priority analysis is based on a snapshot of the extent of ivy in the Park recorded in 1998. Since then, new ivy patches and further spread necessitate the adjustment of priority areas for control.

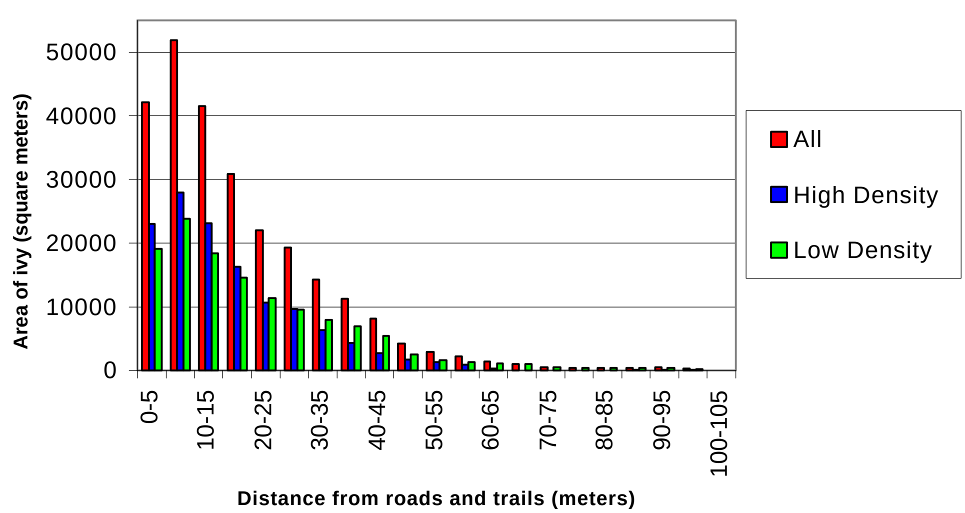
This is inevitably an ongoing process, with continued monitoring required to account for changing ivy abundance and location.

11.0 PREVENTION

11.1 Results

There is a clear visual correlation between area of ivy present and distance from roads and trails. As Figure 11.1 (below) illustrates, the area of ivy within 5 meter intervals drops off exponentially with distance from roads and trails. This pattern is seen for high and low density ivy and for total ivy. For all three data series, a t-test was carried out. In each case, this showed a statistically significant correlation with 99% confidence.

Figure 11.1 - Area of ivy at 5 meter intervals from roads and trails.



This correlation can also be observed spatially in Figure 5 of Appendix D. Figure 5 uses a graduated colour scheme to represent the distance of ivy from roads and trails: the darker the red colour, the closer ivy is to roads and trails. As the map illustrates, with far more dark red than light red, there is more ivy close to roads and trails than further away from them.

11.2 Discussion

This analysis does not provide any indication of why the observed correlation occurs and there are many possible hypotheses. For example, since there is more light that reaches the forest floor near roads and trails, ivy may be able to grow at a faster rate and thus cover more area than in the middle of the forest. This would be particularly dramatic in a coniferous forest where there is a dense canopy for the entire year. Next, there is a well supported theory that plant invasions tend to be more prolific in disturbed sites (Crawley 1986). Since trail and roadsides tend to have more human disturbance than the rest of the forest, this could be another explanation for the greater amount of ivy in close proximity to these regions. Another potential explanation is that roads and trails may be sources of ivy from people bringing in seeds or ivy plants. In particular, management suspects that one major form of introduction of ivy is through people dumping garden clippings along roadsides (Meagher 2002).

This correlation between distance from roads and trails and area of ivy may be important for management of ivy. In order for control programs for invasive plants to be successful, preventative measures must be included. If it is concluded, with more investigation, that the reason for the correlation is due to human activity on roads and trails, raising awareness may help prevent the introduction of ivy plants. Even if the cause of the correlation cannot be determined, simply recognising that the regions closer to roads and trails are likely to have more ivy could be useful in monitoring ivy and controlling efficiently. When carrying out control in the future, it will be important to keep close watch of trail and roadside areas to ensure that the ivy is removed to prevent invasion into the rest of the forest.

12.0 METHODS OF CONTROL

12.1 Potential Methods

There are six potential methods of control for invasive species: manual, chemical, paired manual and chemical, biological, prescribed burning and cultural. In assessing which type of control is most appropriate, one must consider short-term and long-term effectiveness, possible side effects on the native flora and fauna of the area, and cost. In the case of Stanley Park, public reaction to control methods must also be considered. The following sections provide some detail of these methods of control and the potential for their use in controlling ivy.

12.1.1 Manual Control

Manual control is a desirable method as, if it is done carefully, it has relatively small ecological impacts with minimal damage to native species (Hurd *et al.* 2001). Thus it is preferred when the goal is restoration of a natural area and not simply removal of ivy (Morgan 2001). Manual control is also a method that can be carried out by community volunteer groups. This allows for education about ivy biology, its impacts, and the difficulty in removing it.

The cost of manual control is in employment. If carried out by volunteer groups there may be no cost, although management time would be required in training and supervising groups.

Persistent pulling of ivy is one method that provides reasonable control. It is both labour and time intensive and is most effective for small infestations (Hurd *et al.* 2001). Pulling by hand can work, but often the vines snap and viable stubs are left which can re-colonise (Morgan 2001). Also, roots are often left in the ground, where they can send up new shoots (Diedrich 2002). Using shovels and other tools is more effective than hand pulling as they can remove the entire plant by penetrating the mat and removing the roots (Hurd *et al.* 2001). The appropriate tools depend on the terrain, depth of ivy mat, and time of year (Hurd *et al.* 2001).

Pulled plants should not be left on the ground, as they may be able to re-colonise in the right conditions as they can reproduce vegetatively. Plants should be left on a wooden or concrete surface to dry out and decompose (The Nature Conservancy 2001). It is also important that pulling is done carefully so as not to disturb the soil. Not only does soil disruption affect native plants, but it creates prime conditions for re-invasion of ivy (Hurd *et al.* 2001). Due to the high probability of post-control re-invasion, monitoring to ensure that removal efforts have been successful is a key part of the control process.

In areas where ivy is climbing trees, an effective method is to separate the climbing ivy from its roots (The Nature Conservancy 2001). This is done by cutting a 3-foot swath around the tree which kills the ivy as the vines are cut off from their water and nutrient source (The Nature Conservancy 2001). The vines die and fall from the tree. In cases where the vines are too thick to cut, the bark of the vine is stripped and a notch is cut into the exposed part of the vine. This is followed by the application of a herbicide such as glyphosate (Roundup), which will be discussed below (Hurd *et al.* 2001).

One slightly more drastic method of manual control involves using a blowtorch to shock the plant with a hot flame. The heat is intended to make the plant unable to multiply or produce berries for reproduction (Okerman 2001). This method can also be used in combination with a herbicide. This and other options for paired manual and chemical control will be discussed below (Morgan 2001).

12.1.2 Chemical control

The use of chemicals in controlling invasive plant species is controversial. For many managers the decision of whether or not to use herbicides is an ethical one influenced by public reaction (Hurd *et al.* 2001). In addition, there is significant scientific concern about the environmental impacts of herbicides such as effects on non-target native species, and pollution of groundwater (Morgan 2001).

In determining whether herbicide application is appropriate for a particular area, it is important to assess the site conditions (Hurd *et al.* 2001). The following are a list of characteristics that would influence the suitability of a site for herbicide application: proximity to open water, depth of ground water, presence of rare species, site sensitivity to trampling (during application) and other hydrological characteristics such as runoff scenarios, aquifers, and streams (Hurd *et al.* 2001).

In considering the use of herbicides with ivy, there is uncertainty about how effective herbicides are (Morgan 2001). Due to the waxy layer on ivy leaves, herbicides, particularly hydrophilic compounds such as glyphosate (Roundup), have difficulty penetrating the leaves (The Nature Conservancy 2001).

One method designed to allow herbicides to penetrate is the addition of surfactants to the herbicide mix (Morgan 2001). Surfactants are chemicals that break down wax-like surfaces. However, they are known to be toxic to aquatic organisms and little is known about the biodegradability of surfactants in the environment. MONO818 is a surfactant commonly used with Roundup and has been shown to interfere with cutaneous respiration in frogs and gill respiration in Tadpoles (Hurd *et al.* 2001). MONO818 is highly toxic to fish with an LC50 (concentration expected to kill 50% of the population) of 2-3 mg/L for sockeye, rainbow and coho fry (Hurd *et al.* 2001). Thus, this technique should be researched further and avoided unless a formulation is found to be environmentally sound.

It has been shown that salt (NaCl) may have a detrimental effect on ivy. This was first suggested by the observation that ivy was struggling in regions where it was planted on the side of highways that were salted to reduce ice (Morgan, 2001). Further studies, mostly by the horticultural industry, suggest that it is chlorine and not sodium that is detrimental to ivy (Morgan 2001). This discovery may warrant research, but should not be used until more is known about the effects on other organisms in the ecosystem.

Two of the main herbicides used for ivy control are glyphosate (Roundup) and 2,4-D. In determining whether either of these herbicides are appropriate for use in a natural area, it is important to know about their behaviour in the environment and their toxicity to non-target organisms (Hurd *et al.* 2001). Table 12.1 summarises the major characteristics of these two herbicides.

	Glyphosate (Roundup)	**2,4-D**
Mode of Action	• Inhibits aromatic amino acids necessary for protein formation in plants	• Mimics the growth hormone auxin, which causes uncontrolled growth and eventually death
Target	• most annual and perennial plants • high potential for off-target spray effects	• dicots • lower potential for off-target spray effects
Primary Degradation Mechanism	• slow microbial metabolism	• faster microbial metabolism
Half-life	• average = 47 days • range = weeks to years (depending on environmental conditions)	• average = 10 days • range = several hours to several months (depending on environmental conditions)

Adsorption Potential	• high - prevents leaching - prevents uptake by plants - can inhibit microbial degradation	• low to intermediate • depends on formulation, soil organic content and soil pH
Mobility Potential	• low	• intermediate – in many cases not significant due to rapid degradation
Toxicity	• varies between formulations • birds and mammals: glyphosate alone = low toxicity -LD50* for rats = 5,600 mg/kg -LD50 for bobwhite quail = >4,640mg/kg • fish: glyphosate alone = moderately toxic to fish -LC50** of technical grade glyphosate for rainbow trout = 86mg/l • formulations with surfactants are much more toxic -LC50 of MONO818 (a surfactant) for sockeye, rainbow and coho fry = 2-3 mg/L	• can bioaccumulate: even low concentrations can become toxic with time • birds and mammals: moderately toxic -LD50 values range from 300-1000 mg/kg (some animals, such as dogs, are far more sensitive) -LD50 for rats = 764 mg/kg -LD50 for bobwhite quail = 500mg/kg • fish: toxicity depends on formulation -salt formulation: low toxicity, registered for aquatic use -ester formulation: moderate toxicity, LC50 values slightly lower than for mammals
*LD50 (Lethal Dose 50): the single dose of a substance that is expected to kill 50% of the population. **LC50 (Lethal Concentration 50): the concentration of a substance that is expected to kill 50% of the population. Table compiled from Hurd *et al.* (2001).		
Table 12.1 – Characteristics of glyphosate and 2,4-D.		

Apart from environmental impacts of these herbicides, their effectiveness must also be assessed. In some tests to determine the effectiveness of Roundup and 2,4-D at controlling ivy it was determined that two applications (approximately one month apart) were far more effective than one application (The Nature Conservancy 2001). Another study concluded that Roundup and 2,4–D did not control ivy with a single application at rates commonly used in controlling weeds (Derr 1993). Also, there was no significant improvement with the addition of a surfactant (Derr 1993). Thus, controlling ivy with these herbicides requires several applications. In one study, two applications of 2,4-D at a rate of 1.1 kg/ha completely controlled English ivy (Derr 1993). Two applications of Roundup at a rate of 4.5 kg/ha, with or without surfactant, also completely inhibited re-growth (Derr 1993). Re-growth did occur with two applications of Roundup at a lower application rate of 2.2 kg/ha (Derr 1993). Thus, English ivy can tolerate Roundup to a certain degree.

The cost involved in chemical control includes both chemicals and labour. In assessing total cost, multiple applications of the herbicide must be accounted for. This method would likely not involve volunteer participation, as particular skills are required to apply chemicals. It must also be noted that there may be significant public opposition to using herbicides.

