# Forest Ecosystem Classification

# in Manitoba:

# An Analysis of a GIS Alternative

By

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Submitted to the Faculty of Graduate Studies

in Partial Fulfillment of the Requirements for the Degree of

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# FOREST ECOSYSTEM CLASSIFICATION IN MANITOBA: AN ANALYSIS OF A GIS ALTERNATIVE

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**A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree**

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# ABSTRACT

The purpose of this study was to evaluate the systems available in Manitoba for forest inventory and ecosystem classification and to investigate the viability of linking the Manitoba Forest Resource Inventory (FRI) with the Forest Ecosystem Classification (FEC) for Manitoba using a GIS algorithm. The algorithm used information from the FRI to reinterpret an FEC vegetation type for each of the FRI tree stands (or polygons). The FRI is the standard forest inventory tool that is widely used in Manitoba, but primarily contains information that is useful to the forestry industry (such as timber volumes). The FEC is a classification system that contains more comprehensive information regarding the forest ecosystem but has not been mapped across Manitoba.

The algorithm did link the FEC vegetation type descriptions with the FRI polygons but only a weak agreement (16.03%) existed between the vegetation types derived by the algorithm and vegetation types classified on the ground in the field study.

The Common Understory Species that are listed in the FEC for each vegetation type identified in the study area were assessed for utility in classifying ecosystem types. The results indicated that Boreal forest species are common across a wide variety of forest ecosystem types in the study area and the species listed as "Common" in the FEC were not good indicators of FEC vegetation type.

The main conclusion from the study was that all of the options available in Manitoba for classifying forest ecosystems, including the FEC and FRI, do not fulfill the need for a spatially-broad, comprehensive, classification of forest ecosystems at the stand level.

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# INTRODUCTION

## Background

Forest inventories and ecosystem classifications are necessary and valuable tools to support sustainable forest management and ecosystem based management initiatives. Ecosystem classification provides the necessary framework for resource professionals to implement sustainable forest management strategies and practices. By recognizing that forests comprise more than trees, a broad range of values (ecological, social/cultural and economic) associated with forestlands can be integrated into management programs.

Several tools for classifying Manitoba's forests already exist; however, they are employed disparate from each other and/or they are not used to their maximum potential. The two main tools for forest classification in Manitoba currently include:

1. Forest Ecosystem Classification for Manitoba – Field Guide (Zoladeski *et al.*, 1995)
2. Manitoba Conservation (formerly Natural Resources) Forest Resources Inventory (FRI) (DNR, 1999).

The Forest Ecosystem Classification (FEC) for Manitoba (Zoladeski *et al.,* 1995) was developed as a field guide to assist in forest ecosystem classification at an operational scale (i.e. individual tree stands). The FEC is applicable to the commercial forest areas of Manitoba. Thirty-three vegetation types (V-Types) and twenty-two soil types (S-Types) can be identified with the field guide using defined criteria. Each classification includes management interpretations concerning silviculture and wildlife habitat. The FEC provides the scope of information needed for managing diverse forest resources and values; however, it has not been widely applied across the province as a forest management tool and its applicability has not been assessed to date. Limitations and shortcomings of the FEC exist because it was developed by "assembling and synthesizing information from various available sources" rather than using original data collected specifically for classifying Manitoba regions (Zoladeski *et al.*, 1995).

The traditional system for cataloguing Manitoba's forest information, the Manitoba Forest Resources Inventory (FRI), met the demands of the forestry industry through a map and information database of commercially important tree species. The map consists of tree stand polygons (areas) that are augmented by a five-digit code that describe items such as species composition and merchantability. The database also contains other information, such as site moisture regime and status of productivity. This system lacks additional forest information that would be useful in other forest management ventures such as wildlife habitat assessment, conservation initiatives, managing non-timber forest products and values, and conducting environmental impact assessments.

## Purpose and Objectives

The purpose of this study was to test an alternative option for classifying forest ecosystems in Manitoba by linking the broad FRI spatial information with the descriptive information of the FEC.

## Objectives

1. To review the options available in Manitoba for forest inventory and forest ecosystem classification.
2. To link the FEC V-Type descriptions to the FRI polygons using a GIS algorithm. The algorithm is a computer program that uses FRI information as input to reassign FEC V-Types to Manitoba's forest stands.
3. To assess how common the Common Understory Species of the Manitoba FEC V-Types are within the study site.
4. To make recommendations for improved ecosystem classification in Manitoba.

## Hypotheses

1. The FRI polygons and descriptions can be reinterpreted with an FEC V-Type that matches the V-Types classified in the field.

   Null Hypothesis: The FRI polygons and descriptions cannot be reinterpreted with an FEC V-Type that matches the V-Types classified in the field.
2. The understory vegetative species that were observed in tree stands classified as a certain V-Type are the same as the Common Understory Species listed in the FEC for that V-Type.

   Null Hypothesis: The understory vegetative species that were observed in tree stands classified as a certain V-Type are not the same as the Common Understory Species listed in the FEC for that V-Type.

## Methods

An overview of the methods used in this study is outlined below while a full description of the methods is provided in Chapter 3.

Following a literature review, a field study was conducted to identify the vegetative species and to classify forest ecosystems. An electronic database was then created for the data. The two main components of the thesis were then implemented as follows:

1. A new option for classifying forest ecosystems was implemented by linking the FRI and FEC systems using a GIS algorithm. The algorithm interpreted the FRI classifications and reassigned an FEC V-Type to the existing FRI tree stand boundaries (polygons). The algorithm-derived V-Types were then compared to the V-Types classified in the field to assess the agreement between the classification systems.
2. The Common Understory Species listed for each V-Type in the Manitoba FEC were assessed to determine their actual commonness in the field. The understory species that were observed in the field with each V-Type were compared to the Common Understory Species listed in the FEC for the same V-Types.

From the results of the two main components, recommendations were developed for improved forest ecosystem classification in Manitoba.

## Organization

This thesis is organized into six chapters. Following the Introduction, Chapter 2 reviews the related literature. In Chapter 3, the details of the methodology are provided, followed by the study results in Chapter 4. In Chapter 5, the results are interpreted and discussed in relation to the stated objectives. Lastly, the conclusions and recommendations are provided in Chapter 6.

*Chapter 2*

# ECOSYSTEM CLASSIFICATION AND FOREST INVENTORIES

## Introduction

This chapter presents a review of the related literature concerning ecosystem classification and forest inventories. Emphasis is given to current forest ecosystem classification theory, techniques and applications. Pertinent information gaps on this subject are discussed. In order to place this study in context, a variety of forest ecosystem classification systems are addressed and explored for applicability. As well, the tools used in these classification schemes are examined to provide a complete understanding of the current state of forest ecosystem classification in Manitoba.

## Theory of Ecosystem Classification

### Ecosystem Concept

Numerous interpretations for the term "ecosystem" have been recorded (e.g. Golley, 1993; Krebs, 1994; Sadar, 1994; KPMG, 1995; Treitz and Howarth, 1996) since Tansley first coined the word in 1935 as "living organisms interacting with each other and with their physical environment, usually described as an area for which it is meaningful to address these interrelationships" (*in* Sims *et al.,* 1996). In general, the concept of ecosystem has been commonly referred to as the biotic community interacting within its abiotic environment. The flexibility of the term "ecosystem" has allowed for many interpretations coinciding with many approaches and ideas of how and why to study these units of nature.

Rowe (1992, 1996) asserts "the concept of ecosystem...must be that of a real structural-functional volumetric system occupying a relatively fixed earth space". Specifically, he describes an ecosystem as "a real, three-dimensional chunk of life-giving space, a volumetric landscape or waterscape with everything that is in it from bacteria to spruce, from nematodes to elk, plus their matrix of air-water-soil – a segment of the Ecosphere in which organisms live and move and have their being" (Rowe, 1992). With this concept in mind, "ecosystem" becomes the fundamental unit of nature and life bearing entity for all organisms on earth. No organism can survive in isolation from its environment and therefore cannot be separated as such. In essence, an ecosystem is a finite living unit that has inputs and outputs, and experiences a specific set of responses and processes (Treitz and Howarth, 1996). The ecosystem is more profound than simply organisms plus environment; it is a whole system that can be successively dissected into integral and interacting ingredients. It is the ecosystem that is of paramount importance for continued survival on earth at any level and therefore is the natural unit for studying details pertaining to the environment.

Five main motives for ecosystem research are:

1. To gain holistic insight concerning the mechanics of our natural surroundings
2. To address the diversity of values placed on ecosystems
3. To establish a common ground for all resource users
4. To responsibly manage resources from an ecosystem-based management perspective

5. To effectively monitor and forecast the state of our resources.

Ecosystem research for the aforementioned purposes allows all interest groups to better evaluate their positions and actions pertaining to natural resources. More information and a better understanding of the processes and relationships that exist within our ecosystems will help resource managers and decision-makers operate at a consistently higher level than historically realized. Sustainability goals can become reality through the accurate capture and application of ecosystem oriented thinking (KPMG, 1995).

Forests and other landscapes have traditionally been studied from a reductionist perspective. That is, individual ecosystem components were approached in isolation from their abiotic and biotic relationships. However, it is essential that a more holistic approach be taken in order to understand ecosystems in the same manner in which they operate, from a systems perspective (Rowe, 1992).

Complementing the holism that ecosystem thinking provides, societal values and attitudes have evolved in a parallel fashion. Historically, natural resources were perceived as commodities for human consumption with minimal other functions. However, the paradigm is continually shifting to one of humility and consideration for natural resources (Natural Resources Canada, 1997; Treitz and Howarth, 1996). Ecosystem research aids the growing shift towards sustainability through a greater understanding of natural processes.

Another significant reason for studying ecosystems stems from the fact that they establish a common ground for all resource users (Rowe, 1992). Because the ecosystem is the fundamental unit of nature that contains all the elements of the environment, it becomes a natural focus of study crossing many disciplines. The versatility and functionality of using the ecosystem as a basis for study in several fields is apparent in hydrology, forestry, and wildlife management, to name a few. Instead of each discipline devising its own unit of study that operates in isolation, ecosystems provide the ability to compare and manage resources across disciplines.

An ecosystem-based management perspective has been thoroughly described with respect to Manitoba in *Manitoba's Forest Plan...*(KPMG, 1995). By adopting this format for management, the ecosystem becomes the priority figure, which theoretically should equate to responsibly managed natural resources.

However, as Kay and Schneider (1994) discuss, the ecosystem based management concept is not easily put into practice. This difficulty results from a significant lack of knowledge concerning ecosystem processes and cycles. As Rowe (1992) exclaims "We do not understand ecosystems because we cannot understand the 4.6 billion-year-old world of which they are parts". Therefore, it is essential that we continue to study ecosystems and implement adaptive resource management to improve our ecosystem based management skills, as well as our knowledge base.

To truly know and understand the state of our ecosystems will undoubtedly provide a means to better manage our resources. Since nature operates as nested systems, the overall health and integrity of the ecosystem unit can reveal information concerning the state of its constituent resources. By understanding and maintaining the integrity of our ecosystems, individual resources can be monitored and forecasted, which are necessary for sustainability (Rowe, 1996).

Ecosystem integrity is the common denominator that is necessary for sustainability of all sectors. Ecosystem integrity means a healthy, functioning ecosystem that allows its constituent organisms to survive in their niche. Ecosystem integrity is centrally important for maintaining a healthy environment, economy and society.

## Principles of Ecosystem Classification

"Before people can be non-destructive custodians of forest ecosystems they must have at least minimal ecological understanding in the form of a classification of forestland" (Rowe, 1996). As Rowe has proclaimed, forest classifications have a very important duty, which help to manage forest ecosystems and more importantly the actions of people. Therefore, to govern our own actions in a more sustainable fashion, ecosystem classifications provide a starting point from which to base our knowledge.

The two main purposes of classification are to:

1. Establish similar and dissimilar regions of the earth
2. To use this information to heighten our knowledge of the classified phenomena by means of having more manageable and related units to study (Rowe and Sheard, 1981).

As basic as these concepts may seem, classifying the earth's surface is a very complex and involved process. Not only are the systems of the earth poorly understood but also subjectivity arises in determining which constituents are categorically important. Therefore, every classification system beholds a purposive nature and no single format can act as a universal answer to all classifications. However, the classification system that uses the ecosystem as a fundamental unit is more versatile and applicable than other systems that employ a narrow scope and function.

Three important elements of ecosystem classification are scale, boundaries, and time. These elements must be understood for a user to effectively classify ecosystems, as intended.

### *Scale*

Scale is an important factor in ecosystem classifications yet it is precarious and can be difficult to define appropriately. Ecosystems exist at various scales from the entire biosphere through continual "nestings" down to microorganism levels.

Bailey (1996a, 1996b) has explored the significance of mapping ecosystems at various scales and the consequences this has on relationships between ecosystems. Several scales are apparent in the landscape and fit into the broad categories of microscale (homogeneous sites), mesoscale (landscape mosaics), and macroscale (large connected systems of mosaics) (Bailey, 1996a). The scale of a particular classification scheme is dependent on the purpose of the scheme. Obviously, to analyze global climates one would not use scales equal to tree stands.

To aid in the determination of an appropriate scale for study one can use natural phenomena for assistance. Factors such as climate, watersheds, and landforms all have their place in distinguishing the level of resolution. Toman and Ashton (1996) explain that three scales can accommodate ecosystem processes appropriate for forest management. They are forest stands, watersheds, and physiographic regions. These examples reveal that the purposive nature of classification systems will define the appropriate criteria for classification.

### *Boundaries*

Boundaries for ecosystem delineation are related to scale, as "boundaries reflect ecosystem pattern, as well as population processes and patterns" (Sims *et al.*, 1996).

Although boundaries may be difficult to delineate and can be a consequence of the subjectivity of the classifier, they cannot be arbitrarily laid out. Classifications must be functional and as such, must possess fundamental criteria for operation. That is, items such as boundaries, scale, and indicator components must be clearly defined.

Toman and Ashton (1996) proclaim that ecosystems are boundary-less due to the "continuum of ecosystem interactions that can be scaled up or down depending on the spatial focus of observation". However, Bailey (1996a) argues, "permanent boundaries can be identified which allow ecosystems to be recognized regardless of condition". Factors such as climate, landform patterns and local topography operate hierarchically to determine these boundaries. Sims *et al.* (1996) agree that ecosystems necessarily contain boundaries, " Whole or complete ecosystems are those whose boundaries reflect ecosystem pattern, as well as population processes and patterns".

Establishing ecosystem limits can be a difficult process, as many factors are involved that are constantly changing and interacting. However, the whole notion of an ecosystem "must be that of a real structural-functional volumetric system occupying a relatively fixed earth space" (Rowe, 1996). Without boundaries, ecosystem classification and delineation become impossible.

### *Time*

Although natural resource managers and other interest groups speak of ecosystems as concrete entities, they are always in a state of flux. Diverse processes and cycles of inputs and outputs are constantly engaged. This process of ecosystem evolution through time resulting in the "gradual supplanting of one community of plants by another" is known as succession (Natural Resources Canada, 1997). Different seral stages represent the phases along the gradient from a young ecosystem to a mature or stable one. The temporal factor that creates the dynamic nature of ecosystems also contributes to the continuous requirement for more and updated information. Human disturbances in addition to natural evolution contribute to ecosystem changes over time.

Kay and Schneider (1994) have addressed the factor of time as it relates to ecosystems and have concluded that chaotic and dramatic disturbances are natural phenomena that propel ecosystem evolution. As expected, ecosystem behavior inherently possesses an element of unpredictability and no matter how well understood it can never be truly anticipated.

The elements of an ecosystem do have a degree of consistency that is driven by natural forces such as climate, landform, and life history. For example, the boreal forest is characterized by certain communities of species, which evolve through various seral stages. Therefore, ecosystem classifications document a long history of landscape events. As such, a detailed ecosystem classification is only truly relevant at the time of the survey.

The principles of ecosystem classification involve appropriate criteria for which to base the classification system, along with an understanding that ecosystems are fundamental life units. A definition of scale, boundaries, time, and indicator components of the ecosystems under study are essential for classification.

## Frameworks for Classifying Forests and Forest Ecosystems

Numerous frameworks for forest and forest ecosystem classification have been developed across Canada ranging from a national level to a tree stand level. Several authors have provided a précis of these efforts but none have been devoted to the current situation relative to Manitoba (e.g. Bailey *et al.*, 1985; Sims and Rowe, 1992; Sims and Uhlig, 1992; Treitz and Howarth, 1996).

The variety in classification approaches stems from the purposive nature of each classification system, which are all based on different objectives. These alternative methods will be explored from two main perspectives:

1. Those pertaining to landscape level schemes (which includes systems that operate in a hierarchical manner from small scale to large scale delineations);
2. Those pertaining to stand level schemes.

In this manner, a better understanding will be gained concerning the evolution of forest ecosystem classifications through time and space. Information gaps will also be identified. This synopsis of available ecosystem classification mechanisms will then set the context for and establish the relevance of this research.

## Landscape Level

### *Forest Classification for Canada*

The first national framework for forest classification was devised by Halliday as the Forest Classification for Canada (1937). This strategy operated as a geographic description of the Canadian forests by outlining their area distribution. The eight Forest Regions were further divided into Forest Sections, "a geographical distinction based on broad uniformity of association, which is the result of topography, soil, bed-rock, and local climate" (Halliday, 1937).

Halliday's system was pioneering and it served as a basic resource for forest descriptions. As Rowe (1959) discovered, Halliday's efforts were somewhat vague and in need of refinement. Halliday recognized the weaknesses of his work and proclaimed that criticisms and revisions were expected (1937).

At the time of Halliday's work (1937), the paradigm of approaching forests from a holistic perspective was not yet in vogue and timber extraction was still seen as the predominant value in Canadian forests (Sims *et al.*, 1996; McCarthy, 1997). This was also the time during the forest practices era labeled "Conservation" by Natural Resources Canada (1997). This period persisted from the late 19th to mid 20th century. It emerged from the growing concern among citizens that North American forests were inadequately protected – from fires, as well as the increasing scale of industrial demands.

Depletions of the resource base were beginning to be recognized and the paradigm changed from one of exploitation to that of conservation and management. Several significant conservation actions were taken including:

- Creation of forest reserves,
- Establishment of forest fire protection agencies,
- Initiation of reforestation programs,
- Prohibition of wasteful harvesting practices,
- Allocation of area-based, long-term tenures (Hardy, 1997; Natural Resources Canada, 1997).

With these programs in place, the forests of Canada were gaining protection. A structured management framework was emerging; however, a reductionist philosophy was still prominent. This perspective lacked the understanding of a "system view" (Senge, 1990) of the environment and therefore did not incorporate whole ecosystems into the management regime. This is apparent in Halliday's narrow scope of Canadian forests, which only addresses the composition of trees. Forest management was isolated to mainly timber with the balance of forest values being neglected as important resources (McCarthy, 1997). Halliday's work would be the precursor for a long legacy of forest classifications, which was next approached by the efforts of Rowe (1959, 1972).

### *Forest Regions of Canada*

Perhaps the most widely quoted and applied classification of Canada's forests is Rowe's (1972) Forest Regions of Canada. This work evolved as a revised and more robust perspective of Halliday's (1937) Forest Classification for Canada.

Rowe's initial update to Halliday's work appeared in his 1959 edition of the Forest Regions of Canada. In this publication, he maintained Halliday's (1937) framework of eight Forest Regions further divided into Forest Sections. New innovations were introduced including more refined boundary delineations, additional Forest Sections, and a description of the Newfoundland Boreal Forest.

At this time, Rowe (1959) also redefined the Forest Region "as a major geographic belt or zone, characterized vegetationally by a broad uniformity both in physiognomy [*general appearance of a landscape*] and in the composition of the dominant tree species". In this sense, a Forest Region was more uniformly delineated as more specific criteria were being applied to the landscape than simply the prevalence of climax formations.

In 1972, Rowe published an updated version of the 1959 edition of Forest Regions of Canada. This effort remained relatively consistent with his original work, as the Forest Regions map was unchanged. Increased ecological knowledge permitted inaccuracy corrections, refined area descriptions, and taxonomic additions. As well, supplemental maps and data concerning Canadian soils, geology, and climate were appended. Figure 1 illustrates Rowe's interpretation of Canada's forests as it is portrayed in his 1972 publication.

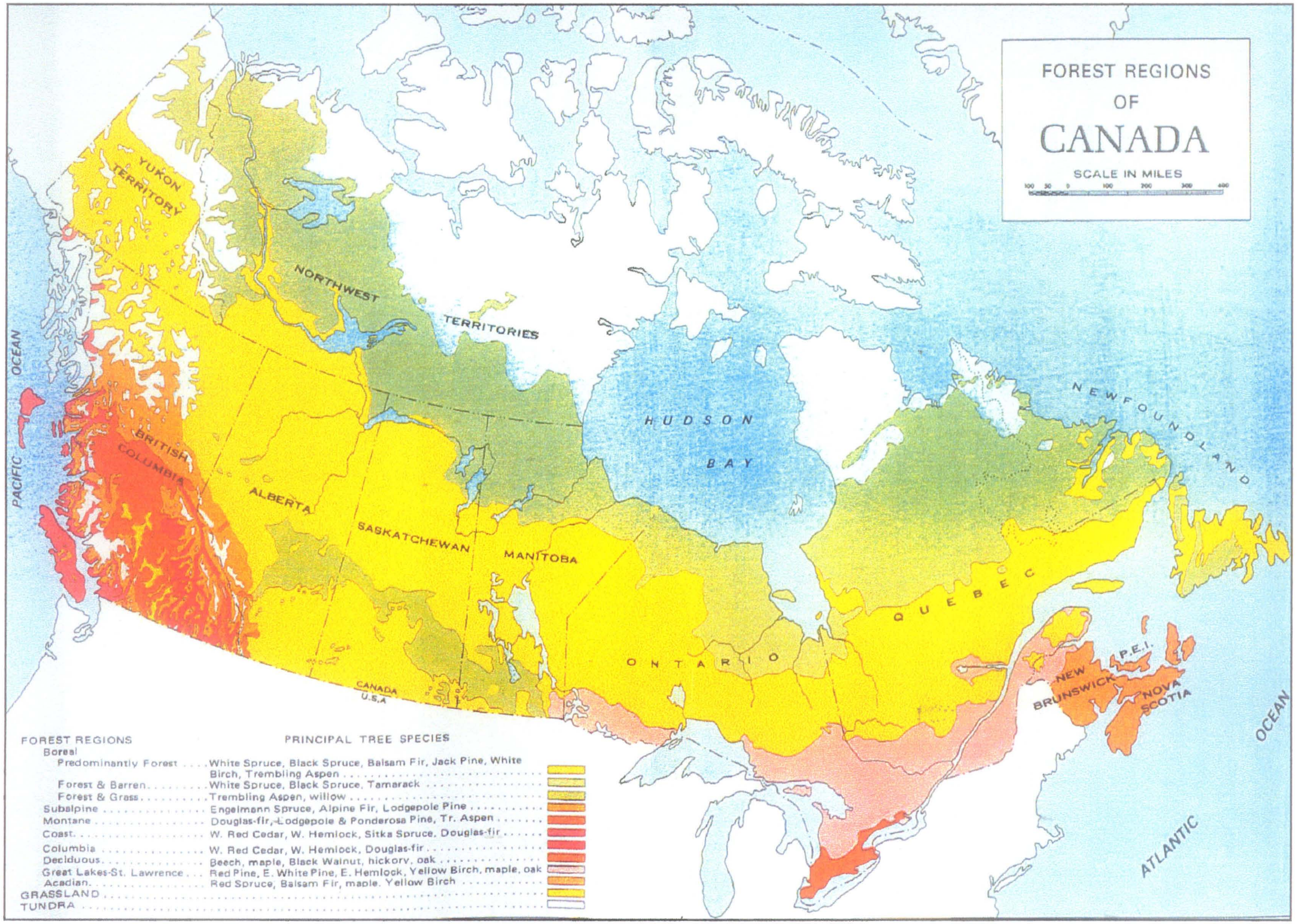



Figure 1. Rowe's Forest Regions of Canada ( Rowe, 1972)

Rowe's (1959, 1972) formats for forest categorization matured during the fourth generation of forestry ("Timber Management") when the importance of a sustained-yield became apparent in Canada (Natural Resources Canada, 1997). From the mid 20th century to the 1980's forest inventories had shown that previous efforts to control logging in the form of licenses were failing to support sustainable extractions. Depletion of the forest resource was increasing so industry incentives were launched to encourage sustained yield practices.

Various forestry committees were also created including the Association of British Columbia Professional Foresters, Canadian Council of Resource and Environment Ministers, and Canadian Council of Forest Ministers. The role of these groups was to develop different strategies for addressing forestry issues such as forest renewal and resource depletion. Long-term goals with specific strategies were developed to work towards sustainability.

Perhaps the most important element of this era was a realization of multiple forest uses and functions rather than industrial yields. Forest values other than timber were emerging as a growing public awareness forced traditional forest management into new directions (Natural Resources Canada, 1997). A holistic, inclusive perspective of the forest and its components superceded the historical view and was being translated in the form of intense forest management.

### *Canada Land Inventory*

Another landscape level classification framework that emerged in Canada was that of the Canada Land Inventory (CLI) which was initiated in 1963 as a federal-provincial agreement under the Agricultural Rehabilitation and Development Act (Environment Canada, 1978; Rees, 1977). The Inventory evolved from the observation of "increasing regional economic disparity, wide-spread improper land use, and a variety of emerging resource and land-use conflicts in all of the provinces" (Rees, 1977). Consequently, the impetus behind the CLI was that of a first step to ameliorate and facilitate the aforementioned tribulations in the form of a comprehensive land use and capability inventory.

Unlike Halliday's (1937) and Rowe's (1959, 1972) narrow scope of classification, the CLI responds to a variety of fields and disciplines. Land capability for agriculture, forestry, recreation, and wildlife were the main categories for classification. However, rather than developing a single system from which to infer information about these disciplines, the CLI adopted individual classification techniques concerning each field of study. Therefore, the CLI is not as holistic as it may initially appear. As explained by Treitz and Howarth (1996) " since it did not treat the various components within an integrated framework, it was not a true ecological classification". The classification system includes four fields:

1. Soil survey data for agriculture feasibility;
2. Mean annual increment per acre for forestry capability;
3. "Quantity of recreation-land-use which may be generated and sustained per unit area of land per year, under perfect conditions" (Environment Canada, 1978) for suitability of recreation
4. Physical land characteristics, meteorological and other influencing factors for wildlife production.

Each one of the categories of this system employed specific methods and experts for classification. The Inventory is mapped at scales of 1:250 000, 1:125 000 and 1:50 000. Figure 2 illustrates the national extent of the CLI. Areas outside the CLI boundary were covered by different land inventories such as the Alberta land Inventory (Natural Resources Canada, 2000).

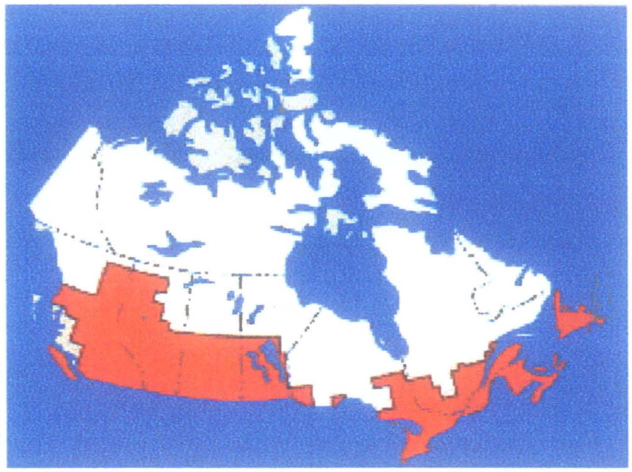


Figure 2. National Coverage of the Canada Land Inventory (Natural Resources Canada, 2000)

The extent of the CLI ranges across Canada but only covers "settled portions of rural Canada and adjoining areas which affect the income and employment opportunities of rural residents" (Environment Canada, 1978). The quality of the framework is directly related to the initial intention of the CLI – to serve as a tool to address the social turmoil concerning land use. As such, the Inventory provides reconnaissance type information for municipal, provincial, and federal land development planning. It was not intended for management purposes of land and resources and therefore does not provide detailed information about the selected candidate sectors.

The CLI was augmented in scope not long after its commencement, as it was apparent that the biological and physical (geoclimatic) features of the land needed to be classified as well (Rees, 1977). This system was intended to serve as the "ecological basis for capability rating for future management of land for agriculture, forestry, recreation, wildlife, and water yields" (Rees, 1977). With this approach, it was recognized that the inventoried ecological features could serve as an overall guide for many of the land use capability ratings that were previously approached on an individual basis. The main advantage of this format was that it was relatively "value-free" and less influenced by oscillating social and economic conditions (Rees, 1977).

One characteristic that makes the CLI a unique and pioneering endeavor is that it engaged the first geographic information system ever built (DeMers, 1997). During the initiation of the CLI in the early 1960's GIS technology was still embryonic and confined in distribution. The keen foresight of the CLI planners recognized the need for a more efficient method to manage the abundance of information concerning Canada's landmass. As such, the Canada Geographic Information System became a fundamental tool of the Inventory and was finally operational in 1972. Its primary purpose was to accept, store, manipulate, and display data from both maps and database tables of each of the sectors (Rees, 1977). Although these functions are commonplace in modern geographic information systems, at the time they were groundbreaking innovations.

The Canada Land Inventory met the objectives for which it was designed; to collect information concerning various land uses to aid in future planning. However, because of this narrow scope, it cannot be readily applied for alternative uses. The onset of the biophysical land classification program relieved this issue somewhat but it was restricted to certain areas and contained scattered information.

### *CCELC Framework*

In 1976 the Canada Committee on Ecological Land Classification (CCELC) was created, which prompted the hierarchical classification system that was later modified and known as the National Ecological Framework for Canada (Ironside, 1989). "The objective of the approach is to delineate, classify, and describe ecologically distinct areas of the earth's surface using various abiotic and biotic factors at each of the levels" (ESWG, 1995). In essence, the CCELC framework was the first attempt to actually classify whole ecosystems rather than individual landform constituents. This strategy follows the "ecosystem based management" philosophy where the objective is sustainability of all elements of the forest in a holistic, connected, systemic process.

This type of framework emerged as a response to the increasing popularity of the ecosystem approach. It was the foundation for the most recent stage of forest management in Canada, Sustainable Forest Management. "Sustainable Forest Management" (Natural Resources Canada, 1997) progressed from a "sustained-yield" idea to one that compromises between conserving resources while accommodating world development. Its philosophy is rooted in the notion that correct and responsible harvesting of resources can continue to provide the world with needed natural capital (Berkes, 1996).

The CCELC framework is composed of a nested hierarchy of progressively finer ecosystem divisions. Seven classification levels theoretically exist: ecozone, ecoprovince, ecoregion, ecodistrict, ecosection, ecosite, and ecoelement, ranging from broad to finer landscape scales. Not all levels have been delineated throughout all areas of Canada. These ecosystem delineations were established through "spatial differences in a combination of landscape characteristics" by a range of stakeholders (ESWG, 1995).

The system operates in a broad manner that encompasses five fundamental components: terrain, hydrology, climate, flora, and fauna (Bajzak and Roberts, 1996). A summary and comparison of the various classification levels are found in Table 1.

| Table 1<br>The Hierarchical Levels of the<br>National Ecological Framework for Canada | | |
|---|---|---|
| **Level** | **Description** | **Common Map Scale** |
| **ECOZONE** | Areas of large land masses representing very generalized ecological units, based on the consideration that the earth's surface is interactive and continuously adjusting to the mix of biotic and abiotic factors that may be present at any given time (e.g. Boreal Shield) | 1:50 000 000<br>to<br>1:10 000 000 |
| **ECOPROVINCE** | Areas of the earth's surface characterized by major structural or surface forms, faunal realms, vegetation, hydrology, soil, and climatic zones (e.g. Island of Newfoundland) | 1:10 000 000<br>to<br>1:5 000 000 |
| **ECOREGION** | A part of an ecoprovince characterized by distinctive ecological responses to climate as expressed by vegetation, soil, water, and fauna (e.g. Northern Peninsula Lowland) | 1:3 000 000<br>to<br>1:1 000 000 |
| **ECODISTRICT** | A part of an ecoregion characterized by a distinctive pattern of relief, geology, geomorphology, vegetation, water, and fauna. | 1:500 000<br>to<br>1:125 000 |
| **ECOSECTION** | A part of an ecodistrict throughout which there is a recurring pattern of terrain, soil, vegetation, water bodies, and fauna. | 1:250 000<br>to<br>1:50 000 |
| **ECOSITE** | A part of an ecosection having a relatively uniform parent material, soil, hydrology, and chronosequence of vegetation. | 1:50 000<br>to<br>1:10 000 |
| **ECOELEMENT** | A part of an ecosite displaying uniform soil, topographical, vegetative and hydrological characteristics. | 1:10 000<br>to<br>1:2 500 |
| source: Bajzak and Roberts, 1996 | | |

Federal, provincial, and territorial governments, environmental interest groups, and the private sector were recruited to contribute the most comprehensive knowledge and techniques to provide "seamless national coverage at each level" (ESWG, 1995). However, the various levels have only been defined and fulfilled as required to meet various planning and management needs.

The resulting identification of fifteen ecozones of Canada were first defined by Wiken (1986) to meet reporting requirements of the first State of the Environment Report for Canada in 1986. Wiken's original work only included terrestrial ecozones but five marine ecozones were later added (Wiken, 1999). The criteria employed to define ecozones respond to broad common characteristics such as major vegetation types, large physiographic divisions, and soil orders (CCEA, 1996; Wiken, 1999). Figure 3 depicts Canada's terrestrial ecozones.

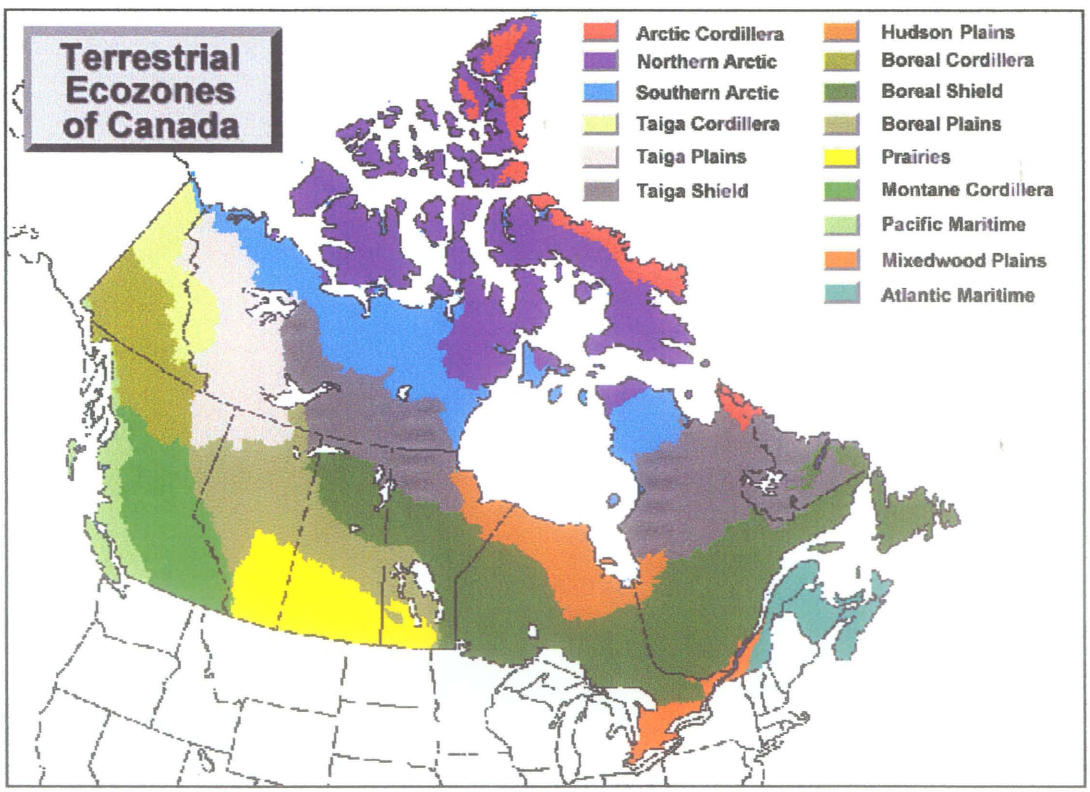



Figure 3. Terrestrial Ecozones of Canada (Environment Canada, 1999a)

Canada's ecoregions have been delineated on a per province basis resulting in 194 categories based on prominent biophysical or physiographic features (ESWG, 1995). Figure 4 illustrates an example of the Boreal Shield Ecozone divided into ecoregions.

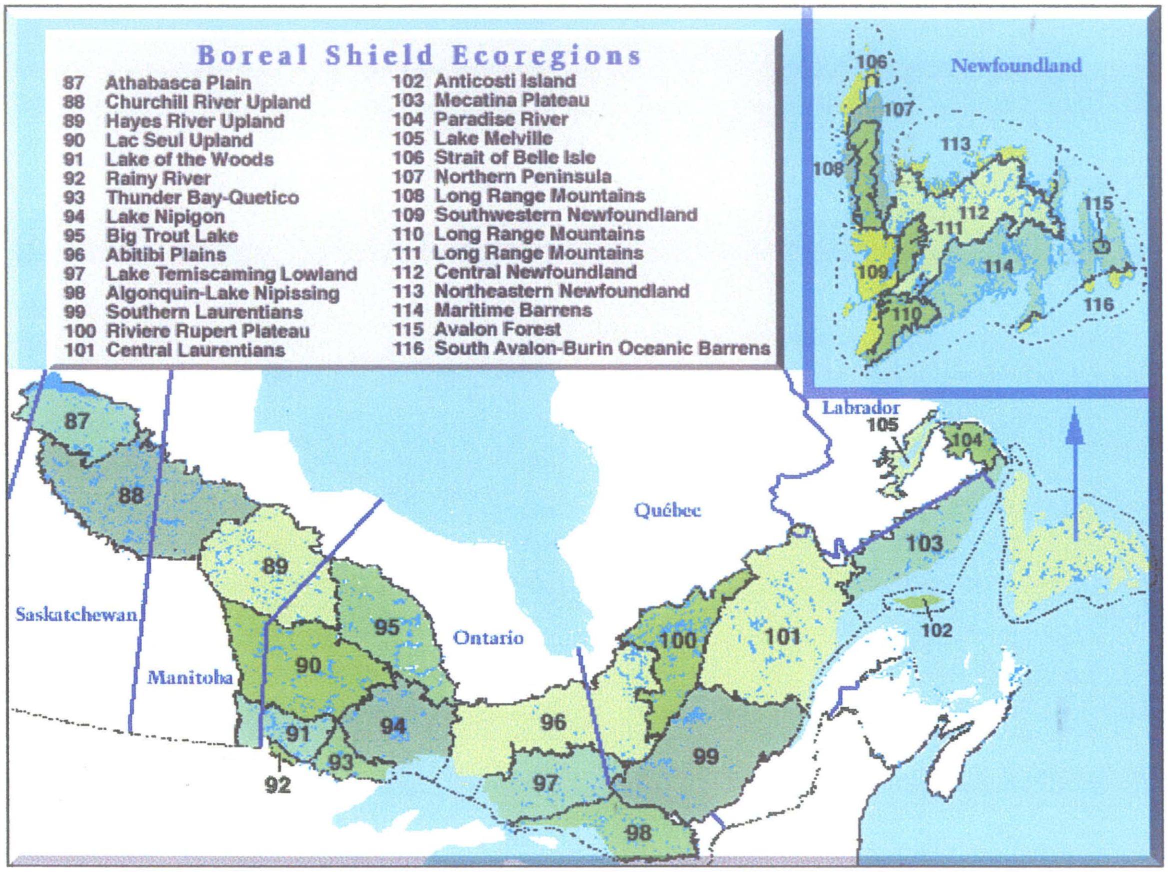



Figure 4. Boreal Shield Ecoregions (Environment Canada, 1999b)

The last level of the CCELC hierarchy that was described in the National Ecological Framework for Canada is the ecodistrict. This grouping is characterized by landform, relief, surficial geologic material, soil, water bodies, vegetation, and land uses. The main applications of the ecodistrict have been related to land evaluation and modeling purposes as apparent in the agroecological resource area (ESWG, 1995).

Further divisions (ecosection, ecosite, ecoelement) of the CCELC framework have been scattered in coverage across the country and employed only in specific and localized areas. These levels of classification become progressively finer in scale and approach forest stand level status; therefore, more widespread and comprehensive programs relative to each province have been employed, such as provincial forest resource inventories.

The CCELC framework provides a comprehensive, holistic evaluation of Canada's ecosystems whose merits are apparent in three notable characteristics:

- It follows natural ecological boundaries of the landscape;
- It acknowledges the importance of the diversity of scales found in ecosystems as expressed through the nested hierarchy; and
- Its scope is holistic in detail so that the framework may be applied and compared across a variety of disciplines.

