Autecology, Ethnobotany and Agronomy of *Balsamorhiza sagittata*:
Northwestern Plateau, British Columbia

by

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ABSTRACT

This research examines an edible and medicinal plant species, *Balsamorhiza sagittata* Pursh (Nutt) (balsamroot, or spring sunflower). Included are: 1) a study of literature concerning previous uses and potential agronomic applications of *B. sagittata*; 2) an ecological study to assess the general habitat requirements of *B. sagittata* at three populations in the Northwestern Plateau of British Columbia; and 3) an agronomic study of *B. sagittata*, the main purpose of which is to explore the development of the species in a cropping system or as a horticulture plant.

Ethnobotanical literature confirms that *B. sagittata* has a long tradition as a highly significant food and medicinal resource on the Northern plateau. A review of botanical and range literature indicates that the species is an ecologically important forb in sagebrush ecosystems.

Ecological data collected was significantly different between the field sites. The only variable that was statistically similar at the Pavilion Mountain, Hat Creek Valley and Botanie Valley research locations was the number of blooms on the *B. sagittata* plants. Furthermore the data did not indicate significant correlations to explain variation in the number of *B. sagittata* plants between sample plots.

Preliminary agronomic experiments indicate that *B. sagittata* can be propagated by seed, both in a greenhouse and at a field location. Treating seeds with ethylene before stratification significantly increased seed germination.

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ACKNOWLEDGMENTS

I embarked on this Master's oblivious to the nature of personal growth it would foster. Now, writing the final pages, I am aware of the enriching journey that it has been. I also recognize how impossible this project would have been without the immense support of collegues and friends.

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The Xaxl'ep have taught me about their land and have provided a unique example of a people who have an immense capacity to care and find laughter in any situation. In particular I would like to thank Art and Marilyn Adolph who welcomed me into their home. In Pavilion Dez Peters Senior inspired me with his wealth of knowledge and sense of humour. Dez and Art helped me to see the land in ways that I never could have seen it on my own.

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DEDICATION

This thesis is dedicated to all people who in the face of globalization and the industrialization of agriculture continue to maintain a strong connection to the land.

- To the Xaxl'ep, a remarkable people who against incredible adversity and struggle continue to protect their knowledge and land for their children and consequently for ours.
- And to my family, generations whose love of nature and strong connection to the land has passed down to me, taught by example and in the ways that they have chosen to live their lives.

1.0 Introduction

Balsamorhiza sagittata: A Case Study in Applied Ethnobotany

We are indebted to the Indigenous Peoples[1] for many of the foods that we eat and medicines in our cupboards. After all, it is the Indigenous Peoples who discovered the diversity of uses for native plants, and incorporated them into their diets. Traditional Peoples frequently went beyond merely harvesting native plant resources. They actively managed landscapes to ensure and increase native plant production. In some cases, management techniques resulted in domestication of plants. Original species became varieties very different from their botanical ancestors. In many Indigenous communities active harvesting and management of plant species is remembered and continues to be practiced to this day. The knowledge that these communities possess is a valuable resource for cultural and physical health, and has the potential to restore damaged landscapes, protect biodiversity, and contribute to the well-being of humans as a whole. Indigenous Peoples know many food and medicinal plants with the capacity to feed and care for people. The tropics currently are areas of intense investigation for medicinal plants and knowledge. The knowledge held by people in temperate regions like British Columbia, however, is also extensive.

This thesis presents a case study of one plant species from the temperate regions that has various traditional uses and a great number of potential future uses. *Balsamorhiza sagittata* (Pursh) Nutt. (Asteraceae) (Figure 1.1), commonly known as arrow-leaved balsamroot or spring sunflower, is considered by ethnobotanist Dr. Nancy Turner to be "ranked among the most versatile food plants used by the peoples of the southern interior" (1997a: 93). A dominant forb in semi-arid grasslands, *B. sagittata* is of cultural and ecological significance throughout its growing region. Traditional ethnobotanical studies document the use of *B. sagittata* as a food and medicine. They also document a range of complex management strategies and harvesting techniques that enhanced this plant resource.

Balsamorhiza sagittata has a variety of possible economic and ecological

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[1] In this thesis the terms 'Aboriginal', 'Indigenous', 'Traditional' and 'First Nation' are used interchangeably.

Figure 1.1 *Balsmaorhiza sagittata,* commonly known as arrow-leaved balsamroot or spring sunflower.

Source: Bob and Nancy Turner

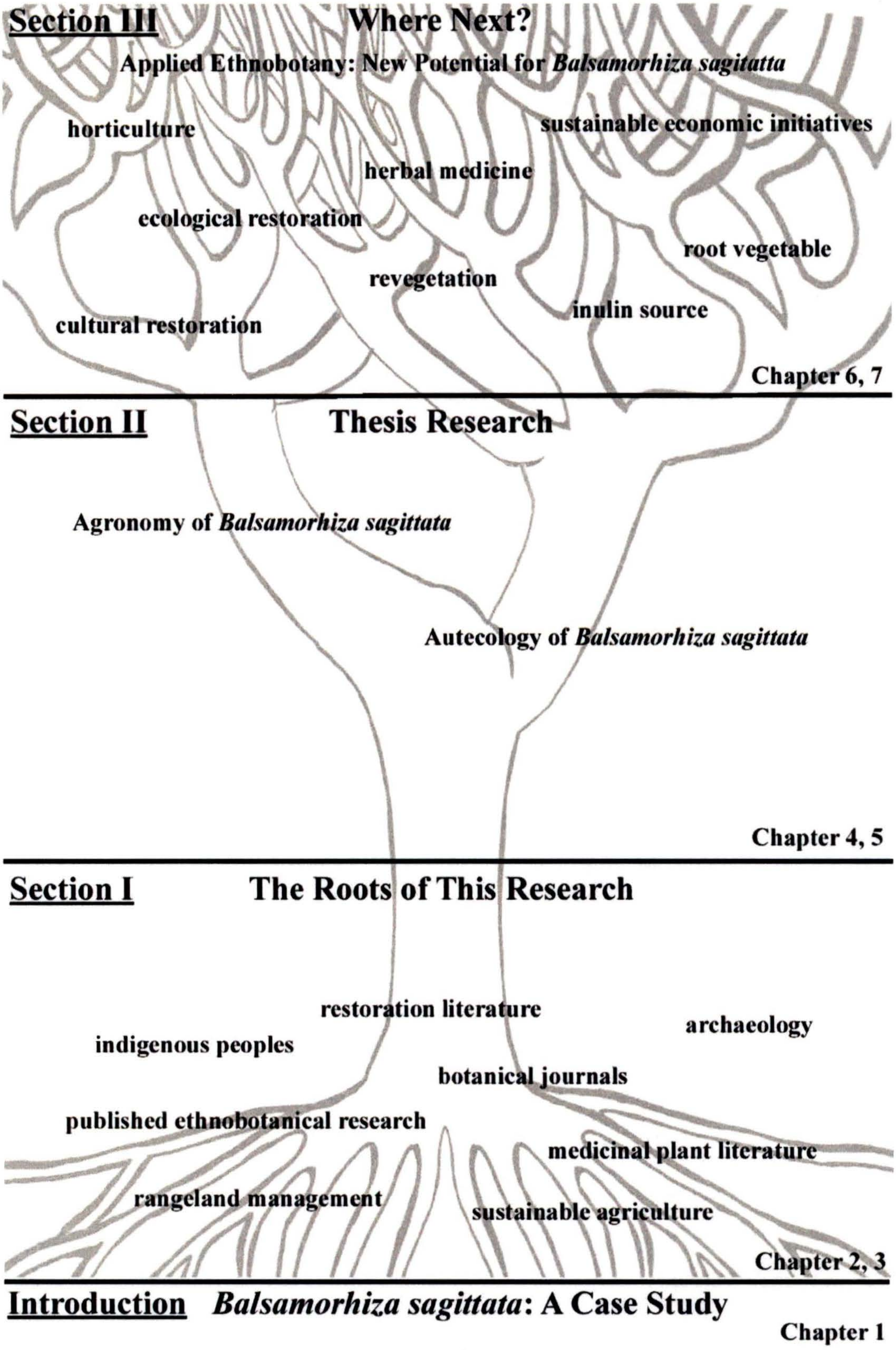
applications. It can be used as an ornamental, an inulin source (processed crop), a herbal medicine (due to antimicrobial properties), for restoration (especially slope stabilization and mine reclamation) and as an edible vegetable. Plants like *B. sagittata* have potential for production in a native plant nursery as well as cultivation in a cropping system.

Before a plant such as *B. sagittata* is marketed for its future potentials there are a number of factors that need to be considered. These include the life history of the plant, its ethnobotanical uses, and agricultural and commercial prospects. In particular it is important to understand what the areas of possible environmental and cultural impacts are before a plant is harvested or cultivated. Plant species such as *B. sagittata* have been used traditionally and presently by many indigenous communities. Because of this previous knowledge the Indigenous People who used the plants should be incorporated in the benefits of any research as well as the design of research projects focused on plants. For my research the Xaxl'ep community was involved in the selection of the plant, research locations and establishing the objectives of the research. I discuss the Xaxl'ep further in section 1.1.1.

In Chapter 2 I summarize the existing body of literature on the autecology of *B. sagittata*. Chapter 3 presents the ethnobotany of the species as determined through an extensive literature search. Chapter 4 summarizes field studies conducted on well-known populations of *B. sagittata* in the Northwestern Plateau of British Columbia. Descriptive ecological sampling was undertaken at the floristic level with characterization of a number of variables in order to evaluate the local status and community characteristics of *B. sagittata*. Chapter 5 explains the steps taken in attempting to grow *B. sagittata* in the field and in a greenhouse environment. The results are discussed and possible influences on germination rates and survivability suggested. Chapter 6 describes the environmental and economic potential for *B. sagittata.* Chapter 7 concludes by addressing specific concerns of economic feasibility for the Xaxl'ep. Figure 1.2 displays the organization of my research.

My research builds on an existing body of literature relating to applied ethnobotany, native plant propagation and the propagation and natural history of *B. sagittata.* As noted above, there are a variety of concerns inherent in marketing a

Figure 1.2 Organization of my thesis.



native plant. These concerns are addressed throughout my thesis. The combined study of the ethnobotany, agronomy and ecology of *B. sagittata* provides a framework for applying ethnobotanical knowledge to community economic development.

1.1 **Background**

This project builds on a considerable body of previous research conducted by ethnobotanist Nancy Turner. Turner, along with linguists and Elders, has spent three decades documenting details of botanical plant uses of the Xaxl'ep People of the Stl'atl'imx (Lillooet) Nation (Turner 1974, 1987, 1989, 1998). In 1997, Turner and the Xaxl'ep began collaboration to determine and assess the potential applications of Xaxl'ep culturally important plants to community economic development, and to the restoration of environments damaged through industrial forestry, overgrazing, and other unsustainable activities (Turner 1997a). Specific fields of interest include harvesting and production of native plants for traditional foods, cosmetics and possibly medicines; habitat enhancement and restoration; plant propagation and nursery production; eco-landscaping; seed production for forestry, restoration, and gardening. This research on *B. sagittata* is one component of the environmentally sustainable economic initiatives being investigated by the Xaxl'ep and is applicable to many of the areas of interest.

1.1.1 The Xaxl'ep

The Xaxl'ep (Stl'atl'imx, or Fraser River Lillooet) People are members of the Interior Salish language family, who trace their ancestry to coyote, the most prominent figure in their oral traditions (Hayden 1997). "Lillooet peoples are categorized into two dialectic groups -Lower Lillooet and Upper Lillooet" (Turner 1974:11). The Xaxl'ep People are on the northeast edge of the Stl'atl'imx Territory, and are thus of the Upper Lillooet group. Stl'atl'imx territory encompasses several ecological zones, each with characteristic vegetation (Turner et al. 1998). Further information on Xaxl'ep culture and environment is presented in Chapter 2.

1.1.2. Indigenous Peoples and Plant Use

Indigenous People are recognized as the primary sources of knowledge for successful and sustainable uses of plant and animal resources, particularly within their culture (Kuhnlein and Turner 1991). Use of plant resources influenced living and seasonal movement patterns of Traditional Peoples as well as their general lifestyles and group dynamics (Turner 1992). The significance of plants to the existence of Indigenous Peoples of the Northwest has been largely underemphasized and is something that the research program of N. Turner, the University of Victoria, is focused on rectifying. First Nations People have managed the plant and animal communities of the interior of British Columbia for thousands of years. In an article for *Business Farmer*, Turner (1999: 6) emphasizes the relationship between First Nations people and the sustainable management of native plants:

> Aboriginal peoples in British Columbia have had a long-standing relationship with native plants, extending back thousands of years. ...Aboriginal peoples...have carefully managed their plant resources to maintain their abundance and productivity.

The Xaxl'ep People have a strong affinity with their land. Knowledge of the land includes a detailed understanding of plants and animals and their habitats, lifecycles and interactions. Plants and the landscape and habitats in which they grow have always been of fundamental importance to the health and well being of the Xaxl'ep People (Turner 1997a). I argue that if a particular plant species is to be used for economic gain then it should directly benefit the original users and involve them in the development and marketing, especially if its use involves knowledge from the original users.

1.2 **Applying Ethnobotany to Community Economic Development**

The practice of ethnobotany has changed over the past century since John Harshberger first coined the term 'ethnobotany' in 1896. In its beginnings ethnobotany was concerned with "the use of plants by people". Ethnobotanical methodology has not followed a rigid structure. Fowler (2001:149) notes that ethnobiologists followed "particularly diverse fields of inquiry, embracing several subdisciplines in biology and anthropology, ethnobotany and ethnobiology [and] were perhaps more consistent in their focus on a subject matter than they were in either how that subject matter was approached or how data were defined and gathered". According to Ford (2001:7), the field of ethnobiology "has not developed significantly with new theories for some time but it has exploded in applied directions, a trend that will continue further in the future". The expanding interest in ethnobotany is also resulting in a shift in ethnobotanical practices to an attempt to include co-operative research and applied projects within the overall objectives of the discipline (Davidson-Hunt 2000). Through the current "ethnobotanical renaissance" (King 1996) there has been a focus on the revitalization of Indigenous cultures.

Throughout British Columbia there is a movement to document Indigenous Peoples' knowledge and to map their uses of the landscape and its resources. In the context of government policy, the documentation of such knowledge is termed a Traditional Use Study or TUS. A critical question is, 'what can be done with this information?' It is a goal of applied ethnobotany to incorporate Traditional Ecological Knowledge (TEK) into contemporary commercial ventures. In *Ethnobotany, Principles and Applications*, Cotton (1996: 313) writes, "interest in the potential application of ethnobotanical research has, in recent years, shown a marked resurgence." Ethnobotanical applications pertaining to ecology can be placed in two major categories: economic development and resource conservation. The greatest underlying values of applied ethnobotany are self-sufficiency, continued connection with the land, resource sustainability, and search and rebuilding of local identities. Many communities are in the process of reconstructing their identity on the basis of their cultural and ecological knowledge. Any development involving these communities should maintain a strong cultural context. Today there are perhaps more opportunities than ever before to apply such traditional botanical knowledge in community economic development (Turner 1997a). Traditional resource management knowledge, from crops to cultural techniques, is fading but can be useful to environmental managers, conservationists, and biologists (Anderson 2001). Chapter 6 presents the ways in which *B. sagittata* can be applied to community development and ecological restoration.

1.2.1 Applied Ethnobotany: Germination and Propagation of Native Plants

The germination and propagation of native plants, possibly leading to the development of a native plant nursery, is a utilization of ethnobotanical knowledge that meets the objectives of both economic development and environmental conservation. Initiatives based on the local knowledge of plants can help to recontextualize traditional botanical knowledge. Plants grown in a Xaxl'ep nursery could be used for horticulture, restoration, education, value-added products, food, medicine and cultural restoration. The Xaxl'ep Ethnobotany (Turner 1998) identifies a number of plants valuable for these uses. A native plant nursery, using the best known germination and propagation techniques would allow for the application of traditional ethnobotanical knowledge through the cultivation of plants that are of cultural and ecological significance, and could result in a continuation of past resource management techniques.

1.2.2 Ecological, Economic and Cultural Benefits of Growing Native Plants

The act of bringing native plants into production is important to conservation and ecological restoration and also has a role in assisting sustainable community development. Throughout the world, native plants are being considered for domestication and commercialization to improve the livelihood of rural peoples (Mwamba *et al.* 2000). Such improvements could be in cultivation systems, income-generating opportunities and nutritional health. An established native plant nursery would provide a community with access to plants and medicines for use in cultural or ecological restoration projects.

Native plants not only have economic and ecological value, but they have strong cultural and symbolic significance. The Xaxl'ep focus on community development has a broader, more human perspective than the market-driven approach to economic growth. The empowerment of the Xaxl'ep to affect the course of social and economic change in their community is best approached from a strategy that is both ecologically and culturally sustainable. Resources also can be defined by their cultural value. Cultural resources may be needed for spiritual, artistic, aesthetic or perceived intrinsic value. Cultural resources include not only sacred places, but biological species as well (Martinez 1999). Local peoples' needs, priorities and preferences should be considered when identifying plants to be cultivated. Many plants may not have market potential but are important culturally; growing them may thus result in a continuation of a people's heritage. With the rise in concern over biodiversity the merit of protecting cultural diversity is gaining appreciation.

Traditional Peoples largely identify with the resources that they have used for generations. It is worth noting that the root meaning of the word *resource* is not 'commodity for extrapolation' or 'raw material', but French for *resoudre*, "to rise again" (Anderson and Nabhan 1991). Increasingly there is an indication that "people are constructing their identity on the basis of their cultural and ecological knowledge" (Davidson-Hunt 1999). Thus, growing native plants can assist with community economic development, ecological restoration and replacement of environmentally detrimental economic initiatives, and can help in cultural preservation and reconstruction. Further details on the feasibility and benefits of growing native plants are provided in Chapter 3 and specifically in Chapter 6.

1.2.3 Why this Research is Ethnobotany

Sometimes ethnobotany is viewed narrowly as encompassing just past or traditional botanical knowledge and practices. The Xaxl'ep did not traditionally cultivate horticultural varieties of plants. The germination and propagation of native plants may thus not seem to be an appropriate means of applying ethnobotanical knowledge to community development. Indigenous people everywhere, however, have survived because of their ability to adapt to changing conditions. Adaptation frequently involves combining traditional knowledge with 'modern' technology to perpetuate indigenous culture. Turner (1997c: 287) illustrates this point:

> Another aspect of sustainable resource use is the ability to adapt to changing circumstances. Indeed the ability to adapt and assume new knowledge, new resources, and new technologies is an important feature of traditional knowledge systems.

Academics use the term "syncretism" to refer to Indigenous Peoples' ability to absorb external technologies and influences and to use them for their own benefit. Wright defines syncretism as "the growing together of new beliefs and old...a way of encoding the values of a conquered [sic] culture within a dominant culture" (1992:150). It is through the selection of some aspects of European culture and technology and the dismissal of others that Indigenous People have been able to maintain their "worldviews and lifestyles" (Turner 1997c: 87). Furthermore, Atleo (1999:11) argues that the combination of science and traditional knowledge can assist in the restoration of the landscape:

> The applications of science and technology that magnificently express human cognition can complement the human spirit. The two working together can create ecosystems that are not only sustainable but also beautiful, bountiful and glorious, as it was in the beginning.

Cultivation of native plants, a continuation of traditional practices, can combine Western technology and values with traditional knowledge to benefit not only the Xaxl'ep and other Indigenous Peoples but the landscape as well. Development of a native plant nursery flows out of past and ongoing customary practices. In his comprehensive book on North American Agriculture, *Cultivated Landscapes of Native North America*, Doolittle (2000:463) notes the changing perspective of Northwest Coast hunter-gatherer societies:

> Calling these people 'agriculturists' is certainly stretching the term. Doing so, however, certainly seems to be in order. The evidence, ethnographic and archaeological, is definitely sparse. But, as scant as it is, it is tantalizing. Some plants were protected, others encouraged, and yet others cultivated. This was observed by some of the earliest ethnographers and then forgotten. Recently, this old work was rediscovered and the topic of agriculture here is now undergoing somewhat of a renaissance. The greatest lesson from the Northwest, at least for now, is that native cultivation continues to be a promising line of research with much to be learned.

Bearing in mind that there is still much to learn, it is recognized that many so-called hunter-and-gatherer communities are guided by the same dynamics as those of horticultural and agricultural peoples (Peacock and Turner 2000). Growing cultural plants in a nursery setting is therefore concurrent with the ideas of the Xaxl'ep peoples' traditional management of native species. Further ways in which Indigenous Peoples interacted with and managed plants are presented in Appendix 1.

1.3 **Intellectual Property Rights**

A current study involving the cultural knowledge or traditional resources of Indigenous Peoples would be remiss without acknowledging the ethical and legal issues of rights to intellectual property and traditional resources (Bannister 2000). Ethnobotanists are becoming increasingly concerned with the accountability of their research. As a result they are working more closely with indigenous and Traditional Peoples to develop codes of conduct (Davidson-Hunt 2000). There also is a developing body of international law to which ethnobotanists must be attentive. The Declaration of Belem, presented in Appendix 2, was one of the first signals that a change was occurring in the practice of ethnobotany. This declaration was developed as a self-regulating set of guidelines during the First International Congress of Ethnobiology held in 1988. It provides a basic set of ethical guidelines for carrying out ethnobotanical research (Posey and Dutfield 1996). There also have been a number of initiatives undertaken to reform international law in order to provide protection for indigenous cultural and natural resources.

Internationally one of the most pressing concerns with any development initiatives that involve traditional knowledge or indigenous communities is Intellectual Property Rights (IPR). The purpose of IPR is summarized by Greaves (1994:4) as "a legally workable basis by which indigenous societies would *own* their cultural knowledge, *control* whether any of that knowledge may be used by outsiders, and require acknowledgment for its authorized commercial use." Posey and Dutfield (1996) stress that the reasons why IPR is becoming a more pressing issue are because more and more traditional lifestyles, knowledge and biogenetic resources of indigenous, traditional and local peoples have been deemed by governments, corporations and others to be of some commercial value, and therefore to be property that might be bought and sold. The knowledge of economic value includes knowledge of agricultural varieties, future agricultural varieties, herbal medicines, musical instruments, plants for technology, and more. It is impossible to fully quantify the market value of traditional knowledge.

The concept of IPR was originally developed to protect individual and industrial inventions. Because IPR has not risen out of an indigenous mandate there are a number of conceptual problems with enforcing it. Typically IPR is established through patents and contracts. However, the extent to which people hold intellectual property rights in law for genetic material is limited by current patent laws and is still an evolving and vigorous area of debate (Posey and Dutfield 1996). IPR laws generally are inappropriate and inadequate for defending the rights and resources of local communities. The protection that IPR offers is primarily economic, whereas the interests of Indigenous Peoples are partly economic, but also linked to self-determination. Greaves (1994) also notes that copyrights and patents are for new knowledge, not for knowledge that already exists. Furthermore, copyrights and patents are conferred on individuals or corporations (legal entities acting as individuals), thus providing ownership rights that are denied to other members of society. Patents also are ineffective because they are meant to confer temporary rights that have a predetermined expiration date. Contracts provide fewer impediments but are difficult to execute. Indigenous Peoples do not usually have the funds to pursue breach of contracts and laws are difficult to enforce across borders. Posey and Dutfield (1996:33) argue that:

> The value of end-products developed from resources and knowledge of Indigenous Peoples is usually far greater than the benefits returning to those peoples....Just compensation is a moral obligation; it can also be argued that international principles make compensation a legal right.

Several international legal instruments contain useful principles and rights that contribute to the protection of Indigenous Peoples' resource knowledge. However these are often ignored.

It is difficult to protect knowledge that extends beyond one group and may exist over a broad geographical region. It is unrealistic to patent a plant that grows naturally across an entire continent. IPR is a tool for reinforcing and defending cultural integrity against ethnocide but its effectiveness is still under debate. For the Xaxl'ep, the plants that they use may be of cultural significance for people throughout the Interior of British Columbia and south into the United States. To protect the plants and the rights of the people who use them, it is recommended that the Xaxl'ep work jointly with neighboring indigenous groups on economic initiatives.

1.4 **Writing About Indigenous Peoples**

It is important to note at the outset that what relates to one group of Indigenous People cannot be assumed for all. In a report by the International Co-operative Alliance, United Nations Department for Policy Coordination and Sustainable Development, it was estimated that there were 300,000,000 indigenous people in the world, in more than 70 countries (2000: UN website). Literature on ethnobotany and anthropology necessarily and repeatedly addresses the complexity of the diversity of Indigenous Peoples. Turner (2000:1276) notes:

> Indigenous Peoples are diverse, and cannot be treated as a single entity, in opposition to industrial or postindustrial society. Each indigenous people has its own unique economic, practical, spiritual, political, and historical relationship to its homeland. Within indigenous societies, too, knowledge is not homogeneous.

Thus the information that follows may be applicable for many Indigenous groups in part or whole. The intention of this paper, however, is to address the Xaxl'ep situation specifically.

1.5 **Conclusion: A Beginning**

According to Balick and Cox (1996), the very course of human culture has been deeply influenced by plants, particularly plants that have been used by Indigenous Peoples around the world. This research on *B. sagittata* illustrates how one species can serve as a case study for the synthesis of ethnobotanical knowledge, modern agriculture, community development and conservation. Projects that find new contexts for traditional knowledge may contribute towards ecosystem resilience, community self-sufficiency and the perpetuation of Indigenous Peoples' connection with the land. Today there are perhaps more opportunities than ever to apply traditional botanical knowledge in community development. While reading this thesis, it is important to remember that this is a case study of one species and in the words of Charles Waterton, a British naturalist: "No doubt there is many a balsam and many a root yet to be discovered, and many a resin, gum and oil yet unnoticed" (1826 *Wanderings in South America*, in Plotkin 1993).

2.0 Autecology of *Balsamorhiza sagittata*

The purpose of this chapter is to present a synopsis of the published literature on the autecology[1] of *B. sagittata*. Information was compiled through an extensive search of ecological, range management, and botanical literature. Most of the literature originates from the western United States. There is little published information based on research conducted in British Columbia. My own field research on the autecology of *B. sagittata* will be covered in Chapter 4.

The natural history of *B. sagittata* has not been thoroughly studied. Predominately, the published research stems from investigations into rangeland management and forage productivity (e.g. Bunting 1985; Hermann 1966; Stubbendiek et al. 1982). The following information is useful in providing a broad understanding of the ecological significance of *B. sagittata* and in developing germination and propagation strategies for its cultivation.

The format used here to present the information on *B. sagittata* is a modified version of that developed by Haeussler and Coates (1986) and Haeussler et al. (1990) in the series on the autecological characteristics of plants in British Columbia. Some topics have been eliminated because of a lack of published research. Other topics were added to support material covered in Chapter 6.0 (Potential Future Uses of *B. sagittata*). Explanatory notes for each topic are provided.

2.1 Description

The first section of this chapter provides a brief botanical description of *B. sagittata* including its growth form, distribution, phenology, variation, and stem, leaf, flower, and fruit characteristics.

2.1.1 Taxonomy of the Genus and Species

Balsamorhiza sagittata (Pursh) Nutt. is in the tribe Heliantheae of Asteraceae

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[1] Autecology is the term most frequently used to refer to the ecology of an individual organism. Haeussler, et al. (1990: 1) defines the study of plant autecology as "the ecological interactions between a plant species or population and its environment."

(Aster or Sunflower family), also known as the Compositae or composite family. The genus name, *Balsamorhiza,* is the Greek term for balsamroot. The roots (*rhiza*, root) are thick with a balsam-like resinous outer bark. The species epithet *sagittata* refers to the 'arrowhead-shaped' (sagittate) leaves. Frequently used common names for *B. sagittata* include: arrow-leaved or arrow-leaf balsamroot, spring sunflower, wild sunflower, gray dock, breadroot, and ***suxwem*** (in the Stl'atl'imx language of the Xaxl'ep). Botanically *B. sagittata* is not a true sunflower although both sunflower (*Helianthus* spp.) and *Balsamorhiza* species belong to the same tribe.

There are 11 species of *Balsamorhiza* in North America. *Balsamorhiza sagittata* is considered to be the most abundant balsamroot species in the intermontane area and the only one with simple deltoid or sagittate leaves (Stevens et al. 1985). *Balsamorhiza sagittata* hybridizes with *B. careyana* (Carey's balsamroot), *B. hookeri* (Hooker balsamroot), *B. incana* (hoary balsamroot), *B. rosea* (rosy balsamroot), and *B. serrata* (toothed balsamroot) (Cronquist 1955; Hermann 1966). Other species of *Balsamorhiza* include *B. deltoidea* (deltoid balsamroot), *B. macrophylla* (large-leaved balsamroot), *B. hirsuta* (hairy balsamroot), *B. macrolepis* (big-scale balsamroot), and *B. sericea* (silky balsamroot).

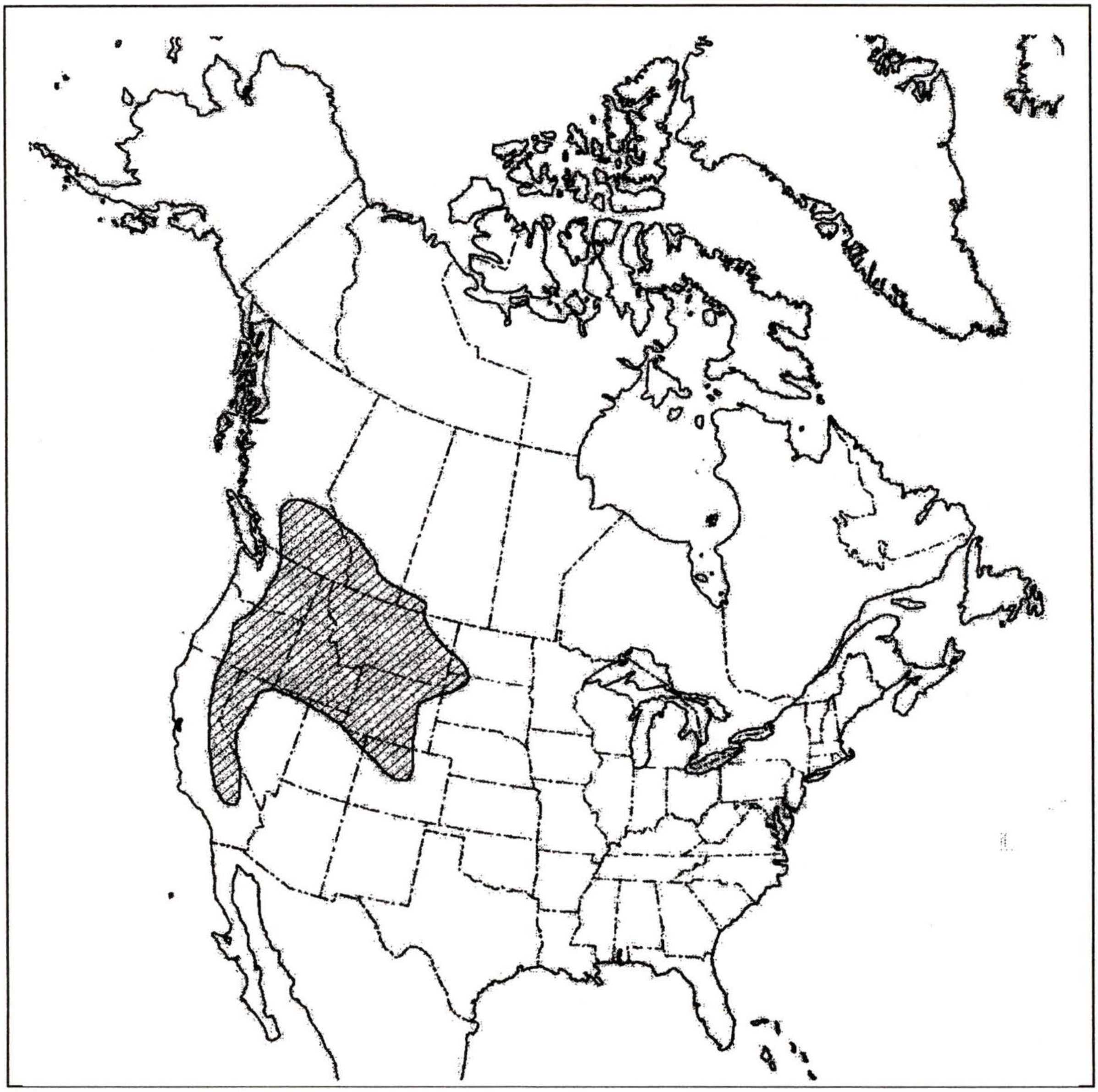
2.1.2 Range

Balsamorhiza sagittata is confined to western North America, occurring along the east side of the Cascades from central British Columbia south to California and east through Nevada, to Colorado, the Black Hills of South Dakota and southern Saskatchewan (Figure 2.1).

2.1.3 Distribution

This dominant forb, a non-grasslike herbaceous plant, is commonly seen in large patches growing on open grassy slopes and in dry forests. It is common and abundant throughout most of its range (USDA 1937): some of the earliest literature refers to *B. sagittata* as a "weed". For example, Spence (1937:27) writes, "on many extensive foothills and low mountain ranges it is one of the dominant weedy species, sometimes

Figure 2.1 Approximate distribution of *Balsamorhiza sagittata* in North America.



Source: *Balsamorhiza sagittata* distribution compiled from numerous literature sources. Map created by Ole Heggen, Department of Geography, University of Victoria.

growing in almost pure stands and commonly making up a large portion of the plant cover."

2.1.4 Altitude

Balsamorhiza sagittata can be found growing in a variety of elevation and moisture conditions but is found predominately on flats and open hillsides at low to mid elevations (300 to 3000 m) (Wasser 1982). It can also be found on warm, dry slopes at subalpine elevations.

Information on altitudinal range of this species is limited. Further understanding of the altitudinal range of *B. sagittata* was determined through general comments on plant distribution. Haeussler and Coates (1986:2) note, "there is a tendency for a species to have the broadest altitudinal distribution in the center of their range, and to become confined to low elevations in the north and to higher elevations at the southern limits of their range." Thus, in British Columbia *B. sagittata* should be found at lower elevations than plants of this species further south as this is the northern extent of its range.

2.1.5 Development and Phenology

Balsamorhiza sagittata (Figure 2.2) is a long-lived, herbaceous perennial that usually starts growth in March and April, and matures by mid-summer. The successful establishment of new individuals is slow, gradual or rare, as this species is typically associated with somewhat closed, late seral communities (Kitchen 1992).

Balsamorhiza sagittata grows from a deep-set, thickened, woody, taproot (Figure2.2 b), and is surmounted by a multicipital caudex (Hitchcock and Cronquist 1973; USDA 1937). The root is crowned by numerous dark-grey dried leafstalks and flower stalks of former years. The root can grow to several centimeters in diameter and up to a meter in length (McLean 1979; USDA 1937). In early work by Spence (1937), root measurements were taken that penetrated the soil to a depth of 270 cm. The resinous taproot has a balsam-bearing bark-like outer layer that gives off a turpentine-like odor (Spence 1937; USDA 1937). The large underground taproot of *B. sagittata* allows the plant to store reserves of energy through the dormant season, which permits rapid growth

Figure 2.2 *Balsamorhiza sagittata,* at flowering showing major anatomical features: a, the entire plant; b, part of the root; c, the leaves; d, flower heads; e, bracts; and, f, an achene.

Source: Stubbendieck et al. 1981. *North American Range Plants.*

of the foliage in the spring (Wasser 1982). The development of roots was found to increase in size relative to the rest of the plant as soil resources (such as water and mineral nutrients) become less available (Kitchen 1992). Thus, a larger taproot would have the ability to store greater quantities of water and perhaps penetrate to more desirable soils.

The leaves (Figure 2.2 c) of *B. sagittata* grow in basal clumps and have long petioles. Coarse basal leaves are large and the lamina are arrowhead shaped (often reaching 30 cm long and 5-15 cm wide) or triangular or heart-shaped. The leaves appear white-woolly, especially beneath, and along the length of the petioles are heavily pubescent (Douglas et al. 1998; Shaw and Monsen 1983; Stubbendiek et al 1986). *Balsamorhiza sagittata* is able to mobilize resources rapidly to produce above ground foliage in early spring, making mature plants excellent competitors.

The flower stems are usually several, erect or ascending, up to 80 cm high and woolly-haired (Stubbendiek et al 1986; USDA 1937). The flower heads (Figure 2.2 d) of *B. sagittata* are sunflower-like, mostly solitary at the ends of stems. Flower heads are 6-10 cm across. The outside (ray) flowers of the head are yellow, showy, petal-like, and up to four cm long (Stubbendiek et al 1986; USDA 1937). Center (disk) flowers of the head are numerous, small, deep yellow, and perfect (USDA 1937). Flower heads are produced continuously over several weeks, with large plants producing 30 or more per plant over this time (Maze et al. 1990).

Balsamorhiza sagittata inflorescence bracts (Figure 2.2 e) grow in a series (involucre) around the base of the flower head. The bracts are lance-shaped to linear-lance-shaped, about two cm long, overlapping in several rows, outer ones often longer and more densely white-woolly and the inner ones thinner (USDA 1937).

Kitchen (1992) notes that *B. sagittata* plants are usually slow to reach reproductive maturity. Generally new plants require three to four years from seedling to flower on the best sites and seven to eight years on the drier sites (Stevens et al. 1985). Single-seeded fruits or achenes of *B. sagittata* (Figure 2.2 f) are thickened, four-angled and three-angled, smooth, and without bristles or scales (USDA 1937). They are relatively large (65-105 seeds per gram) (Kitchen and Monsen 1996).

The phenology of a species varies with regional environmental conditions (Wasser 1982). Species adapted to semiarid regions of western North America employ life history strategies suited to unpredictable and often extreme environmental conditions (Kitchen 1992). Long-lived forbs such as *B. sagittata* grow rapidly in the spring and survive drought through vegetative dormancy. *Balsamorhiza sagittata* begins growth and flowers early, usually in May or June, but this varies according to elevation, aspect and moisture levels. Blaisdell (1956) provides a representative phenology from the Upper Snake River plains in southeastern Idaho (Table 2.1):

Table 2.1 *Balsamorhiza sagittata* phenology in the Upper Snake River plains, Idaho (Blaisdell 1956).

Phenological State	Average date	Range
Snow melt	March 30	-
Growth starts	April 19	-
Flower stalk appears	April 26	24
First bloom	May 9	35
Full bloom	May 25	35
Bloom over	June 4	-
Seed ripe	June 14	17
Dissemination begins	June 18	-
Dissemination ends	July 9	-
Plant drying	July 22	32
Plant dormant	July 31	-

In an early document by the USDA (1937) it is noted that on ranges where *B. sagittata* is common, the flowers are useful as a familiar and reliable indicator of range readiness. Generally the range was considered ready for grazing when the majority of *Balsamorhiza* plants were in full flower. McLean et al. (1964, 1979) state that in some conditions an abundance of *B. sagittata* on rangelands may indicate overgrazing.

2.1.6 Variation

In their research on the autecology of common plant species in British Columbia Haeussler and Coates (1986:2) note, "A plant species is typically composed of a mosaic of populations, each of which differs in genetically-based morphological or physical characteristics that have survival value for the plant in its home environment." An important variation consideration with *B. sagittata* is that the plant can be locally winter hardy, but the species hardiness is likely to vary regionally. Wasser (1982) suggests that growers do not use *B. sagittata* plant materials from habitats differing much from the planned seeding site because of genetically-based variability in cold hardiness. Research by Robson et al. (1988), however, indicates that the greatest source of variation between two populations of *B. sagittata* is the individual plants within populations rather than among-population diversity.

The genus *Balsamorhiza* bears a close resemblance to *Wyethia* (mule's ears) but differs in its leafless stems and in having achenes without a pappus (Robson et al. 1988). Based on an extensive literature search and a review of all available specimens of *Balsamorhiza* in the herbarium of the Royal British Columbia Museum (V) and University of British Columbia herbarium (UBC), I feel confident that there are only two species of *Balsamorhiza* found in British Columbia: *B. sagittata* and *B. deltoidea.* However, *B. hirsuta* is listed in Henry (1915) *Flora of Southern British Columbia and Vancouver Island* and *B. careyana* is mentioned in Taylor and MacBryde (1977) *Vascular Plants of British Columbia.* It is possible that *B. hirsuta* and *B. careyana* did exist in southern British Columbia but are no longer present as they do not appear in current comprehensive field guides (see Douglas et al. 1998; Hitchcock and Cronquist 1973).

2.2 **Habitat**

Haeussler and Coates (1986:3) cite Daubenmire (1974), "An important concept in the discussion of habitat is ecological amplitude, which refers to the range of habitat variation a species can endure. Species that have a wide ecological amplitude are tolerant of a wide variety of environmental conditions, while species with a narrow ecological amplitude are highly specialized for a particular ecological niche." *Balsamorhiza sagittata* is primarily found in rangelands, and as Noss and Cooperrider (1994) note, there is a great diversity of ecosystems that qualify as rangelands. *Balsamorhiza sagittata* can be found in many dry grasslands, shrub, and forest habitat types. Specific ecosystems where *B. sagittata* is prevalent include: Elm - ash - cottonwood, Douglas-fir, Ponderosa pine, Fir - spruce, Lodgepole pine, Western hardwoods, Sagebrush, Chaparral - mountain shrub, Pinyon - juniper, Mountain grasslands, and Plains grasslands (Wasser 1982).

2.2.1 Climatic Relations

Climate is the most significant determinant in the composition of terrestrial ecosystems. Borrowing from Major (1951, 1963) as referenced in Meidinger and Pojar (eds.) (1991:11): "Climate refers to the regional climate that influences the ecosystems over an extended period of time." Literature detailing characterization of the climatic relations of *B. sagittata* is limited. However, some general deductions can be made from rangeland literature. Noss and Cooperrider (1994) note that rangelands are characterized by low or erratic precipitation or by low or erratic moisture availability during the growing season. In general, *B. sagittata* is a cool season plant. Most of the available literature on climate refers to macroclimates, but the local environment may be considerably modified from the macroclimate by local topography and surrounding plant cover. The Coast and Cascade Mountains have a marked effect on the climate of Interior British Columbia. They impede the flow of moist Pacific air masses into the Interior (Young et al. 1992). Therefore, the climate in which *B. sagittata* is most frequently located can be summarized as dry with hot summers and cool winters.