12.1.3 Paired chemical and manual control

Some control methods combine chemical and manual procedures. Many of these entail cutting the woody stems of the ivy with tools such as edgers or trimmers and then treating them with herbicides such as Roundup or 2,4 D. The following results are from a study that illustrates the effectiveness of this particular method. The evaluations of effectiveness were made one year post treatment (Hurd *et al.* 2001).

Treatment	**Effectiveness**
Cutting followed by 25% solution of Roundup	Good Control
Cutting followed by 2% solution of 2,4D	Excellent Control
Cutting followed by 2% solution of Roundup	Slight Control

Table 12.2 – Effectiveness of paired manual and chemical control.

Another study compared ‘wounding’ the ivy, either by cutting or wilting with a blowtorch, and then spraying; to manual control by pulling and digging. In both cases the manual control resulted in less re-growth. This was likely due to thorough removal of roots and to the imperviousness of the ivy leaves to broadcast spray application even with ‘wounding’ (Morgan 2001). Other combined approaches involve manual methods of removal and then treatment of seedlings, which may re-sprout, with a herbicide (Hurd *et al.* 2001)

12.1.4 Biological control

The idea behind biological control is to find out how invasive species are controlled in their native environment and then to replicate those controls. The concept is appealing as it avoids the use of chemicals and can be permanent. One major downfall of biological control is that the species brought in to control the invasive species may end up equally or more problematic (Morgan 2001).

Biological control for English ivy has not been successfully carried out (Morgan 2001). This is mostly because a suitable organism has not been discovered. Ivy is not a food preference for any significant species in its indigenous environment, and thus is not controlled through food chain conventions (Morgan 2001). Ivy has not been shown to be a food preference for organisms outside of its indigenous environment either (Morgan 2001). European roe deer and European red tailed deer will forage on ivy but it is not a preferred food source or a sole food source (Morgan 2001). The European hare will also eat ivy, but only out of desperation (Morgan 2001). The larvae of four species of moth will feed on ivy, but not exclusively or preferentially (Morgan 2001). Finally, goats are known to forage on ivy, but they will forage on almost anything, and thus are not ideal species for biological control (Morgan 2001).

The introduction of diseases has also been considered as a method of biological control for ivy. Most of the research on plant diseases affecting ivy has been carried out by the horticultural industry, which profits from selling ivy as a landscaping plant and is working to protect it from disease (Morgan 2001). It has been discovered that leaf spot may occur on ivy leaves but only when they receive full sunlight and little moisture in the late summer and early fall (Morgan 2001). Ivy is susceptible to bacteria, fungus and mite infestations when the temperature is too hot and either very dry or very wet (Morgan 2001). These conditions typically do not occur in our temperate ecosystems for extended periods, thus these forms of control do not have a significant impact on ivy (Morgan 2001).

Another barrier to biological control of ivy is that there may be significant societal resistance to it. Because ivy is highly valued as a landscaping plant, certain groups, such as the horticultural industry, may strongly oppose biological control as it could potentially spread and destroy ivy in areas where people want it to grow (Okerman 2001). This illuminates the need for cultural control of ivy, or changing societal perceptions about this invasive plant. This is discussed below.

12.1.5 Prescribed burns

Prescribed burning involves the use of fire to control invasive plants. This type of control is most effective against shrubs and young trees (Haber *et al.* 1993). There are major risks involved with prescribed burning, such as harming native species, initiating forest fires and putting property and people at risk (Haber *et al.* 1993). This method of control is not an option in Stanley Park, as fire poses too many threats to people and the Park itself.

12.1.6 Cultural control

In order to control ivy in natural areas, particularly in urban forests, it is important that the amount of ivy in the surrounding urban areas be controlled. Not only does ivy have negative impacts on urban vegetation, but seed production in urban settings can lead to increased ivy invasion in natural areas (Morgan 2001). Ivy is able to thrive in the urban setting largely because of the openness of the environment and the resulting high amount of light available (Morgan 2001).

To effectively control ivy in urban areas, societal perceptions about this invasive plant need to change. It is a common misconception that ivy is not only a hardy and attractive ground cover but that it also supports wildlife (Morgan 2001). The suitability of ivy as a food source for indigenous wildlife has not been determined (Morgan 2001). Also, as has been discussed, ivy has numerous negative impacts on ecosystems.

One method by which societal perceptions about ivy could be changed is through community involvement in control. This allows for people to discover the invasive nature of ivy in natural areas, as well as to learn about its impacts and the difficulty of controlling it.

Another form of cultural control of ivy is though institutional changes. In Oregon State English ivy has just recently become ‘quarantined’ which means that it cannot be commercially propagated, sold, imported, or exported (Diedrich 2002). In some jurisdictions ivy has also been placed on a list of plants which are prohibited from use in any new landscaping and for which control efforts are required by law (Morgan 2001). For example, the Oregon and Washington State Noxious Weed Lists both include English ivy (Diedrich, 2002). In British Columbia, regions such as the Fraser Valley Regional District also have Noxious Weed Lists on which ivy could be placed. Listing ivy could create funds for research and control strategy development (Morgan, 2001). Despite the potential benefits of either quarantining or listing ivy, however, there may be significant resistance from groups such as the horticultural industry, which has an economic interest in the plant.

It is unlikely that Stanley Park management would see it as within their mandate to carry out cultural control of English ivy. It is more feasible for them to focus on minimising sources within the Park and on other forms of control. The Stanley Park Ecology Society, on the other hand, may be interested in this type of control in terms of educating people about the plant. As was suggested earlier, volunteer pulling groups could be an effective method of raising awareness.

12.2 Options for Stanley Park

As has been discussed above, no biological control is presently available for ivy, and prescribed burns are not appropriate for an area such as Stanley Park. Paired manual and chemical control may be a reasonable option, but is likely more time consuming than chemical control alone, and may not be significantly more effective than either chemical or manual control. Cultural control is important in minimising the introduction of ivy into the Park, but this is not a method of actually removing ivy. Thus, the two major options for ivy removal in Stanley Park are manual and chemical control.

As was discussed in the previous section, manual control generally has minimal environmental impact. However, prior to carrying out manual control, assessment of the sensitivity of the area to soil disruption and plant trampling would help prevent unnecessary damage. It may also be important to carry out replanting with desirable species as the disturbed area may be susceptible to further invasion by exotic plants (Masters and Sheley, 2001). Manual control can be very effective but is likely to be an ongoing process, as it is very difficult to completely remove all ivy roots.

Chemical control may be very effective at controlling ivy, as was discussed above, but may require several applications. Both glyphosate and 2,4-D have been found to require at least two applications for successful control (Derr 1993). The potential environmental impacts of glyphosate and 2,4-D have been discussed above. Both can be detrimental to flora and fauna, but can be reasonably safe in the right conditions and with proper, careful application. Since the addition of surfactants to herbicides has not been shown to increase effectiveness, and may have negative environmental impacts, this should not be considered.

13.0 PAID VERSUS VOLUNTEER LABOUR

When designing control programs, the question of who will carry them out is perhaps the most difficult to answer. The choice between paid employees, volunteer programs, or a combination of the two is based on several factors. Individually, employees may have more experience and be more efficient. They may also be better equipped to carry out a specific management plan for control, and may possibly have a less negative impact on the ecosystems in which they are working than large groups of volunteers. On the other hand, volunteer control programs can be very important opportunities to combine hands-on environmental stewardship with education about invasive plants. This opportunity might be particularly great in Stanley Park, where environmental education programs are already running. Finally, volunteer programs require minimal or no financial support, making them a very valuable way to increase conservation resources when funding is scarce. As mentioned in a previous section of this thesis, this is the case for Stanley Park.

For these reasons, we examined volunteer programs for ivy control established in other parks in the United States and Australia. If managers and environmental educators in Stanley Park agree that some kind of volunteer control program for ivy would be useful and/or necessary, these examples might provide a valuable framework.

The most extensive control and education program for *Hedera helix* we have encountered is the Ivy Removal Project, also known as the No Ivy League (NOL), operating out of Forest Park in Portland, Oregon. By 1999, the No Ivy League had grown to nearly 50 chapters in the north-western United States and attracted nearly 11,000 volunteers (Ivy Removal Project 2002a). Working to develop awareness about invasive plants in the community, NOL estimates it has contacted at least 350,000 community members and given 12 youth crews opportunities to work on ivy control strategies (Ivy Removal Project 2002a). NOL's statistics for actual ivy removal are also impressive. According to their website, volunteers and youth crews have removed ivy from over 10,500 trees and have stripped over 100 acres of groundcover ivy from the forest floor in Portland's Forest Park (Ivy Removal Project 2002a).

In addition to effective community outreach and physical control efforts, NOL also demonstrates a keen interest in working with scientists and student researchers to learn more about the "characteristics, behaviour, and ecological relationships" of ivy (Ivy Removal Project 2002g). NOL stresses the importance of studying ivy in order to better develop educational resources and control strategies (both physical and policy-based), and offers a list of possible projects for interested researchers (Ivy Removal Project 2002g).

Ivy control efforts are also being combined with community education in Seattle's urban forest. The City's 214 hectare Discovery Park has year-round volunteer programs for manual ivy control (Seattle Parks and Recreation 2001), and the management of invasive species is specifically addressed in its Vegetation Management Plan (Jones and Stokes 2001). The management objectives this plan is designed to achieve are not unlike the objectives expressed in the most recent management documents for Stanley Park. According to Discovery Park's webpage, its role is to "provide an open space of quiet and tranquillity away from the stress and activity of the city, a sanctuary for wildlife, as well as an outdoor classroom for people to learn about the natural world" (Seattle Parks and Recreation 2002b). Furthermore, Seattle Parks and Recreation (2002b) asserts that, "[m]aintained in its semi-natural condition the Park will continue to offer a biologically rich and diverse natural area for urban dwellers and an unmatched opportunity for environmental education." Finally, matching the goals of Stanley Park's Regeneration Plan (Beese and Paris 1989a) exactly, the Discovery Park Vegetation Management Plan mandates the restoration of the "pre-development character of the Park's forests" (Jones and Stokes 2001).

In keeping with this mandate, the plan calls for the "aggressive" removal of ivy as well as 17 other invasive plant species. The methods chosen for removal include both manual pulling and limited herbicide use, with the latter only in areas where it will not endanger picnickers or berry pickers (Jones and Stokes 2001).

A third example of community involvement in the control of ivy in parks and natural areas is provided by the Friends of Sherbrooke Forest, working in part of the Dandenong Ranges National Park in Australia. This community group hand weeded approximately 5 hectares of ivy between 1981 and 1991, and monitored regeneration of native flora following weeding (Freshwater 1991). Vivien Freshwater (1991), a member of the group, gives specific recommendations for removal of ivy from trees, as well as for monitoring weeded sites for re-invasion.

Given the success of projects outlined above, there seems to be much potential for combining education, control of ivy, and possibly research on rates and mechanisms of invasion, in the forests of Stanley Park. The realisation of this potential, however, depends on the will and resources of Park managers and educational or volunteer groups interested in co-ordinating such programs.

14.0 FEASIBILITY OF CONTROL PROGRAMS

Interviews with Eric Meagher and Emily Gonzales provided information on the feasibility of various control scenarios. Meagher, who is in charge of maintenance in Stanley Park, discussed the feasibility of various methods of control and the use of volunteers in the Park. Gonzales, speaking from an environmental education perspective, contributed insight into the potential for volunteer control programs in Stanley Park.

As was stated earlier, present control of ivy is limited to manual control on trees. This is part of the job description of two employees of the Park. Although removal from trees is important, removal of ground control is also necessary to mitigate the impacts that ivy may be having on native flora and fauna. Thus, Meagher was asked which methods of control he saw as being feasible in the Park, if more extensive control were to be carried out. Meagher stated that the use of herbicides may be appropriate for control of ivy in the Stanley Park. Though the Park has a ‘no herbicide’ policy, exceptions can be made (Meagher 2002). Roundup would be the best choice of herbicide, due to its relatively low environmental impacts (Meagher 2002). Meagher also stated, however, that there would undoubtedly be serious public opposition to the use of any herbicides in the Park, regardless of the purpose for their use or how environmentally sound they are. Thus, it is unlikely that any herbicides would be used for control in the Park. Any expanded control efforts will likely be carried out manually.