These traits result in a tool that is indispensable in the natural resources arena; however, the full potential of this system has not yet been realized. Incomplete coverage of the full hierarchy across Canada, especially at finer scales, is responsible for less than unanimous devotion to the framework. With respect to Manitoba, minimal progress has been made in characterizing the landscape using the finer divisions of the CCELC tool. However, ecosite development for the province has begun but is still in the primary stages (Baydack *et al.*, 2002). To fill in this data gap, other systems, such as the provincial FRI, have been used.

Several other ecological land classification methods have stemmed from the original concept of the CCELC. A synopsis of these efforts has been compiled by Ironside (1989) in the Canada Committee on Ecological Land Classification Achievements

(1976-1989) and Long-Term Plan. More specialized classifications are apparent in these subsequent endeavors such as The Canadian Vegetation Classification System (Strong *et al.,* 1990) and the Ecoclimatic Regions of Canada (Ecoregions Working Group, 1989). However, the original goals and concept behind the CCELC undertakings remained constant throughout these works.

### *Canada's Forest Inventory*

Canada's Forest Inventory (CanFI) was developed as a joint federal, provincial and territorial effort with the very specific intention to evaluate the forest resource for all levels of management planning. It is devoted to timber management through a culmination of surveys to "determine the volume, location, extent, condition, composition, and structure of the forest resource" (Gillis and Leckie, 1996; Leckie and Gillis, 1995). These surveys are conducted provincially in the commercial forest regions across the country, with each province using similar but tailored methods (Gillis and Leckie, 1993). The localized surveys are performed on map scales between 1:10 000 and 1:20 000 which are updated in ten to twenty year cycles. These high resolution surveys are then amalgamated and analyzed in the national inventory. The accumulated information of the Canada Forest Inventory and other sources can be found in the Compendium of Canadian Forestry Statistics (CCFM, 1997).

Rowe's Forest Regions (1972) are the basic units of the Canada Forest Inventory. The forest regions across the country are updated with provincially collected, quantitative forest information concerning area and composition (Gray, 1995). Since the efforts of this system are divided provincially, the inventory has a very extensive area of coverage that can be seen in Figure 5.

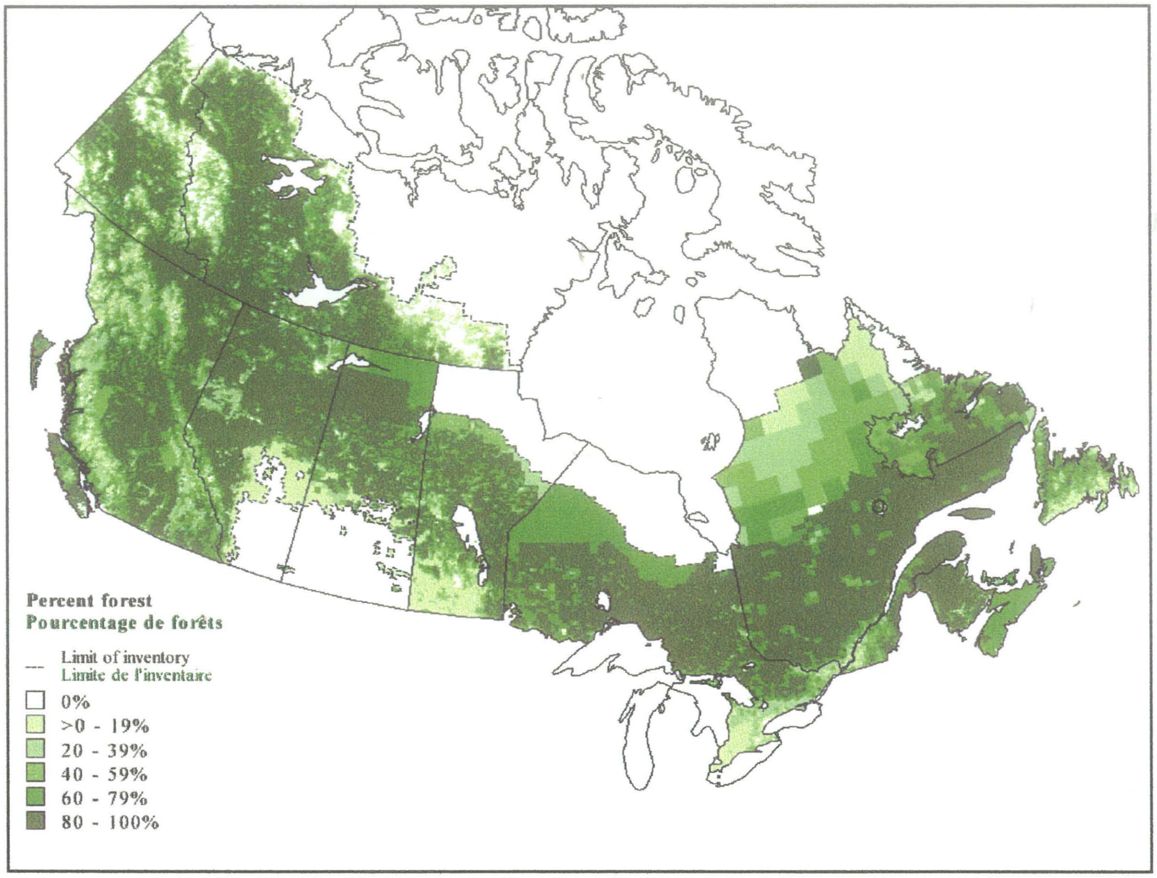



Figure 5. Coverage of Canada's Forest Inventory (Canadian Forest Service, 2001)

Recently CanFI was augmented with additional forest delineations as defined by ecozones and ecoregions (Lowe *et al.*, 1996). The ecozone and ecoregion polygons were overlaid on CanFI and related to the underlying information. In essence, the timber data could then be associated with an ecosystem component.

The forest inventory and classification systems that were described in the previous sections referred to landscape-level systems. An overview of the systems applicable at the stand level is provided in the following sections.

## Stand Level

### *Forest Resources Inventory*

The provincial Forest Resources Inventory (FRI) frameworks have been described and summarized by Gillis and Leckie (1993) who define a forest inventory as "a survey of an area to provide information on the present extent, quality, and location of the forest resource and the manner in which it is changing". A FRI provides information for timber management and extraction through data collection of timber volumes, commercially important species composition, and tree DBH (diameter at breast height).

Across Canada, these inventories employ similar approaches for stratifying and describing the forested landscape. Differences in the approaches result from unique features specific to each region, which include nature of the forest, inventory requirements, historical developments, personnel involved, and budgetary considerations (Gillis and Leckie, 1993). The vastness and diversity of Canada's forests also contribute to the necessity for tailored inventories. Similarities observed among alternative FRIs are the relatively consistent scale of analysis (1:10 000 to 1:20 000), aerial photo interpretation, and the use of timber cruising (DNR, 1998).

For Manitoba, a detailed explanation of FRI procedures has been provided by Manitoba Conservation (formerly Natural Resources) in the form of a field instruction manual (DNR, 1998). The FRI was initiated in 1958 and is updated by re-inventorying every 10 years in areas of high industrial activity and every 25 years in areas of low activity (Gillis and Leckie, 1993). Essentially, the inventory consists of unique forest polygons that are differentiated by tree stand. Descriptive information about the stand narrates the polygon through a five digit numerical code.

The FRI has been well suited to its original intention as a tool for planning and managing forests in the context of sustainable yield (Treitz and Howarth, 1996). It clearly reveals the locations of merchantable timber along with estimates regarding harvest parameters.

Social values and attitudes concerning forests have changed since the onset of the FRI from a resource extraction focus to a holistic, multi-use paradigm. Therefore, the FRI framework is somewhat outdated, as it does not account for these additional interests in the forests. For example, wildlife information and non-commercial species are ignored. As a consequence of the growing interests in forest resources, the FRI is being applied in situations for which it was not intended (e.g. Kearns, 1999).

The Manitoba FRI represents an approach to ecosystem classification; however, the classification criteria are narrowly focused on factors that are important to commercial forestry. "All productive, or potentially productive, forest lands are classified into homogeneous units (stands) according to species composition, crown closure, cutting class, and site" (Gillis and Leckie, 1993). Using these criteria, aerial photographs are acquired and forest stand polygons are delineated and described. Forest inventory field "check" cruises are carried out to verify the classification and collect additional stand information (e.g. age, height, diameter). Typically, only 80 volume samples are carried out annually. Base maps (1:15 840) of forest stand polygons are created concurrently with the polygon interpretation.

The objective of the FRI classification system is to identify merchantable timber stands. It does not account for other ecosystem components such as wildlife, detailed soil characteristics, or successional trends. Timber areas that are not merchantable and areas that are not forest, such as lakes and taiga, are identified within the FRI. These areas have minimal supporting information regarding the environment and often are just labeled (e.g., swamp). Therefore, the FRI is more appropriately viewed only as a forest inventory rather than an ecosystem classification system.

The FRI classifies forest stands in a hierarchical manner, but uses the main identifiers "Covertype" and "Subtype". The cover type and subtype designations only describe the composition of forest stands in general terms. Four broad groups of Covertype exist (Softwood, Hardwood, and two Mixedwood categories) which are followed by the more refined Subtype derivations. Seventy Subtypes exist, which are defined as the interpreted percentage of species composition of a stand (e.g. Subtype 20 equals balsam fir 71-100%). Crown closure, cutting class, and site characteristics augment the Cover and Subtype classifications. These characteristics are combined in a five digit numerical code to define the characteristics of each polygon (i.e., the first two digits represent Subtype, the third digit represents site type, fourth represents cutting class and fifth indicates crown closure).

Field sampling and verification are not comprehensive so previous base maps are used and updated as new information becomes available. As a result, photo interpretation accuracy is not verified for much of the forest area in Manitoba. Forest inventory information has been input into an ARC/INFO GIS database, but has not yet been linked with ecosystem classification information (Acres, 1998). Figure 6 illustrates a section of the FRI stand map showing a typical polygon with its corresponding descriptive (attribute) data.

| Attribute | Value | Description of Field |
|---|---|---|
| *AREA ($m^2$)* | 135589 | Area of the polygon |
| *PERIMETER (m)* | 2539.54 | Length of perimeter of polygon |
| *LND_ID* | 97 | Describes productivity of the polygon |
| *OWN_ID* | 1 | Ownership code for the polygon |
| *ST_ID* | 55 | Status ID for land use |
| *MU_ID* | 35 | Forest Management Unit |
| *SPECIES* | JP9BS1 | Species in polygon (Jack Pine 90% Black spruce 10%) |
| *COVERTYPE* | 04243 | Covertype code describing species composition, site type by landform and moisture regime, age (cutting class) and crown closure |
| *HECTARES* | 135 | Hectares of polygon |
| *BALHECT* | 0 | Area/10 000 (required by DNR) |
| *STDSET* | 5 | Code for coloring polygons |
| *YEAR_ORG* | 0 | Year of origin |
| *TWP* | t30r09ep | Township |

Figure 6. Typical FRI Polygon (highlighted) with Corresponding Attribute Information (DNR, 1998)

### *Forest Ecosystem Classifications*

Specific Forest Ecosystem Classifications have been developed for various regions across Canada. The theoretical purpose of the FEC is to "permit the accurate, consistent and practical description of forest ecosystems so that existing and new management knowledge can be organized, communicated and used more effectively" (Sims and Uhlig, 1992). As such, the FEC theoretically performs as a holistic tool that encompasses a broad range of information to comprehensively define a specific forest stand.

Standard classification criteria of the FEC include characteristic vegetation species, soil characteristics, and management interpretations. These parameters are surveyed by the user within the predefined sample space (e.g. 10 m x 10 m for Manitoba; Zoladeski *et al.*, 1995) and progressively evaluated using classification keys to arrive at a distinct ecosystem type. Fact sheets describing the characteristic conditions of the ecosystem type are provided to confirm the keyed classification. As well, common forest plants representative to the area are illustrated and described to aid in identification. Conveniently, the various provincial FEC systems are compacted into manageable, easy to use field guides that can be consulted while surveying the forest.

The Manitoban version of the FEC was developed by Zoladeski *et al.* in 1995 and was modeled after the Field Guide to the Forest Ecosystem Classification for Northwestern Ontario (Sims *et al.*, 1989). The classification was developed to assist in forest ecosystem classification and management on large scales (i.e. individual tree stands) of particular ecological and silviculture concern for the commercial forest areas of Manitoba. Thirty-three vegetation types (V-Types) and 22 soil types (S-Types) are identified using defined criteria. Each classification includes management interpretations concerning silviculture and wildlife habitat.

The manual is cumbersome and not appropriate for landscape-scale classifications since it is functional at the tree-stand level. It could also be strengthened to fill in data gaps as Zoladeski *et al.* (1995) have stated, "It is anticipated that territorial sampling gaps will be systematically filled-in in the future and that the system will be periodically updated as new data become available". In addition, "... the approach adopted for Manitoba consisted of assembling and synthesizing information from various available sources. This has inevitably resulted in certain limitations and shortcomings" (Zoladeski *et al.,* 1995).

***V-Types***

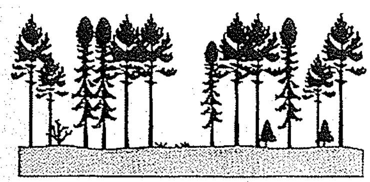
The V-Type is essentially the main component of the classification system as it enables a user to allocate a particular forest stand to a certain vegetation type. The FEC V-Type of a particular forest stand is determined through the use of a field key that is dichotomous in nature (e.g. V28). Classification criteria are initially general, becoming more specific as one works through the key. The general criteria consist primarily of overstory tree composition while subsequent finer divisions are based on understory shrubs, herbs, mosses, and lichens. All of the V-Types are allocated to one of three groupings: mainly hardwood, conifer mixedwood, or conifer. The V-Type key was designed for use in relatively small (10 m x 10 m) plots.

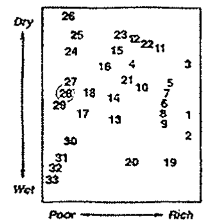
Once the specific V-Type has been decided for an area through the key, the Vegetation Type Fact Sheet for that V-Type can be consulted to confirm the classification (Figure 7).

## V28 • Jack Pine-Black Spruce/Feather Moss

***General Description:*** (n = 22): Jack pine-black spruce stands with an open understory. The dwarf shrub and herb layers are poorly developed, with scattered occurrences of *Alnus crispa, Linnaea borealis, Aralia nudicaulis* and *Cornus canadensis*. The forest floor is covered by a continuous carpet of feather moss. Occurring on fresh to moist, fine-textured mineral soils.

***Overstory Species:*** Jack pine, black spruce, trembling aspen, white spruce, balsam poplar, white birch






***Common Understory Species***

*Shrubs:* *Alnus crispa, Rubus pubescens, Vaccinium myrtilloides, Rosa acicularis, Linnaea borealis,* black spruce, balsam fir, *Viburnum edule, Corylus cornuta, Gaultheria hispidula, Viburnum trilobum*

*Herbs:* *Cornus canadensis, Aralia nudicaulis, Lycopodium annotinum, Maianthemum canadense, Elymus innovatus, Petasites palmatus, Fragaria virginiana*

*Mosses:* *Pleurozium schreberi, Hylocomium splendens, Dicranum polysetum, Ptilium crista-castrensis*

***Forest Floor Cover:*** Moss: 85, Conifer litter: 10, Wood: 2

***Soil/Site Characteristics***

| | |
|---|---|
| Soil Types: | SS3, S2, S4, S6, SS7 |
| Thickness of Organic Layer: | [LFH] (6-15), (1-5), (16-25) |
| Surface Texture: | c. loamy, f. loamy, f. sandy |
| C Texture (when present): | f. loamy, f. sandy, c. sandy, silty |
| Moisture Regime/Drainage: | fresh, dry, moist/well, rapid |
| Mode of Deposition: | morainal, glaciofluvial, lacustrine |

***Comments:*** These forests are successionally intermediate between the younger jack pine communities (V24, V25) and older upland black spruce Types (V27, V29). They are of fire origin.

***Management Interpretations***

| *SH* | *HT* | *SS* | *SPM* | *CT* | *CLCS* | *CFP* | *MSFP* | *MTRP* | *MWFP* |
|---|---|---|---|---|---|---|---|---|---|
| A | C | JP/LFN | A | – | L | M | L | M | L |

Figure 7. Typical V-Type Fact Sheet (Zoladeski *et al., 1995)*

Each fact sheet contains summary information about the typical forest stand for each V-Type. Standard information contained in each fact sheet includes important V-Type characteristics such as overstory and understory floristic composition, forest structure, relationship to other Types, successional trends, soil and site characteristics, and forest management interpretations.

By their nature, forest stands are seldom identical; therefore, each of the V-Types is described from many stands that are more similar to each other than they are to the other V-Types. This means that each V-Type represents a range of vegetation conditions that are described in the fact sheet. When comparing the fact sheet description with the actual stand composition, it can be expected that some species will not occur in the stand that are described in the fact sheet, while some species may occur in the stand that are not described in the fact sheet.

The FEC manual provides an ecosystem classification system that is holistic and applicable to an array of terrestrial boreal forest ecosystem representations. The 33 V-Types serve as primary ecosystem identifiers, while additional information, such as S-Types, help to characterize an ecosystem even more comprehensively. While S-Types have been developed and included as part of the FEC System for Manitoba, they have been excluded from this analysis due to data restrictions and limitations.

Prior to the implementation of the FEC, several classification and/or inventory systems would have to be consulted to acquire the same information that is found using the FEC. Although the initial construction of the FEC was to help manage silvicultural practices and streamline the collection of forest management information, it can be employed by a variety of user groups and integrated with other databases. This versatility allows comparison of information across disciplines and provides a common ground for communication.

Each provincial classification system is unique with respect to the specific information collected and the resulting classifications. However, the governing format of the FEC system remains constant throughout all approaches. Examples of the FEC can be found in Corns and Annas (1986) Field Guide to Forest Ecosystems of West-Central

Alberta, Sims *et al.*'s (1989) Field Guide to the Forest Ecosystem Classification for Northwestern Ontario, and Zoladeski *et al.*'s (1995) Forest Ecosystem Classification for Manitoba Field Guide.

The major drawback of the FEC is that it functions on a very limited expanse of land (10 m x 10 m plots) so that mapping ecosystems using this tool becomes tedious and cumbersome. Also, because it has a relatively short history it has not been unanimously accepted or implemented in areas where its employment would be appropriate. This is the situation in Manitoba where the widespread FRI has been the standard forest classification tool and the FEC is exercised in only specific local applications, such as forestry company assessments (Fraser *et al.*, 1998).

Table 2 displays the strengths and weaknesses of the FRI and FEC classification formats through various parameter comparisons. From this graphic it is clear that both systems do not fulfill all of the criteria and the distinct pitfalls of each format can be seen. Although both systems have their own specific utilities (i.e. the FRI is industry oriented while the FEC is ecosystem oriented) the FEC is more successful in meeting a breadth of functions. This is because the nature of the FEC is more holistic than the narrowly focused FRI. However, in many instances the strengths of one format parallel the weaknesses of the other format. For example, the extent of coverage in Manitoba of the FRI is widespread across the province while the FEC has only been applied in localized surveys.

**TABLE 2**

**Comparisons of the FRI and FEC Systems**

| Parameter | FRI[1] | FEC[2] |
|---|---|---|
| Planning horizon: | | |
| Short-medium term (1-5 years) | XX | XX |
| Long-term (5-20 years) | XX | XX |
| Normal Scale/resolution | 1:15 840 | Ground-based |
| Extent of coverage in Manitoba | Widespread | Local surveys only |
| | | |
| Species composition | XX | XX |
| Working group | XX | X |
| Stand density and spacing | XX | X |
| Present productivity | XX | XX |
| Potential site quality | O | XX |
| Product type/ product amount | X | X |
| Non-commercial forest types | X | X |
| | | |
| Depth of mineral soil | O | XX |
| Depth and type of organic matter | O | X |
| Soil moisture regime | O | XX |
| Soil texture | O | XX |
| Macro/microtopography | O | X |
| Surficial geology/landforms | O | X |

**O = not useful; X = useful; XX = very useful**

[1]FRI= provincial Forest Resources Inventory *(e.g. DNR, 1999)*

[2]FEC = Forest Ecosystem Classification *(e.g. Zoladeski et al., 1995; Sims et al., 1989)*

Adapted from Sims and Uhlig, 1992.

The benefits of both the FRI and FEC systems would be available by amalgamating the two systems. The widespread coverage and mapping characteristics of the FRI could be enhanced with the detailed and holistic FEC descriptions. Consequently, a new, synergized ecosystem classification system would be created that would meet the needs of more users. Valuing the differences of these mechanisms is the key to developing a stronger, broader, and more functional ecosystem classification system than previously available.

One of the most applied fields for ecosystem classification is that concerning timber harvesting (e.g. Carmean, 1996; Kojima, 1996). Tembec of eastern Manitoba and Louisiana-Pacific Canada Ltd. in western Manitoba have employed the FEC system along with the FRI (Fraser *et al.,* 1998; DNR, 1999). Regular pre-harvest assessments are conducted in selected future cutting areas, which include delineation of ecosystem types as defined by the Manitoba FEC (Zoladeski *et al.*, 1995). This information helps to establish sensitive, as well as resilient regions of the forest that guide forest cutting tracts. The companies can be more accountable for their actions as detailed information concerning various landscape qualities are acquired.

Ironically, the forest ecosystem classifications employed for use in the forestry industry are applied in areas scheduled for harvest. Although the classifications aid in timber management regarding harvest, the ecosystem soon becomes altered as a function of the timber harvesting procedures used in this province. However, thanks to the application of the FEC prior to harvest, silviculture treatments and reforestation regimes can be better suited to the original composition of the forest. An appropriate plan of forest regeneration can then be devised objectively using the FEC classifications as a guide.

Wildlife conservation employs ecosystem classifications for management purposes. Habitat suitability indices rely on various ecosystem components, which can be deduced using an ecosystem classification system. Kearns (1999) engaged the provincial FRI to assess a habitat suitability index for the Barred owl. Although the FRI was used for this purpose, a more holistic system, such as the FEC, would have been beneficial as more information regarding the environment could be directly collected rather than interpreted from the FRI.

## Chapter Summary

The review of forest inventories and forest ecosystem classifications has shown that numerous frameworks and techniques have been devised across Canada for classifying landscapes, yet a void still exists in Manitoba. A wide-ranging forest ecosystem classification that operates at a stand level resolution is lacking, which is necessary for detailed resource management and planning. To combat the problem of a lack of widespread ecosystem information, user groups have relied on the information base of the provincial FRI and indirectly interpreted ecosystem information (e.g., Kearns, 1999). Where Manitoba's FEC has been used to classify the province's forest ecosystems, the information is often kept private as the work is conducted by local interest groups or agencies for personal use.

Therefore, this study was implemented to address the need for an improved forest ecosystem classification system in Manitoba while avoiding the complexity of establishing a distinct new system such as ecosites. By linking the wide-ranging coverage of the FRI system with the holistic nature of the FEC system, an improved forest ecosystem classification system for Manitoba would be available. Although not as rigorous as an ecosite classification, the FRI-FEC link would provide resource managers and interest groups with a level of forest ecosystem detail never before experienced in Manitoba.

# *Chapter 3*

## METHODOLOGY

The study was implemented following the framework outlined in Table 3. The following five stages were executed to fulfill the proposed objectives:

- Literature review
- Data acquisition
- Preprocessing
- Link FRI and FEC
- Assessment of Common Understory Species

**TABLE 3**
**Methodology Framework**

| Step | Activities | Products/Results of Activities |
|---|---|---|
| 1. Data Acquisition | a. Collect preharvest assessment data (field study and PFPC)<br>b. Obtain timber cruise lines for study area (PFPC)<br>c. FRI Data (PFPC & Mb. Conservation)<br>d. GIS Ecosystem Algorithm (PFPC & Geospatial International) | a. Field records of preharvest assessment data<br>b. GIS theme layer of transect lines where data were collected<br>c. GIS theme layer of FRI polygons and attributes<br>d. Arc Macro Language Algorithm for assigning V-Types to FRI polygons |
| 2. Preprocessing | a. Develop database of preharvest assessment data | a. Electronic database in Microsoft Access |
| 3. Link FRI and FEC | a. Assess Ecosystem Algorithm for suitability in study area<br>b. Develop GIS theme layer of plot locations and V-Types along the transect lines<br>c. Overlay observed V-Types for each plot over FRI polygons<br>d. Assign the dominant V-Type to each polygon<br>e. Run Ecosystem Algorithm to assign a V-Type to each polygon<br>f. Assess the agreement between the observed V-Types and the GIS derived V-Types for each polygon | a. GIS algorithm that will run using the FRI data for the study area<br>b. GIS theme layer of plot V-Types where data were collected<br>c. GIS theme layer of V-Types in each polygon<br>d. GIS theme layer of dominant observed V-Type for each polygon<br>e. GIS theme layer of a derived V-Type for each polygon<br>f. Error matrix showing agreement of V-Type classifications between datasets |
| 4. Assessment of Common Understory Species | a. Develop a data matrix of vegetation observed within each V-Type<br>b. Reverse rank order Common Understory Species for each FEC V-Type<br>c. Assess frequency of the observed understory species associated with each V-Type<br>d. Calculate Spearman's Rank Correlations for each V-Type using the vegetation frequencies from the field data and the reverse rank order values for the Common Understory Species.<br>e. Evaluate V-Type correlations | a. Data matrix for assessing V-Type and vegetation relationship<br>b. A data matrix of ranking values for each of the Common Understory Species in the FEC<br>c. Graphs and tables to show relationships between understory species and V-Types<br>d. Correlations of species ranks between the two datasets.<br>e. Indication of how well the Common Understory Species are represented in nature |

## Literature Review

A review of the literature and past works concerning forest inventories and forest ecosystem classifications was conducted. This process was used to identify and gain a better understanding of the following points:

- The evolution of forest inventories and forest ecosystem classifications in Manitoba and Canada.
- The current status and information gaps of the forest inventory and forest ecosystem classification systems in Manitoba.
- The methods and procedures used in Manitoba for forest inventories and forest ecosystem classification.

This information was used to place the thesis study in context and identify its purpose.

## Data Acquisition

After the Literature Review, the field data, FRI data, timber cruise data, and GIS algorithm were gathered from different sources.

## Study Site

Field data were required to identify and classify forest ecosystems in the study area. The collected information was used to evaluate the effectiveness of the forest ecosystem classification systems in Manitoba. The research area is contained within Forest Management License 01 of Tembec, located in eastern Manitoba between Lake Winnipeg and the northwestern border of Ontario (Figure 8). This area was chosen as a study site because Tembec regularly conducts pre-harvest assessments in the areas proposed for timber harvest; therefore, an abundance of forest data were available.

Within the study site, five specific areas of data collection were analyzed as a group (Figure 8). The areas of Beaver Creek, Black River South, Loon Straits, Rainy Lake and Wanipigow South were chosen for analyses because a large amount of forest information was available for these areas from the pre-harvest assessments. As well, corresponding FRI data in GIS format were available for these areas.

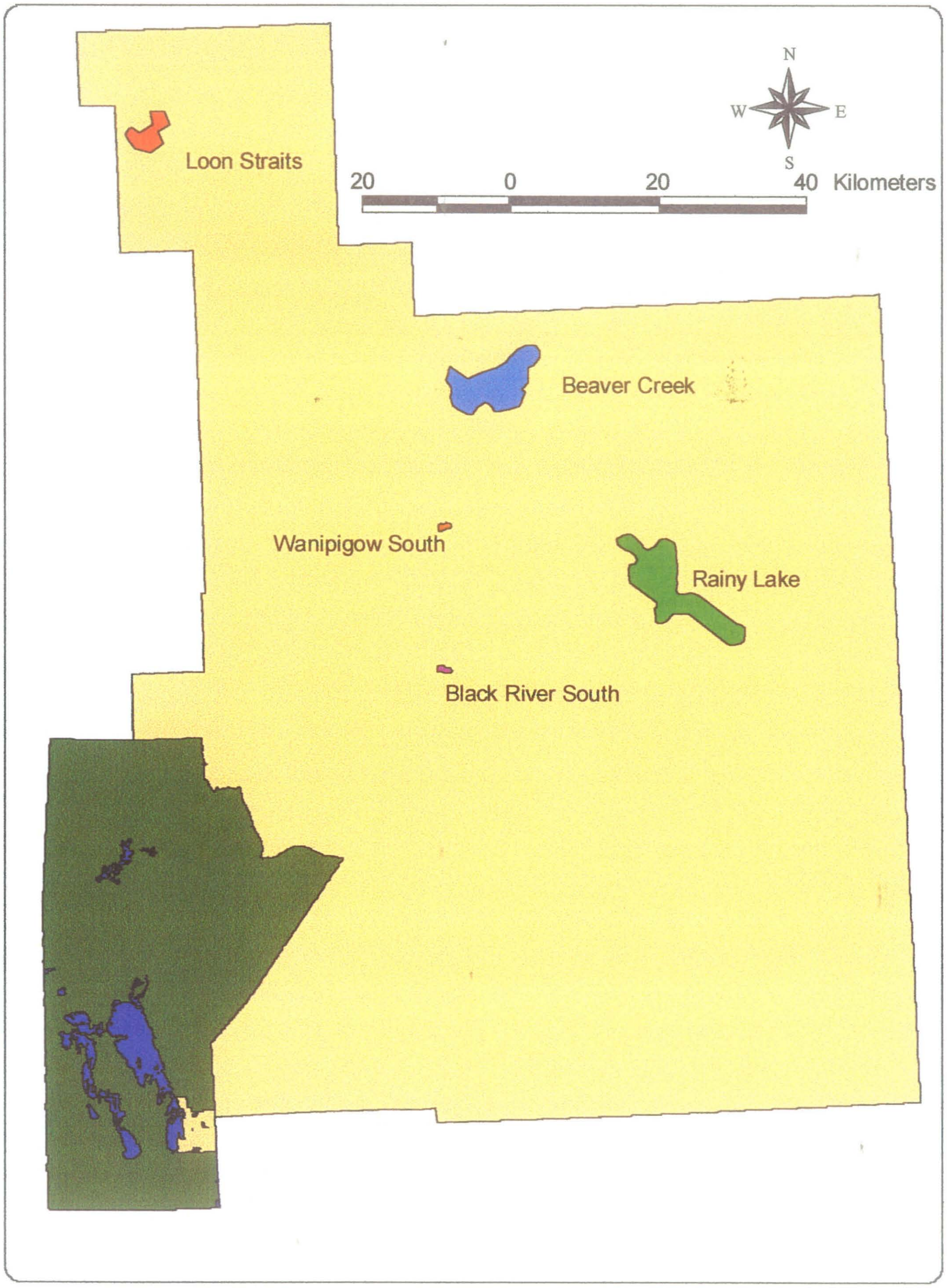



Figure 8. Study Site and Data Collection Areas

The information that was collected during the pre-harvest assessments is summarized in Table 4.

**TABLE 4**
**Summary of Pre-harvest Assessment Data**

| Parameter | Data Collection Details |
|---|---|
| Ground cover vegetation species and abundance | Species were recorded with their percent cover within the 0.5 $m^2$ quadrat. |
| Forest Ecosystem Classification V-Types | Data collectors classified forest ecosystem V-Types using the Manitoba FEC. |
| Forest Ecosystem Classification S-Types | Data collectors classified forest ecosystem S-Types using the Manitoba FEC. |
| Line intercept data for tree species | Species, heights, and distance over intercept line were recorded. |
| Forest Health | Forest health was gauged by the presence of any insect damage, diseases, or other forest problems. The tree species affected and the severity were recorded. |
| Signs of small and large mammals | Indicators of animal presence were recorded. |
| Bird species | Birds that were heard or seen were recorded during 5 minute listening periods. |
| Wildlife species | Wildlife that were observed were recorded. |
| Presence and abundance of woody debris | The percentage of ground covered by woody debris, type of wood and diameter were recorded. |
| Presence and size of tree snags | The number of dead trees, wood type, and diameter were recorded. |
| Cultural/Heritage resources | Any observations of cultural or heritage resources were noted and photographed. |
| Silviculture renewal prescription | One of four silviculture renewal prescriptions was recommended for each plot based on the forest type and conditions. |

From this dataset, the following information for the five study areas was extracted for analysis:

- FEC V-Type
- Ground cover vegetation species and abundance
- Metadata describing the conditions of data collection (such as date, weather conditions, crew members, location).

The study data were collected from 1997 to 1999 from Forest Management Unit 31 (FMU 31) on the east side of Lake Winnipeg (Figure 8) by two Tembec biologists. The author collected a portion of the data with the Tembec crews during the summer of 1997. From 1997 to 1999, a total of 4927 plots along 182 transect lines were sampled within the study area. Not all of the data collected were used in the study for various reasons. For example, the field crews occasionally used the Ontario FEC instead of the Manitoba FEC and sometimes no V-Type classification was provided for a plot. Table 5 provides an overview of the amount of data that was actually used for assessing the algorithm from the collected data in each of the study areas.

**TABLE 5**

**Lines and Plots of each Study Area that were Used in the Study**

| Study Region | Number of Lines | Number of Plots |
|---|---|---|
| Beaver Creek | 67 | 1113 |
| Black River | 2 | 34 |
| Loon Straits | 17 | 306 |
| Rainy Lake | 89 | 1475 |
| Wanipigow South | 1 | 42 |
| Total | 176 | 2970 |

### *Pre-harvest Assessment Data Collection Methods*

In 1996, Tembec implemented scheduled pre-harvest assessments in its operating areas. "A pre-harvest assessment is a site-specific, integrated stand management plan that is developed before harvesting takes place. These assessments were designed to aid in determining necessary harvesting considerations and silviculture treatments while taking into account environmental and wildlife concerns as well as recreational, cultural, commercial and heritage concerns" (Fraser *et al.*, 1998). Pre-harvest assessment collection methods have evolved and changed since their inception; the methods described for this project were valid at the time of the study and do not necessarily represent the current practices or methods used by Tembec.

A transect line on the map was assigned through variable tree stands that were scheduled for harvest; the line was used for referencing all collected information about the stands in the field. That is, timber cruise information and all of the pre-harvest assessment data were gathered at the same time along the same pre-determined transects at 50 meter intervals. Ten meter by ten meter quadrats were used at each interval for all the information required on the pre-harvest assessment field survey sheets (Appendix C). At the centre of each quadrat, a smaller 0.5 m x 0.5 m quadrat was used for observing and recording the understory vegetation species. A total of 250 vegetation species were recorded during the field study (Appendix D). The pre-harvest assessments were conducted throughout the growing season from May to September.

For the FEC V-Types, the field biologists used the Manitoba FEC key to assign a V-Type to each plot. Occasionally, the biologists could not decide on one V-Type for a plot, so both Types were noted on the data sheet. The plots that were classified with more than one V-Type were removed from the data analysis. While collecting the field data, it was noted that occasionally a forest stand would be a pure balsam fir stand;

however, a corresponding V-Type for pure balsam fir does not exist in the FEC. The closest matching V-Type is V21, which refers to White Spruce/Balsam Fir Shrub composition. This V-Type was used to classify pure balsam fir stands in addition to the white spruce and balsam fir stands.

Since the FEC key requires a subjective interpretation of the forest stand by the data collector, different people could interpret the same stand differently and arrive at different V-Types. However, the biologists were trained in classifying V-Types using the FEC and were knowledgeable in identifying native plants. Therefore, the effect of different data collectors would be negligible. The detailed procedures for the pre-harvest assessments are provided in Appendix C (Fraser *et al.,* 1998).

The study area (Figure 8) exists as boreal forest and falls into the Boreal Shield ecozone (Figure 3). The region is characterized by white spruce (*Picea glauca),* black spruce *(Picea mariana),* balsam fir (*Abies balsamifera),* Jack pine (*Pinus banksiana),* white birch (*Betula papyrifera)* and trembling aspen (*Populus tremuloides)* (Rowe, 1972). The boreal forest supports a multi-layered ecosystem that supports life between layers of land and atmosphere. Some common understory species are wild sarsaparilla (*Aralia nudicaulis*) bunchberry (*Cornus canadensis*) and sphagnum moss (*Sphagnum spp.).*

The topography includes peatlands, sand, and morainal deposits as well as Precambrian-aged rock outcrops of the Canadian Shield. Dry, mesic, and wet sites also exist. These characteristics support an array of organisms that function systematically as a three-dimensional, fundamental unit of nature (Rowe, 1990). Figures 9 and 10 illustrate the forest conditions of the study site in mid summer when the data were collected.

Figure 9. Photo of a typical mixedwood forest stand in the study area

Figure 10. Photo of data collectors assessing lichen coverage within the quadrat.

### *Timber Cruise Lines Data*

Timber cruise data were collected at the same time as the pre-harvest assessment data at the same plot locations, along the same predetermined transects within the selected forest stands. Two crews of three people from Tembec collected the timber cruise information each year. The information collected through cruising is tailored to the forestry industry's needs so that only information that is relevant to timber harvesting is gathered. For example, timber volumes calculated using height, species composition, and Diameter at Breast Height (DBH) information were collected during these surveys. The location of the transect lines (for the preharvest assessment information) were acquired from Tembec for the study area. A total of 352 transect lines were used for data collection in the five study areas (Table 5).

### *FRI Data*

The Manitoba Forest Resources Inventory information for the selected study site was acquired from Tembec but originated from Manitoba Conservation. The relevant FRI information for the study area included the tree stand polygons along with their attributes, in a GIS format.

### *GIS Ecosystem Algorithm*

The GIS ecosystem algorithm was developed by Geospatial International and acquired from Tembec. Geospatial International first designed the application to approximate different FEC V-Types based on the FRI polygon boundaries and descriptions.

The algorithm assesses the classification of an FRI polygon in general terms of overstory composition and land type, and then it assigns a V-Type to the polygon that corresponds to the FRI classification. The text version of the algorithm is presented in

Appendix E. The algorithm operates as an ArcInfo program that steps through the FRI database and assesses each polygon record for certain parameters. Initially, the Land ID code (e.g., productive land, nonproductive land) for each polygon is interpreted and a corresponding V-Type is assigned to the polygon. For example, when the Land ID code for a polygon is equal to 701 (Black Spruce Treed Muskeg), the algorithm assigns V-Type V33 (Black Spruce/Sphagnum) to that polygon. The algorithm then cycles through the polygon records and assesses the Subtype code. A corresponding V-Type is then assigned to the polygon. For example, when the FRI Subtype for a polygon is equal to 94 or 95 (Black Ash and White Elm) the V-Type V2 (Black Ash (White Elm) Hardwood) is assigned to the polygon. When a polygon is classified with certain Subtypes, more information is required to assign a V-Type. For example, when the polygon Subtype is equal to 46, the percent composition of species is required to distinguish between V28 and V15; if species one is Jack pine and species two is black spruce at more than 30% then the algorithm assigns V28 to that polygon. Eventually, all of the polygons are assigned with a V-Type or with "unk" for unknown, if the polygon information cannot be interpreted by the algorithm.

The algorithm was employed within the GIS to create a new layer of mapped ecosystems (V-Types) using the preexisting FRI stand classifications, thereby linking the FRI and FEC systems.

## Preprocessing

The preprocessing step was used to prepare the data for further analysis. An electronic database of the field data was developed and the ecosystem algorithm was checked for usability (i.e correct electronic format).

## Database Development

An electronic database for the project was created with the following selected data from the five data collection areas:

- FEC V-Type
- Ground cover vegetation species and abundance
- Metadata describing the conditions of data collection.

Vegetation and V-Type information from the database were used as input for the GIS to develop theme layers. The database information was checked for consistency and usability and certain records of information were discarded for the following reasons:

- No V-Type was recorded on the pre-harvest assessment tally sheet in the field.
- The field crews used the Ontario FEC for classifying ecosystems.
- V-Type sample sizes were too small for further analyses.
- Information about an area was not available in digital GIS format.

Once the unusable data were removed from the database, a total of 24 V-Types remained for analysis.

The relational database was created so that it could be linked to the corresponding map features in the GIS and spatial and nonspatial information could be linked. The database framework was developed following Betz's (1994) nine steps for designing a database:

1. The objects of the database were first listed to determine the necessary themes (i.e. V-Types, vegetation, and metadata). These themes comprised the various tables within the database.

2. Relevant facts about each of the objects were then determined, which act as fields within the tables. This information was taken from the pre-harvest surveys and included items such as line and plot number, vegetation species, and abundance.
3. The objects and facts were then combined to build columns (fields) within the tables. The domains for each field defined the types of values permitted in each column. Most of the domains were textual or numerical.
4. The relationships among tables were determined to model the real-world context of the data. Associations between elements were defined, such as vegetation species and their locations in nature. These relationships consisted of one-to-one, one-to-many, or many-to-many classes depending on the nature of the information.
5. Key identifiers were defined for each table to establish unique records. The key identifiers for the majority of data were the line and plot number, which distinguished the origin of the information.
6. Linking columns were identified, which relate two or more tables. Line and quadrat numbers were linked in almost all tables to relate the location of the data. So, all records with the same line and plot number were collected in the same location, no matter which table they were listed in.
7. Relationship constraints were implemented to ensure the integrity of data. Constraints included rules that certain information be entered before other information, such as plot specifics prior to any other data

entry. This ensured that the location and conditions of data collection were present for before each additional entry.