2.2.2 Site and Soil Conditions

Provided in this section is general information on the characteristic habitats of *B. sagittata*, along with details about effects of landforms, slopes, soil texture, other soil profile characteristics that influence its occurrence and common plant communities where it is found. *Balsamorhiza sagittata* is often a dominant forb on dry foothills and semiarid mountain rangelands. It prefers well-drained, fairly deep soils and open, dry situations, such as southerly exposures, open ridges, and parks (Plummer et al. 1968; USDA 1937). In general, rangeland soils are typically thin and poorly developed (Noss and Cooperrider 1994). Sites where *B. sagittata* occurs are often rocky (Hermann 1966) with silt to loamy soils (Stevens et al. 1985). Further comments on *B. sagittata* soil preferences are included in the section on nutrient relations (2.2.3).

Balsamorhiza sagittata also occurs on open sunny slopes in *Pseudotsuga menziesii* (Douglas-fir) and *Populus* spp. (aspen) forests (USDA 1937). *Balsamorhiza sagittata* occurs in solid stands and commonly in mixed communities (Stevens et al. 1985) with grasses, other forbs and shrubs, including: *Festuca idahoensis* (Idaho fescue), *Artemisia tridentata* (big sagebrush), *Elymus spicatus* (bluebunch wheatgrass), *Juniperus occidentalis* (western juniper), *J. scopulorum* (Rocky Mountain juniper), *J. osteosperma* (Utah juniper), and *Pinus ponderosa* (ponderosa pine) (Plummer et al. 1968; USDA 1937; Wasser 1982; Young and Evans 1979). *Balsamorhiza sagittata* is a climax indicator in several sagebrush and grassland habitat types.

2.2.3 Nutrient Relations

Little research has been published on plant mineral nutrition relations in plant autecology, including *Balsamorhiza*. *Balsamorhiza sagittata* occurs in moderately alkaline to weakly acidic or saline soils (Wasser 1982).

2.2.4 Water Relations

Moisture is arguably the most limiting factor in plant growth. *Balsamorhiza sagittata* is resistant to drought (Wasser 1982). The plants are intolerant of shallow water tables but will briefly survive periods of soil saturation (Stevens et al. 1985). In the southwestern interior of British Columbia, seasonal (May to September) precipitation in the major valleys averages near 100 mm and increases rapidly with increasing elevation. On the Interior Plateau 25 to 35% of the annual precipitation falls as snow (Young et al. 1992). Therefore *B. sagittata* characteristically grows in areas that seasonally have low moisture levels.

2.2.5 Light Relations

As well as water and nutrients, the intensity, duration and quality of light exposure are significant in determining plant growth. The only published information on light relations for *B. sagittata* indicates that the species will tolerate semi-shade (Wasser 1982).

2.2.6 Temperature Relations

Both air and soil temperatures are important in determining plant growth and development. The importance of temperature to *B. sagittata* has not been thoroughly researched. Most of the literature referring to temperature is in reference to seed development and this aspect will be discussed further in the next section. Literature on the temperature variability in southwestern Interior of British Columbia indicates that the freeze-free period (a measure of consecutive days without freezing temperatures) is highly variable from site to site, and in some areas the period averages in excess of 180 days (Young et al. 1992).

2.3 **Reproduction**

Balsamorhiza sagittata, reproduction occurs predominately by seed but there is some indication that the plants may reproduce vegetatively through offshoots from the taproot.

2.3.1 Seed Production and Dispersal

Few studies examine the age of sexual maturity, frequency and size of seed crops, and the method of dispersal for *B. sagittata*. In Idaho, research presently is being conducted on the entomological relationships of *B. sagittata* (Ty Fitzmoris, pers. comm.). At a Society for Conservation Biology Conference in Missoula, Montana (June 2000), Fitzmoris, an entomologist, informed me that *B. sagittata* pollen is too heavy for wind pollination and thus it is assumed to be insect pollinated. During my field work (summer 2000) I observed numerous insects on *B. sagittata* plants and *B. sagittata* flowers attract hummingbirds and butterflies (Cannings et al. 1997).

The literature states that *B. sagittata* is spread entirely by its seed and that it is predominately animal disseminated (Shaw and Monsen 1983). Seed quantity is impacted if developing seed heads are not attacked by insects and are protected from grazing (Stevens et al. 1985). Seed production in *B. sagittata* is synchronized, at least in part, by the effects of weather (such as precipitation and spring frost) on resource allocation (Kitchen 1992). Potentially, a lack of winter snowfall may result in less moisture contained in the root and ultimately in a reduced number of developed seed heads.

2.3.2 Seed Viability and Germination

Studies on germination rates (Young and Evans 1979) and seed development (Maze et al. 1990) of *B. sagittata* have been published. The evolutionary characteristics of *Balsamorhiza* and *Wyethia*, a closely related genus, have also been analyzed (Young and Evans 1979).

Haeussler and Coates (1986:6) note, "Seed viability refers to both the germinative capacity of the seed and the length of time it can remain in a quiescent state before it loses its ability to germinate". In *B. sagittata*, seed yield generally is abundant, but seed crops are often lost to late frosts, insects, and grazing animals. Viability of seed often is low due to insect damage (Shaw and Monsen 1983). Maze et al. (1990) found that low seed viability in *B. sagittata* also results from a high rate of ovule abortion. In general, reproductive output intensity is tied to *B. sagittata*'s stored reserves and cycles of bumper crops, spaced by years of minimal or no seed production, are common (Kitchen 1992).

Seeds of most North American plants are dispersed in a dormant state to prevent them from germinating too late in the year for seedlings to survive the winter (Haeussler and Coates 1986; Maze et al. 1990). Young and Evans (1979) found that a three-month stratification of 0 degrees Celsius is required to break seed dormancy in *B. sagittata*. On sagebrush rangelands, continuous snow cover for three months provides for successful natural cool-moist stratification of seeds (Young and Evans 1979). In experiments undertaken by Kitchen (1992), determined experimentally that less than one percent of seeds planted in midsummer and fall remained dormant in the following spring.

2.3.3 Vegetative Reproduction

Balsamorhiza sagittata regenerates vegetatively from the very large, deep-seated, woody taproot which is surmounted by a many-headed caudex. This bears several rosettes of leaves from which new aerial stems arise each year (Hitchcock and Cronquist 1973; Patterson et al. 1985; Spence 1937). However, evidence of whether new taproots are formed which would enable these individual rosettes to become truly individual plants has not been published. Presently, Dr Sandra Peacock is conducting research on traditional harvesting practices and whether roots broken while harvested regenerate, at a historic root digging ground known as Komkanetkwa (Kamloops, British Columbia).

2.4 **Insect Use**

There are numerous references to the impact of insects on seed quality but there is no other known published information on further interactions between *B. sagittata* and insects. Fitzmoris (personal communication) observed some insects roll fuzz from *B. sagittata* leaves to make nests. Few other plants provide this valuable material. At the Conservation Biology Conference in Missoula, Montana in 2000, numerous local scientists expressed their interest in *B. sagittata*, noting that it may be a keystone species as indicated by the number of insect species that utilize it and the overwhelming influence of the plant on so many other organisms.

2.5 **Wildlife and Range**

The low elevation and south-facing aspects of hill slopes where *B. sagittata* is typically found attract many animals including mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), bighorn sheep (*Ovis canadensis*), and Rocky Mountain elk (*Cervus canadensis*) (Meidinger and Pojar 1991). These large ungulates are limited by the condition of their range (Plummer et al. 1968). The following section reviews the utilization of *B. sagittata* as a food plant and for shelter by other wildlife and domestic range animals.

2.5.1 Food

Literature reviews indicate that *B. sagittata* has been studied predominately in relation to rangeland issues. In particular, the nutritional value and significance of *B. sagittata* as a food for large game mammals, including mule deer, elk, and bighorn sheep, is well documented (Kufeld 1973; Kufeld et al. 1973; Plummer et al. 1968; Wikeem and Pitt 1991). In many plant communities a major portion of total forage production is provided by *B. sagittata* (Stevens 1985). The palatability and use of the species varies geographically (Shaw and Monsen 1983). Mule deer use *B. sagittata* year round (Kufeld et al. 1973). Wikeem and Pitt (1991) note that the vigor of *B. sagittata* was unaffected by bighorn sheep grazing despite the dietary importance of the plant. *Balsamorhiza sagittata* is also valuable winter and spring forage for Rocky Mountain elk (Kufeld 1973).

Kufeld et al. (1973: 4) provide some important insights into studies of ungulate food preferences:

> All methods used in studies of deer food habits contain problems, either in identification, quantification, or both. The possibility of bias toward large, conspicuous plants or, in stomach analyses, slowly digested plants or those with distinctive morphological features is obvious. Furthermore, abundance, availability, and palatability of plants on the ranges where the individual studies were made influence their presence in the diet.

Nevertheless, the frequent references to *B. sagittata* in the literature on food plants of large ungulates and on restoration of rangelands for large game are an indication of the significance of *B. sagittata* as an important dietary component for these animals.

The importance of *B. sagittata* for domestic animals on rangeland has also been reviewed (Blaisdell 1958; Bork 1998). *Balsamorhiza sagittata* has fair palatability for all classes of livestock and when green is especially palatable to domestic sheep (Hermann 1966; Stubbendiek et al. 1982; Wasser 1982). On spring ranges, it is an important and palatable forage because it develops early (Stevens et al. 1985; USDA 1937). Flower and flowerbud heads are often preferred over the foliage (Hermann 1966).

The nutritional value of *B. sagittata* has been rated fair in energy and poor in protein (Hermann 1966). In the River of No Return Wilderness Area of Idaho, *B. sagittata* was found to have sufficient protein to meet requirements for domestic sheep during June and July but protein content was declining in August. The plant was found to exceed required calcium levels but did not meet the adequate dietary phosphorus levels set by the National Research Council (Elliott and Flinders 1984)

There is also some information on deer mice preference of B. *sagittata* seeds (Everett et al. 1978). Finally, blue grouse use *B. sagittata* for food (Martin et al. 1951).

2.5.2 Other Resources

Balsamorhiza sagittata provides a high degree of environmental protection (shelter) for wildlife species during one or more seasons (Elliott and Flinders 1984). These include small mammals, small non-game birds and upland game birds such as blue grouse which are able to hide in the large and numerous leaves of *B. sagittata.*

2.6 **Responses to Disturbance and Management**

Rangelands are subject to a wide variety of disturbances, including fire and trampling by animals (Noss and Cooperrider 1994). This section reviews the literature on how *B. sagittata* is adapted to habitat alteration. The majority of the literature on disturbance is in reference to management for livestock and big game.

2.6.1 Fire

In relation to range management issues, a number of papers have been written on the impacts of fire - natural, accidental and as an intentional tool for controlling sagebrush dominance. Fire suppression has allowed woody species such as *Artemisia tridentata* (big sagebrush), *Pinus* spp. (i.e. pinyon pine), and *Juniperus* spp. (juniper) to invade millions of acres of grasslands or mixed grassland/shrublands (Noss and Cooperrider 1994). Millions of acres of western rangeland are dominated by stands of sagebrush, which is largely the result of overgrazing, together with drought (Pechanec et al. 1954). Heavy livestock grazing has also reduced fuel for fires and has permitted pinyon and juniper to rapidly invade adjacent communities.

Fire is one of the oldest, most widely adaptable, and least expensive methods of controlling sagebrush (Pechanec et al. 1954). Sagebrush is burned in rangeland management because it has low value for livestock forage, watershed protection and wildlife habitat (Pechanec et al. 1954; Smith and Busby 1981). Prescribed fire can be a useful tool in many big sagebrush communities if the fires are carefully planned and livestock do not graze the burn for two growing seasons (Write et al. 1979). Removal of sagebrush releases grasses and forbs from competition. When prescribed fire is used as a vegetation manipulation technique in land management the manager is using secondary succession to meet specific objectives (Bunting 1985). Furthermore fire is a natural process in rangeland ecosystems. Natural fire occurred every 10 to 30 years in sagebrush - grasslands. Drought, competition and fire played a complementary role in limiting the distribution of shrubby species (Wright et al. 1979). The rolling hills and valley terrain of southern interior British Columbia have been shaped by ground fires, which were common historically (Meidinger and Pojar 1991).

All plants are affected by fire, but the extent of damage or benefit varies with the plant species, season, soil moisture and the frequency of the fire (Smith and Busboy 1981). Some aspects of community structure are greatly affected by fire and others change little (Bunting 1985). Responses of individual species also depend on the intensity of the fire.

Balsamorhiza sagittata usually is undamaged (Pechanec et al. 1954) or slightly damaged by fire (Smith and Busby 1981). In published studies, *B. sagittata* increased in frequency, density and size after fire (Bunting 1985; Merrill et al. 1980; Pechanec et al. 1954; Young and Evans 1979). *B. sagittata* is reported to re-establish to preburn levels within two to five years in northern Idaho (Patterson et al. 1985). Bunting (1985) notes that *B. sagittata* after exposure to fire produces more biomass than non-exposed plants. On a burned area in north-central Idaho *B. sagittata* were, on average, 22 percent taller than unburned plants (Merrill et al. 1980). An increase in plant numbers is especially evident after fire in degraded plant communities (Young and Evans 1978). However, this increase must await seed production (Wright et al. 1979). *B. sagittata* plants develop slowly until the community becomes closed. Productivity and basal cover of *B. sagittata* are then reduced as perennial grasses and shrubs dominate. *B. sagittata* may remain in the community for a long time in a suppressed state until another fire occurs (Bunting 1985).

In general, plants such as *B. sagittata* which do not invest in above-ground woody tissue, have a relatively rapid above-ground growth rate and benefit from surface disturbances, such as fire, that eliminate competition from taller woody species (Kitchen 1992).

Wikeem and Pitt (1983) state that there is little published information regarding the history and effects of fire on rangelands in British Columbia. The British Columbia Fish and Wildlife Branch along with the British Columbia Forest Service has used fire to increase forage production and quality for the benefit of bighorn sheep, elk and deer (Wikeem and Pitt 1983). Research needs to be undertaken to determine if the effects of fire on *B. sagittata* in British Columbia are similar to the impacts in the United States.

2.6.2. Grazing

In their book *Saving Nature's Legacy: Protecting and Restoring Biodiversity* (1994) Noss and Cooperrider note that a primary use of rangelands has historically been livestock grazing. "Grazing is the most severe and insidious of the impacts on rangelands" (Noss and Cooperrider 1994: 221). The cumulative effect of more than 100 years of unregulated grazing has been tremendous.

In British Columbia the demand for beef brought the cattle drives from the United Sates and started the ranching industry. The intermediate grasslands of Interior British Columbia include some of the first agricultural lands to have been claimed and farmed by Euro-Canadians. Initially the natural grasslands were utilized for overwintering herds before they were taken to the Cariboo gold fields. Cattle ranching continues to be the major form of agriculture within southwest Interior British Columbia (Young et al. 1992).

The effects of livestock grazing on biodiversity on rangelands are many and complex. Some problems are only temporary but many are long term. Moderate or heavy grazing over several years will usually change plant community composition (Noss and Cooperrider 1994). Grazed plants lose a certain amount of leaf area and this loss inhibits the ability to capture energy through photosynthesis and ultimately to translocate energy back into roots for storage. Noss and Cooperrider (1994:232) note, "If individual plants are continuously grazed so that they cannot store enough energy for their reserves to last through the dormant season and regrow during the next season, they eventually die out".

Balsamorhiza sagittata has a long history as a grazing forb on rangelands. A 1937 USDA publication noted that when *B. sagittata* is in full bloom, the range is ready for grazing. The effects of grazing on *B. sagittata* vary. Parish et al. (1996) note that grazing by domestic sheep has lead to a decrease in the abundance of *B. sagittata* in some areas of Interior British Columbia. On the other hand, Stubbendiek et al. (1982) argue that there are no losses as a result of livestock grazing, and Wasser (1982) notes that established *B. sagittata* is strongly tolerant of grazing. McLean (1979) notes that a dominant presence of *B. sagittata* can be an indication of overgrazing. However, "Evidence also indicates that with continued heavy grazing it may decrease in abundance" (McLean 1979: 20). Plummer et al. (1968) maintain that *B. sagittata* withstands grazing if 50 percent of its foliage remains. The plant is not very successful at reproducing on grazed ranges, probably because the seeds are low in viability and grazing of flower heads reduces the chance of production of a satisfactory seed crop (Shaw and Monsen 1983; USDA 1937). Low rates of reproduction in response to grazing may also be caused by soil compaction and trampling, which makes it hard for seedlings to get established (Shaw and Monsen 1983).

There is an argument that domestic livestock are simply performing the ecological functions (grazing, removal of vegetation) previously performed by native ungulates or other herbivores. Noss and Cooperrider (1994) accept that herbivory is a natural process on rangelands as in all ecosystems. Depending on the scale at which it is observed, herbivory may be considered a continuous process of nutrient cycling or as a disturbance. Many plant species have evolved in the presence of ungulates and are well adapted to withstand grazing. As noted by Noss and Cooperrider (1994), cattle do have similar forage preferences to other large ungulates, but their foraging habits differ: Native species would have moved about more freely than livestock and had much lower densities (Noss and Cooperrider 1994).

In an interview with Turner, Secwepemc elder Mary Thomas commented on the impacts of grazing on wild food plants such as *B. sagittata*. Mary Thomas states, "Now because of trampling of cattle and introduced weeds, the balsamroot plants are only about 30-40 cm high, and are almost impossible to dig" (cited in Turner et al. 2000:1284).

Information provided by Indigenous Peoples is valuable for providing a more detailed perspective of past conditions of ecosystems.

In southern British Columbia a number of livestock exclosures have been constructed to assess the recovery rate of vegetation previously grazed. Observations and measurements indicate that *B. sagittata* proportions are greater inside the exclosures than out. McLean and Tisdale (1972) estimate that it takes from 20 to 40 years of full rest for overgrazed ranges in the rough fescue and ponderosa pine zones of southern British Columbia to recover to excellent range condition.

2.6.3 Herbicides

Forbs are present in great variety and abundance in climax communities with precipitation in excess of 28 to 30 cm per year. They may account for as much as 50 percent of the herbaceous production. As indicated, *B. sagittata* is a dominant forb in some climax communities. For this reason herbicides, at least in the opinion of Wright et al. (1979), are undesirable to manage sagebrush communities where *B. sagittata* is typically the most abundant forb (Wright et al. 1979). Pechanec et al. (1954) adds that where many desirable broad-leaved herbs are present, herbicide spraying is not recommended.

2.6.4 Soil Disturbances and Vegetation Manipulation

Studies of *B. sagittata*'s response to agricultural treatments, such as cultivation using heavy equipment, can provide useful information. Livestock grazing is often accompanied by planting and establishment of forage monocultures: Few if any vegetation manipulation projects have been carried out to restore biodiversity or even species diversity. Generally intensive use management is conducted with the single-minded purpose of increasing livestock forage (Noss and Cooperrider 1994)

Pechanec et al. (1954) reviewed a number of mechanical vegetation manipulation techniques. Chaining is the process of dragging an anchor chain between two tractors to mow down brush. An older but similar practice is railing which results in the uprooting, breaking off, or pressing down of sagebrush by pulling a heavy rail across it. In both methods of vegetation management most grasses and forbs are relatively undamaged. Plowing or disking is also used to control sagebrush. These cultivation methods kill nearly all perennial forbs, grasses, and shrubs, except those that spread by rootstocks or sprout from roots. When harrowing is used plants are seldom killed. Pechanec et al. (1954) note that two or more years after harrowing, plant communities showed stimulated sprouting and twig growth, particularly on low spreading bushes. The technique of beating, where the machine beats up and shreds the woody and herbaceous top growth, results in little damage to the grasses and forbs growing beneath the sagebrush. Grubbing cuts the roots about eight to ten cm below the surface of the plant. With this technique perennial grasses, forbs and shrubs that do not spread by rootstock or rhizomes are almost completely eliminated.

The impacts of mechanical vegetation management on specific species were not included in published work by Pechanec et al. (1954) but, based on the notes above it can be determined that grubbing, and plowing or disking would have the greatest negative impact on *B. sagittata*. However, mechanical land management may result in soil compaction because of the use of heavy machinery, and disturb the plant's natural cycles, which potentially stresses the plant during the seed reproduction phase. Based on the review of the literature on the use of fire (Section 2.6.1) as a management technique it appears that burning would be the optimal method of rangeland vegetation manipulation.

2.7 **Summary**

The reproductive biology of *B. sagittata*, its interactions with insects, and other specific ecological relationships have not been documented thoroughly. Furthermore, research specifically related to *B. sagittata* in British Columbia, the northern extent of the plant's distribution, is limited.

Balsamorhiza sagittata has been researched as a food plant for domestic livestock and large wild ungulates for almost a century. Given the decline in rangeland quality as a result of overgrazing, the impacts of various vegetation management techniques to *B. sagittata* have been studied. Chapter 5.0 will summarize the exploratory research that I have conducted on *B. sagittata* in the southwest interior of British Columbia.

3.0 Ethnobotany of *Balsamorhiza sagittata*

The purpose of this chapter is to synthesize the documented literature on the ethnobotanical aspects of *B. sagittata*. The information presented in this chapter has been gathered from previously written, published and unpublished documents, including published ethnobotanical writings, ethnographies, conference papers, journal articles, dissertations and field guides. *Balsamorhiza sagittata* was used by Indigenous Peoples of the Interior Plateau for food, medicine, and in technology. The biological features of *B. sagittata,* along with its widespread abundance, established its utilization by all Interior Salish groups. A complex knowledge of harvesting and processing was needed to make this plant a useful food and medicine. The uses of *B. sagittata* and the techniques used to harvest and process this plant are characteristics of managed landscapes throughout the Interior Plateau. The review provided here, along with the documented autecological features of *B. sagittata* covered in Chapter 2, provides a foundation for research into potential future applications outlined in Chapter 6.

In this section, I first provide a brief description of the Interior Plateau region and its indigenous inhabitants. Next I summarize the cultural importance of *B. sagittata* and the practices used in its harvesting, processing and managing. Indigenous Peoples of Western Canada were not strictly hunter-gatherers but, in fact, practiced a form of incipient agriculture to facilitate food security.

This chapter focuses on the use of *B. sagittata* by the Stl'atl'imx, Secwepemc, Nlaka'pamux and Okanagan-Colville Salishan peoples of the Plateau Culture Area. I have focused primarily on British Columbia because ethnobotanical research within these groups has been more extensive then other Interior Salish areas to the South. The work of scholars such as Dr. Nancy Turner, Dr. Harriet Kuhnlein, Dr. Sandra Peacock, Dr. Kelly Bannister, and Dawn Loewen, has provided a fairly comprehensive overview of food and medicinal plants, and their uses and processes on the Interior Plateau. In particular, research by Peacock (1998) and Bannister (2000) has revealed complex relationships pertaining to *B. sagittata* and how the processing of this plant has contributed towards human health and nutrition.

3.1 **The Northern Plateau: Landscape and Peoples**

In this section I briefly describe the landscapes and peoples of the Interior Plateau of British Columbia. The Interior Plateau region is defined by distinct physiography and by the cultural traditions shared by its Indigenous Peoples.

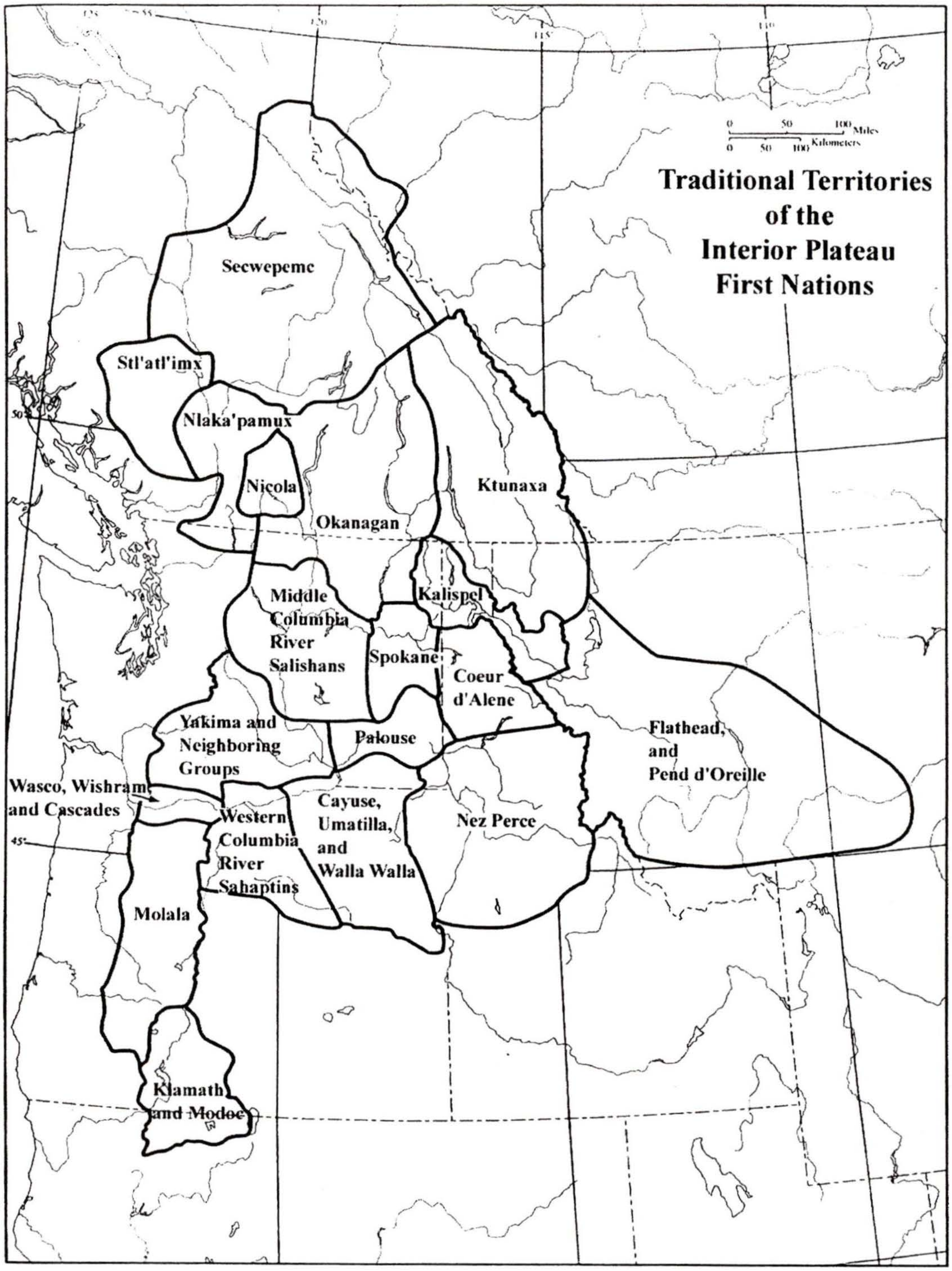
Geographically, the Interior Plateau encompasses the intermountain zone of south-central British Columbia and north-central Washington State. The Rocky Mountains on the east and the Coast Range to the west demarcate the region. The topography is characterized by gently rolling uplands, highlands and mountains, deeply incised river valleys and lakes of the Fraser, Thompson and Columbia drainages. Climatically, hot dry summers and cold, relatively moist winters characterize the area. The diversity of the landscape combined with dramatic weather patterns influenced by the Coastal Mountain rain shadow has resulted in a diversity of flora and fauna (Parish et al. 1996). This heterogeneous environment results in a wide variety of ecosystems and hence a diverse subsistence base.

The Interior First Nations of British Columbia represent more than 20 different groups distinguished by the languages that they speak. The southern interior portion of the Columbia and Fraser River Plateau, is the traditional territory of Interior Salish speaking peoples including Stl'atl'imx (Lillooet), Nlaka'pamux (Thompson), Okanagan and Secwepemc (Shuswap), as well as the Ktunaxa (Kutenai) of southeastern B.C., Tsilhqot'in (Chilcotin), Dakelh (Carrier), and Nicola Valley Athapaskan (Nicola). Figure 3.1 outlines the approximate traditional territories of the Interior Plateau peoples.

Walker (1989) summarizes the cultural traits shared by the Interior Salish:

- riverine (linear) settlement patterns.
- reliance on a diverse subsistence base of anadramous fish and extensive game and root resources.
- a complex fishing technology similar to that seen on the Northwest Coast.
- mutual cross-utilization of subsistence resources among the various groups comprising the populations of the area.
- extension of kinship ties through extensive intermarriage throughout the area.

Figure 3.1 The approximate traditional territories of the Interior Plateau peoples.



Source: Map based on Kennedy and Bouchard, (1989) Lillooet, in *Handbook of North American Indians*, Plateau, Vol.12 William C. Sturtevant (editor) and Deward E. Walker, Jr. (volume editor).

- extension of trade links throughout the area through institutionalized trading partnerships and regional trade fairs.
- limited political integration, primarily at the village and band levels, until adoption of the horse.
- relatively uniform mythology, art styles, and religious beliefs and practices focused on the vision quest, shamanism, life-cycle observances, and seasonal celebrations of the annual subsistence cycle.

Interior Salish people shared similarities in diet and in the acquisition of food resources: they relied on fish and game, utilized a higher portion of plants in the diet than coastal groups; and, annually migrated from permanent winter homes for a seasonal round to gather resources (Turner et al. 1980).

A diverse variety of plants contributed to the diet of Canadian First Nations. Kuhnlein and Turner (1991:9) note: "As of 1990, about 550 different species of plants have been documented in the literature as having been utilized in one way or another in the traditional diets of Indigenous Peoples in Canada." For the Interior Plateau peoples Peacock and Turner (2000) estimate that Indigenous Peoples employed at least 300 plant species for food, medicine and material. The different food plants can be classified into major categories: root vegetables, green vegetables, fleshy fruits, seeds, nuts and grains, and mushrooms.

Plant foods and other plant resources were harvested in annual cycles that were based on seasonal availability of resources, beginning in spring with plant shoots and tree cambium, and the harvesting and digging of bulbs and other root foods. In the summer people harvested more roots and picked berries. The fall months were spent collecting berries, nuts and black tree lichen. During the winter, people of the Interior Plateau survived mainly on preserved foods.

The landscape and ecosystems of the Interior Plateau have influenced the Indigenous Peoples who have lived in the region for thousands of years; in turn the land has been altered by their presence. Although not always apparent to the untrained eye, this landscape has the imprint of generations of aboriginal people who sought to intensify their food supplies through management of the local environment. Using *B. sagittata* as an example I will now review the diversity of uses for one plant and the complex knowledge that was required to utilize and sustain, and perhaps enhance this resource.

3.2 **Traditional Uses of *Balsamorhiza sagittata***

Traditional ethnobotanical studies have documented the use of *B. sagittata*, by Indigenous Peoples, throughout its known habitat. Leaves, roots, stems, shoots and seeds were used by First Nations Peoples as food, medicine and material. The differentiation of plants for food and plants as medicine is an artificial construct that was not recognized to the same extent by Indigenous Peoples (Kuhnlein and Turner 1991; Turner et al. 1990). Nlaka'pamux (Thompson) elder, Hilda Austin expresses this opinion: "our food is our medicine. If you eat it often, that's a medicine" (as quoted in Turner et al. 1990:43). Peacock (1998:12) adds that *B. sagittata*, in particular, blends the division between food and medicine: "Neither food nor medicine accurately describes balsamroot, but rather that it has a place on the concentration-related (or situation-related) continuum, ranging from food to poison, and including medicines." Nevertheless, for the purpose of summarizing the diversity of ways *B. sagittata* was used, I have divided this section into food and medicine.

3.2.1 A Staple Root Vegetable

Balsamorhiza sagittata, as a single plant, has provided food in many forms: young shoots, achenes, flower and bud stems and taproots were all incorporated into peoples' diet. This plant also was available over an extended period of time, thus it is easy to concur with the statement of Turner (1997b) that *B. sagittata* is an extremely versatile plant. All of the Interior Salish groups ate the roots, as did the Tsilhqot'in and Ktunaxa peoples (Turner 1997b).

Peacock (1998) indicates that root foods in particular have been an important component of prehistoric economies for thousands of years. Kuhnlein and Turner (1991) state that there are approximately 125 species of plants that were used as root vegetables in Canada. In south-central British Columbia, *B. sagittata* was used extensively by Indigenous Peoples (Mullin et al. 1997).

Turner (1997b) notes that many people regarded cooked *B. sagittata* roots as a treat or dessert, but the plant played a much greater role than this. What makes root vegetables so important is that they contain carbohydrates that are usually maximized at the end of the leaf-growing season, and over the dormant season before new shoots appear (Kuhnlein and Turner 1991). The carbohydrates in *B. sagittata* roots are dominated by inulin (Bannister and Peacock 1998; Kuhnlein and Turner 1991; Mullin et al. 1998). Peacock (1998:65) notes, "Both starch and fructans are complex, or large, carbohydrates which resist digestion in the small intestine." *Balsamorhiza sagittata* roots also provide dietary value in the form of mineral nutrients and fiber (Kuhnlein and Turner 1991; Mullin et al. 1997).

Prior to consumption, the roots of *B. sagittata* are subjected to a long, slow cooking process in an earth oven. The process of pit cooking dates back millennia. Recently Peacock (1998) and Mullin et al. (1998) demonstrated that pit cooking of inulin-containing roots in earth ovens increases their digestibility for humans by converting inulin to simple sugars such as fructose and glucose. Thus, inulin becomes sweet upon cooking, due to a partial conversion to the sugar, fructose (Kuhnlein and Turner 1991). Cooked roots were then eaten or dried for storage (see also Section 3.2.5).

Although *B. sagittata* is not considered harmful there is reason to believe eating too many roots may cause drowsiness (Turner et al. 1990).

Other Food Uses

In addition to the food value of roots, other parts of *B. sagittata* added nutrition to the diets of Indigenous Peoples. Many aboveground parts of *B. sagittata* fall under the category of "green vegetables" including shoots, stems, leaves, and bud-stalks. These plant parts contain moisture, carotene and other vitamins, as well as minerals such as iron, calcium and magnesium (Kuhnlein and Turner 1991; Patterson et al. 1985).

Shoots were the first component of *B. sagittata* to be harvested in the spring. The shoots were eaten raw and considered to be a good famine food because they were available when few other foods could be found (Turner 1997b).

Bud stems were eaten in April and May when the flower buds were still tightly closed. Stems were gathered, peeled and eaten raw, or steamed, or boiled (Turner et al. 1998; Turner 1997b). Turner (1997b: 93) notes the stems have "a pleasant nutty taste, reminiscent of the smell of young sunflower seeds." Some Indigenous Peoples also peeled and ate young leaf stalks raw in the spring (Angove and Bancroft 1983; Parish et al. 1996; Turner 1997b, 1998). Willard (1992) notes that the leaves could be boiled as a potherb and that this would reduce toughness. However, few First Peoples would consider the leaves edible.

Balsamorhiza sagittata achenes (seeds), similar to sunflower seeds, were pounded to be used as flour (Parish et al. 1996). The achenes provided a source of protein, fat and carbohydrates.

Information on the harvesting and processing of the various food parts of *B. sagittata* are outlined in sections 3.2.4 and 3.2.5.

3.2.2 A Herbal Medicinal

Similar to *B. sagittata*'s diverse food uses, different parts of the plant also had distinct medicinal uses. As noted, the value of *B. sagittata* as a medicine is closely connected with *B. sagittata* as a food. Johns (1990) argues that the origins of medicine may be a direct consequence of the dietary habits of early humans, with plant chemicals influencing human dietary needs.

The pitch from the bark of *B. sagittata* root was traditionally, and continues to be, used in the Interior of British Columbia to make a salve for skin infections and wounds (Bannister and Peacock 1998). The literature also notes numerous other uses for *B. sagittata* roots including as a vitamin supplement (Turner et al 1990), antimicrobial, expectorant, disinfectant, and immune stimulant (Tilford 1993). Stubbendieck et al. (1982) note that the Cheyenne boiled the roots, stems, and leaves and drank the decoction for stomach pains and headaches as well as steaming the plant and inhaling the vapors for the same purposes. Willard (1992) argues that the root is a good expectorant, stimulates saliva, softening dried mucus of the lungs, and stimulating bronchioles. Furthermore, *B. sagittata* root contains an immune-stimulating factor similar to *Echinacea* spp. but milder (Moore 1993). Mashed roots were used by Nevada First Nations as a dressing for syphilitic sores (Willard 1992).

Balsamorhiza sagittata roots contain a variety of compounds that likely result in its many medicinal uses. An antibacterial compound (belonging to a group of toxic chemicals called Thiophene) was recently isolated and purified from raw roots (Matsuura et al. 1996). Inulin, the complex carbohydrate described above, may stimulate the growth of beneficial bacteria in the intestine (Mullin et al. 1998). In a study by McCutcheon et al. (1992) an extract of *B. sagittata* was one of a few plant extracts from a hundred tested, which exhibited the broadest spectra of activity against at least 10 types of bacteria. McCutcheon et al. (1994) also tested the antifungal activity of *B. sagittata* extract against nine fungal species and found it active against all nine. Bannister (2000) studied how the traditional means of processing *B. sagittata* roots affects the availability of medicinal compounds. Because the roots were used by Native Peoples to treat a variety of ailments, many different preparations were employed (see Section 3.2.5).

In Secwepemc medicine, both the leaves and the resinous roots of *B. sagittata* are used to treat a variety of skin ailments (Bannister 2000). The powdered leaves of *B. sagittata* also were used on wounds to reduce infections (Mary Thomas, pers. comm. to N. Turner 1996, cited in Turner et al. 2000). Fresh and dried leaves have some antibacterial properties. Drying leaves alters their chemistry to make them useful on sores, rashes, and poison ivy (Bannister 2000). Smoke from the leaves was inhaled as a treatment for headaches (Willard 1992). The achenes of B. *sagittata* were eaten for dysentery (Turner et al. 1990).

Research by McCutcheon et al. (1992, 1994) represents the first time that the efficacy of some of the herbal medicines of British Columbian Native Peoples has been validated scientifically. Many more medicinal plants remain to be investigated. McCutcheon et al. (1994:169) note: "The results reported here seem to support our assertion that the North American flora is worthy of further pharmacological investigation and that the ethnobotanical literature can be useful in guiding this research." The information presented on the medicinal uses and properties of *B. sagittata* lend weight to the argument that British Columbian ethnobotany is worthy of further research.

3.2.3 Material Uses

In addition to the plant's use as a food and medicine, *B. sagittata* was also used in material ways. In the winter, the Okanagan stuffed the large, hairy leaves of *B. sagittata* in their moccasins to keep their feet warm. The leaves were also used as slippers to teach children how to walk softly. "Young Okanagan boys training to acquire supernatural power would wrap the leaves around their feet, pinning them on with bluebunch wheatgrass stems, and walk on them to see how far they could get without tearing them. This exercise prepared them for walking silently in the woods" (Turner 1998:146).

As noted above, the leaves were smoked like tobacco (Parish et al. 1996), and the burning leaves were also used to fumigate a room (Willard 1992). Hellson and Gadd (1974, cited in Willard 1992) note that the root was burned as incense for ceremonial occasions by the Blackfoot Indians.

Certain plant products were especially suitable as tinder for transporting or storing embers. The dry upper root of *B. sagittata* was used as a slow-match (Turner 1998). In the Stl'atl'imx story 'Nkolstem' it is recounted that at a place called 'Kmikstin', which was abandoned by its inhabitants, an old woman left behind had a slow-match consisting of the upper part of a dry *B. sagittata* root, which she had lighted when the villagers left. With this she lighted a fire for the chief's son, who had been abandoned (Teit 1912, cited in Turner 1998).

3.2.4 Harvesting

The uses of *B. sagittata* described above would not have been possible without people having harvested large quantities of plants and managing this valuable resource. The Upper Stl'atl'imx, for example, gathered large quantities of *B. sagittata* (Teit 1906, cited in Turner et al. 1998). Peacock and Turner note some root vegetable resource management strategies as "selectively harvested by season, age, size, life-cycle stage; part of seasonal round harvesting cycles; most said to be enhanced by periodic landscape burning; propagules often incidentally or intentionally replanted; some weeded during harvest; specific sites harvested in several-year cycles" (2000:140). A broader look at traditional resource management is provided in Appendix 1.

The gathering and processing of food plants, in particular roots, was primarily the work of women (Alexander 1992; Turner et al. 2000). Root harvesting began in April and May in river valleys and continued throughout the summer at higher elevations. Turner (1997b) notes that the roots became stringy and tough in the summer, which would have rendered the plant less desirable as a food source. However, Secwepemc elder, Mary

Thomas (Nesconlith Band) recommends digging the roots after flowering, in mid summer, when the medicinal qualities of the root are "highest" (quoted in Bannister and Peacock 1997). Large quantities of roots were also processed at high elevation intertribal harvesting grounds (Kennedy and Bouchard 1989).

The shoots, which were an important early green vegetable, turn bitter as they emerge from the ground so only white underground shoots were eaten. The shoots were located from the position of dead leaves and flower stalks of the previous years growth (Turner 1997b).

The seeds of *B. sagittata* were harvested after the flowers had withered and gone to seed. People collected the small black seeds by shaking them from the dried seed heads into a container (Turner 1997b).

On the Interior Plateau there are a number of documented root harvesting grounds that display spectacular shows of spring wildflowers. Turner notes, that "little is known about the effects of prolonged and continuous harvesting on populations of wild food plants" (1992:413). Places such as Botanie Valley, Pavilion Mountain, Hat Creek Valley and Komkanetkwa are still rich in root resources despite many generations of intensive harvesting.

It is interesting to note that some variation in plant nutrient contents and medicinal compounds may be the result of elevation and location of harvest. Bannister (2000) comments on how results of her research differ from that of Bohm et al. (1989). Bannister (2000) speculates that species collected or processed under different conditions may not have a consistent antimicrobial profile.

Roots were not harvested randomly. Harvesters followed guidelines according to a number of well-defined criteria based on both cultural and biological considerations (Peacock 1998). For example, the largest plants or "mother roots" were never dug as food (Turner et al. 2000). These large plants provided a source of food-seeds, and continued propagation of species. The ideal size of root to harvest was from plants with 6-12 leaves and having taproots about the size of carrots (Turner et al. 2000).

Harvesting of roots required little in the way of specialized equipment. Roots were dug or pried up with a digging stick. Turner et al. (1990:25) describe the appearance of the digging stick, "the usual design was a pointed stick about 0.8 m long, sometimes curved, with a handle of wood or horn inserted at the other end. The stick could be reversed within the handle when the point got dull". The stick would be inserted into the ground beside the plant that was to be dug and then pulled back to pry the plant out.