Since funding for increased control by maintenance employees is limited, volunteer control programs are an attractive option for Stanley Park (Meagher 2002). As Meagher illuminated, however, there is one major obstacle to volunteer control of ivy in Stanley Park: maintenance employees in the Park are part of a strong, established union (Meagher 2002). Thus, it is very difficult to make use of volunteers for any activities that could potentially be maintenance jobs (Meagher 2002). Although the union is allowing volunteers to do more than they could in the past, it is still not at the stage where it allows extensive use (Meagher 2002). Often it will allow volunteers to take part in maintenance-type activities if it is a special event and is not ongoing (Meagher 2002). Volunteer ivy control programs would need to be consistent and ongoing in order to be successful. To allow this, the union would have to be convinced that it was not a job than the maintenance crew would ever be asked to carry out. This would be difficult considering that two employees are presently carrying out ivy control. Despite this major setback, Meagher sees great potential for volunteerism in the Park and thinks that with time there will be more opportunity to make use of volunteers. Thus, implementing volunteer control programs may be a matter of waiting until the union is more receptive to the use of volunteers.

Presuming volunteer control will eventually be allowed in Stanley Park, questions arise as to who would co-ordinate the program and whether there would be interest in taking part. Emily Gonzales had some useful insights into these questions. Gonzales saw ongoing volunteer control as the only way that ivy would be successfully controlled in the Park. She stated that SPES may be interested in organising a program, but thought the Vancouver Natural History Society may be in a slightly stronger position due to their extensive membership and consistent number of volunteers (Gonzales 2002).

One area in which SPES may be able to partner with a volunteer control program is though re-vegetation. SPES has a native plant garden with the goal of educating people about native plant gardening (Gonzales 2002). In addition, some of these plants could potentially be used in replanting cleared areas. However, the scale of the SPES native plant garden is not large enough to provide plants for a large control program (Gonzales 2002). Thus, Gonzales suggested that the Park Board may be in a better position to provide native plants if re-vegetation of large areas is required. Including replanting as part of a control program would help switch the focus from invasive plant removal to restoration. Gonzales felt that making the end goal of a volunteer control program something positive, such as restoration, would be important.

In establishing a volunteer ivy control program, it would be critical to make education part of the process (Gonzales 2002). Although Gonzales sees the value in stewardship programs, she stressed the importance of ensuring that the people involved have a thorough understanding of exactly what they are doing and why. Also, in order for control to be effective and minimally disruptive to the forest, education about manual control methods would be necessary. Thus, control programs would need to be co-ordinated by a knowledgeable individual who could provide the educational part of the activities.

Gonzales thought that there would be interest in volunteer control programs in Stanley Park. In fact, SPES gets phone calls from members of the public and groups that want to come to the Park and take part in stewardship activities such as pulling invasive plants (Gonzales 2002). However, due to the union consideration, SPES is often forced to direct these potential volunteers elsewhere (Gonzales 2002).

Gonzales also suggested that there may be resistance to a control program in the Park. With some people finding ivy aesthetically pleasing, public awareness would be required to convince people that control is important. As was found with deciduous tree removal in the Park, the public generally has a range of opinions about active management of the forest.

Through speaking with Emily Gonzales and Eric Meagher, manual control by volunteers seems to be the best control option. In fact, with herbicides being too controversial, and with limited funding for further control efforts by maintenance employees, manual volunteer control programs may be the only option. However, due to present union restrictions, this type of program may need to be implemented incrementally, as the union becomes more receptive to the use of volunteers.

15.0 RECOMMENDATIONS AND FUTURE RESEARCH

15.1 Recommendations

Our research has provided evidence that English seems to be having significant negative impacts on the diversity and composition of native vegetation in Stanley Park, and may in turn be adversely affecting native wildlife. Furthermore, these impacts may have serious implications for both Park management and the environmental education potential of the Park. Thus, an expanded control program in the near future is highly recommended.

Since funding is not available for paid employees to carry out sufficient control, volunteer programs could greatly increase the resources available for this stewardship activity. As has been discussed above, union regulations currently prohibit extensive use of volunteers in Stanley Park. Therefore, we recommend that Stanley Park management work with the union to allow for the establishment of volunteer control programs. If this occurs, the process will likely be gradual, with volunteer participation in control efforts increasing incrementally. If the acceptance of volunteer use by the union proceeds to a sufficient level, we recommend that organisations such as the Stanley Park Ecology Society or the Vancouver Natural History Society develop a volunteer program for the removal of ivy and for the associated re-vegetation. The development of such a program could be enhanced through partnerships between multiple organisations and with the support of Park management.

The most feasible method for control of ivy in Stanley Park is manual control. Not only is it the only method that can be carried out by volunteers, but it has also been shown to be a favourable option in terms of effectiveness, environmental impacts, and public reaction. In order to direct control efforts to the regions of the Park where they are most needed, the priority areas determined by our GIS analysis should be useful. In addition, the priority focus of control efforts should be updated through monitoring of ivy spread and establishment in new areas. Monitoring following control efforts is also important to determine the efficacy of removal activities.

Considering that an extensive ivy control program in Stanley Park may take considerable time to establish, ivy will continue to be a major component of the forest in some areas. In order to take advantage of its presence, we recommend that environmental education about invasive plants, and ivy in particular, be continued and expanded. With the public's general lack of knowledge about invasive plants, this educational opportunity could aid in gaining support for control programs both in Stanley Park and elsewhere. Also, raising awareness about the potential sources of invasive plants may help prevent further invasion of Stanley Park and other valuable natural areas.

An important factor in determining the urgency of control efforts and in projecting future invasion of ivy in Stanley Park is its rate of spread. We were unable to assess this important factor given the time-frame of our thesis. Thus we recommend that management establish a monitoring program in order to determine approximate rates of spread of ivy in the Park. As is discussed below, this is also an important topic for future research.

15.2 Future Research

With the current lack of scientific research about ivy biology and invasion dynamics, considerable study is required to gain a more complete understanding of ivy's impact on natural areas. This thesis has attempted to address some of the gaps in our knowledge about ivy in Stanley Park. However, further research within the Park is required to develop the most effective control and prevention strategies.

15.2.1 Research on English ivy in Stanley Park

There is presently no data on the speed with which ivy is invading the forest of Stanley Park. Rates of spread of ivy are influenced by many factors, including the type of forest it is invading and the associated light levels, the developmental stage of the ivy plant, and whether it is climbing trees or growing along the ground. The complex spread of ivy makes it difficult to estimate rates based solely on site and ivy characteristics. Thus, time series data is required to quantitatively assess rates of spread. Monitoring ivy over time is a process that would be relatively easy for management to carry out and would provide useful data to project the future extent of ivy. GIS may also be a useful tool for management to use in modelling future spread.

The correlation that we discovered between the area of ivy and its proximity to roads and trails suggests a need for further research to determine the cause of this relationship. One hypothesis about the cause is related to the disturbance around roads and trails. An assessment of how disturbance influences the invasion of ivy would therefore help determine which management actions and user activities are appropriate in the Park. A second hypothesis is that roads and trails may be corridors of invasion due to human introduction though careless actions such as dumping garden clippings. Determining and limiting the sources of ivy in the Park are a key part of preventing further invasion. One final hypothesis is that ivy can more easily colonise areas with greater light levels. Thus further research on the relationships between light levels and ivy invasion may be useful.

15.2.2 General English ivy research

There are several major topics that are not well understood in terms of general characteristics of English ivy. These include ivy growth patterns, mechanisms of invasion, and effects on native species and ecosystem processes.

As has already been discussed, *Hedera helix* has complex growth patterns influenced by many factors. Although some of these factors have been identified, for many it is not clear qualitatively, much less quantitatively, how they impact ivy growth. This information could enable prediction of which environments are more susceptible to invasion . Another aspect of ivy invasion that is not fully understood is its mechanisms of invasion. Understanding these mechanisms would also help to identify susceptible areas and prevent further spread.

In our research we attempted to determine the impact of ivy on native plant diversity and composition. However, there is still much research required on this topic, such as determining which plant species are affected by ivy. This would allow for a more detailed analysis of how the changes in vegetation associated with ivy invasion impact bird species. As well as the loss of native plant species used as a food source, there are other unexplored effects that ivy may have on birds. First, little is known about the suitability of ivy as a food source for birds and other wildlife. If ivy is out-competing other berry producing plants, this is important information. Second, the effect of the structural changes that extensive ivy invasion has on bird habitat is unknown. Thus, the specific interactions between ivy and birds need further exploration. Also, the impact of ivy invasion on other wildlife species has not been studied, but is important to assess.

Finally, there is little or no information available about the effects of ivy on ecosystem characteristics, such as hydrology, soil nutrient levels, and slope stability. Further research into these potential effects is important in assessing the impact of ivy on ecosystems as a whole.

16.0 CONCLUDING REMARKS

Throughout the course of our research, we have worked with two major objectives. First, we hoped to add to the currently limited scientific information about the effects of English ivy invasion on natural areas. Second, we aimed to provide information that would be useful in management decisions about the need for, and the feasibility of expanded control programs. The recommendations and suggestions for future study that conclude this thesis are intended to meet these objectives. As has been the case with other invasive species in other natural or semi-natural areas, successful control of the ivy invasion will require a combination of increased public awareness, expanded removal efforts, and further research.

17.0 REFERENCES

Alpert, P., and T.E. Colton. 1998. Lack of Public Awareness of Biological Invasions by Plants. *Natural Areas Journal* 18(3): 262-266.

Barnea, A., J.B. Harborne, and C. Pannell. 1993. What part of fleshy fruits contain secondary components toxic to birds and why? *Biochemical Systematics and Ecology*, 21(4): 421-429

Beese, W.J., and G.J Paris. 1989a. *Stanley Park Regeneration Program*. Vancouver Board of Parks and Recreation and MacMillan Bloedel Limited Woodlands Services, Vancouver.

Beese, W.J., and G.J. Paris. 1989b. Stanley Park – Stand Map. (map). Vancouver Board of Parks and Recreation and MacMillan Bloedel Limited Woodlands Services, Vancouver.

Beese, W.J. 1988a. The Forest Vegetation of Stanley Park. In A. Chen and V. Schaefer (Eds.), *The Natural History of Stanley Park* (pp. 5-9). Discovery Press, Vancouver.

Beese, W.J. 1988b. Stanley Park – Site Associations. (map) In A. Chen and V. Schaefer (Eds.), *The Natural History of Stanley Park* (pp. 5-9). Discovery Press, Vancouver.

Belyea, R., and M. St.Louis. 1992. *Stanley Park Technical Report*. Belyea, Sorensen and Associates, Vancouver.

Bradfield, G. 2001. Biology 406 lecture content. UBC, Vancouver.

Bridge, G. 2001. Everyday Ecologies: Cities, Nature and Teaching Urban Ecology. *Journal of Geography* 100: 154-165.

Cabeza, M., and A. Moilanen. 2001. Design of reserve networks and the persistence of biodiversity. *Trends in Ecology & Evolution* 16:242-248.

Carey, R.J., A.M. Kuris, J.H. Myers, and D. Simberloff. 2000. Eradication Revisited: dealing with exotic species. *Trends in Ecology and Evolution* 15(12): 515-516.

Catterall, C.P., R.J. Green and D.N. Jones. 1989. Occurrence of birds in relation to plants in a subtropical city. *Australian Wildlife Research* 18:189-301.

Clergeau, P. 1992. The effect of birds on seed germination of fleshy-fruited plants in temperate farmland. *Acta Oecologica* 13(6): 679-686.

Coblentz, B.E. 1990. Exotic Organisms: A Dilemma for Conservation Biology. *Conservation Biology* 4(3): 261-265.

Crawley, MJ. 1986. Life history and environment. In M.J. Crawley (Ed.), *Plant Ecology* (pp 253-290). Blackwell Scientific, Oxford.

Cronk, Q.C.B., and J.L. Fuller. 1995. *Plant Invaders: The threat to natural ecosystems.* Earthscan Publications Ltd: London, UK and Sterling, VA.

Derr, J.F. 1993. English Ivy (*Hedera helix*) Response to Postemergence Herbicides. *Journal of Environmental Horticulture* 11(2): 45-48.

Dextrase, A. 1996. Alien Species in the Great Lakes of North America: Problems, Solutions and Outstanding Issues. In G.O. Lee and C.D.A. Rubec (Eds.), *Conserving Vitality and Diversity: Proceedings of the World Conservation Congress Workshop on Alien Invasive Species* (pp.63-81). Environment Canada, Ottawa.

Diaz, S., and M. Cabido. 2001. Vive la différence: plant functional diversity matters to ecosystem processes. *Trends in Ecology & Evolution* 16:646-654.

Diedrich, S. 2002. Personal Communication. 31 January 2002.