8. The design was then evaluated to reveal any flaws, such as anomalies or redundancies, and ensured that the data were reliable and stable.
9. Finally, the design was implemented in the computer using the relational database tool (Microsoft Access).

The pre-harvest assessment data were entered in the electronic database from original field recording sheets. Once the database was developed, the two main components of the project, linking the FRI and FEC systems and the assessment of the Common Understory Species, were implemented.

## FRI/FEC Linking Process

The process for linking the FRI and FEC systems using the ecosystem algorithm is outlined below.

### Assess Ecosystem Algorithm

The Ecosystem Algorithm was assessed for applicability in the study area. FRI classifications and the corresponding V-Types in the algorithm were checked for logic and consistency. The algorithm was also slightly modified to function within the selected GIS application. A text version of the modified algorithm is provided in Appendix E.

### GIS Data Processing

Figure 11 illustrates the GIS processes for linking the FRI and FEC systems and assessing the Ecosystem Algorithm by comparing the field data V-Types with the algorithm-derived V-Types. The figure illustrates the following steps:

- The FRI polygon data were acquired in GIS format. The field data with classified V-Types for each plot were acquired and transformed into GIS format for the same areas as the FRI data.
- The field plot data were then overlaid on the FRI polygons.
- A new theme layer emerged from the overlay consisting of V-Types within each polygon.
- The most dominant (most abundant) V-Type was then assigned to each polygon.
- The right side of the diagram illustrates how the algorithm assigned V-Types to the FRI polygons using the FRI data.
- Lastly, the dominant V-Types for each polygon were compared to the algorithm V-Type classifications for the same polygons.

The details of these steps are described in the sections below.

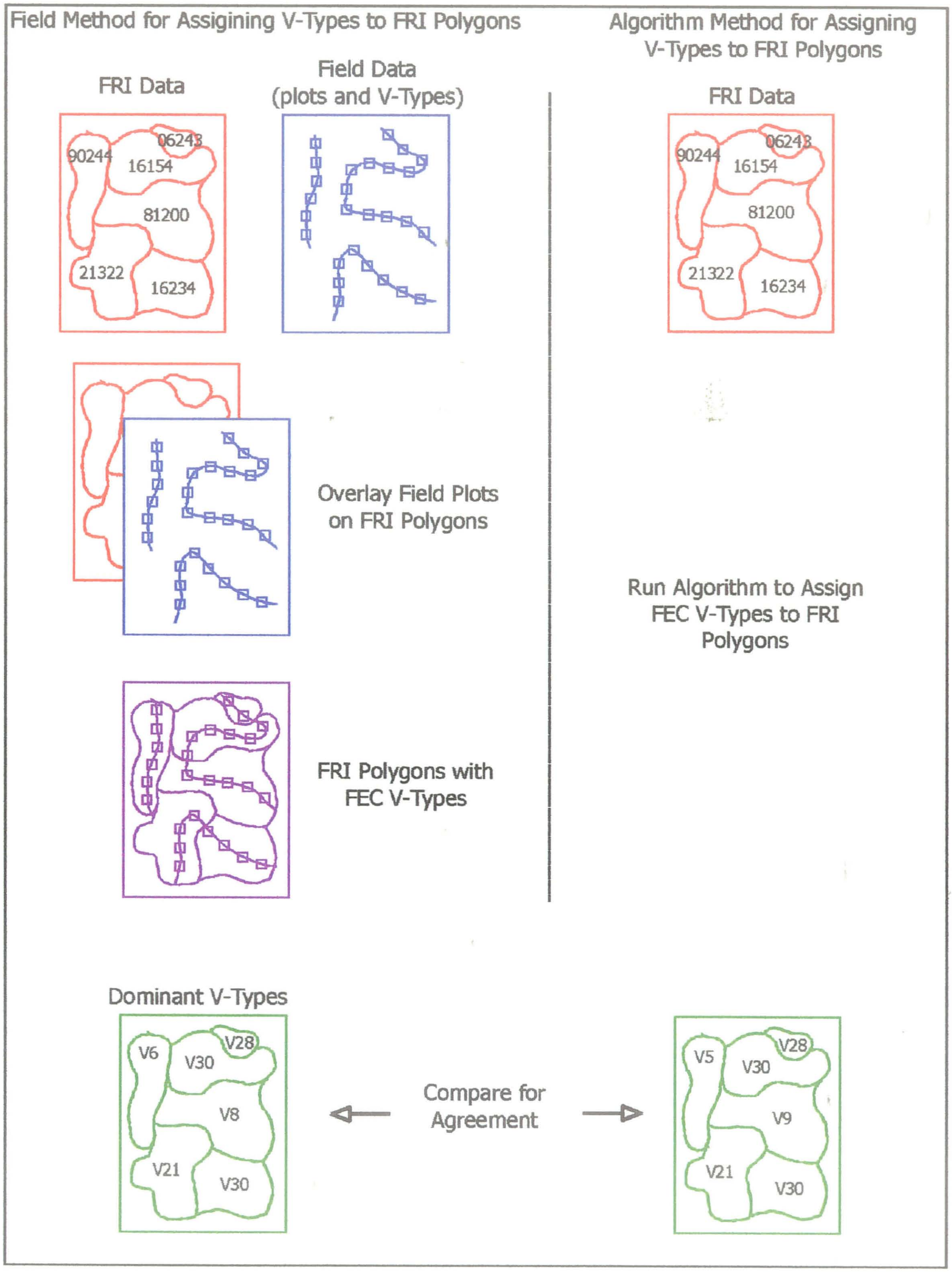



Figure 11. GIS Process for Assessing the Ecosystem Algorithm

### *Create Theme Layer of Plot Locations*

Using a GIS script, a theme layer (a linked map and database focused on one subject) was created of the sample plots at 50 m intervals along the timber cruise transect lines. After the data were collected, the plot locations required slight adjustments in the theme layer to more accurately represent where the crews had actually collected the data. Plot maps that were created in the field were used for plot location reference.

Once the locations of the plots were delineated in the GIS, the V-Types that were classified in the field were assigned to the plots. The FRI polygons and attribute data were acquired in GIS format and did not need further integration.

### *Overlay V-Types on Polygons*

The theme layer of field V-Types in each plot was overlaid on to the FRI polygon theme layer. A new theme layer was created of the field V-Types within each polygon.

### *Assign Dominant V-Types*

The dominant (most abundant) V-Type was assigned to each FRI polygon. A GIS theme layer of FRI polygons with dominant V-Types was created from this step. A single V-Type for each polygon was necessary to compare the algorithm derived V-Type with the dominant V-Type classified in the field. Theoretically, one V-Type should emerge as a dominant ecosystem type within each FRI polygon, since each polygon is assumed to represent a homogeneous classification. However, a single dominant V-Type for each polygon did not always emerge and several different V-Types were often classified for the plots within one polygon. The polygons that contained a tie for dominant V-Type were noted and a separate GIS theme layer was created of co-dominant V-Types per polygon.

### *Run Ecosystem Algorithm*

The ecosystem algorithm was executed in the GIS to derive FEC V-Types from the FRI data. A new thematic layer of V-Types was produced using the FRI polygons as boundaries for the new FEC classifications.

## Data Analysis

The polygon layer that contained the dominant V-Types and the polygon layer that contained the algorithm-derived V-Types were compared to assess the agreement between the two classification methods. An error matrix was used to calculate the percent agreement of classifications between the two datasets. Figure 11 illustrates the GIS process to test the ecosystem algorithm for agreement with the field data.

## Assessment of Common Understory Species

The Common Understory Species of the FEC V-Types were evaluated for their actual "commonness" in the field. The Common Understory Species are listed in the FEC to aid in classifying ecosystems so a plot that has been classified as a certain V-Type should generally contain the species listed for that V-Type. This circular relationship of classifying an ecosystem type using the Common Understory Species and then comparing the species found in that plot with the listed species should ideally be a perfect correlation. This relationship for each V-Type was assessed by comparing the listed Common Understory Species with the observed species using Spearman's Rank Correlation.

The data used for this analysis was from the five field study areas and consisted of ground cover vegetation that was found in each plot during the pre-harvest assessments. The frequency of the observed understory species were calculated for each V-Type and entered into a data matrix.

The Common Understory Species for each V-Type are listed in the FEC in declining order of importance within each vegetation category of shrub, herb, moss, and lichen. That is, "the most frequently found cited first" (Zoladeski *et. al*, 1995). Since no quantitative data are associated with the Common Understory Species of the FEC, the species were reverse rank ordered in the data matrix for each V-Type (Walker, 2002). The reverse rank method was used so that the most important species (i.e., the first one listed) would have the highest value. This method of assigning values to the species allows statistical methods to be performed, such as Spearman's Rank Correlation.

Species that were observed in the field but not listed as a Common Understory Species for a V-Type were removed from the analysis. Similarly, species that were listed but not observed were removed from the analysis. All of the species that were removed from either the FEC Common Understory Species List or from the field data species list were noted. These species required removal from the analysis because Spearman's Rank Correlation requires the same sample size in both datasets. A total of 109 species were used for Spearman's Rank Correlation. In addition, all species of one genus were amalgamated for that genus if the FEC list only contained the genus. For example, if *Dicranum fuscescens, Dicranum polysetum, and Dicranum scoparium* were recorded in the field for a plot and the corresponding V-Type for that plot only listed *Dicranum spp.* as a Common Understory Species, then the frequency of the individual species was combined in the data matrix as *Dicranum spp.*

The Spearman Rank Correlations were calculated for each of the 24 V-Types using the frequencies of the species from the field data versus the reverse rank order values for the Common Understory Species of the FEC. The correlations were then evaluated for significance and trends.

## Assumptions:

Several assumptions were made throughout the study as described below:

- FRI descriptions were accurate with respect to polygon delineation and stand composition.
- FRI polygons represented a homogeneous classification (as a single FRI classification type, not as a single vegetation type).
- The field crews consistently classified V-Types correctly in the study area.
- Pre-harvest assessments were accurate with respect to vegetation species identification, abundance, and frequency.
- Pre-harvest and timber cruise plots were accurately located at 50 m intervals along the predetermined transect lines.
- GIS features accurately represented their real entities.

*Chapter 4*

# FRI / FEC LINK AND THE COMMON UNDERSTORY SPECIES

The results of the FRI/ FEC link and the assessment of the FEC Common Understory Species are presented in this chapter following brief observations regarding V-Types and vegetation.

## V-Types

The field crews assigned a V-Type to each plot using the Manitoba FEC. A total of 24 V-Types were used for data analysis. Certain V-Type classifications were more common than others in the study area. Figure 12 illustrates the V-Type sample sizes (i.e., the number of plots classified with each V-Type) in a bar graph in descending order. The sample sizes ranged from 1046 plot classifications of V26 to 8 plots classified with V21 and V27. The average V-Type sample size was 127 plots. V26 is a distinct outlier with respect to sample size, as it was observed with a greater frequency than any other V-Type and was encountered 584 more times than the next highest V-Type (V28 with a frequency of 462 plot classifications).

Occasionally, the field crews could not decide on one V-Type for a plot, so both Types were noted on the data sheet. This type of discrepancy occurred in 97 plots with 21 combinations (Table 6). The majority of discrepancies involved V26, which was present in 13 of the 21 combinations.

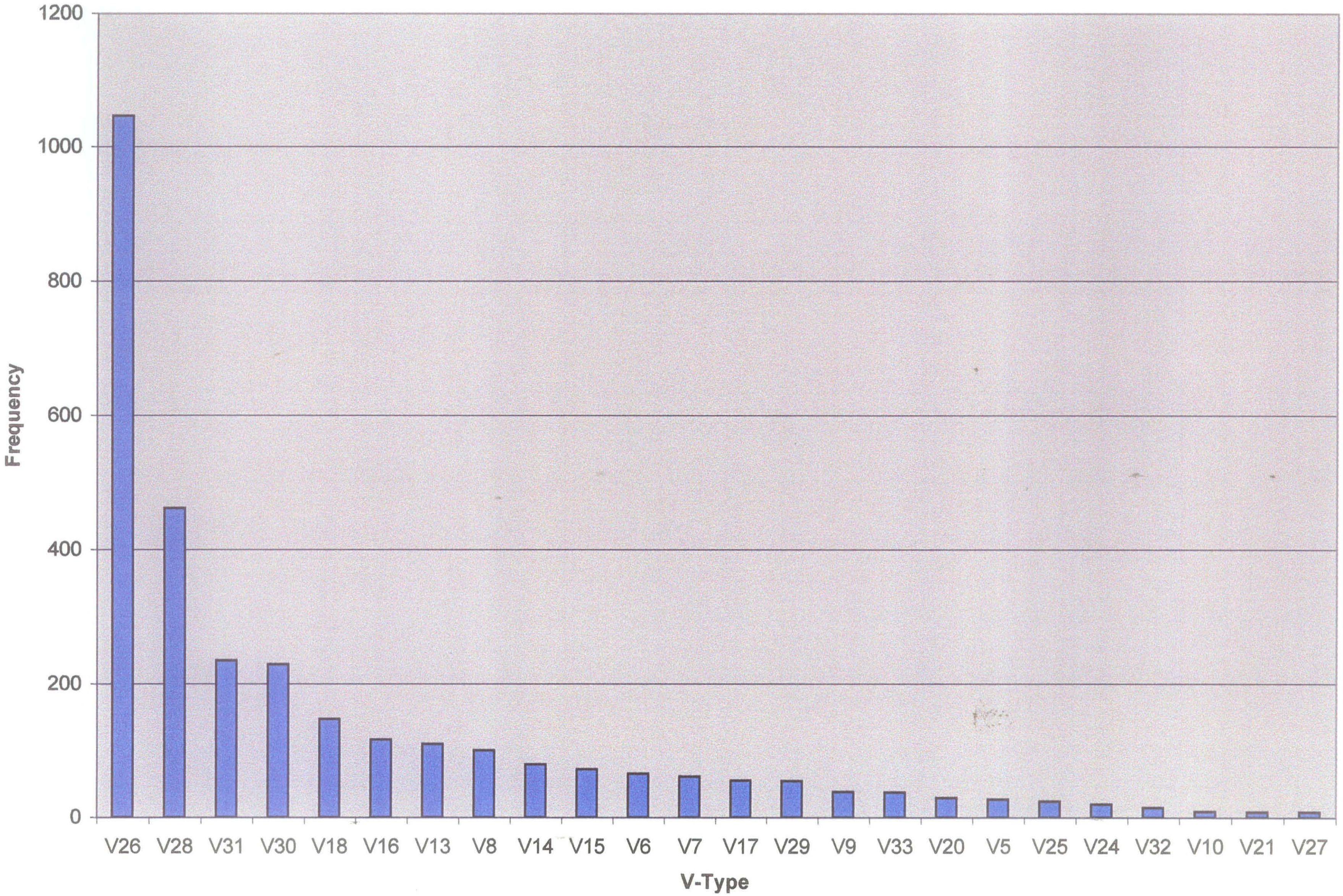



Figure 12. V-Type Sample Sizes

| TABLE 6<br>Inconclusive V-Types | |
|---|---|
| **V-Types Assigned to a Single Plot** | **Frequency** |
| V8/V26 | 3 |
| V8/V28 | 1 |
| V9/V31 | 1 |
| V15/V26 | 4 |
| V16/V26 | 3 |
| V16/V33 | 1 |
| V17/V26 | 2 |
| V17/V31 | 1 |
| V18/V26 | 4 |
| V18/V31 | 1 |
| V20/V26 | 1 |
| V20/V31 | 3 |
| V25/V26 | 2 |
| V26/V27 | 2 |
| V26/V28 | 15 |
| V26/V29 | 2 |
| V26/V30 | 2 |
| V26/V31 | 38 |
| V26/V33 | 5 |
| V28/V31 | 5 |
| V29/V33 | 1 |

## Vegetation

A total of 250 vegetation species were recorded during the field study (Appendix D). The number of individual plant species observations was equal to 16 308. None of the species that were encountered were listed as rare or endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2002). The species were generally common boreal forest species.

The frequency of each species occurrence was calculated individually and per V-Type. Most of the species (94.8%) were observed less than 5% of the time, which caused the data to be positively skewed near zero. The species with the highest observations was the moss, *Pleurozium schreberi*, which was observed in 1920 plots, while 78 of the species were observed only once. Generally, each species was observed an average of six times (i.e., in six plots).

## V-Type and Understory Vegetation Relationship

The relationships between understory vegetation and V-Types were assessed for how strongly the species were connected with the assigned V-Types. The relationships that emerged from the analysis were then compared to the relationships defined in the FEC. The species observed on the ground for a particular V-Type were compared to the species listed as "Common Understory Species" for that V-Type.

Figure 13 illustrates graphically the frequency or sample size of each V-Type along with the number of observed species with each of those V-Types. The V-Types are ordered along the X-axis in a decreasing fashion with respect to the number of vegetation species observed with the V-Type. A general trend exists in that the number of species associated with the V-Types is related to the sample size of the V-Type. The Pearson Product-Moment Correlation gives $r = 0.725$, which indicates a strong linear relationship between these two variables. As the V-Type frequency increases the number of species associated with that V-Type also increases. This trend can be attributed to the fact that the likelihood of encountering rare species increases with an increasing sample size.

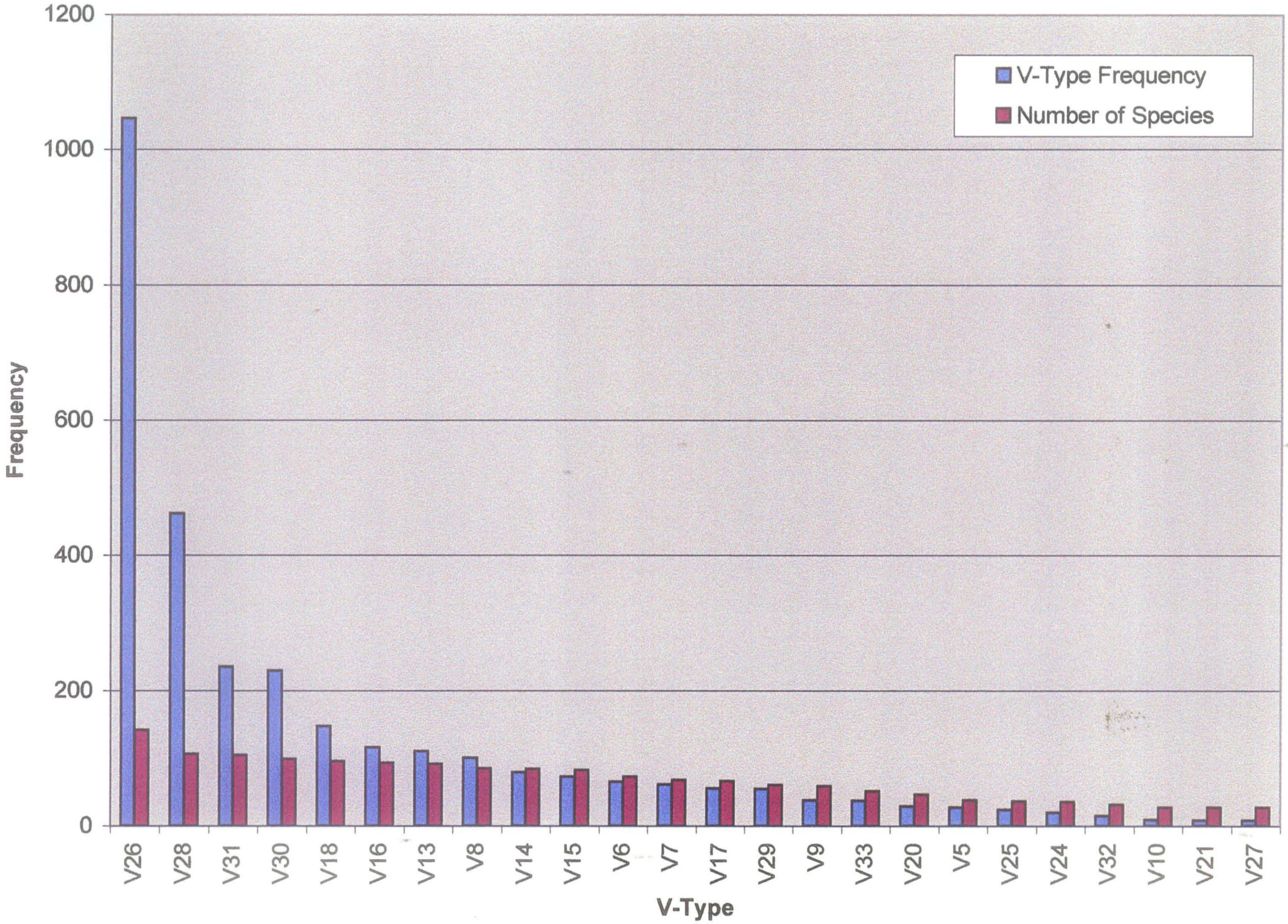



Figure 13. V-Type Sample Sizes and Number of Vegetation Species Observed with Each V-Type

A data matrix of the vegetation observed with each classified V-Type was created. The data were first standardized to a maximum of one and a minimum of zero by dividing the number of species by the V-Type sample size. This standardization accounts for different V-Type sample sizes. The data matrix is presented in Appendix F. Table 7 summarizes the V-Type sample size, how many species (not individual plants) were observed with each V-Type and the standardized proportion of species associated with each V-Type.

**TABLE 7**

**Summary of V-Type and Vegetation Data**

| V-Type | Sample Size (3046 total plots) | No. of Species Observed (250 total sp.) | Proportion of Species per Plot |
|---|---|---|---|
| V26 | 1046 | 141 | 0.13 |
| V28 | 462 | 104 | 0.23 |
| V31 | 235 | 93 | 0.4 |
| V30 | 229 | 81 | 0.35 |
| V18 | 147 | 106 | 0.72 |
| V16 | 116 | 93 | 0.8 |
| V13 | 110 | 85 | 0.77 |
| V8 | 100 | 98 | 0.98 |
| V14 | 79 | 71 | 0.9 |
| V15 | 72 | 83 | 1.15 |
| V6 | 65 | 67 | 1.03 |
| V7 | 61 | 66 | 1.08 |
| V17 | 55 | 84 | 1.53 |
| V29 | 54 | 46 | 0.85 |
| V9 | 38 | 59 | 1.55 |
| V33 | 37 | 51 | 1.38 |
| V20 | 29 | 36 | 1.24 |
| V5 | 27 | 58 | 2.15 |
| V25 | 24 | 31 | 1.29 |
| V24 | 20 | 38 | 1.9 |
| V32 | 15 | 27 | 1.8 |
| V10 | 9 | 35 | 3.89 |
| V21 | 8 | 27 | 3.38 |
| V27 | 8 | 27 | 3.38 |
| **Average** | **127** | **67** | **1.37** |

The average frequency for all the species was 0.082, that is, each species was observed, on average, less than 10% of the time with any given V-Type. The minimum frequency was 0.001 (exhibited by 30 species) while the maximum observed frequency was 0.944 (*Pleurozium schreberi).*

Table 7 and the data matrix (Appendix F) show that the V-Types contained a range of species abundances and frequencies with an average of 67 species per V-Type. Three V-Types (V21, V27, V32) contained the least variety of vegetation species (27 out of a possible 250), while V26 contained the highest variety of species (141). However, V26 also had a significantly higher sample size at 1046 compared to the average sample size of 127, which resulted in the lowest proportion of species per plot at 0.13.

Bar charts illustrating the percentage that each species was encountered with each V-Type were created (Appendix G). All were positively skewed, with the majority of species present less than 20 percent of the time for each V-Type. The graphs are also color-coded to indicate which species were listed in the FEC as Common Understory Species for each V-Type.

*Pleurozium schreberi* and *Cornus canadensis* were found to be outliers in the data. They were the only two species observed in plots classified as each of the 24 V-Types. For comparison, each species showed up, on average, in association with six V-Types. *Pleurozium schreberi* was observed with every V-Type with varying frequency, but generally displayed a higher frequency than other species. It had an average frequency of 0.510 across the V-Types (i.e. it was present 51% of the time), which greatly exceeds the matrix average of 0.082. The lowest frequency observed for *P. schreberi* was 0.037 in V5 while the highest frequency was associated with V29 at

0.944. This means that 94.4% of the time that a plot was classified as V29, *P. schreberi* was observed in it.

*Cornus canadensis* was also observed with every V-Type. This species had an average frequency (0.376) that was also higher than the matrix average (0.082). The minimum frequency for *C. canadensis* was 0.035 with V20, while the highest frequency was 0.850 with V24.

Most species were observed infrequently, showing up in less than 10% of the total observations. Seventy-eight of the species (31.2% of the total) were present in only one V-Type. The histograms (Appendix H) show this trend of many species with low abundance tapering off to few species with high abundance.

## Common Understory Species

For each V-Type, a listing of Common Understory Species is provided in the FEC to aid in classifying V-Types in the field. The list is divided into shrubs, herbs, mosses, and lichens that are characteristic of each V-Type. The species are listed in declining order of frequency (commonness) within each division. Ideally, the Common Understory Species for each V-Type should be most frequently encountered in the field. The bar charts in Appendix G display the species that were observed and whether or not they were also listed as Common Understory Species in the FEC. Red bars indicate species that were observed in the field and were listed as Common Understory Species in the FEC, while blue bars indicate species that were observed in the field but not listed as Common Understory Species. The species that were listed in the FEC but not observed are also noted on the charts.

A total of 56 species were listed as Common Understory Species that were not observed in the field (Table 8). No clear trend exists where certain species regularly were listed as Common Understory Species in the FEC but were not observed. *Alnus crispa* was identified as the most frequently listed Common Understory Species that was not observed in the field, with respect to V-Type. It was listed as a Common Understory Species within nine V-Types (V5, V9, V10, V15, V16, V18, V24, V25, V27) and was not observed in any of the plots classified as any of the nine V-types. A total of 453 plots were classified with one of the nine V-Types and not one of the plots contained *Alnus crispa*. The next most frequent species were *Viburnum edule* and *Viburnum trilobum,* which were listed as a Common Understory Species in five V-Types but were not observed in any of the plots classified as these V-Types. The remaining 54 species listed as Common Understory Species within four or less V-Types but were not actually observed in the field in plots classified as these V-Types.

**TABLE 8**
**Summary of Species Listed as Common Understory Species in the FEC That were not Observed in the Field**

| Species | V-Types that have the species listed as a Common Understory Species but the plots classified with these V-Types in the field did not contain these species | Total number of plots classified with the V-Types where the species was not observed |
|---|---|---|
| *Alnus crispa* | V5, V9, V10, V15, V16, V18, V24, V25, V27 | 453 |
| *Viburnum trilobum* | V5, V9, V14, V15, V28 | 678 |
| *Viburnum edule* | V10, V16, V24, V28, V29 | 661 |
| *Mertensia paniculata* | V8, V9, V14, V21 | 225 |
| *Picea mariana* | V10, V20, V27, V32 | 61 |
| *Elymus innovatus* | V8, V24, V28 | 582 |
| *Aster ciliolatus* | V13, V17, V29 | 219 |
| *Drepanocladus uncinatus* | V5, V7, V13 | 198 |
| *Equisetum arvense* | V8, V21, V29 | 162 |
| *Cornus stolonifera* | V17, V20, V21 | 92 |
| *Rosa acicularis* | V21, V25, V29 | 86 |
| *Populus tremuloides* | V10, V17, V21 | 72 |

| TABLE 8 Continued<br>Summary of Species Listed as Common Understory Species in the FEC<br>That were not Observed in the Field | | |
|---|---|---|
| **Species** | **V-Types that have the species listed as a Common Understory Species but the plots classified with these V-Types in the field did not contain these species** | **Total number of plots classified with the V-Types where the species was not observed** |
| *Vaccinium vitis-idaea* | V24, V25, V32 | 59 |
| *Fragaria virginiana* | V21, V24, V25 | 52 |
| *Epilobium angustifolium* | V5, V10, V27 | 44 |
| *Andromeda glaucophylla* | V20, V33 | 66 |
| *Schizachne purpurascens* | V9, V24 | 58 |
| *Amelanchier spp* | V9, V21 | 46 |
| *Juniperus communis* | V24, V25 | 44 |
| *Oryzopsis asperifolia* | V24, V25 | 44 |
| *Vaccinium oxycoccos* | V20, V32 | 44 |
| *Arctostaphylos uva-ursi* | V5, V21 | 35 |
| *Vaccinium myrtilloides* | V5, V27 | 35 |
| *Hylocomium splendens* | V21, V24 | 28 |
| *Calamagrostis canadensis* | V21, V32 | 23 |
| *Ptilium crista-castrensis* | V10, V27 | 17 |
| *Agrostis hyemalis* | V26 | 1046 |
| *Aulacomnium palustre* | V31 | 235 |
| *Geocaulon lividum* | V18 | 147 |
| *Alnus rugosa* | V16 | 116 |
| *Apocynum androsaemifolium* | V16 | 116 |
| *Peltigera polydactyla* | V13 | 110 |
| *Acer spicatum* | V8 | 100 |
| *Shepherdia canadensis* | V15 | 72 |
| *Matteuccia struthiopteris* | V6 | 65 |
| *Corylus cornuta* | V17 | 55 |
| *Lonicera villosa* | V9 | 38 |
| *Eriophorum spissum* | V33 | 37 |
| *Sarracenia purpurea* | V33 | 37 |
| *Vaccinium ulignosum* | V33 | 37 |
| *Caltha palustris* | V20 | 29 |
| *Equisetum fluviatile* | V20 | 29 |
| *Larix laracina* | V20 | 29 |
| *Mitella nuda* | V20 | 29 |
| *Dicranum spp.* | V5 | 27 |
| *Prunus pensylvanicum* | V5 | 27 |
| *Amelanchier alnifolia* | V25 | 24 |
| *Anemone quinquefolia* | V25 | 24 |
| *Lycopodium complantum* | V25 | 24 |

| TABLE 8 Continued<br>Summary of Species Listed as Common Understory Species in the FEC<br>That were not Observed in the Field | | |
|---|---|---|
| **Species** | **V-Types that have the species listed as a Common Understory Species but the plots classified with these V-Types in the field did not contain these species** | **Total number of plots classified with the V-Types where the species was not observed** |
| *Trientalis borealis* | V25 | 24 |
| *Cladonia spp.* | V24 | 20 |
| *Pinus banksiana* | V24 | 20 |
| *Symphoricarpos albus* | V24 | 20 |
| *Smilacina trifolia* | V32 | 15 |
| *Ledum groenlandicum* | V10 | 9 |
| *Abies balsamifera* | V21 | 8 |
| *Aralia nudicaulis* | V21 | 8 |
| *Cladina mitis* | V27 | 8 |
| *Linnea borealis* | V21 | 8 |
| *Rubus idaeus* | V21 | 8 |
| *Rubus pubescens* | V21 | 8 |

Spearman's Rank Correlation was used to determine the amount of agreement between the FEC Common Understory Species and the species that were observed in the field for each V-Type. This statistic analyzes the amount of correlation between the rankings of the variables in the two datasets and not the correlation between the absolute values. Spearman's Rank Correlation calculates a value between −1 and +1 with +1 indicating a perfect correlation, -1 indicating a perfect negative correlation and zero indicating no correlation.

Before the analysis was performed, the Common Understory Species were reverse rank ordered so that these species could be evaluated quantitatively. In the FEC the Common Understory Species that are expected to be most frequently found in the field are cited in a sequence of declining order. Therefore, the reverse rank order was used to assign a number to the species so that the first species in the list of Common Understory Species would be associated with the highest value. The frequency values of the observed species were used to represent rank so that the species with the highest frequency had the highest rank.

Only 109 species out of the 250 that were observed were used in the analysis because the Spearman Rank Correlation requires an equal amount of variables in the two datasets that are being analyzed. Therefore, the species that were observed but not listed in the FEC were removed from the analysis and the species that were listed in the FEC but not observed were removed from the analysis.

Table 9 displays the results of the Spearman Rank Correlation analysis for each V-Type with respect to Common Understory Species. All of the correlations between the field V-Types and the FEC V-Types were positive with respect to vegetation species. This indicates that in general, the same ranking trend existed within the two datasets. If the correlations were negative, this would indicate that the rankings of species between the two datasets were opposite to one another (e.g. if one species was ranked high (common) in the FEC, the field data would display a low ranking (uncommon) for the same species).

**TABLE 9**
**Spearman Rank Correlations of V-Types using the Common Understory Species of the FEC and the Observed Species from the Field Data**

| V-Types | Spearman Rank Correlation Value |
|---|---|
| V5 | 0.467 |
| V6 | 0.307 |
| V7 | 0.632 |
| V8 | 0.283 |
| V9 | 0.366 |
| V10 | 0.404 |
| V13 | 0.369 |
| V14 | 0.347 |
| V15 | 0.24 |
| V16 | 0.424 |
| V17 | 0.459 |
| V18 | 0.324 |

| TABLE 9 Continued<br>Spearman Rank Correlations of V-Types using the Common Understory Species of the FEC and the Observed Species from the Field Data | |
|---|---|
| **V-Types** | **Spearman Rank Correlation Value** |
| V20 | 0.333 |
| V21 | 0.087 |
| V24 | 0.386 |
| V25 | 0.485 |
| V26 | 0.552 |
| V27 | 0.372 |
| V28 | 0.453 |
| V29 | 0.525 |
| V30 | 0.486 |
| V31 | 0.56 |
| V32 | 0.292 |
| V33 | 0.404 |

The correlations ranged from 0.087 for V21 to 0.632 for V7 and the average correlation was equal to 0.398. These correlations are not strong as none exceed 0.632 (an optimum correlation would be equal to 1). They range from a very weak and negligible correlation to a moderate level of correlation. It is important to note that only the species listed in the FEC as Common Understory Species, which were actually observed in the field were used in the Spearman calculations; so even with the extraneous species being eliminated, the correlations still are not strong. Taking into account that 141 species (out of 250) that were observed in the field were omitted from the analysis and that 56 species that were listed in the FEC as Common Understory Species were not observed at all, and also omitted from the analysis, indicates quite a weak correlation between the Common Understory Species listed in the FEC versus the actual species that were observed in the field.

Each of the 24 V-Types was assessed individually with respect to the agreement between the FEC listings of Common Understory Species and the species identified as common from the field data. The bar charts in Appendix G depict the frequency of each species per V-Type as a percent. The charts also indicate which FEC Common Understory Species were observed in the field. The Spearman Rank Correlations were used to compare the rankings of the observed species and the listed Common Understory Species for each V-Type.

## FRI and FEC Link

### Ecosystem Algorithm Assessment

The assessment of the Ecosystem Algorithm revealed that the algorithm was developed for use with a format of the FRI data that was different than the FRI data format used in the study. The algorithm used data that were in tiles while the study data were not in tiles. Tiles are commonly used in GIS when large amounts of data for a large geographic area exist, such as the FRI. They are a way of dividing the data into manageable pieces. Therefore, instead of having one large layer of data, smaller tiles of data are "cut" from the large dataset, which can be worked with individually and are more manageable. Adjustments to the algorithm programming code were made so that the algorithm would access the available FRI data properly. The modified version of the algorithm is presented as text in Appendix E.

The algorithm itself was written in Arc Macro Language, which is a computer program language that is only compatible for use within an ESRI Arc Info platform. For versatility, the algorithm could be rewritten to function using a more universal language, such as SQL.

Observations of the FRI Covertypes and Subtypes revealed that four of the possible 70 Subtypes were not addressed or interpreted in the algorithm. The missing Subtypes were 08, 09, 48, and 49 and all refer to Scots Pine stands. None of these

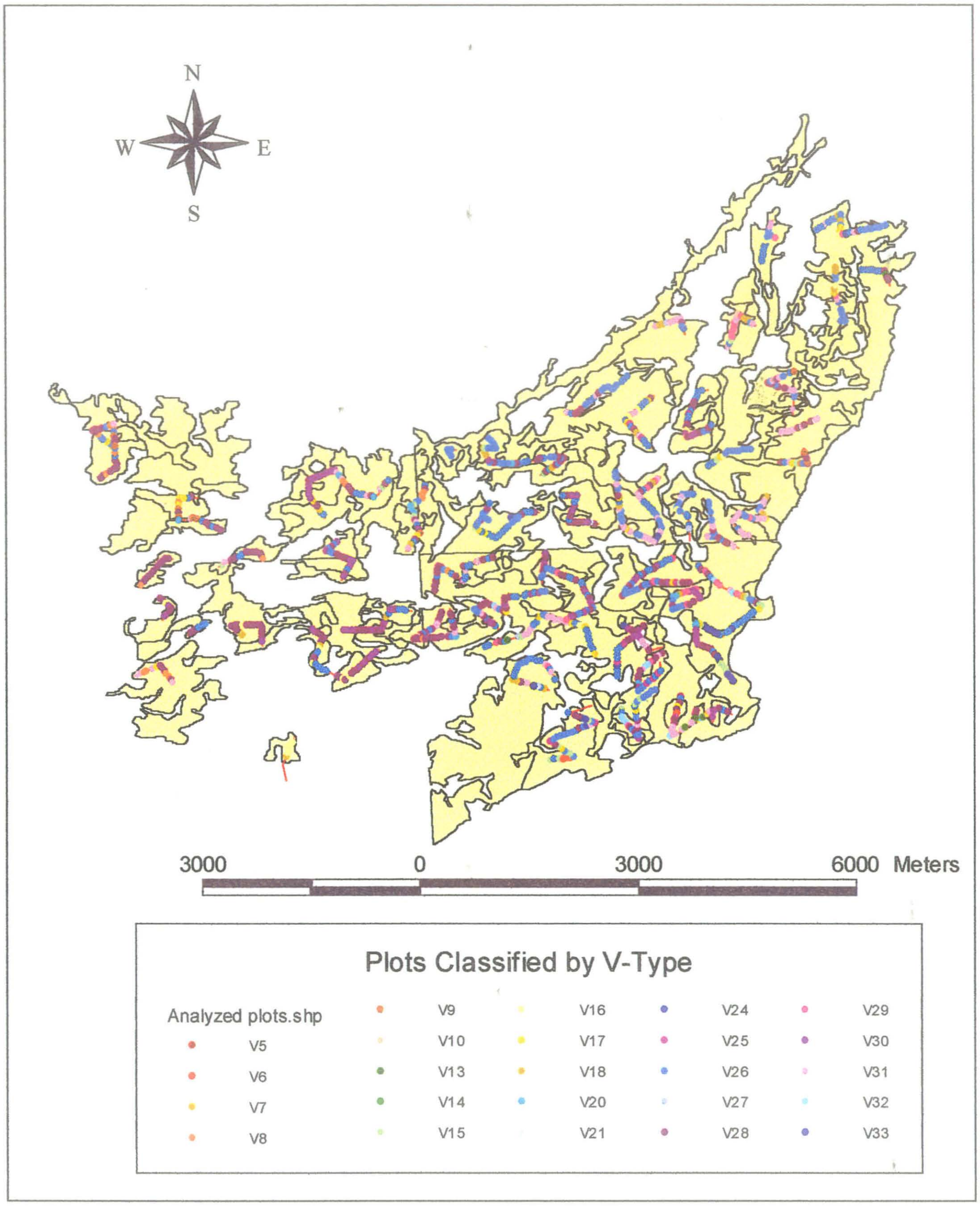



Figure 14. Beaver Creek Plot V-Types Overlaid on the FRI

The most common V-Type found in each polygon was then assigned as the "dominant" V-Type for that polygon. The dominant V-Type was used to represent a rough approximation of the ecosystem type within each polygon. The dominant V-Type was determined by calculating which V-Type occurred most often within a polygon. A total of 19 dominant V-Types from the field data were assigned to the study polygons, with the most abundant being V26 with 54 polygons, followed by V28 in 24 polygons.

A single dominant V-Type for 38 polygons could not be identified because more than one (up to three) were tied to be the most abundant for these polygons. All of the dominant V-Types for a single polygon were noted and the tied dominant V-Types were then compared to the algorithm V-Types for each polygon.

After the assessment of the theme layers, the V-Type classifications of the algorithm were compared to the V-Type classifications from the field for each polygon.

## Results of Algorithm Classifications

The ecosystem algorithm was applied to the FRI data for the study area and V-Type classifications were assigned to each polygon. Ten different V-Types and "unk" were classified for the 196 polygons. The frequency for each of the V-Type assignments is presented in Table 10.

| TABLE 10<br>Frequencies of the Algorithm<br>V-Type Interpretations | |
|---|---|
| **Polygon Interpretation** | **Number of Polygons Interpreted** |
| unk | 23 |
| V6 | 1 |
| V9 | 16 |
| V15 | 13 |
| V17 | 3 |
| V20 | 7 |
| V21 | 1 |
| V24 | 16 |
| V28 | 65 |
| V29 | 12 |
| V30 | 39 |
| Total | 176 |

Subtype 99 resulted in classifications of "unk" because these stands are not hardwoods as defined in the algorithm; they actually represent areas that are non-productive forested land or non-forested land (water, muskeg, beaver floods etc.). In the FRI data, the Subtypes involving 99 are just a combination of 99 plus the Land_ID, such as 701, that results in the five-digit code (e.g., 99701). Because there are no species associated with Subtype 99, the algorithm cannot interpret this code and results in a classification of "unk".