As indicated above, large quantities of roots were dug. As well, probably 100-200 stems (per family) were picked (Teit 1906, cited in Turner 1992). Turner et al. (2000:1277) note, "Even a conservative accounting would have led to severe depletion of such resources unless they were in some way managed and enhanced. The highly selective and careful harvesting techniques employed by Indigenous Peoples of the Interior Plateau "can lead to increased capacity for propagation. Even when large quantities of a plant product are harvested, the productivity of the plant populations can be maintained" (Turner et al. 2000:1277). Peacock and Turner (2000) have traced the emergence of systems of wild plant food production on the Canadian Plateau through the archeological record and ethnographic documentation to develop a more comprehensive model of wild plant food harvesting. In their paper, 'Just Like a Garden' Peacock and Turner (2000) detail the methods of landscape management used by Interior British Columbia First Peoples to secure and increase the availability of important food sources. "Plateau peoples were not 'passive' food procurers, but active plant managers 'cultivating' a wide range of plants and in doing so, cultivating the landscape" (Peacock 1998:10). Similar findings were reported by Anderson (1993) who conducted research in California. As indicated by Turner et al. (2000:1281), "the traditional management of wild root crops in south-central British Columbia is a good example of how the many facets of TEKW [TEK and wisdom] are woven together to provide ecologically sustainable, nutritious, and culturally valued food sources".

Increasingly, Indigenous Peoples and scholars argue that TEK has major importance in contemporary resource management. A discussion of traditional resource management techniques, the increasing interest by non-aboriginal people in this knowledge and the potential application of TEK to resource management is provided in Appendix 1.

3.2.5 Processing, Storage, and Preparation

Rendering *B. sagittata* useful as a food and medicine requires a complex knowledge of processing and preparation techniques. Work by Peacock and Bannister 1998 (see also Peacock 1998; and Bannister 2000) indicates that traditional processing methods of *B. sagittata* for food and medicine do affect some of the underlying phytochemcial composition and biological activities of the plant. Thus the processing techniques undertaken depend on the plant part and how it was to be used.

Processing was not only necessary to break down the roots of *B. sagittata* into a digestible form or to extract the medicinal pitch but also because of a need for preserving for later use. The seasonality of plant foods made preservation necessary (Turner et al. 1990). Heat was the primary differential processing method - essentially creating multiple uses for a single plant part.

The following section summarizes, by plant part used, how *B. sagittata* was processed.

Roots: Pit Cooking

Peacock (1998) has demonstrated the necessity of heat in the processing of *B. sagittata* prior to its consumption as food. Turner et al. (2000) add that pit cooking is a complex and highly effective method for cooking and flavoring large quantities of root vegetables and other foods with minimal use of containers or utensils. In experimental reconstructions, Peacock and Turner (2000) have found that the pit temperature can reach 100 degrees Celsius after a couple of hours and that relatively high temperatures can be sustained for many hours. The length that plants were left to cook depended on the species. *B. sagittata* would have cooked for 48 hours or more (Peacock 1998). The prolonged cooking greatly enhanced the digestibility of the food, and hence its nutrient value (Kuhnlein and Turner 1991).

Pit cooking of *B. sagittata* in earth ovens has long been assumed to be a means of increasing the digestibility for humans (Peacock and Bannister 1998). As indicated in the section on *B. sagittata* as a food plant, pit cooking of peeled and unpeeled roots results in the cleavage of much of the inulin into fructose units, thereby rendering it available for digestion and energy metabolism (Peacock 1998). Heat and other factors are required to increase the availability of carbohydrates by a process of chemical degradation, which relies on heat, acid and the moisture sensitive nature of inulin (Peacock 1998).

There are a number of components necessary in pit cooking. The necessities for proper chemical conversion during pit cooking have been researched and summarized by Mullin et al. (1997) and Peacock (1998). The components include adequate temperature for a sustained period of time, adequate moisture provided by steam from water added at a specified time, adequate acidity, provided by volatile organic acids emitted by moistened branches added to the pit. The moistened branches used in the Interior of British Columbia include *Pseudotsuga menziesii* (Douglas-fir), *Rubus parviflorus* (thimbleberry), *Amelanchier alnifolia* (saskatoon), *Rosa* spp. (wild roses), *Calamagrostis rubescens* (timber grass) and *Penstemon fruticosus* (shrubby penstemon) -used as flavoring (Peacock 1998; Turner et al. 2000). The specifics of pit cooking varied between cultures, but construction and use had several similar components: rock heating, water, vegetation, and a basin-shaped pit.

The process of pit cooking began with the digging of a circular earth oven about 60 cm wide and 80 cm deep (Mullin et al. 1997). Stones were heated on a fire kindled within or beside the oven, then spread out across the bottom of the roasting pit before a thin layer of dirt was added. The heating element of stones was then covered by layers of vegetation and food, followed by the addition of a few liters of water. The entire pit was then covered with mats or a dense layer of vegetation and soil to hold in the steam.

Pit cooking allows for large quantities of food to be prepared with minimal use of containers or utensils. Cooked roots were strung on a string or skewered and dried. Dried roots were then stored by hanging or layering in baskets or bags. The processing of root vegetables was a subsistence strategy, and the storage assured an abundance during times of scarcity.

Pit cooking extends well back in the archaeological record and is indicative of intensification of roots as important foods (Peacock 1998). The historical processing of large quantities of edible roots has created massive rock-filled basins and mounds up to eight meters in diameter, which are permanent features on the landscape. Radiocarbon age estimates indicate a continued use throughout the last 2,500 years (Peacock 1998). Peacock adds (1998:3) "Archaeological remains of earth ovens, represent a tangible, direct link between past subsistence strategies and present ethnobotanical knowledge."

Stems and Shoots

Stems and shoots would have required little processing. These greens were primarily picked by hand and eaten raw at the location. However, recently people have sautéed, then frozen the stems in bags, or preserved them in canning jars.

Seeds (Achenes)

Seeds were pounded with a mortar and pestle, or in a buckskin bag to make flour. Flour with the addition of oil, water and broth could be used to create porridge. Seeds could also be combined with deer grease, pine nuts, pounded Saskatoon berries or Douglas-fir sugar (Turner et al. 1980; Turner 1997b). Seeds could be kept up to six years if stored in airtight containers (Turner 1997b). Dried salmon skins were common storage containers (Turner et al. 1980).

Medicinal Preparation

The preparation of *B. sagittata* for medicinal uses is different than for food. Peacock and Bannister (1998) provide a description by Mary Thomas: the large roots are peeled, boiled in water and left to stand until a layer of pitch collects at the surface. The pitch is applied directly to infected areas while the cooled pitchy water can be used as a soaking solution or wash. Leaves were collected and then dried and crumpled into a fine powder that could be sprinkled on wounds, sores or infections such as poison ivy (Mary Thomas, cited in Bannister 2000).

An undesirable chemical agent present in *B. sagittata* is thiophene E. Work by Peacock and Bannister (1998:10) indicates that "traditional processing of balsamroot for medicine may selectively eliminate, or at least greatly reduce the presence of this potentially undesirable chemical agent". Peacock and Bannister have found that when traditional procedures were used, the antimicrobial components of *B. sagittata* were present. The processing of medicinal plants is consistently undertaken with care and respect for the plants being used (Turner et al. 1990).

3.2.6 Ritual, Mythology, and Other Cultural Aspects

Ritual and traditional narratives can add to a greater understanding of the cultural significance of *B. sagittata*. Myths may incorporate regulations and harvesting instructions that ensure sustainability and teach respect for a particular species (Kuhnlein and Turner 1991). Further evidence of the importance of *B. sagittata* can be inferred from stories and the naming of places. Many places around southern Interior British Columbia are named after important root vegetables (Turner et al. 2000) and people were sometimes named after these plants (Turner et al. 1990).

An example of the significance of *B. sagittata* is apparent in ceremonies such as the 'First Fruits' and 'First Roots' ceremonies of the Okanagan-Colville of British Columbia (Turner et al. 1980). Spiritual acknowledgment secured a plentiful harvest for the present and future. The importance of *B. sagittata* is also evident in myths recorded by ethnographer James Teit and documented by Turner et al. (1990, 2000). In particular there was a prayer addressed to the 'Sunflower-Root' by youth partaking in the first plant products of the season: "I inform thee that I intend to eat thee. May thou always help me to ascend, so that I may always be able to reach the tops of mountains, and may I never be clumsy! I ask this from thee, Sunflower-Root. Thou art greatest of all in mystery" (Teit 1990, cited in Turner et al. 1990:177; Turner et al. 2000:1284). Failure to recite this prayer before eating was said to "make the person partaking of the food lazy" (Teit 1990, cited in Turner et al. 1990:177).

Several rituals relating to harvesting and processing of *B. sagittata* have been documented (Peacock 1998; Turner et al. 1990, 2000). Nlaka'pamux women, while digging roots, had to abstain from sexual intercourse. A man was not to come near the cooking pit while the roots were being cooked. Women painted their faces red, or painted a large black or red spot on each cheek before harvesting roots. Prayers were offered when people went to dig plants. There were taboos against a bereaved spouse eating *B. sagittata* for a whole year after the bereavement. The leaves of *B. sagittata* were also used in puberty rituals for girls.

3.3 **Current Use**

Turner et al. (1998) note that the use of plants in traditional ways has continued to the present day, although some applications have been much reduced over the last century. "As part of the cultural heritage of the Xaxl'ep and other Stl'atl'imx people, it is also practical knowledge that could have strong benefits in community and economic development, if applied in sustainable ways" (Turner et al. 1998:3).

The current uses of *B. sagittata* further demonstrates the cultural significance of this plant and the value of its medicinal properties. "As a Secwepemc medicine, the resinous roots are still important today in treating a variety of skin ailments, including infections" (Bannister and Peacock 1996:3). However, Kuhnlein and Turner (1991:1) note, "collective wisdom of resource use in natural environments known by Indigenous People is disappearing in the face of 'modernization' and 'technological development'." The harvesting, processing and cooking of *B. sagittata* is a lengthy process that can take days to complete (Turner and Ignace 1990-1997). Given the availability of commercial foodstuffs, the pit cooking of *B. sagittata* is now generally limited to special occasions. The dietary patterns of Indigenous Peoples are being displaced with modern processed foods that result in health problems for Aboriginal communities and loss of a valuable resource for everyone.

Turner (1992:408) notes "there is every indication that use of native plants remained in many ways similar to prehistoric use patterns until approximately fifty or sixty years ago, within the living memories (and sometimes direct experiences) of contemporary native elders." The knowledge retained by Elders is a valuable resource that needs to be recorded and taught back to community members before it is lost. Kuhnlein and Turner (1991) indicate that elders are anxious to have traditional food ways documented, because they recognize that the knowledge will be lost to future generations if the current trends continue.

3.4 **Summary**

The Interior of British Columbia is termed the Plateau region and is designated by a unique physiography and Indigenous cultural similarities. One of the most versatile cultural resources of this region is a plant called *Balsamorhiza sagittata* or arrow-leaved balsamroot. As a food, *B. sagittata* was used as a root vegetable, green vegetable and seed source. Medicinally *B. sagittata* roots and leaves were used and continue to be used to treat a wide variety of ailments. Research by Peacock (1998) and Bannister (2000) has illustrated that the use of appropriate differential heat processing methods made antibacterial compounds available in *B. sagittata* tissues useful as a medicine, but eliminated them from *B. sagittata* tissues used as food. This processing technique is just one example of the sophistication of past and present plant knowledge utilized by Indigenous People to secure, enhance and provide the necessary components of life from the plant resources of the Interior Plateau. This resource knowledge base is being increasingly recognized as having potential applications in current resource management practices and sustainable community development.

Ethnobotany plays a significant role in the introduction of plants for contemporary uses. The ethnobotanical background presented in this Chapter (3) and the ecological and biological background reviewed in Chapter 2 establishes a context for investigating *B. sagittata* further in an autecological (Chapter 4) and agronomic (Chapter 5) context and the potential future uses of *B. sagittata* (Chapter 6).

4.0 *Balsamorhiza sagittata* Habitat Analysis

Background and Rationale

In Chapters 2 and 3 I have presented information on the ecological and ethnobotanical significance of *Balsamorhiza sagittata.* In Chapter 6 I outline some of the possible commercial markets for *B. sagittata.* In this chapter I present my research on existing populations of *B. sagittata.* As Bye (1985:378) notes, "We must go beyond the obvious of what and how people used a resource and look at biological diversity in terms of population dynamics as well as genetic diversity." The material I present is for a small geographical area within *B. sagittata*'s range.

The literature reviewed indicates that, while the importance of *B. sagittata* in rangeland management and the nutritional and antimicrobial components has been well studied, many of the ecological characteristics, particularly in Canada, have not been documented. It is important to learn more about *B. sagittata* in order to further understand how to sustain and grow it. Because of the lack of previously published studies and the need to understand the results from my germination experiments (Chapter 5) I investigated habitat characteristics and plant species composition of three discrete but geographically proximate sites in southwestern British Columbia.

The ecological component of my research employed an inductive approach to describe vegetation rather than using experimental, hypothesis-testing methodologies. Kent and Coker (1992:12) state that "with induction, the data are collected without formulation of a prior hypothesis and, if necessary, explanations are then derived from the data collected." My research was exploratory in nature and I have used statistics to isolate factors of likely significance for the growth of *B. sagittata.* Exploratory research is primarily concerned with the search for pattern and order in data (Kent and Coker 1992). I made observations in dense stands where wild seedlings were well established. The three sites selected have known uniform populations of B. *sagittata* and were likely traditional harvesting areas formerly used by Interior First Nations including the Xaxl'ep.

I collected, observed, and measured a variety of environmental (essentially abiotic) and species (biotic) parameters at each site. Vegetation description was at the floristic level, and included estimates of cover of *B. sagittata* and associated plant species.

The objectives of my research were: 1) To understand the conditions under which *B. sagittata* grows by determining which characteristics the sites have in common; and, 2) To determine applications of this information to agricultural production of *B. sagittata.* Specific questions investigated through data analysis included:

- How are the plots at each site similar or different;
- How do the conditions affect the number of *B. sagittata* plants;
- Do the three sites have different quantities and growing rates of *B. sagittata*; and,
- Can it be deduced that the conditions at one site are better than the others?

I infer that conditions which are not common or are inconsistent between sites are not likely crucial to the growth and productivity of *B. sagittata.* Specifically my goal was to look at what factors were uniform in the plots and common between sites in order to establish a better understanding of where and how to grow *B. sagittata* and to provide suggestions for future experimental analysis.

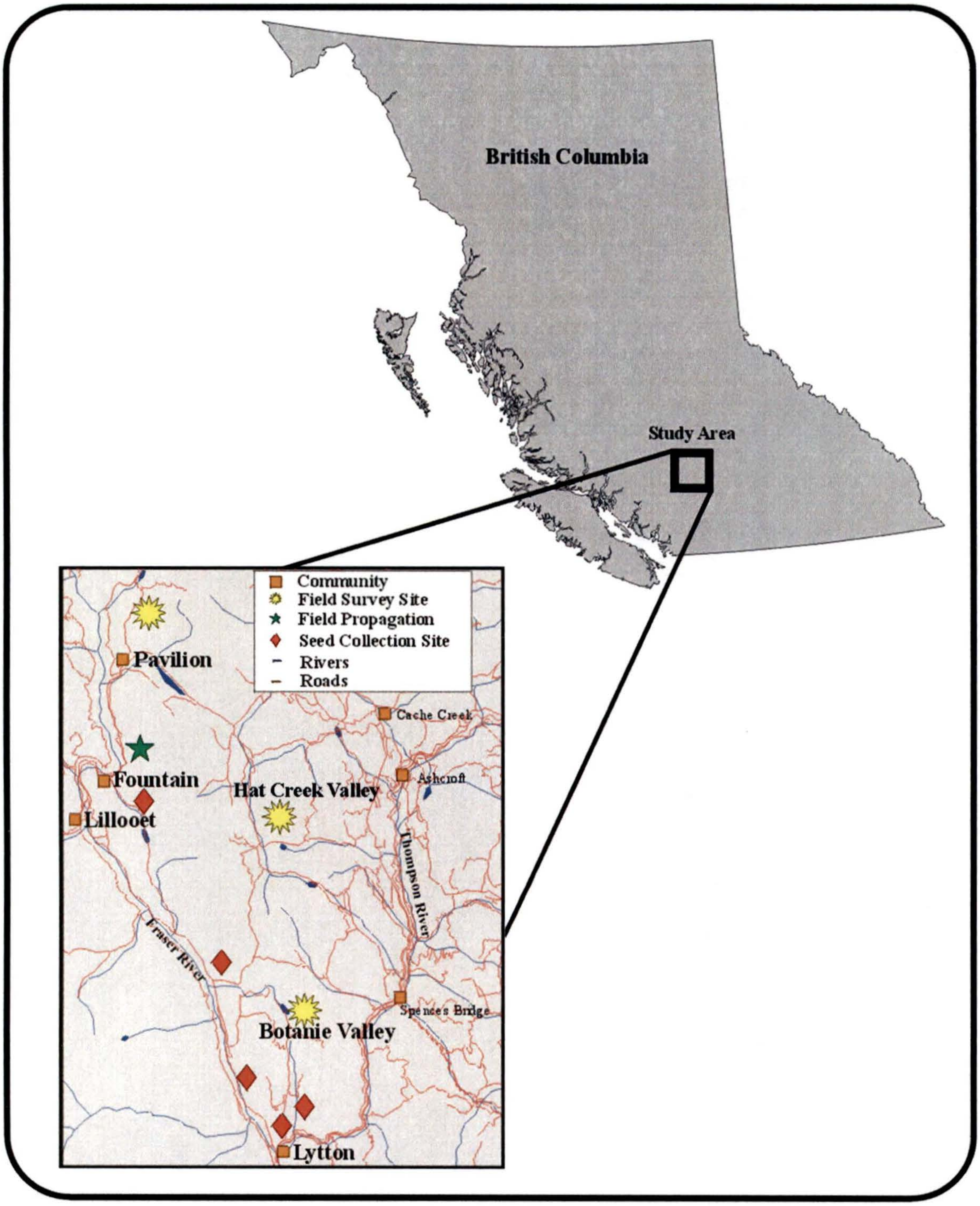
4.1 **Field Methods**

4.1.1 Site Descriptions

Three research sites were chosen: Pavilion Mountain, above the village of Pavilion and east of Lillooet; Upper Hat Creek Valley on the east slope and across the road from Twin Creeks Ranch; and, Ministry of the Environment Ecological Reserve (No. 88) adjacent to Botanie Valley (see map, Figure 4.1). All three of these sites have well-known dense populations of *B. sagittata.* The locations selected are representative of the elevation and habitat of the five seed gathering sites as well as the field location for propagation (e.g. grassland to sparsely forested, south-facing slope, well drained). The three sites are also all located within the drainage basin of the Fraser River Valley. The Fraser River Valley was selected as the boundary for this work in order to reduce possible genetic variations that may occur in broadly distributed populations of *B. sagittata*.

All three survey sites are located within the Interior Douglas-fir Biogeoclimatic

Figure 4.1 Map of field sites for *Balsamorhiza sagittata* autecological research and seed collection.



Zone (IDF)[1], which dominates the low- to mid- elevation landscape of south-central interior British Columbia (see IDF zone map, Figure 4.2). Meidinger and Pojar (1991) describe the IDF ecosystem in detail. Climatic conditions of IDF ecosystem are characterized by warm, dry summers, a fairly long growing season, and cool winters. The main factor controlling the climate is the rain shadow created by the Coast, Cascade, and Columbia mountain ranges. Mean annual temperature is 1.6-9.5 degrees Celsius. The average temperature is below 0 degrees Celsius for 2-5 months, and above 10 degrees Celsius for 3-5 months. Mean annual precipitation ranges from 300 to 750 mm, except in the wettest area where the precipitation exceeds 1000 mm. Twenty to 50% of the precipitation falls as snow. June is the wettest month. In the IDF zone, moisture deficits commonly occur during the growing season and frost can occur at any time.

A combination of edaphic and topographic conditions and fire history has led to the development of large grassland communities in parts of the IDF. *Balsamorhiza sagittata* can be a dominant species in these grasslands. The three sites studied for this research are classified as 'very dry warm IDF' (IDFxw). Plant species commonly associated with IDFxw include yarrow (*Achillea millefolium*), bluebunch wheatgrass (*Agropyron spicatum*), nodding onion (*Allium cernuum*), saskatoon (*Amelanchier alnifolia*), kinnikinnick (*Arctostaphylus uva-ursi*), showy aster (*Aster conspicuus*), pinegrass (*Calamagrostis rubescens*), Richardson's or northwest sedge (*Carex richardsonii/concinnoides*), *Cladonia* spp., northern bedstraw (*Galium boreale*), Rocky Mountain juniper (*Juniperus scopulorum*), *Peltigera* spp., ponderosa pine (*Pinus ponderosa*), red-stemmed feathermoss (*Pleurozium schreberi*), Douglas-fir (*Pseudotsuga menziesii*), stonecrop (*Sedum* spp.), soopolallie (*Shepherdia canadensis*), and birch-leaved spirea (*Spiraea betulifolia*). For a detailed description of species variety and composition see Meidinger and Pojar (1991).

Some selected wildlife species in the IDF zone of south-aspect Douglas-fir and ponderosa pine parkland include mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), golden-mantled ground squirrel (*Shermophilus lateralis*), northern pocket gopher (*Thomamys talpoides*), and black bear (*Ursus americanus*)

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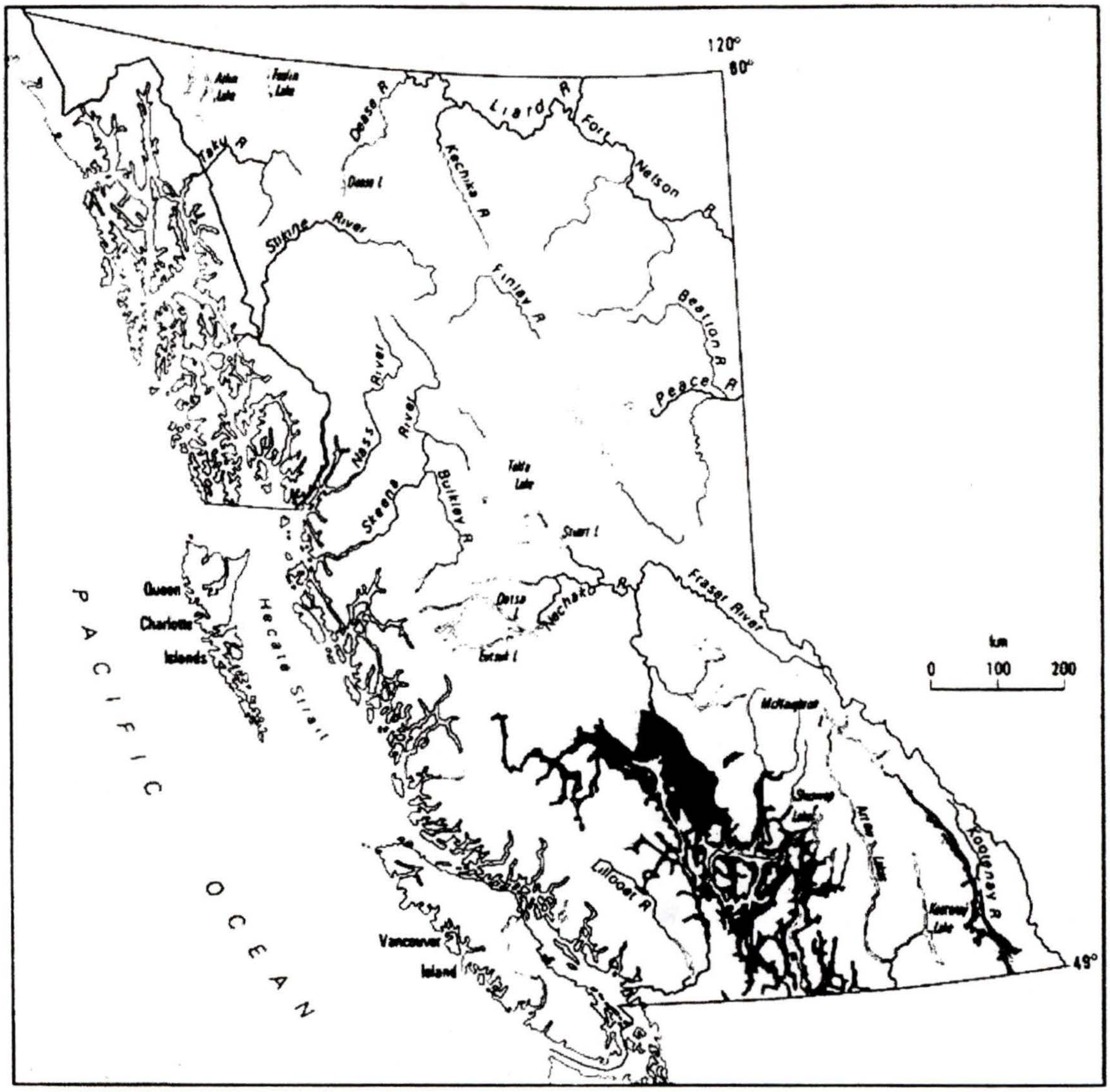
[1] British Columbia Ministry of Forests biogeoclimatic ecosystem classification is a widely used, common framework for classifying ecosystems and developing management prescriptions.

Figure 4.2 Interior Douglas-fir Biogeoclimatic Zone (IDF), which dominates the low- to mid- elevation landscape of south-central interior British Columbia.



Source: Redrawn from Meidinger and Pojar (editors) 1991. *Ecosystems of British Columbia.*

(Meidinger and Pojar 1991).

As noted previously, I selected my three survey sites on the basis of their well-known populations of *B. sagittata.* I located sites primarily through word of mouth, from First Nations recommendations and consultation with environmentalists, naturalists and botanists. Dr. Nancy Turner had visited Pavilion Mountain and collected *B. sagittata* there with Xaxl'ep elder, Sam Mitchell in 1974 and she suggested this location. Pavilion elder and Honourary Chief Dez Peters, Senior, recommended a particular location on Pavilion Mountain and gave permission to conduct research within his hunting territory. Peter McAllister, an environmentalist and resident of Hat Creek Valley had contacted Turner about large populations of *B. sagittata* on his land. I acquired permission to conduct research at this site from McAllister. Botanie Valley is well known for its dramatic displays of wildflowers, many of which, including *B. sagittata*, are traditional food plants for Interior First Peoples (Turner et al. 1990). To conduct research in this area I chose the Skwaha Lake Ecological Reserve (No. 88). I received verbal permission to conduct research in the Reserve from staff at the Lytton Indian Band office and obtained a research permit administered by the Ministry of Environment, Lands and Parks, BC Parks, Thompson River District (Ecological Reserve Permit No. TR0010194).

Brief descriptions of each of the three sites follow. Specific site descriptions, location information and dates are summarized in table 4.1.

Pavilion Mountain

Pavilion Mountain takes the form of a high Montane Parkland ridge, tending east west, which is at the start of the Marble Range. My research site was located on Diamond S Ranch, which occupies much of the rangeland on Pavilion Mountain. The slope on which we worked descended southwest to a relatively flat valley occupied by Gillian Stream (Figure 4.3). During days spent collecting data we frequently saw deer (*O. hemionus* or *O. virginianus*), black bears (*U. americanus*), marmots (*Marmota flaviventis*) and a large number of cattle, which had access to the site. Thirty percent of the sample plots had signs of cattle activity, including dung and trails. A number of *B. sagittata* plants in the plots had severed leaf and flower stems indicating herbivory (63.3% of the 30 plots surveyed). Many of the remaining leaves were showing signs of

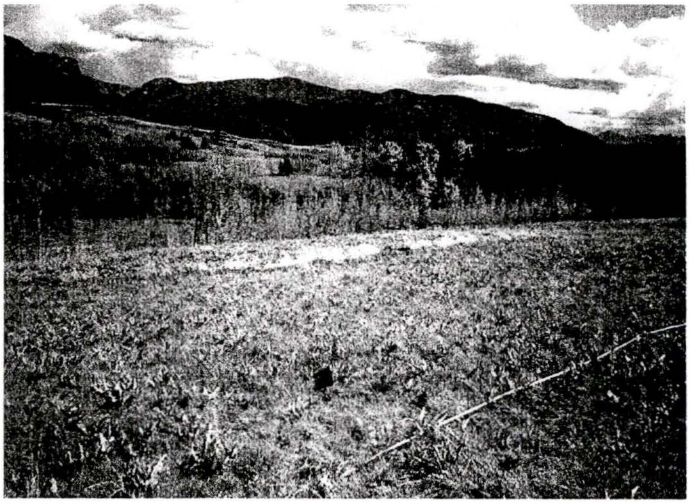
Table 4.1 Autecology research field site description table including location information and dates.

Site Name

	Pavilion Mountain	Hat Creek Valley	Botanie Valley
Dates Surveyed	May 29-31, 2000	June 2-4, 2000	June 16-18, 2000
Latitude/Longitude	N 50 56 24, W 121 49 24	N 50 39 09, W 121 34 23	N 50 23 39, W 121 30 15
Approximate Elevation	1310 m	1271 m	1336 m
Site Location	Pavilion Mountain above village of Pavilion, east of Lillooet; access through Diamond S ranch. Slope descends southwest to Gillian Stream and valley.	Upper Hat Creek Valley on east slope and across road from Twin Creeks Ranch; Valley situated in the inter-riverine transition zone between the Fraser and Thompson Plateaus.	Ministry of the Environment, Skwaha Ecological Reserve off of Botanie Valley near southern end of Clear range, which occupies the "V" between the Fraser and Thompson rivers, north of Lytton.
Average Slope Gradient	9%	22%	24%
Average Aspect	SE 140°	SW 260°	S 190°
Average Slope Position	upper slope	mid slope	lower slope
Microtopography	straight, minor drainage	straight, slight convex with shallow drainage	straight, concave

Figure 4.3 Pavilion Mountain field survey site, photo taken from the bottom of the research site (0, 0) looking up and northeast.

Figure 4.4 Division of Pavilion Mountain field site by non-native species.



insect herbivory. The site itself had two distinct areas. One half had more non-native species and a lower diversity of species but larger *B. sagittata* plants. The other had smaller plants but greater species diversity and bare patches of soil (see Figure 4.4).

Hat Creek Valley

Hat Creek Valley is in the inter-riverine transition zone between the Fraser and Thompson Plateaus. It was used historically by both the Nlaka'pamux and Secwepemc peoples and possibly Stl'atl'imx (Peacock 1998). The altitude of the base of the valley is 1050 m, and the surrounding mountains of the Clear and Marble Ranges reach as high as 2150 m. Figure 4.5 shows a view of the Hat Creek Valley research site. As at the Pavilion Mountain site, bears (*U. americanus*), marmots (*M. flaviventis*) and deer (*O. hemionus* or *O. virginianus*), were observed. However, few plants displayed signs of herbivory (one plot had cropped leaves). Only one of the 30 plots had any indication of recent impacts as a result of cattle but grazing trails were visible across the ridge. Many insects were photo-documented at the site yet these plants were not as impacted from insect herbivory as those at Pavilion. *Balsamorhiza sagittata* plants had few blooms in comparison to the number of buds, which were aborted relatively close to the ground and dry to the touch.

Botanie Valley

The Skwaha Ecological Reserve is near the southern end of the Clear range, which occupies the triangular area just north of the junction of the Fraser and Thompson rivers, north of Lytton (Figure 4.6). Teit (1900 cited in Peacock 1998:115) states that "Botani Valley, situated in the mountains, some ten miles from Spences Bridge, and about fifteen miles from Lytton, has been from time immemorial a gathering place for the upper divisions of the tribe [Nlaka'pamux peoples], chiefly for root-digging during the months of May and June."

Bears (*U. americanus*) were also observed at the Botanie Valley site and there was indication of their extensive use of the area (overturned rocks and scat). No other mammals were seen, and signs of cattle did not extend up past the flatter base of the slope. Only one plot had signs of herbivory. As indicated previously, Botanie Valley is well known for its outstanding wildflower displays and rare plants. "Acres of densely

Figure 4.5 Photo of Hat Creek Valley site taken from the Northeastern corner of the plot facing southwest down the valley.

Figure 4.6 Botanie Valley field site in the Skwaha Ecological Reserve, photo taken up hill towards Northeast.

packed balsamroot plants, together with less abundant species like common red paintbrush and upland larkspur, present a spectacular sight during peak flowering" (Krajina et al. 1975:224).

4.1.2 Sampling Methods

Measurements were made of a number of abiotic and biotic variables. Overall site descriptions, both quantitative and qualitative, were carried out at each of the sites. Observations of plant communities and percent cover of associated plant species were documented. Characteristics of *B. sagittata* were recorded. All *B. sagittata* populations were sampled while the plants were in flower to ensure consistency of phenology for estimating species cover and to assess plant characteristics at a single critical reproductive stage for this species. The entire sampling protocol was completed with the help of one volunteer field assistant. Each site took between three to four days to complete. Nomenclature follows Hitchcock and Cronquist (1973).

Sampling Grid

Within a selected area, homogeneous for *B. sagittata*, sub-plot locations were established using a stratified random sampling design. At each site, a 30 x 30 m plot was centrally located within an area of uniform physiognomy (features on surface) and *B. sagittata* phenology. Placement was deliberately structured and not random, in an attempt to include a uniform and representative area of *B. sagittata.* Thirty 1 x 1 m sub-plots were then located randomly within the 30 m square plot using a table of random numbers (see Figure 4.7).

Environmental Parameters

For each site, a description and measurements of the location were recorded (Table 4.2). The measurements included: approximate latitude, longitude and elevation (using a GPS); aspect (derived using a compass), slope angle (using an Abney clinometer), and slope position. In addition, a number of characteristics of the site were subjectively observed and recorded including: the general physiognomy; drainage conditions; microtopography; and disturbance observations (e.g. bear activity, small

Figure 4.7 Diagram of plot dimensions and format. Thirty 1 m x 1 m subplots were located randomly within the 30 m square plot.

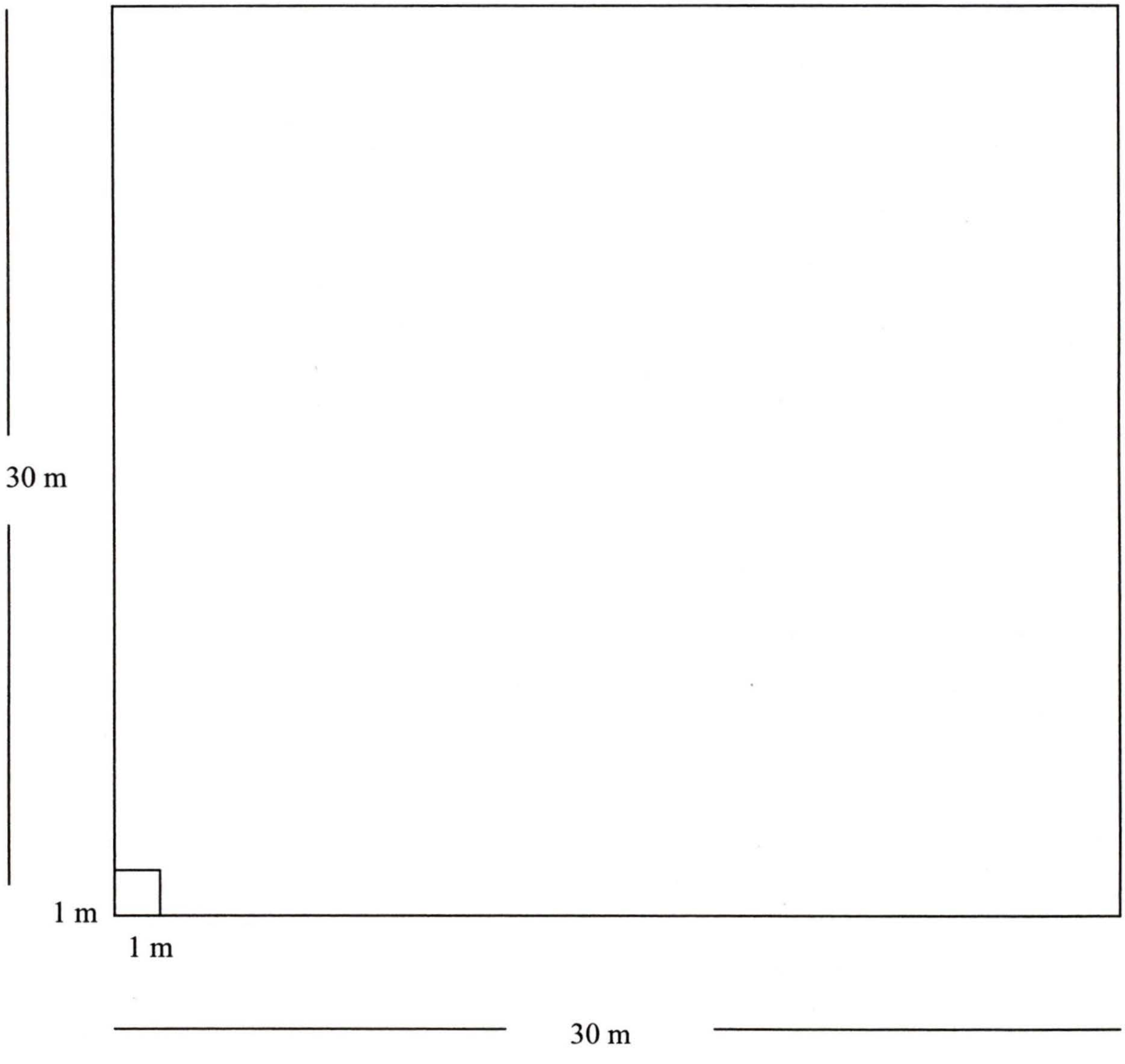


Table 4.2 Environmental variables measured for three populations of *Balsamorhiza sagittata.*

Variable Name	Definition
soildpt1-4	Soil depth, number of cm up to 40 for each corner of each plot. High numbers equal more rockiness (measured from 40 cm mark to soil surface). Average of four points calibrated for each plot.
fire	Categorical variable, 3 levels indicating the presence or absence of fire: 3-charcoal obviously present in soil sample; 2-trace amounts present; 1-no charcoal found in sample.
cattle	Categorical variable indication of cattle: 1-signs of cattle; 2-absent.
herbivor	Categorical variable for signs of herbivory: 1-leaves or bud stalks eaten, 2-none obviously eaten.
wdiffrnc	Soil wet weight (grams) minus soil dry weight to get a value indicating percent soil moisture on a weight basis.
pH	Substrate pH at trowel depth.
soiltext	Description of soil texture (e.g. sand, loam, silt).
perliter	Estimated percentage of plot with surface litter cover.
dpthlitr	Estimated average depth of leaf litter on the plot (cm).
cwd	Estimated percent of coarse woody debris on plot.
perbare	Estimated percent of plot that was bare soil.
percrust	Estimated percent of plot covered by bryophytes and lichens.
perherb	Estimated percent of plot covered by herbaceous layer.
pershrub	Estimated percent of plot shrub layer.
totalspp	Total number of vascular plant species present in plot; used as an index of biodiversity.
native	Number of native species present in plot.
nonnative	Number of introduced species present in plot.
per?	The estimated percent of plot occupied by each of the other plant species was also recorded, for a total of up to 52 species.

mammal activity, grazing, trails through the site, insects, etc). Litter depth was measured within each plot and percent cover for litter, coarse woody debris and bare soil were estimated. An index of substrate rockiness was calculated, based on Thomson et al. (1996), by averaging 120 rock depth measurements (from the corners of the 30 plots) obtained by hammering a piece of rebar into the ground until it reached rock or a depth of 40 cm.

To examine soil properties, approximately 100 g of soil was taken from below the surface layer in each plot (A horizon). The soil samples were placed in doubled Ziploc bags and kept in a cool, dark location until they could be tested in a lab facility. Soil pH was measured by combining approximately 50 mg of soil with 100 ml of distilled water. The mixture was stirred every five minutes for a total of 30 minutes then measured with a pH meter (Oakton phTestr 2). To measure moisture, approximately 150 ml of soil was measured to the nearest 0.1 g and weighed. The soil was placed in a Fisher Isotemp Forced Draft Oven heated to 70 degrees Celsius to dry for 24 hours. The soil was then weighed a second time to determine a dry weight and the difference used to estimate soil moisture levels. Hand texturing of fine sediments was employed in each plot in order to determine soil texture. Detailed soil information was acquired from *Soils of Ashcroft Map Area Soil Survey Report No. 26* (Young et al. 1992). Soil information for the three sites is summarized in Table 4.3. Planting site information is included in the table for comparison purposes.

Vegetation Parameters

All visible herbaceous plants and shrubs in the plots at the time of surveying were counted and their percent cover was visually estimated. Some species in the plots may have been overlooked because they were not yet visible above ground. Large woody bushes and trees were uncommon at the sites and did not occur in any of the grid plots. The bryophytes and lichens were combined and were treated as a single entity, and given a joint estimated percent cover value per plot (variable 'percrust'). For the vascular plants, when species identification proved difficult in the field, we collected samples for closer examination and comparison at the University of Victoria Herbarium. Appendix 3 lists all species recorded at the three sites.

Table 4.3 Soil information for the *Balsamorhiza sagittata* field sites.

	Pavilion Mountain	Hat Creek Valley	Botanie Valley	Planting Site*
Soil Association	Timber	Medicine	Chasm	Courtney
Forest Zone	Interior Douglas-fir seral ponderosa pine	Interior Douglas-fir seral ponderosa pine	Interior Douglas-fir no seral ponderosa pine	Interior bunchgrass zone
Soil Parent Material	medium/moderately fine textured morainal deposits: slightly to moderately stony	medium and moderately coarse textured morainal deposits; slightly/moderately stony	coarse and moderately textured; colluvial and fan deposits slightly to very stony	moderately course and medium textured colluvial fan deposits with, thin loamy eolian cappings, slightly/moderately stony
Common Soil	Degraded Eatric, Brunisol	Calcareous Black	Degraded Eatric, Brunisol	Orthic Brown
Drainage	well drained; soil moisture does not normally exceed field capacity for significant part of year	well drained; soil moisture does not normally exceed field capacity for significant part of year	well drained; soil moisture does not normally exceed field capacity for significant part of year	well drained; soil moisture does not normally exceed field capacity for significant part of year
Landform Class	moraine (glacial till)	moraine (glacial till), bedrock	colluvium, bedrock	fluvial/fluvial glacial
Slope Class	very steeply sloping	steeply sloping to hilly	very steeply sloping to extreme	steeply sloping to strongly sloping
Soil Components	modal soil development; soil lithic phase less than 50 cm deep over bedrock (less common)	modal soil development	modal soil development; soil varies due to cold air pooling	modal soil development; different development due to changes in ecology
Soil Texture	silt	silt/sand	silt/sand	silt/sand

Information derived from Young et al. 1992. *Soils of Ashcroft Map Area.*

Within each of the plots all *B. sagittata* individuals were counted. Before commencing documentation of individual plots I dug a number of plants outside of the field site to be certain that I could differentiate between one plant and groups of plants. We also counted leaves, flowers, aborted buds, and herbivore-damaged scapes. For three plants per plot (the largest and those from the SE and NW corners) we recorded the length and width of the largest leaf and longest flower stems. Table 4.4 lists the *B. sagittata* variables recorded.