Drayton, B., and R.B. Primack. 1996. Plant species lost in an isolated conservation area in Metropolitan Boston from 1894 to 1993. *Conservation Biology* 10:30-39.

Ehrenfeld, J.G., and N. Scott (ed.). 2001. Invasive Species and the Soil: Effects on Organisms and Ecosystem Processes. *Ecological Applications* 11(5): 1259-1260.

Elliott, C. 1995. The ivy debate: Is this vine a friend or foe? *Horticulture* 73(3): 21-25

Er, K. 2002. Personal Communication. 22 Feb. 2002.

Freshwater. V. 1991. Control of English ivy (*Hedera helix*) in Sherbrooke forest – a practical experience. *Plant Protection Quarterly* 6(3): 127.

Grass, A. 1988. Reptiles and Amphibians. In A. Chen and V. Schaefer (Eds.), *The Natural History of Stanley Park* (pp. 24-30). Discovery Press, Vancouver.

Grime, J.P. 1997. Biodiversity and ecosystem function: the debate deepens. *Science* 277:1260-1263.

Gonzales, E. 2002. Personal Communication. 14 March 2002.

Gould, A.M., and D.L. Gorchov. 2000. Effects of the exotic invasive shrub *Lonicera maackii* on the survival and fecundity of three species of native annuals. *American Midland Naturalist* 144: 36-50.

Greig-Smith, P. 1983. *Quantitative plant ecology – 3rd Ed.*. Blackwell Scientific, Oxford.

Haber, E., C. Keddy, and D.J. White. 1993. *Invasive Plants of Natural Habitats in Canada*. Environment Canada, Ottawa.

Hacket, W.P., and I. Wallerstein. 1989. Inflorescence Induction and Initiation in *Hedera helix*. *Israel Journal of Botany* 38: 71-83.

Hale, M. 1993. Ecology and environmental education in the urban environment. In M. Hale (Ed.), *Ecology in Education* (pp.131-144). Cambridge University Press, Cambridge.

Hansen, A.J., M. Hunter, W.C. McComb, M.G. Raphael, and R. Vega. 1995. Bird habitat Relationships in Natural and Managed Forests in the West Cascades of Oregon. *Ecological Applications* 5(3): 555-569.

Harmer, R., G. Peterken, G. Kerr, and P. Poulton. 2001. Vegetation changes during 100 years of development of two secondary woodlands on abandoned arable land. *Biological Conservation* 101: 291-304.

Harvey, M.R. 1993. Learning about ecology through contact with vegetation. In M. Hale (Ed.), *Ecology in Education* (pp.99-121). Cambridge University Press, Cambridge.

Heckman, C.W. 1999. The Encroachment of Exotic Herbaceous Plants into the Olympic National Forest. *Northwest Science*, 73(4): 264-276.

Higgins, S.I., R.M. Cowling, and D.M. Richardson. 2000. Using a dynamic landscape model for planning the management of alien plant invasions. *Ecological Applications* 10(6): 1833-1848.

Hobbs, R.J., and L.F. Huenneke. 1992. Disturbance, diversity, and invasion: implications for conservation. *Conservation Biology* 6:324-337.

Hobbs, R.J., and H.A. Mooney. 2000. *Invasive Species in a Changing World*. Island Press, Washington, D.C.

Holdnak, M., M. Niederhofer, and F.E. Putz. 1999. Controlling Invasive Exotics: A Tallow Tree Replacement Program Campaign in Florida. *Journal of Arboriculture* 25(2): 98-101.

Hurd, C., J.M. Randall, and M. Tu. 2001. “Weed Control Methods Handbook: tools and techniques for use in natural areas.” The Nature Conservancy. Accessed 12 December 2001. <http://tncweeds.ucdavis.edu/handbook.html>.

Idziak, C., and W.A. Kenney. 2000. The state of Canada’s municipal forests- 1996-1998. *The Forestry Chronicle* 76(2): 231-234.

"Invasive Plant Primer." *Invasive Plants Fact Book*. Accessed 20 February 2002. <https://www.denix.osd.mil/denix/Public/ES-Programs/Conservation/Invasive/yard.html>.

Ivy Removal Project. "Project Benchmarks." Accessed 20 February 2002a. <http://www.noivyleague.com/Pages/proj_benchmarks.html>.

Ivy Removal Project. "Reasons for Removal." Accessed 2 February 2002b. <http://www.noivyleague.com/Pages/ivy_removal.html>.

Ivy Removal Project. "State's Noxious Weeds List." Accessed 2 February 2002c. <http://www.noivyleague.com/Pages/what_h_noxious.html>.

Ivy Removal Project. "Impact on Forests." Accessed 2 February 2002d. <http://www.noivyleague.com/Pages/ivy_forests.html>.

Ivy Removal Project. "Impact on Trees." Accessed 2 February 2002e. <http://www.noivyleague.com/Pages/ivy_trees.html>.

Ivy Removal Project. "Seeds of Destruction." Accessed 2 February 2002f. <http://www.noivyleague.com/Pages/what_h_seeds_destruct..html>.

Ivy Removal Project. "Research Perspectives." Accessed 20 February 2002g. <http://www.noivyleague.com/Pages/res_acad_perspectives..html>.

Ivy Removal Project. "Impact on Slopes" Accessed 2 February 2002h. <http://www.noivyleague.com/Pages/ivy_slopes.html>.

Jones and Stokes. 2001. *Discovery Park Draft Vegetation Management Plan*. Seattle Parks and Recreation, Seattle.

Kalkhoven, J.T.R., and R.H.A.C. van Ruremonde. 1991. Effects of woodlot isolation on the dispersion of plants with fleshy fruits. *Journal of Vegetation Science* 2: 377-384.

Kautesk, B.M., and W.C. Weber. 1988. The Birds of Stanley Park. In A. Chen and V. Schaefer (Eds.), *The Natural History of Stanley Park* (pp. 31-35). Discovery Press, Vancouver.

Kent, M., and P. Coker. 1992. Vegetation description and analysis: a practical approach. CRC Press, Boca Raton, Florida.

Kershaw, K.A. 1964. *Quantitative and dynamic ecology*. Arnold, London.

Kourtev, P.S., J.G. Ehrenfeld, and W.Z. Huang. 1998. Effects of exotic plant species on soil properties in hardwood forests of New Jersey. *Water, Air, and Soil Pollution* 105: 493-501.

Lee, G.O. 1996. Anatomy of a Public Partnership. In G.O, Lee and C.D.A. Rubec (Eds.), *Conserving Vitality and Diversity: Proceedings of the World Conservation Congress Workshop on Alien Invasive Species* (pp.43-49). Environment Canada, Ottawa.

Lembi, C.A., and M.A. Ross. 1985. *Applied Weed Science*. Burgess Publishing Company, Minneapolis.

Loeb, R.E.. 1992. Long-term human disturbance of an urban forest, New York City. *Forest Ecology and Management* 49: 293-309.

Loreau, M. 2000. Biodiversity and ecosystem functioning: recent theoretical advances. *Oikos* 91: 3-17.

Lovejoy, A. "From the garden: Destroying English ivy is a joyous chore." *Seattle Post-Intelligencer*. 3 January 2002. Accessed 20 February 2002. <http://seatlepi.nwsource.com/nwgardens/52994_lovejoy03.shtml>.

Masters, R.A., and R.L. Sheley. 2001. Principles and practices for managing rangeland invasive plants. *Journal of Range Management*. 54(5): 502-517.

Margules, C.R., and R.L. Pressey. 2000. Systematic conservation planning. *Nature* 405: 243-252

Meagher, E. 2002. Personal Communication. 22 March 2002.

Merilees, W. 1988. The Forgotten Mammals. In A. Chen and V. Schaefer (Eds.), *The Natural History of Stanley Park* (pp. 37-38). Discovery Press, Vancouver.

Mooney, H.A., and F.E. Putz (Eds.). 1991. *The Biology of Vines*. Cambridge University Press, Cambridge.

Morgan, A. 2001. "An Assessment of Ivy control Methods and Strategies." No Ivy League. Accessed 12 December 2001. <www.noivyleague.com/Pages/cont_assess.html>.

Ogle, C.C, G.D La Cock, G. Arnold, and N. Mickleson. 2000. Impact of an exotic vine *Clematis vitalba* (F. Ranunculaceae) and of control measures on plant biodiversity in indigenous forest, Taihape, New Zealand. *Austral Ecology* 25: 539-551.

Okerman, A. 2001. "Combating the "Ivy Desert": The Invasion of *Hedera helix* (English ivy) in the Pacific Northwest United States" University of Minnesota Restoration and Reclamation Review. Accessed 19 November 2001. <http://www.hort.agri.umn.edu/h5015/00papers/okerman.htm>.

Pallochuck, R. 2001. Personal Communication. 25 November 2001.

Pallochuck, R. 1998. Map of Ivy in Stanley Park. (map). Vancouver Board of Parks and Recreation, Vancouver.

Palmer, J.A. 1998. *Environmental Education in the 21st Century: Theory, Practice, Progress and Promise*. Routledge: London and New York.

Robertson, D.J., M.C. Robertson, and T. Tague. Colonisation dynamics of four exotic plants in a northern Piedmont natural area. *Bulletin of the Torrey Botanical Club*, 121(2): 107-118.

Seattle Parks and Recreation. "Discovery Park." Accessed 27 February 2002. <http://www.cityofseattle.net/parks/Environment/discovparkindex.htm>.

Seattle Parks and Recreation. "Wild and Wonderful Winter Programs at Discovery Park." *Community Notices*. 21 December 2001. Accessed 27 February 2002. <http://www.cityofseattle.net/parks/communitynotices/current/17_Wild_Wonderful_Winter_Programs_at_Discovery_Park.htm>.

Snow, B., and D. Snow. 1988. *Birds and berries – A study of ecological interactions*. T & AD Poyser, London.

Soule, M.E. 1990. The Onslaught of Alien Species, and other Challenges in the Coming Decades. *Conservation Biology* 4(3): 233-238.

Stanley Park Ecology Society. 2002. Personal Communication. 7 March 2002.

Stanley Park Ecology Society. 2001. Stanley Park Ecology Society Homepage. Accessed 17 February 2002. <www.vcn.bc.ca/spes/>.

Stanley Park Task Force. 1992. *Stanley Park Task Force: Final Report*. Vancouver Board of Parks and Recreation, Vancouver.

Steele, R.M. 1985. *The Stanley Park Explorer*. Whitecap Books, Vancouver.

The Nature Conservancy. 2001. "*Hedera helix* (English ivy)". *Weeds on the Web: Wildland Invasive species program.*. Accessed 12 December 2001. <http://tncweed.ucdavis.edu/esadocs/hedeheli.html>.

Tilman, D. 1999. The ecological consequences of changes in biodiversity: a search for general principles. *Ecology* 80:1455-1474.

UNESCO. 1977. *The International Workshop on Environmental Education: Belgrade, October 1975: Final Report*. UNESCO, Paris.

Vancouver Board of Parks and Recreation. 1993. *Stanley Park Maintenance Plan.* Vancouver Board of Parks and Recreation, Vancouver.

Vancouver Parks and Recreation. "Welcome to Stanley Park!" *Parks and Gardens*. City of Vancouver. Accessed 8 November 2001a. <http://city.vancouver.bc.ca/parks/3.htm>.

Vancouver Parks and Recreation. "SPDetail." *Parks and Gardens*. City of Vancouver. Accessed 8 November 2001b. <http://city.vancouver.bc.ca/parks/3.htm>.

Wareing, M. 1990. *The Stanley Park Regeneration Program –An Wholistic Forestry Viewpoint*. Western Canada Wilderness Committee, Vancouver.

Westman, W.E. 1990. Park Management of Exotic Plant Species: Problems and Issues. Conservation Biology 4(3): 251-260.

Whittaker, R.H. 1978. *Ordination of plant communities*. Hague, Junk.

APPENDIX A – VEGETATION SURVEYS

1.0 Species observed

The following table lists all species observed during the vegetation surveys. For each species, at each site, the total numbers of quadrats and sectors that contained the species are given. These help to illustrate the prevalence of each species at each site.