It is notable that V26 was never assigned to any of the polygons by the algorithm, especially since it was the V-Type that was classified the most in the field plots. The algorithm logic was supposed to interpret Land_ID equal to 711 (Jack Pine Treed Rock) and 712 (Black Spruce Treed Rock) as V26. Three polygons with a Land_ID equal to 711 and one with 712 existed in the FRI data of the study areas. These polygons did not contain any species information and had a Subtype equal to 99;

therefore, based on the Subtype information, the algorithm skipped over the Land_ID interpretation and assigned "unk" to these polygons. Another downfall of the algorithm regarding V26 was that no other provisions aside from the interpretation of the Land_ID of 711 and 712 were made for classifying V26. Any Land_ID from 700 to 799 is considered to be "unproductive forest" in the FRI. The majority of V26 stands sampled were productive, which are not accounted for by the algorithm.

None of the interpretations that were dependent on Land_ID were interpreted correctly, based on the algorithm logic. The Land_ID equal to 701, 702, 711, and 712 were supposed to result in a direct interpretation of a V-Type. All of the 17 polygons with these Land_IDs had Subtypes of 99 and consequently no species information. Therefore, like with V26, the algorithm skipped over the Land_ID interpretation and assigned "unk" to these polygons based on the absence of species.

## V-Type Comparison for Agreement

An error matrix was created to assess the agreement between the algorithm V-Type classifications and the dominant V-Type classifications for each polygon (Table 11). In general, the V-Type classifications from the algorithm and the field data did not strongly agree. For the classification of V-Types using the algorithm and the dominant V-Types for each polygon, a total of 25 out of 156 classifications were in agreement (16.03%). Four V-Types (V20, V28, V29, V30) had polygon classifications that agreed between the two datasets.

Table 11. Error Matrix of Classifications for Algorithm V-Types and Dominant V-Types

| | V-Types Classified from Ecosystem Algorithm | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dominant V-Types per Polygon | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V8 | V9 | V10 | V11 | V12 | V13 | V14 | V15 | V16 | V17 | V18 | V19 | V20 | V21 | V22 | V23 | V24 | V25 | V26 | V27 | V28 | V29 | V30 | V31 | V32 | V33 | unk |
| V1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V6 | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| V7 | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| V8 | | | | | | | | | 2 | | | | | | 1 | | | | | | | | | | | | | 2 | | | | | | |
| V9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| V10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V13 | | | | | | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | |
| V14 | | | | | | | | | 2 | | | | | | | | | | | | 1 | | | | | | | | 1 | | | | | |
| V15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | 1 |
| V16 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 1 | | | | | 2 |
| V17 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| V18 | | | | | | | | | 1 | | | | | | 1 | | 1 | | | | | | | | | | | 4 | 1 | | | | | |
| V19 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V20 | | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | 2 |
| V21 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V22 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V23 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V25 | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V26 | | | | | | | | | | | | | | | 5 | | 1 | | | 1 | | | | 8 | | | | 26 | 3 | 2 | | | | 6 |
| V27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V28 | | | | | | | | | | | | | | | 1 | | | | | | | | | 5 | | | | 14 | | 3 | | | | 1 |
| V29 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| V30 | | | | | | | | | | | | | | | | | 1 | | | 3 | | | | 1 | | | | 1 | 1 | 8 | | | | 4 |
| V31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 3 | 9 | | | | 3 |
| V32 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| V33 | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | 3 | | | | 1 |

Total number of classifications: 156

Indicates Classification Agreement

Number of classifications that agree: 25

Agreement = 16.03%

The 38 polygons that were identified as having co-dominant V-Types were compared to the algorithm derived V-Types. If any of the V-Types identified as co-dominant for a polygon agreed with the algorithm V-Type, a match was noted. A match was observed within six polygons, with five of them involving classifications of V28 and one of V30. An agreement of 15.8% was achieved using the co-dominant V-Types.

## Chapter Summary

The comparisons of the Common Understory Species in the FEC and the observed species from the field data indicated generally a weak correlation between the two datasets. The Spearman Rank Correlation values were weak to moderate and a total of 56 species that were listed in the FEC as Common Understory Species were not observed at all in the field in plots classified with their respective V-Types.

The assessment of the algorithm indicated that ten of the possible 33 FEC V-Types were not interpreted at all in the algorithm. The classification assessment revealed that only four V-Types had classifications that agreed between the two datasets and that the algorithm V-Type classifications resulted in very low agreement (16.03%) with the field data V-Types. These results are interpreted and discussed in the next chapter.

*Chapter 5*

# DISCUSSION OF THE FRI/FEC LINK AND THE COMMON UNDERSTORY SPECIES

## Utility of the Common Understory Species

The Common Understory Species of the FEC were assessed for agreement with the understory species that were observed in the field study (Appendix G). In general, the majority of species listed as Common Understory Species were observed in plots classified with their respective V-Types. A range existed in how frequently each of the species was observed, but generally the Common Understory Species that were also observed in the field data were clustered in the top 50% of the most frequently observed species for each V-Type. For each V-type, generally no more than two species, including the Common Understory Species, were observed more than 50% of the time. Most of the species were observed less than 10% of the time. These results indicate that a wide variety of species were observed (250 in total) in an array of V-Types.

None of the V-Types were found to have Common Understory Species that truly represented the species found in the field with each V-Type. To be Common the species would be expected to be present in plots classified with their respective V-Types than in plots classified as other V-Types. In addition, their Spearman Rank Correlations were not strong between the observed species and the FEC Common Understory Species. A correlation of one would be expected because the FEC was used to classify each plot and then the vegetation in those same plots were used to evaluate the FEC Common Understory Species. The lack of a correlation between the frequently observed species and the FEC Common Understory Species could be attributed to the original data collection and classification methods of the FEC. When the Manitoba FEC was developed, a dedicated sampling and research program specific for classifying Manitoba's forest ecosystems was not implemented (Zoladeski *et al.*, 1995). Instead, the FEC of Northwestern Ontario (Sims *et al.*, 1989) was used as a template and modified using scattered data that were gathered from various sources for small portions of Manitoba (Zoladeski *et al.*, 1995). For many of the Manitoba V-Types, small sample sizes of data were used for testing the Ontario classifications for Manitoba applicability. Some of the classification sample sizes were as small as five plots, which is not a reliable sample size. As well, the information sources varied, so the data from the different authors were inconsistent and uneven emphases on different ecosystem components was apparent (Zoladeski *et al.,* 1995). The FEC authors were aware that shortcomings and limitations are apparent in the FEC, "It is anticipated that territorial sampling gaps will be systematically filled-in in the future and that the system will be periodically updated as new data become available" (Zoladeski *et al.*, 1995).

The Common Understory Species of the Manitoba FEC may not be indicative of the Manitoba forest ecosystems because the Northwestern Ontario FEC was used as a model and different conditions exist in Manitoba and Ontario. Of course, a distinct break in ecosystems does not occur at the border between Manitoba and Ontario but an ecological gradient does exist between the two provinces. This difference in forest types is apparent in the boreal forest ecoregions that exist within the two provinces (Figure 4).

So, the Common Understory Species that are listed for each V-Type in the Manitoba FEC may be more representative of Ontario conditions that Manitoba conditions.

The lack of a strong correlation between the FEC Common Understory Species could also be attributed to the broad area of Manitoba for which the FEC is supposed to be applicable. Only 33 V-Types with a handful of Common Understory Species are supposed to "identify and describe accurately the major forest conditions in the commercial forest areas in the Province of Manitoba (Zoladeski *et al.*, 1995). Manitoba has a great expanse of forestland with a variety of land types (15 ecoregions) so it is not surprising that the FEC Common Understory Species are not truly representative of the study area. But since the focus of this study was confined to a relatively small study area in eastern Manitoba (which has more similar conditions to Ontario, and likely the Northwestern Ontario FEC, than other parts of Manitoba), the FEC classifications and Common Understory Species should be applicable. In addition, the study area for this project coincided directly with the location where specific samples were collected for developing the Manitoba FEC (in the Manitoba Model Forest area). Therefore, the Manitoba FEC should operate the best in the study area since it was a main source of input in development of the FEC classifications.

The species that were frequently observed were regularly observed across most of the V-Types. *Pleurozium schreberi* and *Cornus canadensis* were very common and were observed with every V-Type. *Aralia nudicaulis*, *Clintonia borealis*, and *Maianthemum canadense* among a variety of other species were also common with most V-Types. Therefore, it appears that the species that were observed frequently are generally common as boreal forest plants rather than as common plants representative of V-Types. Of course, some species will be more indicative of ecosystem types than others, but in general, boreal species exist in a wide variety of forest ecosystems. Due to this adaptability for various ecosystems and constant environmental changes, the Common Understory Species should not be used as true indicators of a V-Type, as mentioned in the FEC (Zoladeski *et al.*, 1995). The overstory species are the major identifying factors of V-Type and Common Understory Species should be used only to augment and clarify the V-Type classification.

Of more concern than the observed Common Understory Species, are the species that were listed as Common Understory Species that were not observed in the field study (Appendix G). A total of 56 Common Understory Species within 23 V-Types were not observed. Even in the V-Types with large sample sizes (e.g. over 1000) some of the listed Common Understory Species were not observed. The Common Understory Species are listed in the FEC in declining order with the most frequently found cited first. The Common Understory Species that were not observed were not always listed last in the FEC, but appeared in various locations throughout the listings. Therefore, the rankings and order of the Common Understory Species should not be rigorously relied upon for identifying the species that are expected to be most common. The low Spearman Rank Correlations also support this fact that the rankings in the FEC do not match the frequency of the species in the field.

This anomaly of not observing the species identified as Common in the FEC may be attributed to the fact that the study data were used from a selected area of eastern Manitoba, which may not be representative of the entire province. Manitoba comprises several different forest regions (e.g., Canada's Forest Regions, Figure 1) so the FEC may be more applicable elsewhere. The Manitoba FEC sampling locations were not selected from equal portions of the province so the FEC may be more accurate for regions that were sampled more fully. Therefore, in other regions of the province, the Common Understory Species may be more representative of their associated V-Types.

The FEC is supposed to be applicable for the commercial forest areas of the entire province so it should not fail in some regions and be valid in others. Different forest types are expected in different regions of the province and the FEC contains a range of V-Types, from hardwoods to softwoods. The V-Type fact sheets should be representative of the different areas, since the FEC is a Manitoba field guide and not a region-specific field guide. The Common Understory Species cannot be relied upon as representative of the V-Types for which they are associated.

## FRI/FEC Link

The Ecosystem Algorithm was applied to the FRI data to reinterpret an FEC V-Type for the forest stand polygons. The V-Type information collected in plots in the field was compared to the V-Types assigned to the polygons by the algorithm. A strong agreement between the two datasets for the V-Types classified for each polygon was not found. An agreement of only 16% was achieved using the dominant V-Types for each polygon compared to the algorithm-derived V-Types. With such a low agreement between datasets, the existing algorithm cannot be relied upon for adequately classifying polygon V-Types.

Five potential factors could account for the discrepancies between the classifications from the field data and the algorithm:

1. Logic errors in the algorithm
2. GIS errors
3. Errors in the field data
4. Incorrect information in the FRI data

5. Lack of a strong correlation between FRI data and the FEC V-Types.

## Algorithm Logic Errors

The first cause for classification discrepancies could be attributed to errors in the logic in the algorithm. Incorrect logic would result in the data being misinterpreted and a wrong classification assigned to a polygon. Several problems with the algorithm were noted. The algorithm did not have provisions for classifying all of the 33 possible V-Types. Seven V-Types were not addressed in the algorithm at all. A total of 512 plots were classified in the field with one of these missing V-Types and 19 polygons had these V-Types as dominant. Therefore, these 19 polygons did not have a chance to be interpreted correctly or agree with the field V-Types, which account for almost 10% of the polygon classifications.

The algorithm also amalgamated the interpretation for some V-Types; specifically V24 and V25 were combined, as well as V30, V31, and V32. From these combinations, V25, V31, and V32 were not classified by the algorithm, which were assigned to 17 polygons as dominant. This type of error can account for approximately 9% of the classification disagreement, which was calculated by simply dividing the number of polygons (17) by the total number of polygons that were classified (176).

Another logic problem with the algorithm was the misinterpretation of 17 polygons with Land_ID information equal to 701 (Black Spruce Treed Muskeg), 702 (Tamarack Larch Tree Muskeg), 711 (Jack Pine Treed Rock), and 712 (Black Spruce Treed Rock). All of the interpretations that were supposed to rely on these Land_IDs were misinterpreted as "unk", instead of their direct V-Type conversions. The misinterpretation of these 17 V-Types results in almost 9% of the classification disagreement.

In the algorithm, Subtype 99 is defined to represent hardwoods, which would result in a classification of V3. However, the FRI data uses Subtype 99 to represent areas not defined with species. Therefore, hardwood polygons that should have been interpreted with V3 were assigned "unk" because of the lack of species information to classify. In the field data, no plots were classified as V3 so the misinterpretation of Subtype 99 for hardwoods was not an issue. If the algorithm was to be used in areas where hardwoods exist, the algorithm logic would have to be edited to correctly interpret Subtype 99.

## GIS Errors

Spatial errors in the data could be possible in that the location of the collected data could have been misrepresented in the GIS. For instance, the plot locations in the GIS may have not been accurately placed in the context of the study area. Spatial errors in the GIS are not a significant factor because the plot locations within the polygons were confirmed with the timber cruise maps. As well, the precise location of the plot in nature was not as important as having the plots in the correct polygons in the GIS.

## Field Data Errors

The V-Types that were classified for each plot in the field were used as a standard and the algorithm classifications were compared against them. These field classifications were assumed to be correct interpretations of the landscape, relative to the FEC key. However, incorrect plot classifications may have resulted in less than optimal agreement between the algorithm and field classifications.

Since the FEC key requires a subjective interpretation of the forest stand by the data collector, different people could interpret the same stand differently and arrive at different V-Types. In addition, it is possible that the field crews may have misinterpreted stands with potentially similar V-Types. With over 3000 classified plots and the amalgamation of plot V-Types into a dominant V-Type for each polygon occasional errors in V-Type assignments would be negligible.

The field crews collecting the original data for use in the FEC development may have also contributed some errors. They would also have to rely on subjective decisions about forest characteristics in developing the classification key. For example, the percentage amount of a given species within a quadrat is difficult to identify accurately. Therefore, the FEC may have been developed with errors from the original data collection crews.

The actual locations of where the data were collected by the field crews may have contained errors. The field crews decided where the transect lines and plots should be located based on a map and compass. Since a GPS was not used, slight errors in the exact position of the data are possible. For example, the plot locations in the GIS required slight adjustments from their strict 50 m placements by the GIS script. The maps created by the field crews indicated where the data were actually collected relative to the FRI stand polygons. The plots were moved within a few meters of their original 50 m positions to reflect where the data were actually collected. The anomaly of data not being collected rigorously at exactly 50 m intervals would not however have resulted in any significant errors because the plots were used to evaluate entire polygons rather than individual micro-ecosystems.

The errors in the field data were probably not major contributors to the classification disagreements. In the field, only two people were classifying the plots with V-Types. These people were experienced and trained in using the FEC key and interpretations. They also had worked previously in collecting field data within the study area, so they possessed a good knowledge of the landscape conditions and the FEC system.

The areas of where the data were collected could contribute to disagreement in V-Type classifications. Not all of the polygons in the study areas were represented equally by the transect lines or plots. Some of the polygons were sampled extensively with a large number of plots that traversed through the majority of the polygon, while other polygons were only sampled with a small number of plots. The polygons with a small number of plots may have been represented incorrectly by their low number of assigned V-Types. However, a single V-Type was needed for each polygon and the dominant V-Type was used as a first approximation of ecosystem type in each polygon. The variety of V-Types recorded within a single polygon indicates that each polygon is not a uniform tree stand, at least with respect to the operational scale of the FEC.

## FRI Data Errors

The FRI information is derived through aerial photo interpretation and timber volume sampling. Field checks of the aerial photo interpretation are not directly conducted but are updated from timber volume sampling data. Errors can result in the information by misinterpretation of the aerial photos and/or incorrect polygon delineation of tree stands. Therefore, disagreement between the algorithm V-Types and the field data V-Types may have been attributed to incorrect FRI cataloging.

## Lack of Correlation between the FRI and FEC

The information contained within the FRI was assumed to be correct in that each polygon represented a homogeneous classification with respect to stand composition. A single V-Type (i.e., a dominant V-Type) could then be assigned to each polygon as an approximation of ecosystem type for that polygon. From the field data, it was evident that each polygon did not represent a uniform stand from the variety of V-Types assigned within one polygon. An example of this V-Type heterogeneity can be seen in Figure 14, where several plot V-Types were classified within the polygons. The variety of V-Types recorded within a single polygon indicates that each polygon is not a uniform tree stand, at least with respect to the operational scale of the FEC.

The heterogeneity of polygons that was represented by the various V-Types within one stand indicates that the polygon delineations are too big for reinterpretation of a single V-Type. That is, the FEC operates at a finer scale than the FRI and essentially requires an assessment of every tree within the 10 m by 10 m plot to determine the appropriate V-Type. Although the FRI utilizes approximately 70 different Subtypes for describing tree stands, they are applied to larger areas than the FEC system. So a stand may be homogeneous with respect to a classification on a broad scale, but when plots of 10 m by 10 m are assessed within the stand, a patchwork of classifications emerge. Thus, a variety of V-Types can be assigned within a single polygon.

A Geomatics (1995) study in the Manitoba Model Forest investigated the possibility of re-interpreting the FRI with V-Types using 1:15 840-scale color infrared photography. The process involved analyzing the forest stands for species composition in the infrared photographs by using a key to derive a V-Type: "Results of the project have demonstrated that a finer interpretation of the landscape is possible and that interpretation of the Manitoba FEC V-Types is readily accomplished. The finer interpretation results in smaller and more numerous polygons when compared with existing forest inventory polygons" (Geomatics International Inc., 1995). These findings support the fact that the FRI polygons are not homogeneous units at a scale equal to that used in the FEC.

From the Geomatics results and the variety of V-Types recorded within the study polygons, trying to apply a single V-Type to a polygon is not feasible. This type of classification of a polygon results in a loss of information about the polygon. More specifically, a single V-Type cannot be trusted to be representative of the entire polygon. As well, the FRI polygon descriptions are based on overstory species, whereas the FEC V-Types also rely on understory species for classification, which are just not available in the FRI data.

## Ecosystem Classification Options

Although the algorithm failed to be a useful and reliable tool for assigning V-Types to the FRI polygons in the study area, the need still exists to map ecosystems at this scale. Three solutions exist for creating an inventory of ecosystem types for Manitoba using the FEC and FRI systems:

1. Reinterpret the FRI with V-Types using infrared photo interpretation as described by Geomatics International (1995).

2. Develop a GIS algorithm that interprets the FRI data and reinterprets groupings of V-Types, rather than individual V-Types.
3. Systematically sample areas of the province and assign V-Types to the stands using the FEC key.

## Infrared Photo Interpretation

As described by Geomatics International (1995), finer polygon divisions of the FRI can be achieved than what is currently available. By analyzing infrared photographs, one can define V-Types within the existing polygons using a classification key. The degree of accuracy of this method is unknown but Geomatics International (1995) found in a pilot test that this approach worked well for separating hardwoods and softwoods, for identifying treed rock, bare rock, treed muskeg and open muskeg, and separating tamarack and black spruce. The results also indicated that hardwood species could not be distinguished, the percent composition in Jack pine and black spruce stands was difficult to estimate, and black spruce, white spruce and balsam fir were not distinguishable in mixed stands. This method requires a photo interpreter to review almost every tree in the forest on the photos, so it would be time consuming and costly. This option does not address the initial issue of this study which was to find an improved efficient method for classifying ecosystems than what is currently available.

## Algorithm for Grouped V-Types

Another possibility for developing an ecosystem map for Manitoba involves using an algorithm that interprets FRI information, but instead of using individual V-Types, logical V-Type groups could be assigned to each polygon. The groupings of V-Types would involve broader descriptions and likely be more representative of the existing polygons. The detailed interpretations of the 33 V-Types would be lost but a general overview of the Manitoba's ecosystems would be achieved. Admittedly, this option does not offer much improvement over the current FRI system for inferring information about the forest ecosystem.

The FEC includes "Overview Groupings" of the FEC V-Types for generalizing different forest characteristics (Zoladeski *et al.,* 1995). A total of eleven groupings exist, which are based on their floristic, physiognomic, soil, and site characteristics. These Overview Groupings could be used in the algorithm. Such an algorithm should be developed using a universal computer language that is flexible in a variety of platforms. Therefore, different users could employ the algorithm for different purposes.

## V-Type Sampling Across Manitoba

By systematically assessing sample plots and classifying V-Types for them, a comprehensive and accurate inventory of Manitoba's forest ecosystems could be attained. This method would ensure that tree stands were being interpreted correctly because each V-Type would be classified as it was intended – in the field. This type of V-Type classification for the province would be very slow and costly but could be joined with data collection efforts already in place, such as volume sampling for the FRI. This method is currently being realized as each forestry company has begun collecting FEC information during their pre-harvest assessments. The FEC information is then compiled in a central provincial database.

## Chapter Summary

The FEC Common Understory Species were evaluated for actual "commonness" in the field and usability for aiding V-Type classification. The results of the assessment indicate that the Common Understory Species are not good indicators of the V-Types they are supposed to represent and should not be solely relied upon for classifying V-Types in the field. The main cause of the lack of correlation between the FEC Common Understory Species and the observed species in the field is probably attributable to the methods used in developing the Manitoba FEC classification system. That is, a dedicated research, sampling, and quantitative classification program was not implemented. The Northwestern Ontario FEC system was used as a basis for the Manitoba classifications that were rudimentarily confirmed with fragmented data from various sources in localized areas across the province. This weak methodology for developing the classification system is evident in the Common Understory Species, which were not found to be common.

The option of linking the FRI and FEC systems using a GIS algorithm failed as a reliable resource for classifying Manitoba's ecosystems. The failure was mainly attributed to voids and errors in the algorithm logic so that not all V-Types could possibly be classified, as well as problems in the correlations between the FRI and FEC systems. That is, the FRI operates at a larger scale and involves less forest information than the FEC so trying to interpret more information (V-Types) out of minimal information (FRI polygon data) results in incorrect classifications.

*Chapter 6*

# CONCLUSIONS AND RECOMMENDATIONS

The main intent of this research was to improve the state of forest ecosystem classification in Manitoba by reviewing the current forest ecosystem classification systems and analyzing a GIS alternative. Through this research the state of forest ecosystem classification in Manitoba has been improved, as a greater understanding of the strengths and weaknesses of the current classification practices has been gained. A review of the current forest ecosystem classification systems was conducted, an alternative classification technique was evaluated, and the effectiveness of the Common Understory Species of the FEC was assessed. The implications of the research findings related to these activities are discussed below.

In reviewing the various options available in Manitoba for forest inventory and ecosystem classification, the advantages and disadvantages of the systems were identified. From this review, it was concluded that from a management perspective, an ecosystem classification system that is applicable at the tree stand level does not currently exist in Manitoba. The most commonly used systems to fill in this gap are the provincial Forest Resources Inventory (FRI), which does not contain comprehensive ecosystem information, and the Forest Ecosystem Classification (FEC), which is not provincially applied.

This lack of a provincially-based ecosystem classification system was the impetus behind the assessment of an alternative option for developing a first approximation ecosystem map by linking the benefits of the FRI and FEC systems using a GIS algorithm. The algorithm was successful in classifying the FEC polygons with FEC V-Types, but the accuracy of the classifications was too low to be relied upon. From the use of this algorithm, it was found that the scale of the two systems differs too much for a direct reclassification between the FRI and FEC. Therefore, the FEC should not be used as a provincial ecosystem mapping tool and should only be used for the purpose that it was intended: for classifying forest sites in the field. Since the algorithm was not successful in reclassifying the FRI polygons, the Null Hypothesis was accepted: the FRI polygons and descriptions cannot be reinterpreted with a FEC V-Type that matches the V-Types classified in the field.

In considering the applicability of the Common Understory Species of the FEC V-Types within the study site, it was noted that the listed species were not accurate representations of the species in the field. The species listed in the FEC were compared with the species recorded in the field and it was found that generally a poor correlation existed. A total of 56 species that were listed were not observed at all in the V-Types for which they were supposed to be indicators. The Spearman Rank Correlation also confirmed that the species observed in the field did not match the species listed in the manual as none of the correlations were greater than 0.632. The conclusion from these results is that the understory species listed in the FEC are not good indicators of V-Type and cannot be relied upon as an aid in classifying a site. Site classification is dependent on the overstory as well as the understory species, so the accuracy of the overstory species as indicators requires confirmation before a conclusion can be drawn regarding the applicability of the V-Types in general. In general, classification systems and the conventions used should be tested sufficiently prior to implementation so that they are statistically significant and defensible. Since the FEC Common Understory Species were not indicative of the common species found in nature, the Null Hypothesis was accepted: the understory vegetative species that were observed in tree stands classified as a certain V-Type are not the same as the Common Understory Species listed in the FEC for that V-Type.

From this research, the current state of forest ecosystem classification in Manitoba was shown to be less than optimal due to the following causes:

- The FRI fails to represent ecosystems since it was only intended as a timber management tool and not as an ecosystem classification tool
- Flaws in the FEC system exist, such as the misrepresentation of "common" Manitoba species and incomplete ecosystem types, such as pure balsam fir stands
- There is a lack of widespread ecosystem maps for use in resource management, conservation initiatives, environmental assessment and other applications.

These shortcomings were identified during the research project, which can be used as stepping-stones for identifying a better classification system for this province. The failures of the current systems have been identified, such as the discrepancies in Common Understory Species and the incompatible scale for a FRI-FEC link, which can then be ruled out as useful ecosystem classification tools. This information can be used to build upon for developing new ecosystem classification systems and techniques, such as Manitoba's ecosites. However, Ruta (2002) found difficulty in applying the ecosite classification system in the field, which leads to the conclusion that all classification systems require verification prior to implementation. New systems should be tested rigorously for applicability in their intended area and for how well they meet the needs of the intended users.

## Recommendations

Based on the conclusions and results of the study, the following recommendations were developed:

- The Ecosystem algorithm V-Type classifications of the FRI polygons do not strongly agree with V-Types classified in the field data. As it exists, the algorithm cannot be relied upon for reliably classifying the FRI polygons with FEC V-Types and an alternative method for classifying forest ecosystems on a broad scale should be investigated.
- The FRI polygons are not homogeneous units with respect to the operational scale of the FEC. The polygon scale contains too much information for one V-Type classification, which results in misrepresentation of the polygon. Therefore, attempting to use the FRI data as a basis for interpreting the 33 FEC V-Types is not feasible and other methods should be developed for classifying forest ecosystems.
- A review of the 33 FEC V-Types is required to determine the effectiveness of the V-Type classifications in Manitoba.
- The Common Understory Species listed for the FEC do not accurately represent forest conditions in the field and should not be rigorously relied upon as indicators for classifying V-Types. The Common Understory Species in the FEC should be reviewed for applicability across the province and amended as necessary.

- To improve the functionality of using understory species as V-Type indicators, the species that were unique, rather than common to each V-Type should be used. By focusing on species differences between V-Types and uniqueness of V-Type species, classification would be more reliable and the species could be used as indicators of V-Type rather than frequent components of several V-Types.
- A V-Type to describe pure balsam fir stands does not exist within the Manitoba FEC, which is problematic because pure balsam fir stands exist in Manitoba. Therefore, a new V-Type should be developed for the FEC that addresses pure balsam fir stands. As well, the FEC should be supplemented with information and classifications that are applicable to all forested areas of the province.
- Sampling should be conducted in areas of the province that were neglected in the development of the FEC. New information could be used to refine existing classifications and potentially produce new ones.
- The Manitoba FEC was created using the Northwestern Ontario FEC as a template and classifications were checked for applicability in Manitoba by reviewing forest data from various sources. A dedicated research program for classifying Manitoba's forest ecosystems was not undertaken and consequently several shortcomings of the FEC exist. An entirely new approach from the FEC is required to classify Manitoba's forest ecosystems accurately using a dedicated sampling and research program. Development of Manitoba's ecosites is one potential option to move beyond the limitations and shortcomings of the Manitoba FEC.

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| Term | Definition |
|---|---|
| Physiognomy | The general appearance of a landscape, situation etc. |
| Polygon | An area of a tree stand delineated on a map of the Forest Resource Inventory. |
| Pre-harvest Assessment | A forest survey conducted in areas planned for harvest. Collected information includes ecological and cultural parameters. |
| Sere/ Seral Stage | The sequence of communities in successions is termed a sere and each stage seral. |
| Silviculture | The theory and practice of controlling the establishment, composition, growth, and quality of forest stands to achieve the objectives of management. |
| Snag | A standing dead tree from which the leaves and most of the branches have fallen. |
| S-Type | 22 soil types of the Forest Ecosystem Classification for Manitoba. |
| Stand | A community of trees possessing sufficient uniformity in composition, age, arrangement, or condition to be distinguishable from the forest or other growth on adjoining areas, thus forming a silvicultural or management entity. |
| Subtype | The species composition of the FRI in broad groups within the cover type. It is indicated by the first two digits in the FRI descriptions. |
| Succession | The gradual supplanting of one community of plants by another. |
| Timber Cruise | Surveying the forest for merchantability; data collected includes diameter at breast height, tree species, and tree height. |
| Understory | A lower stratum or layer in a plant community; in forests. |
| Vegetation Type Fact Sheet | Descriptive information for each of the 33 V-Types of the Forest Ecosystem Classification for Manitoba. |
| V-Type | Vegetation Type. Name given to one of the possible 33 forest ecosystem classifications of the Forest Ecosystem Classification for Manitoba. |

*Appendix B*

## LIST OF ACRONYMS

| Acronym | Definition |
|---|---|
| CanFI | Canada's Forest Inventory |
| CCELC | Canada Committee on Ecological Land Classification |
| CCFM | Canadian Council of Forest Ministers |
| CLI | Canada Land Inventory |
| DBH | Diameter at Breast Height |
| FEC | Forest Ecosystem Classification |
| FRI | Forest Resources Inventory |
| GIS | Geographic Information System |
| S-TYPE | Soil Type – used in the Forest Ecosystem Classification System |
| V-TYPE | Vegetation Type – used in the Forest Ecosystem Classification System |

*Appendix C*

## PRE-HARVEST ASSESSMENT METHODOLOGY

Detailed vegetation surveys for vegetation under 1 m in height are conducted to provide information as to the number of species and the relative quantity of each of these species. The ground vegetation cover composition is surveyed using the Daubenmire (1959) method to determine the canopy-coverage of species. In this method, the relative percent coverage of each species growing within each 0.25 $m^2$ quadrat is estimated using a series of percentage intervals (0-5, 5-25, 25-50, 50-75, 75-95, 95-100%) as set out by Daubenmire. All vegetation found rooted within the 0.25 $m^2$ quadrat is recorded and classified to genus and species wherever possible. Each plant species identified is checked against the current Committee on the Status of Endangered Wildlife in Canada (COSEWIC) lists to ascertain their status (if any) as vulnerable, threatened or endangered. All species are also checked to see if they were listed as protected under the Manitoba Endangered Species Act.

The shrub strata (includes species that are 1 m to 10 m in height) is measured using the line-intercept method described by Smith (1980). The line-intercept is one-dimensional and is most useful for sampling shrub stands and the woody understory of the forest. The line-intercept method consists of taking observation on the transect at the 50 m intervals. For each interval, the plant species found and the distance they covered along that portion of the line-intercept are recorded. Only those plants touched by the line or lying under or over it are considered. For shrubs or small trees, the shadow distance or distance covered by a downward projection of the foliage above is used.

Wildlife data are collected concurrently with the vegetation surveys using a modified version of the protocol developed by the Manitoba Forestry/Wildlife Management Project under the auspices of Manitoba Natural Resources. Animal use along the transects is recorded to aid in the identification of any potentially sensitive wildlife areas. A millihectare plot is used at each interval along the transect to collect these data. Avian fauna information is collected in a slightly different manner even though the same transects are used. Bird listening posts are established every 200 m along the transect. At each of these points a period of five minutes is used to listen for any and all identifiable bird species. All other pre-harvest data are also collected at these listening posts as well. At the other 50 m intervals where no listening posts are established, the crew records any incidental bird species they happen to hear.

Similar to wildlife data, information regarding forest health (new for 1998 field season), renewal prescriptions, cultural/heritage resources and Forest Ecosystem Classification V-Types and S-types is collected using a millihectare plot at each 50 m interval along the transect. (Fraser *et al.*, 1998).

# PRE-HARVEST ASSESSMENT RECORDING SHEET

*(source: Fraser et al., 1998)*

## PLOT INFORMATION

QUADRAT # ____ LINE #: ____ TWP: ____ DATE: ____ LINE NO.: ____

BLOCK NO: ____ LOCATION: ____ CREW: ____

### Ground Cover Vegetation

1 (0-5%); 2 (5-25); 3 (25-50); 4 (50-75); 5 (75-95); 6 (95-100)

| SPECIES | % Cov |
|---|---|
| | |

### Line Intercept Data

| SPECIES | cm |
|---|---|
| 1.0-2.0 m | |
| 2.0-10.0 m | |

### Browse Data

low (1-5 stems); medium (6-20 stems) high (>20 stems)

Browse Intensity:

Species Browsed:

### Snag Presence

low (1-2); medium (3-5); high (>5); none

Snags:

Avg DBH (ocular estimate): cm

Softwood ______ Hardwood ________

### Downed Woody Debris

low (0-5%); medium (6-25%); high (>25%) - based on % ground cover estimate

Debris:

Avg DBH (ocular estimate): cm

Softwood ______ Hardwood ________

### Small Mammal Sign

Observations:

### Large Mammal Sign

Observations:

### Forest Health

Pest DM SC AR G RCW B HC HD D

Tree spp.

Severity:

Outside: Y N Bearing: Between Plots _____ and _____

### Renewal Prescription

N DT DG SH

% hardwood ______________

### Incidental Bird

### Incidental Wildlife

### FEC Type

V-type:

S-type:

### Photo Record

Yes _______ No ________

Film # _____ Roll # _____

### Cultural/Heritage Resources

Observations:

Forest Health Codes: N = nil L = Light M = Moderate S = Severe

*Appendix D*

# UNDERSTORY VEGETATION SPECIES

| Scientific Name | Common Name |
|---|---|
| *Abies balsamea* | Balsam Fir |
| *Acer negundo* | Manitoba Maple |
| *Acer spicatum* | Mountain Maple |
| *Actaea rubra* | Baneberry |
| *Agropyron spp.* | Agropyron species |
| *Agropyron trachycaulum* | Slender Wheat Grass |
| *Agrostis hyemalis* | |
| *Agrostis scabra* | Rough Hair Grass |
| *Alnus crispa* | Green Alder |
| *Alnus rugosa* | Speckled Alder |
| *Alnus spp.* | Alder |
| *Amelanchier alnifolia* | Saskatoon |
| *Amelanchier sanguinea* | Roundleaf Serviceberry |
| *Andromeda glaucophylla* | Bog-Rosemary |
| *Andromeda polifolia* | Dwarf Bog-Rosemary |
| *Anemone borealis* | |
| *Anemone canadensis* | Canada Anemone |
| *Anemone quinquefolia* | Wood Anemone |
| *Apocynum androsaemifolium* | Spreading Dogbane |
| *Apocynum spp.* | Dogbane |
| *Aralia nudicaulis* | Wild Sarsaparilla |
| *Arboreal lichen* | |
| *Arctostaphylos uva-ursi* | Common Bearberry |
| *Aster ciliolatus* | Fringed Aster |
| *Aster spp.* | Aster species |
| *Astragalus spp.* | Milk-vetch |
| *Betula occidentalis* | River Birch |
| *Betula papyrifera* | Paper Birch |
| *Betula pumila var. glandulifera* | Dwarf Birch |
| *Botrychium spp.* | Fern |
| *Botrychium virginianum* | Viriginia Grape Fern |
| *Brachythecium spp.* | Brachythecium species |
| *Bryum pseudotriquetrum* | Tall Clustered Thread Moss |
| *Bryum spp.* | Bryum species |
| *Buellia punctata* | Button Lichen |
| *Calamagrostis canadensis* | Bluejoint |
| *Caltha palustris* | Marsh Marigold |
| *Campanula rotundifolia* | Common Harebell |
| *Carex spp.* | Sedge |
| *Ceratodon spp.* | Ceratodon species |
| *Chamaedaphne calyculata* | Leatherleaf |
| *Chimaphila umbellata* | Prince's Pine |

| Scientific Name | Common Name |
|---|---|
| *Circaea alpina* | Small Enchanter's-Nightshade |
| *Circaea palustris* | |
| *Circium spp.* | |
| *Cladina mitis* | Green Reindeer Lichen |
| *Cladina rangiferina* | Grey Reindeer Lichen |
| *Cladina spp.* | Reindeer Lichen |
| *Cladina stellaris* | Northern Reindeer Lichen |
| *Cladonia borealis* | Red Pixie Cup |
| *Cladonia cariosa* | Ribbed Cladonia |
| *Cladonia chlorophaea* | False Pixie Cup |
| *Cladonia coccifera* | Red Pixie Cup |
| *Cladonia coniocraea* | Tiny Toothpick Cladonia |
| *Cladonia crispata* | Shrub Funnel Cladonia |
| *Cladonia deformis* | Deformed Cup |
| *Cladonia pyxidata* | Brown Pixie Cup |
| *Cladonia spp.* | Cladonia Lichen |
| *Cladonia sulphurina* | Sulphur Cup |
| *Cladonia uncialis* | Prickle Cladonia |
| *Climacium dendroides* | Common Tree Moss |
| *Clintonia borealis* | Bluebead Lily |
| *Comandra spp.* | Comandra species |
| *Coptis trifolia* | Goldthread |
| *Cornus canadensis* | Bunchberry |
| *Cornus stolonifera* | Red-Osier Dogwood |
| *Corydalis sempervirens* | Pink Corydalis |
| *Corylus cornuta* | Beaked Hazelnut |
| Crustose lichen | Crustose lichen |
| *Curynchium spp.* | |
| *Cypripedium acaule* | Stemless Lady's Slipper |
| *Danthonia intermedia* | Timber Oat Grass |
| *Dicranum flagellare* | Whip Fork Moss |
| *Dicranum fuscellum* | |
| *Dicranum fuscescens* | Curly Heron's-bill Moss |
| *Dicranum montanum* | |
| *Dicranum polysetum* | Electric Eels |
| *Dicranum scoparium* | Broom Moss |
| *Dicranum spp.* | Cushion Moss |
| *Dicranum undulatum* | Wavy Dicranum |
| *Diervilla lonicera* | Bush Honeysuckle |
| *Disporum trachycarpum* | Fairybells |
| *Drosera rotundifolia* | Round-leaved Sundew |
| *Dryopteris austriaca* | Spinulose Shield Fern |
| *Dryopteris dendroides* | |
| *Dryopteris spp.* | Fern |

| Scientific Name | Common Name |
|---|---|
| *Epilobium angustifolium* | Fireweed |
| *Epilobium palustre* | Marsh Willowherb |
| *Equisetum arvense* | Common Horsetail |
| *Equisetum fluviatile* | Swamp Horsetail |
| *Equisetum palustre* | Marsh Horsetail |
| *Equisetum pratense* | Meadow Horsetail |
| *Equisetum scirpoides* | Dwarf Scouring Rush |
| *Equisetum spp.* | Horsetails |
| *Equisetum sylvaticum* | Woodland Horsetail |
| *Eriophorum spp.* | Cotton Grass |
| *Eurhynchium pulchellum* | Common Beaked Moss |
| *Eurhynchium spp.* | Beaked Moss |
| Fern spp. | Fern |
| Foliose lichen | Foliose lichen |
| *Fragaria spp.* | Strawberry species |
| *Fragaria vesca* | Woodland Strawberry |
| *Fragaria virginiana* | Wild Strawberry |
| *Galium boreale* | Northern Bedstraw |
| *Galium triflorum* | Sweet-scented Bedstraw |
| *Gaultheria hispidula* | Creeping Snowberry |
| *Gaultheria procumbens* | Teaberry |
| *Gentianella amarella* | Northern Gentian |
| *Geocaulon lividum* | Northern Bastard Toadflax |
| *Geum aleppicum* | Yellow Avens |
| *Glyceria striata* | Fowl Manna Grass |
| *Goodyera repens* | Lesser Rattlesnake Plantain |
| *Gramineae spp.* | Grass |
| *Gymnocarpium dryopteris* | Oak Fern |
| *Habenaria orbiculata* | Round-leaved Bog Orchid |
| *Habenaria spp.* | Orchid |
| *Hedwigia spp.* | |
| *Helodium spp.* | Feather Moss |
| *Heuchera richardsonii* | Alumroot |
| *Hieracium spp.* | Narrow-leaved Hawkweed |
| *Hylocomium splendens* | Stair-step Moss |
| *Hypnum spp.* | Pigtail Moss |
| *Impatiens capensis* | Spotted Touch-me-not |
| Impatiens spp. | Impatiens |
| *Juncus spp.* | Rush |
| *Juniperus communis* | Common Juniper |
| *Kalmia polifolia* | Northern Bog Laurel |
| *Larix laracina* | Tamarack, Larch |
| *Lathyrus ochroleucus* | Creamy Peavine |
| *Lathyrus spp.* | Peavine |