4.2 **Data Analysis and Results**

During completion of the field data it soon became apparent that some of the variables would not be relevant for analysis. I will briefly list these and indicate why I did not use them. Some environmental variables that I expected to be present were either absent or my measurement methods were not sensitive enough to provide an indication of their presence. Evidence of fire, such as charcoal, which has been indicated as having a strong positive influence in the growth of *B. sagittata* (see Chapter 2), was not observed in the three sites assessed. Available literature does indicate that fire has played a significant role in the development of the plant diversity in the IDF Biogeoclimatic Zone (Meidinger and Pojar 1991). Coarse woody debris (CWD) was not prevalent in any of the plots at Pavilion Mountain or Hat Creek, and was only in three plots at Botanie. The absence of CWD is the result of having very few trees at the site.

The influences of cattle, although having potentially significant influences on the long-term growth of *B. sagittata*, were not included as variables in the data analysis. Signs of cattle were present at Pavilion Mountain and minimally at Hat Creek Valley.

The impact of grazing is difficult to assess because of its long-term cumulative effects and because signs of cattle such as dung and trails can remain years after the site was last grazed. Because of the potential inaccuracies in assessing cattle impacts I chose merely to note the signs of cattle (summarized in the site descriptions) at each site but not to include the information in any quantitative analysis.

Soil texture did not vary between the plots and therefore was not included in data analysis. Soil texture is summarized for each site in the soil table (Table 4.3). For each plot I recorded the percent cover of each species of plant present. Although these

Table 4.4 *Balsamorhiza sagittata* variables recorded at the three field sites.

Variable name	Definition
basa#	Number of *B. sagittata* plants in the plot.
percovba	Estimated percent of plot covered by *B. sagittata.*
leaf#p1-20	Number of leaves for each *B. sagittata* in plot (1 to 20).
height#p1-20	Height (base of plant to tip of largest flower stem or leaf (cm) for each *B. sagittata* plant in the plot (1 up to 20).
flow#p1-20	Number of flowers for each *B. sagittata* in plot (1 up to 20).
bud#p1-20	Number of buds for each *B. sagittata* in the plot (1 up to 20).
lngthlal	Largest *B. sagittata* plant, length of largest leaf in cm (base to tip)
widthlal	Largest *B. sagittata* plant, width largest leaf (cm) at widest point.
stemleng	Largest *B. sagittata*, length longest stem (cm) base to flower head.
lfnlrg	Number of leaves for largest *B. sagittata* plant.
hghtlrg	Height of largest *B. sagittata* in plot (cm). Leaf or flowerstalk.
flwrnlrg	Number of flowers for largest *B. sagittata.*
budblrg	Number of flower buds for largest *B. sagittata.*
lngthnw	Most Northwestern *B. sagittata* plant, length largest leaf (cm) (base to tip).
widthnw	Most Northwestern *B. sagittata* plant, width largest leaf (cm) (at widest point).
stemnw	Most Northwestern *B. sagittata* plant, length longest stem (cm) (base to flower head).
lngthse	Most Southeastern *B. sagittata* plant, length largest leaf (cm) (base to tip).
widthse	Most Southeastern *B. sagittata* plant, width largest leaf (cm) (at widest point).
stemse	Most Southeastern *B. sagittata* plant, length longest stem (cm)

data may have interesting results in detailed analysis as a component of habitat type or to study the impacts of soil or moisture retention properties, consultation with staff at Agriculture and Agri-Food Canada has lead me to believe that at this level of research and for the purpose of preliminary investigations it is more relevant to assess the general abundance of species combined and to determine the ratio of native versus non-native species.

I also chose to limit the analysis of the plant size data collected on *B. sagittata.* I recorded the leaf number, height, flower number and bud number for every *B. sagittata* plant in each plot. However, analysis of all these data are beyond the scope of my research and would be more appropriate for future investigations into *B. sagittata* growth rates under different conditions. As noted previously, I also recorded more detailed measurements of three pre-determined *B. sagittata* plants in each plot. For my data analysis I have chosen to use the specific plant information for the largest *B. sagittata* plant in each plot. Again, the total information on the three pre-determined plants may be valuable in future in-depth analysis of *B. sagittata* phenology. However, the research that I have conducted is preliminary and has the goal of ascertaining in what conditions *B. sagittata* are currently growing within the study area.

To examine the similarities or discrepancies between the sites, I first calculated descriptive statistics and plotted box plots for the remaining variables. All data analysis was completed with the statistical package SPSS, version 10.0 for Windows. The data obtained are summarized in Appendices 4 and Appendices 5.

According to the descriptive statistics (primarily means) the values of the variables are different between the sites. In order to determine if the values were significantly different I then calculated ANOVA's. The results of the ANOVA's are presented in Tables 4.5 and Table 4.6. Using a significance of $p=0.05$, it appears that the differences in the environmental variables were significant between the sites. The *B. sagittata* measurements taken are also significantly different between the sites with the exception of the number of flowers per plant ($p=0.071$). The numbers of *B. sagittata* plants in each plot are significantly different at the three sites, however the significance is not strong ($p=0.042$). In this case the mean numbers for Pavilion Mountain are higher than Hat Creek and Botanie, although only marginally.

Table 4.5 Results for ANOVA's of environmental variables based on research sites.

Variable	df	F	Significance/Decision
% bare soil	2	60.654	.000 - significant difference among sites
% microbyotic	2	16.479	.000 - significant difference among sites
% herbaceous	2	24.098	.000 - significant difference among sites
% shrubs	2	3.849	.025 - significant difference among sites
% native	2	68.138	.000 - significant difference among sites
% non-native	2	7.8	.001 - significant difference among sites
% unknown	2	27.385	.000 - significant difference among sites
total species	2	4.929	.009 - significant difference among sites
pH	2	16.722	.000 - significant difference among sites
soil moisture	2	14.204	.000 - significant difference among sites
depth litter (cm)	2	9.997	.000 - significant difference among sites
% litter	2	21.551	.000 - significant difference among sites
soil depth	2	12.898	.000 - significant difference among sites

Table 4.6 Results of ANOVA for *Balsamorhiza sagittata* variables based on research site.

Variable	df	F	Significance/Decision
# of *B. sagittata*	2	3.28	.042 - significant difference among sites
% *B. sagittata*	2	5.64	.005 - significant difference among sites
Largest *B. sagittata*			
length largest leaf (cm)	2	13.40	.000 - significant difference among sites
width largest leaf (cm)	2	9.28	.000 - significant difference among sites
longest stem length (cm)	2	5.30	.007 - significant difference among sites
leaf number	2	5.31	.007 - significant difference among sites
height (cm)	2	13.20	.000 - significant difference among sites
flower number	2	2.73	.071 – no significant difference among sites
bud number	2	8.67	.000 - significant difference among sites

There are a number of potentially significant relationships that may exist between environmental and *B. sagittata* variables. To investigate which conditions are most significant to *B. sagittata* establishment and growth I conducted correlation analysis. Before performing correlations between the environmental variables and *B. sagittata* I first determined which of the variables would be the most representative of the species. To avoid entering into a level of complexity that is beyond my research objectives, I determined that it would be best to use one *B. sagittata* factor when conducting correlation analysis with the environmental variables.

The process of selecting which *B. sagittata* variable to use involved both statistical analysis and reflection. To assist in understanding the relationships between the parts of *B. sagittata* which indicate phenology and development I conducted correlation analysis between the *B. sagittata* variables. At a significance level of 0.01 for a 2-tailed test (Kendall's tau) the number of plants and the percent of the plot covered by *B. sagittata* exhibit different correlations for each site. Pavilion had a weak positive correlation of 0.37. Hat Creek was positive and moderate at 0.60. Botanie had no correlation (0.21) between the percent cover and number of *B. sagittata*. I had expected that this correlation would be much stronger. The variables for the largest plants were not consistently correlated with environmental variables nor were correlations high. Upon reflection I determined that measurements for the largest plant are not representative of the overall growing conditions for *B. sagittata*. Bartolome (1989) notes that plant height has not been shown to be an effective measure of plant productivity outside of improved pastures. There is no reason to believe that one large plant indicates better growing conditions than many smaller ones. Furthermore, because *B. sagittata* is a long-lived plant, factors that allowed for one plant to become established may not be prevalent in consecutive years. Finally, percent cover of *B. sagittata* could be strongly influenced by herbivores such as deer, whose populations fluctuate, and insect predation.

My sampling was conducted when *B. sagittata* was in peak bloom and the number of flower heads was not significantly different among the three sites (p=0.071). I considered this variable when investigating correlation between environmental parameters and *B. sagittata* establishment and growth. There are, however, a number of reasons that do not make this variable an accurate representation of *B. sagittata* success.

Flower head counts may be more a factor of short-term weather fluctuations than environmental influences. Furthermore, a large number of blooms that may occur one year are not an indication of the long-term survivability of the species or constant growing conditions. Finally, flowers and flower stems are an important food source for many ungulates and humans harvest the stems. Both of which would reduce the number of flower heads. Because I am interested in the general abundance of *B. sagittata* I selected a variable which is representative of the plant's longevity. I chose to investigate the number of *B. sagittata* plants in each plot at the three sites. The descriptive statistics for the number of *B. sagittata* at each site are presented in Table 4.7.

Table 4.7 Descriptive statistics for the number of *Balsamorhiza sagittata* at each of the three research field sites.

	Density of *Balsamorhiza sagittata*			
Field Site	Mean	Minimum	Maximum	Standard Deviation
Pavilion Mountain	7.37	2	20	4.24
Hat Creek Valley	5.33	1	11	2.52
Botanie Valley	6.73	2	12	2.32

The distributions of the data for each of the three sites are presented in the three histograms (Figures 4.8 a-c). I conducted correlation analysis to determine if any of the environmental variables are strongly correlated to the variables representative of the *B. sagittata* population.

For the correlation analysis I have chosen to treat each site individually because of concerns that the sites have differences that are not quantifiable or clearly measured through my investigation procedures and because the majority of the variables are significantly different between the three sites. I investigated relationships among the variables by first plotting bivariate scattergrams to examine the variables visually and to suggest hypotheses (Figures 4.9 a-m). Based on the scattergrams it appears that relationships among the variables are similar at each field survey location and none are strongly correlated. Variables such as soil depth (Figure 4.9 m) do not differ enough

Figure 4.8 Frequency distribution for number of *Balsamorhiza sagittata* per meter^2.

Figure 4.8a Pavilion Mountain

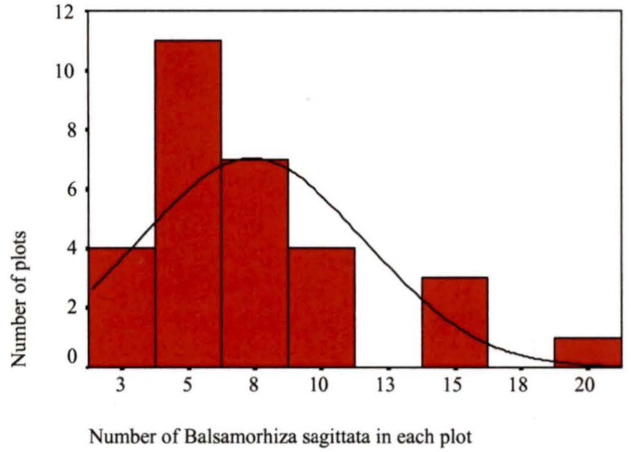


Figure 4.8b Hat Creek Valley

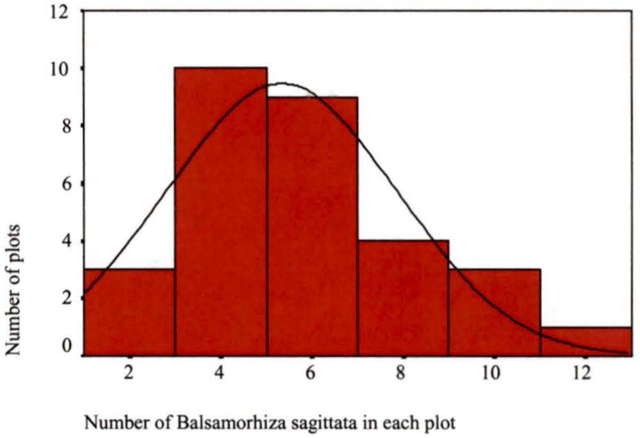


Figure 4.8c Botanie Valley

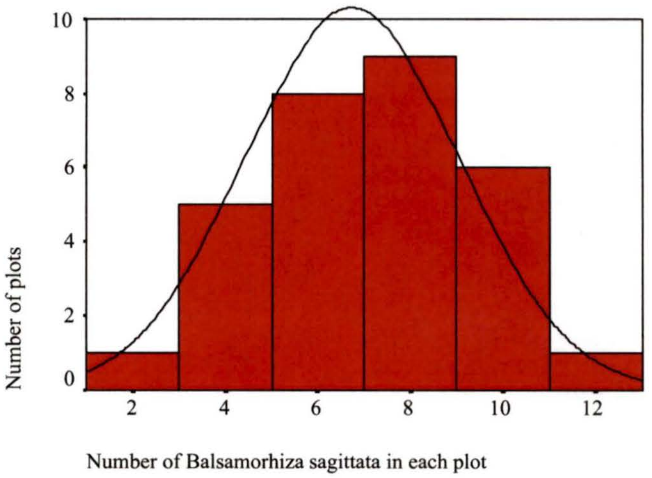


Figure 4.9 Bivariate scattergrams for environmental variables and number of *Balsamorhiza sagittata* plants at the three field research sites.

Figure 4.9a Exposed Substrate

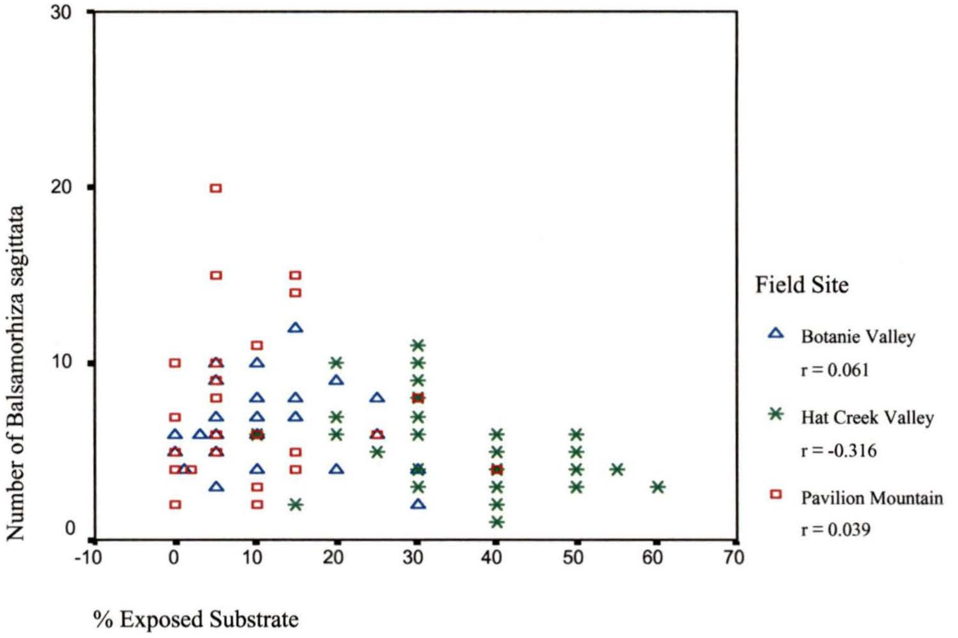


Figure 4.9b Microbyotic Crust

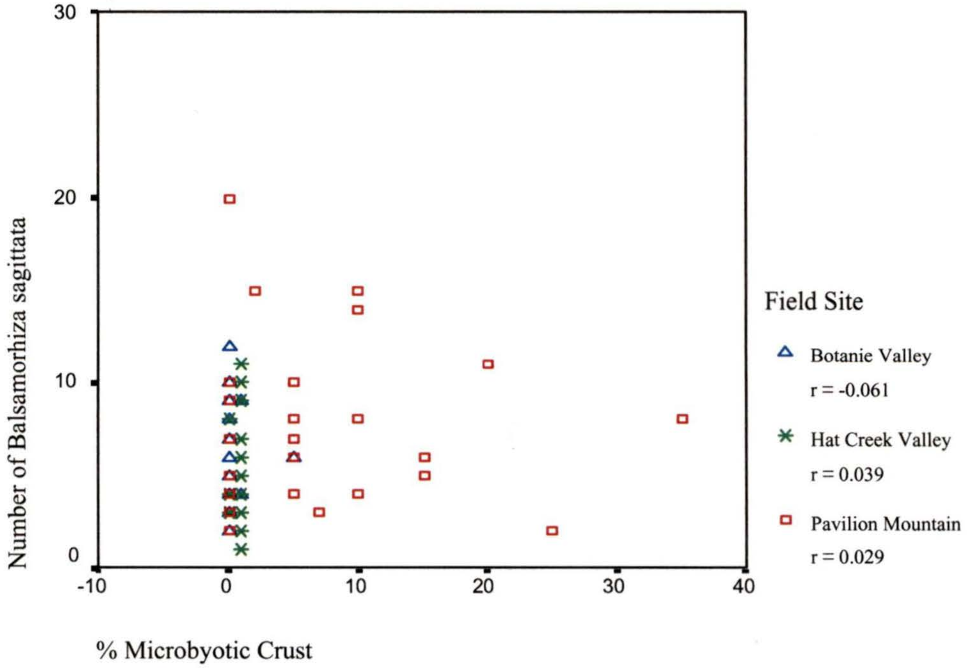


Figure 4.9c Herbaceous Plants

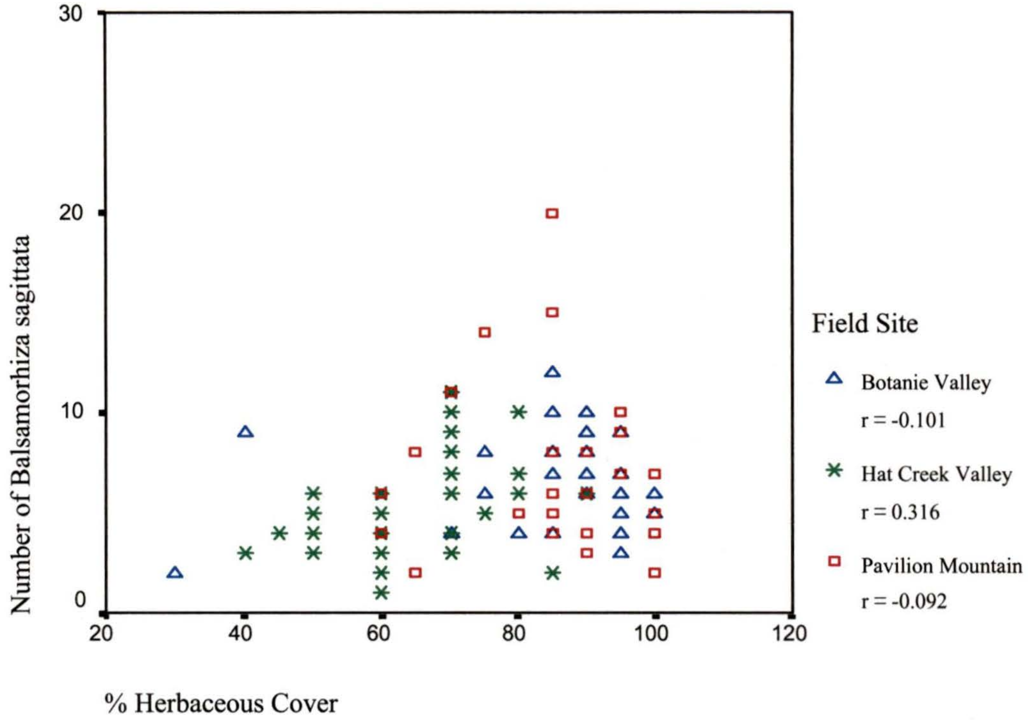


Figure 4.9d Shrub Plants

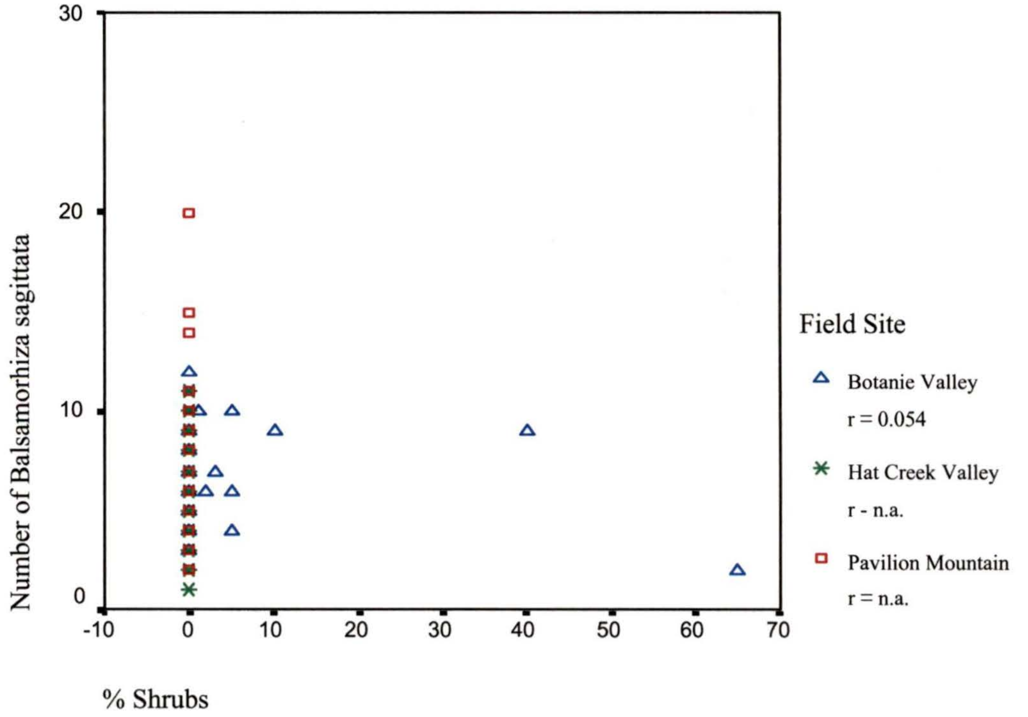


Figure 4.9e Native Plant Species

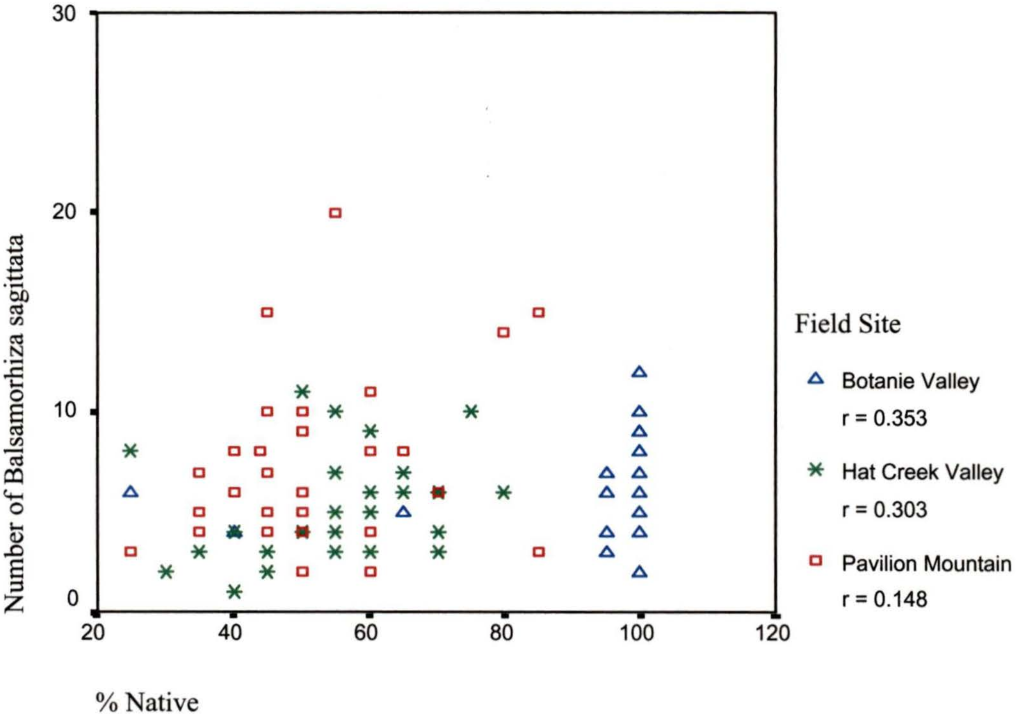


Figure 4.9f Non-native Plant Species

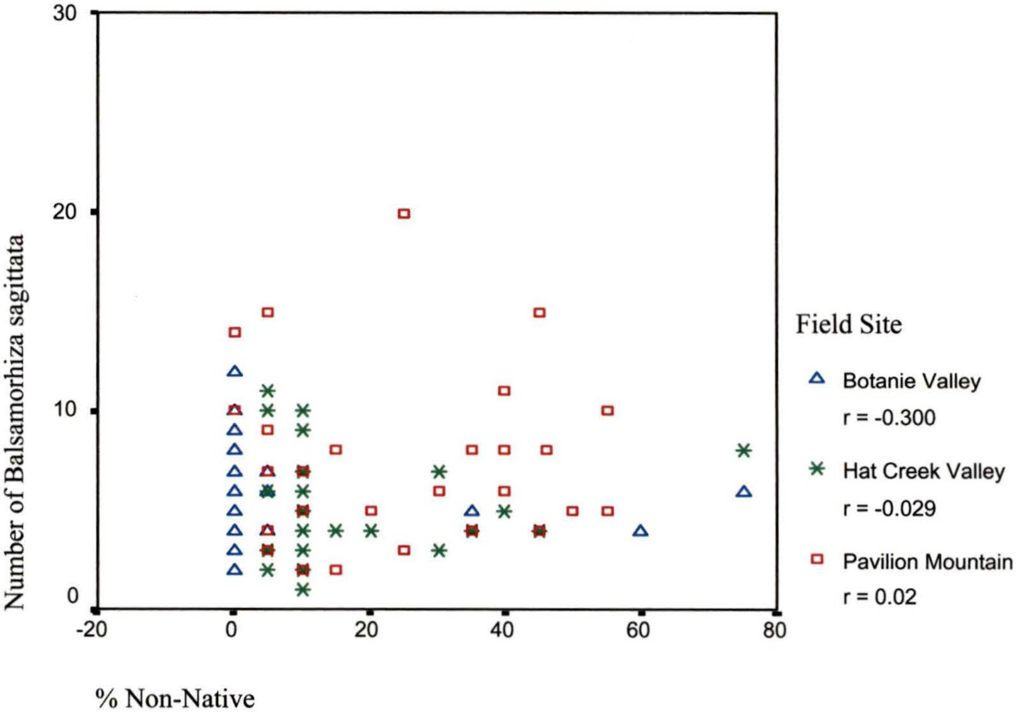


Figure 4.9g Unable to Identify if Native or Non-native

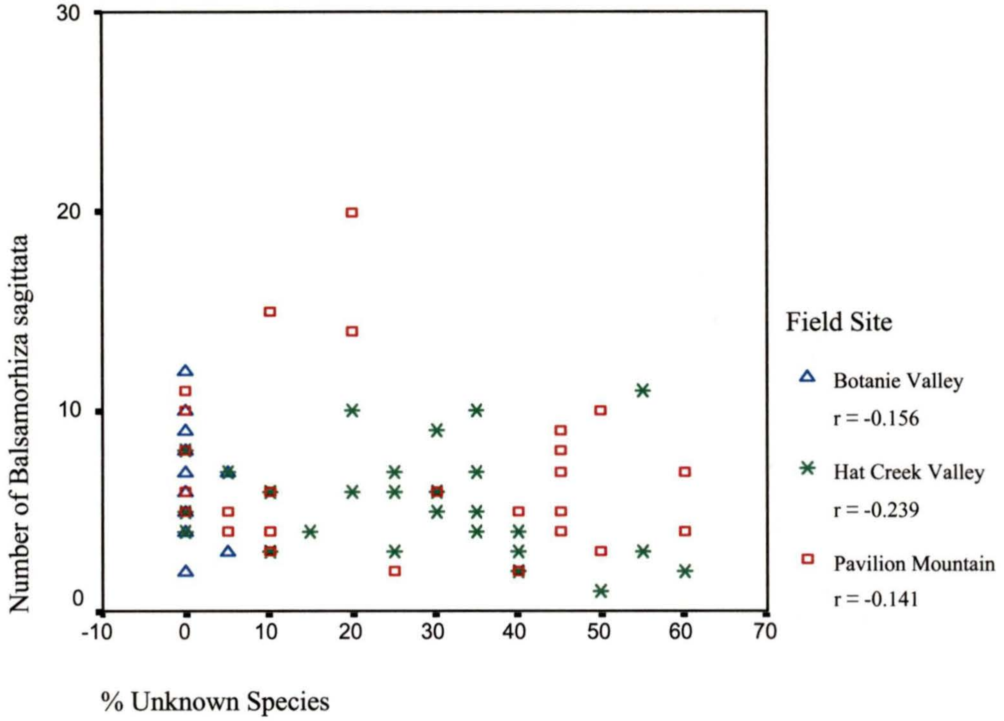


Figure 4.9h Total Species Diversity

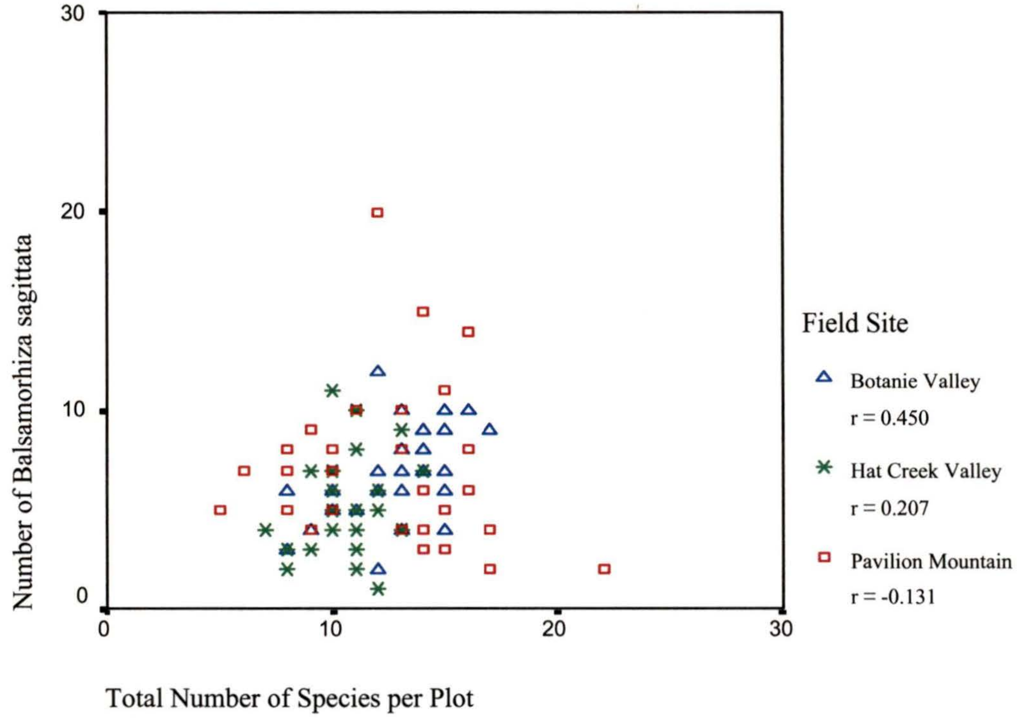


Figure 4.9i Soil pH

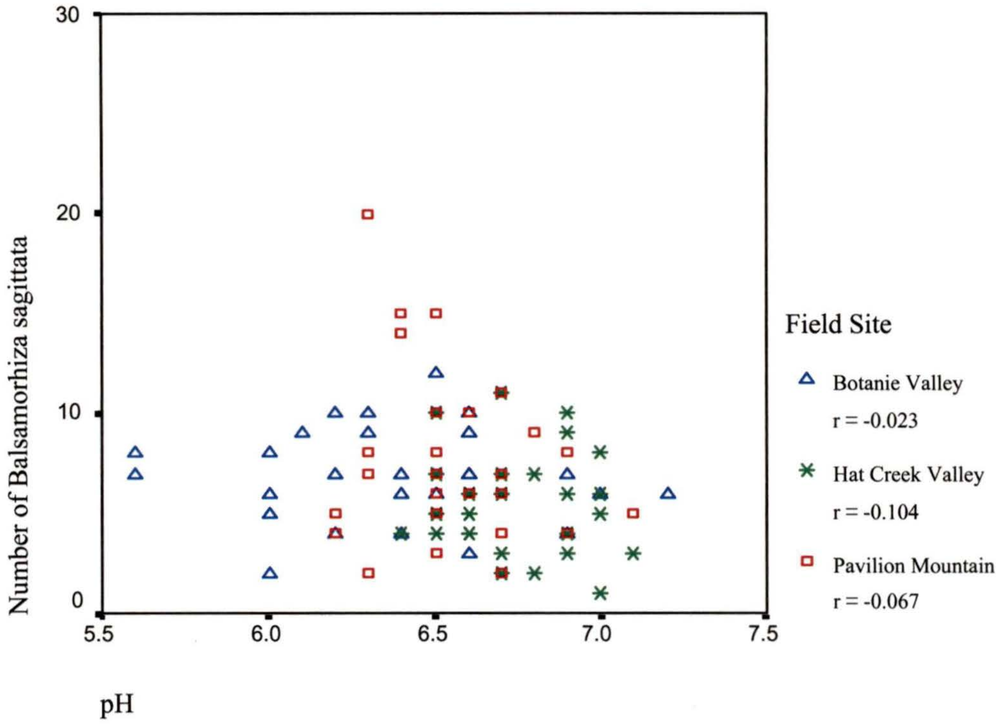


Figure 4.9j Soil Moisture

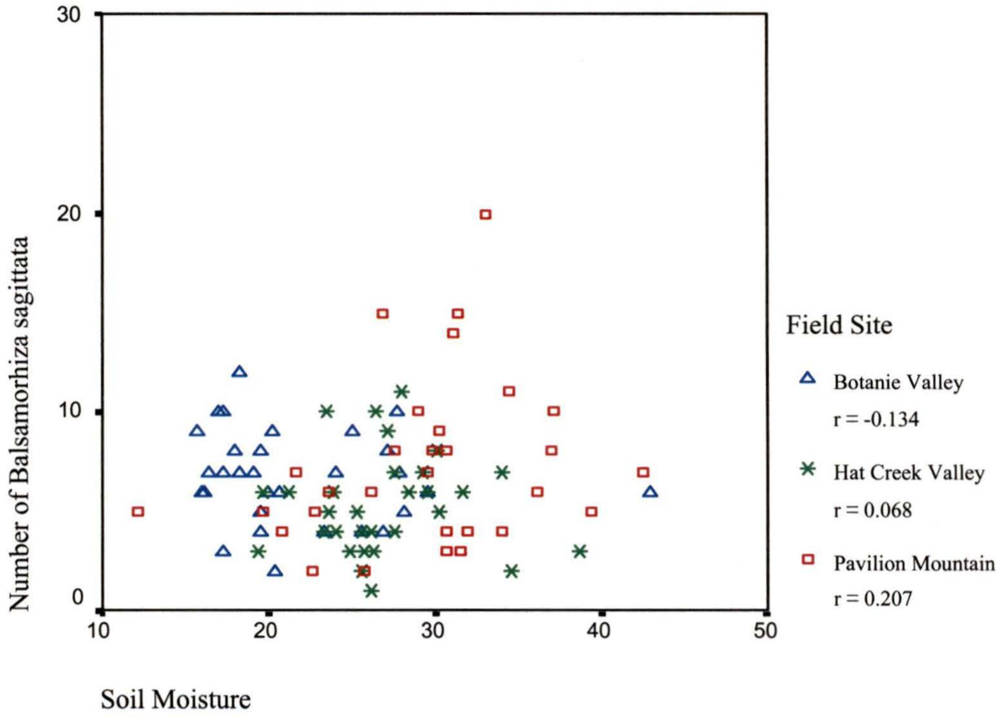


Figure 4.9k Litter Depth (cm)

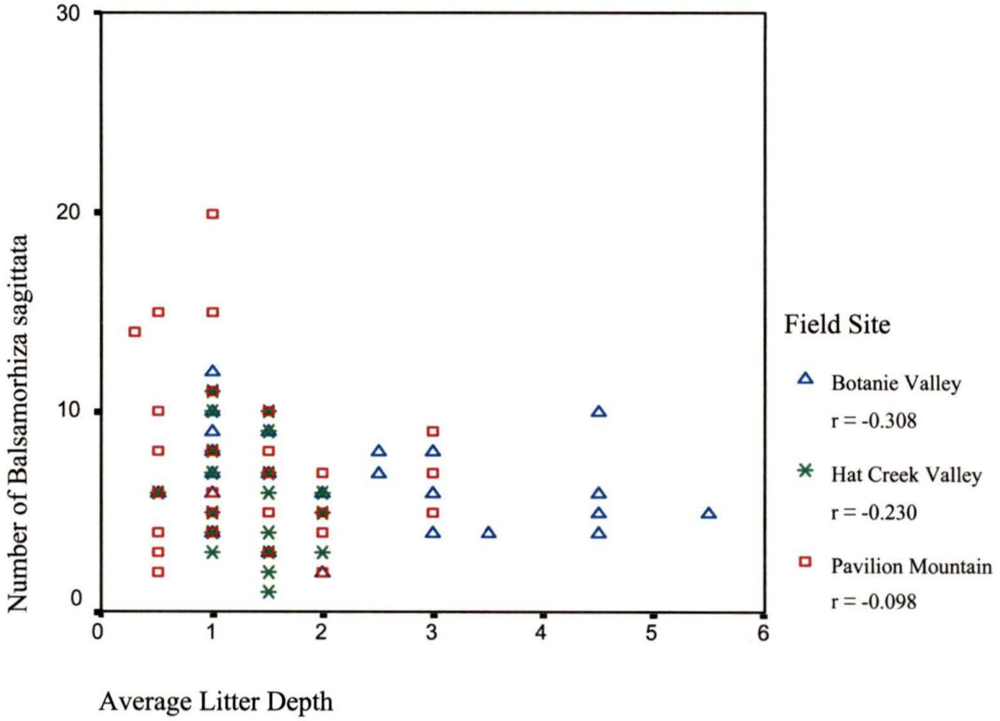


Figure 4.9l Percent Coverage of Litter

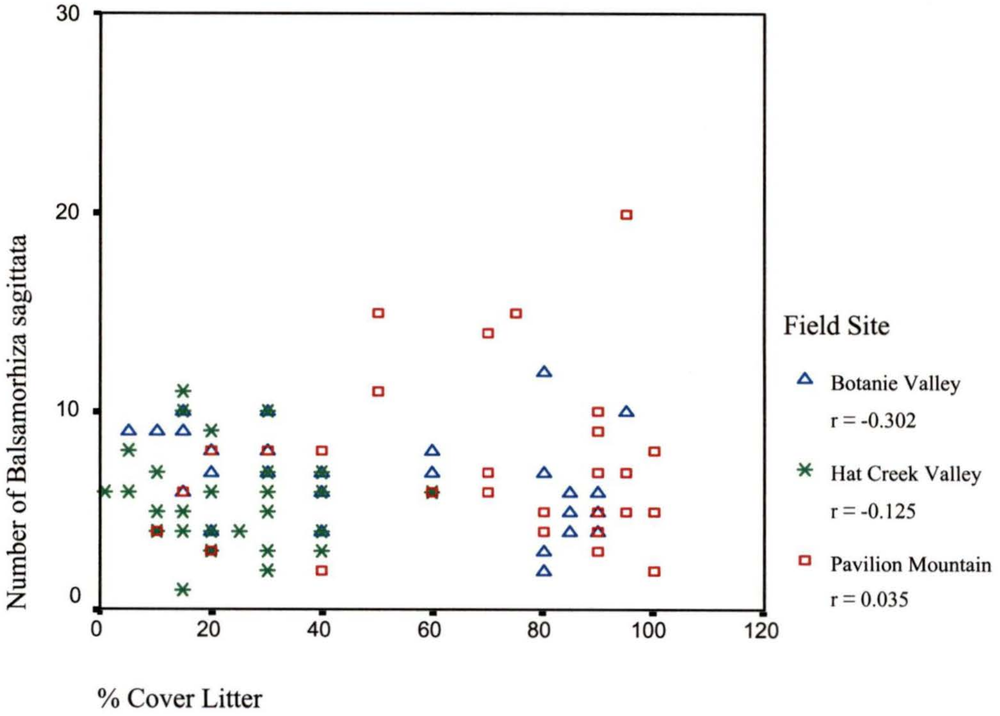
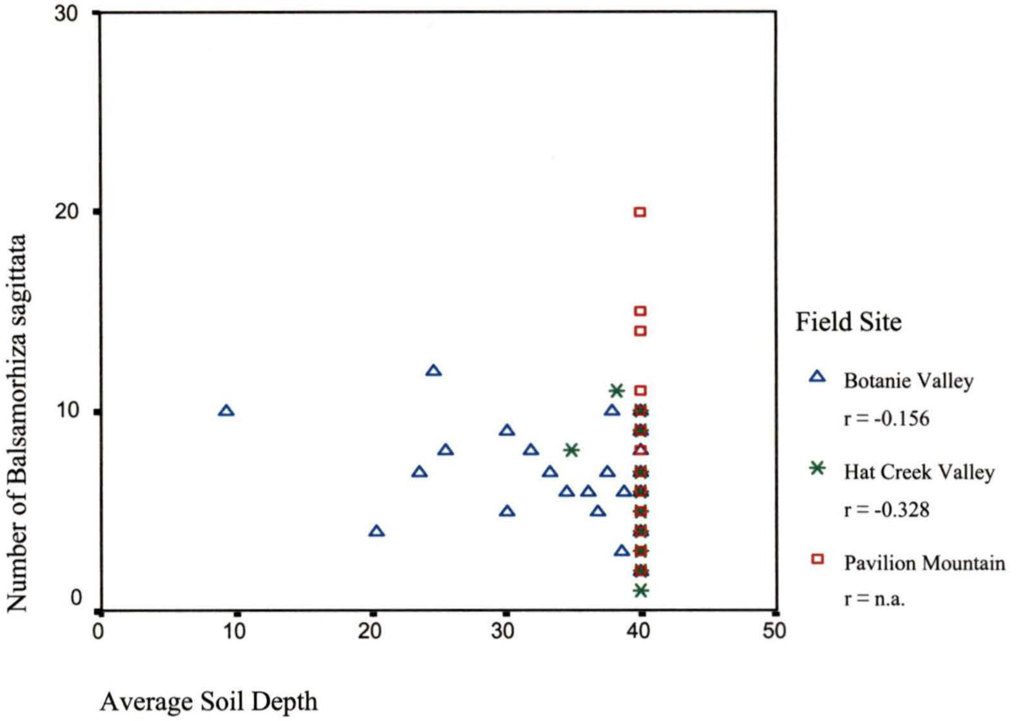


Figure 4.9m Soil Depth (cm)



between plots to indicate any correlation and therefore were not investigated any further. Shrubs (Figure 4.9 d) were found in very few plots and thus do not contribute to an analysis of variables influencing the frequency of *B. sagittata*. In general, the scattergrams do not indicate strong correlations between the environmental variables and the number of *B. sagittata* plants within a site. Based on the scattergrams I hypothesize that of the variables collected, the diversity of native plants, and total species diversity are positively correlated with the number of *B. sagittata* plants at a site. The percentage of the plot with exposed substrate is negatively correlated with the number of *B. sagittata* plants.