		Ivy site		No-ivy site	
Common Name	**Scientific Name**	**# of quadrats**	**# of sectors**	**# of quadrats**	**# of sectors**
1) Invasive species					
English ivy	*Hedera helix*	56	30	0	1
holly	*Ilex sp.*	7	20	5	15
2) Trees					
big leaf maple	*Acer macrophyllum*	0	1	0	0
red alder	*Alnus rubra*	0	0	0	0
red cedar	*Thuja plicata*	0	0	0	2
western hemlock	*Tsuga heterophylla*	8	18	31	28
3) Shrubs					
red elderberry	*Sambucus racemosa*	0	5	0	0
huckleberry	*Vaccinium parvifolium*	15	25	30	26
salal	*Gaultheria shallon*	3	5	35	25
salmon berry	*Rubus spectabilis*	9	20	9	17
trailing blackberry	*Rubus ursinus*	1	3	0	7
vine maple	*Acer circinatum*	11	29	15	23
4) Herbs and grasses					
foam flower	*Tiarella trifoliata*	0	0	20	19
unknown grass		1	2	0	0
5) Ferns					
deer fern	*Blechnum spicant*	4	12	6	18
lady fern	*Athyrium filix-femina*	0	0	3	6
licorice fern	*Polypodium glycyrrhiza*	0	0	0	4
spiny wood fern	*Dryopteris expansa*	34	30	47	29
sword fern	*Polystichum munitum*	19	20	12	22
6) Mosses					
beaked moss	*Kindbergia spp.*	6	14	24	0
cat-tail moss	*Isothecium myosuroides*	0	0	3	4
cedar moss	*Plagiothecium undulatum*	9	17	55	0
lanky moss	*Rhytidiadelphus loreus*	0	0	0	1
star moss	*Rhizomnium glabrescens*	12	19	30	24
unknown moss 1		0	0	0	1
unknown moss 2		9	19	11	29

unknown moss 3		15	23	19	25
unknown moss 4		0	1	1	19
unknown moss 5		2	6	4	8
unknown moss 6		0	0	2	3
unknown moss 7		4	17	15	20
total # of quadrats in each site = 60					
total # of sectors in each site = 30					

2.0 Explanation of methodology

Please Note: The following simple explanations are intended to aid in the interpretation of the results presented in Part I of this thesis. For a more detailed explanation of the computational steps of each method, as well as their relative advantages and disadvantages, see any text on quantitative plant ecology. Examples are Kent and Coker 1992, Greig-Smith 1983, Whittaker 1978, and Kershaw 1964.

The majority of the following text has been summarised from the lecture content of Biology 406: Plant Ecology I, taught in the fall of 2001 by Dr. Gary Bradfield at the University of British Columbia. Specific details are cited as Bradfield, 2001.

Bray-Curtis Ordination

Ordination is a fundamental method in quantitative plant ecology. This method begins with the arrangement of data about the species observed with a number of sampling units in a plot-species matrix, or table. Each plot is a row in the table, while each species observed is a column. In our case, the data in the cells of the table are the percent cover values for each species measured in each plot (an average from the six quadrats in that plot). Conceptually, this data forms a point cloud with as many dimensions as there are species (Bradfield 2001). Each plot is located in the point cloud according to the abundance of each species it contains. The function of ordination, then, is to reduce the number of dimensions to two by finding the axes through the point cloud that explain the most variation (Bradfield 2001, Kershaw 1973). Once the plot-species table is entered into software such as PC ORD, the best three axes are computed. These are ranked in the order of the amount of variation in the point cloud they are able to explain with one dimension. The cumulative variation explained with the best two axes is equal to the variation explained by a plot of these two axes, such as those given in Figures 4.1-4.4 and 4.8.

Though there are many different types of ordination, the type chosen for our analysis was Bray-Curtis. This method begins by choosing the two most dissimilar plots in the plot-species matrix, and using these as endpoints for the ordination. All other plots are then arranged between these endpoints along the first and second ordination axes. This method is less vulnerable to distortion than other ordination methods (Whittaker 1978), particularly when the relationships between the plots are not assumed to be linear (Bradfield 2001). This is the reason we chose Bray-Curtis, since our plots are from two different sites and are not necessarily linearly related.

In interpreting ordination graphs, there are two things to look for. First, the graph is only meaningful if the axes capture a reasonable amount of variation. The cumulative variance explained by the first two axes is given in the ordination output (see output later in this

Appendix). Second, the spatial arrangement of the plots in the graph indicates the relative differences of the vegetation in each of the plots (Bradfield 2001). Environmental variables, such as soil moisture or light intensity, if measured at each plot, can be overlaid on the graph as vectors showing the direction of increase in each variable. This can be used to help explain the variation in the plots. Since we did not collect environmental data, our interpretation is limited to looking for spatial separation of plots from the two separate sites. If the plots in the Ivy site are consistently separated from those in the No-ivy site, we interpret this as a difference in vegetation composition between the two sites. In the absence of environmental data, we can only speculate that this difference may be related to the presence or absence of ivy.

Outlier Analysis

Outlier analysis is used to identify plots that are significantly different from all others. It is especially important to identify and remove outliers from the plot-species matrix before completing a Bray-Curtis ordination (Bradfield 2001). This is because Bray-Curtis picks the most dissimilar plots as endpoints to the ordination axes. If outliers are present in the matrix, they may be chosen as endpoints, resulting in an artificial separation of the plots that is based on the one plot's extreme differences, rather than on general trends between all plots.

Outliers are identified based on their distance from all other plots in the matrix. In our analysis, we identified and removed plots with a distance of greater than 2 standard deviations of the mean distance between all plots.

Beals Smoothing

Beals Smoothing is a data adjustment technique to address the prevalence of zero-values in the matrix. In many vegetation surveys, including ours, the majority of the values in the matrix are zeros. Unlike other percent cover values, a zero-value can mean two things (Bradfield 2001). First, it can mean that the species with a zero-value for percent cover does not exist in the plot because the environmental conditions or species interactions in the plot will not allow it. Second, it can mean that the species does not exist in the plot simply because it has not spread there yet (Bradfield 2001). Because of this ambiguity, we cannot conclude that a zero-value means a particular species does not exist in the plant community of a particular plot.

Beals Smoothing was developed to address this problem. This technique replaces zero-values in the matrix with non-zero values that indicate the probability of the species occurring in the plot based on the other species present in the plot and the co-occurrence of the species in all other plots (Bradfield 2001). Following this, ordination can be carried out on the adjusted matrix.

Relativisation by Species

Relativisation is another data adjustment technique. Because some species in the plot-species matrix will always occur at greater percent covers than other, less prevalent species, the ordination can be dependent completely on the species with values of higher magnitude, missing the variation indicated by the occurrence of rare or physically smaller species (Bradfield 2001). To decrease the weight of dominant species in the matrix, each value in the matrix is divided by the maximum value for that species in all plots (Bradfield 2001). Percent cover values are thus converted so that they range between 0 and 1. Following this, ordination can be carried out on the adjusted matrix.

Jackknife Estimates

Jackknife estimates are estimates of the total number of species present in a sampling area, including a probabilistic number of rare species missed in the sampling units (Bradfield 2001). These estimates are generated using a species area curve (see examples later in this Appendix). To create a species area curve from a plot-species matrix, PC ORD randomly picks an increasing number of plots from the matrix, and records the average number of species present in that number of plots, over many repeated trials (Bradfield 2001). For example, PC ORD first picks one random plot many times, and averages the number of species over all times. It then picks two random plots, then three, and so on. The resulting curve shows how quickly the number of species increases as the sample size increases. This curve can be extrapolated to estimate the total number of species present in a sampling area. This is the jackknife estimate. The curve also indicates whether sufficient sampling has been done. If the jackknife estimate is much higher than the actual number of species observed, sampling was insufficient to capture the variation in vegetation.

3.0 Data analysis output

a) Bray-Curtis output for ordination of unmodified data (Figure 4.1)

```
*************************** Bray-Curtis Ordination
***************************
PC-ORD, Version 3.20
27 Feb 2002, 11:38

Bray-Curtis of plot data

Ordination of plots    in species  space.        19 plots          23
species

          The following options were selected:

      Distance measure = SORENSEN 1-2W/A+B
      Endpoint selection = VAR.-REGRESSION
      Projection geometry = EUCLIDEAN
      Calculation of residuals = EUCLIDEAN


          Output options selected:

      Write distance matrix
  *   Write axes 1 through 3
      Write no residual distance matrix


Bray-Curtis of plot data

     Endpoints for axis 1: A8        B8
     Distances (ordination scores) are from A8
```

Sum of squares of non-redundant distances
in original matrix = .711995E+02

Regression coefficient for this axis = -10.77
Variance in distances from the first endpoint = .70

Axis 1 extracted 25.76% of the original distance matrix
Cumulative: 25.76%
Sum of squares of residual distances remaining = .528613E+02

Ordination scores on axis 1

Score	Name	Seq.	Score	Name	Seq.	Score	Name	Seq.	Score	Name	Seq.
.217	A1	1	.403	A2	2	.443	A3	3	.130	A4	4
.086	A5	5	.285	A6	6	.020	A7	7	.000	A8	8
.196	A9	9	.373	A10	10	.340	B1	11	.216	B2	12
.480	B3	13	.602	B4	14	.595	B6	15	.178	B7	16
.940	B8	17	.278	B9	18	.504	B10	19			

Bray-Curtis of plot data

Endpoints for axis 2: A4 A9
Distances (ordination scores) are from A4

Regression coefficient for this axis = -8.65
Variance in distances from the first endpoint = .45

Axis 2 extracted 17.65% of the original distance matrix
Cumulative: 43.41%
Sum of squares of residual distances remaining = .402916E+02

Ordination scores on axis 2

Score	Name	Seq.	Score	Name	Seq.	Score	Name	Seq.	Score	Name	Seq.
.557	A1	1	.494	A2	2	.554	A3	3	.000	A4	4
.481	A5	5	.355	A6	6	.217	A7	7	.250	A8	8
.837	A9	9	.345	A10	10	.475	B1	11	.242	B2	12
.495	B3	13	.533	B4	14	.345	B6	15	.165	B7	16

```
     .250 B8         17    .544 B9         18    .224 B10       19
```

Bray-Curtis of plot data

```
     Endpoints for axis 3: A7        B10
     Distances (ordination scores) are from A7


     Regression coefficient for this axis  = -4.25
     Variance in distances from the first endpoint = .47


     Axis 3 extracted  13.19% of the original distance matrix
     Cumulative:  56.60%
     Sum of squares of residual distances remaining = .308982E+02

     Ordination scores on axis 3
    Score   Name   Seq.  Score   Name   Seq.  Score   Name   Seq.  Score
Name   Seq.
   ------ -------- ---- ------ -------- ---- ------ -------- ---- ------ ----
---- ----
     .179 A1         1    .394 A2         2   -.013 A3         3    .140 A4
4
     .116 A5         5    .185 A6         6    .000 A7         7    .029 A8
8
     .140 A9         9    .257 A10       10    .313 B1        11    .212 B2
12
     .445 B3        13    .300 B4        14    .282 B6        15    .342 B7
16
     .029 B8        17    .433 B9        18    .590 B10       19


****** Calculations completed. There were 3 Bray-Curtis axes calculated
******
```

b) Species-area curve for the Ivy site

```
***************************** Species-area Analysis
*****************************
PC-ORD, Version 3.20
 1 Mar 2002, 13:55
species area of ivy site

             Species-area curve for   18 species  in   10 plots

                    X = Average number of species
 Number of 0    10    20    30    40    50    60    70    80    90   100
110
 Subplots  +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--
+--
        1|     X                     O
        2|        X           O
        3|         X      O
        4|         X   O
        5|          XO
        6|         OX
        7|       O  X
        8|     O     X
        9|   O       X
       10|O          X
           +-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
           .0    .1    .2    .3    .4    .5    .6    .7    .8    .9   1.0
                 O = Average Sorensen Distance: 1-2w/A+B


 NO.    AVERAGE
 SUB-   NO. OF  AVERAGE
 PLOTS  SPECIES DISTANCE
------ -------- --------
     1     8.80    .4572
     2    12.58    .3341
     3    14.49    .2679
     4    15.57    .2227
     5    16.27    .1841
     6    16.79    .1487
     7    17.20    .1152
     8    17.53    .0838
     9    17.80    .0506
    10    18.00    .0000

 Estimates of total number of species:
         18.0 = Number of species observed
         19.8 = First-order jackknife estimate
         19.3 = Second-order jackknife estimate

 Additional information used for jackknife estimates:
            0 = Number of columns in matrix with no positive values
            2 = Number of species with only 1 occurrence
            3 = Number of species with only 2 occurrences

*********************** Completed species-area analysis
```

c) Species-area curve for the No-ivy site

```
***************************** Species-area Analysis
*****************************
PC-ORD, Version 3.20
 1 Mar 2002, 13:59
species area of no-ivy site

             Species-area curve for   21 species  in   10 plots

                    X = Average number of species
 Number of 0    10    20    30    40    50    60    70    80    90   100
110
 Subplots  +--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--
+--
         1|        X               O
         2|          X      O
         3|           X O
         4|           O
         5|         O  X
         6|       O    X
         7|      O     X
         8|    O       X
         9|   O        X
        10|O            X
           +-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
           .0    .1    .2    .3    .4    .5    .6    .7    .8    .9   1.0
                 O = Average Sorensen Distance: 1-2w/A+B

 NO.    AVERAGE
 SUB-   NO. OF  AVERAGE
 PLOTS  SPECIES DISTANCE
------ -------- --------
     1    13.20    .4078
     2    16.47    .2878
     3    17.98    .2228
     4    18.88    .1809
     5    19.50    .1479
     6    19.96    .1204
     7    20.31    .0953
     8    20.58    .0718
     9    20.80    .0448
    10    21.00    .0000

 Estimates of total number of species:
         21.0 = Number of species observed
         22.8 = First-order jackknife estimate
         23.7 = Second-order jackknife estimate

 Additional information used for jackknife estimates:
            0 = Number of columns in matrix with no positive values
            2 = Number of species with only 1 occurrence
            1 = Number of species with only 2 occurrences

********************** Completed species-area analysis
**********************
```

APPENDIX B – INTERVIEWS AND SURVEYS

1.0 Interview questions

a) *Interview # 1*
   Eric Meagher
   Supervisor of Maintenance for Stanley Park
   Vancouver Board of Parks and Recreation

Questions:

1) What are your overall management objectives for the forest of Stanley Park?
2) What implications do invasive plants might have, if any, for management according to those objectives?
3) Has there been control of invasive plants in the past? Has it been considered?

