AN ABSTRACT OF THE THESIS OF

Rosemary A. (Welch) Streatfeild for the degree of Master of Science in Geoscience in Geography presented on March 13, 1995. Title: Ecological Survey and Interpretation of the Willamette Floodplain Research Natural Area, W. L. Finley National Wildlife Refuge, Oregon.

Abstract approved: ______________________________
Robert E. Frenkel

The purpose of this study was to: (1) evaluate land use and vegetation history of the Willamette Floodplain Research Natural Area; (2) characterize present day vegetation; (3) evaluate the relation of vegetation to environment, and (4) establish a baseline dataset for future trend analysis in order that response of different plant species to fire frequencies may be assessed.

I used historical records, aerial photographs, interviews, and literature to ascertain land use and vegetation history. I assumed that the RNA had been maintained as prairie by periodic aboriginal burning. Fire ignited by settlers continued as a management tool into the late 19th century. Grazing was a major disturbance in the late 19th and early 20th centuries, and plowing or some other soil disturbance on the raised elongated mounds may have occurred. With removal of livestock grazing in the

early 1960s and only a sporadic burning program, shrub cover increased markedly over the past several decades.

I surveyed vegetation in the summer of 1991 in 36 random permanent plots. I classified species cover with two-way indicator species analysis, identifying two major communities. One is dominated by tall dense *Rosa eglanteria*, *Hypericum perforatum*, and many alien weedy species located on slightly elevated mounds, and the other is dominated by shorter but also dense *Rosa eglanteria*, *Deschampsia cespitosa*, and many species with wetland affinity on intermounds. Monotypic patches of *Spiraea douglasii* also occur on intermounds.

Species composition strongly correlates with microtopography related to an indirect soil moisture index based on wetland status of individual species. Composition correlates less strongly with year since last burn. I confirmed vegetation-environment relations by null hypothesis analysis, tested by multi-response permutation procedure. Vegetation significantly differs on mounds vs. intermounds and vegetation significantly reflects burning history. I ordinated floristic data by non-metric scaling.

I also tallied nested frequency data as a baseline for future trend analysis in order to assess change in vegetation in response to fire frequency. Frequency change of *Rosa eglanteria* will best be detected by change in a 0.01 m^2 plot size, *Holcus lanatus* by a 0.10 m^2 plot, and remaining species by a 1.00 m^2 plot.

Ecological Survey and Interpretation of the Willamette Floodplain Research Natural Area, W. L. Finley National Wildlife Refuge, Oregon

by

Rosemary (Welch) Streatfeild

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APPROVED:

Major Professor, representing Geography

Chair of Department of Geoscience

Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Rosemary (Welch) Streatfeild, Author

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ECOLOGICAL SURVEY AND INTERPRETATION OF THE WILLAMETTE FLOODPLAIN RESEARCH NATURAL AREA, W.L. FINLEY NATIONAL WILDLIFE REFUGE, OREGON

CHAPTER 1: INTRODUCTION

Insight into universal nature provides an intellectual delight and sense of freedom that no blows of fate and no evil can destroy.
Alexander von Humboldt, 1805

THE WILLAMETTE VALLEY

The Willamette Valley, located in western Oregon between the Cascade Range to the east and the Coast Range to the west, is a 200 km north-south trending depression with isolated basaltic buttes occurring in the more southerly extent (Figure 1, page 2). Valley widths range from 30 to 50 km, with a relatively low gradient (Franklin and Dyrness, 1988). In the late Pleistocene (11,000 to 50,000 years ago), a large freshwater lake occupied parts of the Willamette Valley as far south as Eugene on several occasions, and the valley partially filled with silt as a result. During the late Wisconsin stages of glaciation (18,000 to 20,000, and again 13,000, years ago), floods derived from glacial lake Missoula swept down through the Columbia gorge into the Willamette Valley, again depositing silts, sand and gravels (Orr et al., 1992).

Current climate is cool and wet in the winter, and warm and dry in the summer. Average January and July temperatures are 4.0°C and 18.9°C respectively. Average annual rainfall is 1,004 mm, of which only 47 mm falls between June and August (Franklin and Dyrness, 1988).