The next step in the analysis of my field data was to examine the relationships among the variables using the nonparametric Kendall's tau coefficients to gauge the strength and direction of the bivariate relationships between environmental variables and *B. sagittata* numbers. Kendall's tau describes the strength of the association between variables measured at the ordinal level (Norusis 1997). I chose to eliminate shrub cover and soil depth from any further analysis, as the data are constant amongst the individual plots and three sites. The results of the correlation analysis are displayed in Table 4.8. A concern with using this multiple simultaneous test is the increased probability of finding significant variables by chance alone (i.e. Type I error).

According to the results acquired using Kendall's tau correlation analysis, the number of *B. sagittata* plants at each of the sites was not strongly correlated with any of the environmental variables. At a significance level of p=0.05, there are a few variables that indicate a weak association with the number of plants. In particular, the Botanie Valley plots had weak positive correlations to the percent cover of native plant species (35%) and total species (45%). At Botanie Valley there appears to be a weak negative association between the number of plants and percent cover of litter (31%) and average depth of litter (30%). The results from the data analysis of the Pavilion Mountain variables indicate that there are no environmental variables correlated with the number of *B. sagittata* plants. For Hat Creek Valley the percent of ground without vegetation indicates a weak negative correlation (32%) and a weak positive association with the percent cover of native species (30%). Based on the low level of correlation indicated in the results, none of these variables can be stated as strongly correlated with the number of

Table 4.8 Results of Kendall's tau correlation analysis for environmental variables and number of *Balsamorhiza sagittata* plants.

Field Location	Exposed Substrate % Cover	Microbyotic % Cover	Herbaceous % Cover	Native Species % Cover	Non-native Species % Cover	Species Unknown % Cover	Total Species	pH	Soil Moisture	Depth Litter	Litter % Cover
Pavilion	0.04	0.03	-0.09	0.15	0.02	-0.14	-0.13	-0.07	0.21	-0.10	0.04
Hat Creek	-0.32*	0.04	0.32*	0.30*	-0.03	-0.24	0.21	-0.10	0.07	-0.23	-0.13
Botanie	0.06	-0.06	-0.10	0.35*	-0.30	-0.16	0.45*	-0.02	-0.13	-0.31*	-0.30*

* Correlation is significant at the 0.05 level (2-tailed).

B. sagittata plants.

It is also possible in analyses such as this that environmental variables are correlated with each other and cause significant factors to be masked. In order to better understand the relationship between environmental variables, I conducted further correlation analysis using Kendall's tau on the environmental variables at each site. Based on the results of the correlation analysis, the environmental variables are not consistently related to each other at each of the three sites. Pavilion Mountain had the greatest number of correlations that could be categorized as moderate or strong (greater than 50%) (Table 4.9). The percent cover of herbaceous plants is negatively correlated with the percent of the field site exposed substrate (76%) and negatively correlated with the percent of the site covered in microbyotic species (65%). The remainders of the significant correlations are related to the amount of litter present in the plots. The average depth of litter is negatively correlated with exposed substrate (58%), and the microbyotic species cover (62%), and positively correlated with cover of herbaceous species (67%). The percent cover of litter is also correlated with exposed substrate (52%); microbyotic species cover (67%) and positively correlated with cover of herbaceous species (52%).

For the Hat Creek Valley field plot, (Table 4.10), there is only one correlation that can be considered moderate and this is between unknown species and native species. This association is difficult to assess, as the unknown species could be native or non-native. The analysis of the data from the Botanie Valley site, revealed three correlations (Table 4.11). As with the Pavilion Mountain site, the percent of the herbaceous cover in the plots is negatively correlated with extent of exposed substrate (90%). Percent cover of non-native and native species is negatively correlated (86%). The depth of litter is positively correlated with the percent cover of litter. These correlations are all expected because they are dependent on one another.

The statistical test, Analysis of Variance, conducted to assess the relationship between the environmental and *B. sagittata* variables at the three field sites indicates that the data are significantly different. The results obtained through the correlation analysis do not indicate that any variables are highly associated with the number of *B. sagittata* at any of the three sites.

Table 4.9 Results of Kendall's tau correlation analysis for environmental variables at the Pavilion Mountain site.

	Microcrust % Cover	Herbaceous % Cover	Native Species % Cover	Non-native Species % Cover	Species Unknown % Cover	Total Species	pH	Soil Moisture	Depth Litter	Litter % Cover
Exposed Substrate % Cover	0.41**	-0.76**	0.44**	0.17	-0.42**	0.21	0.16	-0.16	-0.58**	-0.52**
Microcrust % Cover		-0.65**	0.39**	0.22	-0.41**	0.34*	0.27	-0.03	-0.62**	-0.53**
Herbaceous % Cover			-0.41**	-0.25	0.43**	-0.25	-0.20	0.18	0.67**	0.52**
Native Species % Cover				-0.09	-0.40**	0.38**	-0.03	-0.11	-0.57**	-0.35*
Non-native Species % Cover					-0.57**	0.02	0.08	0.02	-0.05	-0.05
Species Unknown % Cover						-0.16	-0.03	0.06	0.34*	0.31*
Total Species							-0.06	-0.08	-0.36*	-0.26
pH								-0.21	-0.09	-0.26
Soil Moisture									0.12	0.13
Depth Litter										0.61**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4.10 Results of Kendall's tau correlation analysis for environmental variables at the Hat Creek Valley site.

	Microcrust % Cover	Herbaceous % Cover	Native Species % Cover	Non-native Species % Cover	Species Unknown % Cover	Total Species	pH	Soil Moisture	Depth Litter	Litter % Cover
Exposed Substrate % Cover	-0.14	-1.00**	0.01	0.24	-0.12	-0.18	0.11	-0.20	-0.13	-0.44**
Microcrust % Cover		0.14	0.16	-0.14	0.08	0.13	-0.29	0.01	0.03	0.13
Herbaceous % Cover			-0.01	-0.24	0.12	0.18	-0.11	0.20	0.13	0.44**
Native Species % Cover				-0.12	-0.52**	0.16	-0.13	-0.07	0.12	-0.09
Non-native Species % Cover					-0.46**	0.09	-0.04	-0.08	-0.02	-0.07
Species Unknown % Cover						0.01	0.17	0.14	-0.34	0.15
Total Species							-0.11	0.09	-0.03	-0.09
pH								0.18	0.00	-0.14
Soil Moisture									-0.01	0.07
Depth Litter										0.49**

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 4.11 Results of Kendall's tau correlation analysis for environmental variables at the Botanie Valley site.

	Microcrust % Cover	Herbaceous % Cover	Native Species % Cover	Non-native Species % Cover	Species Unknown % Cover	Total Species	pH	Soil Moisture	Depth Litter	Litter % Cover
Exposed Substrate % Cover	-0.07	-0.90**	0.24	-0.25	0.01	0.25	-0.01	-0.05	-0.41**	-0.27
Microcrust % Cover		0.06	-0.08	0.12	-0.09	0.06	0.29	-0.20	-0.05	-0.11
Herbaceous % Cover			-0.28	0.27	0.04	-0.32*	0.05	0.00	0.35*	0.27
Native Species % Cover				-0.86**	-0.37*	0.37*	0.38*	-0.21	-0.23	-0.45**
Non-native Species % Cover					-0.13	-0.38*	0.26	0.26	0.27	0.38*
Species Unknown % Cover						-0.05	0.28	-0.05	-0.69	0.16
Total Species							0.08	-0.03	-0.40**	-0.49**
pH								-0.12	-0.25	-0.02
Soil Moisture									0.26	0.23
Depth Litter										0.59**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

The correlations for the environmental variables at the Botanie Valley site are all expected. Herbaceous cover in the plots is negatively correlated with exposed substrate (90%). Percent cover of non-native and native species is negatively correlated (86%). The depth of litter is positively correlated with the percent cover of litter. What is surprising is the infrequency of correlations between the environmental variables. Upon reflection on the data collection methods and variables being measured, I believe that neither was sensitive enough to record significant correlations.

According to the statistical analysis (ANOVA) the averages for the environmental variables at each site are significantly different. The properties of the variables examined can be summarized as follows:

- the percentage of exposed surface area averaged between 8.4% and 35% at the three sites;
- the percent cover of microcrust species was between 0.9% and 6.8%;
- the percent cover of herbaceous species averaged between 65% and 86.3%;
- shrubs and trees were rarely present in the plots;
- the percent cover of native species averaged between 51.3% and 93.5%;
- the percent cover of non-native species was between 6.2% and 23.7%;
- the percent cover of species that I was unable to identify was between 0.33% and 27.8%;
- the total species diversity at the three sites was between 11 and 13 species in each plot;
- pH was on average between 6.34 and 6.75;
- soil moisture averaged 21.76 to 29.3 grams (wet soil weight minus dry for 150 ml of soil);
- litter depth (cm) was between 1.24 and 2.23;
- percent cover of litter was between 23% and 66.8%;
- soil depth was, on average, no less than 34.9 cm at the three sites;
- the number of *B. sagittata* plants in each plot averaged between 5 and 7; and,
- the percent cover of *B. sagittata* was between 24.3% and 32.7%.

Many of the environmental variables at the three sites may in fact be dependent on *B. sagittata*. *Balsamorhiza sagittata* can be aggressive and it is possible that the presence of other species and the amount of litter cover are influenced by *B. sagittata*. The litter cover would in turn influence pH levels, and moisture content of the soil. An increase in the depth of litter and percent cover of litter results in less exposed soil and thus less area for microcrust species to exist.

4.3 **Discussion**

Based on the data analysis presented, few definite conclusions can be drawn from this research. Data analysis for ecological variables can be difficult. The complex structure and dynamics of plant communities, combined with a highly variable environment, places limitations on any conclusiveness in plant ecology. Kent and Coker (1992:Preface) note, "Achieving a correct balance between the mathematical and statistical as opposed to the biological, ecological and geographical components of vegetation description and analysis is a difficult and demanding task." Furthermore, the statistical methods chosen can lead to incorrect results. Thomson et al. (1996:1698) discuss two major concerns with correlation analysis, "Conventional correlation analysis… (1) fundamentally conflicts with the basic ecological concept of limiting factors, and (2) ignores spatial structure in data [nearby data points cannot be considered as independent samples], which can produce spuriously high correlations".

However correlation studies still are important in ecology, and may become more so as spatial studies proliferate. Kent and Coker (1992:113) note, "despite the criticisms, it would seem that exploratory data analysis has much to offer and represents an approach which would be of value to many vegetation scientists". In particular, some concerns may be insignificant to the level of the research being undertaken. Vegetation scientists usually choose to ignore problems such as spatial autocorrelation, since a great deal of their work is inductive and descriptive rather than deductive, and does not involve the use of inferential statistics (Kent and Coker 1992).

With my research and analysis, a number of variables that may be important were not included. Certainly factors such as snow depth, grazing by mule deer, fire regimes, and history of grazing all could affect the growth rates of *B. sagittata*. Furthermore, the sites were not chosen because they were representative of the general population of *B. sagittata* nor because they indicate the variety of habitats where *B. sagittata* grows. Also, because *B. sagittata* is a long-lived perennial, major historical components that are no longer visible and likely unrecoverable may have had influences I was unable to detect or measure.

Some of the variables for the three sites may not have been significantly correlated because of the time that the surveys were completed. All three sites were surveyed when I determined that they were in full bloom. The first survey was conducted on Pavilion Mountain, a relatively open plateau. The second survey was done at the Hat Creek Valley site, a broad valley. The final location was the Botanie Valley site, which is more closed in comparison to the other two sites, and has a greater amount of forest vegetation in the area. From the start of the fieldwork at Pavilion Mountain to the finish at Botanie Valley there is a spread of 21 days (May 29^{th} to June 18^{th}). In an area with a fairly short growing season and dramatic moisture and temperature fluctuations 21 days can potentially influence the measurements of environmental variables and the growth of associated plant species. Not all plant species develop at the same rate and because of the same factors. One indication of the possibility of this are the values acquired for species unknown in the plots. At the first site there was an average of 25 % of the plot covered by unknown species, at the Botanie Valley site there was less than 1 %. Soil moisture also dropped from the first site surveyed to the second and then to the third.

The ecological niche which *B. sagittata* occupies may be influenced by more than environmental factors. Where a plant grows in the wild may not be its optimal habitat. Thomson et al. (1996:1699) argue: "We tend to interpret such [habitat] preferences as indicating physiologically optimal habitats...the realized niche is frequently more restricted than the fundamental niche". Factors such as herbivory from cattle and deer, seed predation from insects and mice, and availability of pollinators may limit the ability for *B. sagittata* to germinate and develop to full capacity in some areas. It is also possible that conditions may be ideal for one stage in phenology or development (i.e. germination) but detrimental to others. Thus a high population may be surviving with difficulty.

With field data, bivariate scattergrams often show "factor ceiling" distributions wherein data points are widely scattered beneath an upper limit, often due to the action of other factors. Although most ecological information in such a graph resides in the upper limit, standard correlation/regression does not characterize such limits (Thomson et al.

1996). Some of the scattergrams in figure 4.9 exhibit a "factor ceiling" limit in the data distribution. For example, there are no high values for the number of *B. sagittata* in a subplot at the Pavilion Mountain site when the percent of exposed substrate, microbyotic crust, or pH, are high. In comparison at Hat Creek Valley and Botanie Valley there does not appear to be a "factor ceiling" for these three variables.

Thomson et al. (1996:1712) note: "Communicating the results of descriptive ecological studies would be simpler if we had a commonly accepted terminology and statistical machinery for treating such distributions. Currently we have neither." Determining the successful microsite conditions for a given species is fundamental for understanding the population dynamics of the species, species composition of communities and diversity of a species. It is also essential for the management and restoration of degraded ecosystems.

4.4 **Suggestions for Future Work**

The autecology of *B. sagittata* may vary tremendously. A broader geographic analysis is needed in order to determine optimal growing conditions and the geographic distribution of the species. Because historical events may have a strong impact on the germination and distribution of *B. sagittata*, an understanding of its life expectancy would be beneficial. As indicated in Chapter 2 (2.3.3 Vegetative Reproduction) Dr. Sandra Peacock is currently researching the ability of *B. sagittata* to propagate vegetatively and whether leaf number can be used as an indication of plant age. Peacock's work can also help us to understand how historic events affect *B. sagittata*. *Balsamorhiza sagittata* is a long-lived plant and it is probable that past events such as grazing, human harvesting and fire may have influenced current populations. The relationship of the plant to moisture levels and temperature fluctuations is also poorly understood. The size and conditions of *B. sagittata* plants are visibly different when growing in minor depressions and drainages. At Pavilion Mountain, *B. sagittata* plants were bigger with more blooms when growing in the weedy area. Are the weeds there because there is more moisture or do they allow greater moisture retention? In other words, are the weedy grasses there for the same reason that the *B. sagittata* plants are bigger? At Hat Creek, *B. sagittata* plants in small gullies had more blooms than those on the raised area. It is likely that these areas allowed greater moisture retention, but leads to the question: when is the crucial time in the phenological stage for increased soil moisture to make a difference? Is it important for there to be a snow pack in place before a frost? At Botanie Valley, the *B. sagittata* plants near the trees were larger and had more bloom than those growing in the open. Again, I expect that moisture, perhaps the accumulation of snow, is an important factor in its increased size. Depressions in the soil retain moisture at the surface longer, have greater atmospheric moisture and less extreme temperature regimes, altered light intensity and tend to lead to more soil coverage of seed and better contact of the seed with soil (Evans and Young 1989). These factors all may play a role in influencing *B. sagittata* growth.

This year (2001), there was a plethora of *B. sagittata* blooms. Many local residents of the Lillooet/Hat Creek area indicated that they had not seen so many flower heads in years. Interestingly the snow pack in the surrounding hills was estimated to be only 60% of the average amount. Quantifying moisture and temperature in the region is difficult because Environment Canada maintains only a limited automated station in Lillooet, which measures only temperatures and liquid precipitation. Accurately measuring snowfall would be a problem under this situation. To study *B. sagittata* ecology, it would be desirable to have a complete weather station at the research site.

The questions relating to *B. sagittata* plant longevity and seasonal soil moisture are just a small example of the extent of research that still needs to be conducted. It would also be beneficial to compare sites where *B. sagittata* grows in large patches to similar sites where *B. sagittata* does not occur. The work I did, may, however, serve to indicate conditions that established populations of *B. sagittata* have in common.

4.6 **Summary**

The ecological component of my research was conducted during the summer of 2000 at three sites in the Fraser River Valley area near Lillooet. All three sites have well-established populations of *B. sagittata*. We recorded data on 43 variables, 25 related to the sites and 18 specifically for *B. sagittata*. Data analysis conducted on the recorded variables indicates that the parameters measured are significantly different for all three locations. No variables were strongly correlated with the number of *B. sagittata*. Further controlled experiments and wide scale environmental comparisons need to be conducted in order to ascertain the optimal growing conditions for *B. sagittata* and to apply this information to developing *B. sagittata* in a cropping system.

5.0 Agronomy of *Balsamorhiza sagittata*

Background and Rationale

Chapter 6 reviews the potential for *Balsamorhiza sagittata* as an herbal medicine, vegetable, inulin source, for restoration, and horticulture. Given the concern that market demand may exceed sustainable wild harvesting of plant species, as has been documented for medicinal plants such as *Echinacea angustifolia*, it is of interest to ascertain the conditions in which *B. sagittata* can be germinated and propagated. The purpose of this component of my research was to study the feasibility of cultivating *B. sagittata* in an agronomic or horticultural cropping system, examined through germination and propagation experiments in Xaxl'ep Territory east of Lillooet and at Agriculture and Agri-Food Canada's research facility at Agassiz, British Columbia. Beyond the basics of how to grow a plant, I set out to germinate and propagate *B. sagittata* in a way that would allow it to be used in horticulture and ecological restoration projects.

Little is known about the cultivation of native plants that once were crops for Indigenous People (Peacock and Turner 2000) and very little research on the propagation of *B. sagittata* has been documented. My research objectives were influenced by the difficulties inherent with growing *B. sagittata*. First of all, *B. sagittata* has low seed viability (Young and Evans 1979). Experiments, therefore, were conducted to enhance seed germination. Secondly, *B. sagittata* is adapted to very dry conditions so it was of interest to determine if *B. sagittata* seedlings would survive in a greenhouse environment (usually humid), which can accelerate plant development. *Balsamorhiza sagittata* has a very long taproot (can be over one meter in mature plants). Taprooted plants are difficult to transplant. Thus, even if seedlings did germinate and survive in a greenhouse environment, I was interested in determining whether or not the seedlings, with their entire taproots, would survive transplanting to the field environment. Finally, I conducted investigations to determine whether directly seeded *B. sagittata*, directly seeded and transplanted seedlings, and greenhouse seedlings could survive with minimal care in field plots. "Minimal care" implies minimal input of labour, water and soil additives (such as fertilizers), which is ecologically more appropriate and financially more beneficial.

The initial selection of seed treatments normally is based on already known information about growing conditions of a plant. When treatments and growing conditions are understood, the final use of a plant dictates propagation strategies. For example, if a plant is desired for horticulture or restoration, then it is necessary to be able to germinate it readily in the field or to transplant it. If *B. sagittata* is to be used as a medicinal, vegetable, or inulin source, plants should be sown and propagated directly in a field environment. Throughout each of the following sections I will describe why I chose some techniques over others and the difficulties that I encountered in following the procedures I chose. Each of the methods that I applied has different requirements of labour, time, cost and space. Assessing the advantages and disadvantages of the various propagation techniques ultimately will be the responsibility of the grower. I hope, however, that my experiences, as described here, will provide insights to assist in any assessments.

5.1 **Methods**

5.1.1 Seed Collection and Preparation

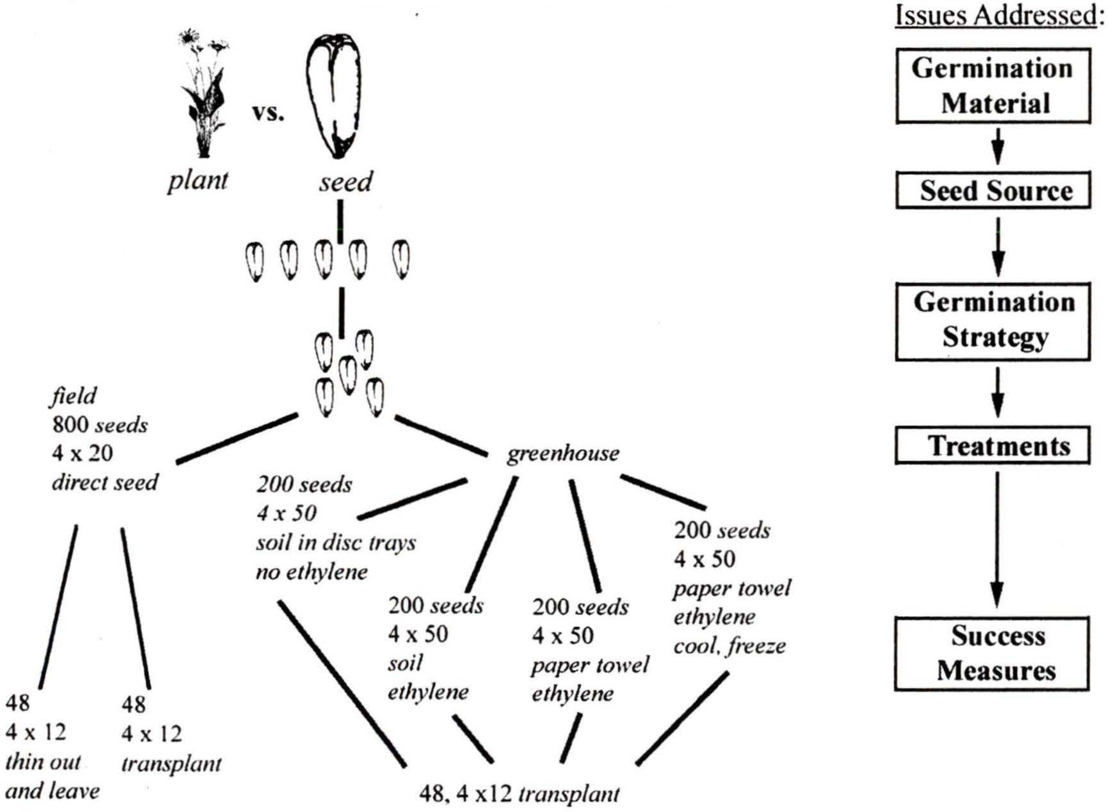
Seed Germination Versus Vegetative Propagation

This chapter outlines the choices I made and steps I followed in developing a protocol for growing *B. sagittata* (Figure 5.1).

Decisions on how to grow native species are compounded by the fact that the documented information on propagation of native plants is limited. Landis and Dumroese (2000:112) write: “The demand for native plants continues to increase but published information on how to propagate natives is extremely limited”. Native plant propagation requires experimentation and innovation. Rose et al. (1998: vii) write: “With so many species-specific propagation requirements and very little information available in the literature, native plant growers must refine their techniques based on trial and error and their available equipment, supplies, and facilities”. To formulate my hypotheses, therefore, I reviewed previously published research and conducted informal interviews with nursery growers who have worked with *B. sagittata* or similar species such as *E. angustifolia*. Plant physiologist Dr. Pat Bowen, staff at Agriculture and Agri-Food Canada, Agassiz and the Xaxl’ep peoples interest in using *B. sagittata* influenced the germination and transplanting experiments followed. Limited finances and time also

Figure 5.1 Germination of *Balsamorhiza sagittata* seeds. Chapter format, and the steps chosen in developing a cultivation strategy.

Objective: To grow *Balsamorhiza sagittata* in a method that is environmentally sustainable and requires low economic input.



- vegetative propagation or seed germination
- environmental impact minimization

- seed collection locations
- 5 sites chosen
- minimize environmental impact
- seeds combined to eliminate bias
- concerns about genetics addressed
- seed cleaning decisions
- seed purity and viability

- greenhouse treatment artificial stratification
- ethylene, no ethylene
- soil, paper towels
- field treatment natural stratification

- data recorded in greenhouse and field until plants senesce (July 2000)
- counts for germination
- greenhouse survival count
- field survival count
- measurement of leaf numbers and height in greenhouse

Discussion: An analysis of the results and challenges of growing *Balsamorhiza sagittata.*

influenced the methodology that I followed.

To begin with I needed to choose between growing plants by seed or vegetatively propagating *B. sagittata*. Many mature plants are notoriously difficult to germinate from seed and even when this is successful, they may be extremely slow growing. In the end, I chose seed propagation over vegetative propagation for two major reasons: 1) seed propagation preserves greater genetic diversity; and 2) harvesting of seeds minimizes the impact on natural populations of *B. sagittata*.

Vegetative propagation is done through techniques including grafting, rooted cuttings, and tissue culture. Plants propagated through vegetative means are identical to the parent plant. Rose et al. (1981:1) state that "seed propagation is encouraged whenever possible because it is easier to capture and preserve genetic variation with this method than with vegetative propagation”. If *B. sagittata* is to be used for restoration purposes then it is necessary to consider genetic diversity, and thus seeding is preferable. The genetic variation contained within a species is paramount for its survival and capacity for future evolution (Hipkins 1999).

Seeds are a food source for insects, mammals, and birds. Thus the removal of seed or fruits in the wild can have an impact throughout the food web. Therefore, the collection of seeds for germination necessitates the conservation practice of taking a small quantity from any given individual or population. Luna (2000:95-96) notes that selective seed collection is “an ancient practice and continues today, not only for plant use but now also in the collection of seeds and cuttings for the purpose of restoration”. Many Indigenous cultures have understood the necessity only to collect what resources are needed in order not to impede the successful perpetuation of the species on which they have depended.

Unfortunately, some people see the collecting and transplanting of live plants as a means of reducing the challenges of seed germination or vegetative propagation. The removal of live plants from their natural setting has a detrimental impact on the populations of plants and on the ecosystem from which they are taken. Parish et al. (1998:24) discuss the impact of whole plant harvesting:

> In the past it was common to transplant wild plants to the garden, and some of our rarest and most beautiful wildflowers are threatened with extinction because of past collecting practices. One might think that digging up a few plants from the wild is harmless, but this is not the case, and the uncontrollable collection of native plants has caused significant harm. In addition the chances of successfully transplanting well established native plants from the wild are very low.

Vrijmoed (1999: 156) strongly states that "for obvious reasons the collection of plants is unacceptable." Furthermore, such plants are hardest to introduce successfully into the garden. Again, seed germination is recommended over vegetative propagation and wild plant collecting, I chose therefore, to attempt to germinate *B. sagittata* from seed rather than vegetatively.

Seed Collection: The Question of Location

I established and followed a strict seed collection mandate of removing less than 5% of a population in each collection area. I collected seed from five separate locations between Lytton and Xaxl'ep (near Lillooet), in late June 1999. I collected only four seed heads along Fountain Valley road because the population was not large enough to collect anymore. As this is the closest population of *B. sagittata* to the field planting site and the plants are within the Xaxl'ep territory, I determined that some seed should be collected from here. The weight of the full flower heads including seed collected at each site is illustrated in Table 5.1. This information could be valuable in estimating how much seed is contained in a certain amount of pre-cleaned flower heads. Areas where I collected seed are marked on the map provided in Chapter 4 (Figure 4.1).

Table 5.1 The weight of the full flower heads including seed collected at each site.

Location	Weight (g)	Number of Flower Heads
Fountain Valley Road	1.7	4
Highway 12 appox 15 km south of Lillooet	27.6	46
Highway 12 approx 3 km north of Lytton	30.8	59
Botanie Valley Rd, 5 km from Lytton turn	21.1	41
Botanie Valley Rd, 2 km from Lytton turn	59.4	88

Decisions on how much seed to collect and where to collect from were influenced by a number of factors. There are few regulations for seed collecting in British Columbia. However, given an increase in an understanding of natural systems, escalating human impact on the earth and concerns voiced at the Rio Conference's Convention on Biodiversity (1992), there is a probability that seed collection from wild populations will be regulated in the future. Landis (1999) and Vrijmoed (1999) express concerns that seed origin be consistent with geographic location, elevation, and biogeoclimatic zone of planting destination in an effort to maintain the genetic variation of the species. With the desire to reduce genetic variation in my study, I collected seed from a small fraction of *B. sagittata*'s total geographical area of coverage.

I harvested the seed by hand. Mechanical seed harvesting means are being implemented in some areas in the collection of some native seeds, and Redente et al. (1982) suggest harvesting *B. sagittata* seed with a combine where terrain permits. However, the amount of seed required for this experiment did not warrant mechanical collection. Rather I removed the ripe heads and later shook the seeds out into a paper bag.

Further concerns about genetic integrity are related to the mixing of seeds. The combining of seed from a number of similar locations is common in germination and propagation experiments. Seed frequently is collected over a number of years before being utilized. Young and Evans (1979) collected seeds from numerous *B. sagittata* plants and those from each location were comprised in a single collection. Due to the necessity to avoid bias that may result from seed used from only one population, I chose to combine the seed from the five locations. This technique was chosen because there was not enough seed to equally replicate each experiment and in order to avoid possible bias in seed from one collection location verses another. Similar procedures were followed by Anderson (1993).

The impact of mixing seeds from different places and the genetic influence on wild plants is still relatively unknown. Burton and Burton (1998:9) express concerns with combining seeds to propagate native plants:

> Developing a line of cultivated seed from wild plants (sometimes called an 'ecovar') brought together to inbreed from a wide range of locations may contradict some definitions of what constitutes 'native' plant material. Purists frequently argue that only plants or seeds collected locally should

> be used for restoration work, and that any cultivation inevitably constitutes some selection against the genetic diversity needed for local survival and continued evolution.

A great deal of research still needs to be undertaken on plant population genetics. Presently, however, it seems that the only solution is to minimize genetic disruption as much as possible.

Selecting seed from locations in close proximity to where they will be planted extends beyond concerns of genetic conservation. The geographical area from which seed is collected can also be a factor in how well seed germinates and transplants into local situations. Landis (1999) and Vrijmoed (1999) argue that local seed is more suitability adapted to the environment of the planting site. Seed source affects seedling performance in two ways: cold tolerance and growth rate. Landis (1999) notes that there can be an inherent variability in phenology, growth rate, and cold hardiness between ecotypes. *Balsamorhiza sagittata*, in particular, may vary in relation to cold tolerance (Wasser 1982). In general, seedlings grown from seed collected from higher latitudes or elevations will grow slower but tend to be more cold hardy than those grown from seed from lower elevations or more southern latitudes (Rose et al. 1998). Ideally, therefore, *B. sagittata* seeds like other native species should be collected from the area in which they will later be planted. Because of possible variation in seed due to elevation and geographical differences, harvesting was very site specific: geographical locations similar to each other and to the field-planting site were selected.

Seed Cleaning

Seeds of many species will not germinate soon after harvesting and will benefit from additional drying (Vrijmoed 1999; Young et al. 1984). This period of drying time also allows for seeds to finish developing and reach moisture equilibrium. The time period that is required before seeds will germinate is termed ‘afterripening’. Young et al. (1984) note that afterripening requirements are not responsive to external stimuli and nothing can be done to speed up the process. Proper seed cleaning makes subsequent handling of the seeds in the germination process much simpler because there is no need to sort through non-viable seeds and excess chaff. Shortly after harvesting I manually cleaned the seeds of chaff and combined the seed collected from the different locations. I determined that achenes released from dried seed heads with little or no manual stimulation were mature and were used in experiments. There are technical means of seed cleaning and selection. Redente et al. (1982) suggest: mechanical flail, clipper, dry, fan, and macerator-chopper. Although manual cleaning meant many hours of work, it did allow for better quality control. Once cleaned, I weighed the total seeds and determined that I had 53.6 grams or approximately 4824 seeds. The cleaned *B. sagittata* seeds were kept in paper bags in a dry well ventilated room (approximately five months).

Seed Purity and Viability

Seed purity and viability are important in determining how many seeds are needed to grow a certain number of plants and how much space is required both in the greenhouse and field site. I determined seed purity by taking six separate samples (0.5 grams) of seed after it had been cleaned and combined. I then further cleaned the six samples and seeds not obviously well developed were removed. I determined that seeds were mature if dark in colour, hardness of seed (indicating low moisture content), and plump in appearance, indicating a mature embryo (Vrijmoed 1999). I then counted the remaining seeds to determine how much pure seed was in each sample. An average was established (45 seeds/ .5 g) and this number was used to determine how much seed was needed to sow in the field plot and stratify at the greenhouse.

Seed viability simply refers to whether or not the seed is alive (Young et al. 1984). Viability does not indicate if the seed will germinate. Viability can be determined by cutting the seed to determine if an embryo is present or through more complex viability tests that involve the use of chemicals such as tetrazoleum (Roberts 1972). Tetrazoleum indicates the activity of enzymes of the dehydrogenase group, which are responsible for reduction processes in living tissue (Roberts 1972). The active compound (triphenyltetrazolium) is imbibed by the seed as a colourless solution and is reduced by the enzymes to a red-colour. In the absence of active enzymes dead tissues remain unstained, and the distribution of living and dead areas of the embryo can be studied. Although I experimented with tetrazoleum tests for seed viability, results were inconclusive and thus have not been included here. I suspect that the reasons for difficulty with using tetrazoleum are largely do to the fact that no protocols have been developed for *B. sagittata* seeds. The closest species that I could find in the Tetrazoleum Testing Handbook (Grabe 1970) were sunflowers (*Helianthus* spp.), and the reference likely refers to the domesticated variety which have much larger seeds. The recommended one percent solution that I used may have been too concentrated, as it appeared to turn the entire seed red. It was difficult, therefore to differentiate alive from undeveloped seed. Because of these concerns I did not determine seed viability myself but assumed an approximate seed viability of 40% based on work by Young and Evans (1979).

Germination is defined by Scott et al. (1984:1192) as "a qualitative developmental response of an individual seed that occurs at a point in time." There are a number of seed conditions that result in poor seed germination including a high percent of embryoless seed, dried-out seed, seed with impermeable coats, seeds that have not fully ripened, and seeds exhibiting various internal dormancy problems (Leiss 1985). Conducting germination tests is standard practice when investigating growing requirements for native plant species, although such tests may require several weeks. Given the time limits on my research, the available literature on germination rates for *B. sagittata* seed (Young and Evans 1979), combined with insights gained from personal communication with a number of native plant nurseries and home gardeners I used protocols from this previous research as a foundation for my germination experiments.

5.1.2 Germination

Germination experiments were conducted in a freezer, at Agriculture and Agri-Food Canada's research facility in Agassiz, British Columbia, for artificial stratification, and in field trials, Xaxl'ep territory east of Lillooet, which simulated natural stratification.

5.1.2.1 Greenhouse Germination

It often is difficult to determine what needs to be done with seeds in sowing them. Do seeds need to be directly sown? If so, at what time of year? Should a seed be stratified[1] first? Is it necessary to scarify[2] seed? Some plants do not transplant well and

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[1] Stratification is the peregrination treatment of seeds to break dormancy; accomplished by exposure to heat or cold, soaking or other treatment of the seed.

must be germinated initially in large pots. Other species need a light soil spread very thinly over the seed surface. Is the seed viable? How long will it remain viable if stored? The answers to these questions and many more are determined through a combination of chance and extensive experimentation. The challenge lies not only in finding the best formula for the seeds to germinate but also in ensuring that the seedlings are at the ideal size at the right time of year which is crucial for retail sales and restoration. I conducted an extensive literature review and informal interviews to assemble existing information on the germination of *B. sagittata.* A number of formal and informal experiments on germination of *B. sagittata* seed have been performed (Bastin, pers. comm. 1999; Costanzo, pers. comm. 1999; Evans et al. 1982; Redente et al. 1982; Young and Evans 1979). Using these results I designed a comprehensive stratification experiment.

Preliminary trials by Young and Evans (1979) determined that seeds of *B. sagittata* are dormant and that this dormancy is not broken with dry storage. According to Maguire and Overland (1959:1) "Dormancy commonly occurs in seeds of non-cultivated plants... and may be due to any one of a number of factors: impermeable seed coat, rudimentary embryo, dormant embryo or germination inhibitors". Osborne (1981) notes that seeds have two purposes in plant life: dispersal of new individuals of the same species; and, maintaining the survival of the species through conditions when the external environment is not conducive to active growth. Research by Kitchen and Monsen (1996) indicates that seed dormancy in *B. sagittata* prevents summer or fall germination. Attempting ecological restoration with seeds requires knowing how to break seed dormancy. If we are able to understand this process than it is possible to ascertain the best time to plant *B. sagittata* (Kitchen and Monsen 1996).

Seed Treatments

I conducted greenhouse experiments under the guidance of Dr. Pat Bowen and supporting staff at Agriculture Canada. My experimental design consisted of four treatments replicated four times with 50 seeds per disc tray (Figure 5.2) or Ziploc bag. In total, eight circular disc trays (approximately 3 cm deep and 23 cm in diameter) with

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[2] Scarification is the process of mechanically or chemically breaking the hard exterior coat of a seed in order to facilitate the penetration of water and atmospheric gases.

Figure 5.2 Image of disc tray used for greenhouse seed stratification.

holes for drainage were sterilized in a fungicide cleaner (Virkon Disinfectant Virucide Fungicide) and filled with moistened Sunshine mix (a commonly used brand-name potting soil). I placed fifty seeds, in five rows of 10 in shallow grooves on the surface of the soil and covered the seeds with a light dusting of Sunshine mix. I watered half of the trays with an ethylene releasing solution (Ethrel ethephon) treatment. I treated the other four with water only. I placed all eight trays individually in bags and secured them in a walk-in cooler. Based on the information provided I assumed that the optimum amount of time to stratify *B. sagittata* seed is 12 weeks at 0 degrees Celsius in cool, moist conditions. I began the greenhouse stratification on November 30, 1999.

I set up a second stratification experiment on February 9, 2000. I soaked paper towels in the ethylene releasing solution and placed 50 seeds on each of the four paper towels, rolled and placed them in individual Ziploc bags. I treated 200 other seeds with an initial pre-chill that included two days in a refrigerator, followed by one week in a freezer before I placed the seeds on ethylene soaked paper towels and sealed them in Ziploc bags for the freezer stratification period. Table 5.2 presents the treatments, number of seeds and initial date sown for each of the stratification experiments that I followed.

Table 5.2 *Balsamorhiza sagittata* seed stratification treatments.

Treatment Definition	No. of Replicates, Seeds	Date
stratified on soil, no ethylene	4 replicates, 200 seeds	November 30, 1999
soil with ethylene	4 replicates, 200 seeds	November 30, 1999
paper towel, with ethylene	4 replicates, 200 seeds	February 9, 2000
paper towel, ethylene, pre-chill	4 replicates, 200 seeds	February 9, 2000
direct seed	4 replicates, 800 seeds	October 16, 1999

A minimum of 48 plants were needed for transplanting to the field (12 per plot for 4 plots). It is important to have choice when selecting the plants to be transplanted to ensure the seedlings have an advantage for surviving in the field. Infected or weak plants would be less likely to survive transplanting. Because of this desire for choice, my goal was to end up with about 100 plants (from all greenhouse germination treatments combined) at the end of the greenhouse period (late Spring 2000). Given that Young and Evans (1979) established viability for *B. sagittata* at 40% I estimated that at least 250 seeds needed to be stratified. In total, I sowed 800 seeds into either disc trays or placed in bags to be stratified.

Stratified seed can be sown just before it germinates or can be allowed to germinate in flats and then transplanted (Vrijmoed 1999). Young and Evans (1979) chose eight weeks as the optimal germination time even though germination after this period was only 50 percent of that obtained after 12 weeks, because some seeds germinated during stratification. According to Young and Evans (1979: 73-74) "the problem is that optimum temperatures for germination were essentially temperatures for the optimum stratification". This complicates stratification of *B. sagittata* seed because the emerging radicles may be damaged before sowing. In order to minimize damage to the emerging seedlings the flats and bags were monitored daily for germinates and these were sown every few days. I considered seeds to be germinated when the radicles and cotyledons became visible (Feghahati and Reese 1994; Nichols and Heydecker 1968). The first seeds began to germinate around January 14th, 2000. As seeds germinated, staff at Agriculture Canada and I began transplanting germinated seeds into sterilized Styrofoam (105 ml volume 4 x 15 cm) trays containing a customized soil mixture, designed by greenhouse manager Mark Gross. The mixture approximated the pH and texture of soil samples (see Section 5.1.2.2) taken from the seed collection locations. Gross developed his mix to conform to the sandiest of the field soil samples to ensure good drainage, as this is an important factor in container growing. The formula for the potting mix was based on Sunshine mix #4, and consists of a ratio of one liter of Sunshine mix: one liter of screened river sand: 0.5 liters of extra perlite. Approximately 4 grams of ground limestone per liter of mix was added to bring the pH up to approximately 7.0. Similar to processing seeds, experimentation with planting media is necessary to achieve maximum propagation success.