At this point we will present the findings of our study on the effects and extent of English ivy in the forest of Stanley Park.

4) Based on this new data, do you think the issue of invasive plants (and in particular English ivy) in the park should be addressed? Why or why not?

At this point we will discuss with Eric the options for control of English ivy. The two basic options are manual control and chemical control.

5) Which option, if any, do you think is more feasible? Why or why not?

b) *Interview #2*
   Emily Gonzales
   Past Director
   Stanley Park Ecology Society

We will start by giving Emily a summary of results from the project. She is already familiar with the project, as we have discussed it with her before.

Questions:

1) What implications do you think invasive plants (particularly English ivy) might have for environmental education in Stanley Park?

2) What do you think should be done about invasive plants in Stanley Park, if anything? Why?

3) Do you think organising volunteer pulling groups through SPES would be within their mandate and would be of interest to the public?

2.0 Survey questions

Stanley Park Ecology Society

PO Box 5167 Vancouver , BC V6B 4B2
604 257-6908 ph. 604 257-8378 fax
spes@vcn.bc.ca
www.stanleyparkecology.ca

This survey is being conducted through a partnership between the Stanley Park Ecology Society (SPES) and Tannis Nelson, a student from the BCIT Fish, Wildlife and Recreation program. Your responses to this survey will be very valuable in helping us determine how to enhance visitors' experiences in the natural areas of Stanley Park. **You will receive a coupon for a free SPES program for completing this survey.**

1) Did you know that:

a) Stanley Park has an ecology society?	Yes	No
b) SPES runs nature education programs for all ages?	Yes	No
c) Stanley Park's forests are patrolled over the summer	Yes	No

2) How often do you come to Stanley Park? (check one)

☒ First time ☒ Weekly ☒ Monthly
☒ Seasonally (4x/year) ☒ Twice a year ☒ Annually

3) When you are in Stanley Park, *how much of your time* do you spend in the following areas? (check appropriate category for each)

a)	Natural Areas (forested trails)	☒ none	☒ some	☒ most	☒ all
b)	Aquarium	☒ none	☒ some	☒ most	☒ all
c)	Seawall	☒ none	☒ some	☒ most	☒ all
d)	Train/Children's Farmyard	☒ none	☒ some	☒ most	☒ all
e)	Beach	☒ none	☒ some	☒ most	☒ all
f)	Other: ____________________	☒ none	☒ some	☒ most	☒ all

4) If you visit a natural area in Stanley Park, is it to: (circle appropriate category for each)

a)	Get exercise	☒ never	☒ rarely	☒ sometimes	☒ often
b)	Be in a natural environment	☒ never	☒ rarely	☒ sometimes	☒ often
c)	Learn about the natural environment (bird watching, plant identification, etc.)	☒ never	☒ rarely	☒ sometimes	☒ often
d)	Other:_________________________	☒ never	☒ rarely	☒ sometimes	☒ often

5) If you spend little or no time in the natural areas of Stanley Park, is it because: (check all that apply)

☒ You do not feel safe ☒ The trails are not paved
☒ You are worried about getting lost ☒ You are not interested
☒ You do not know about the trails ☒

Other:____________________________

6) Which of the following options do you think would encourage people to explore Stanley Park's natural areas? (check all that apply)

☒ More patrollers ☒ More markers on the trails
☒ Educational signs on trails ☒ Opportunities to walk with a group
☒ Other: ____________________________

7) Have you or your family participated in educational programs in Stanley Park? ☒ Yes ☒ No ☒ I don't know

a) If "Yes", which programs? (check all that apply)

☒ Sunday Discovery Walks ☒ Evening Walk & Talk (i.e. Owl Prowl) ☒ Family Workshops
☒ Children's Nature Story & Craft ☒ Birthday or other private function ☒ Bat Walk

☒ ESL Wildside Walk ☒ Birding in Stanley Park ☒ Saturday Species Counts

☒ School Program ☒ Volunteered ☒ Other: ____________________

b) If "No", is it because: (check all that apply)
☒ You haven't heard about them ☒ You are not interested
☒ They are too expensive ☒ You don't have time
☒ Other: ___________________________

8) If you were unaware of SPES programs before, how likely are you to participate now that you are aware?

☒ Not likely ☒ Likely ☒ Very likely

9) If you are interested in participating in SPES programs: (check all that apply)

a) Which seasons would you come to programs? ☒ Spring ☒ Summer ☒ Fall ☒ Winter
b) Which days would you come to programs? ☒ Weekdays ☒ Saturdays ☒ Sundays
c) Which times would you come to programs? ☒ Daytime (8 am - 4 pm) ☒ Evenings (4 pm - 8 pm)
d) What is the best length for programs? ☒ Less than 1 hr ☒ 1-2 hours ☒ 2+ hours
e) How much do you think should ecological education programs cost?
☒ $0 ☒ $1 to $5 ☒ $6 to $10 ☒ $10+

10) What topics are you interested in learning about through educational programs? (check all that apply)
☒ General Ecology ☒ Environmental Issues ☒ Human History
☒ Natural History (such as: ☒ Birds ☒ Plants ☒ Mammals ☒ Trees ☒ Marine)
☒ Other: ______________________

About You: **Sex**: M F **Country**: ______________ **Postal Code/Municipality**: ____________________
Age Category: ☒ 18-25 years ☒ 25-50 years ☒ 50+ years
Survey Location in Stanley Park:
☒ Nature House ☒ Information Centre ☒ Forest Trail ☒ Beach ☒ Seawall
☒ Plaza (Train & Farmyard) ☒ Prospect Point ☒ Totem Poles ☒ Aquarium ☒ Other: _____________
Choice of coupon:
☒ Discovery Walk (Who: adults When: every Sunday, 1 - 3 pm)
☒ Family Workshop (Who: 5+ and their families When: monthly on a Saturday, 1 - 3 pm)
☒ Nature Story & Craft (Who: preschool When: 1st & 3rd Saturday each month, 11 am - 12 pm)
☒ No Thank You

Thank You!

3.0 Survey answers

(Please Note: all values given as percentages of 133 total respondents. Where questions were not answered by all respondents, values do not add to 100).

(available only in printed copy)

APPENDIX C – SPES PROGRAMS

Winter 2001/2002

Sunday Discovery Walks: Different leaders and topics each week. Cost:$5

Listening to the past: art, archaeology and myth join together to provide an exciting tour with archaeologist Peter Ord of the objects and areas that offer clues to the Park's first inhabitants.

Rock around the Park: Explore the fascinating world of Stanley Park's rocks and the stories they can tell us with world-travelling geologist Christ Kenton.

Living Cathedrals: Come explore Stanley Park's living giants in a walking documentary of the relationships between humans and forests with forester and educator, David MacVicar.

Winter Solstice: Celebrate winter solstice, the shortest day of the year, with naturalist Jennifer Swanston. Explore the way that the natural world is included in mid-winter celebrations.

The Pond in Winter: Like Henry Thoreau, we can anticipate spring in mid-winter, by observing signs of the next season beginning to show themselves. Join Dr. Jennifer Getsinger for a walk around Beaver Lake and bring a Nature Journal for recording winter sights and clues of spring.

Temperate Rainforests, Timeless Giants: Walk in the lush temperate woods and experience these truly timeless biological systems with Vancouver's own international tree biologist, Dr. Reese Halter.

Divers and Dabblers: Ducks and other waterfowl are among the easiest bird species to learn to identify and Stanley Park in winter is one of the best places to see lots of them. Learn about their lifestyles and discover how they coexist with birder Cathy Aitchison.

Birds of a Feather Swim Together: Observe the aquatic and marine birds while learning about their life histories, what makes them unique and conservation issues with biologist Brianne Addison.

The New Lost Lagoon Wetland: Learn about the water cycle, aquatic pollutants, wetland ecology and ecological engineering in this walk around the new Biofiltration Wetland on Lost Lagoon.

The Rainforest Cycle – Eagles to Salmon: The salmon cycle is an important part of life in the temperate rainforest. Discover the many connections that lead us from salmon to eagles in a rainforest.

Love Birds: Birds of a feather are flocking together. Learn about their courting behavior and how they mate, with naturalist Gordon Thompson.

Winter Ecology: How does the forest survive the winter and prepare for spring? Join Terry Taylor to discover the unseen preparations that precede the returning of the sun.

Art and Nature: Enrich your experience in nature with a series of activities exploring different methods for observing and recording discoveries with artist Kirsty Robbins. No artistic skills are needed, just a desire to study and learn about nature in a new and exiting way.

Spring Birds: The birds are coming and going. Renowned birder Al Grass will give us a tour of Stanley Park's migrating birds.

Back in Time to O'Brockton Point: Discover the secret buried treasure in Stanley Park with history buff Gordon Thompson.

Forest Ecosystems: Explore Stanley Park's deep, dark forests with forester Drew Hart.

Evening Programs:

Explore the Natural side of Stanley Park: Rare birds, ancient cedars and abundant wildlife – Stanley Park is more than the seawall!! Discover what the depths of Stanley Park has to offer in a slide show by the Stanley Park Ecology Society – cost: by donation

Raptors!: Learn about and meets falcons and hawks with Ted Williams from O.W.L - cost: $8

Other Programs:

Birding in Stanley Park: with Al Grass, last Sunday each month - Cost: by donation.

Species Monitoring: Join our volunteers at the Lost Lagoon Nature House every Saturday at 9am to help count the birds and mammals in Stanley Park – cost: free.

Children's Winter Programs: Nature Story and Craft: Nature games, stories and crafts for 3-6 year olds at the Lost Lagoon Nature House – cost: 2$

Turtles: Come swim with the turtles…at least in your bathtub. We'll make homemade soap with a little turtle toy inside.

Slimy Slugs: Make your own slime as we explore the world of snails and slugs.

Just Ducky!: Thousands of ducks are wintering on lost Lagoon. Come make your own POP-UP duck card so you can take one home with you.

Lovely Ladybugs: Ever wish a Ladybug wouldn't fly away? Come make your own ladybugs as we learn about these fascinating insects.

Family Workshops: (Activities and nature exploration for everyone over 5 years old and their families – cost: $8/family of 4 or $3/individual)

Nature Detectives: Use your senses to discover nature in the forest.

Insect Safari: Uncover insects in the rainforest then design your own edible insect!