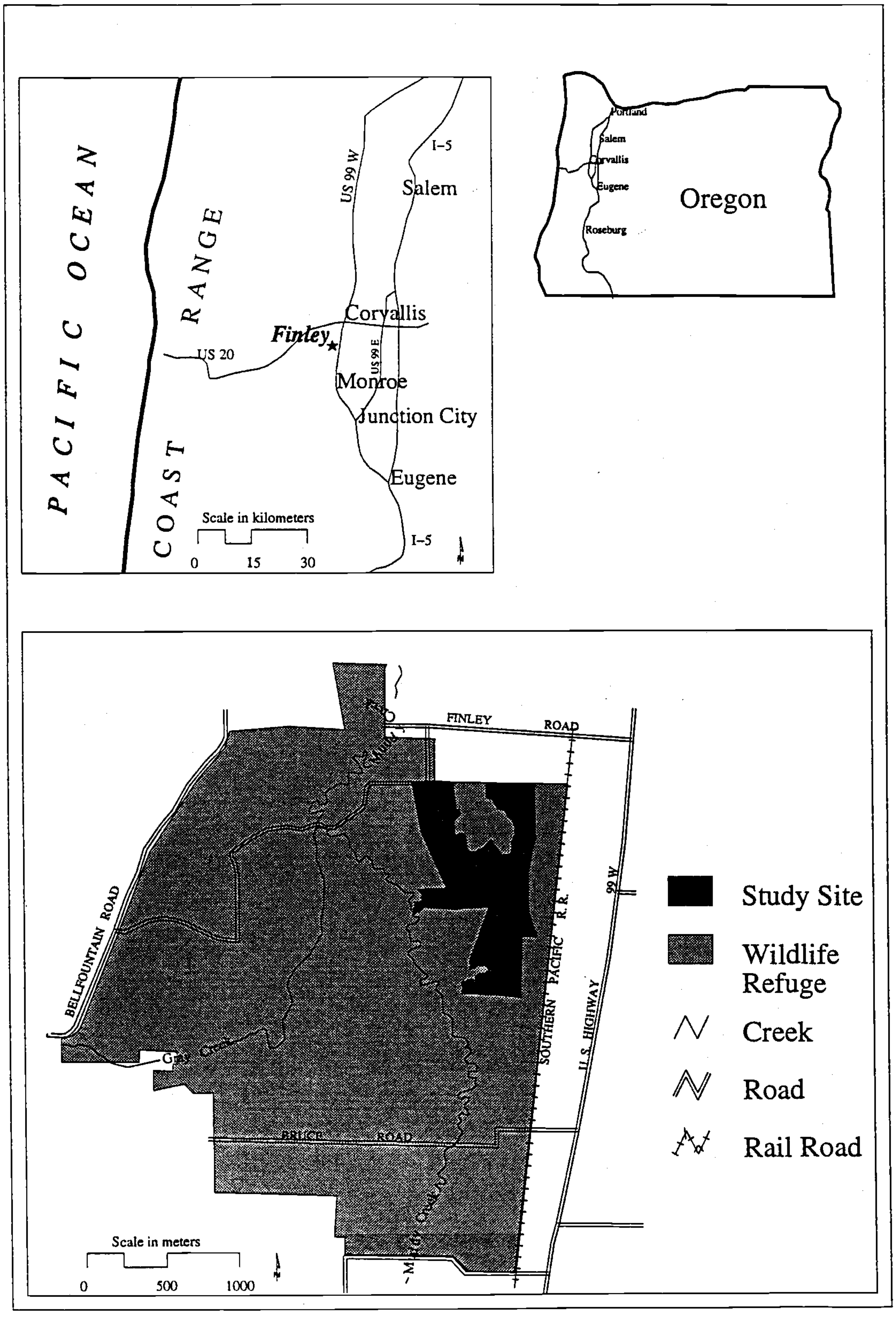

Figure 1. Location of study site with respect to Oregon and the Willamette Valley.

American Indians, known as the Kalapuya, inhabited the valley when white settlers moved into the area in the early 19th century (Boyd, 1986; Towle, 1982; Johannessen et al., 1971; Habeck, 1961). How long the Indians had been living in the valley is not documented. The oak savanna and prairie of the valley was apparently maintained through burning activities carried out by the Kalapuya to promote growth of their preferred plants and provide wildlife habitat (Boyd, 1986). This practice was common throughout many of the summer-dry regions of the United States, particularly where vegetative systems support fire-tolerant vegetation (Dorney and Dorney, 1989). The Kalapuya practiced subsistence collection, emphasizing local wild plants and game. Bulbs of the camas lily and seeds from tarweed, fruits from the hazel and oak trees, and numerous berries were important components of their diet, along with meat and clothing from deer, elk and waterfowl (Boyd, 1986).

The vegetation within the valley at settler contact has been very generally described through land survey records and written documents by early settlers. Vegetation was comprised of a mélange of distinctive formations, including prairie, savanna, marshes, riparian strips and wooded swales with low deciduous and tall deciduous forests along waterways, and coniferous forest on slopes rimming the valley. Both wet and dry prairies were common (Habeck, 1961; Johannessen et al., 1971; Towle, 1982). This mosaic of vegetation probably dominated the valley for over several thousands of years, and was as much a product of aboriginal burning as of climate and soils. Many of its floristic elements were initiated with the relatively warm, dry climate of the Hypsithermal (8,000 - 4,000 years ago) (Boyd, 1986; Hansen, 1947).