Ethylene

As already indicated, *B. sagittata* has a very low germination rate of 40 %. I conducted one experiment to determine if an inoculant during stratification assists in the germination rate. In research on *Echinacea* spp. ethylene has been shown to effectively stimulate seed germination (Bowen, pers. comm. 1999; Feghahati and Reese 1994). Under the recommendation of Bowen, I applied an Ethrel ethephon treatment to half of the seed at 10 ml to 14.4 lt.

Ethrel (trade name) ethephon (common name) is an ethylene releasing substance commercially available that rapidly breaks down in water at neutral or alkaline pH values to release ethylene gas. Ethrel ethephon is widely employed on research studies as a source of ethylene. Ethylene gas is a naturally occurring plant hormone that is associated with fruit ripening among other functions. It is difficult to predict everything it can affect. The ability of certain gases to stimulate fruit ripening has been used for many years, particularly on kiwis and oranges. Ethylene has also been used to promote the flowering of mangos and bromeliad species including pineapples. It was a Russian physiologist Dimitry N. Neljubow (1876-1926) who first established that ethylene affects plant growth. Neljubow noted that ethylene inhibited stem elongation, increased stem thickening, and caused a horizontal growth habit (Salisbury and Ross 1978). Several fungal species produce ethylene including some that normally grow in soils. Thus ethylene might be important in promoting germination of seeds and the growth of seedlings even in natural conditions.

5.1.2.2 Field Germination

Horticulturists have long solved stratification problems by fall-planting seeds and allowing nature to supply the treatment (Young et al. 1984). Current literature indicates that direct sowing of seed is the most efficient means of propagation because *B. sagittata* establishes poorly after transplanting (Kruckeberg 1982; Redente et al. 1982). As indicated in Chapter 2, *B. sagittata* is very slow growing, thus it is necessary to remove competitive species when field planting and the seeds should be covered after sowing (Young and Evans 1979).

Description of Field Site

In order to determine if *B. sagittata* does well when naturally stratified I sowed seed directly into a field site (October 16, 1999). I cleared a plot measuring 10 m x 5 m of vegetation on land in close proximity to Chief Art Adolph and Marilyn Adolph's home (Xaxl'ep Territory, east of Lillooet). The plot is situated on the southwest side of the Adolph's house just over a small berm. We chose this site for a number of reasons: south-facing slope (characteristic aspect of *B. sagittata* populations observed in the vicinity); natural substrate that had not been disturbed; sagebrush habitat visibly consistent with *B. sagittata* plant communities; and, close to people who were interested in the project and could monitor the site for weeds and disturbances such as cattle. There was no known population of *B. sagittata* at the site. There is no evidence that *B. sagittata* maintains a persistent soil seed reserve (Kitchen and Monsen 1996). Because of these two factors it can be assumed that any *B. sagittata* seedlings are from seed directly sown rather than an existing seed bank.

I began preparation of the field site with the removal of weedy species that blanketed the plot: mustards (*Sisymbrium* spp., *Brassica* spp.) and grasses (*Agropyron repens*, *Bromus tectorum*) and other herbaceous annuals (e.g. *Kochia scoparia*). The plot was dug first with a pitchfork. I found that I could only go down about 20 cm before hitting hard compacted soil. The next step was to turn over the soil and break up the clumps using a shovel. Finally I raked the site and removed rocks bigger than approximately 5 cm in diameter. Figure 5.3 shows the site at the time of seeding.

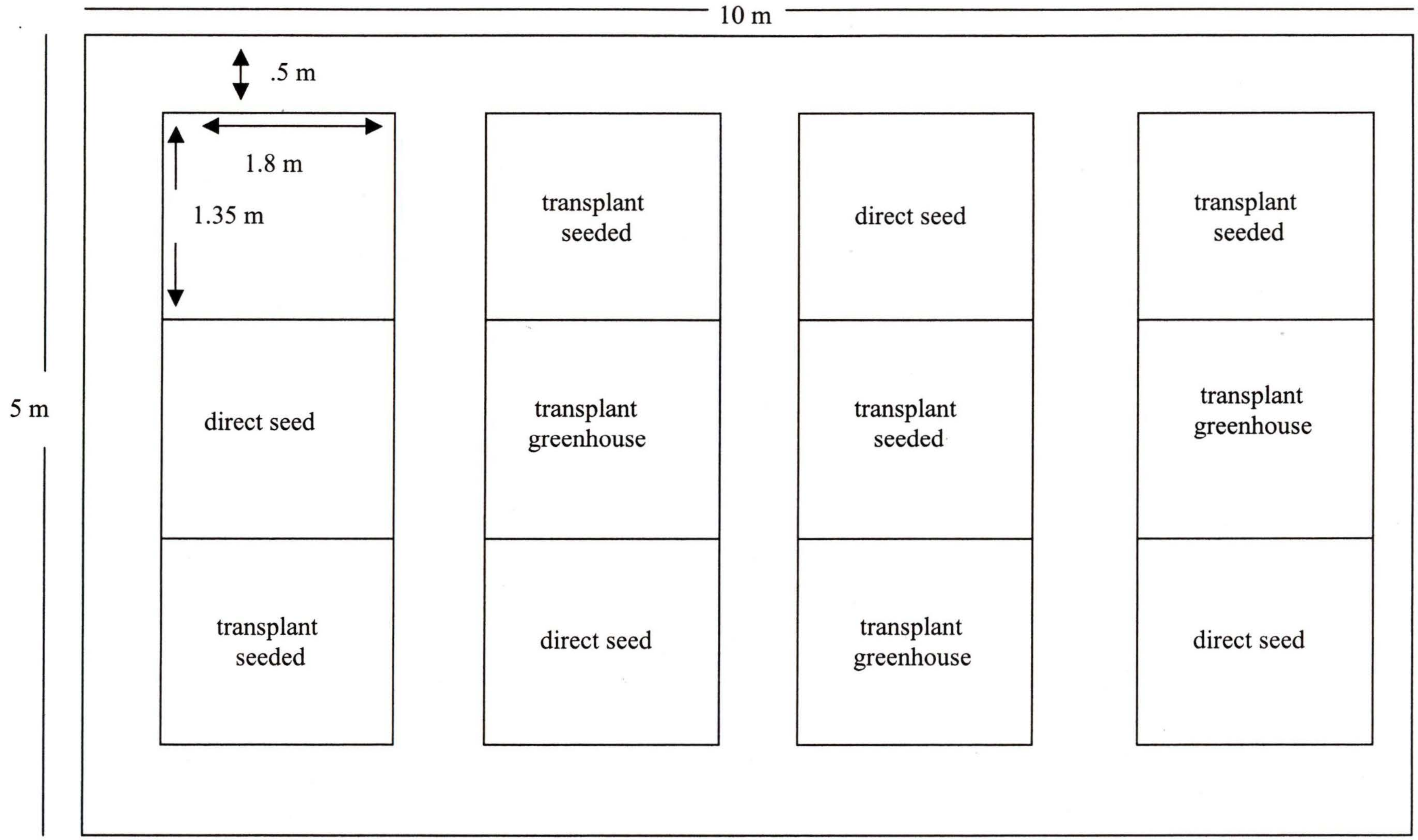
Experimental Design

The experimental design was a randomized complete block consisting of four blocks (replicates); each block was comprised of three experimental units including one for the control. Each block measured 4 x 1.8 meters. The blocks were laid out with a surrounding 0.5 m buffer, and there was 0.5 m between the plots. Each plot was 135 cm by 180 cm allowing for 12 mature plants to each have a 45 x 45 cm area. Plot dimensions were determined under recommendations from Bowen. The treatments were applied at random to the plots in each block. The treatments included: direct seeding, direct seeding transplants from the field location and greenhouse transplants. A diagram of the plot and treatments assigned to blocks is included as Figure 5.4.

I created four trenches approximately five cm wide in each of the four direct seeding replicates. I then divided 200 seeds (2.3 g) among the four trenches (number of seeds based on experiments by Baskin and Baskin 1998; Young and Evans 1979). The literature indicated that for native plants, including *Phacelia* spp., *Erythronium* spp. and *Balsamorhiza* spp., the number of suggested replicates ranged from three to five, and

Figure 5.3 Field planting site at the time of seeding.

Figure 5.4 Diagram of the field plot and treatments assigned to blocks.



recommended seed density per replicate varied between 100 and 300. I added to each of the four plots, also in the shallow trenches, three nylon bags about 5 cm by 10 cm containing 25 seeds and sown shut with polyester thread. These bags were the idea of Dr. Geraldine Allen (pers. comm. 1999). The nylon bags were added to monitor rate of seed germination and as a possible indication of small mammal disturbance of seeds. Allen speculated that mice, among other creatures, may be attracted to the large achenes and this situation would be indicated by disturbed or partially eaten bags. Without the bags to show exact location of seeds, if the seed did not germinate and the bags were not used it would be difficult to locate seed in the soil. Therefore, it would be difficult to determine possible reasons for the lack of germination (i.e. whether seed was not viable or whether it had been eaten).

I covered the seeds and nylon bags with soil and lightly compacted the surface. In September of 2000 I removed the seed bags. They were not disturbed by rodents and contained ungerminated seeds that had begun to decay. Therefore, I concluded that the germination rates were not influenced by mammal disturbance. Regular maintenance, such as weeding, by me was not possible because of the distance from Victoria to Xaxl'ep. I did weed the plots once in April, and beginning in late May I tended the plots once a week for six weeks. At this time weeds were removed and, if dry, the plots were watered. Marilyn Adolph also weeded periodically.

Soil Samples

I obtained soil samples from the five seed collection sites and from each of the four field replicates (October 9-10) and tested the pH. To test pH, I added 50 g of soil to 100 ml of distilled water and stirred every five minutes for 30 minutes. I then tested each sample with a hand held pH meter that was calibrated with a solution. I measured the pH to determine what level was needed for the greenhouse soil mixture. Further analysis of the soil was completed by Griffin Lab to assess the mineral composition of the soil (Table 5.3). Soil at the seed collection sites was taken from one spot only to obtain a basic understanding of the conditions that *B. sagittata* was growing in. Because I did not obtain replicates, analysis could not be done on the soil information, and any comments are purely descriptive. The soil information presented provides examples for further

5.3 Results from Soil Analysis Obtained at Seed Collection Sites and Conducted by Griffin Laboratories Corporation.

	Botanie		**Botanie**		**Fountain**		**Field**	
Soil Test	**Valley 1**	**(rating)**	**Valley 2**	**(rating)**	**Valley**	**(rating)**	**Plot**	**rating**
organic*	2.2	L	5.6	M	3	L	7.7	H
pH	6.6	M	7.4	M	7.1	M	7.8	H
nitrate**	8	VL	10	VL	14	L	58	M
phosphorous	42	H	29	M	47	H	304	VH
potassium	184	H	295	VH	232	H	1418	VH
magnesium	214	H	320	VH	346	VH	576	VH
calcium	930	M	2467	H	1420	H	2659	VH
sodium	47	VL	14	VL	36	VL	64	M
sulphate	20	L	36	VH	25	M	64	H
boron	0.47	L	0.88	L	0.19	L	5.84	VH
copper	1.4	H	2.5	H	7.5	VH	1.5	H
iron	44	H	25.6	H	204	VH	14.8	M
manganese	8.9	H	7.6	H	92.2	VH	10.6	VH
zinc	1.1	L	1.3	L	3.4	M	2.3	M

* organic matter is recorded as a percent (%) of the sample.

** other measurements are ug/mL of dry soil.

Key to Ratings
L = low
M = moderate
H = high
V = very

investigations over long periods of time. In general, the percent organic matter is much higher at the field-planting site, which is expected as it has been heavily grazed and contained a number of weedy species. Of particular concern is the high boron level found because of its toxicity to plants at extremely low concentrations. An agrologist at Griffin Laboratories commented on the value of boron and suggested that it should not be this high naturally in the soil and leaches out over time. This leads me to believe that the area used for the field plantings was not the original soil but may be some form of landfill.

5.1.3 Transplanting

One of the greatest difficulties with growing *B. sagittata* ex-situ is transplanting the seedlings. In order to better understand how to transplant *B. sagittata* I conducted two different experiments. In mid-May 2000 I removed seedlings from the greenhouse and placed them in cold frames for acclimation before transplanting. On May 27, I selected 48 seedlings from those grown in the greenhouse and transplanted them into the 4 replicate plots (12 each) of the established field site. In the remaining four replicate plots I transplanted 48 seedlings from the direct-sown plots.

Both types of seedlings were difficult to transplant. With the greenhouse containers it was problematical to extract an intact soil core in order to have minimal root disturbance. The field grown seedlings had thin, long roots that were hard to follow to their entirety and transplant without damage.

The most serious concern was whether transplanted *B. sagittata* would establish. Based on this decision and in consultation with Bowen, I decided to add fertilizer to the field plots. On May 5, 2000 I treated the field plots with ammonia nitrate at a rate of 30 kg per hectare.

5.2 **Results**

Throughout the germination and transplanting experiments I made careful observations and collected both quantitative and qualitative data. The range of data to be collected was influenced by the literature reviewed and Bowen. Unfortunately, my data collection frequency was constrained by the geographical distance from Victoria to the greenhouse in Agassiz and the field plots east of Lillooet. I obtained germination counts;

leaf counts and measurements every other week from February through May (2000) when I made trips to Agassiz to transplant seedlings. I obtained one germination count at the beginning of May for the field plots. I gathered information on survivability in the field on a weekly basis from the time of transplanting (May 27, 2000) until the plants senesced at the end of June 2000.

5.2.1. Measuring Results

I obtained the following data: 1) bi-weekly germination counts for the greenhouse stratification treatments; one germination total for the field plot; 2) leaf height (cm) and number of leaves, taken bi-weekly (seven times), for the greenhouse germination; 3) total number that survived greenhouse phase; 4) total number that survived to senesce in the field. Table 5.4 and Table 5.5 summarize the data obtained.

Descriptions of the seed treatments are abbreviated in the data tables and figures. The abbreviations represent the following:

- soil / no eth, refers to seeds stratified on soil without ethylene;
- soil / eth, are seeds stratified on soil with ethylene;
- pap. tow. / eth, are seeds stratified on paper towel with ethylene;
- pap. tow. / eth / frz are seeds stratified on paper towel with ethylene after a series of freezing treatments;
- direct seed are the seeds sown directly into the ground at the field site;
- dir. sd trnsplnt are seedlings from the field site that were transplanted; and,
- grnhs trnsplnt are seedlings that were transplanted from the greenhouse.

Total germination of *B. sagittata* seed for all treatments averaged 18 percent. The ethylene-treated seed sown into Sunshine Mix had the greatest germination rate at 28 percent. Germination was poor - 2.5 percent - for the seeds not treated with ethylene. Ethylene-treated seed on paper towel averaged 25 percent germination. Ethylene-treated seeds that also had cooling and freezing treatments germinated at 21 percent. The direct seeded seedlings had an average germination rate of 13 percent. It appears that the seeds treated with ethylene exhibited 'vigor', defined by Brown and Mayer (1988:121) as "those in which germination was extensive and rapid", in comparison to the non-ethylene seedlings.

Table 5.4 Data summary for germination rates, plant heights and leaf numbers of *Balsamorhiza sagittata.*

		Replicate 1				Replicate 2				Replicate 3				Replicate 4					
Treatment	Total # Seeded	# Germ.	Avg. Leaf #	Avg. Height (cm)	# Surv.	# Germ.	Avg. Leaf #	Avg. Height (cm)	# Surv.	# Germ.	Avg. Leaf #	Avg. Height (cm)	# Surv.	# Germ.	Avg. Leaf #	Avg. Height (cm)	# Surv	Total Num Germ.	% Germ.
soil/ no eth	200	**2**	**1**	**0**	**0**	**2**	**1**	**7**	**2**	**0**	**0**	**0**	**0**	**1**	**2**	**5.7**	**1**	**5**	**2.5**
soil/ eth	200	**14**	**1**	**1.95**	**6**	**10**	**1**	**4.49**	**6**	**19**	**2**	**3.98**	**11**	**13**	**1**	**4.44**	**9**	**56**	**28**
pap.tow. /eth	200	**12**	**3**	**4.27**	**7**	**11**	**2**	**4.75**	**8**	**17**	**2**	**3.38**	**11**	**10**	**2**	**5.16**	**8**	**50**	**25**
pap.tow. /eth/ frz	200	**12**	**3**	**4.38**	**10**	**11**	**2**	**5.04**	**8**	**11**	**2**	**3.59**	**7**	**8**	**1**	**1.85**	**4**	**42**	**21**
direct seed	800	**32**	**n.d.**	**n.d.**	**n.d.**	**5**	**n.d.**	**n.d.**	**n.d.**	**33**	**n.d.**	**n.d.**	**n.d.**	**31**	**n.d.**	**n.d.**	**n.d.**	**101**	**13**

n.d. indicates no data recorded

Table 5.5 Data summary for *Balsamorhiza sagittata* plants that survived one growing season: direct seed transplants, greenhouse transplants, and direct seeded.

Treatment	Total No. Planted or Transplanted	Replicate 1 Transplant Survived	Replicate 2 Transplant Survived	Replicate 3 Transplant Survived	Replicate 4 Transplant Survived	percent Survived	percent expected survival based on number seeds planted
control, direct seeded	53	8	5	10	3	**49.1**	**6.4**
direct seed, transplant	48	0	1	5	0	**12.5**	**1.6**
greenhouse transplant	48	8	9	11	8	**75**	**18.8**

It could be argued that it is inappropriate to compare the greenhouse germination with the field germination rates since the first is measuring germination while there is only one observation for the field data and is thus a measure of emergence. Furthermore, the conditions of the experiments in the greenhouse are very different than those of the field. Nevertheless, for the purpose of this research, which is to assess the best means of germinating *B. sagittata* seeds, and given that I was aware of the difference in conditions and that this was the point of conducting the field germination trials, I suggest that such a comparison is relevant to my study.

At the time when the seedlings were ready to be transplanted to the field (May 2000) I took final counts and assessed survivability. The germination treatments did not seem to have an effect on the ability of seedlings to survive greenhouse conditions. For the seeds that I germinated on soil without ethylene, survivability averaged 60 percent, seedlings on soil with ethylene 57 percent, seedlings on paper towel with ethylene 68 percent and seedlings conditioned through cool and freezing treatments, 69 percent.

In the field, seedling survivability averaged 46 percent, with the greenhouse seedling transplants having the greatest proportion surviving (75 %). Direct seeded seedlings also did fairly well, averaging 49 percent survivability. Direct seeded transplants were the lowest, at 13 percent survival rate.

5.2.2 Data Analysis and Results

Germination indices are frequently referred to in the literature for assessing germination strategies. However Brown and Mayer (1988) argue that these indices retain no information on either the rate or the start of germination. Scott et al. (1984:1194) note that a germination index "confounds effects contributed by the time of germination with the number of seeds responding, and it provides no information about distribution of germination events over time." Based on work by Brown and Mayer (1988) and Scott et al. (1984) that systematically dismiss previous attempts at standardizing germination indices and given that the majority of agriculture research is investigated using Chi-square and ANOVA (Analysis of Variance), I have chosen to analyze my data on *B. sagittata* based on these methods. Within agricultural experimentation, approaches for assessing the impacts of various techniques are relatively standard (Little and Hills 1978).

Of particular significance in agricultural research is the subject of mean separation (determining which of several means are significantly different).

I assessed the germination differences and survivability success as a result of the various treatments with SPSS to execute Chi-square and ANOVA tests. Chi-square tests and contingency tables were used to analyze variables that were expressed as numbers out of a total: number of germinates, seedlings that survived the greenhouse period, and transplant survival. For measured variables, differences in leaf height and number of seedlings, ANOVA test were executed. Analysis of variance (ANOVA) is a simple, yet powerful testing technique that is standard procedure in an increasing proportion of agricultural experimentation. A review of the agricultural experimentation literature indicates that ANOVA's are crucial to statistical analysis in agriculture. The statistical analyses were run for final observations only.

Standard ANOVA methods are appropriate for a data analysis where germination of all viable seed is observed, but they are inappropriate when some viable seeds fail to germinate (Scott et al. 1984). Specifically, ANOVA is inappropriate because means and variances are underestimated when some response times are not known. I used, therefore, Chi-square to analyze the germination data.

The null hypotheses that I tested are: (1) there is no difference in the mean germination rates; (2) there is no difference in the mean survival rate in the greenhouse; (3) there is no difference in the mean survival-until-senesce numbers; and, (4) there are no differences in mean height and leaf number.

The field germination data were not included in some of the analyses because there was only one observation for germination dates and there were no observations for leaf number and height during the initial growing period.

Variables included in the data analysis are listed in Table 5.6.

Table 5.6 *Balsamorhiza sagittata* variables used in germination analysis.

Variable name	Definition
trtmtype	Greenhouse Treatment Type
germdate	Germination date
wks2germ	# of weeks to germinate
srvgrhs	# survived greenhouse
leaf#t7	# of leaves (final observation)ratio

leafmean	Leaf # average for each replicate
hght7	Height (final observation)
hgtmean	Leaf height average for replicate
plotid	Field Site plot ID number (1-12)
fieldtrt	Field Site Treatment type
fldlef#4	# of leaves (Final observation)
htfldt4	Height (Final observation)
srvsens	Total # survived to Senesce/replicate

In assessing stratification and in order to apply information to the field of native plant propagation results need to be in an applicable format. Essential information includes cumulative percent germination based on treatment. Figure 5.5 presents the cumulative germination curves for the different seed stratification treatments. From the graph it is apparent that *B. sagittata* is slow to germinate, making it difficult to perform germination tests. Because the curve uses bi-weekly intervals, direct seed data could not be included as there was only one observation at full germination. The number of weeks to germination was determined from the date the seeds were sown.

The reason why it may be considered necessary to examine the germination line graph in some detail is that two seed stocks may have precisely the same final percentage germination, but these may be arrived at via two distinct germination curves, and this difference may have important agronomic implications (Nichols and Heydecker 1968). Some reasons why it is important to know when the majority of the seedlings have germinated include:

- potential use of herbicides before the emergence of the crop makes it increasingly important to know the likely time to seedling emergence so that the applications of these herbicides can be timed as late as possible;
- with precision drilled crops it is important that plants emerge simultaneously in order to reduce the smothering of latecomers due to competition from earlier germinating neighbours (Nichols and Heydecker 1968);
- when germinating seedlings in a greenhouse the target time for transplanting is important; and,
- graphical evaluation with cumulative percent germination, median response time and probability density (germination rates) are useful as a first step in analysis (Scott et al. 1984).

Figure 5.5 Cumulative percent germination in response to ethylene, media, and low temperature treatments of *Balsamorhiza sagittata* seed.

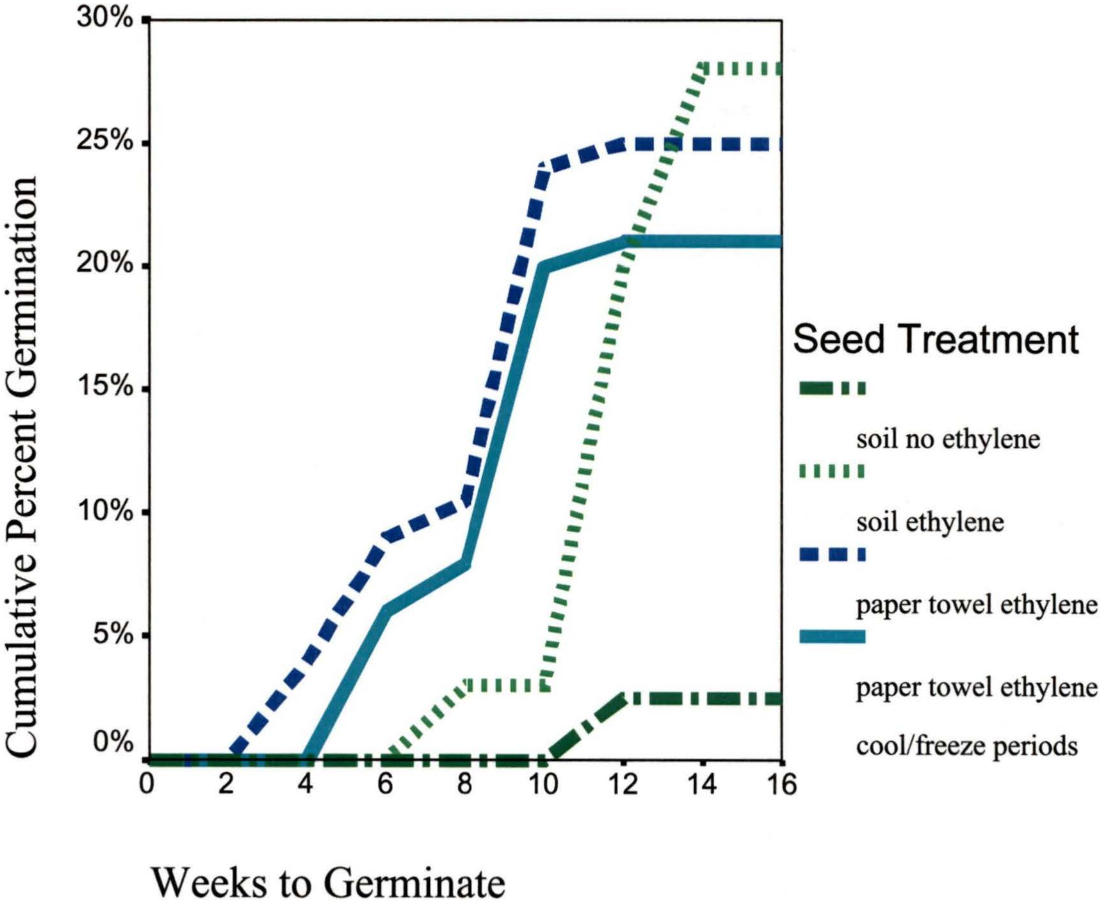


Figure 5.6 shows box plots for germination numbers of each treatment, survival for the greenhouse treatments, survival of the three transplant treatments, leaf number at the final observation of greenhouse treatments, and leaf height at the final observation of greenhouse treatments.

The box plots allow for graphical representation of the data and provide a visual assessment of variance and normalcy. The box plots display the following: the box extends from the 25th to 75th percentile (spread of variability); 50% of cases have values within the box; the thick line inside the box is the median (indication of central tendency); outlying values are expressed with a circle or asterisks; and, whiskers extend to largest and smallest observed values within 1.5 box lengths (Norusis 1997).

Example of a boxplot and the information that it displays.

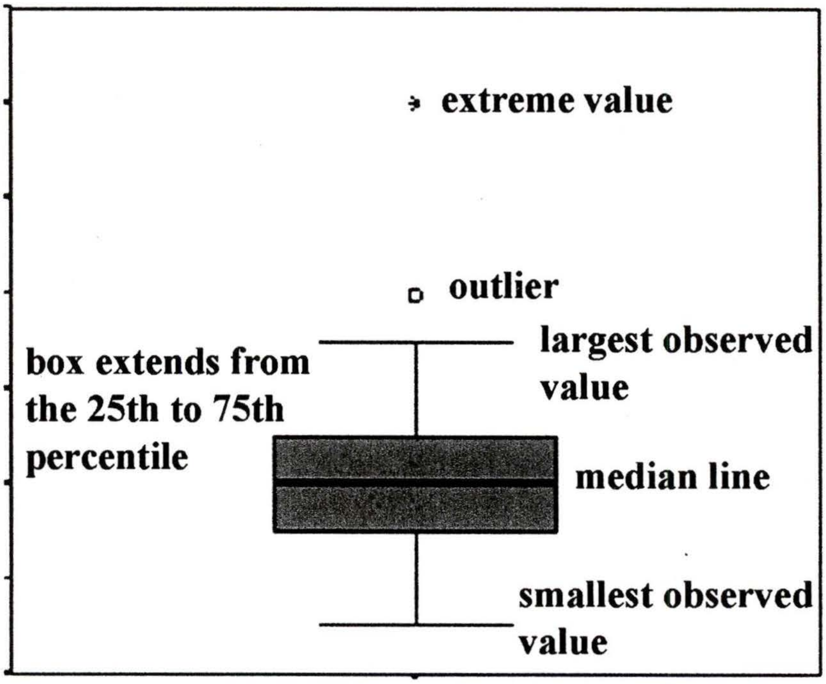


Figure 5.6 Boxplots for agronomic experiment data.

Figure 5.6a *Balsamorhiza sagittata* seed germination by treatment.
Greenhouse - 4 Replicates, 50 seeds in each
Direct Seed - 4 Replicates, 200 seeds in each

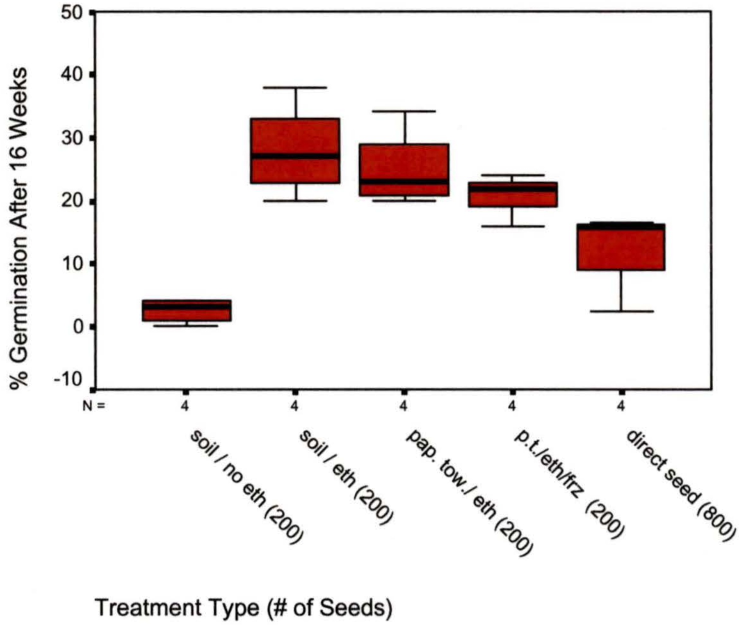


Figure 5.6b *Balsamorhiza sagittata* seedlings that survived to be outplanted: based on number that germinated.

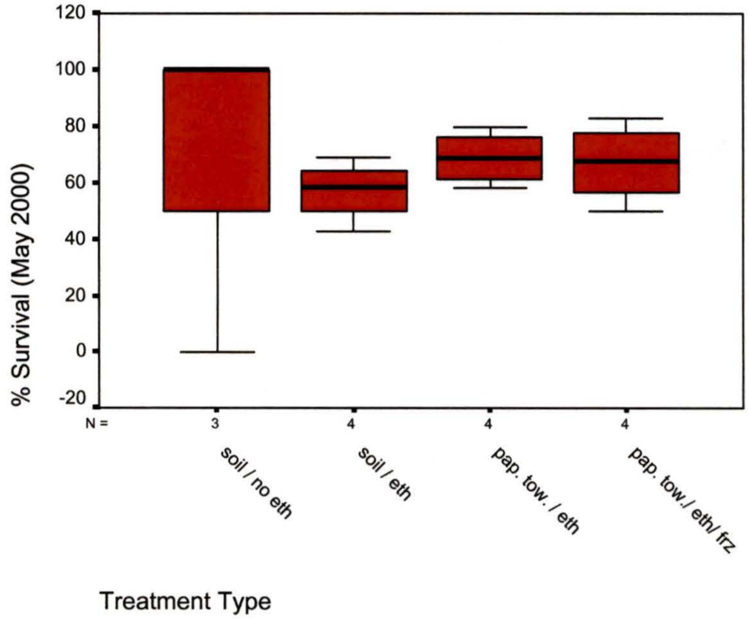


Figure 5.6c *Balsamorhiza sagittata* seedling heights by treatment at final greenhouse observation.

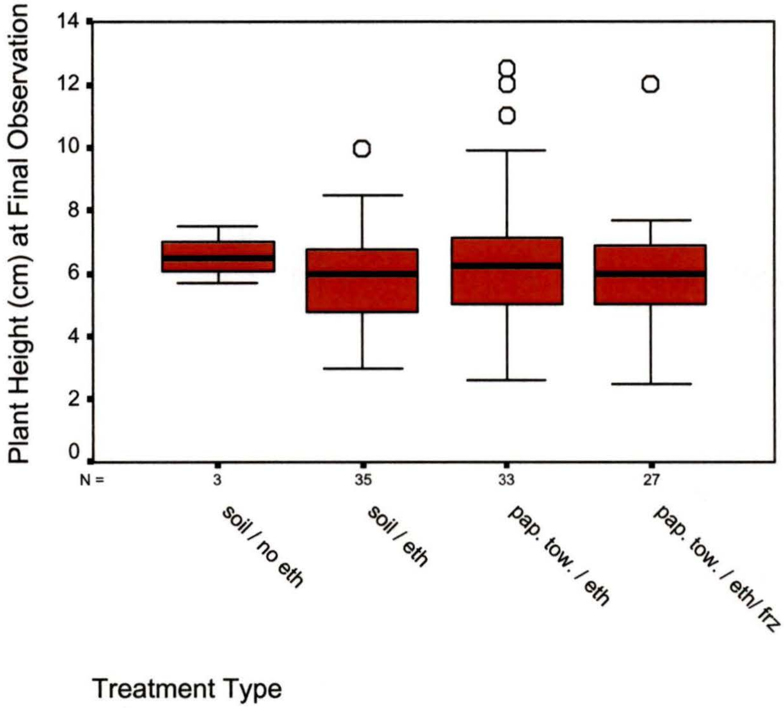


Figure 5.6d *Balsamorhiza sagittata* seedling leaf number by treatment at final greenhouse observation.

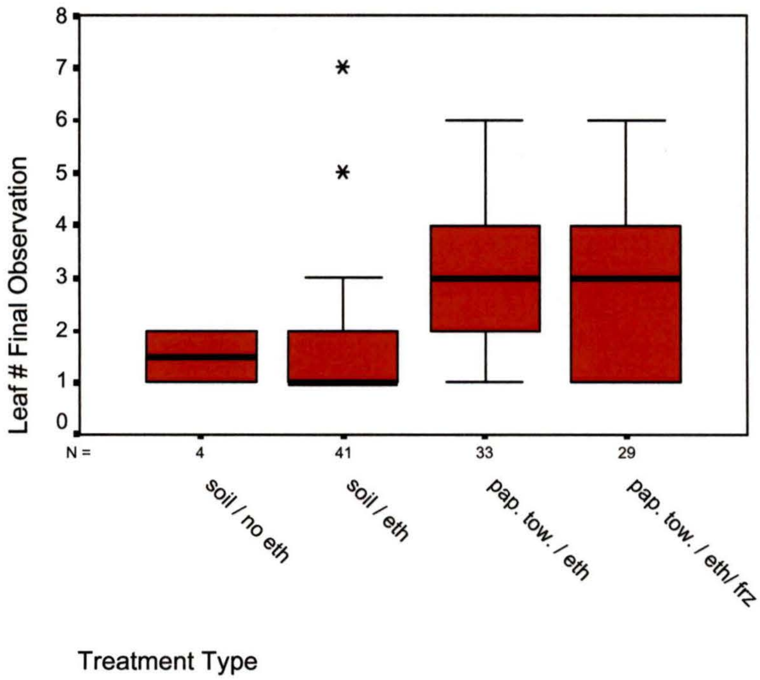
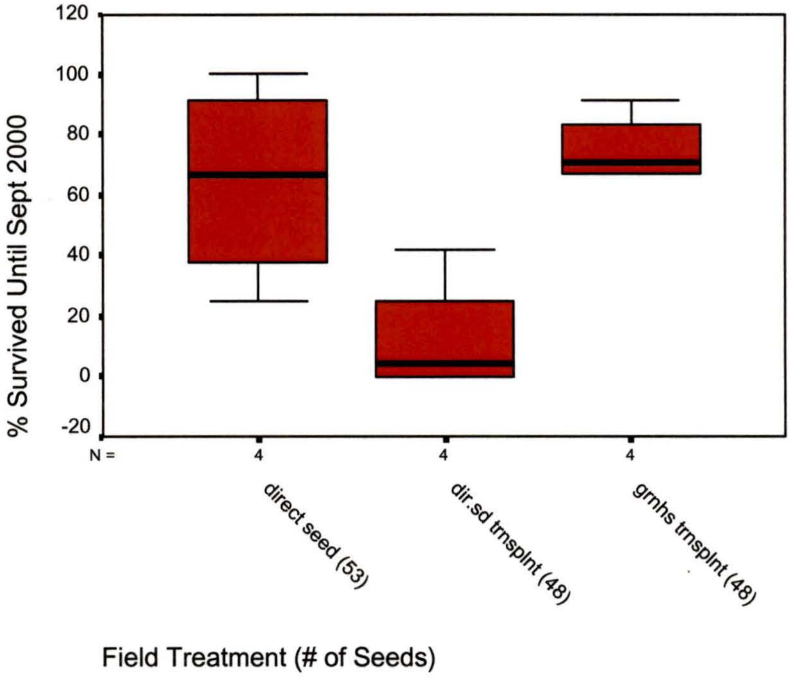


Figure 5.6e Percent of germinated *Balsamorhiza sagittata* seed that survived to senesce. Direct Seed, Transplants from Field, Transplants from Greenhouse



My observations and measurements of seedlings in the form of descriptive statistics and plots suggest that there are significant differences in the average germination rates (five tests) and transplant survival rates (three tests) among the techniques tested. The box plots (Figure 5.6) can be summarized as follows:

- The average rate of germination for the seed stratified in the greenhouse without ethylene is much lower than for the others (Figure 5.6 a). The variances for the three tests with ethylene are not equal but similar. The germination rate of direct sown seed overlaps the variances for the greenhouse treatments.
- For the total number of seedlings that survived to be out-planted (Figure 5.6 b), based on the number that germinated, the ethylene-treated seedlings are again similar in mean and variance. The seedlings that did not receive ethylene in the stratification treatment numbered only five and are thus different in mean and variance. They

possibly do not accurately represent how seedlings, germinated without soil, might survive in greenhouse conditions.

- The box plot for leaf numbers in the greenhouse (Figure 5.6 c) indicates that the paper towel germinated seedlings and soil germinated seedlings are similar. However these treatments have different variances. The paper towel germinated seedlings were partitioning their resources, to leaves rather than roots. I observed that seedlings treated with ethylene on paper towels had much faster growth rates and produced multiple leaves in comparison to those stratified without ethylene, which had only one or two leaves.
- Box plots for seedling height (Figure 5.6 d) depict similar means and variances for all greenhouse stratification treatments.
- For the results from the end of one growing season (Figure 5.6 e) it appears that the direct seeded and greenhouse grown transplants are closer in mean and variance with the direct seed transplants being visually different.

The chi-square test is used to compare the distribution of frequencies realized in an experiment with the distribution predicted from a hypothesis (Youden 1932). The smaller the value of chi-square the better the agreement of the expected and actual frequencies. As has been indicated, chi-square was used to compare the means of the germination totals and the survival rates in the greenhouse and field. The results are summarized in Table 5.7. Detailed SPSS outputs are provided in Appendix 6.

Table 5.7 Pearson chi-square analysis for germination and survivability of *Balsamorhiza sagittata*.

Response Variable	df	Asymptotic sign. (Pearson Chi-sq. 2-sided test)	Decision
germination with direct seeding treatment	4	<0.001	treatments significantly different
germination without direct seeding treatment	3	<0.001	treatments significantly different
greenhouse survival	3	0.574	treatments not significantly different
field survival	2	<.001	treatments significantly different

Given a significant difference (p=0.05) only the greenhouse survival number was not influenced by the treatment type. Therefore it appears that the treatment of seeds for stratifying and the method of field transplanting do significantly influence the number that germinated and survived to senesce in the field. However, it should be noted that the seedlings that germinated without ethylene numbered less than five and Chi-square is not sensitive to a cell size less than five. With contingency tables post hoc tests are difficult.

The results for the ANOVA tests on average leaf number and leaf height are included in Table 5.8.

Table 5.8 ANOVA for the effects of germination treatments on greenhouse seedling leaf number and height of *Balsamorhiza sagittata*.

Response Variable	df	F	P value and Significance
leaf number at final observation	3	4.020	.034 -significant
leaf height at final observation	3	0.223	.878 -not significant

Using a significance of p=0.05, the stratification treatments did not significantly influence the height of the seedlings, but did influence the number of leaves.

The primary interest of this research is a comparison of the proportions of seedlings that germinated and survived to be out planted and the field season. The means listed at the beginning of this section are beneficial in understanding the influence of the various treatments. In the next section I provide my opinion, based on observations and literature, of the results and what I feel are the potential influences on germination number and field survivability for *B. sagittata.*

5.3 Discussion

In the spring of 2001 I returned to the field plot at Xaxl'ep, which was the final destination for the plants germinated through the methodology described in this chapter. Of the 149 plants established in the early summer of 2000 only four appeared to be still alive. There are some important conclusions to be drawn from the controlled experiment - germination and transplanting seedlings of *B. sagittata.*

A further understanding of the results obtained in my research can be acquired through an investigation of the following: influence of potential sampling errors; concerns with the analytical methods used; limitations in the field experimental design; and, complications in the greenhouse. The different rates of germination and survivability could be the result of anything from random error to unknown differences in the soil, but the statistical tests take these into consideration.

In any seed germination research there are an immense number of internal and external factors that affect living organisms, which must be taken into account. There are limited possibilities to control these factors. Sampling vagaries will occur. There is not a simple one-to-one relation between cause and effect (Little and Hill 1978). These variables are almost universal in the field of agriculture. Variations resulting from multitude of causes can bring variable results, no matter how much effort was put into controlling all known factors (Little and Hill 1978). There are many genetic and environmental differences, which are beyond the control of an experimenter. Within my research design, I took a number of steps to limit the confounding effects of variability and experimental error including replication, randomization, and local control.

For statistical analysis methods such as ANOVA the quality of the sample is crucial. ANOVA procedures are not immune from violations of sampling assumptions. However, careful and consistent data collection would have reduced the level of variability in sampling.