Spend Spring Break in Stanley Park:

Mornings: 9:30-12:00 – The Art of Nature (8-12 yr old): Learn how to capture nature in words and drawings. Nature journaling encourages curiosity for studying and learning about the fascinating world of nature. Al materials are provided in this indoor and outdoor program – cost: $60 (including drawing materials and sketchbook)

Afternoons: 1-3 pm – Nature Games (8-12 yr olds): Get to know the wild side of Stanley Park through games, crafts and exploration. See the forest for the trees, go dipping at the wetland and explore a low tide beach – cost: $60

APPENDIX D – GIS ANALYSIS

1.0 Detailed methods

a) Priority areas

i) Calculating A

The digital map of site associations was clipped with a buffered theme of roads during the digitising process to ensure that site associations would be the correct size (accounting for the area of the roads). We used 3.5 meter buffers to produce a 7 meter wide road as this was its approximate width on our paper maps. Clipping with this buffer theme split some of the site association polygons (see Figure 1, this Appendix). For the priority analysis, however, they were not treated as separate and the original polygon boundaries were utilised. There was one case, however, where the new boundary produced by a road was utilised. This was because the original polygon was very large, with part of it containing large patches of ivy and the other part containing many small patches. Since we could see that one half would likely be a very different priority than the other, it made sense to consider the actual site association polygon to be two smaller polygons.

We began our analysis by clipping the map of site associations with ivy. From the table of the new theme produced, we summarised the site associations by area of ivy. The resulting table showed the amount of ivy within each site association.. From the attribute table of our site associations theme, we also summarised site associations by area to give the total area of each site association. The two tables resulting from the summary operations were joined. In the destination table, the site associations with no ivy at all were queried out and removed as they do not need ivy control and thus have no priority.

The area of each site association not yet affected by ivy was calculated and site associations were ranked, with highest rank given to the site association with the least unaffected area. The percent of each site association covered with ivy was also calculated, and site associations were ranked again, with the highest rank given to the one with the highest percent covered with ivy. These two ranks were added for each site association. This summed rank is the letter A in the priority calculation. Thus all polygons from the same site association would be given the same value for A in calculating their priority.

Before continuing with this analysis, we inspected the seven site associations containing ivy, and determined that site association 4.1 was most likely to be lost completely. Due to the nature of our GIS procedure to determine priority, however, it may not have been given top priority. This is a very small site association (0.81 ha in area), with only a small amount of ivy. There is potential, though, for ivy invasion from adjoining site associations, putting its small and unique vegetation communities at risk. For simplicity, our analysis did not include adjacency to highly affected polygons, but we wanted to ensure that 4.1 was given top priority. We therefore removed site association 4.1 from the rest of the analysis, and placed it first on the list of priority areas.

ii) Calculating S, M, and L

The next stage in the priority analysis was determining the number of small, medium, and large patches in each polygon. The original map of ivy depicted high and low density patches as separate polygons. For this part of the analysis, however, adjacent polygons needed to be merged, as their combined areas made larger patches than would have been indicated by their areas as separate polygons. Thus, the first step was to clip a box theme (a digitised box around the entire ivy theme) with the ivy theme. This produced the ivy patch theme, in which adjacent patches were joined. Figure 3 in this Appendix shows a map of this theme, with the patches classed by size. As previously mentioned, small patches are those <500 m^2, medium patches are 500-5000 m^2, and large patches are >5000 m^2.

Once we had the ivy patch theme, we could begin determining the number of patches of each size in each polygon. To start, the first polygon listed in the site associations theme was manually selected . Then, using select by theme, all polygons in the ivy patch theme that intersected the selected site association polygon were selected. These records were promoted and the numbers of small, medium, and large patches were noted. This same process was carried out for all site association polygons. The numbers of small, medium and large patches in each polygon were S, M, and L, respectively, in the priority calculation for each polygon.

iii) Calculating D

The final stage in the analysis was calculating value for D, which is based on the percentage of each polygon covered with high density ivy. First, we reclassified the ivy theme by density to create a new theme of high density ivy. We then clipped the site associations theme with this theme of high density ivy patches. From the table associated with the resulting theme, we summarised the site association polygons by area of high density ivy. We also summarised the polygons by area from the attribute table for the site associations theme, to determine the size of each polygon. This was necessary because, as was stated earlier, some of the polygons were split when clipped with the buffered road. The two tables resulting from the summary operations were joined and polygons with no ivy were removed from the destination table. Next, the percentage of each polygon covered with high density ivy was determined and polygons were ranked with the highest rank given to the polygon with the highest percentage covered. This ranking corresponds to D in the priority calculation.

b) Prevention

Trails and roads were digitised as separate themes, so the first step in the analysis was to merge the two themes. Next, trails and roads were buffered by 5 meters. The ivy theme was then clipped by this buffer to produce a theme of ivy within 5 meters of the trail. From the resulting table, ivy density was summarised by area to show the total area of high and low density ivy within 5 meters of the roads and trails. Next the trails and roads were buffered by 10 meters. The ivy theme was clipped with this buffer to produce a theme of ivy within 10 meters of the trail. Ivy density was summarised by area to show the total area of high and low density ivy within 10 meters of the roads and trails. To find the ivy area between 5 and 10 meters, the area of high and low density ivy within 5 meters from the trail was subtracted from the area within 10 meters of the trail. The same procedure was carried out up to a distance of 105 meters from roads and trails. This distance was chosen because the buffer of 105 meters covers all ivy in the Park.

2.0 Flow charts

(available only in printed copy)

3.0 Maps

Key to Site Association Numbers	
1.0	salal-swordfern
2.0	swordfern-spiny wood fern (typical)
2.1	swordfern-spiny wood fern (steep/colluvial)
3.0	foamflower-swordfern
4.0	ladyfern-foamflower-swordfern (typical)
4.1	ladyfern-foamflower-swordfern (ravine)
5.0	deerfern-salal
6.0	skunk cabbage
From: Beese 1988b	