| Scientific Name | Common Name |
|---|---|
| *Lathyrus venosus* | Purple Peavine |
| *Ledum groenlandicum* | Labrador Tea |
| *Lepidozia spp.* | Lepidozia species |
| *Linnaea borealis* | Twinflower |
| *Liparis spp.* | Twayblade |
| *Listera cordata* | Heart-leaved Twayblade |
| *Lonicera dioica var. glaucescens* | Twining Honeysuckle |
| *Lycopodium annotinum* | Stiff Club-moss |
| *Lycopodium clavatum* | Running Club-moss |
| *Lycopodium complanatum* | Ground-cedar |
| *Lycopodium obscurum* | Ground Pine |
| *Lycopodium spp.* | Club-moss |
| *Lycopus spp.* | Water Horehound |
| *Lysimachia ciliata* | Fringed Loosestrife |
| *Lysimachia thyrsiflora* | Tufted Loosestrife |
| *Maianthemum canadense* | Wild Lily-of-the-Valley |
| *Marchantia polymorpha* | Green-tongue Liverwort |
| *Matteuccia struthiopteris* | Ostrich Fern |
| *Melampyrum lineare* | Cow-wheat |
| *Mentha arvensis* | Wild Mint |
| *Menyanthes trifoliata* | Buck-bean |
| *Mertensia paniculata* | Tall Lungwort |
| *Mitella nuda* | Bishop's Cap |
| *Mnium spp.* | Mnium species |
| *Moneses uniflora* | One-flowered Wintergreen |
| Moss spp. | Moss |
| *Muhlenbergia racemosa* | Muhly |
| *Orchis rotundifolia* | Round-leaved Orchid |
| *Orchis spp.* | Orchid |
| *Oryzopsis asperifolia* | Rough-leaved Rice Grass |
| *Oryzopsis pungens* | Northern Rice Grass |
| *Oryzopsis spp.* | Rice Grass |
| *Panicum linearifolium* | |
| *Peltigera spp.* | Peltigera Lichen |
| *Petasites palmatus* | Palmate-leaved Colt's Foot |
| *Petasites sagittatus* | Arrow-leaved Colt's Foot |
| *Petasites vitifolius* | Vine-leaved Colt's Foot |
| *Philontis spp.* | Aquatic Apple Moss |
| *Physcia spp.* | Physcia Lichen |
| *Picea glauca* | White Spruce |
| *Picea mariana* | Black Spruce |
| *Pinus banksiana* | Jack Pine |
| *Plagiomnium spp.* | Plagiomnium species. |
| *Pleurozium schreberi* | Big Red Stem |

| Scientific Name | Common Name |
|---|---|
| *Polygonum cilinode* | |
| *Polygonum spp.* | Buckwheat |
| *Polypodium spp.* | Polypody Fern |
| *Polypodium virginianum* | Rock Polypody |
| *Polytrichum commune* | Common Haircap |
| *Polytrichum juniperinum* | Juniper Hair-cap |
| *Polytrichum pilferum* | Awned Hair-cap |
| *Polytrichum spp.* | Hair-cap |
| *Polytrichum strictum* | Slender Hair-cap |
| *Populus balsamifera* | Balsam Poplar |
| *Populus tremuloides* | Trembling Aspen |
| *Potentilla palustris* | Marsh Cinquefoil |
| *Potentilla spp.* | Potentilla species |
| *Potentilla tridentata* | Three Toothed Cinquefoil |
| *Prunus pensylvaticum* | Pin Cherry |
| *Prunus virginiana* | Choke Cherry |
| *Pteridium aquilinum* | |
| *Pteridium spp.* | |
| *Ptilium crista-castrensis* | Knight's Plume |
| *Pylaisiella polyantha* | Stocking Moss |
| *Pyrola asarifolia* | Common Pink Wintergreen |
| *Pyrola grandiflora* | Arctic Wintergreen |
| *Pyrola minor* | Lesser Wintergreen |
| *Pyrola secunda* | One-sided Wintergreen |
| *Pyrola spp.* | Wintergreen |
| *Pyrola virens (P. chlorantha)* | Green Wintergreen |
| *Ranunculus spp.* | Buttercup |
| *Rhamnus alnifolia* | Alder-leaved Buckthorn |
| *Rhytidiadelphus spp.* | |
| *Ribes americanum* | Wild Black Currant |
| *Ribes glandulosum* | Skunk Currant |
| *Ribes hudsonianum* | Northern Black Currant |
| *Ribes oxyacanthoides* | Northern Gooseberry |
| *Ribes spp.* | Currants/Gooseberries |
| *Ribes triste* | Swamp Red Currant |
| *Rosa acicularis* | Prickly Rose |
| *Rubus acaulis* | Stemless Raspberry |
| *Rubus chamaemorus* | Cloudberry |
| *Rubus idaeus* | Wild Red Raspberry |
| *Rubus pubescens* | Dewberry |
| *Rubus spp.* | Raspberry |
| *Salix spp.* | Willow |
| *Sambucus spp.* | Sambucus species |
| *Sanicula marilandica* | Snakeroot |

| Scientific Name | Common Name |
|---|---|
| *Sarracenia purpurea* | Pitcher-plant |
| *Schistidium rivulare* | |
| *Schizachne purpurascens* | False Medic |
| *Scirpus spp.* | Bulrush |
| *Scutellaria spp.* | Skullcap |
| *Shepherdia canadensis* | Canada Buffaloberry |
| *Smilacina stellata* | Star-flowered False Solomon's Seal |
| *Smilacina trifolia* | Three-leaved False Solomon's Seal |
| *Solidago spp.* | Goldenrod species |
| *Sorbus scopulina* | Western Mountain Ash |
| *Sphagnum spp.* | Sphagnum moss |
| *Spirea alba* | Narrow-leaved Meadowsweet |
| *Stachys palustris* | Swamp Hedge-Nettle |
| *Stereocaulon tomentosum* | Woolly Coral |
| *Streptopus roseus* | Rose Twisted Stalk |
| *Symphoricarpos albus* | Common Snowberry |
| *Tetraphis pellucida* | Common Four-tooth Moss |
| *Thalictrum spp.* | Meadow Rue |
| *Thuidium recognitum* | Hook-leaf Fern Moss |
| *Tomenthypnum spp.* | Fuzzy Fen Moss |
| *Trientalis borealis* | Starflower |
| *Umbilicaria hyperborea* | Blistered Rocktripe |
| *Umbilicaria muhlenbergii* | Plated Rocktripe |
| *Umbilicaria spp.* | Rocktripe |
| Unknown dicot | Unknown dicot |
| Unknown lily | Unknown lily |
| Unknown monocot | Unknown monocot |
| Unknown moss | Unknown moss |
| *Urtica dioica* | Stinging Nettle |
| *Usnea hirta* | Sugary Beard |
| *Usnea scabrata* | Scruffy Beard |
| *Usnea spp.* | Usnea Lichen |
| *Vaccinium angustifolium* | Low Sweet Blueberry |
| *Vaccinium myrtilloides* | Common Blueberry |
| *Vaccinium oxycoccos* | Small Bog Cranberry |
| *Vaccinium vitis-idaea* | Lingonberry |
| *Viburnum edule* | Low Bush-Cranberry |
| *Viburnum rafinesquianum* | Downy Arrow-wood |
| *Viburnum trilobum* | High Bush-Cranberry |
| *Vicia americana* | Wild Vetch |
| *Viola adunca* | Early Blue Violet |
| *Viola borealis* | Great Spurred Violet |
| *Viola canadensis* | Canada Violet |

| Scientific Name | Common Name |
|---|---|
| *Viola nephrophylla* | Bog Violet |
| *Viola renifolia* | Kidney-leaved Violet |
| *Viola spp.* | Violet |
| *Woodsia ilvensis* | Rusty Woodsia |
| *Xanthoria fallax* | Powdered Orange Lichen |

*Appendix E*

# MODIFIED ECOSYSTEM ALGORITHM

*(Geospatial International)*

```
/* Program      : addvtype.aml
/* Author       :
/* Update Date : March 14, 1996
/* Updated by   :
/*****************************************************************
*************
/*  addvtype.aml - adds a manitoba vtype class to the forested sta
nd.
/*
/*****************************************************************
*************
    &TYPE *** Processing..................................
    &IF [iteminfo union -poly vtype -exists] &then dropitem union.
pat union.pat vtype
    &IF [EXISTS UNION -COVER] &THEN &DO
                  &type FIRST DO!
      &if NOT [iteminfo union -poly vtype -exists] &then &DO
                        &type SECOND DO!
      &s conifer = WP RP JP SP BS WS BF TL EC
      &s hardwood = TA LA BA CO W WB HB B MM AS E HH BO
      /*
      additem union.pat union.pat vtype 3 3 c
      DISPLAY 0
      ap
      res union poly area > 0
      cursor cur1 declare union poly rw
      cursor cur1 open
      &do &while %:cur1.AML$NEXT%
      &Type CURSE THAT DO!
        &s pcnt = 0
        /* map out land_id > 700 and < 1000
        &if %:cur1.lnd_id% > 699 and %:cur1.lnd_id% < 1000 &then &
do
           &type DO IT!
           &select %:cur1.lnd_id%
              &when 701
                &s :cur1.vtype = v33
              &when 702
                &s :cur1.vtype = v20
              &when 703
                &s :cur1.vtype = v19
              &when 704
                &s :cur1.vtype = unk
              &when 711, 712
                &s :cur1.vtype = v26
              &when 713
                &s :cur1.vtype = v3
              &when 701
```

```
            &s :curl.vtype = v33
          &otherwise
            &s :curl.vtype = unk
       &end
    &end
    &else &do
       &type DO THE DO!
       &s covtype = [substr %:curl.covertype% 1 2]
       &s site = [substr %:curl.covertype% 3 1]
       &s cutclass = [substr %:curl.covertype% 4 1]
       &s mu = %:curl.mu_id%
       &select %covtype%
          &when 88, 98                 /* balsam poplar
             &s :curl.vtype = v1
          &when 94, 95                 /* black ash ( white elm
)

             &s :curl.vtype = v2
          &when 83, 84, 93, 96, 97, 99, 9A, 9B, 9C, 9D, 9E
             &s :curl.vtype = v3       /* misc. hardwoods.
          &when 85, 86, 87, 92         /* birch
             &s :curl.vtype = v4
          &when 80, 81, 82, 90, 91     /* aspen types
             &do
               &call checkspecies
               &call species
               &if [null %sp1%] &then &do
                 &s sp1 = TA
                 &s sp1_pcnt = 10
               &end
               &if %covtype% = 90 &then &do
                 &if %sp1_pcnt% > 8 and %sp2%. ne BF. ~
                     and %sp3%. ne BF. &then &s :curl.vtype =
v5

                 &else &s :curl.vtype = v6
               &end
               &else &if %covtype% = 91 &then &s :curl.vtype =
 v6

               &else &if %covtype% = 80 &then &s :curl.vtype =
 v9

               &else &if %covtype% = 81 &then &s :curl.vtype =
 v9

               &else &if %covtype% = 82 &then &do
                 &if %site% = 1 &then &do
                   &s test = pass
                   &s test2 = 0
                   &s pcnt = 0
                   &do i = 2 &to 6
                     &if [keyword [value sp%i%] %conifer%] > 0
```

```
 &then &do
                  /* test for vtype v7/v8 first
                  /* this could be modified to work
                  /* correctly -> see the c program
                  &s pcnt = %pcnt% + [value sp%i%_pcnt]
                  &if %test% = pass and ~
                      [keyword [value sp%i%] WS BS BF] ~
                       > 0 &then &s test pass
                  &else &s test = fail
                &end
                &else &if ^ [null [value sp%i%]] &then
                   &s test = fail
                /* test for vtype v6 here
                &if %i% < 4 and [keyword ~
                    [value sp%i%] BF WB] > 0 &then ~
                    &s test2 = %test2% + 1
                &else &if ^ [null [value sp%i%]] &then
                   &s test2 = 3
              &end
              &if %test% = pass and %pcnt% >= 4 &then
                &s :curl.vtype = v9
              &else &if %test2% > 0 and %test2% < 3 &then

                &s :curl.vtype = v6
              &else &s :curl.vtype = v9
            &end
            /* test for vtype v6 and v9 on all other site
s

            &else &do
              &s test = 0
              &do i = 2 &to 6
                &if %i% < 4 and ~
                    [keyword [value sp%i%] BF WB] > 0 &th
en ~

                    &s test = test + 1
                &else &if ^ [null [value sp%i%]] &then
                    &s test = 3
              &end
              &if %test% > 0 and %test% < 4 &then
                &s :curl.vtype = v6
              &else &s :curl.vtype= v9
            &end
          &end
          &else &ty Aspend %covtype% is not fitting in!!!
!!

        &end
     &when 43                    /* white pine to v11
       &s :curl.vtype = v11
```

```
               &when 41, 42              /* red pine mixed wood to v
12
                 &s :curl.vtype = v12
               /* v13/v14 and v21 white spruce mixed wood and
               /* white spruce/balam fir
               &when 20, 21, 22          /* balsam fir pure
                 &s :curl.vtype = v21
               &when 60, 61, 62
                 &s :curl.vtype = v13    /* balsam fire mixed
               &when 10, 11, 50, 51      /* white spruce pure and mi
xed
                 &do
                   &call checkspecies
                   &call species
                   &if [null %sp1%] &then &do
                     &s sp1 = WS
                     &s sp1_pcnt = 10
                   &end
                   &s pcnt = 0
                   &do i = 2 &to 7
                     &if [keyword %hardwood% [value sp%i%]]  > 0 &t
hen ~
                       &s pcnt = %pcnt% + [value sp%i%_pcnt]
                   &end
                   &if %pcnt% > 2 &then &S :curl.vtype = v13
                   &else &if %sp1_pcnt% >= 5 and %sp2% = BF and ~
                         %sp2_pcnt% >= 1 &then &s :curl.vtype = v21
                   &else &if %sp3% = . and %sp2_pcnt% < 3 &then ~
                     &s :curl.vtype = v21
                   &else &if %pcnt% = 0 and %sp1_pcnt% > 6 &then ~
                     &s :curl.vtype = v21
                   &else &s :curl.vtype = v13
                 &end
               /* v 15/16, and v 28 jackpine mixed woods and jack-p
ine spruce
               &when 44, 45
                 &s :curl.vtype = v15
               &when 46
                 &do
                   &call checkspecies
                   &call species
                   &if [null %sp1%] &then &do
                     &s sp1 = JP
                     &s sp1_pcnt = 10
                   &end
                   &if %sp2% = BS and %sp2_pcnt% >= 3 &then ~
                      &s :curl.vtype = v28
                   &else &s :curl.vtype = v15
```

*Appendix F*

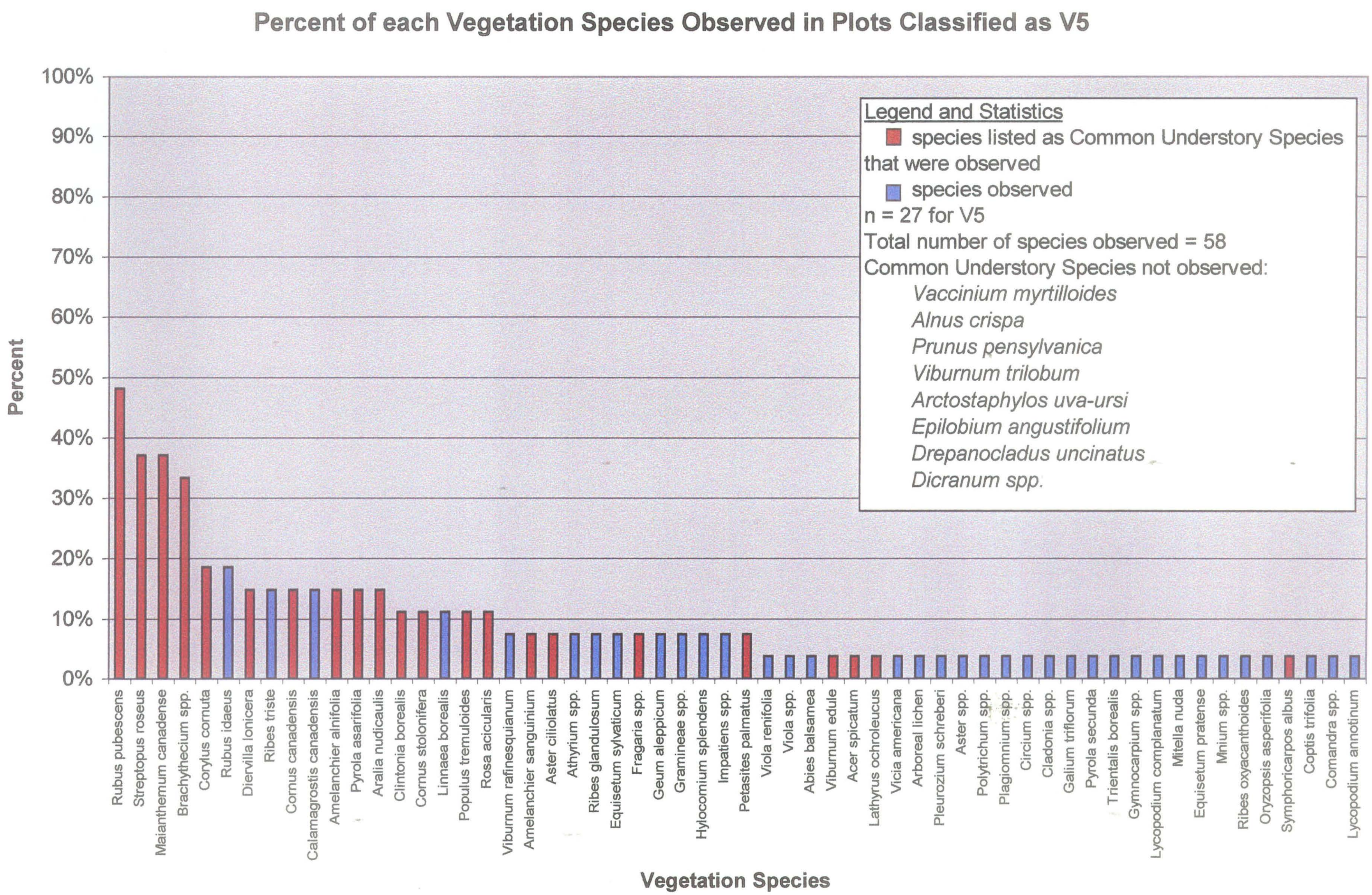
# STANDARDIZED DATA MATRIX OF V-TYPES AND VEGETATION FREQUENCIES

| | V-Types | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vegetation Species | V5 | V6 | V7 | V8 | V9 | V10 | V13 | V14 | V15 | V16 | V17 | V18 | V20 | V21 | V24 | V25 | V26 | V27 | V28 | V29 | V30 | V31 | V32 | V33 | Ave. | Count |
| Abies balsamea | 0.04 | 0.14 | 0.15 | 0.12 | 0.05 | 0.11 | 0.10 | 0.08 | 0.06 | 0.03 | 0.05 | 0.07 | | | | | 0.01 | | 0.00 | | | 0.00 | 0.07 | | 0.07 | 16 |
| Acer negundo | | | | | | | | | 0.01 | | | | | | | | | | | | | | | | 0.01 | 1 |
| Acer spicatum | 0.04 | 0.08 | 0.05 | | | | 0.06 | 0.04 | 0.01 | 0.01 | | | | | 0.05 | | | | | | | | | | 0.04 | 8 |
| Achillea spp. | | | | | | | | | 0.01 | | | | | | | | 0.00 | | | | | | | | 0.01 | 2 |
| Agropyron spp. | | | | | | | | | | | 0.02 | 0.01 | | | | | 0.00 | | | | | | | | 0.01 | 3 |
| Agropyron trachycaulum | | | | | | | | | | | | | | | | | 0.00 | | | | | | | | 0.00 | 1 |
| Agrostis scabra | | | | | | | | | | | | | | | | | 0.00 | | | | | | | | 0.00 | 1 |
| Alnus crispa | | | | | | | 0.02 | | | | 0.02 | | | | | | 0.00 | | 0.00 | | 0.00 | 0.01 | | | 0.01 | 6 |
| Alnus rugosa | | 0.02 | | 0.01 | 0.03 | | 0.01 | 0.01 | 0.03 | | 0.02 | 0.01 | 0.03 | | | | 0.00 | | | 0.02 | 0.00 | 0.09 | 0.20 | 0.03 | 0.03 | 15 |
| Amelanchier alnifolia | 0.15 | 0.06 | 0.05 | 0.04 | | | 0.03 | 0.04 | 0.01 | 0.01 | 0.02 | | | | 0.10 | | 0.02 | | 0.01 | | | 0.00 | | 0.03 | 0.04 | 14 |
| Amelanchier sanguinium | 0.07 | | 0.03 | 0.03 | | | 0.03 | | | 0.01 | | | | | | | 0.00 | | | | | | | | 0.03 | 6 |
| Amelanchier spp. | | | | | | | | 0.01 | | | | | | | | | 0.00 | | | | | | | | 0.01 | 2 |
| Andromeda glaucophylla | | | | | | | | | | | | | | | | | | | | | | 0.00 | | | 0.00 | 1 |
| Andromeda polifolia | | | | | | | | | | | | | | | | | | | | | 0.01 | | | | 0.01 | 1 |
| Anemone canadensis | | 0.03 | | | | | | | 0.01 | | | 0.01 | | | | | | | | | | | | | 0.02 | 3 |
| Anemone quinquefolia | | | | | | | | | 0.01 | 0.02 | | 0.01 | | | | | | | | | | | | | 0.01 | 3 |
| Anemone spp. | | | | | | | | | | | | | | | | | 0.00 | | | | | | | | 0.00 | 1 |
| Apocynum androsaemifolium | | | | | | | | | | | | | | | | | 0.00 | | | | | | | | 0.00 | 1 |
| Apocynum spp. | | 0.02 | | | | | | | | | | | | | | | | | | | | | | | 0.02 | 1 |
| Aquilegia canadensis | | | | | | | | | | | | | | | | | 0.00 | | | | | | | | 0.00 | 1 |
| Aralia nudicaulis | 0.15 | 0.18 | 0.23 | 0.24 | 0.24 | 0.11 | 0.17 | 0.18 | 0.17 | 0.09 | 0.18 | 0.13 | | | 0.20 | 0.04 | 0.04 | | 0.06 | 0.04 | 0.01 | | | | 0.14 | 18 |
| Arboreal lichen | 0.04 | 0.03 | 0.02 | | | | 0.04 | | 0.03 | | | | | 0.13 | | | | | 0.00 | | 0.01 | 0.00 | | | 0.03 | 9 |
| Arctostaphylos uva-ursi | | | | 0.01 | 0.03 | | | | 0.06 | 0.08 | 0.02 | 0.01 | | | 0.35 | 0.08 | 0.29 | | 0.12 | 0.09 | 0.09 | 0.03 | 0.07 | 0.05 | 0.09 | 15 |
| Aster ciliolatus | 0.07 | 0.02 | 0.02 | 0.03 | 0.05 | 0.11 | | | 0.03 | 0.01 | | | | | 0.05 | | 0.00 | | 0.00 | | | | | | 0.04 | 11 |
| Aster spp. | 0.04 | | | 0.03 | | | | 0.01 | | 0.01 | | 0.01 | | | | | | | | | | | | | 0.02 | 5 |
| Athyrium filix-femina | | | | | | | | | | | | 0.01 | | | | | | | | | | | | | 0.01 | 1 |
| Athyrium spp. | 0.07 | | | 0.01 | | | | | | | | | | | | | | 0.13 | | | | | | | 0.07 | 3 |
| Aulacomnium palustre | | | | | | | | | 0.01 | | 0.02 | 0.01 | | | | | 0.00 | | 0.00 | | | | | | 0.01 | 5 |
| Betula papyrifera | | 0.02 | 0.03 | | | | | | | | | 0.01 | | | | | | | | | | | 0.07 | | 0.03 | 4 |
| Betula pumila var. glandulifera | | 0.02 | 0.02 | | | | | | | | | | 0.03 | | | | | | | | 0.03 | 0.01 | | 0.03 | 0.02 | 6 |
| Brachythecium spp. | 0.33 | 0.25 | 0.38 | 0.12 | 0.13 | 0.44 | 0.10 | 0.01 | 0.06 | 0.01 | 0.13 | | | 0.25 | | | 0.00 | 0.25 | 0.00 | | 0.01 | | | 0.03 | 0.15 | 17 |
| Bromus ciliatus | | | | | 0.03 | | | | | | | | | | | | | | | | | | | | 0.03 | 1 |
| Bryum spp. | | | 0.02 | | | | | | | | | | | | | | | | | | | | | | 0.02 | 1 |
| Buellia punctata | | | | | | | | | | | | | | | | | 0.00 | | | | | | | | 0.00 | 1 |
| Calamagrostis canadensis | 0.15 | | 0.03 | 0.08 | | | 0.04 | 0.15 | | 0.03 | 0.05 | 0.05 | 0.07 | | | 0.04 | 0.00 | 0.13 | 0.00 | | 0.10 | 0.06 | | 0.14 | 0.07 | 16 |
| Caltha palustris | | | | 0.01 | | | | 0.01 | | | | | | | | | | | | | | 0.00 | | | 0.01 | 3 |
| Calypso bulbosa | | | | | 0.03 | 0.11 | | | | | | 0.01 | | | | | | | | | | | | | 0.05 | 3 |
| Campanula rotundifolia | | | | | | | | | | | | | | | | | 0.00 | | | | | | | | 0.00 | 1 |
| Carex spp. | | 0.15 | 0.05 | 0.04 | 0.03 | | 0.06 | 0.08 | 0.08 | | 0.07 | 0.03 | 0.34 | | 0.05 | | 0.01 | 0.13 | 0.01 | 0.02 | 0.10 | 0.15 | 0.33 | 0.19 | 0.10 | 19 |
| Catoscopium spp. | | | | | | | | | | | | | | | | | | | | | | 0.00 | | | 0.00 | 1 |
| Ceratodon spp. | | | | | | | | | | | | | | | | | 0.00 | | | | | | | | 0.00 | 1 |
| Chamaedaphne calyculata | | | | | | | | | | | | | 0.31 | | | | 0.00 | | 0.00 | | 0.17 | 0.17 | 0.07 | 0.03 | 0.11 | 7 |
| Chimaphila umbellata | | | | | | | | 0.03 | | 0.03 | | 0.01 | | | | | 0.02 | | 0.02 | | | | | | 0.02 | 5 |
| Circaea alpina | | | | 0.05 | | | 0.02 | 0.22 | | | | 0.02 | | | | | | | | | 0.02 | | | | 0.06 | 5 |
| Circium arvense | | | | 0.01 | | | | | | | | | | | | | | | | | | | | | 0.01 | 1 |
| Circium spp. | 0.04 | | | | | | | | | | | | | | | | | | | | | | | | 0.04 | 1 |
| Cladina mitis | | | | | 0.03 | | | | 0.03 | 0.01 | | 0.02 | | 0.13 | | 0.13 | 0.45 | | 0.06 | 0.02 | 0.01 | 0.00 | | 0.03 | 0.08 | 12 |
| Cladina rangiferina | | | | 0.01 | 0.03 | | | 0.01 | 0.01 | 0.11 | | 0.04 | | | | | 0.52 | | 0.12 | 0.02 | 0.01 | 0.01 | | 0.03 | 0.08 | 12 |

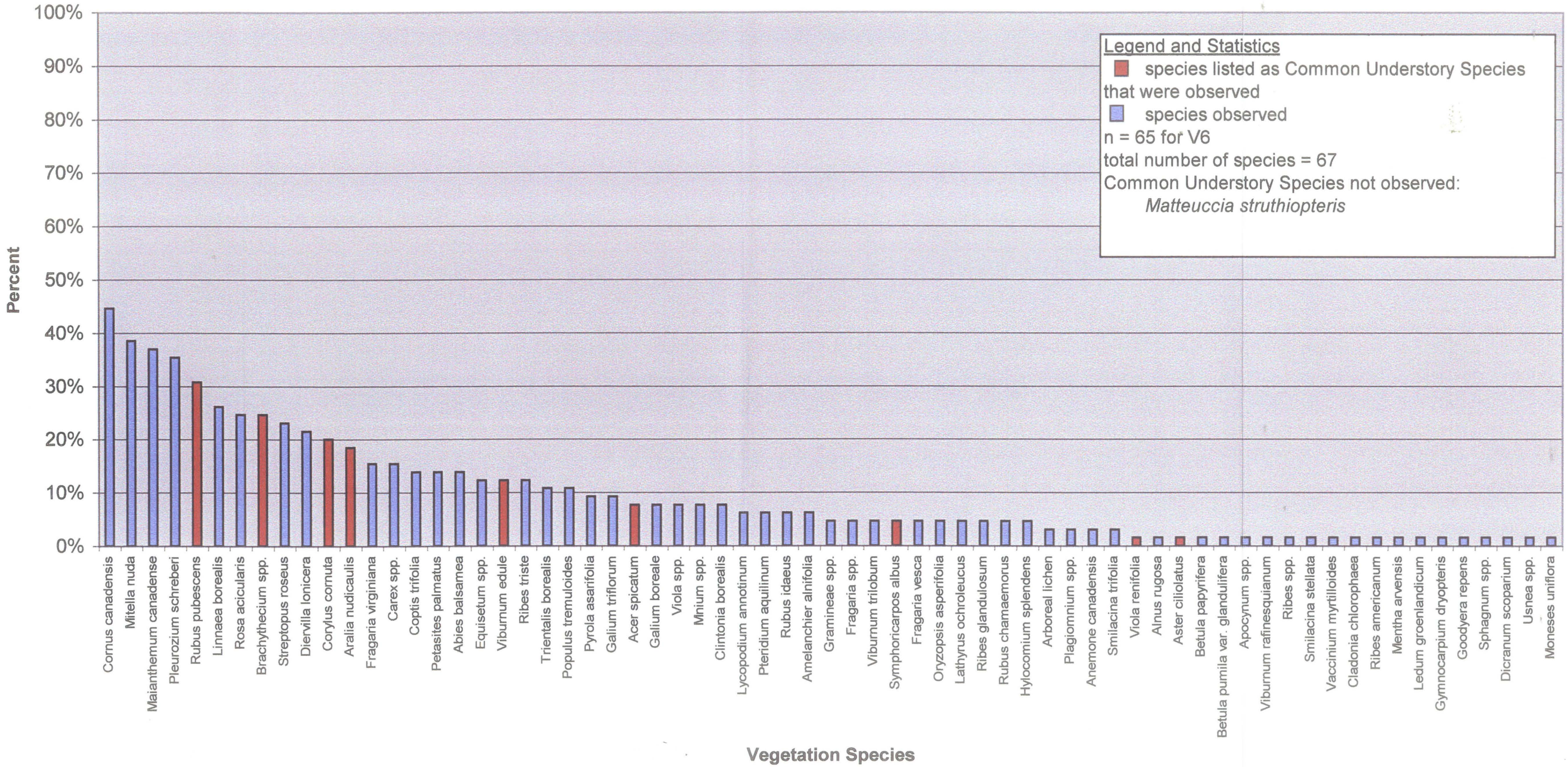
| Vegetation Species | V5 | V6 | V7 | V8 | V9 | V10 | V13 | V14 | V15 | V16 | V17 | V18 | V20 | V21 | V24 | V25 | V26 | V27 | V28 | V29 | V30 | V31 | V32 | V33 | Ave. | Count |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rosa spp. | | | | 0.02 | | | 0.01 | | | 0.03 | 0.02 | 0.01 | | | | | 0.00 | | 0.02 | | | | | | 0.02 | 7 |
| Rubus acaulis | | | | | | | | | | | | 0.01 | | | | | | | | | | | | | 0.01 | 1 |
| Rubus chamaemorus | | 0.05 | | | | | 0.02 | 0.01 | | | | | | | | | | | | 0.02 | 0.07 | 0.11 | 0.07 | | 0.05 | 7 |
| Rubus idaeus | 0.19 | 0.06 | 0.15 | 0.05 | 0.03 | | 0.05 | 0.05 | | 0.01 | 0.02 | 0.03 | 0.03 | | | | 0.01 | 0.13 | 0.00 | | 0.01 | 0.00 | | | 0.05 | 16 |
| Rubus pubescens | 0.48 | 0.31 | 0.30 | 0.43 | 0.37 | 0.22 | 0.28 | 0.35 | | 0.15 | 0.38 | 0.27 | 0.21 | | 0.15 | 0.08 | 0.01 | 0.13 | 0.04 | 0.06 | 0.09 | 0.09 | 0.07 | 0.11 | 0.21 | 22 |
| Salix spp. | | | | 0.01 | | | 0.01 | | | | | | | | | | 0.00 | | 0.00 | | 0.00 | 0.03 | | 0.05 | 0.02 | 7 |
| Sanicula marilandica | | | 0.03 | | | | | | | | | 0.01 | | | | | | | | | | | | | 0.02 | 2 |
| Schizachne purpurascens | | | | | | | | | | | | 0.01 | | | | | | | | | | 0.00 | | | 0.01 | 2 |
| Scutellaria spp. | | | | | | | | | | | | | | | | | | | | | | 0.01 | | | 0.01 | 1 |
| Shepherdia canadensis | | | | | | | | | | | | | | | | | 0.00 | | | | | 0.00 | | | 0.00 | 2 |
| Smilacina stellata | | 0.02 | 0.05 | | | | 0.03 | | | | | | 0.03 | | | | 0.00 | | | | 0.00 | | | | 0.02 | 6 |
| Smilacina trifolia | | 0.03 | | 0.01 | | | 0.05 | | 0.11 | | 0.04 | | 0.07 | | 0.05 | | 0.00 | | 0.01 | 0.04 | 0.22 | 0.26 | | 0.11 | 0.08 | 13 |
| Solidago spp. | | | | | | | | | | | | 0.01 | | | | | 0.00 | | | | | | | | 0.00 | 2 |
| Sorbus scopulina | | | | | | | | | | | | | | | | | | | 0.00 | | | | | | 0.00 | 1 |
| Sphagnum spp. | | 0.02 | | 0.03 | | 0.11 | 0.03 | 0.03 | 0.04 | 0.02 | 0.11 | 0.04 | 0.72 | 0.25 | | 0.08 | 0.02 | | 0.04 | 0.20 | 0.76 | 0.76 | 0.80 | 0.89 | 0.26 | 19 |
| Spirea alba | | | | 0.01 | | | | | | | | | | | | | 0.01 | | 0.00 | | | | | | 0.01 | 3 |
| Stereocaulon tomentosum | | | | | | | | | | | | | | | | | 0.01 | | | | | | | | 0.01 | 1 |
| Streptopus roseus | 0.37 | 0.23 | 0.11 | 0.03 | 0.05 | | 0.05 | 0.01 | 0.08 | 0.02 | 0.02 | 0.03 | | 0.13 | | | | | 0.00 | | 0.00 | | | | 0.08 | 14 |
| Symphoricarpos albus | 0.04 | 0.05 | 0.03 | 0.02 | 0.03 | 0.11 | | 0.01 | | 0.01 | 0.02 | 0.02 | | | | | 0.00 | | | 0.02 | | | | | 0.03 | 12 |
| Thuidium recognitum | | | 0.02 | 0.01 | | | | | | | | | | | | | | | 0.00 | | | | | 0.03 | 0.01 | 4 |
| Tomenthypnum spp. | | | | | | | | | | 0.01 | | | | | | | | | | | | | | | 0.01 | 1 |
| Trientalis borealis | 0.04 | 0.11 | 0.21 | 0.24 | 0.24 | | 0.10 | 0.16 | 0.15 | 0.14 | 0.15 | 0.18 | 0.17 | | 0.05 | | 0.01 | 0.13 | 0.08 | 0.04 | 0.09 | 0.05 | 0.07 | 0.03 | 0.12 | 21 |
| Umbilicaria muhlenbergii | | | | | | | | | | | | | | | | | 0.00 | | | | | | | | 0.00 | 1 |
| Umbilicaria spp. | | | | | | | | | | | | | | | | | 0.01 | | | | | | | | 0.01 | 1 |
| Unknown dicot | | | | | | 0.11 | | | | | | | | | | | | | | 0.02 | | | | | 0.06 | 2 |
| Urtica dioica | | | | 0.01 | | | | | | | | | | | | | | | | | | | | | 0.01 | 1 |
| Usnea spp. | | 0.02 | | | | | | | 0.01 | | | | | | | | | | | | | | | | 0.01 | 2 |
| Vaccinium angustifolium | | | 0.02 | | 0.05 | | 0.04 | | | 0.03 | 0.07 | 0.03 | | | 0.15 | 0.13 | 0.07 | | 0.06 | 0.06 | 0.01 | 0.03 | | | 0.06 | 13 |
| Vaccinium myrtilloides | | 0.02 | 0.02 | 0.09 | 0.13 | 0.11 | 0.04 | 0.04 | | 0.22 | 0.13 | 0.16 | 0.03 | | 0.20 | 0.13 | 0.38 | | 0.25 | 0.20 | 0.09 | 0.10 | | 0.14 | 0.13 | 19 |
| Vaccinium oxycoccos | | | | | | | | | | | | | | | | | 0.00 | | | | 0.01 | 0.08 | | 0.08 | 0.04 | 4 |
| Vaccinium vitis-idaea | | | | 0.02 | 0.21 | | 0.01 | 0.01 | | 0.08 | 0.09 | 0.09 | 0.03 | 0.13 | | | 0.06 | 0.13 | 0.10 | 0.20 | 0.22 | 0.40 | | 0.30 | 0.13 | 16 |
| Viburnum edule | 0.04 | 0.12 | 0.03 | 0.03 | 0.13 | | 0.01 | 0.08 | | | 0.05 | 0.01 | | 0.13 | | | | | | | 0.00 | | | | 0.06 | 11 |
| Viburnum rafinesquianum | 0.07 | 0.02 | 0.02 | 0.01 | | | 0.04 | | | | | | | | | | | | | | | | | | 0.03 | 5 |
| Viburnum trilobum | | 0.05 | | | | | 0.02 | | | | | | | 0.13 | | | | | | | | | | | 0.06 | 3 |
| Vicia americana | 0.04 | | | | | | | | | | 0.02 | | | | | | | | | | | | | | 0.03 | 2 |
| Viola adunca | | | | | | | | | 0.01 | | | | | | | | 0.00 | | | | 0.00 | | | | 0.01 | 3 |
| Viola borealis | | | | | | | 0.01 | | 0.01 | | | | | | | | | | | | | | | | 0.01 | 2 |
| Viola canadensis | | | | 0.01 | | | | 0.01 | | | 0.04 | 0.01 | | | | | | | 0.00 | | | 0.01 | | 0.03 | 0.02 | 7 |
| Viola nephrophylla | | | | | 0.03 | | 0.01 | | | 0.01 | 0.02 | 0.01 | | | | | | | | | 0.00 | | | 0.03 | 0.01 | 7 |
| Viola renifolia | 0.04 | 0.02 | 0.10 | 0.02 | | 0.11 | 0.04 | 0.01 | 0.03 | 0.01 | 0.09 | 0.01 | | | | | | | 0.01 | | 0.00 | 0.02 | 0.07 | 0.03 | 0.04 | 16 |
| Viola spp. | 0.04 | 0.08 | | 0.03 | | | 0.05 | 0.16 | 0.03 | 0.01 | 0.02 | 0.06 | 0.07 | | | | 0.00 | | 0.00 | | 0.01 | 0.02 | | | 0.04 | 14 |
| Vulpicida pinastri | | | | | | | | | | | | 0.01 | | | | | | | | | | | | | 0.01 | 1 |
| Woodsia ilvensis | | | | | | | | | | | | | | | | | 0.00 | | | | | | | | 0.00 | 1 |
| Average | 0.09 | 0.10 | 0.08 | 0.07 | 0.13 | 0.19 | 0.06 | 0.09 | 0.06 | 0.06 | 0.09 | 0.06 | 0.12 | 0.18 | 0.16 | 0.12 | 0.04 | 0.18 | 0.04 | 0.09 | 0.07 | 0.06 | 0.17 | 0.10 | 0.08 | 6 |
| Count | 58.00 | 67.00 | 66.00 | 98.00 | 59.00 | 35.00 | 85.00 | 71.00 | 83.00 | 93.00 | 84.00 | 106.00 | 36.00 | 27.00 | 38.00 | 31.00 | 141.00 | 27.00 | 104.00 | 46.00 | 81.00 | 93.00 | 27.00 | 51.00 | 66.96 | 1607 |
| % of total sp. Observed | 23.20 | 26.80 | 26.40 | 39.20 | 23.60 | 14.00 | 34.00 | 28.40 | 33.20 | 37.20 | 33.60 | 42.40 | 14.40 | 10.80 | 15.20 | 12.40 | 56.40 | 10.80 | 41.60 | 18.40 | 32.40 | 37.20 | 10.80 | 20.40 | | |