Throughout my research I attempted to conduct experiments in a controlled repeatable way. Unfortunately there were a number of factors that jeopardized a controlled research experiment. In particular there were a number of factors relating to the experiments that may have influenced seed germination rates and survivability. Although factors reducing germination and transplanting success would have affected some seedlings more than others they may assist in explaining the low germination rates and survival numbers.

During the greenhouse experiments a number of concerns arose. The seeds that were stratified in the cooler developed a fine hair-like mold that may have resulted in reduced germination rates. I observed that the mold-infected seeds, however, still were capable of germination. Costanzo (pers. comm. 1999) found that in her seed germination experimentation *B. sagittata* seed in growth chambers failed because of mold.

A problem with the use of paper towels is that emerging radicles and root hairs may become embedded in the paper substrate and removal can cause root damage (Hendry and Grime 1993). In order to reduce this concern newly germinated seedlings should have been transplanted as soon as possible, but because I could not schedule transplanting every day, I believe some seedlings grew on the towel too long.

Once out of the cold stratification phase, the disc trays were taken to the greenhouse and initially the seeds continued to germinate. However, some of the seed trays became very dry. I believe more germination would have occurred if the seeds had been kept moist. Again, my absence from the site may have resulted in higher seed mortality. The seedlings in the greenhouse were attacked by aphids, fungus knats, and some seedlings leaves exhibited nutrient deficiency or chlorosis.

Of greater long term concern is the influence that the greenhouse itself can have on seedling development. Landis (1999:144) writes "the phenotype of a seedling is a function of its genotype (seed source or origin of cutting) and the environment of the nursery in which it was grown". The nursery environment is a combination of its geographic location, type of propagation facility, and the methods of seedling culture. Researchers such as Landis (1999) have found that when seeds from the same seed lot of a species are grown at different nurseries, even in the same geographic area, the seedling morphology of the crops often is visibly different. Native plants from the same seed collection batch grown at different nurseries may also be physiologically different. This response has been called the 'nursery effect' or 'greenhouse effect', and is an example of environmental imprinting, in which seedlings are influenced by nursery site conditions. Notably, the differences between nursery environments may be enough to affect initial seedling establishment and development of perennials for many years. This is certainly a factor to be taken into account in any large-scale growing of native species like *B. sagittata*.

At a more basic level, germination could be the result of the seed itself. Vrijmoed (1999) note that seed is not always produced reliably every year. Many native plants produce good seed irregularly and it is best if a number of years' seed can be combined. Young and Evans (1979) found that *B. sagittata* seed could be stored for at least five years. Susan Bastin (pers. comm. 1999) at C.E. Jones Nursery, formerly in Victoria, found that some years they had good *B. sagittata* germination and other years they had "total failure" (zero germination).

Growing plants in a field location may be economically more feasible than greenhouse germination because there is not the added input of a greenhouse facility, regular watering and increased labour input. Although field growing reduces cost and solves a problem of nutrient loss due to leaching from pots, it does pose a number of other concerns. At the field location, the primary concern in my study was the effect of the weeds on seedling development. *Balsamorhiza sagittata* is extremely slow growing and thus does not compete well with other more aggressive plants (Young and Evans 1979). Weeds can be aggressive, making it difficult to germinate and protect seeded plants in the field, and some will inevitably be lost. Before the field site was planted, we discussed the idea of applying soil to the surface to prevent many annual weed seeds from germinating, and to suppress the emergence of many perennial weeds. However, we concluded that new soil would likely give different plant growth results than the native soil (Bowen, pers. comm. 1999). In the interest of maintaining the field plots as close to the natural conditions for *B. sagittata* and in order to keep cost at a minimum we decided not to add soil. When I visited the site on May 5, 2000 the plots were covered in weeds to the point where I could barely find the *B. sagittata* seedlings. A number of seedlings may have been weak or damaged by the subsequent removal of the adjacent weeds. Application of chemical herbicides, such as Round-up, was another alternative for weed control but these were determined to be detrimental to the environment and would increase the financial cost, and thus were not considered as an option. The ecological benefit of growing a plant in its native soil is potentially stronger than the security of propagation in pots. Another factor that may be important in this regard is the presence of the mycorrhiza components of soil and their benefits for plants.

The real benefits of the germination techniques are not reflected simply by numbers of seeds acquired at the nursery. There is a need for further long-term feedback not only on germination rates but also ultimately on the survival of seedlings in the field. When I was transplanting the seedlings a unique feature about the seedlings became apparent to me. Without exception, all germinates that were treated with ethylene were not producing much of a radicle while the field-sown plantlets all had long, thin radicles (up to 4 cm). I hypothesize that although the ethylene-treated seedlings transplant more easily, unless they are able to develop long roots quickly, they will have problems in over-wintering and will not be as strong in summer drought as the non-ethylene treatment seedlings.

Little and Hill (1978) note that nearly all problems encountered by an agriculturist are those requiring inductive reasoning and these problems can never be answered with 100% certainty. The purpose of my experiments was to provide a means of making observations (probability sampling) that can be used for making plausible generalizations about the germination and propagation of *B. sagittata*. To recommend optimal seed germination and propagation methods for *B. sagittata* at this time is premature. It is not known how the seedlings over wintered and will develop over consecutive years. Therefore, a multi-year study is suggested to discover which treatment is the most efficient under different germination and transplanting conditions.

5.4 Suggestions for Future Work

There are a number of other standard practices in horticulture and agriculture that could be applied to the germination and propagation of *B. sagittata*. Seeds could be stratified in sand, which would help reduce the opportunity for pathogenic fungus (Bastin pers. comm. 1999). Another way of avoiding fungus is to rinse the seed with fungicide before they are stratified (Hendry and Grimes 1993). Seeds could be sown directly into specialized plugs, which open like a book (Styro 77 or 32 Hilson). These trays would produce a better plug that could be transplanted with minimal damage to roots. Young et al. (1984) suggest using nitrate ions (fertilizer such as ammonia nitrate or calcium nitrate), which enrich the substrate, and enhance germination of seeds. Scarification of seeds can be tested through mechanical scarification as used on *Echinacea angustifolia* (Feghahati and Reese 1994) or by chemical means (Vivrette 1999; Young et al. 1984). One chemical that is frequently used is gibberellic acid. The mode of action of gibberellic acid in seed germination is not known, but low concentrations can enhance germination in a number of species (Young et al. 1984).

As indicated in Chapter 2, *B. sagittata* is well adapted to fire. Investigations into treating seeds with fire to increase germination have been studied (Brown and Staden

1998; Landis 1999). Smoke derived from burning plant material has been shown to stimulate seed germination in wildflower species from fire-dependent plant communities in South Africa and Australia (Brown and Staden 1998). In research by Landis (1999) smoke treatments produced significant increases in seed germination for 22 of 34 annual forbs and shrubs.

Research also needs to be conducted on the significance of mycorrhizae. The use of mycorrhizae for native plant production is increasingly being investigated (St. John 1999). There is a growing awareness that individual species are highly developed to complex soil conditions.

Seedlings could be retained in a greenhouse environment for one growing season and planted out in the fall when they are dormant. This may ease shock caused by transplanting from warm-moist to hot-dry environmental conditions.

It seems that many of the decisions that I had to make in developing this research design were influenced between a triangle of what is cheapest for the Xaxl'ep, what is the most environmentally conscious, and what is a standard agriculture practice. In the end it was decided that the plants were the primary concern. Because this is a prototype we needed the plants to live and further reductions in cash input and chemicals can take place in future experiments. Ideally experiments could be undertaken that would reflect all three of these considerations.

Mander et al. (2000) write that the lack of understanding with respect to the cultivation and economics of producing useful Indigenous plants can be considered one of the most limiting factors in commercialization. Producers are reluctant to undertake the research needed to commercialize native plants, as there is no indication of the potential costs and returns of producing plants for traditional markets. There appears to be little understanding of Indigenous plant cultivation in agricultural systems, particularly concerning the performance of plants and economics of production and marketing processes.

For the purpose of retail sale by the Xaxl'ep people it is unclear whether field propagation would be most appropriate to the Xaxl'ep area. This question needs to be further researched before finalizing a choice between a nursery structure with plantings in pots or '*in-situ*' field propagation.

5.5. Summary

In this chapter I reviewed the procedures that I followed in an attempt to better understand how to germinate and propagate *B. sagittata*. Through an extensive literature search and numerous informal interviews I developed an experimental design with the objective of adding to the existing knowledge base on how to germinate *B. sagittata*.

I collected *B. sagittata* seeds in June 1999 from five locations in close proximity to one another and from a geographical area similar to the field planting location. I planted seeds in plots in October 1999 for natural stratification. In November 1999 I conducted a number of experiments to determine if seed germination could be increased through a stratification process. Emerging seedlings were planted into long plug cells in a greenhouse. At the end of May I transplanted seedlings from the greenhouse and direct sown seedlings into randomized blocks at the field location. Throughout the greenhouse phase I recorded the number of seedlings and leaf number and height on a bi-weekly basis. For the field site I documented the survivability, leaf height and number of seedlings from the time of transplanting until when the seedlings senesced late June.

Based on the data obtained and by using statistical analyses methods of Chi-square and ANOVA, I argued that the stratification treatments significantly influenced germination rates and transplant survival rates but did not influence the survival numbers in the greenhouse. Treatments also influenced the number of leaves but did not significantly alter plant height.

Of all the treatments, seeds on paper towel soaked in ethylene had the highest germination rate (28% and 25%) followed by seeds on Sunshine mix treated with ethylene. The ethylene treated seedlings had visibly smaller radicles.

Based solely on the research conducted I would recommend direct seeding if *B. sagittata* is to be used and or marketed as a medicinal, vegetable or inulin source. Growing plants in a field environment requires little economic or labour input. If *B. sagittata* plants are to be used for horticulture or restoration then I suggest placing seedlings on ethylene soaked paper towels in Ziploc bags. As seeds germinate they should be transplanted into long plugs that contain a relatively low bulk density soil mixture. Seedlings could then be transplanted to the field site or into pots outside when the danger of frost has passed.

6.0 Applied Ethnobotany: New Potential for *Balsamorhiza sagittata*

In keeping with the ethnobotanical goals outlined in Chapter 1 (Introduction), this chapter expands upon the ecological and cultural importance of *B. sagittata* to illustrate potential commercial uses of this plant. Not only does *B. sagittata* play an important role in a number of existing ecosystems and continues to have ethnobotanical value to Indigenous Peoples of the Interior Plateau, it also has promise for commercial endeavors and ecological restoration. *Balsamorhiza sagittata* has a variety of potential economic and ecological applications: as an ornamental, for restoration (slope stabilization and mine reclamation), in herbal medicine (antimicrobial properties), as an inulin source (processed crop), and as a vegetable. Within this chapter the various possible future uses of *B. sagittata* are considered separately. In each section I will review the plant science and ethnobotany to indicate how this research has lead to ideas on the potential utilization of *B. sagittata*. The ideas for future uses that I present are case studies of feasible economic initiatives.

Research material for this chapter was gathered through investigations in ecological restoration, herbal medicines, horticulture and food systems. Specific examples and discussion of economic development concerns are predominately in reference to the Xaxl'ep People, for whom this research was initially undertaken. It is believed, however, that the information presented here holds potential for other Indigenous communities with a cultural and ecological history associated with *B. sagittata*, and the germination and propagation of native plant species in general.

6.1. **Current Investigations into New Uses for *Balsamorhiza sagittata***

6.1.1 Horticulture

There is a trend towards gardening with native plants. *Balsamorhiza sagittata* is ideal as a horticulture variety. A number of literature sources indicate that the striking yellow flowers, which bloom in early spring, as well as the plant's large soft, pastel-colored leaves make it excellent for marketing as a horticulture variety (Angove and Bancroft 1983; Cannings et al. 1997; Parish et al. 1996). In *Gardening with Native Plants of the Pacific Northwest*, A.R. Kruckeberg (1982:43) comments on the beauty of *B.*

sagittata; "the rites of spring in sagebrush country are truly celebrated when fields of yellow appear." The flowers also attract hummingbirds and butterflies (Cannings et al. 1997), which may appeal to the home gardener. Once established *B. sagittata* is long lived and requires little watering and fertilization, as it is well adapted to the dry Interior of British Columbia. The difficulty with propagating *B. sagittata* as a horticulture variety is the low seed viability, and its long taproot, which makes the marketing of seedlings for transplanting uncertain.

In Northwest North America the practice of gardening with native plants lags behind that of New England and the southern United States, but the interest is increasing. *Hortus West*, a magazine focused on the native plant industry, states that "native plants are becoming increasingly popular additions to residential landscapes and backyards" (1999:World Wide Web). Recently *Hortus West* authors Clement Hamilton, Midori Murai and Cynthia Gilbert analyzed the trend towards an increasing number of native plant nurseries by comparing the number of nurseries and their species lists in the first issue of *Hortus Northwest* (now *Hortus West*) with those of 1998. The ten-year trend indicated a marked growth in the number of native plant nurseries and in the numbers of species carried by them. In conclusion, Hamilton et al. (1998:100) write:

> We live in a dynamic, exciting time in the evolution of the nursery industry, as ecological and horticultural perspectives are blended to create (shall we say it?) a new paradigm of landscaping. The past ten years have seen a phenomenal growth in the many uses of Pacific Northwest native plants.

In the preface to his informative book, *Gardening with Native Plants of the Pacific Northwest*, A.R. Kruckeberg (1982) writes that a general fascination with plants is experiencing a 'rebirth,' as illustrated by the increase in the number of field guides available and the 'profusion' of plants being grown indoors and out. Most importantly, Kruckeberg (1982: preface) notes, "the urge to grow native plants in one's own garden or at the summer cabin is very much on the upswing." The result of the increase in the desire to garden with native plants is an increasing market for native species.

The Southern Interior of British Columbia is one of the fastest growing regions of Canada in terms of human population and urbanization (Cannings et al. 1997). The increase in population combined with a growing awareness of our natural ecosystems and the necessity for water conservation indicate a potential increase in demand for native plants. Since cities in this region are concentrated along the river valleys, it follows that "these areas of exceptional biological richness are seriously threatened by urban sprawl and encroachment" (Naturescape 1999: World Wide Web). Gardening with native plants could help to alleviate the pressure of reduced habitat.

For the homeowner, "the use of native plants as living ornaments in our built environment (cities, suburbia, rural communities) is a logical extension of our concern for preserving some of the Northwest's natural features" (Kruckeberg 1982: preface). Naturescape, a component of the Habitat Conservation Trust Fund, has initiated a vigorous campaign to "promote caring for wildlife habitat at home" (Cannings et al. 1997:2). The interest in native plant gardens extends beyond the aesthetic qualities of the plants. "Xeriscape (ZEER-i-scape), the application of water conservation to create landscapes compatible with local [low moisture] conditions," (Cannings et al. 1997:14) is increasing in awareness and use. Native plants are adapted to the climatic conditions of their given landscape. Gardening with native plants can assist with the conservation of water (thus reducing utility bills in many urban environments), as well as preserving the plants themselves and providing habitats for a variety of animals.

Home gardeners also are interested in attracting butterflies and birds to their gardens. Planting native species provides ideal food and shelter for the birds and butterflies indigenous to the area and enhances people's appreciation of their local natural landscape and ecosystems. The increase in an ecological conservation mind ethic has also led to an increase in the demand for native plants. Whether it is for the beauty of the native plants themselves, for conservation concerns, a desire to save money and water, an interest in birds and butterflies or to lessen our impact on the earth, home owners interested in gardening with native plants require a source of native plant seed and seedlings.

Another area where native plants are increasingly being used is in school grounds. Awareness is growing amongst communities and teachers that children need aesthetically pleasing and stimulating environments in which to learn and play (Samborski 2000). Native plants, food plants and horticultural varieties are being used in the 'greening' of school grounds. Native plants are also being used in parks, museums and, at First Nations Band Council Offices to develop ethnobotanical gardens. Greening of schools and development of ethnobotanical gardens enhances cultural awareness and adds to a growing sense of community pride while creating attractive landscapes.

6.1.2 Ecological Restoration and Revegetation

Restoration of natural ecosystems requires a source of native plants in order to reestablish previously damaged habitats. "Re- introducing native plants to degraded land is an integral consideration in ecosystem restoration" (Burton 1998: 8). In this section I will provide a general overview of restoration and discuss why *B. sagittata* is particularly important for habitat recovery.

The need for restoration is the result of a number of causes that can be generalized as: habitat destruction, impact of invasive species, and pollution (Given 1994). As early as the 1930's, the excessive erosion of western rangelands was recognized (Spence 1937). In the Interior of British Columbia there are specific negative impacts resulting in the loss of natural habitat: lowering of the water table, agriculture, herbicide spraying, dam construction, soil compaction, erosion, mining, wetland drainage, industrial development, competition from introduced exotics, logging, commercial collection, and disappearance of symbionts (pollinators, dispersers) (Given 1994). In an article written for *Menziesia*, the newsletter for the Native Plant Society of British Columbia, Burton and Burton (1998:8) argue that:

> It has become necessary to revegetate large areas of land in British Columbia, due to extensive logging, mining, road construction, and other industrial activities. Plants are needed for aesthetic and functional purposes: for 'visual green-up', to control erosion, to restore soil structure and productivity, to grow more timber, and to provide suitable habitat for animal life.

In particular, the grasslands of the southern Interior Plateau are considered one of the most endangered ecosystems in Canada (Cannings et al. 1997). Within the Xaxl'ep traditional territory (my focus study area), for example, the landscape and native plant communities have been altered by private and corporate logging practices, hydroelectric lines and overgrazing. The Xaxl'ep have expressed an interest in restoring these areas to benefit wildlife to improve the quantity and quality of water and to allow for healthy sustainable harvesting of traditional foods, medicines and plants used for technology.

In an attempt to repair, or at least to begin the process of mending some of the damage done to natural systems, use of native plants is often a legally required component of environmental projects such as wetland mitigation and ecological restoration. For this reason, native plants and seeds are in high demand (Hortus West 1999; Rose et al. 1998).

Restoration is divided into a number of different actions that reflect the level of repair that is being undertaken. MacMahon and Jordan (1994) define the different initiatives that are currently being undertaken:

- **Restoration** - ecological restoration means to restore something to its former or original state;
- **Rehabilitation** - any attempt to restore elements of structure or function to an ecological system, without necessarily attempting complete restoration to any specified prior condition;
- **Reclamation** - rehabilitative work carried out on the most severely degraded sites;
- **Re-creation** - attempts to re-construct an ecosystem on a site so severely disturbed that there is virtually nothing left to restore, and;
- **Ecological Recovery** - letting the system alone, generally in the expectation that it will regain desirable attributes through natural succession.

In all of these forms, there is a potential for *B. sagittata* to assist in recovery of the landscape towards its healthy natural state.

Much of the initial native plant propagation experimentation and marketing of native plants is related to restoration. The only book that specifically focuses on propagation of Interior British Columbia plants was funded by the Ministry of Forests, "the initial seed work involved seed collection, stratification and the growing of planting stock for revegetation projects along the Salmon River near Salmon Arm" (Hudson 1998:Forward). Personal correspondence with proprietors of native plant nurseries in British Columbia indicates that their main market is still from restoration projects.

An increasingly important focus in restoration is to provide plants for local use from local sources. Lesica and Allendorf (1999) argue that in restoration it is important to use local sources for plant material to lessen the chance of contaminating the resident gene pool. Seeds collected and plants grown in an area similar to where they will be planted not only have a greater possibility of survival but also are more similar genetically than plants from a different region. For the Xaxl'ep to grow their own plants for restoration would not only decrease the cost of purchasing these plants but would reflect the Xaxl'ep concern for ecosystem integrity.

Through its effects on land and human communities, restoration has a crucial role to play in the conservation of diversity. Higgs (1997) argues that good restoration requires an expanded view that includes historical, social, cultural, political, aesthetic and moral aspects. Examples of the intertwining of culture and restoration are prevalent in seven groups of Indigenous Peoples in the United States and Canada who are currently using native plant species for restoration and to reintroduce populations of species of cultural significance (Luna 2000). These tribal groups are the: Blackfoot, Anishenaabe, Choctaw, Salish-Kootenai, Mohawk, Navajo and Ktunaxa-Kinbasket[1]. Luna (2000:95) summarizes the focus of these groups: "In response to their rich ethnobotanical heritage, the need for restoration, cultural education, and providing employment opportunities, at least seven native nations have developed native plant nurseries for restoration projects in recent years. Integration of culture and ecology is a distinctive feature of their restoration projects".

Balsamorhiza sagittata is a native species that is well adapted to a number of ecosystems, is drought tolerant, and may be of major ecological significance; thus, this plant is well-suited to use in many restoration sites of the Interior Plateau. It is a dominant forb that serves as a food source for a number of animals and has complex and diverse interactions with insects that have been largely unresearched.

Balsamorhiza sagittata also is being experimented with in mine reclamation of oil-shale or coal-mined lands and revegetation for soil stabilization (Jones, 1999; Wasser, 1982). Traditionally a cover of agronomic species is used to begin slope stabilization and mine reclamation. However, using exotic species may not be compatible with the end-use

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[1] Blackfeet are synonymous with the Blackfoot in Canada. The Salish-Kootenai are combined of Salish and Ktunaxa who reside on a Flathead reserve. The Ktunaxa and Kootenai are the same language group.

objectives of forestry or wildlife habitat, and on these sites the establishment of native species is more desirable. Native species are selected for these sites based on their ability to improve the nutrient status of the soil and on their palatability to wildlife. As has been indicated, *B. sagittata* is long-lived and has deep taproots that are beneficial in slope stabilization. Furthermore, *B. sagittata* is an important food source for many large mammals and ungulates, which are the major wildlife resources in the vicinity of several mines in British Columbia (Jones 1999).

6.1.3 Herbal Medicinal Applications

Increasingly native plants are also being grown for medicine and food to be used by Indigenous Peoples and consumers in general. Native plants are not only a foundation of herbal medicine, but they are the basis for many pharmaceutical medicines. Herbal medicines differ from pharmaceuticals in that they have not been chemically replicated or synthesized but continue to be produced directly from the plant materials and may contain a mixture of beneficial compounds.

Research of plants based on ethnobotany has and continues to be a valuable means of identifying which plant species have a higher than normal random probability of containing medically relevant compounds of interest (Bannister 2000). The pursuit of new medicines derived from plants growing in tropical areas has been a particularly high-interest area of research, but the medicinal properties of plants used by North American Indigenous Peoples has not received such attention. McCutcheon et al. (1992:213) write:

> This field of ethnobotanical research [pharmaceuticals] has expanded greatly in recent years as the value of this type of research has come to be more widely recognized. However, in North America the growth of this recognition has lagged far behind the rest of the world. The public's interest and support has been captivated by the exotic and mystical appeal of tropical ethnobotany but this interest has not yet progressed to include North American ethnobotany.

A study in 1992 by McCutcheon et al. marks the first screening of British Columbia's native plants for antibiotic activity. McCutcheon et al. (1992) determined that 87 percent of the plants which had been documented as being used medicinally by native peoples in British Columbia, were found to have antibiotic activity against at least two bacteria.

More specifically, 95% of the plants designated as potentially antibiotic, based on ethnobotanical data, exhibited antibiotic activity. In a second broad study, McCutcheon et al. (1994) conducted research on antifungal properties of British Columbia native plants which until recently had attracted little investigation. The catalyst for McCutcheon et al.'s (1994:157) research is that "The number of immunosuppressed and immunocompormised patients succumbing to fungal infections, [and] the demand for new antifungal compounds has risen dramatically". Given the growing need for effective antifungal therapeutics, the authors believed it would be worthwhile to conduct antifungal screening of the traditional medicines of British Columbian Native Peoples. To conclude, McCutcheon et al. (1994:168) note, "The selection of plants based on traditional usage appears to increase the probability of acquiring plants with antifungal activity." In screening these plants for antibiotic and antifungal activity, it was hoped that the data obtained will not only provide useful leads towards the discovery of new medicines but also encourage further interest and research in North American ethnobotany and ethnopharmacology (McCutcheon et al. 1992, 1994).

Growth of mediculture (cultivation of medicinal and aromatic plants) to meet the increasing demand in the food, pharmaceutical, perfume, flavour, and cosmetic industries is occurring worldwide. Current research is being conducted on the antibiotic, antifungal, antibacterial and methylated flavonal properties of *B. sagittata* (Bannister 2000; Matsuura et al. 1996; McCutcheon et al. 1994). The significant concentrations of antimicrobial components in the pitch of *B. sagittata* make this plant an excellent candidate for herbal medicines. A thorough review of the medicinal compounds and potential of *B. sagittata* is presented in Chapter 3.

To summarize, *B. sagittata* has been and continues to be an important medicinal plant for the people of the Interior Plateau. Scientific investigation indicates that *B. sagittata* has concentrations of a number of important medicinal compounds that hold potential not only as herbal medicines but in the development of new pharmaceuticals as well. Growing this plant may provide a sustainable source for a number of important medicines.

6.1.4 Root Vegetable and Inulin Source

Agriculture and Agri-Food Canada have shown an interest in developing sustainable productive systems of agriculture and working with indigenous peoples on traditional food and medicinal plants. Increasingly Agriculture Canada is concerned with land stewardship, especially in the area of plant ecology (P. Bowen, pers. comm. 1999). Specifically there is an interest in the nutritional value, possible health benefits, and commercial availability of inulin containing foods such as *B. sagittata*. Plants such as *B. sagittata* have the potential for a cash cropping systems that are environmentally and economically sustainable.

A number of studies have been undertaken on the nutritional components of *B. sagittata* (Bannister and Peacock 1998; Kuhnlein and Turner 1991; Mullin et al. 1997). *Balsamorhiza sagittata* roots are an excellent carbohydrate source mainly composed of inulin, which is broken down into fructans when the roots are cooked. Fructans are one of the major sources of food energy as well as being responsible for maintaining general health. Fructans are non-carcinogenic, have a low caloric value and an ability to maintain colonic health. Mullin et al. (1997:774) state, "In modern society the inclusion of fructans in the diet should be viewed as beneficial to improved health."

Some wild food crops known to be used by Indigenous People, and which have now been directly adapted for commercial markets, are: chia seeds, pinyon nuts, Jerusalem artichokes, wild rice, maple syrup, pecans, black walnuts, cranberries, saskatoon berries and blueberries (Nicholson et al. 1971; Turner 1981).

Not only does a plant such as *B. sagittata* have potential as a new vegetable and inulin source but also as a source of agriculture genes. With the rapid spread of information there is an expanding awareness that we may be eliminating our last caches of future resources such as crop genetics and medicines. To quote Kuhnlein and Turner (1991:8) "Another area of usefulness for information on indigenous plant foods is for genetic research and development of agricultural crops." Germplasm conservation programs and databases of indigenous foods are valuable sources for enhancing existing crops and for the development of new ones (Duke 1977; Turner 1981).

To simply market traditional Indigenous People's food plants as novelty items or luxury gourmet treats, however, is not enough. Nabhan (1989:193) argues:

> Even so we will have missed the point if we only select one of these profitable natives, create new hybrids with it, and grow them in monocultures just like any conventional cash crop. The Native American agricultural legacy is more than a few hardy, tasty cultigens waiting to be 'cleaned up' genetically for consumers, and then commercialized as novelty foods. Our goal must be something beyond blue corn chips, tepary bean party dips, amaranth candy, sunflower seed snacks, and ornamental chilies. These nutritious crops deserve to be revived as mainstays of human diets, and not treated as passing curiosities. These cultivated foods are rich in taste and nutrition, yes, but they are also well adapted to the peculiarities of our land.

The documentation of Indigenous People's knowledge of natural plant food resources will benefit humankind in many ways (Kuhnlein and Turner 1991). The greatest benefit from increasing awareness and availability of indigenous foods is for Indigenous Peoples themselves. Many aboriginal communities have high rates of diabetes, which has been closely linked to dependence on Western diets as opposed to traditional diets.

A large percentage of the foods that we eat originated in the gardens of the Indigenous Peoples of the America's. The potential, as is evident with *B. sagittata*, has not reached a limit.

6.2 **Cultivation versus Collection**

As has been indicated, *B. sagittata* has a number of potential commercial and restoration uses. For some of these, the long taproot of the plant makes it difficult to remove wild specimens and transplant them to other locations, even if this were desirable. For other purposes such as medicines and food plants it is possible to harvest plants from natural habitats. However, for the commercial marketing of *B. sagittata* I argue that it is better to establish the plant in a cropping system than to wild harvest.

Increasingly people are turning their attention to the wisdom of First Nations peoples and the medicinal properties of native plants. For many important medicinal and food plants, 'wildcrafting', in which plants are harvested from the wild, has gone beyond the point of sustainability. Harvesting of wild plants for food and medicine by individuals is seldom a problem if done carefully and with discretion. There are, however, certain plants that are particularly affected by disturbance and harvesting practices (Kuhnlein and

Turner 1991). This is especially a problem with plants such as *B. sagittata* that have edible underground parts and edible shoots. In these situations, harvesting may destroy an entire plant. Kuhnlein and Turner (1991) provide examples of food plants in Canada which have been impacted by over harvesting mostly by non-Indigenous people: Canada wild leeks (*Allium tricoccum*) and fiddlehead ferns (*Matteuccia struthiopteris*) have been overharvested from wild areas and their populations have been seriously depleted in some areas. In terms of plant demographics, American ginseng (*Panax quinquefolius),* goldenseal (*Hydrastis canadensis*), echinacea (*Echinacea purpurea, E. angustifolia*), and cascara (*Rhamnus purshiana*) have been greatly reduced in numbers, to near extinction in some localities, by overharvesting for medicinal purposes (Cech 1999; Crawford 1999; Dreyfuss 1999). Wildcrafting can be sustainable if "every act of taking is coordinated with an act of planting" (Cech 1999:1). Unfortunately a demand that exceeds plant availability frequently overruns sustainable harvesting. Cech (1999:1) writes:

> This lesson is nowhere more apparent than in the case of large-scale silviculture in the Pacific Northwest, where re-forestation is used as a justification for cutting of old-growth forests. There is a lot of difference between digging a thirty-year-old Ginseng and pushing a ripe Ginseng seed (or twelve of them, for that matter) into the ground.

Before *B. sagittata* is marketed as the next popular herbal remedy, serious research must be conducted on germination and propagation, and development in a cropping system including a near natural system such as zero-tillage.

The use of herbal medicine is widespread and growing, with as many as three in ten Americans using botanical remedies in a given year (Barrett et al. 1999). The end of 1998 marked three consecutive years in which echinacea was the most popular medicinal herb worldwide (Li 1998). Echinacea is used to enhance the body's own resistance to infection, and can be useful in the prevention of colds and flu. Some botanists have observed and expressed concerns over dramatic declines in wild *E. angustifolia* populations (as well as other species) because of current international demand. Tilford writes that echinacea "...is such a popular herb that it is currently being wiped out by over harvesting, commercial greed and habitat destruction" (1993:52). In Montana, the practice of wild-harvesting *E. angustifolia* is increasingly referred to as "strip-mining".

Tools have been designed to make digging more efficient. Hundreds of holes can be seen in the hills where plants have been removed, resulting in the degradation of prairie lands. The state of Montana recently enacted legislation, effective April 20, 1999, which imposes a $1000 per day fine for collecting echinacea roots from state lands (Klein 1990). Fortunately, *Echinacea* spp. are now widely cultivated in a cropping system in order to meet market demands.

In Montana not only are medicinal plants being overharvested but removal of large amounts of huckleberries (*Vaccinium* spp.) is impacting the bear population and wars have erupted over mushrooms in United States National Forests (Smith 2000). In British Columbia there is a tremendous interest in and demand for natural health products. The concern towards overharvesting of wild species has led some to promote provincial regulations for harvesting of non-timber forest products (Von Hagen and Fight 1999).

The cultivation of medicinal and food plants is an alternative to the impacts of over harvesting. The propagation and processing of medicinal and aromatic plants shows an annual growth rate of five to ten percent internationally, resulting in an estimated more than US $50 billion globally generated in medicinal plant products yearly (Singh and Kumar 1998). With the development of suitable agrotechnologies, a large number of the medicinal plants that are still collected from wild sources may soon be cultivated to maintain the regular supply of raw material of desired quality. Pre-determined cultivation techniques for medicinal plants in British Columbia may help to prevent the destruction of the natural environment when herbal remedies from local native plants increase in public awareness. This is an excellent alternative to harvesting plant foods from natural areas, since it makes them more readily available without affecting their abundance in the wild.

It appears that the general public has overlooked the art of traditional peoples' food production, which depended upon the cultivation of a sustainable crop by selective digging, burning, tending and pruning. It also is possible that demand exceeds the forests' ability to supply the quantities of berries, mushrooms and medicinal plants that are currently being taken. Whether it is for medicinal purposes, re-vegetation of logging roads, stream stewardship, wetland restructuring or mine reclamation, the "demands for planting stock are increasing each year" (Hudson 1998: Introduction). Propagation of medicinal and edible plants in their natural ecosystems would allow the continued benefit of these native plants while reducing and perhaps mitigating the impact on the wild populations. "Commercial horticulture and the nursery trade have an important role in conservation; providing there are adequate safeguards to avoid unacceptable exploitation, the nursery trade can be regarded as a potential major ally for plant conservation" (Given 1994:135). It is vital that we preserve plant diversity.

6.3 **Suggestions for Future Work**

The germination and propagation of native plants is a complex process that often requires time and a great deal of innovation. Extensive research needs to be conducted on the current practices of growing *B. sagittata* and related species such as *Echinacea angustifolia*. In Chapter 6 I review the germination and propagation experiments that I conducted for *B. sagittata* but these are not definitive means of growing this plant. It takes years and immense resources to come up with a more detailed comprehension of how to domesticate a native plant species. It is also vital that we continue to build on the ecological knowledge base for this species. In Chapter 4 I provide more information that can help us to understand how this plant grows and interacts in its natural environment. However, this is some of the first research to be conducted on *B. sagittata* in British Columbia and by no means does it provide a completed picture of the autecology of this species. For a plant of such ecological and cultural importance further research is vital. An understanding of Indigenous Peoples' resource management practices would also greatly benefit in the comprehension of the plant's phenology. Working with Indigenous Peoples, who have been the traditional users and caretakers of species such as *B. sagittata,* is vital in terms of both the acquisition of knowledge and respect.

For many Indigenous communities, outside economic development initiatives have resulted in high rates of failure in the past. Historically, enterprises imposed from afar, without proper consultation with communities have inevitably been unsustainable. The need for projects to be socially and culturally sustainable should therefore be a major consideration. The germination and propagation of species that are culturally and ecologically important to the area in which they are to be produced is one way of creating economic development initiatives that have relevance to the community.

A thorough analysis of business opportunities and economic feasibility of native plant propagation is beyond my ability and the scope of this paper, but is a major area that needs further research. In Chapter 7 I address some issues that are of particular relevance to the Xaxl'ep and the field of ethnobotany. Further research into the market potential and marketing of *B. sagittata* needs to be conducted by someone who specializes in business and economics.

6.4 **Summary**

In summary, this chapter has reviewed four key areas of applied ethnobotany in which *B. sagittata* has potential: horticulture, ecological restoration, medicine, and, vegetable and inulin source. From the material presented in this chapter it is apparent that a thorough analysis of the ethnobotany, autecology and germination of *B. sagittata* is a relevant and promising pursuit. Although some of the markets for *B. sagittata* could be fulfilled through the harvest or 'wildcrafting' of plants in their natural environment, it is my opinion that it would be more ecologically and potentially economically sustainable to germinate and propagate this plant in a controlled environment, preferably on Xaxl'ep or other First Nations' lands and under their control.

7.0 Reflections

7.1 Combining Economic Development, Environmental Sustainability and Cultural Integrity

Successful economic initiatives in Indigenous communities should include the dual components of restoring the landscape and promoting culture. Development initiatives need to consider culture and the environment before their viability can be fully determined. A key concern for many communities is that sustainable development initiatives must incorporate and reflect elements of traditional knowledge and practices (Weinstein 1995). Economic initiatives focused on native plant species, such as development of a nursery, are especially relevant where people are interested in finding ways to maintain a land-based livelihood.

The Xaxl'ep value system ensures a combination of sustainable resource use, eco-system integrity, and cultural transmission (Weinstein 1995). Any economic development initiatives on Xaxl'ep land should reflect the concerns of Xaxl'ep elders and councilors. Weinstein (1995: 6) summarized the Xaxl'ep's concerns for compatible land use planning and resource use:

> 1. take care of the land first (ecological);
> 2. go slow - development based on a long-term plan (sustainability);
> 3. include work done by a band company (benefits);
> 4. heal and nurse forest and land after cutting (healing damages);
> 5. result in no damage to water (preserve water supply and quality);
> 6. avoid *the cutting of corners* that comes from a primary focus on money and profit (full commitment to principles); and,
> 7. be based on a land use plan that has a heart and feelings toward the land and the people traditionally dependent on this land (socially-based planning).

The insight and sensitivity of the advice given by the Xaxl'ep community are applicable to a variety of rural based development plans that have sustainability as part of their mandate.

Beyond the complexity of integrating culture, economy and the environment, many concerns relate specifically to the domestication process of native plants. The steps from the selection of native plant varieties to the development of a product for sale include:

- community interaction/botanical research;
- indigenous knowledge/identification of potential new products;
- market survey;
- natural area management/agroforestry/farm production;
- identification of economical efficient management/production/marketing;
- market recommendations for implementation; and,
- resource management/production/product development/distribution/marketing and monitoring (based on Sinclair et al. 1996).

Indicated by the expansiveness of this list is that there are a number of concerns to address in the domestication and commercialization of native plants.

Mander et al. (2000) state that the lack of understanding for producing useful indigenous plants, with respect to cultivation and economics, can be considered one of the most limiting factors in commercialization. Producers are reluctant to undertake the research needed to commercialize native plants, as there is no indication of the potential costs and returns of producing plants for traditional markets. There is little documentation of indigenous plant cultivation in agricultural systems, particularly concerning the performance of plants and economics of production and marketing processes.

The stages necessary to bring a plant to production, and the facilities and equipment required constitute the majority of concerns relating to the creation of a native plant nursery. It is important to note that every native plant nursery has requirements specific to a particular location, product, market and proprietors. Common to all nurseries are a number of general conditions that must be met. The greatest necessities are those which are crucial to the growth of plants: seeds, water, soil, and sun.

The Interior of British Columbia is extremely dry in many places. The Fountain Valley, which comprises the majority of Xaxl'ep Territory, however, is a relatively lush area surrounded by an arid landscape. The Xaxl'ep realize the significance of this valley, and they are concerned with protecting and restoring the watershed. Weinstein (1995: 4) writes:

> For the Xaxl'ep, water is the number one concern. Traditions recognize water as the connector. Water looks after people, fish, animals and trees. Xaxl'ep elders say 'without water we are lost.' The Fountain Valley is a lush, green jewel in an otherwise parched landscape. The ecology of the territory depends on the supply of water. And the residential occupancy of reserve lands and their use for agriculture depends on both water flows and water quality.

Because of the fragility of this landscape, and the Xaxl'ep concern with protecting water supply and quality, any development initiatives in the valley need to take this into consideration.

The Fountain Valley is narrow with steep slopes, and it is possible that any development initiative may put pressure on current land uses. Singh and Kumar (1998) note that in many arid and mountainous regions, areas for additional crops and for increasing agriculture production are simply unavailable. The cultivation of native plants and other forms of agriculture therefore must be made complementary to each other, conservation and sustainability are keys. Both require similar resources - water, light, soil, and nutrients - which are potentially limited and/or scarce. It is necessary therefore to implement only well developed strategies to achieve targeted output both in medicinal and traditional agricultural crops, through proper and optimal utilization of available resources. The underlining imperative is that any development initiatives in Xaxl'ep Territory do not negatively impact the Xaxl'ep community. Water used for a nursery, for example, should not detract from home gardens and existing agriculture irrigation.

7.2 **Considerations When Combining Ethnobotanical Research and Scientific Investigation**

Ethnobotany encompasses the broad research field of people and their relationship with plants. Ethnobotanical research has the potential for large scientific, community, environmental, nutritional and medicinal contributions. Anderson (2001: 183) argues that: "we have to see ethnobiology as a science whose ultimate end is not just knowledge but knowledge applied to saving nature and, as a part of that, to using resources more efficiently in order that humans and other creatures can live decent lives without wiping out the resource base". The expectations for ethnobotanists go beyond the research level and criteria of science. Ethnobotanists' "work can and should take place both at the community level, in assisting local cultural groups to document, perpetuate and protect their botanical and ecological knowledge, and at broader regional, national and international levels in helping to define policy and legislation to ensure the recognition and protection of such knowledge" (Turner 2000:16). The research undertaken by ethnobotanists is expected to support both the cultural and ecological resilience of ecosystems.

The complexity of ethnobotanical research projects is intensified by the obvious necessity that all research takes place through the participation and guidance of the communities in which the knowledge is based. Ford notes that, "the difference between past ethnobiological practices and the future is that the native people will set the agenda and determine the consequences of any newly discovered information" (Ford 2001:6). A key component to community-based research is accountability. Previously scholars may have been accountable to their university and the peer group of their research field, but now they must logically be accountable to the people from whom the knowledge derives and to whom the knowledge belongs. Although the tremendous potential in ethnobotanical research lies in the synergy possible through interconnecting these different approaches and ways of knowing, the tasks undertaken are broad and lacking in set methodology which causes greater difficulty in implementation.

Draft protocols for researchers are evolving and these frequently encompass the following mandates:

- to promote inclusion of First Nations in research projects;
- to assist communication between researchers and communities; and,
- to ensure that researchers provide benefits to the communities, such as copies of data and reports.

In addition, for researchers investigating traditional ecological knowledge, the protocols suggest:

- for researchers to clearly state their intent and receive appropriate approval for their research;
- to train and include community members in their projects; and,
- to respect wishes for limited or unacceptable circulation of data, especially those related to private or spiritual matters (based on Craig 1998).

The complexity of these demands needs to be recognized and addressed by all parties when undertaking new research initiatives so that realistic expectations are established. Another serious concern is that the requirements for working within the framework of community-based research may impede the implementation of rigorous scientific investigation.

My intention was to incorporate both traditional and ecological knowledge and scientific methodology in my research, and to incorporate First Nations' values and perspectives throughout the project. The strength of the interpretation lies in its interdisciplinary approach and theoretical foundations. However, the interdisciplinary nature of the research and diversity of objectives also created extra challenges in the hard science aspect of my thesis.