Figure 1 - Site associations in the forest of Stanley Park

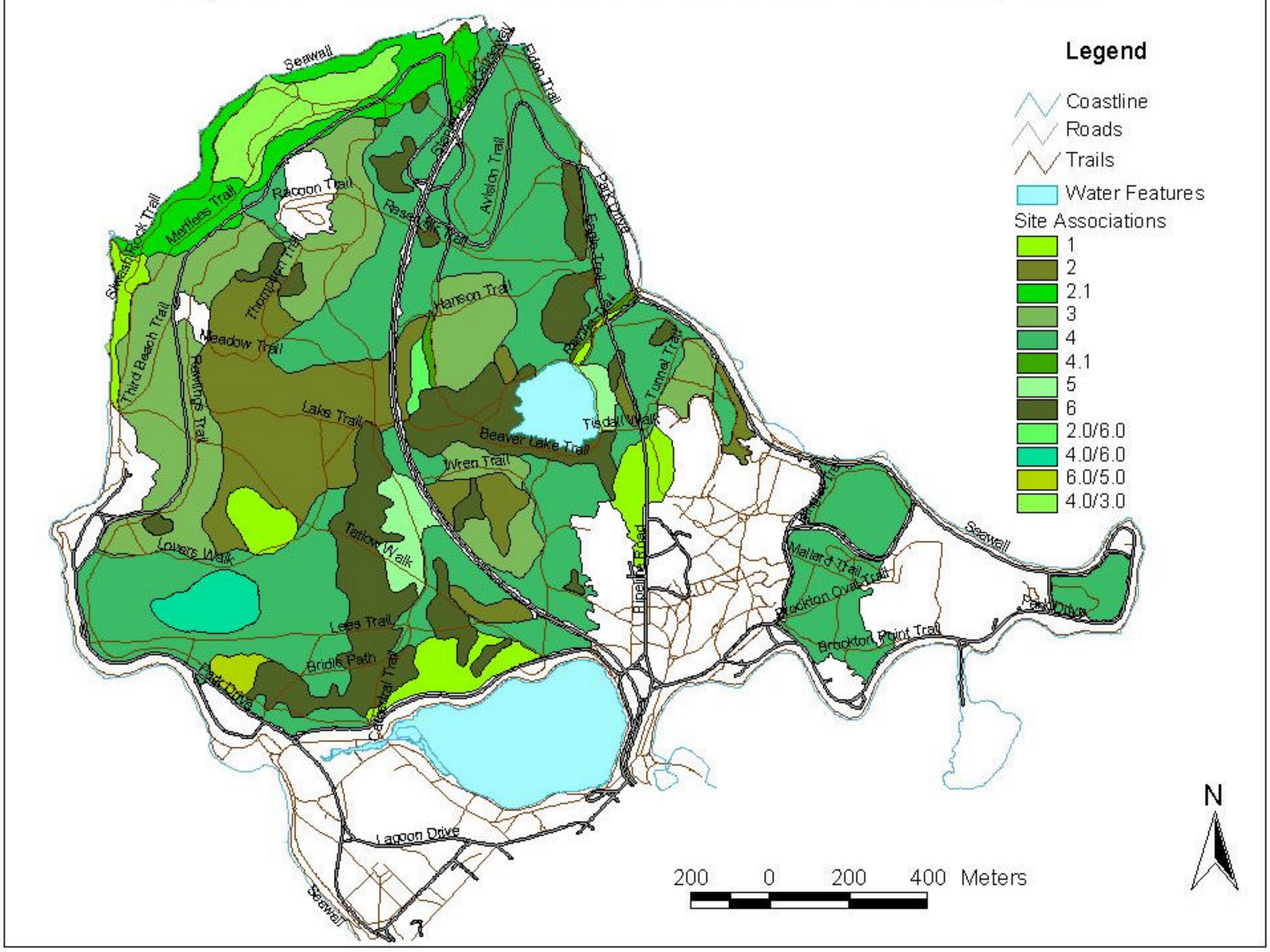


Figure 2 - English ivy in the forest of Stanley Park

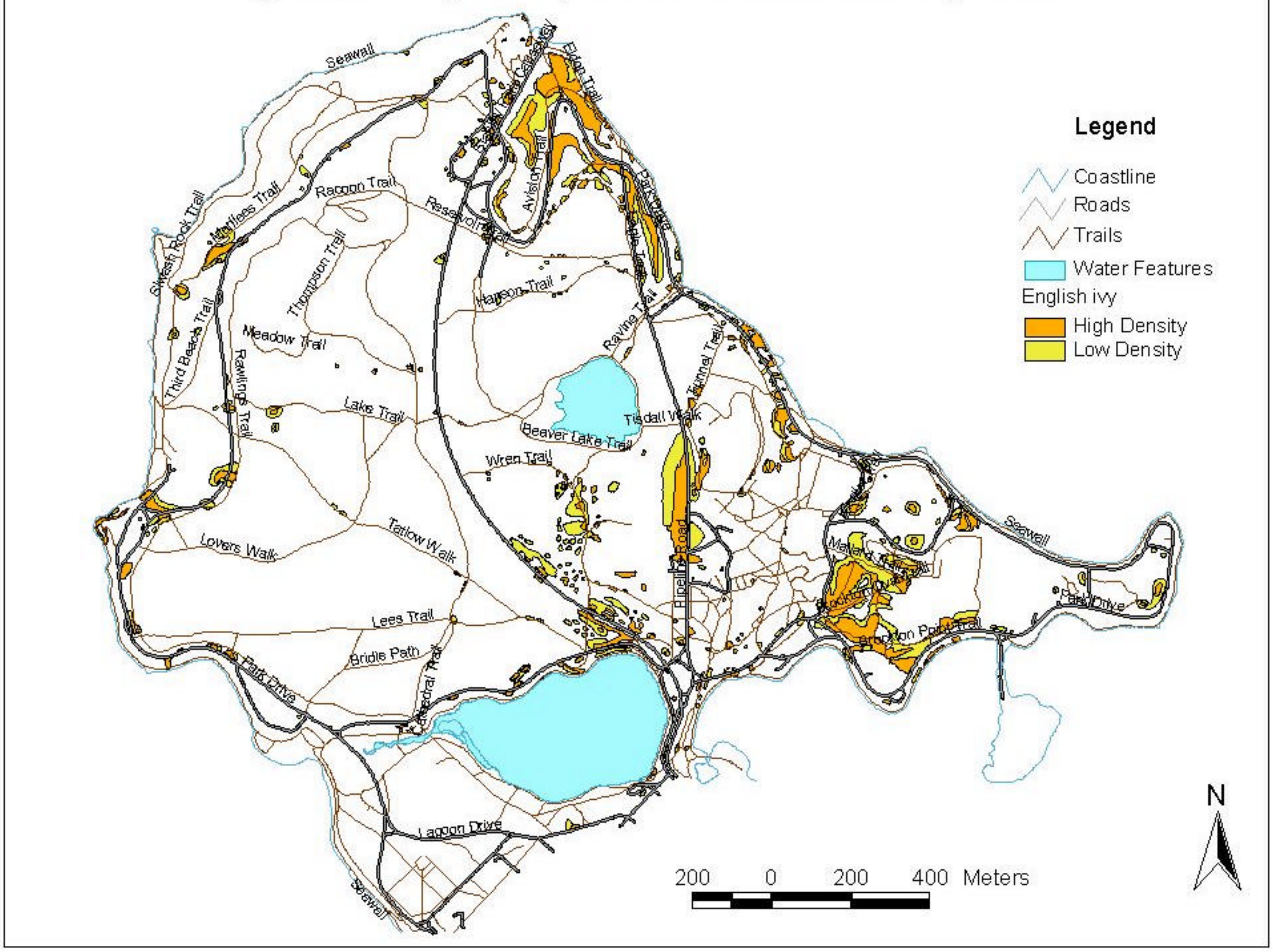


Figure 3 - Location and size of ivy patches in the forest of Stanley Park

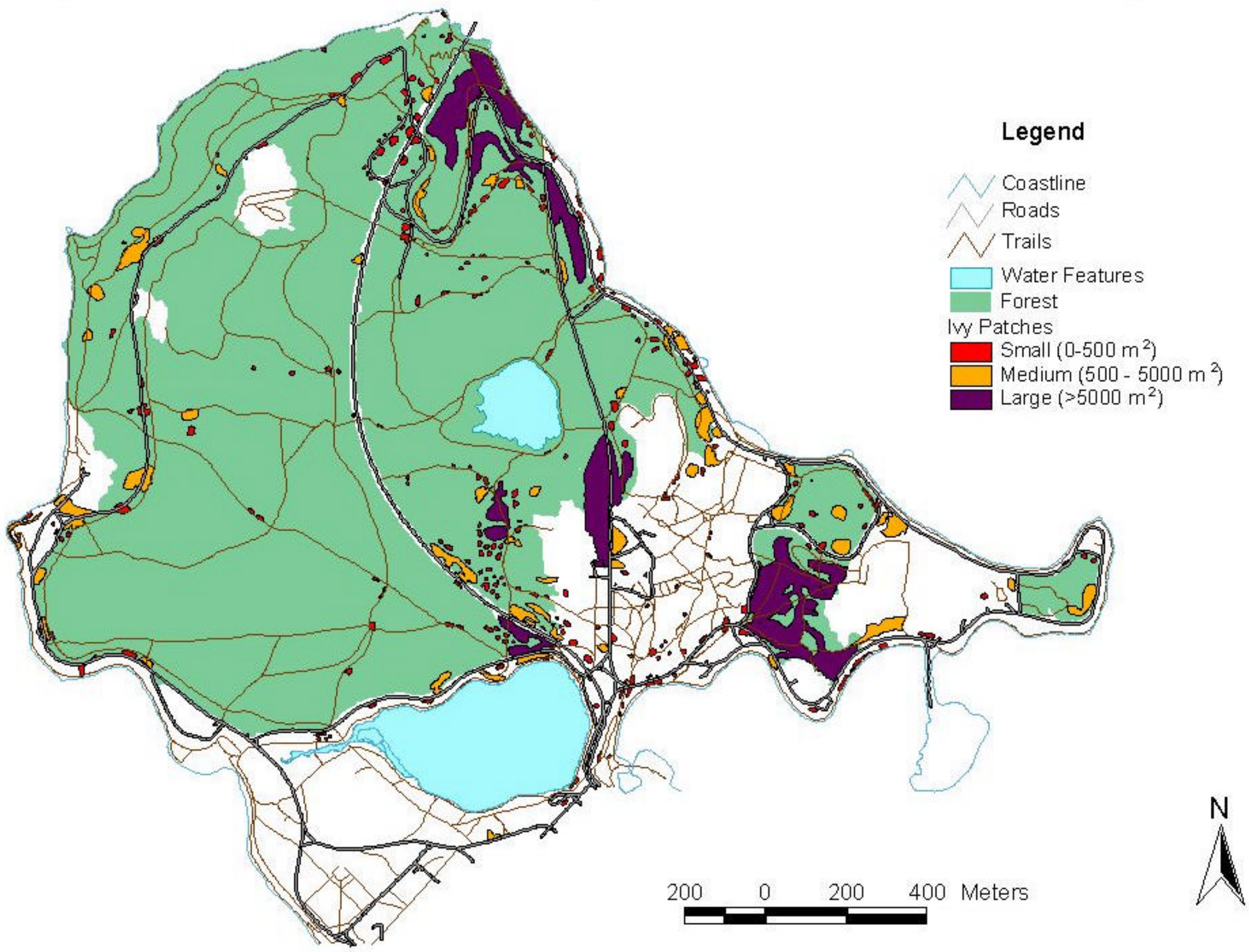
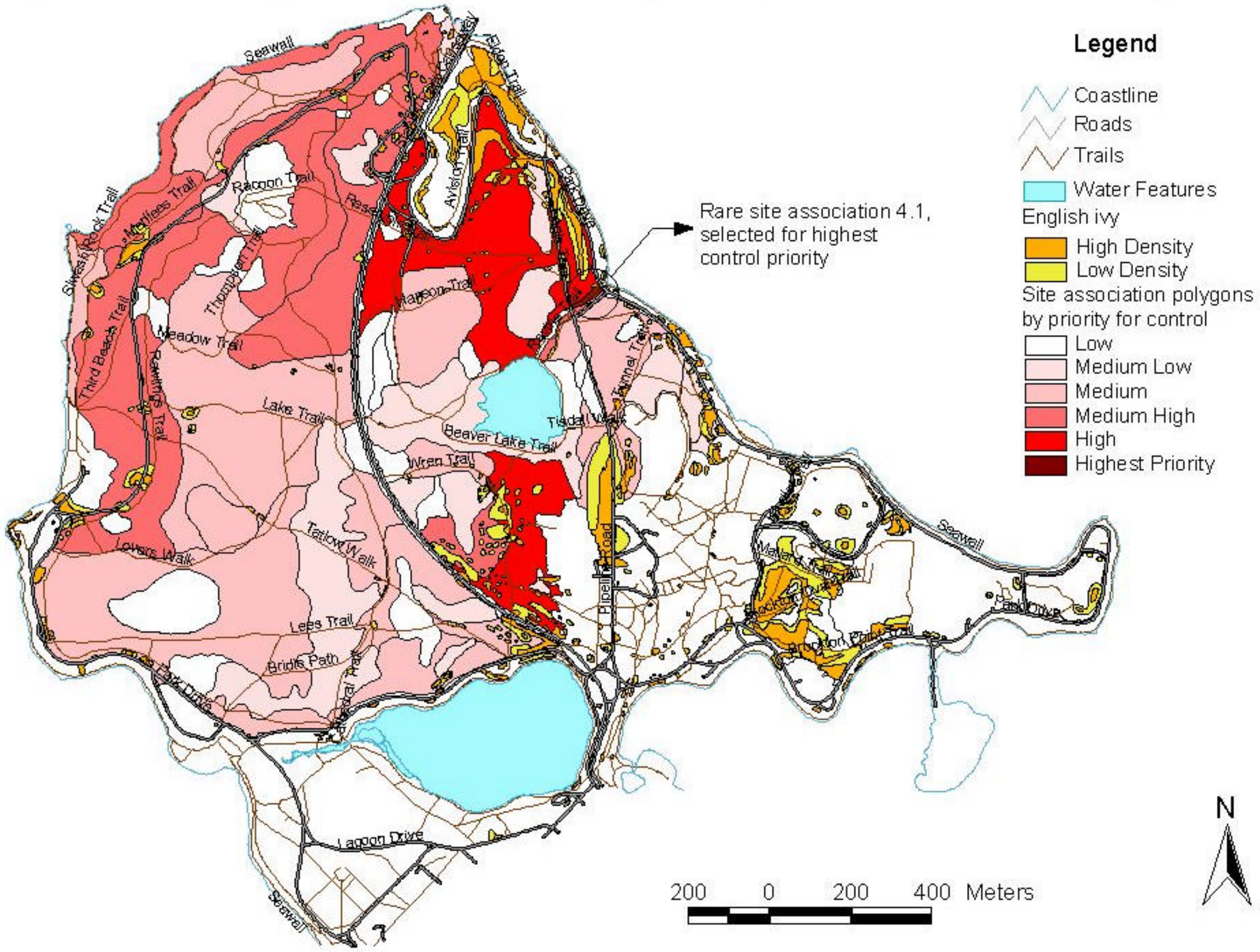


Figure 4 - Priority control areas for English ivy in the forest of Stanley Park



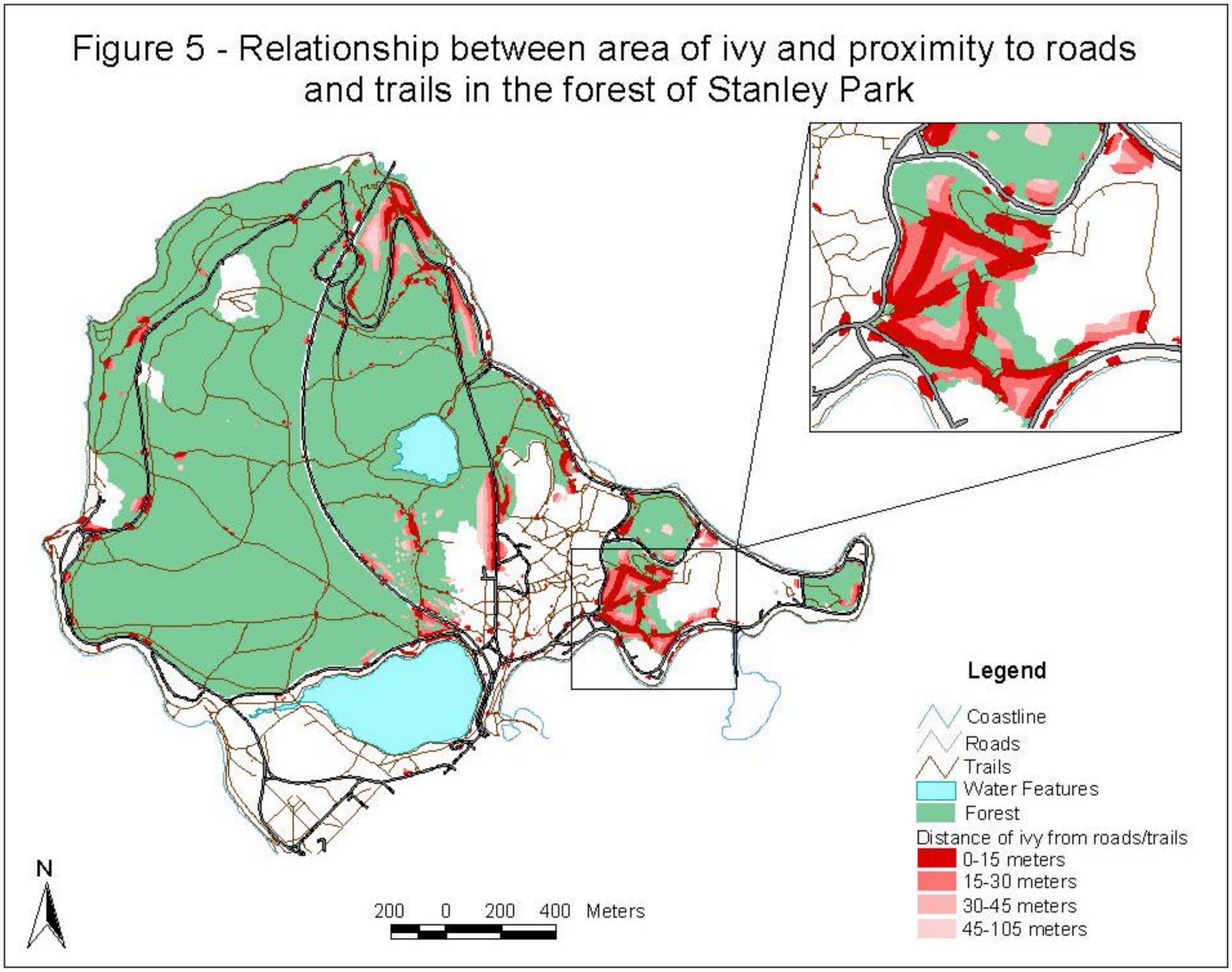


Figure 5 - Relationship between area of ivy and proximity to roads and trails in the forest of Stanley Park
Legend
Coastline
Roads
Trails
Water Features
Forest
Distance of ivy from roads/trails
0-15 meters
15-30 meters
30-45 meters
45-105 meters
N
200 0 200 400 Meters