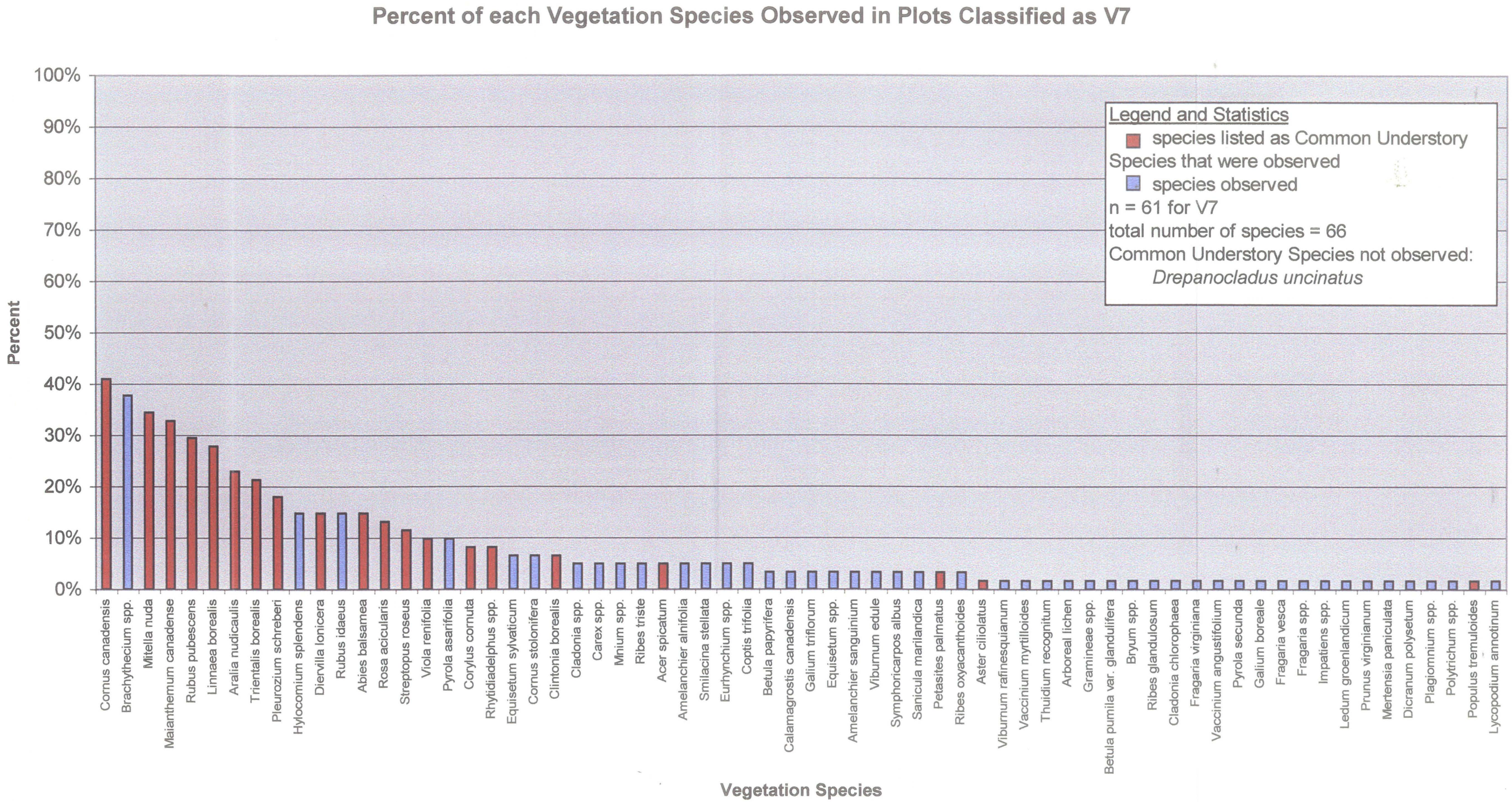
*Appendix G*

# PERCENTAGE THAT EACH SPECIES WAS OBSERVED WITH EACH V-TYPE


Percent of each Vegetation Species Observed in Plots Classified as V5
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 27 for V5
Total number of species observed = 58
Common Understory Species not observed:
Vaccinium myrtilloides
Alnus crispa
Prunus pensylvanica
Viburnum trilobum
Arctostaphylos uva-ursi
Epilobium angustifolium
Drepanocladus uncinatus
Dicranum spp.
Rubus pubescens
Streptopus roseus
Maianthemum canadense
Brachythecium spp.
Corylus cornuta
Rubus idaeus
Diervilla lonicera
Ribes triste
Cornus canadensis
Calamagrostis canadensis
Amelanchier alnifolia
Pyrola asarifolia
Aralia nudicaulis
Clintonia borealis
Cornus stolonifera
Linnaea borealis
Populus tremuloides
Rosa acicularis
Viburnum rafinesquianum
Amelanchier sanguinium
Aster ciliolatus
Athyrium spp.
Ribes glandulosum
Equisetum sylvaticum
Fragaria spp.
Geum aleppicum
Gramineae spp.
Hylocomium splendens
Impatiens spp.
Petasites palmatus
Viola renifolia
Viola spp.
Abies balsamea
Viburnum edule
Acer spicatum
Lathyrus ochroleucus
Vicia americana
Arboreal lichen
Pleurozium schreberi
Aster spp.
Polytrichum spp.
Plagiomnium spp.
Circium spp.
Cladonia spp.
Galium triflorum
Pyrola secunda
Trientalis borealis
Gymnocarpium spp.
Lycopodium complanatum
Mitella nuda
Equisetum pratense
Mnium spp.
Ribes oxyacanthoides
Oryzopsis asperifolia
Symphoricarpos albus
Coptis trifolia
Comandra spp.
Lycopodium annotinum
Vegetation Species

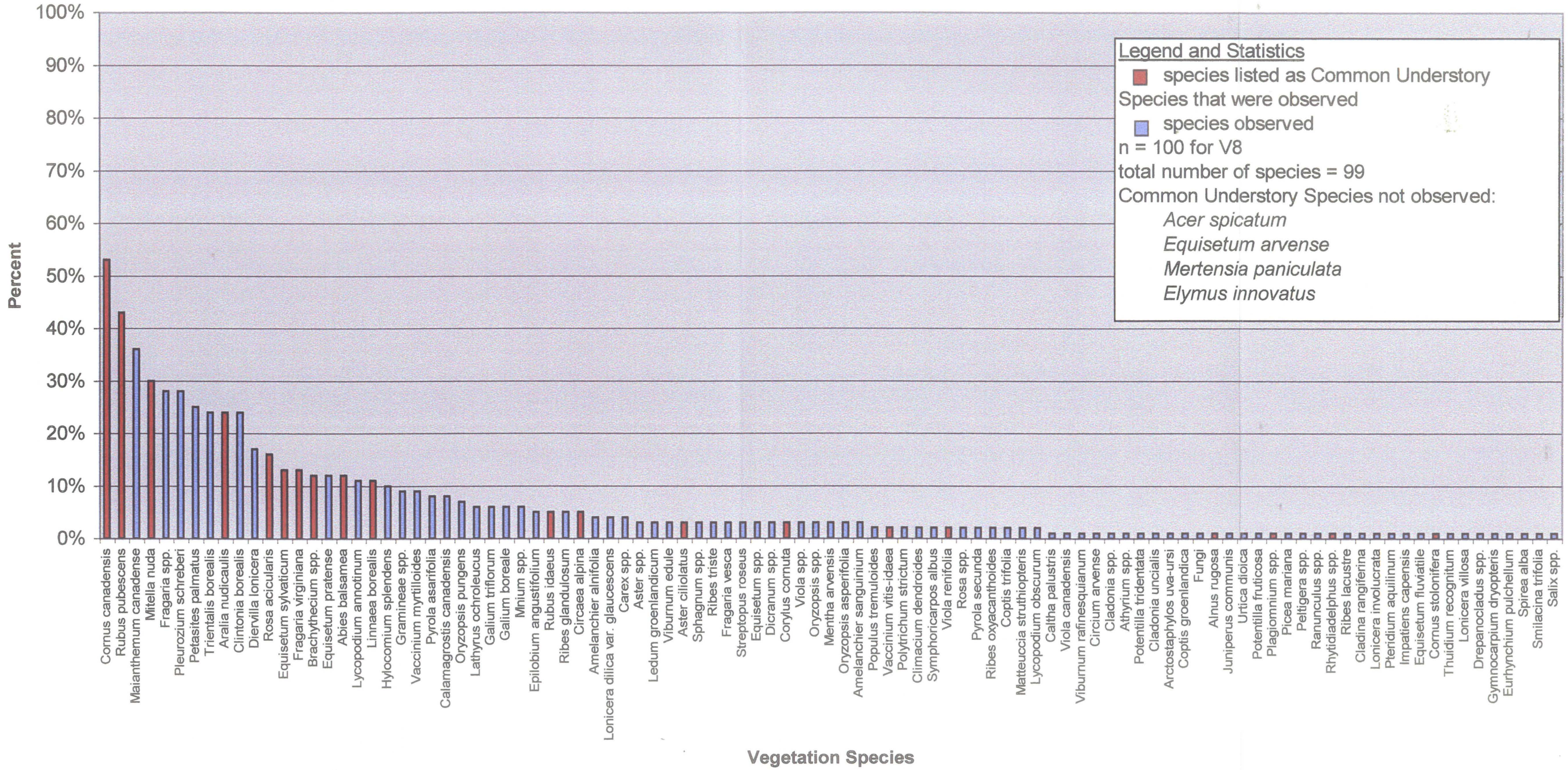
## Percent of each Vegetation Species Observed in Plots Classified as V6

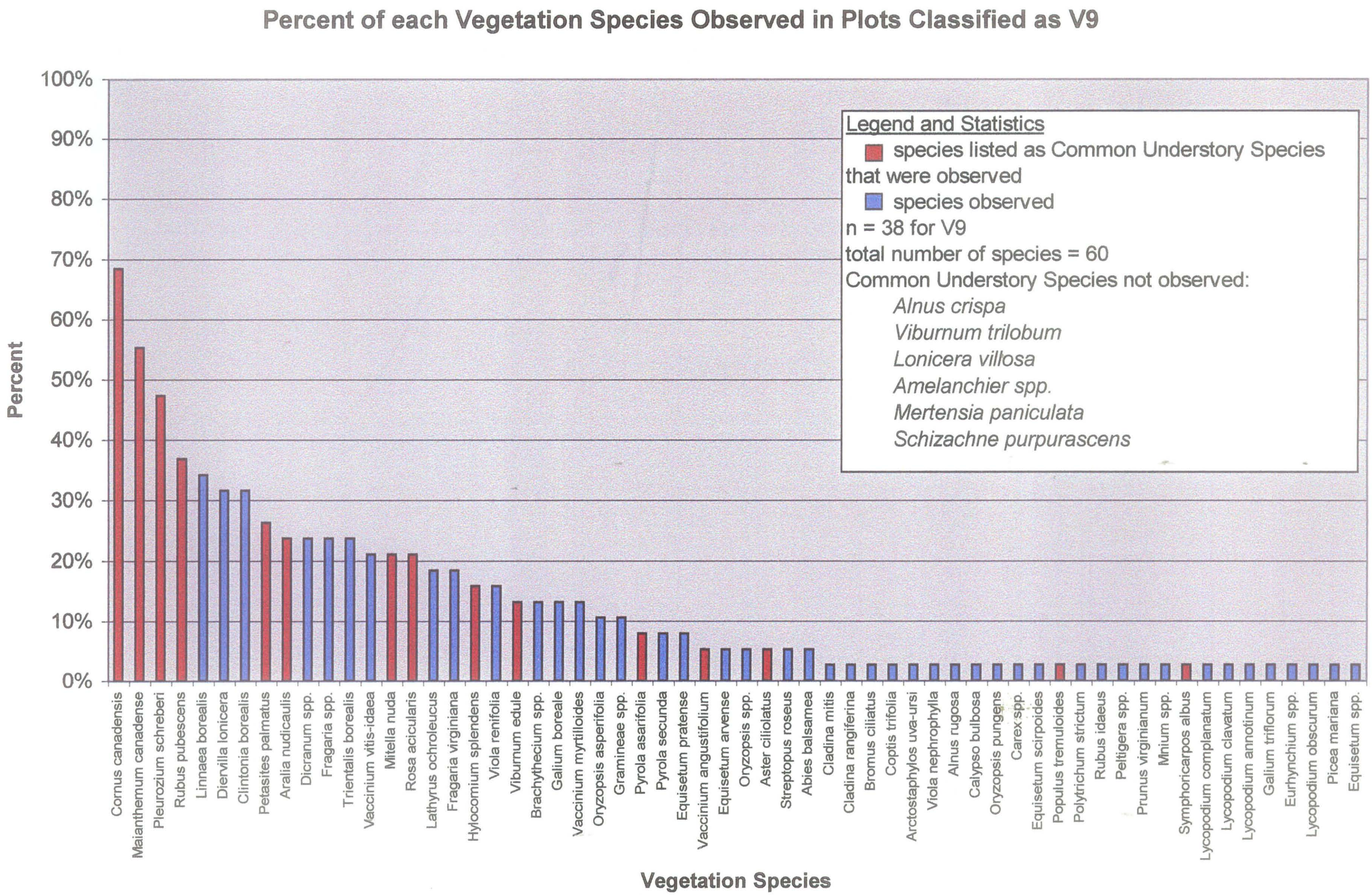




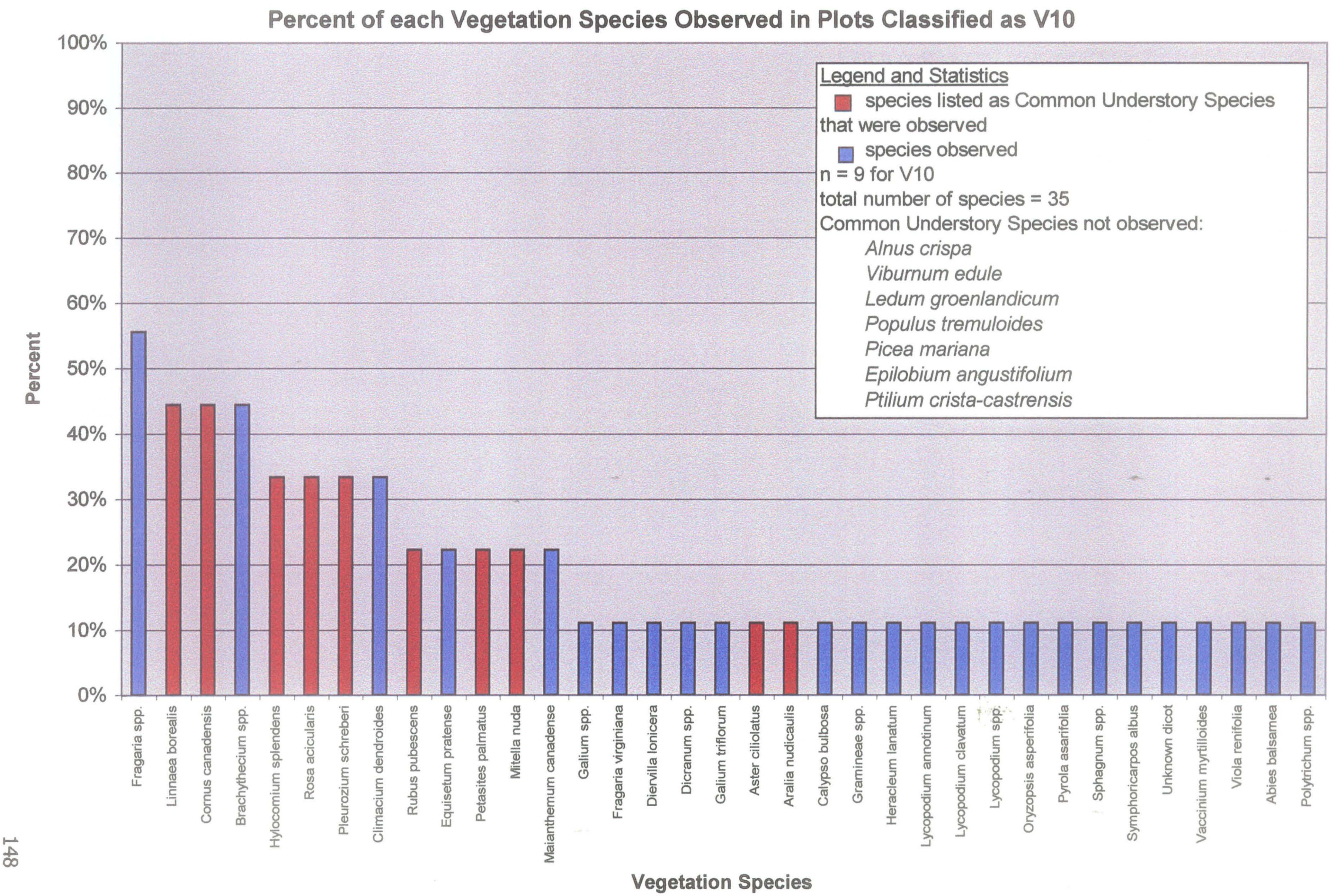
Percent of each Vegetation Species Observed in Plots Classified as V7
Percent
Vegetation Species
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 61 for V7
total number of species = 66
Common Understory Species not observed:
Drepanocladus uncinatus

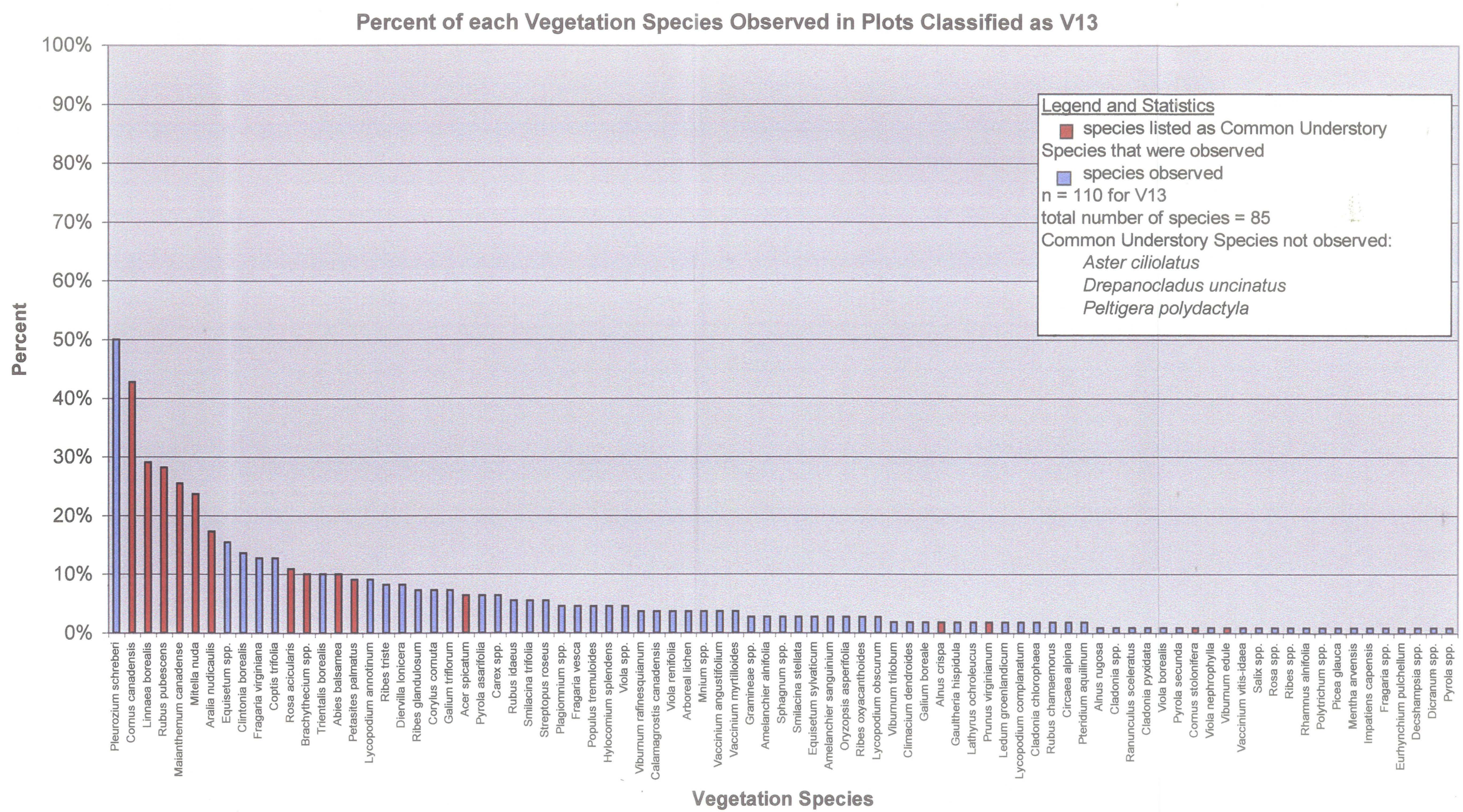
## Percent of each Vegetation Species Observed in Plots Classified as V8

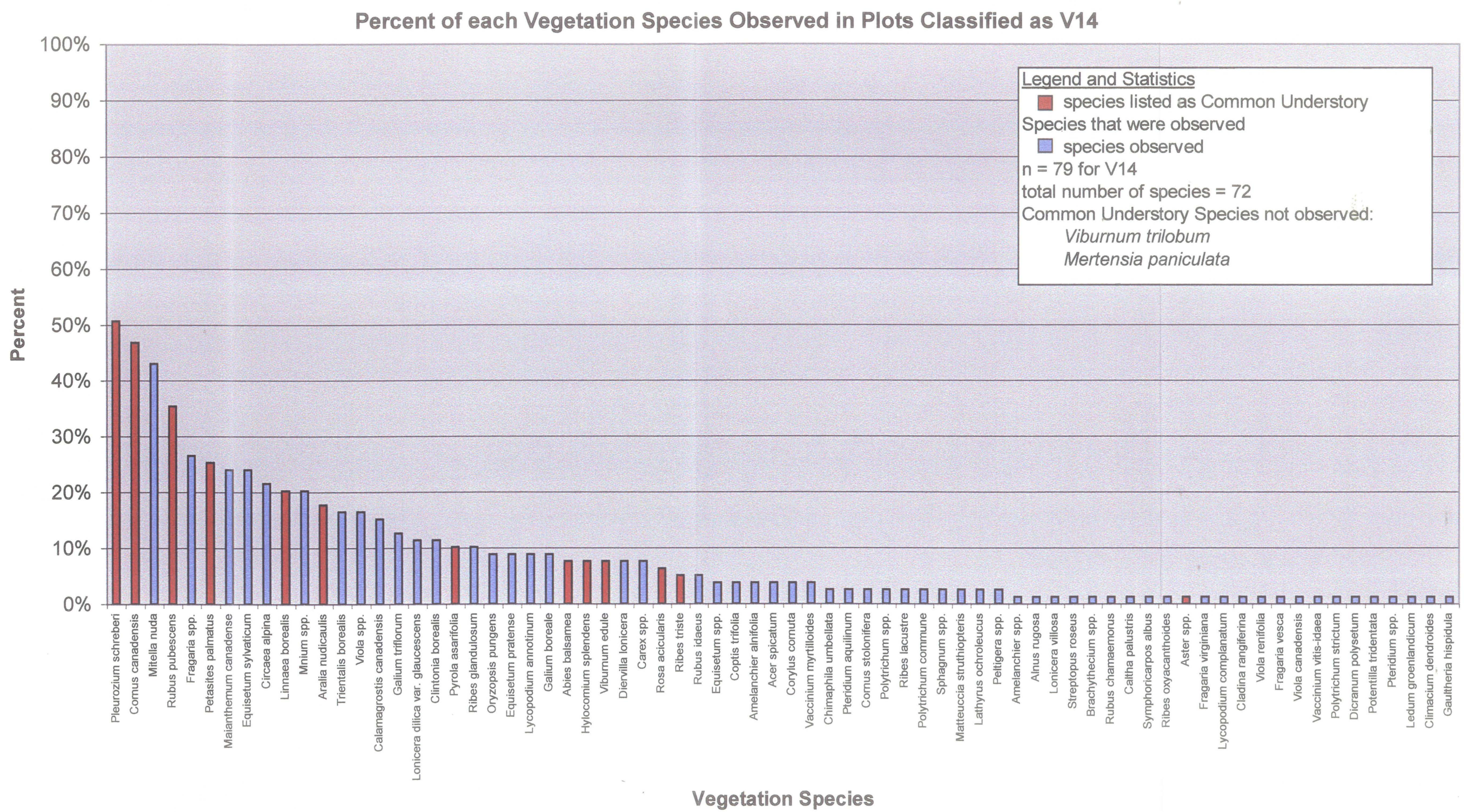




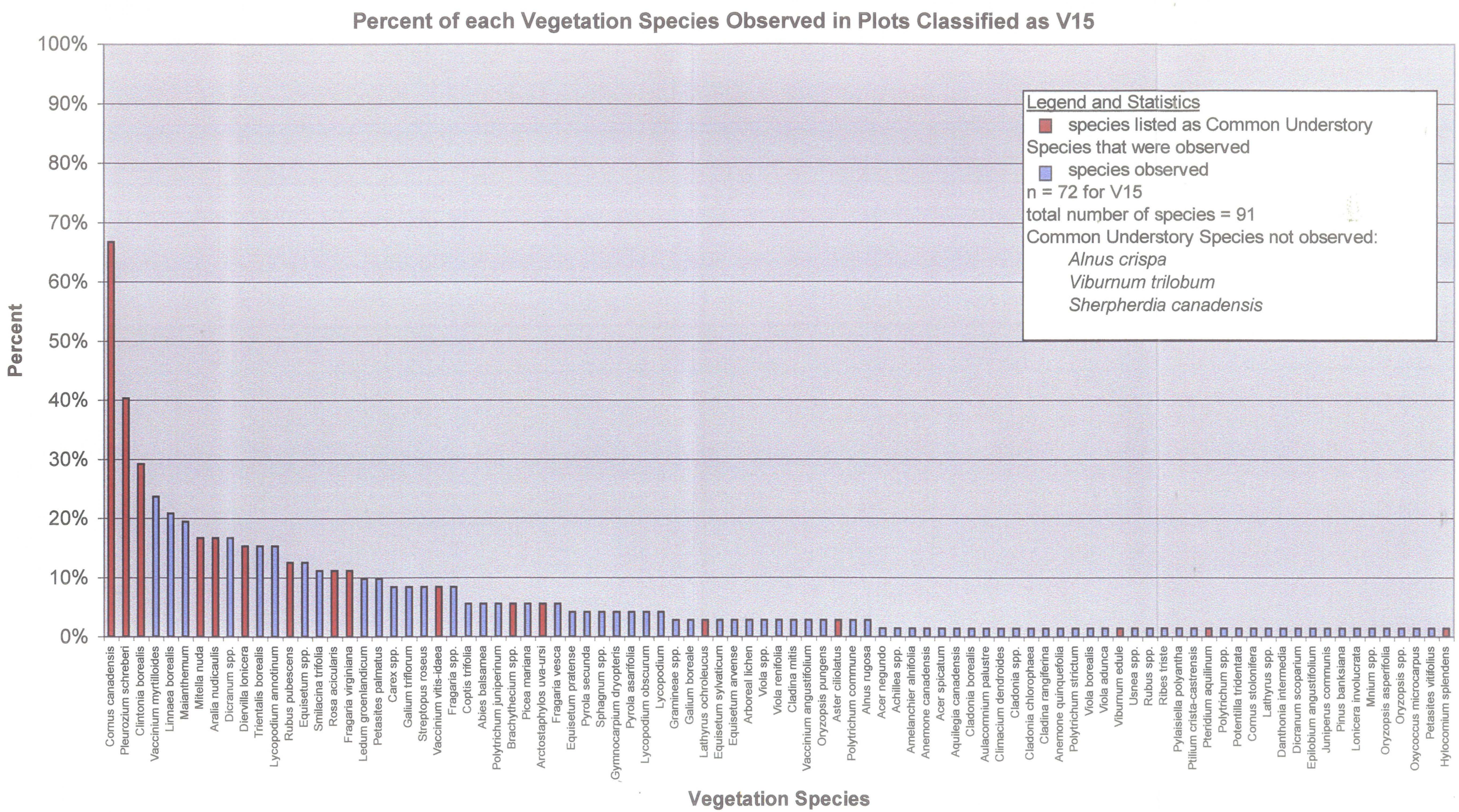
Percent of each Vegetation Species Observed in Plots Classified as V9
Percent
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 38 for V9
total number of species = 60
Common Understory Species not observed:
Alnus crispa
Viburnum trilobum
Lonicera villosa
Amelanchier spp.
Mertensia paniculata
Schizachne purpurascens
Cornus canadensis
Maianthemum canadense
Pleurozium schreberi
Rubus pubescens
Linnaea borealis
Diervilla lonicera
Clintonia borealis
Petasites palmatus
Aralia nudicaulis
Dicranum spp.
Fragaria spp.
Trientalis borealis
Vaccinium vitis-idaea
Mitella nuda
Rosa acicularis
Lathyrus ochroleucus
Fragaria virginiana
Hylocomium splendens
Viola renifolia
Viburnum edule
Brachythecium spp.
Galium boreale
Vaccinium myrtilloides
Oryzopsis asperifolia
Gramineae spp.
Pyrola asarifolia
Pyrola secunda
Equisetum pratense
Vaccinium angustifolium
Equisetum arvense
Oryzopsis spp.
Aster ciliolatus
Streptopus roseus
Abies balsamea
Cladina mitis
Cladina rangiferina
Bromus ciliatus
Coptis trifolia
Arctostaphylos uva-ursi
Viola nephrophylla
Alnus rugosa
Calypso bulbosa
Oryzopsis pungens
Carex spp.
Equisetum scirpoides
Populus tremuloides
Polytrichum strictum
Rubus idaeus
Peltigera spp.
Prunus virginianum
Mnium spp.
Symphoricarpos albus
Lycopodium complanatum
Lycopodium clavatum
Lycopodium annotinum
Galium triflorum
Eurhynchium spp.
Lycopodium obscurum
Picea mariana
Equisetum spp.
Vegetation Species


Percent of each Vegetation Species Observed in Plots Classified as V10
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 9 for V10
total number of species = 35
Common Understory Species not observed:
Alnus crispa
Viburnum edule
Ledum groenlandicum
Populus tremuloides
Picea mariana
Epilobium angustifolium
Ptilium crista-castrensis
Fragaria spp.
Linnaea borealis
Cornus canadensis
Brachythecium spp.
Hylocomium splendens
Rosa acicularis
Pleurozium schreberi
Climacium dendroides
Rubus pubescens
Equisetum pratense
Petasites palmatus
Mitella nuda
Maianthemum canadense
Galium spp.
Fragaria virginiana
Diervilla lonicera
Dicranum spp.
Galium triflorum
Aster ciliolatus
Aralia nudicaulis
Calypso bulbosa
Gramineae spp.
Heracleum lanatum
Lycopodium annotinum
Lycopodium clavatum
Lycopodium spp.
Oryzopsis asperifolia
Pyrola asarifolia
Sphagnum spp.
Symphoricarpos albus
Unknown dicot
Vaccinium myrtilloides
Viola renifolia
Abies balsamea
Polytrichum spp.
Vegetation Species

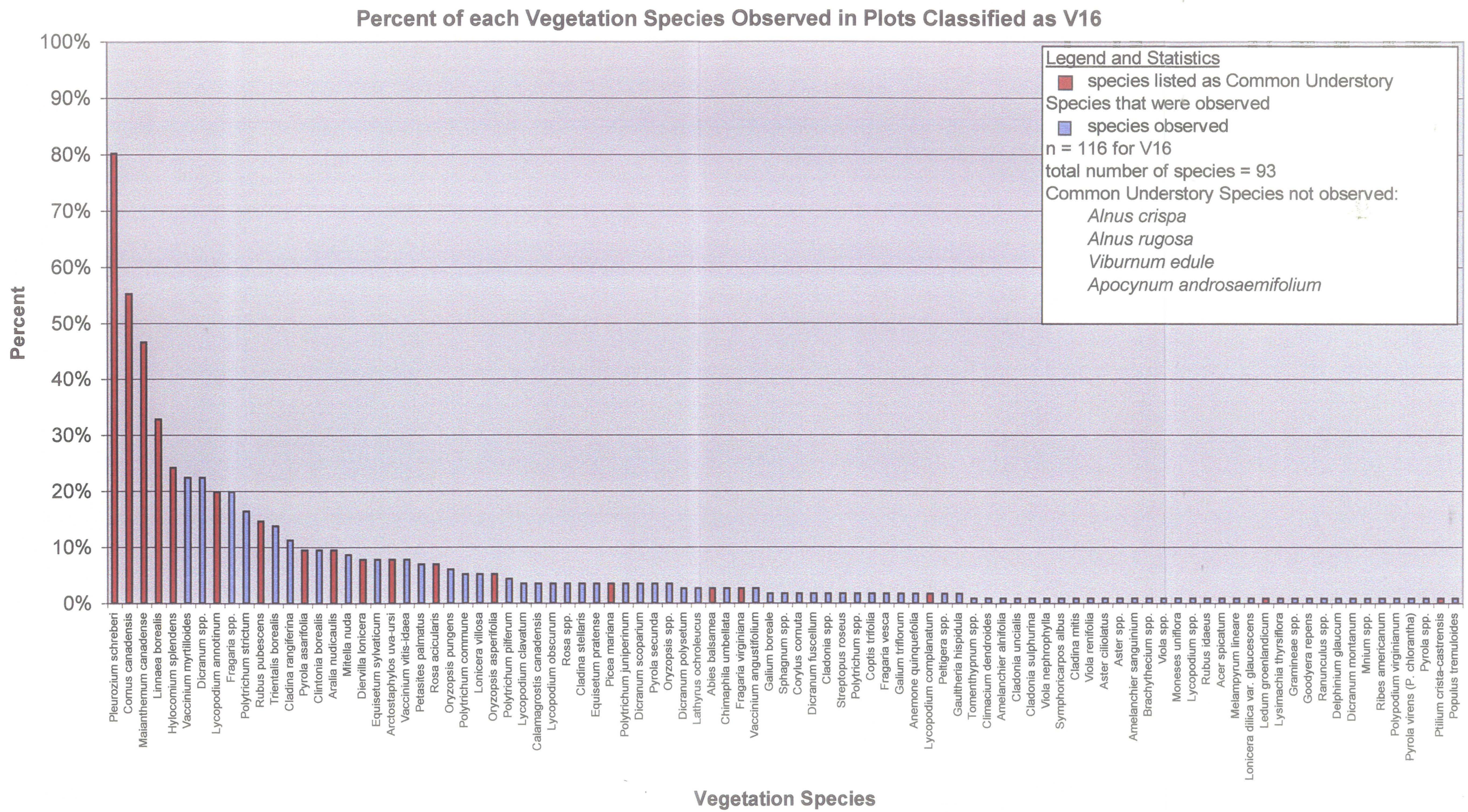

Percent of each Vegetation Species Observed in Plots Classified as V13
Percent
Vegetation Species
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 110 for V13
total number of species = 85
Common Understory Species not observed:
Aster ciliolatus
Drepanocladus uncinatus
Peltigera polydactyla



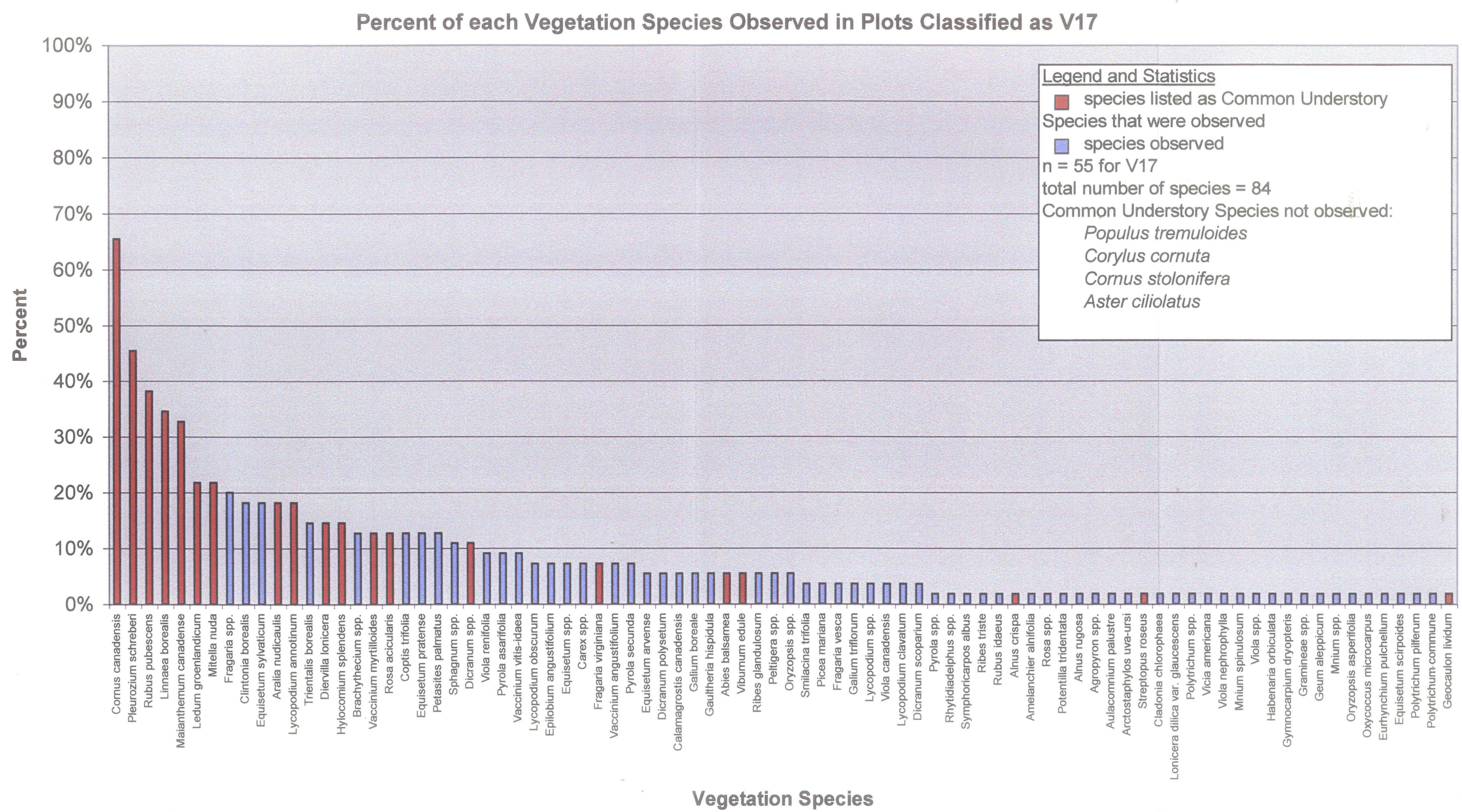
Percent of each Vegetation Species Observed in Plots Classified as V14
Percent
Vegetation Species
Legend and Statistics
species listed as Common Understory
Species that were observed
species observed
n = 79 for V14
total number of species = 72
Common Understory Species not observed:
Viburnum trilobum
Mertensia paniculata