7.3 **Summary**

My thesis has provided an opportunity to work in collaboration with the Xaxl'ep people, Agriculture and Agri-Food Canada and scholars at the University of Victoria. I have undertaken research on four different aspects of *Balsamorhiza sagittata*: ethnobotanical uses, autecology, agronomy, and future uses of the species. This research has been presented as a case study of the unrealized potential for native plants. I have argued that all research on native plants and the benefits of this knowledge should first be conducted with and presented to the communities who are the original users of these plant species. It is my opinion that the knowledge still maintained by Indigenous communities is beneficial to future food security, medicines, environmental restoration and resource management. As well, this knowledge is crucial to Indigenous communities for cultural sustainability and restoration.

The major findings of my research include:

- *Balsamorhiza sagittata* is an important rangeland plant for both domestic and native ungulates as well as insects and birds. The species is relatively under-researched botanically and the full significance of this dominant forb is speculated upon but not proven. This research indicates that *B. sagittata* is an important species for restoration of damaged grasslands and sagebrush ecosystems in the Interior Plateau of British Columbia (Chapter 2).

- *Balsamorhiza sagittata* was one of the most important food plants for peoples of the Interior Plateau and was a crucial medicinal plant throughout its growing area. The plant has been proven scientifically to possess significant nutritional and medicinal qualities. The importance of this plant ethnobotanically is an indication of its future potential (Chapter 3).
- Investigations on three populations of *B. sagittata* in the Northwestern Interior Plateau did not result in any particular characteristics appearing common between the three sites nor were any of the variables correlated significantly to the frequency of *B. sagittata* in the plots (Chapter 4).
- Germination and propagation of *B. sagittata* both in a greenhouse environment and in field experiments revealed that although the plant had a low germination rate it could be grown from wild seed. Ethylene-treated seeds had increased rates of germination. Seedlings transplanted to the field site had higher survival rates than seedlings transplanted within the field location or those that remained in-situ (Chapter 5).
- *Balsamorhiza sagittata* has a number of potential uses: food, medicine, horticulture and restoration. Each of these applications requires different strategies for germination and marketing but the diversity of possible initiatives is an indication of not only this plant's utility but the benefits of Traditional Ecological Knowledge and Ethnobotany to sustainable community development initiatives, ecological restoration and resource management (Chapter 6).

The role of ethnobiology and Traditional Ecological Knowledge in the future is unknown. It is apparent, however, that ethnobiological knowledge is an invaluable resource for salvaging environments as well as satisfying worldwide dietary and health needs and securing sustainable economic initiatives for Indigenous communities.

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Appendix 1

Traditional Ecological Knowledge and Applications to Resource Management

Methods of Resource Management

Traditionally, the Indigenous People of the Interior Plateau have been viewed as hunter-gatherers, which were passive food procurers. Indigenous People have been frequently depicted as "ecologically noble savages" living in harmony with nature and having little or no lasting impact on the environment (see Denevan 1992). The "Pristine myth", a product of 19th century romanticist and primitivism writers, viewed the North American landscape as a "sparsely populated wilderness, a world of barely perceptible human disturbance" (Denevan 1992:367). Historians, ethnobotanists, geographers, anthropologists and botanists are increasingly arguing that humans were not passive hunter - gatherers but have been a keystone species in the evolution of the North American landscape. Evidence is indicating that the landscapes of the America's have been extensively humanized.

The landscape has been altered through the management of resources at three levels: *species*, which enhances longevity, reliability and productivity of any culturally significant plant species; *community*, creates and maintains productivity in selected communities; and *landscape*, the totality of people's management effects, throughout a large geographic area (Peacock 1998; Peacock and Turner 2000). Indigenous Peoples "practiced a range of techniques of plant propagation, habitat management and enhancement, and soil fertilization that maximized the productivity of plant foods and materials. These management practices blur the division between foragers and horticulturists" (Turner et al. 2000:1276). In models of people-plant interactions (Ford 1985 and Harris 1989, cited in Peacock 1998) wild plant food production represents an intermediate point between foraging and farming. Peacock (1998:6) notes the "differences between one end of the spectrum and the other are largely ones of degree (scale and intensity), not kind". To support the argument that Indigenous resource management techniques did more than extract plants of cultural significance, Peacock and Turner (2000:133) write "It has always been puzzling to us that the most productive, prolific areas to find particular edible or useful plants, especially wild root vegetables, are invariable in those localities where they have been traditionally harvested in immense quantities." In order to understand the effects of traditional resource management it is important to look at specific actions taken.

The Indigenous Peoples of the Interior Plateau practiced many tactics to insure food supply. Some of these tactics were social - controlling access to the resource, managing the labor force, exchange, moving to a more productive area - and other strategies were technological. Technological strategies required the management of the resource itself. Specific management techniques used on *B. sagittata* include burning and digging. Ownership was the predominate social tactic, controlling and influencing its growth and abundance.

Burning is considered a major component of wild plant food production (Peacock 1998). Peacock and Turner (2000) argue that burning was designed to create and maintain productive parkland and ecotones. A quote by the late Baptiste Ritchie, (Lil'wat [Stl'atl'imx] Elder 1971, cited in Peacock and Turner (2000:133)) validates Peacock and Turner's logic in reasoning why areas were burned:

> They [Stl'atl'imx, or Lillooet] burned the [hills] so that they would get good crops there. They told others who went there "Do the same at your place, do the same at your place." Their own hills were just like a garden.

The practice of landscape burning, and the resulting enhancement of successional species, indicates that ecological succession was and is also recognized by aboriginal peoples (Turner et al. 2000:1279). Peacock (1998) does not list *B. sagittata* as one of the plants specifically burned to increase productivity, thus benefits to this species may have been coincidental. In Chapter 3 I summarize the range management literature that details how *B. sagittata* increases in abundance and size in burned areas and requires fire to release it from competition.

Digging is the primary means by which roots were extracted for use as food and medicine. Ford (1985) notes that digging or tilling softens soil and encourages the appearance or germination of certain species of plants. Other plant management techniques outlined by Ford (1985) and others (Peacock and Turner 2000) include tending, which encourages plant growth by means of weeding, pruning, and other methods to limit competition or to care for the plant

Ownership of harvesting sites was usually through individuals, families and village groups (Kuhnlein and Turner 1991; Turner 1997a). In the Interior Plateau ownership was mostly through communities and families. Ownership would ensure the proper management of an area and regulate harvesting times.

As has been outlined above, hunter-gatherers did more than passively adapt to the local environment. Based on Ford's model (1985) Peacock and Turner (2000) suggest that the Indigenous Peoples of the Plateau were essentially cultivators who managed and maintained plant resources to ensure a predictable, productive, and continued supply of culturally significant plant species. Through the use of these sophisticated strategies and disturbance regimes, Indigenous Peoples of British Columbia have domesticated their environment to a certain extent and, in doing so, helped to conserve genetic, specific, and structural biodiversity. The landscape that Europeans first encountered was not a 'pristine wilderness' but an actively managed landscape. As Peacock (1998:56) notes, "It was this mosaic of productive resource patches which became the 'natural' scenes Europeans first encountered and mistook for wilderness". Research by Peacock and Turner (2000) has done a great deal to dissolve the dichotomy between hunter-gatherer and agriculturist.

In this section I have presented documented evidence that aboriginal peoples of British Columbia's Interior Plateau have traditionally been active managers of their plant resources. In the next section I will place these resource management techniques in the larger context of TEK(W) and outline how they may be applicable to modern resource use.

The Study and Application of Traditional Ecological Knowledge and Wisdom

As indicated, Indigenous Peoples used a number of techniques to manage, sustain and potentially enhance resources. This knowledge, a part of a system of knowing called Traditional Ecological Knowledge and Wisdom (TEK and TEKW) is increasingly seen as having potential for contemporary resource management. In this section I will define TEK(W), review its emergence as a field of study and outline how it may contribute to resource management.

Traditional Ecological Knowledge and Wisdom, as a field of study, emerged about 20 years ago. A subfield of ethnobiology, TEK(W) research is conducted by an interdisciplinary group consisting of biologists, anthropologists, geographers, historians, ethnobotanists, linguists, archaeologists, paleobotanists and resource management specialists.

There is no universally accepted definition of TEK(W), however, that put forward by Fikret Berkes (1999b:8) is widely accepted and increasingly referred to. Berkes describes TEK(W) as:

> The cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission about the relationship of living beings (including humans) with one another and with their environment.

In a more detailed summary, Berkes adds "TEK is an attribute of societies with historical continuity in resource use practices; by and large, these are non-industrial or less technologically advanced societies, many of them indigenous or tribal" (1999a: 151).

The term TEK(W) is ambiguous since the words *traditional* and *ecological* are ambiguous. For many, *tradition* means old and unchanging (Lewis 1993). Societies, however, change over time and are constantly adopting new practices (Hunn 1993). Thus tradition does not mean an inflexible adherence to the past but rather time-tested and wise. Some scholars have chosen to refer to 'indigenous' instead of traditional but this eliminates ecological knowledge that may be held by non Indigenous Peoples (Johnson 1992). Difficulties with referring to *ecological knowledge* arise when ecology is narrowly defined as a branch of biology, in the domain of Western science (Berkes 1999). It is widely accepted that in TEK(W), ecological knowledge takes on a broader meaning to refer to the knowledge "however acquired, of relationships of living beings with one another and with their environment" (Berkes 1999:7).

In TEK(W), values and beliefs are important: not religion but use of emotionally powerful cultural symbols to encourage particular moral codes and management systems. Peacock and Turner write, "management decisions were not solely economic ones, but were embedded in social contexts and encoded in religious philosophies and oral traditions" (Peacock and Turner, 2000:133).

There are a number of events that reflect a growing awareness of the significance of traditional ecological knowledge. These events (Table A1) have lead to an increase in research relating to the application of Traditional Ecological Knowledge and Wisdom for resource management.

Table A1. Critical events: applications of TEK(W) for resource management.

- 1980 **American Association for the Advancement of Science,** San Francisco, California. Symposium, Resource Managers: North American and Australian Hunter-Gatherers
- 1987 **World Commission on Environment and Development** *Our Common Future,* Brundtland Report TEK/contemporary resource management concerns gradually recognized.
- 1989 **United Nations General Assembly**, San Jose, Costa Rica called for a global meeting that would devise strategies to halt and reverse effects of environmental degradation.
- 1991 **International Workshop on Indigenous Knowledge and Community Based Resource Management**, University of Manitoba, Winnipeg UNESCO Canada, Man and Biosphere Program Canadian Environmental Assessment Research Council
- 1991 **Common Property Conference**, University of Manitoba, Winnipeg International Program on Traditional Ecological Knowledge International Development Research Center (Canada) International Association for the Study of Common Property
- 1991 "Lost Tribes, Lost Knowledge," **Time Magazine** (Sept. 23) cover story. TEK becomes a media, certified public issue
- 1992 **Earth Summit**, Rio de Janeiro, Brazil United Nations Conference on the Environment and Development Agenda 21 -recognition of the contribution of Indigenous Peoples and their knowledge to the quest for a sustainable future.
- 1992 **International Institute for Sustainable Development** (established) University of Manitoba, Winnipeg.
- 1992 **Capturing Traditional Environmental Knowledge**, Workshop: Dene Cultural Institute, International Development and Resource Center, Hay River, Northwest Territories.
- 1998 **Bridging Traditional Ecological Knowledge and Ecosystem Science**, Flagstaff, Arizona
- 1998 **Indigenous Knowledge, Western Science and Environmental Conservation: Working Together in Collaborative Relationships,** Front Royal, Virginia Conference

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Represented in the events listed is the relatively recent emergence of an academic interest in the utilization of TEK(W) for resource management. Interest in TEK(W) has moved from predominately ideological to an increased awareness by the general public and recently to ground level concerns for application.

Scholars argue that this increase interest in TEK(W) is the result of a number of separate and overlapping factors. First, despite the measures taken, such as Canada's Indian Act, which determined to 'get rid of the Indian Problem', Indigenous People have survived (Trosper 1998). Through a system of incorporating Western features such as technology and religion, and adopting what is desirable, Indigenous People have subsisted. Paradoxically, aboriginals and researchers have perceived the continued loss of Indigenous knowledge alike. This has resulted in a massive movement to document traditional ecological knowledge. Ethnobotanist Dr. Nancy Turner (1997b: 275) articulately expresses the concerns of many:

> The loss of indigenous knowledge is a loss to all humanity. The wisdom and knowledge of Indigenous Peoples is needed now, more than ever, to help us develop more sustainable ways of living. Western science alone has not been successful in accomplishing this.

Failures in Western resource science (e.g. Canada's East and West Coast commercial fisheries) have resulted in conservationists and resource specialists looking elsewhere for management strategies (Berkes 1995). In relation to the latter reason, Native American leadership predicted that modern human manipulation of nature would lead to dangerous unintended consequences, and it has (Trosper 1998). Increasingly people want scientists to become more responsible for their actions, and native worldviews clearly bind knowledge and ethics (Trosper 1998). Next, an increased concern for sustainability has lead people to re-examine subsistence and to look for alternative examples of living (Trosper 1998). Finally, the rapid use of diminishing resources and the ease with which the world is becoming accessible, is bringing Westerners into more contact with Indigenous Peoples, such as those in the Amazon, that have been relatively unaltered by globalization. Related to the increase in contact, but not dependent on it, is the reduction in the chasm between indigenous knowledge and Western science (Berkes et al. 1998).

Coinciding, yet not directly as a result of an increased awareness of TEK(W), have been changes in perceptions and the importance of resource management in the Western world. These changes are not because of awareness in TEK(W) but are reflective of the same reasons that scholars are beginning to pursue TEK(W) as an alternative paradigm in resource management. Alvarez and Diemer (1998) summarize the perceptual shift in natural resource management in a series of what they term 'landmarks':

- **Landmark 1**: Resource Management for Fueling Growth; follows the industrial revolution; natural resources play an important role in determining competitive advantage of a nation in the industrial enterprise.
- **Landmark 2**: Resource Management for Growth, Rehabilitation and Future Generations; immediately following World War II; application of physical and social sciences to development-planning; ecological sciences are applied to conservation and development.
- **Landmark 3**: Resource Management for Sustainability: Technical/Growth Centered; during the period of oil spills in U.S. and Europe in 1960's and 1970's; current development and economic growth levels are unsustainable.
- **Landmark 4**: Resource Management for Environmental Improvement; associated with United Nations Conference on the Human Environment; operationalized and development planning that included resolving environmental and economic conflicts.
- **Landmark 5**: Resource Management for Sustainability: A People Centered Approach; global framework for ecology and conservation; collaborative governance of the earth's resources and commons.
- **Landmark 6**: Resource Management as Community Ecodevelopment for Sustainability: creation of the World Commission on Environment and Development, 1983; "humanity has the ability to make development sustainable-to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, cited in Alvarez and Diemer 1998:55).

From these landmarks, Alvarez and Diemer (1998:55) argue that an evolving pattern is revealed with regards to "the formal role of the lay person in resource management". The Western science resource management paradigm is moving "toward greater recognition of the human context in resource management" (Alvarez and Diemer 1998:55). Increasing pressure for a human context is resulting in the emergence of a new paradigm in resource management. In practice, resource management is still centered on maximum sustained yield; nevertheless, pressure is there for the dominant paradigm to change. The emerging new paradigm is not TEK(W), but it is increasingly parallel with concepts central to traditional ecological knowledge.

The processes that constitute the knowledge base in TEK(W) are as varied as Traditional Peoples and the ecosystems they inhabit. Predominant in the literature is fire. However, managing the landscape takes more than just fire. In relation to issues of scale and intensity, it is increasingly becoming apparent that the ecological management practices of hunter - gatherers can be studied to create theoretical models of human and resource interactions and ecological implications (Gadgil et al. 1997; Hughes 1983; Lewis 1993). The principles and practices of vegetative management, whether controlled through strategic ecological or economic courses of action via social controls and political maneuvering or by virtue of the power of symbol and ritual, resulted in higher production and quality of the plant and animal resources on which Traditional Peoples depended.

Table A2 outlines systems of land and resource management employed by traditional peoples.

Table A2. Indigenous horticultural methods and ecological effects.

Horticultural Method	*Ecological Effects*
· selective harvesting and replanting	· reduces intra-species competition; intentional dispersal of propagules
· digging and tilling	· incidental dispersal of propagules; local soil disturbances; recycles nutrients, aerates soil; increases moisture-holding ability; possible reduction of allelopaths
· tending and weeding	· reduces inter-species competition; soil modification
· sowing and transplanting	· replenishes population; dispersion of propagules to new habitats

· pruning and coppicing	· removes dead material reducing plant vigor stimulates vegetative reproduction and eventually flowering and fruiting
· landscape burning	· reduces competition; accelerates recycling of mineral nutrients; blackened ground encourages spring growth; selection for annual or ephemeral habit; synchronization of fruiting; maintains successional stages; creates opening

Source: Peacock 1998 (based on Ford 1985; Harris 1989).

Recent analysis by biogeographers confirms the influences of traditional peoples. That Indigenous People have altered the landscape is increasingly being recognized (Gadgil et al. 1997). Biotic distributions, which may have assumed to be purely natural, cannot be understood without appreciation of the cultural imprints on certain landscapes, even ones that appear to be pristine or uninhabited (Anderson 1993, 1996; Nabhan 1997).

The study of Traditional Ecological Knowledge and Wisdom has its beginnings in ethnobiology and thus begins with the referential naming of plants and animals. Hunn (1993:13) argues that there is a great deal more to be gained from the study of traditional societies and their resource management practices, "Once the referential meaning has been established a whole world of other cultural meanings is accessible to the student of that system of traditional ecological knowledge." Given the emergence of a new paradigm that has allowed for a bridge between TEK(W) and science, what are the types of information that can be acquired through the study of TEK(W)? Anderson (1999) suggests six sources of such information:

- biology of plant, fungi, and animal species;
- human uses of species;
- former abundance, densities and distribution of plant fungi and animal species;
- details of management regime;
- cultural purposes of management; and,
- quality and quantity of plant and material gathered.

This information can then be applied to the task of combining resource management and TEK(W) to meet the increasing imperative to effectively manage the earth's resources.

There is a need to move beyond the rhetoric and look at the ground level potential for practical applications of Traditional Ecological Knowledge and Wisdom. Awareness of the potential protocols and problems associated with incorporating TEK(W) into resource management is crucial. There has been a strong argument for the application of TEK(W) to conservation, co-management, applied ecology, adaptive management, and participatory management. Turner et al. (2000:1275) write "TEKW [wisdom] is acknowledged as having fundamental importance in the management of local resources, in the husbanding of the world's biodiversity, and in providing locally valid models for sustainable living." There are a number of situations that provide examples of where TEK(W) is successfully being applied.

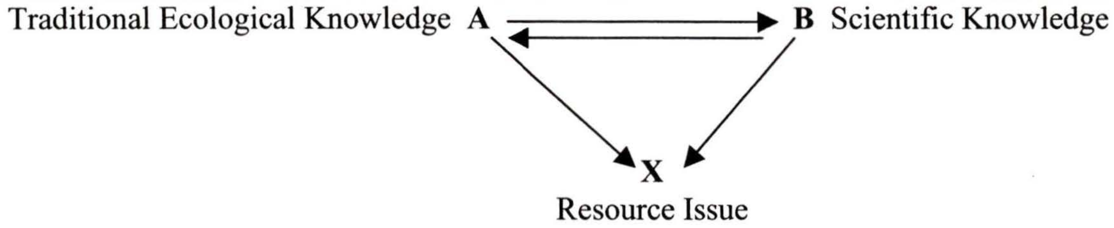
One highly valuable area in which TEK(W) has been utilized is in the collection of information on species and ecosystems for conservation purposes. New biological and ecological insights aid in the documentation and understanding of the complexity of ecosystems with relevance to science and ecology (Johnson 1992). Specific examples include Johannes' (1981) study on tropical fish taxonomy and management practices in the South Pacific and Nabhan's (1997) work with people in the southwestern United Sates and Mexico to document rare plants and the role that Indigenous People play in their protection. The pursuit of TEK(W) will contribute to a deeper understanding of the diverse ways in which humans interact with the landscape (Dwyer 1994). People who are dependent on the local resources for their livelihood are able to assess true costs and benefits of development and contribute this knowledge to environmental assessment (Johannes 1993).

Resource management has been expanded to include ecological restoration. Good restoration requires a broad view that includes historical, social, cultural, political, aesthetic, and moral aspects (Higgs 1997). Traditional Peoples frequently have detailed knowledge of succession and habitat preferences of different species (Gadgil et al. 1993). TEK(W) can assist in an understanding of what was there and contribute to ecosystem maintenance and restoration (Anderson 1993; Lewis 1993; Stevens 1999).

As well as information on species and habitats that can be used for restoration and conservation purposes, TEK(W) can be applied to resource management practices. Some wildland areas would benefit from the reintroduction of management and harvesting regimes that authentically mimic indigenous techniques (Anderson 1996). Since natural resources are also cultural resources, federal recognition of culturally important biological species is an essential first step in recognizing the relevance of co-management to ecosystem management (Martinez 1999). Information on areas such as wetlands, tropical forests, circumpolar regions and dryland, high altitude and coastal areas (Johnson 1992) as well as individual species such as caribou (Berkes 1999b) is relevant for contemporary resource management (Freeman 1993). As indicated, TEK(W) is based on detailed observations of the dynamics of the natural environment that includes feedback, learning, social system-ecological systems linkages, and resilience enhancing mechanisms that are akin to adaptive management (Berkes et al. 1998). TEK(W) can contribute to protected areas and conservation education where residents can continue traditional lifestyles through joint management (Gadgil et al. 1993; Johnson 1992; Mitchell 1997).

Based on the examples provided, TEK(W) can assist in species discovery, rare plant monitoring, environmental assessment, restoration, education, co-management and adaptive management. TEK(W) can provide qualitative knowledge, which parallels scientific knowledge and can even suggest new areas of research. The dominant resource management paradigms did not develop in an ideological vacuum, nor did they develop without scientific controversies (Berkes 1995). Similarly a new paradigm that allows for a bridge between scientific resource management and TEK(W) will develop out of debates such as those presented. The above management techniques are made feasible through the integration of two forms of knowledge: science and TEK(W). As illustrated in Figure A1 science is a necessary contribution to the systematic management of resources but it is not supreme. As for TEK(W), context is crucial. For example, fire is important but it is necessary to know where fire was used and when. In a rapidly changing world either system alone is inadequate.

Figure A1. Combining science and traditional ecological knowledge.



Specific issue in which both (A) and (B) share common interest, concern and collaborative approach to management of resources.

Source: Adapted from Alvarez and Diemer 1998.

For the purpose of resource management the diachronic observations predominant in TEK(W) can be of great value and can complement the synchronic observations which Western science is based. Furthermore, the resource management systems of indigenous people often have outcomes that are analogous to those desired by Western conservationists (Dwyer 1994). TEK(W) can complement scientific knowledge by providing practical experience in living within ecosystems and responding to ecosystem change. We are beginning to realize that two divergent paradigms can mesh and produce a better understanding and management of public lands in conjunction with traditional values (Housley and Hanes 1997).

In return Traditional Peoples can benefit from "a recognition and in some cases a verification of the significance of traditional beliefs and practices" (Lewis 1993:11). Warren, cited in Healey (1993:24) adds, "Traditional Ecological Knowledge can be employed to enhance local self-sufficiency, both in continuation of traditional subsistence strategies and for the development of market-oriented projects of carefully managed commercial exploitation of natural resources." In conclusion Hunn (1993:15) argues the validity of studying TEK(W),

> Systems of TEK provide alternatives to those of modern science; their value should be assessed impartially on the basis of a careful and comprehensive analysis. If we ignore these traditions on the assumptions that we already have all the answers we need, we will never know what more we might have learned.

As Hunn (1993) has stated, the value of TEK(W) is largely unrealized and the potential is great. Today the people of the Americas benefit from Traditional Ecological Knowledge and Wisdom in more ways than we are aware of. But the benefits of this knowledge were not complete when Europeans adapted foodstuffs such as the potato to their diet. There is still an immense amount of knowledge yet to benefit all of us.

Appendix 2

Declaration of Belem, 1998

Leading anthropologists, biologists, chemists, sociologists, and representatives of several indigenous populations met in Belem, Brazil, to discuss common concerns at the First International Congress of Ethnobiology and to found the International Society of Ethnobiology. Major concerns outlined by conference contributors were the study of the ways that indigenous and peasant populations uniquely perceive, utilize, and manage their natural resources and the development of programs that will guarantee the preservation of vital biological and cultural diversity. This declaration was articulated.

As ethnobiologists, we are alarmed that:

SINCE

- tropical forests and other fragile ecosystems are disappearing,
- many species, both plant and animal are threatened with extinction,
- indigenous cultures around the world are being disrupted and destroyed;

and GIVEN

- that economic, agricultural, and health conditions of people are dependent on these resources,
- that native peoples have been stewards of 99% of the world's genetic resources, and,
- that there is an inextricable link between cultural and biological diversity;

We, members of the International Society of Ethnobiology, strongly urge action as follows:

1) henceforth, a substantial proportion of development aid be devoted to efforts aimed at ethnobiological inventory, conservation, and management programs;

2) mechanisms be established by which indigenous specialists are recognized as proper authorities and are consulted in programs affecting them, their resources, and their environments;

3) all other inalienable human rights be recognized and guaranteed, including cultural and linguistic identity;

4) procedures be developed to compensate native peoples for the utilization of their knowledge and their biological resources;

5) educational programs be implemented to alert the global community to the value of ethnobiological knowledge for human well-being;

6) all medical programs include the recognition of and respect for traditional healers and the incorporation of traditional health practices that enhance the health status of these populations;

7) ethnobiologists make available the results of their research to the native peoples with whom they have worked, especially including dissemination in the native language;

8) exchange of information be promoted among indigenous and peasant peoples regarding conservation, management, and sustainable utilization of resources.

Source: Greaves (ed) 1994: *Intellectual Property Rights for Indigenous Peoples, A Sourcebook.*

Appendix 2

Plant Species Recorded in the *Balsamorhiza sagittata* Field Research Plots

Scientific Name	Common Name
Achillea milleforium	yarrow
Agoseris glauca	short beaked agoseris
Allium cernuum	nodding onion
Amelanchier alnifolia	saskatoon
Antennaria rosea	rosy pussytoes
Arabis holboellii	Holboell's rockcress
Arenaria capillaris	thread-leaved sandwort
Artemisia frigidia	pasture sage
Aster sp.	unknown aster species
Astragulus sp.	unknown vetch species
Balsamorhiza sagittata	arrow-leaved balsamroot
Bromus vulgaris	Columbia brome
Calamagrostis rubescens	pinegrass
Calochortus macrocarpus	sagebrush mariposa lily
Castilleja hispida	harsh paintbrush
Castilleja miniata	common red paintbrush
Cerastium arvense	field chickweed
Claytonia lanceolata	Western spring beauty
Collinsia parviflora	small-flowered blue-eyed Mary
Comandra umbellatum	pale comandra
Crepis intermedia	hawkweed
Delphinium nuttallium	upland larkspur
Dodecatheon pulchellum	few-flowered shooting star
Erigonum heracleoides	parsnip-flowered buckwheat
Erythronium grandiflorium	yellow glacier lily
Festuca idahoensis	Idaho fescue
Fritillaria lanceolata	chocolate lily
Fritillaria pudica	yellow bell
Geranium viscosissium	sticky geranium
Geum triflorum	old man's whiskers
Hedysarum boreale	northern sweet-vetch
Helianthella uniflora	
Heuchera cylindrica	round-leaved alumroot
Hydrophyllum capitatum	ballhead waterleaf
Lithospermum ruderale	lemonweed
Lomatium dissectum	fern-leaved desert-parsley
Lomatium macrocarpum	large-fruited desert-parsley
Lomatium nudicaule	barestem desert-parsley
Lomatium triternatum	narrow-leaved desert-parsley
Poa pratensis	Kentucky bluegrass

Polemonium micranthum	showy Jacob's-ladder
Populus tremuloides	trembling aspen
Potentilla glandulosa	sticky cinquefoil
Rhinanthes minor	yellow rattle
Rosa acicularis	prickly rose
Senecio canus	woolly groundsel
Senecio integerrimus	Western groundsel
Solidago multiradiata	Northern goldenrod
Taraxacum officinale	common dandelion
Tragopogon dubius	yellow salsify
Vicia americana	American vetch
Zigadenus venenosus	meadow death-camas

Appendix 4

Descriptive Statistics for Environmental Variables Field Data

	Pavilion Mountain Descriptives					Hat Creek Valley					Botanie Valley				
Variable	Mean	Min.	Max.	Std. Dtn.	Var.	Mean	Min.	Max.	Std. Dtn.	Var.	Mean	Min.	Max.	Std. Dtn.	Var.
% bare soil	8.4	0	40	9.54	90.938	35	10	60	12.53	156.9	10.97	0	30	8.46	71.62
% microcrust	6.8	0	35	8.39	70.37	0.9	0	1	0.31	0.09	0.23	0	5	0.94	0.87
% herbaceous	86.33	60	100	12.1	146.44	65	40	90	12.53	156.9	85.5	30	100	15.65	241.99
% shrubs	0	0	0	0	0	0	0	0	0	0	4.87	0	65	13.59	184.6
% native	51.3	25	85	14.69	215.87	56	25	80	13.03	169.66	93.5	25	100	17.92	320.95
% non-native	23.7	0	55	18.09	237.25	16	5	75	15.5	240.35	6.17	0	75	17.99	323.59
% unknown	24.67	0	60	21.77	474.02	27.83	0	60	16.38	268.42	0.33	0	5	1.27	1.61
total species	13	5	22	3.74	13.97	11	7	14	1.64	2.69	13	8	17	2.31	5.34
pH	6.56	6.2	7.1	0.22	0.49	6.75	6.4	7.1	0.19	0.36	6.34	5.6	7.2	0.38	0.14
soil moisture	29.3	12.13	42.56	6.46	41.76	26.88	19.31	38.64	4.23	17.88	21.76	15.65	42.93	5.87	34.43
depth litter (cm)	1.24	0.3	3	0.79	0.63	1.33	0.5	2	0.44	0.2	2.23	0.5	5.5	1.37	1.88
% litter	66.83	10	100	30.41	924.97	23.03	1	60	12.98	168.45	49.5	5	95	30.64	938.53
soil depth	40	40	40	0	0	39.77	34.75	40	0.99	1	34.88	9.25	40	7.57	57.25

Appendix 5

Descriptive Statistics for *Balsamorhiza sagittata* Variables Field Data

	Pavilion Mountain Descriptives					Hat Creek Valley					Botanie Valley				
Variable	Mean	Min.	Max.	Std. Dvtn.	Var.	Mean	Min.	Max.	Std. Dvtn.	Var.	Mean	Min.	Max.	Std. Dvtn.	Var.
# of *B. sagittata*	7.37	2	20	4.24	17.96	5.33	1	11	2.52	6.37	6.73	2	12	2.32	5.38
% *B. sagittata*	24.3	10	40	8.07	65.06	31.5	10	60	11.68	136.5	32.7	15	70	11.12	123.7
largest *B. sagittata*															
length largest leaf (cm)	15.5	9.5	25	3.66	13.4	17.5	12	26	3.23	10.43	20.5	12	31	4.3	18.51
width largest leaf (cm)	8.05	5	11	1.51	2.27	9.13	5.5	17	2.32	5.36	10.4	6	15	2.28	5.21
longest stem length (cm)	12.9	0	37.5	16.34	266.9	26.55	0	50	16.82	282.8	26.4	0	62	22.17	491.5
leaf number	27.3	4	56	13.99	195.5	38.57	16	68	14.6	213.2	28.8	4	64	15.01	225.3
height (cm)	32.5	18	42	6.88	47.29	38.73	28.5	55	7.26	52.75	44.5	17	67	12.06	145.4
flower number	0.97	0	7	1.65	2.72	2.2	0	14	2.95	8.72	1.23	0	6	1.57	2.46
bud number	1.17	0	6	2.05	4.21	2.57	0	8	2.78	7.7	4.67	0	16	4.51	20.3

Appendix 6

Results of Chi-square Analysis of Seed Germination and Seedling Survival Rates in the Greenhouse and Field

Balsamorhiza sagittata Seed Germination Number by Treatment Type:
Contingency Table and Chi-Square Test

			Treatment Type				
			soil no eth	soil eth	paper towel eth	paper towel eth / freezer	direct seed
# Germinated	no	Count	195	144	150	158	699
		Expected Count	168.3	168.3	168.3	168.3	673.0
		% of Total	12.2%	9.0%	9.4%	9.9%	43.7%
	yes	Count	5	56	50	42	101
		Expected Count	31.8	31.8	31.8	31.8	127.0
		% of Total	.3%	3.5%	3.1%	2.6%	6.3%
Total		Count	200	200	200	200	800
		Expected Count	200.0	200.0	200.0	200.0	800.0
		% of Total	12.5%	12.5%	12.5%	12.5%	50.0%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	71.538	4	.000
Likelihood Ratio	79.119	4	.000
Linear-by-Linear Association	.051	1	.822
N of Valid Cases	1600		

0 cells (.0%) have expected count less than 5. The minimum expected count is 31.75.

Balsamorhiza sagittata Seedling Survival in the Greenhouse by Treatment: Contingency Table and Chi-Square Test

			Treatment Type			
			soil no eth	soil eth	Paper towel eth	paper towel eth / freeze
# Survived Greenhouse	no	Count	2	24	16	13
		Expected Count	1.8	20.1	18.0	15.1
		% of Total	1.3%	15.7%	10.5%	8.5%
	yes	Count	3	32	34	29
		Expected Count	3.2	35.9	32.0	26.9
		% of Total	2.0%	20.9%	22.2%	19.0%
Total		Count	5	56	50	42
		Expected Count	5.0	56.0	50.0	42.0
		% of Total	3.3%	36.6%	32.7%	27.5%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	1.990	3	.574
Likelihood Ratio	1.979	3	.577
Linear-by-Linear Association	1.868	1	.172
N of Valid Cases	153		

2 cells (25.0%) have expected count less than 5. The minimum expected count is 1.80.

Balsamorhiza sagittata Seedlings that Survived to Senesce in Response to Field Treatments: Contingency Table and Chi-Square Test

			Treatment Type		
			direct seed	direct seed transplant	green house transplant
# Survived Field	no	Count	27	42	12
		Expected Count	28.8	26.1	26.1
		% of Total	18.1%	28.2%	8.1%
	yes	Count	26	6	36
		Expected Count	24.2	21.9	21.9
		% of Total	17.4%	4.0%	24.2%
Total		Count	53	48	48
		Expected Count	53.0	48.0	48.0
		% of Total	35.6%	32.2%	32.2%

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	38.175	2	.000
Likelihood Ratio	41.813	2	.000
Linear-by-Linear Association	5.989	1	.014
N of Valid Cases	149		

0 cells (.0%) have expected count less than 5. The minimum expected count is 21.91.

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Research Interests

The *in-situ* preservation and restoration of traditional systems of agriculture for food security and biodiversity conservation.

Traditional systems of land and resource management by Indigenous peoples and the integration of traditional ecological knowledge and western scientific perspective.

Education

2001	M.Sc., Interdisciplinary Studies, Geography / Environmental Studies University of Victoria, Victoria, British Columbia Title: Autecology, Ethnobotany and Agronomy of *Balsamorhiza sagittata*: Northwestern Plateau, British Columbia Thesis Committee: Dr Nancy Turner (School of Environmental Studies), Dr Peter Keller (Department of Geography), Dr Mike Edgell (Department of Geography), and Dr Pat Bowen (Agriculture and Agri-Food Canada).
1994	B.A. (Honours) Geography Queen's University, Kingston, Ontario Course concentration: cultural geography, geographic information systems, archaeology. Research focus: traditional ecological knowledge, Latin America, traditional systems of agriculture, crop origins and dispersals.
1995	*Conversational Spanish*, Utatlan Spanish School, Guatemala
1992	*Conversational French*, Algonquin College, Ottawa, Ontario

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Academic Experience

Teaching

2001 **Teaching Assistant**, School of Environmental Studies, University of Victoria, BC
Traditional Systems of Land and Resource Management ES 353
Teach lectures, grading, student mentoring.

2001 **Lab Instructor**, Department of Geography, University of Victoria, BC
Geography of Resource Management GEOG 350
Instruct labs on current resource issues and evaluate students.

2001 **Teaching Assistant**, Restoration of Natural Systems Program, University Victoria, BC
Principles and Concepts in Ecological Restoration ER 311
Assisted with instruction of course material and student evaluation.

2001- **Teaching Assistant**, Restoration of Natural Systems Program, University 1999 Victoria, BC
Field Study in Ecological Restoration ER 312A, and ER 312B
Assisted with course preparation, field school instruction and student evaluation.

2000 **Teaching Assistant**, Department of Geography, University of Victoria, BC
Aboriginal Peoples and Resource Stewardship GEOG 490
Coordinator and major instructor of one week field school.

2000 **Teaching Assistant**, School of Environmental Studies, University of Victoria, BC
Biodiversity and Conservation Biology ES 318
Assisted with course preparation, and student evaluation.

2000- **Teaching Assistant**, School of Environmental Studies, University of 1999 Victoria, BC
Plants and Human Cultures (Ethnobotany) ES 416
Assisted with course preparation, field trips and student evaluation.

1999 **Lab Instructor**, Department of Geography, University of Victoria, BC
Statistical Methods in Geography GEOG 321
Instruction of labs, and student evaluation.

1999 **Teaching Assistant**, School of Environmental Studies, University of Victoria, BC
Environmental Impact Assessment ES 410
Assisted with course preparation, and student evaluation.

Research

2001 **Inventory and Mapping**, Finnerty Gardens, University of Victoria, BC
Identify, research, record and map the ornamental gardens on campus.

1999 **Research Assistant**, Dr Nancy Turner, University of Victoria, BC
Research, organization of references, assist with development of Society of Ethnobiology web site.

1999 **Research Assistant**, Dr Nancy Turner, University of Victoria, BC
Assist with the research, development and writing of a large Social Sciences and Humanities Research Council of Canada grant. Grant approved Spring 2000.

1996 **Research Assistant**, Dr Terry Willard, Wild Rose College, Calgary, AB
Cultivation of herbal medicinal plants.

Internships

1998 **Ecological Restoration**, US Parks Service, The Presidio, San Francisco, CA
One year internship in ecological restoration of coastal ecosystems. Experiences included extensive outreach to the urban community, supervision of volunteers, experimentation in plant germination, mapping, plant monitoring, liaison to the Cultural Conservancy and organization of library.

1996 **Curriculum Development and Trail Maintenance**, Monteverde Cloud Forest Preserve, Monteverde, Costa Rica. One month resident internship. Duties included the development of educational materials and maintenance and construction of trails throughout the park.

Memberships

Society of Ethnobiology
Friends of Ecological Reserves
Victoria Natural History Society
Native Plant Society of British Columbia
Orion Society
University of Victoria Canoe Polo Club
University of Victoria Kayak Club

Publications and Presentations

Report

2000 **Commissioned Report** (refereed) Chambers, Kimberlee. The British Columbia Institute for Co-operative Studies, University of Victoria, Victoria, BC. 42 pages. Title: Assessing the Feasibility of Applying the Co-operative Model to First Nations Community Based Development Initiatives: A Case Study of the Xaxl'ep and a Native Plant Nursery.

1999 **Commissioned Report** (not refereed) Chambers, Kimberlee. Xaxl'ep First Nation, Lillooet, BC, 59 pages. Title: Applying ethnobotanical knowledge for sustainable economic practices. An analysis of native plant nurseries in the Pacific Northwest and plants in the Xaxl'ep ethnobotnay with horticulture potential.

Abstracts

2000 **Poster** Chambers, Kimberlee. 14th Annual Meeting, Society for Conservation Biology Conference, Missoula, MT. June 9 to 12. Title: Agronomic, Ecological and Ethnobotanical Aspects of *Balsamorhiza sagittata* (Pursh) Nutt. (Asteraceae).

2000 **Poster** Chambers, Kimberlee. 23rd Annual Conference, Society for Ethnobiology, Ann Arbor, MI. March 29 to April 1. Title: Past Uses and Future Potential of Arrow-leaved balsamroot.

Special Publications

2000 **Research Summary** Chambers, Kimberlee. *The Log*, Friends of Ecological Reserves Newsletter, Fall. Title: Past Uses and Future Potential of Arrow-leaved balsamroot.

Unpublished Colloquia Papers and Invited Lectures

2000 **Invited Speaker**, Aboriginal People and Agri-Food Conference, Vancouver, BC. Title: Propagation of Culturally Significant Plants for Traditional and New Uses.

2000 **Invited Speaker**, 16th Annual Meeting, BOTANY BC, Big Bar Ranch, BC, July 14 to 16. Title: Plants of Interior British Columbia: Traditional Uses and Contemporary Applications.

2000 **Guest Lecture**, Plants and Human Culture, ES 416 class, University of Victoria, BC. Title: Applied Ethnobotany: a case study of *Balsamorhiza sagittata* and the Xaxl'ep.

2000-1999 **Invited Speaker**, UVIC Speakers Bureau, Victoria, BC.
Numerous lectures throughout Victoria and surrounding area including, community groups, penitentiaries and seniors homes. Topics vary but focus on ethnobotany in British Columbia and conservation issues.

1999 **Invited Speaker**, Native Plant Study Group, Horticultural Society, Victoria, BC. Title: Ethnobotany in British Columbia and what it means for the future.

Workshop

2000 **Principle Organizer**, Xaxl'ep First Nation, Lillooet, BC
Develop and instruction of three day (June 19 to 21) workshop with Xaxl'ep and surrounding First Nations (over 30 participants). Instructors included Dr N. Turner and Dr S. Peacock. Materials covered encompassed ethnobotany, botanical field survey techniques, seed germination and propagation from cuttings, and pit cooking.

Academic Awards

Scholarships

2000	The Ethel N. Lohbrunner Bursary University of Victoria, BC	$575.00
1999-2000	Dean's Interdisciplinary Graduate Scholarship University of Victoria, BC	$5000.00
1999	Dean's Graduate Bursary University of Victoria, BC	$500.00
1999	The Derrick Sewell Graduate Scholarship Department of Geography, University of Victoria, BC	$2375.00

Research and Travel Grants

2001	Research Grant Global Forest, Vancouver, BC	$1700.00
2000	Research Grant for Field Work Friends of Ecological Reserves, Victoria, BC	$500.00
2000	Student Travel Grant Society for Conservation Biology	US$200.00
1999-2000	Graduate Student Travel Grant University of Victoria, BC	$1000.00
1999-2000	Graduate Teaching and Research Fellowship University of Victoria, BC	$6000.00

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