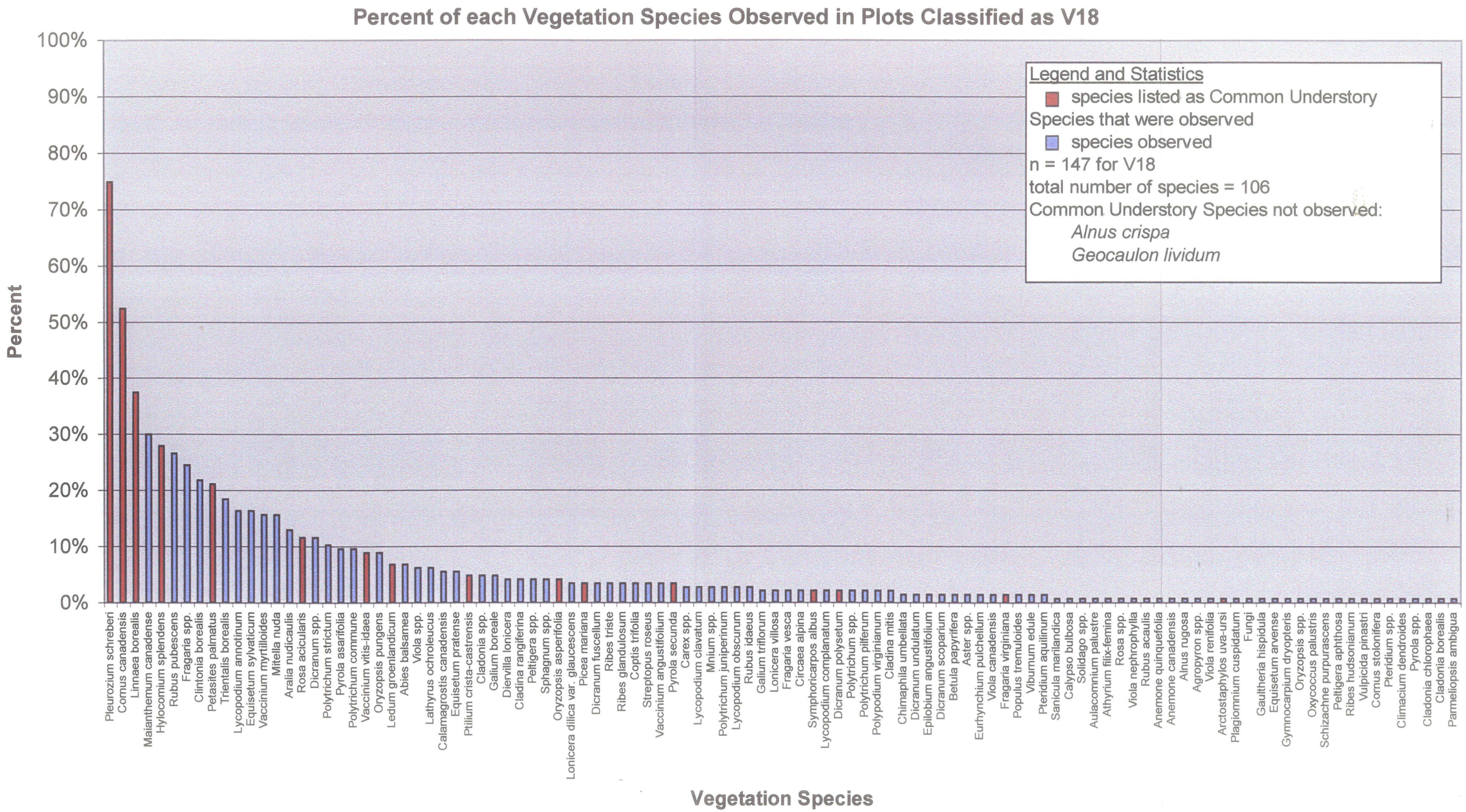
Percent of each Vegetation Species Observed in Plots Classified as V15
Percent
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 72 for V15
total number of species = 91
Common Understory Species not observed:
Alnus crispa
Viburnum trilobum
Sherpherdia canadensis
Vegetation Species
Cornus canadensis
Pleurozium schreberi
Clintonia borealis
Vaccinium myrtilloides
Linnaea borealis
Maianthemum
Mitella nuda
Aralia nudicaulis
Dicranum spp.
Diervilla lonicera
Trientalis borealis
Lycopodium annotinum
Rubus pubescens
Equisetum spp.
Smilacina trifolia
Rosa acicularis
Fragaria virginiana
Ledum groenlandicum
Petasites palmatus
Carex spp.
Galium triflorum
Streptopus roseus
Vaccinium vitis-idaea
Fragaria spp.
Coptis trifolia
Abies balsamea
Polytrichum juniperinum
Brachythecium spp.
Picea mariana
Arctostaphylos uva-ursi
Fragaria vesca
Equisetum pratense
Pyrola secunda
Sphagnum spp.
Gymnocarpium dryopteris
Pyrola asarifolia
Lycopodium obscurum
Lycopodium
Gramineae spp.
Galium boreale
Lathyrus ochroleucus
Equisetum sylvaticum
Equisetum arvense
Arboreal lichen
Viola spp.
Viola renifolia
Cladina mitis
Vaccinium angustifolium
Oryzopsis pungens
Aster ciliolatus
Polytrichum commune
Alnus rugosa
Acer negundo
Achillea spp.
Amelanchier alnifolia
Anemone canadensis
Acer spicatum
Aquilegia canadensis
Cladonia borealis
Aulacomnium palustre
Climacium dendroides
Cladonia spp.
Cladonia chlorophaea
Cladina rangiferina
Anemone quinquefolia
Polytrichum strictum
Viola borealis
Viola adunca
Viburnum edule
Usnea spp.
Rubus spp.
Ribes triste
Pylaisiella polyantha
Ptilium crista-castrensis
Pteridium aquilinum
Polytrichum spp.
Potentilla tridentata
Cornus stolonifera
Lathyrus spp.
Danthonia intermedia
Dicranum scoparium
Epilobium angustifolium
Juniperus communis
Pinus banksiana
Lonicera involucrata
Mnium spp.
Oryzopsis asperifolia
Oryzopsis spp.
Oxycoccus microcarpus
Petasites vitifolius
Hylocomium splendens

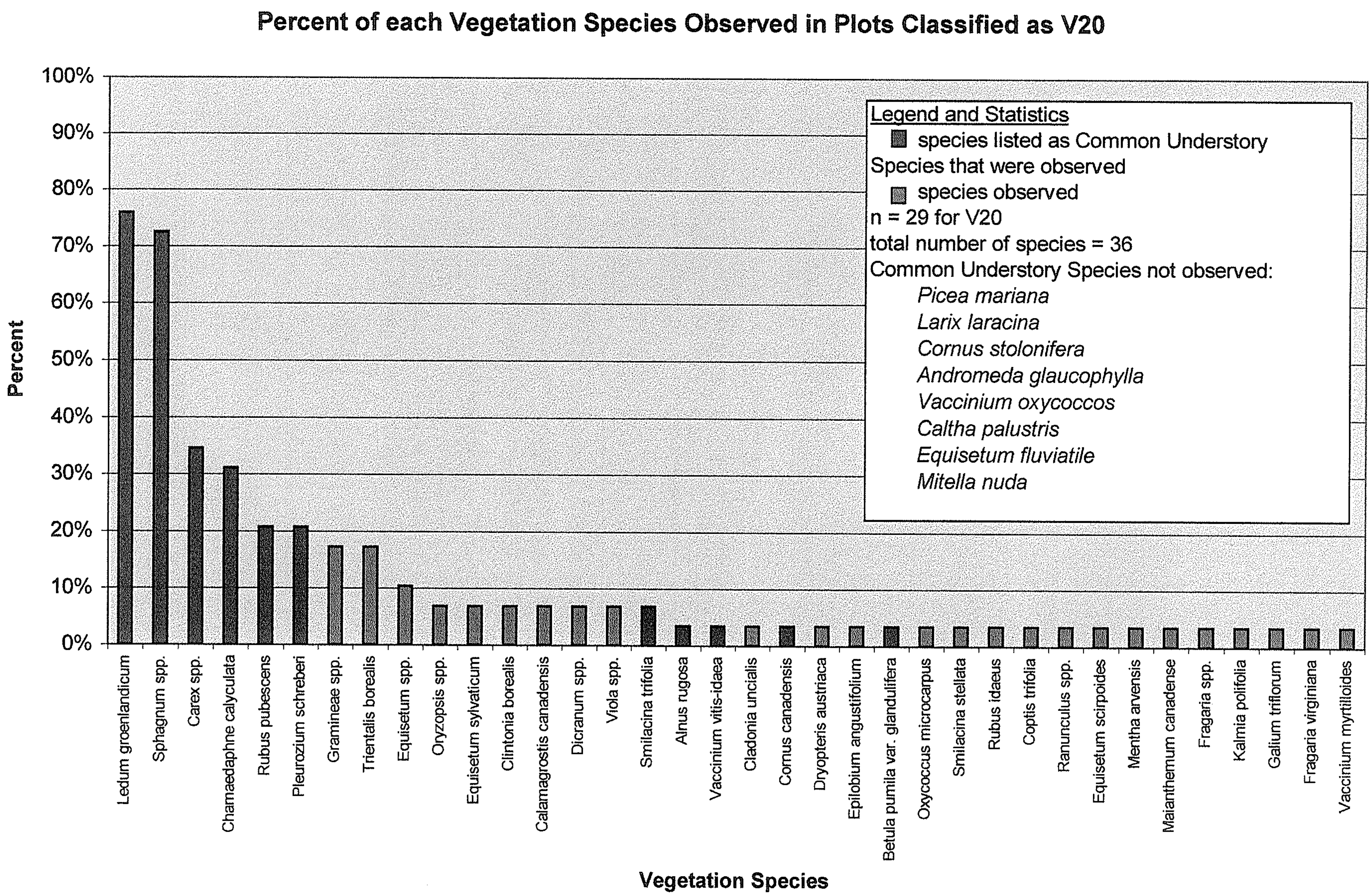


Percent of each Vegetation Species Observed in Plots Classified as V16
Percent
Vegetation Species
Legend and Statistics
species listed as Common Understory
Species that were observed
species observed
n = 116 for V16
total number of species = 93
Common Understory Species not observed:
Alnus crispa
Alnus rugosa
Viburnum edule
Apocynum androsaemifolium

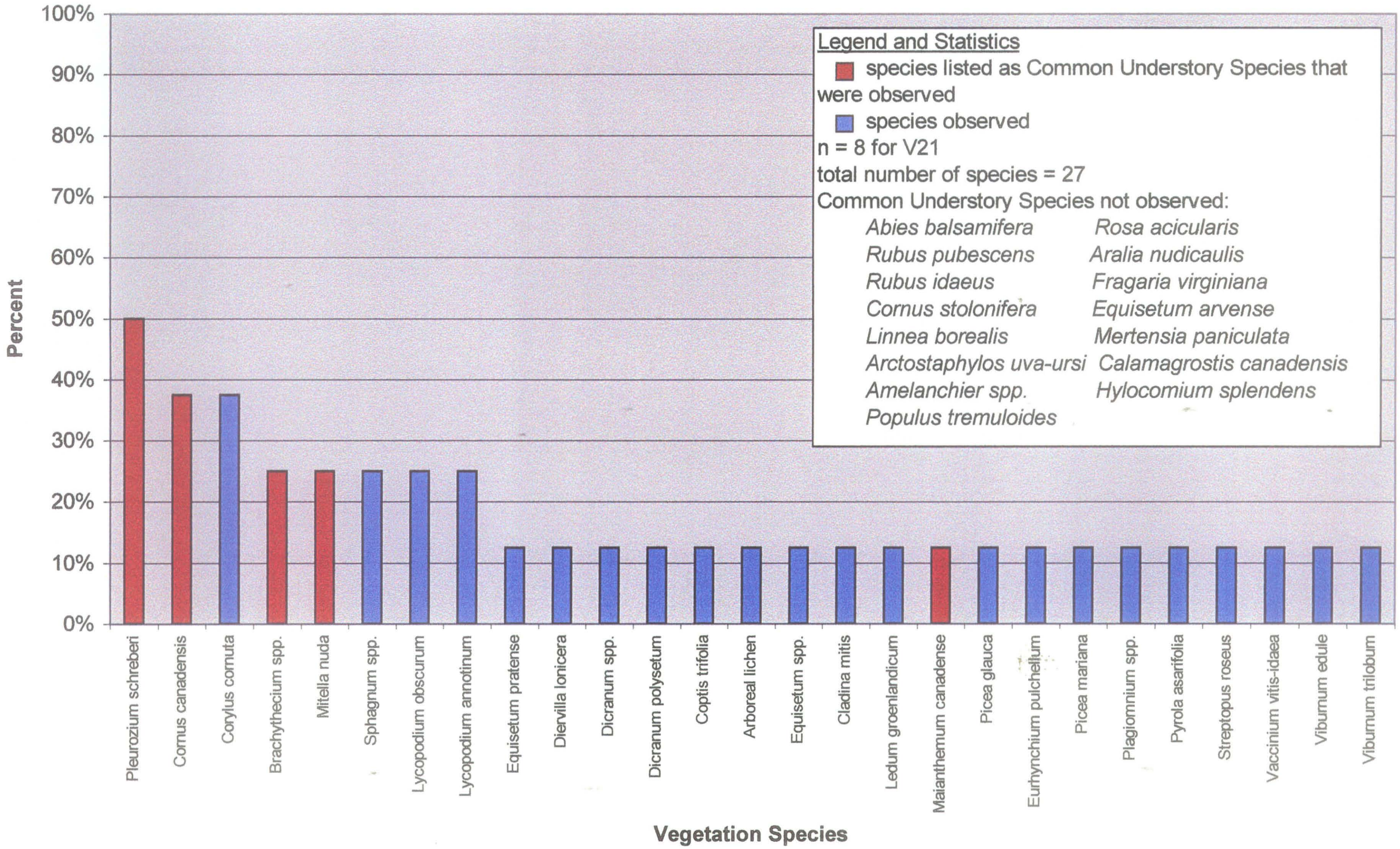


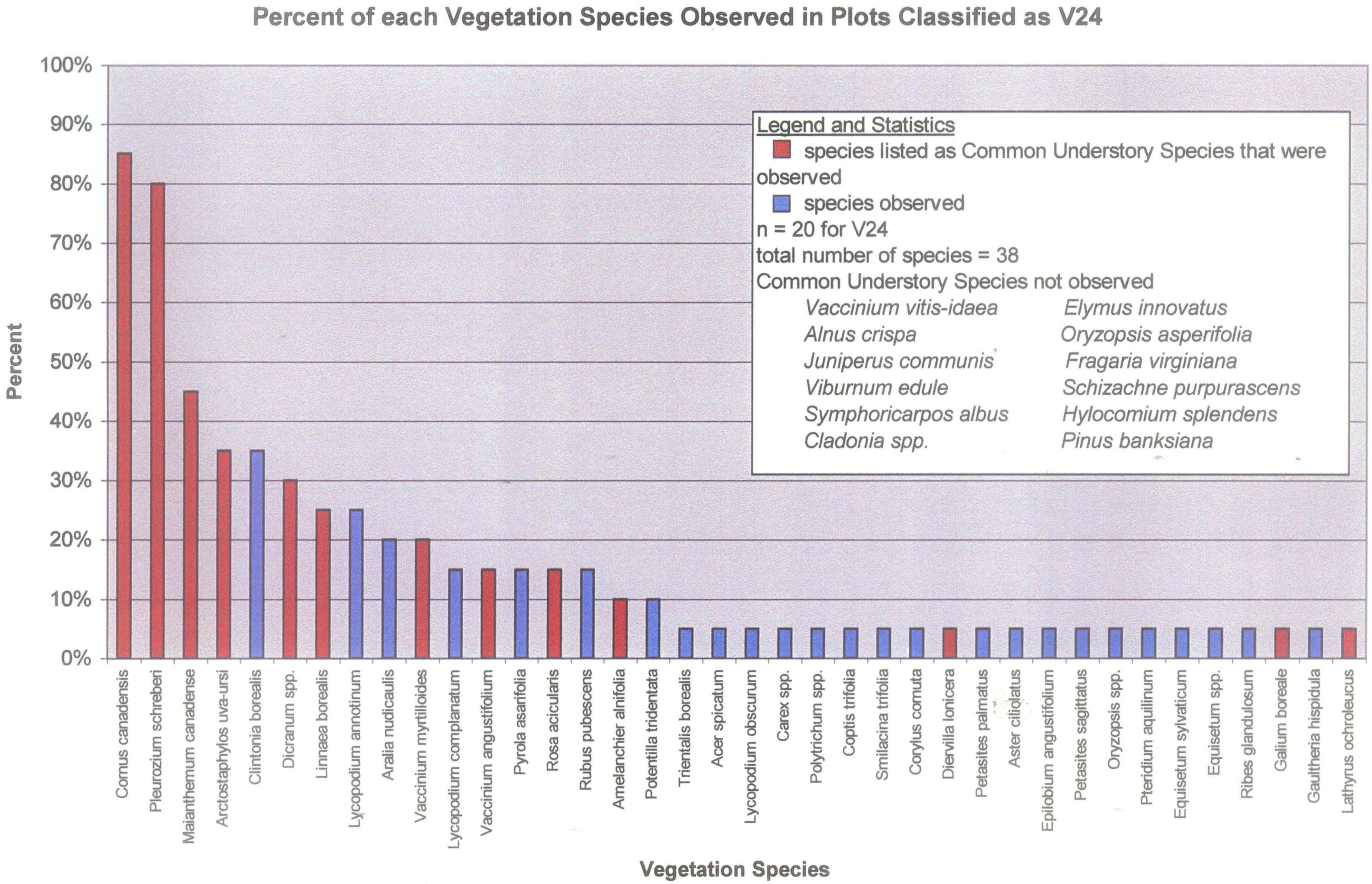
Percent of each Vegetation Species Observed in Plots Classified as V17
Percent
Vegetation Species
Legend and Statistics
species listed as Common Understory
Species that were observed
species observed
n = 55 for V17
total number of species = 84
Common Understory Species not observed:
Populus tremuloides
Corylus cornuta
Cornus stolonifera
Aster ciliolatus


Percent of each Vegetation Species Observed in Plots Classified as V18
Legend and Statistics
species listed as Common Understory
Species that were observed
species observed
n = 147 for V18
total number of species = 106
Common Understory Species not observed:
Alnus crispa
Geocaulon lividum
Percent
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Vegetation Species
Pleurozium schreberi
Cornus canadensis
Linnaea borealis
Maianthemum canadense
Hylocomium splendens
Rubus pubescens
Fragaria spp.
Clintonia borealis
Petasites palmatus
Trientalis borealis
Lycopodium annotinum
Equisetum sylvaticum
Vaccinium myrtilloides
Mitella nuda
Aralia nudicaulis
Rosa acicularis
Dicranum spp.
Polytrichum strictum
Pyrola asarifolia
Polytrichum commune
Vaccinium vitis-idaea
Oryzopsis pungens
Ledum groenlandicum
Abies balsamea
Viola spp.
Lathyrus ochroleucus
Calamagrostis canadensis
Equisetum pratense
Ptilium crista-castrensis
Cladonia spp.
Galium boreale
Diervilla lonicera
Cladina rangiferina
Peltigera spp.
Sphagnum spp.
Oryzopsis asperifolia
Lonicera dilica var. glaucescens
Picea mariana
Dicranum fuscellum
Ribes triste
Ribes glandulosum
Coptis trifolia
Streptopus roseus
Vaccinium angustifolium
Pyrola secunda
Carex spp.
Lycopodium clavatum
Mnium spp.
Polytrichum juniperinum
Lycopodium obscurum
Rubus idaeus
Galium triflorum
Lonicera villosa
Fragaria vesca
Circaea alpina
Symphoricarpos albus
Lycopodium complanatum
Dicranum polysetum
Polytrichum spp.
Polytrichum piliferum
Polypodium virginianum
Cladina mitis
Chimaphila umbellata
Dicranum undulatum
Epilobium angustifolium
Dicranum scoparium
Betula papyrifera
Aster spp.
Eurhynchium pulchellum
Viola canadensis
Fragaria virginiana
Populus tremuloides
Viburnum edule
Pteridium aquilinum
Sanicula marilandica
Calypso bulbosa
Solidago spp.
Aulacomnium palustre
Athyrium filix-femina
Rosa spp.
Viola nephrophylla
Rubus acaulis
Anemone quinquefolia
Anemone canadensis
Alnus rugosa
Agropyron spp.
Viola renifolia
Arctostaphylos uva-ursi
Plagiomnium cuspidatum
Fungi
Gaultheria hispidula
Equisetum arvense
Gymnocarpium dryopteris
Oryzopsis spp.
Oxycoccus palustris
Schizachne purpurascens
Peltigera aphthosa
Ribes hudsonianum
Vulpicida pinastri
Cornus stolonifera
Pteridium spp.
Climacium dendroides
Pyrola spp.
Cladonia chlorophaea
Cladonia borealis
Parmeliopsis ambigua

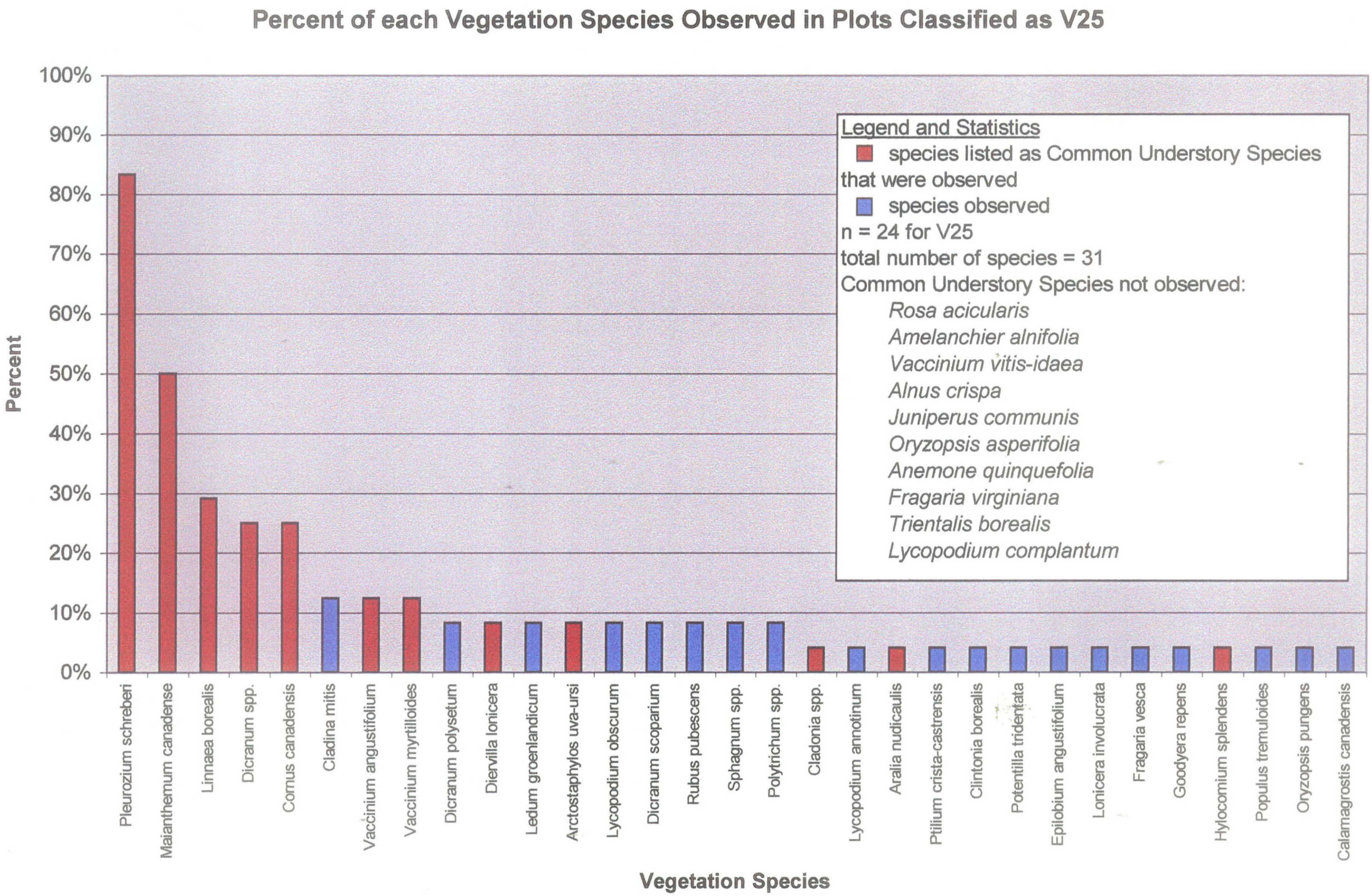

Percent of each Vegetation Species Observed in Plots Classified as V20
Percent
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 29 for V20
total number of species = 36
Common Understory Species not observed:
Picea mariana
Larix laracina
Cornus stolonifera
Andromeda glaucophylla
Vaccinium oxycoccos
Caltha palustris
Equisetum fluviatile
Mitella nuda
Ledum groenlandicum
Sphagnum spp.
Carex spp.
Chamaedaphne calyculata
Rubus pubescens
Pleurozium schreberi
Gramineae spp.
Trientalis borealis
Equisetum spp.
Oryzopsis spp.
Equisetum sylvaticum
Clintonia borealis
Calamagrostis canadensis
Dicranum spp.
Viola spp.
Smilacina trifolia
Alnus rugosa
Vaccinium vitis-idaea
Cladonia uncialis
Cornus canadensis
Dryopteris austriaca
Epilobium angustifolium
Betula pumila var. glandulifera
Oxycoccus microcarpus
Smilacina stellata
Rubus idaeus
Coptis trifolia
Ranunculus spp.
Equisetum scirpoides
Mentha arvensis
Maianthemum canadense
Fragaria spp.
Kalmia polifolia
Galium triflorum
Fragaria virginiana
Vaccinium myrtilloides
Vegetation Species

Percent of each Vegetation Species Observed in Plots Classified as V21

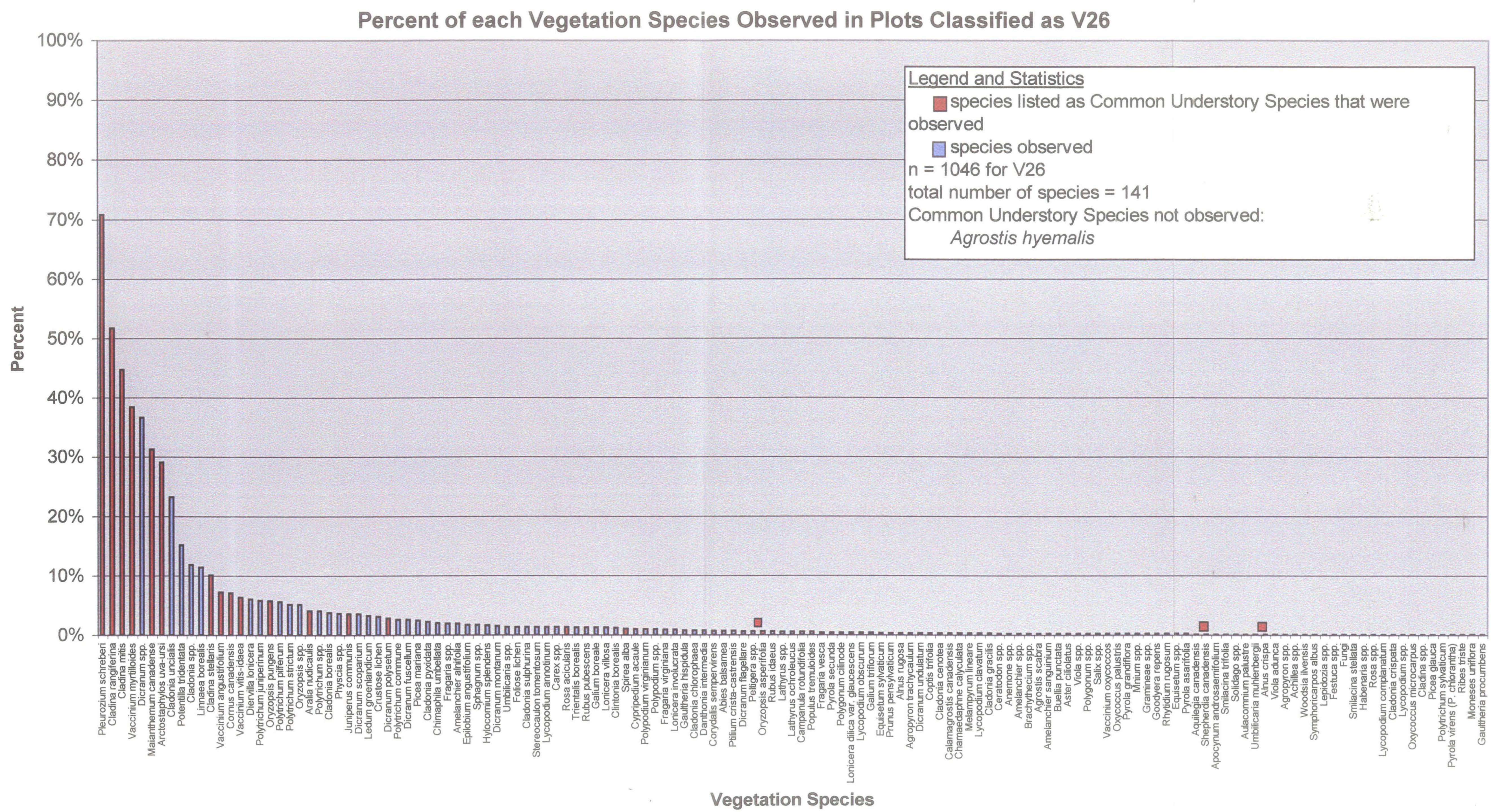




Percent of each Vegetation Species Observed in Plots Classified as V24
Percent
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Vegetation Species
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 20 for V24
total number of species = 38
Common Understory Species not observed
Vaccinium vitis-idaea
Elymus innovatus
Alnus crispa
Oryzopsis asperifolia
Juniperus communis
Fragaria virginiana
Viburnum edule
Schizachne purpurascens
Symphoricarpos albus
Hylocomium splendens
Cladonia spp.
Pinus banksiana
Cornus canadensis
Pleurozium schreberi
Maianthemum canadense
Arctostaphylos uva-ursi
Clintonia borealis
Dicranum spp.
Linnaea borealis
Lycopodium annotinum
Aralia nudicaulis
Vaccinium myrtilloides
Lycopodium complanatum
Vaccinium angustifolium
Pyrola asarifolia
Rosa acicularis
Rubus pubescens
Amelanchier alnifolia
Potentilla tridentata
Trientalis borealis
Acer spicatum
Lycopodium obscurum
Carex spp.
Polytrichum spp.
Coptis trifolia
Smilacina trifolia
Corylus cornuta
Diervilla lonicera
Petasites palmatus
Aster ciliolatus
Epilobium angustifolium
Petasites sagittatus
Oryzopsis spp.
Pteridium aquilinum
Equisetum sylvaticum
Equisetum spp.
Ribes glandulosum
Galium boreale
Gaultheria hispidula
Lathyrus ochroleucus

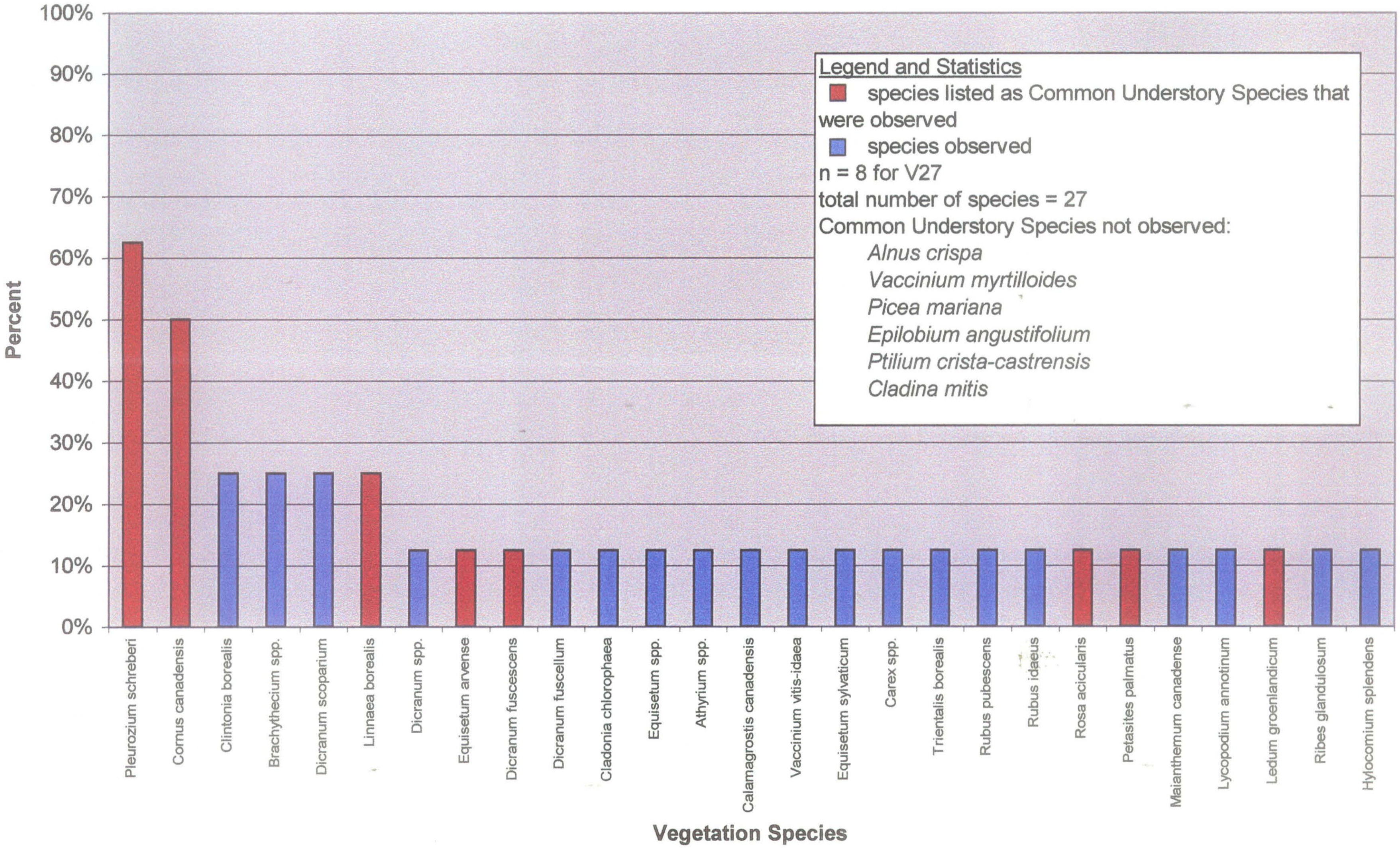


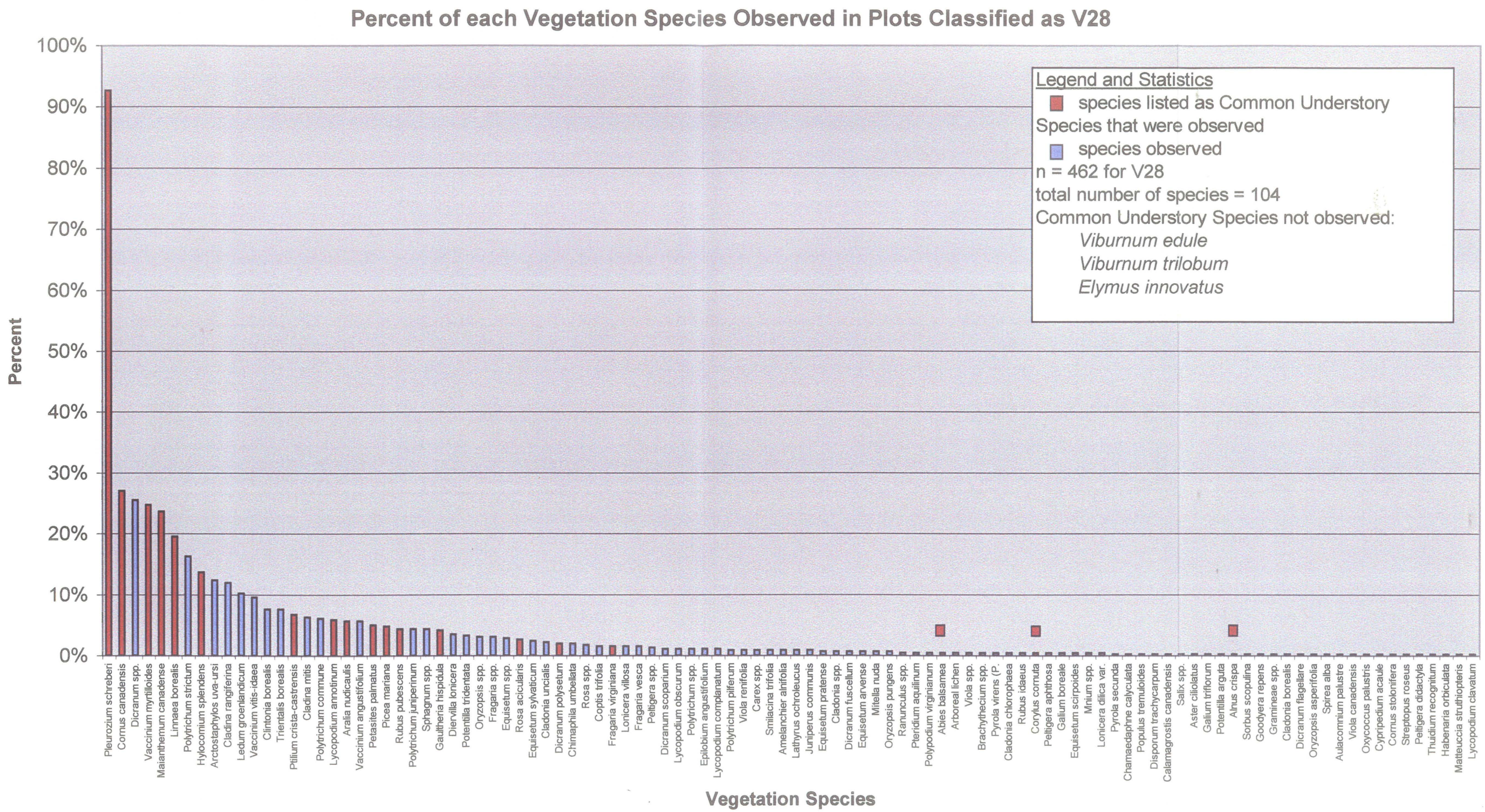
Percent of each Vegetation Species Observed in Plots Classified as V25
Percent
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 24 for V25
total number of species = 31
Common Understory Species not observed:
Rosa acicularis
Amelanchier alnifolia
Vaccinium vitis-idaea
Alnus crispa
Juniperus communis
Oryzopsis asperifolia
Anemone quinquefolia
Fragaria virginiana
Trientalis borealis
Lycopodium complantum
Pleurozium schreberi
Maianthemum canadense
Linnaea borealis
Dicranum spp.
Cornus canadensis
Cladina mitis
Vaccinium angustifolium
Vaccinium myrtilloides
Dicranum polysetum
Diervilla lonicera
Ledum groenlandicum
Arctostaphylos uva-ursi
Lycopodium obscurum
Dicranum scoparium
Rubus pubescens
Sphagnum spp.
Polytrichum spp.
Cladonia spp.
Lycopodium annotinum
Aralia nudicaulis
Ptilium crista-castrensis
Clintonia borealis
Potentilla tridentata
Epilobium angustifolium
Lonicera involucrata
Fragaria vesca
Goodyera repens
Hylocomium splendens
Populus tremuloides
Oryzopsis pungens
Calamagrostis canadensis
Vegetation Species

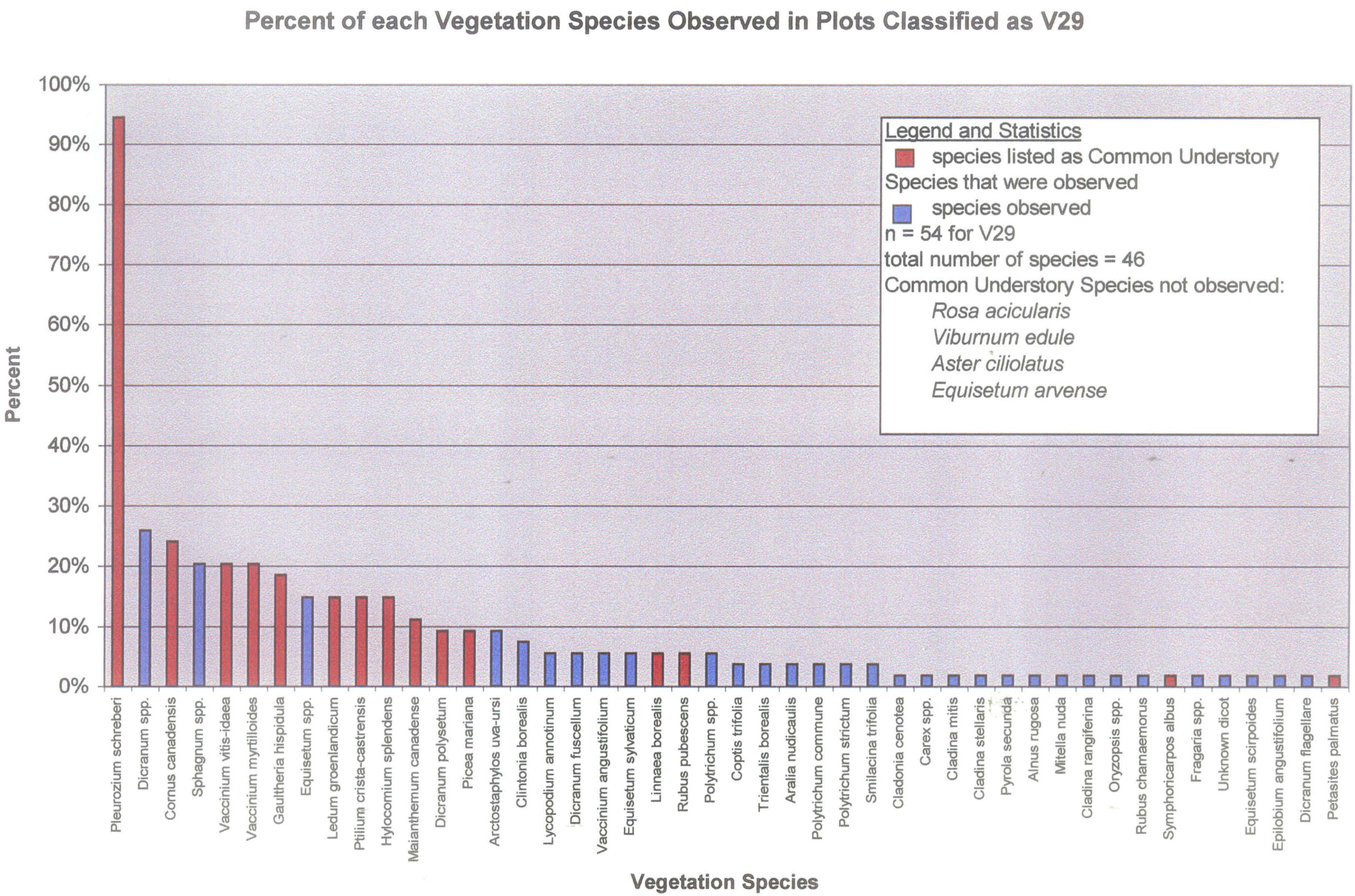


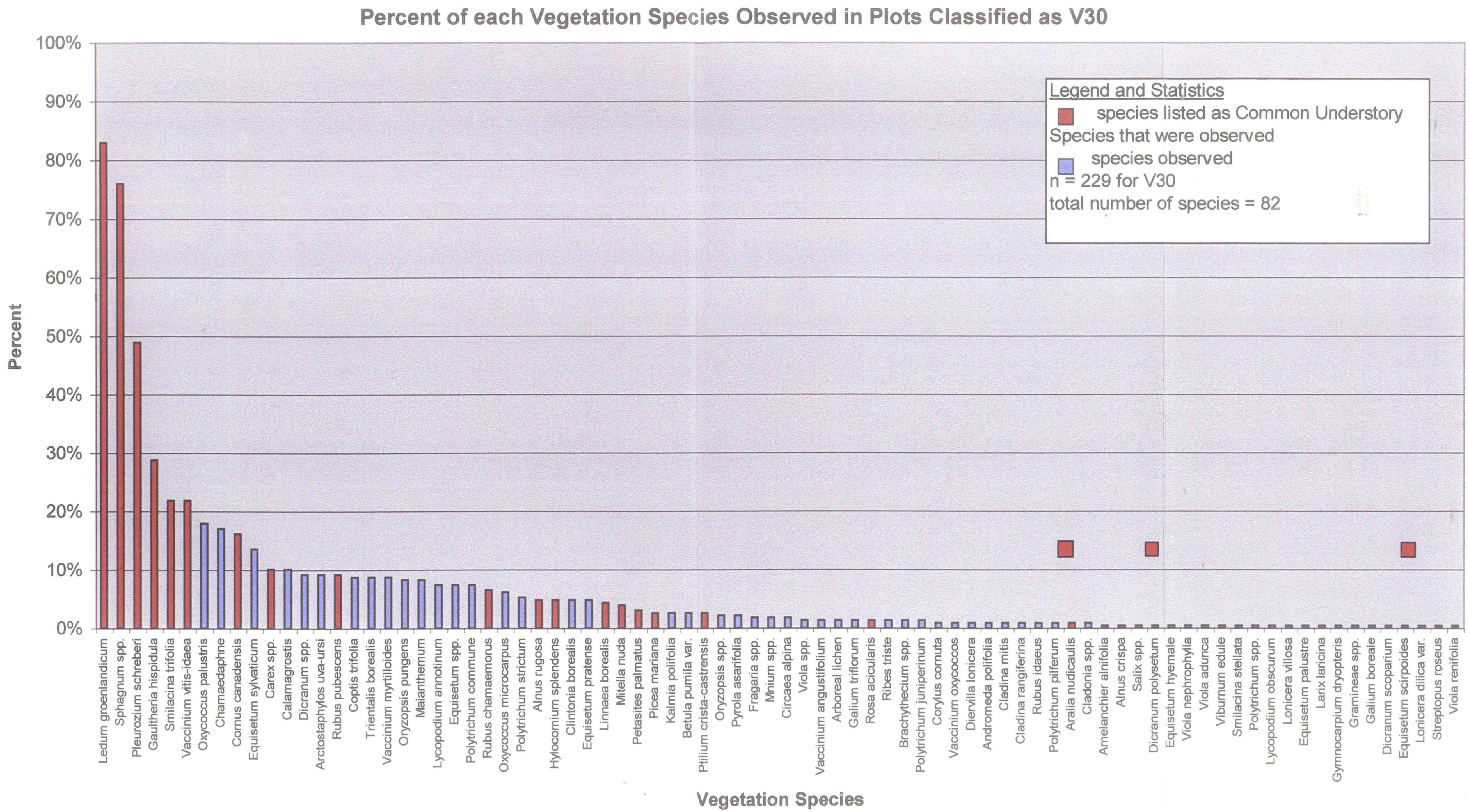
Percent of each Vegetation Species Observed in Plots Classified as V26
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 1046 for V26
total number of species = 141
Common Understory Species not observed:
Agrostis hyemalis
Percent
Vegetation Species

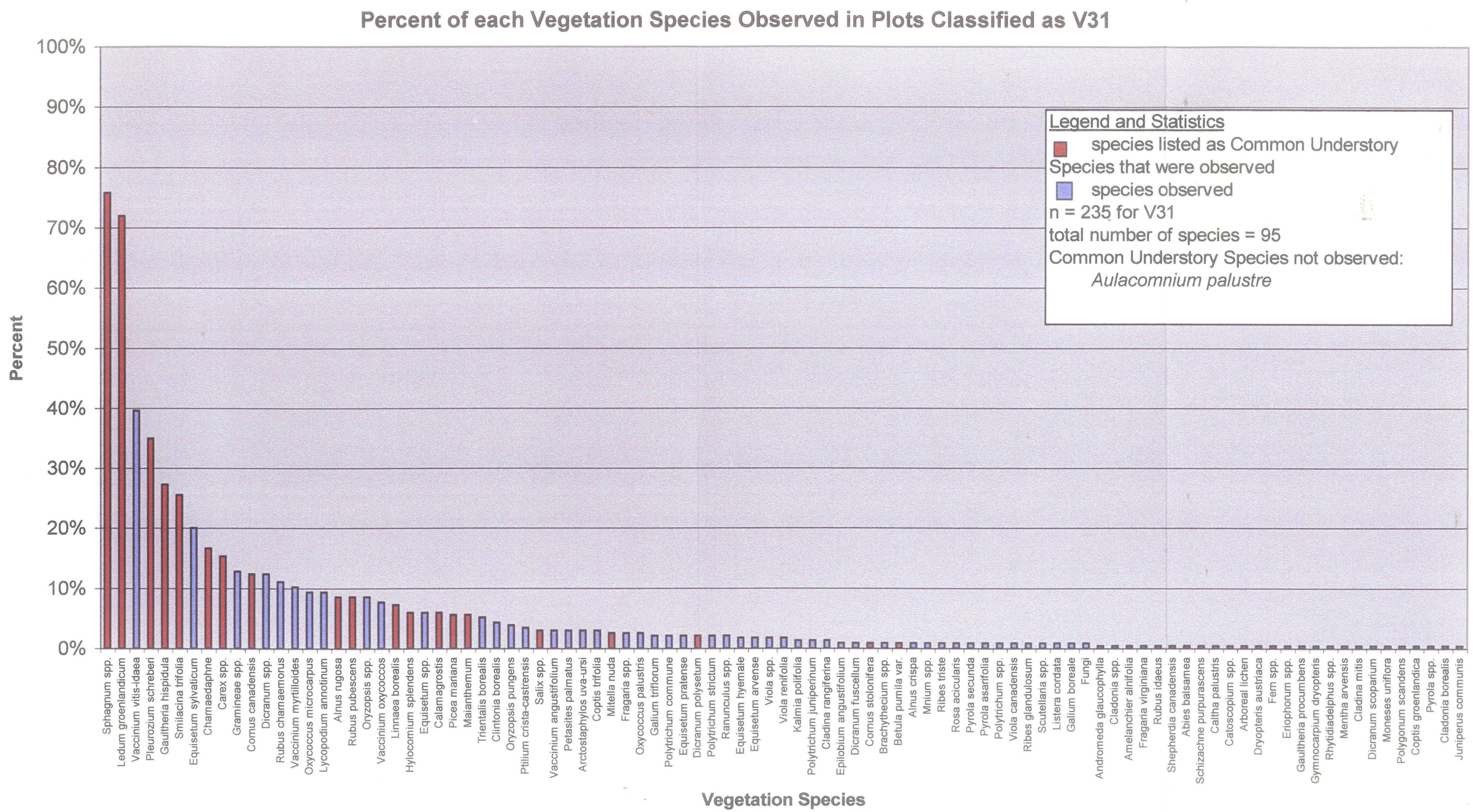
## Percent of each Vegetation Species Observed in Plots Classified as V27



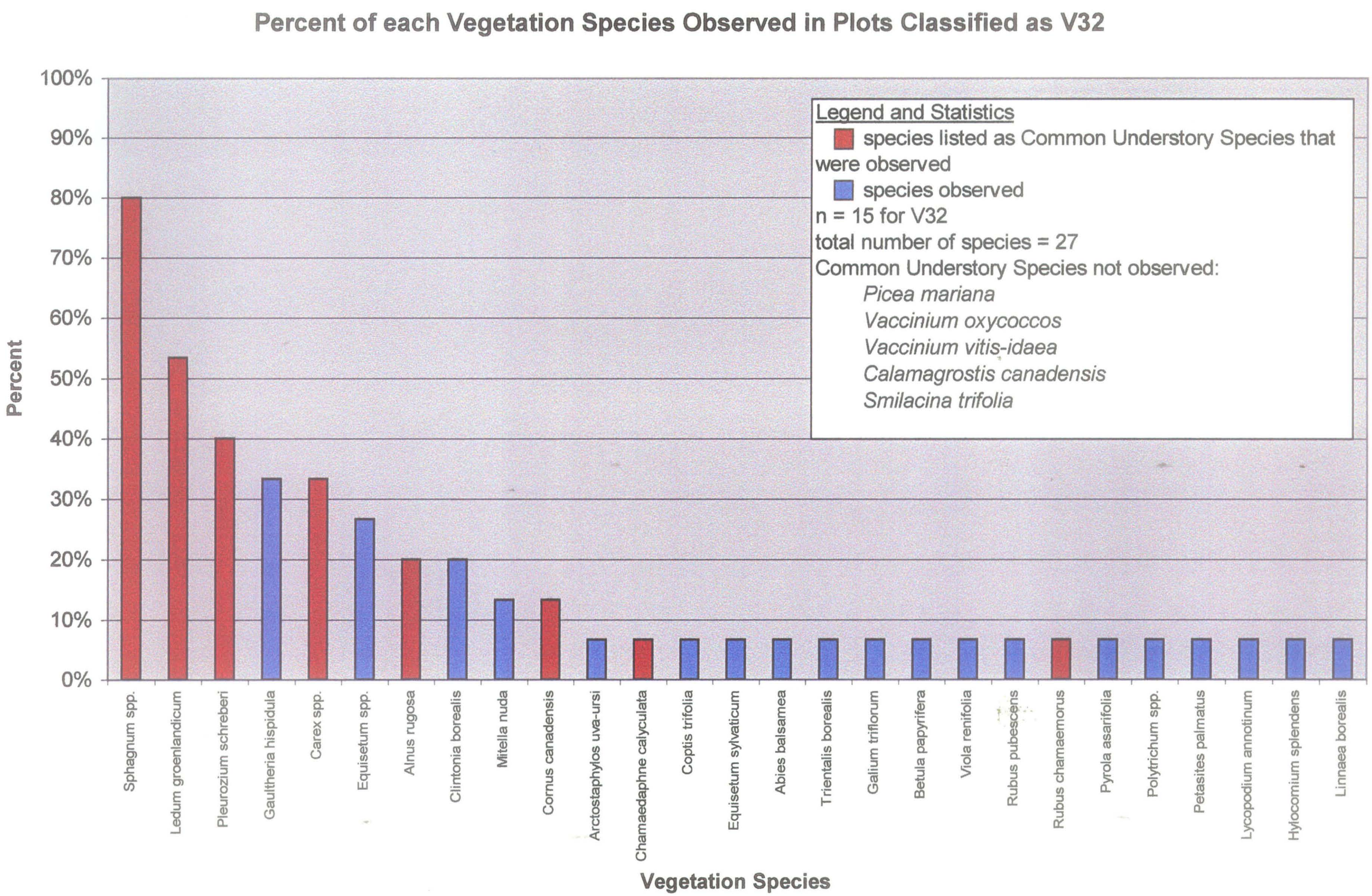

Percent of each Vegetation Species Observed in Plots Classified as V28
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 462 for V28
total number of species = 104
Common Understory Species not observed:
Viburnum edule
Viburnum trilobum
Elymus innovatus
Pleurozium schreberi
Cornus canadensis
Dicranum spp.
Vaccinium myrtilloides
Maianthemum canadense
Linnaea borealis
Polytrichum strictum
Hylocomium splendens
Arctostaphylos uva-ursi
Cladina rangiferina
Ledum groenlandicum
Vaccinium vitis-idaea
Clintonia borealis
Trientalis borealis
Ptilium crista-castrensis
Cladina mitis
Polytrichum commune
Lycopodium annotinum
Aralia nudicaulis
Vaccinium angustifolium
Petasites palmatus
Picea mariana
Rubus pubescens
Polytrichum juniperinum
Sphagnum spp.
Gaultheria hispidula
Diervilla lonicera
Potentilla tridentata
Oryzopsis spp.
Fragaria spp.
Equisetum spp.
Rosa acicularis
Equisetum sylvaticum
Cladonia uncialis
Dicranum polysetum
Chimaphila umbellata
Rosa spp.
Coptis trifolia
Fragaria virginiana
Lonicera villosa
Fragaria vesca
Peltigera spp.
Dicranum scoparium
Lycopodium obscurum
Polytrichum spp.
Epilobium angustifolium
Lycopodium complanatum
Polytrichum piliferum
Viola renifolia
Carex spp.
Smilacina trifolia
Amelanchier alnifolia
Lathyrus ochroleucus
Juniperus communis
Equisetum pratense
Cladonia spp.
Dicranum fuscescens
Equisetum arvense
Mitella nuda
Oryzopsis pungens
Ranunculus spp.
Pteridium aquilinum
Polypodium virginianum
Abies balsamea
Arboreal lichen
Viola spp.
Brachythecium spp.
Pyrola virens (P.
Cladonia chlorophaea
Rubus idaeus
Corylus cornuta
Peltigera aphthosa
Galium boreale
Equisetum scirpoides
Mnium spp.
Lonicera dilica var.
Pyrola secunda
Chamaedaphne calyculata
Populus tremuloides
Disporum trachycarpum
Calamagrostis canadensis
Salix spp.
Aster ciliolatus
Galium triflorum
Potentilla arguta
Alnus crispa
Sorbus scopulina
Goodyera repens
Gramineae spp.
Cladonia borealis
Dicranum flagellare
Oryzopsis asperifolia
Spirea alba
Aulacomnium palustre
Viola canadensis
Oxycoccus palustris
Cypripedium acaule
Cornus stolonifera
Streptopus roseus
Peltigera didactyla
Thuidium recognitum
Habenaria orbiculata
Matteuccia struthiopteris
Lycopodium clavatum
Vegetation Species


Percent of each Vegetation Species Observed in Plots Classified as V29
Percent
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Vegetation Species
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 54 for V29
total number of species = 46
Common Understory Species not observed:
Rosa acicularis
Viburnum edule
Aster ciliolatus
Equisetum arvense
Pleurozium schreberi
Dicranum spp.
Cornus canadensis
Sphagnum spp.
Vaccinium vitis-idaea
Vaccinium myrtilloides
Gaultheria hispidula
Equisetum spp.
Ledum groenlandicum
Ptilium crista-castrensis
Hylocomium splendens
Maianthemum canadense
Dicranum polysetum
Picea mariana
Arctostaphylos uva-ursi
Clintonia borealis
Lycopodium annotinum
Dicranum fuscellum
Vaccinium angustifolium
Equisetum sylvaticum
Linnaea borealis
Rubus pubescens
Polytrichum spp.
Coptis trifolia
Trientalis borealis
Aralia nudicaulis
Polytrichum commune
Polytrichum strictum
Smilacina trifolia
Cladonia cenotea
Carex spp.
Cladina mitis
Cladina stellaris
Pyrola secunda
Alnus rugosa
Mitella nuda
Cladina rangiferina
Oryzopsis spp.
Rubus chamaemorus
Symphoricarpos albus
Fragaria spp.
Unknown dicot
Equisetum scirpoides
Epilobium angustifolium
Dicranum flagellare
Petasites palmatus


Percent of each Vegetation Species Observed in Plots Classified as V30
Percent
Vegetation Species
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 229 for V30
total number of species = 82

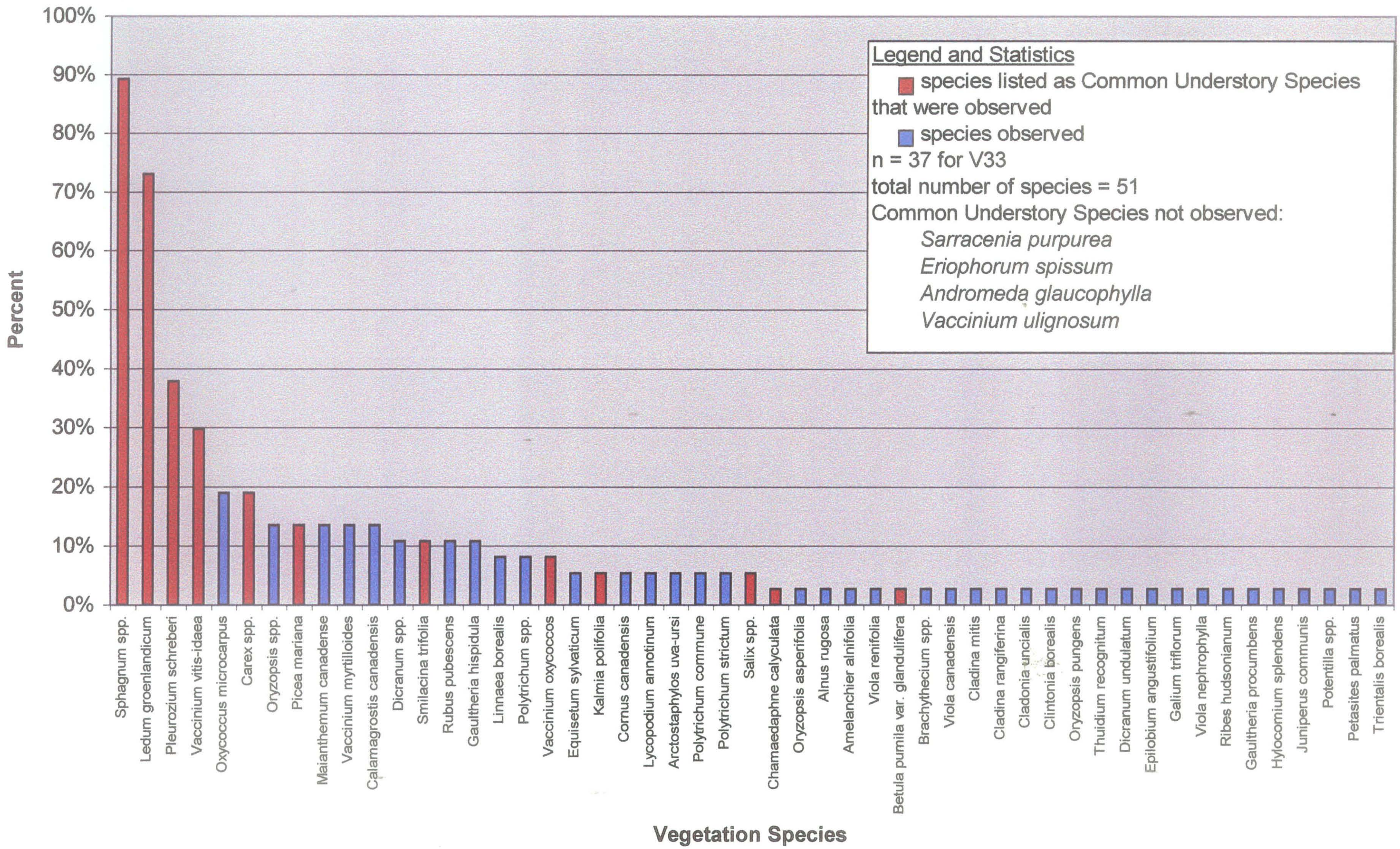


Percent of each Vegetation Species Observed in Plots Classified as V31
Percent
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Legend and Statistics
species listed as Common Understory
Species that were observed
species observed
n = 235 for V31
total number of species = 95
Common Understory Species not observed:
Aulacomnium palustre
Sphagnum spp.
Ledum groenlandicum
Vaccinium vitis-idaea
Pleurozium schreberi
Gaultheria hispidula
Smilacina trifolia
Equisetum sylvaticum
Chamaedaphne
Carex spp.
Gramineae spp.
Cornus canadensis
Dicranum spp.
Rubus chamaemorus
Vaccinium myrtilloides
Oxycoccus microcarpus
Lycopodium annotinum
Alnus rugosa
Rubus pubescens
Oryzopsis spp.
Vaccinium oxycoccos
Linnaea borealis
Hylocomium splendens
Equisetum spp.
Calamagrostis
Picea mariana
Maianthemum
Trientalis borealis
Clintonia borealis
Oryzopsis pungens
Ptilium crista-castrensis
Salix spp.
Vaccinium angustifolium
Petasites palmatus
Arctostaphylos uva-ursi
Coptis trifolia
Mitella nuda
Fragaria spp.
Oxycoccus palustris
Galium triflorum
Polytrichum commune
Equisetum pratense
Dicranum polysetum
Polytrichum strictum
Ranunculus spp.
Equisetum hyemale
Equisetum arvense
Viola spp.
Viola renifolia
Kalmia polifolia
Polytrichum juniperinum
Cladina rangiferina
Epilobium angustifolium
Dicranum fuscellum
Cornus stolonifera
Brachythecium spp.
Betula pumila var.
Alnus crispa
Mnium spp.
Ribes triste
Rosa acicularis
Pyrola secunda
Pyrola asarifolia
Polytrichum spp.
Viola canadensis
Ribes glandulosum
Scutellaria spp.
Listera cordata
Galium boreale
Fungi
Andromeda glaucophylla
Cladonia spp.
Amelanchier alnifolia
Fragaria virginiana
Rubus idaeus
Shepherdia canadensis
Abies balsamea
Schizachne purpurascens
Caltha palustris
Catoscopium spp.
Arboreal lichen
Dryopteris austriaca
Fern spp.
Eriophorum spp.
Gaultheria procumbens
Gymnocarpium dryopteris
Rhytidiadelphus spp.
Mentha arvensis
Cladina mitis
Dicranum scoparium
Moneses uniflora
Polygonum scandens
Coptis groenlandica
Pyrola spp.
Cladonia borealis
Juniperus communis
Vegetation Species



Percent of each Vegetation Species Observed in Plots Classified as V32
Legend and Statistics
species listed as Common Understory Species that were observed
species observed
n = 15 for V32
total number of species = 27
Common Understory Species not observed:
Picea mariana
Vaccinium oxycoccos
Vaccinium vitis-idaea
Calamagrostis canadensis
Smilacina trifolia
Percent
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Sphagnum spp.
Ledum groenlandicum
Pleurozium schreberi
Gaultheria hispidula
Carex spp.
Equisetum spp.
Alnus rugosa
Clintonia borealis
Mitella nuda
Cornus canadensis
Arctostaphylos uva-ursi
Chamaedaphne calyculata
Coptis trifolia
Equisetum sylvaticum
Abies balsamea
Trientalis borealis
Galium triflorum
Betula papyrifera
Viola renifolia
Rubus pubescens
Rubus chamaemorus
Pyrola asarifolia
Polytrichum spp.
Petasites palmatus
Lycopodium annotinum
Hylocomium splendens
Linnaea borealis
Vegetation Species

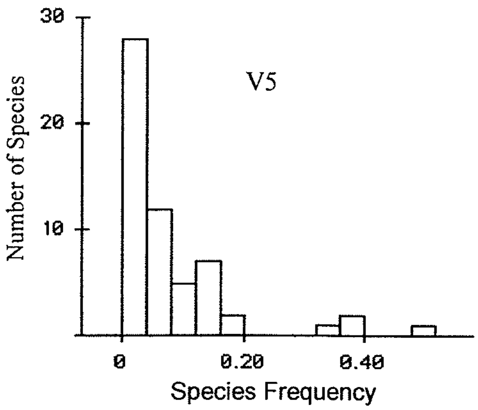
## Percent of each Vegetation Species Observed in Plots Classified as V33

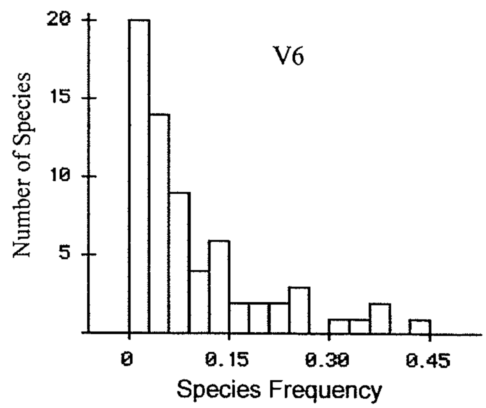


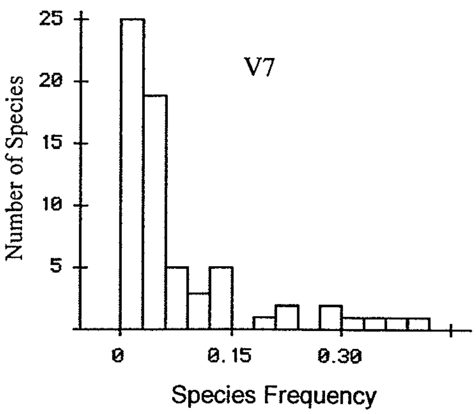
*Appendix H*

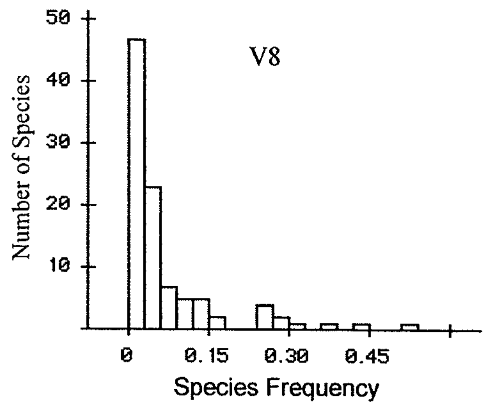
# HISTOGRAMS OF SPECIES FREQUENCIES PER V-TYPE

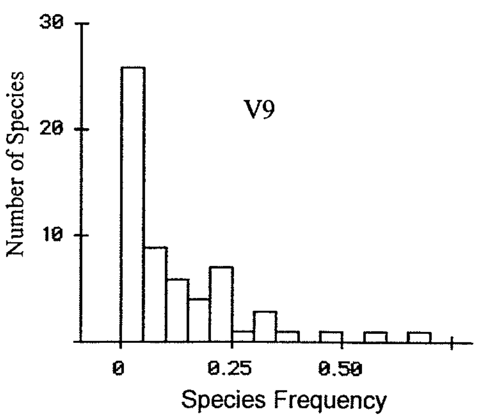
## Histograms for Species Frequency of Each V-Type

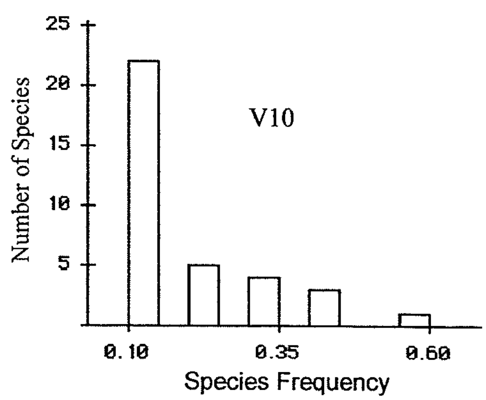


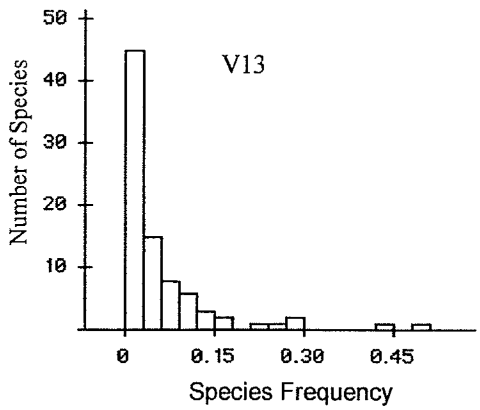



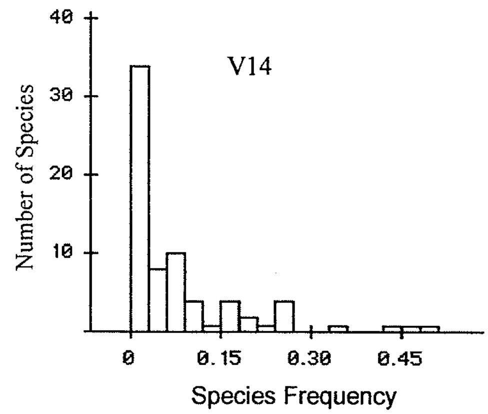



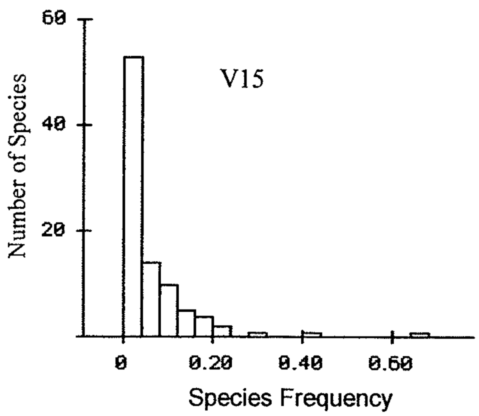



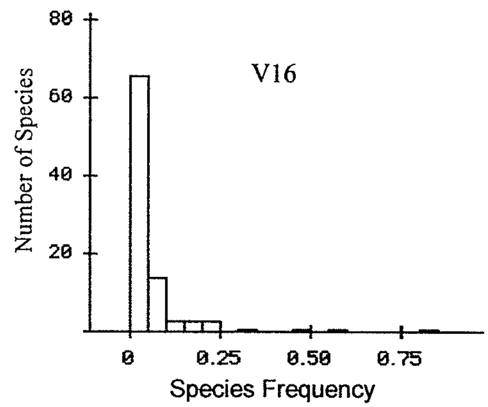



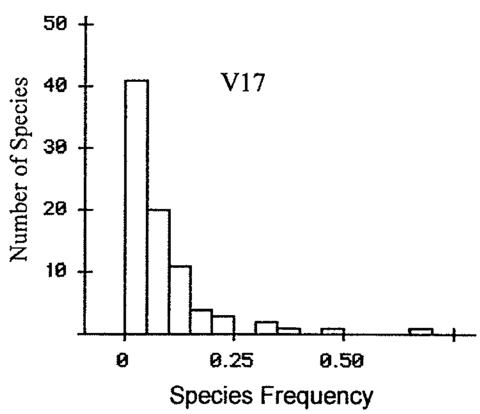



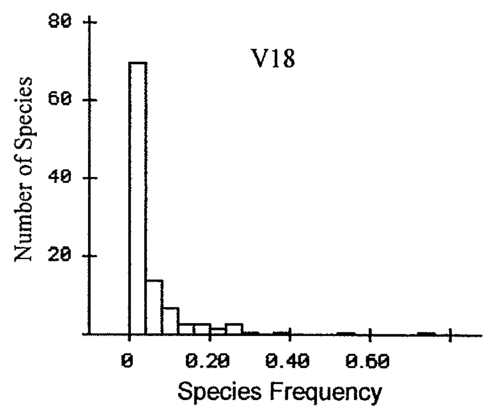

V13
Number of Species
50
40
30
20
10
0
0.15
0.30
0.45
Species Frequency

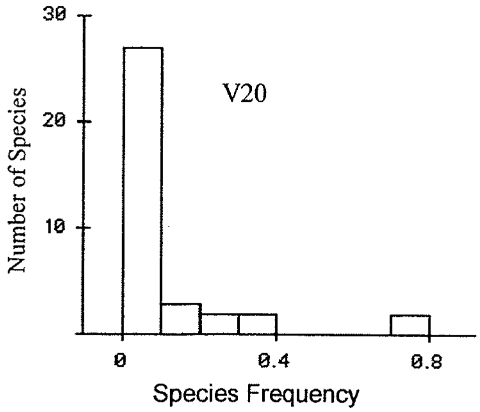

V14
Number of Species
40
30
20
10
0
0.15
0.30
0.45
Species Frequency

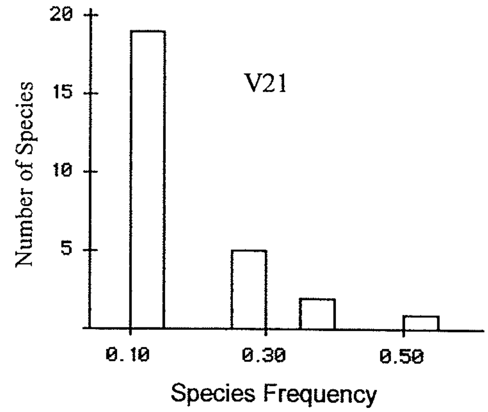

V15
Number of Species
60
40
20
0
0.20
0.40
0.60
Species Frequency

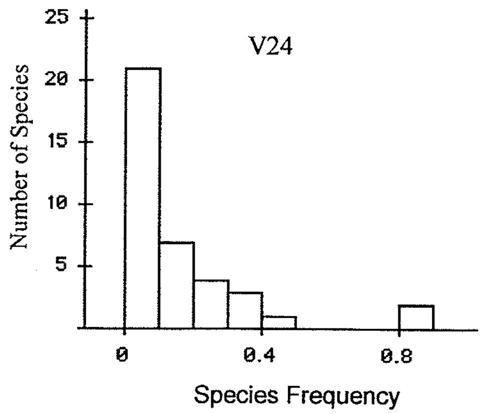

V16
Number of Species
80
60
40
20
0
0.25
0.50
0.75
Species Frequency

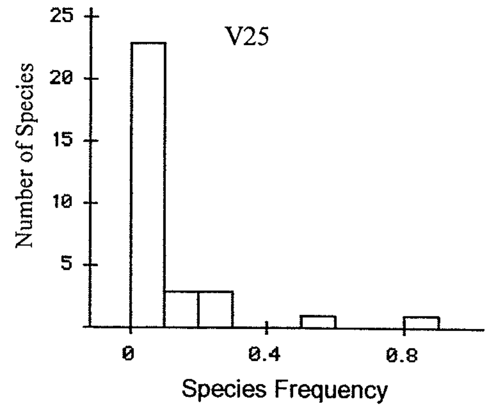

V17
Number of Species
50
40
30
20
10
0
0.25
0.50
Species Frequency

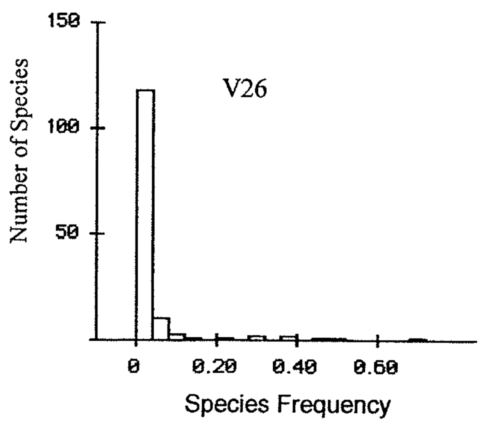

V18
Number of Species
80
60
40
20
0
0.20
0.40
0.60
Species Frequency

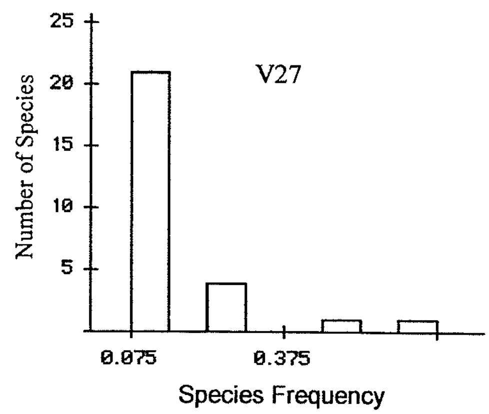

V20
Number of Species
30
20
10
0
0.4
0.8
Species Frequency

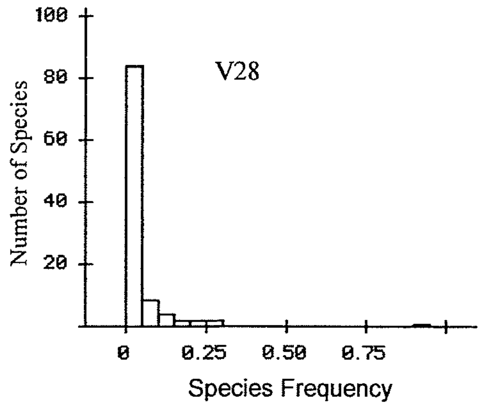

V21
Number of Species
20
15
10
5
0.10
0.30
0.50
Species Frequency

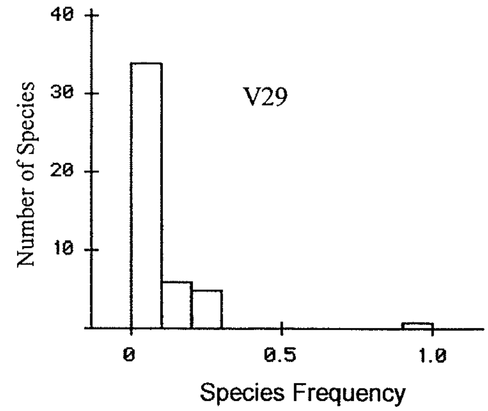

V24
Number of Species
25
20
15
10
5
0
0.4
0.8
Species Frequency

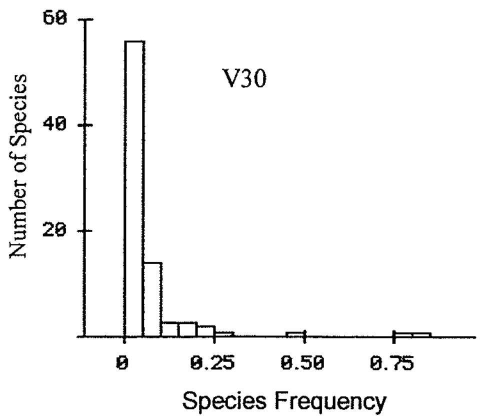

V25
Number of Species
25
20
15
10
5
0
0.4
0.8
Species Frequency

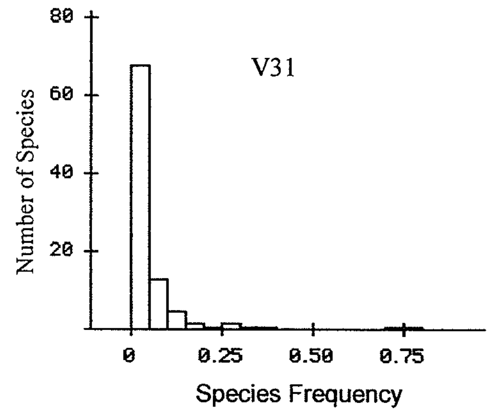

V26
Number of Species
150
100
50
0
0.20
0.40
0.60
Species Frequency

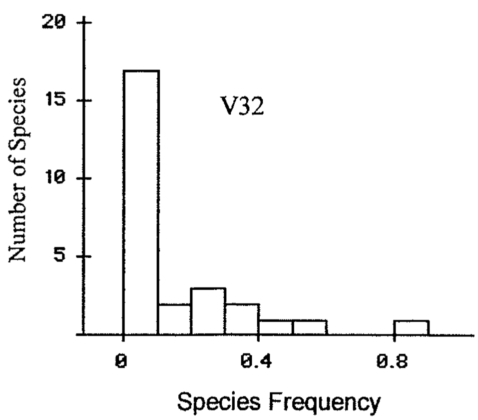

V27
Number of Species
25
20
15
10
5
0.075
0.375
Species Frequency

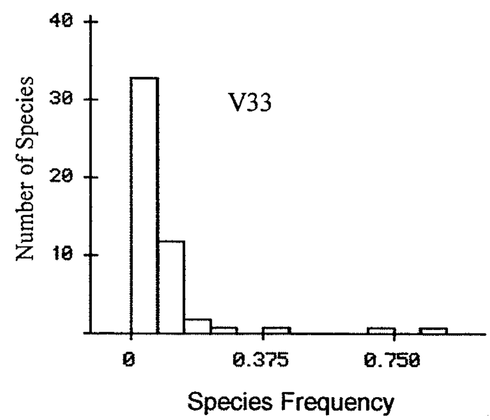

100
80
60
40
20
Number of Species
V28
0
0.25
0.50
0.75
Species Frequency


40
30
20
10
Number of Species
V29
0
0.5
1.0
Species Frequency


60
40
20
Number of Species
V30
0
0.25
0.50
0.75
Species Frequency


80
60
40
20
Number of Species
V31
0
0.25
0.50
0.75
Species Frequency


20
15
10
5
Number of Species
V32
0
0.4
0.8
Species Frequency


40
30
20
10
Number of Species
V33
0
0.375
0.750
Species Frequency