Prior to the arrival of European settlers early in the 19th century, annual burning had largely discontinued because disease had decimated much of the Indian population. Prairie conditions were maintained in many places through continued burning by settlers and grazing, but in sites which remained undisturbed oak and eventually Douglas-fir forests became established. The increased shade and altered soil conditions facilitated a change in the undergrowth plant communities. In time, Douglas-fir began to invade the forest fringes. Today, Douglas-fir dominates most sites abandoned by settlers between the 1850s and about the 1920s. Closed oak woodland occupies recently abandoned pastures and prairies dating from 75 to 30 years ago. Without the occurrence of frequent fires, Douglas-fir will eventually replace the oaks as the dominant species on drier sites (Towle, 1982; Johannessen et al., 1971; Thilenius, 1968; Smith, 1949). The role of further succession is problematic (cf., Franklin and Dyrness, 1988). Evidence of this progression is from (1) historic sources such as Township and Range records, (2) structure of present day vegetation, (3) tree cores, and (4) air photographs. The native grasses that were not adapted to grazing have mostly been replaced by alien species. Grass seed production is one of the dominant crops today in heavy soil areas.

It thus appears that the presettlement vegetation was anthropically manipulated by burning and that without the influence by the Kalapuya the valley would have been occupied by a closed forest, a far less hospitable place for settlement by mid-nineteenth century immigrants (Boag, 1992).

Little is known of the composition and structure of the presettlement wet prairie vegetation. Nelson (1919) compiled a list of grasses near Salem. Of his 106 species, 55 were determined to be introduced and 51 native (Habeck, 1961). The dominant grasses found in the region included wet prairie species such as *Deschampsia cespitosa, Agrostis exarata* and *Panicum capillare*, and dry prairie species such as *Festuca rubra, Danthonia californica, Elymus glaucus* and *Stipa lemmonii*. Shrubs such as *Corylus cornuta*, *Berberis aquifolium* and *Rosa* species together with a variety of forbs coexisted within the grasslands (Habeck, 1961). Remnants of these relatively undisturbed communities remain in a few areas. Since the early 1800s many new species have been inadvertently introduced related to agricultural disturbance, development of the railroad, contaminated seed supplies, and nursery trade, as well as deliberate introduction of pasture grasses and forbs (Towle, 1982).

Over the past century land use has changed and farming practices and manipulation techniques have fluctuated, pursuant to the whims of the economy and progression of technology (Towle, 1982). These modifications have resulted in a diminished extent of prairie and oak savanna in the valley, as well as altered species composition and vegetation structure. The grazing regime, which replaced annual burning after settlers arrived, caused the devastation of many of the native grasses whose structure and physiology were not suited to this form of disturbance. Large herbivores such as elk, deer and antelope existed but had not been abundant in the region prior to cattle and sheep introduction (Towle, 1982).

WILLAMETTE FLOODPLAIN RESEARCH NATURAL AREA

The William L. Finley National Wildlife Refuge is situated in the Willamette Valley about 16 km south of Corvallis, Oregon (Figure 1, page 2). It is administered by the U.S. Fish and Wildlife Service. The Willamette Floodplain Research Natural Area (hereinafter referred to as the RNA), established in 1966, began as a 97-ha (239-acre) tract of ash forest and wet prairie within the Refuge (Franklin, 1972). In 1986, this area was increased to 210 ha (519 acres).

Topography in the RNA is essentially flat, with elevation ranging from 82 to 88 m. It is located on valley bottom alluvium underlain by unconsolidated silt sands and gravels from the Wisconsin age, known as the Willamette silts. Soil series mapped in the RNA are approximately 65%

Dayton silt loam and 20% Woodburn silt loam, and 15% Waldo silty clay loam (Knezevich, 1975; Franklin, 1972). The Dayton series is a deep, poorly drained soil consisting of a shallow silt loam over clay, formed in water-deposited silt, underlain by older materials. It supports oak, shrubs, and grasses where not cultivated. The Woodburn series is a deep, moderately well-drained silt loam surface soil, with a silty clay loam subsoil, formed in silty alluvium. It supports native grass, hazelnut, poison-oak, blackberry, oak and Douglas-fir where not cultivated. The Waldo series is a deep, poorly drained soil, consisting of a moderately deep surface silty clay loam with a clay subsoil. It was formed in recent alluvium, and supports tussock, sedge, willow, ash and grass where not cultivated (Knezevich, 1975).

The RNA consists mostly of grasslands and shrubs, which are found on the Dayton and Woodburn silts, and minor areas of forest occupying mainly the Dayton and some of the Waldo clays (Franklin, 1972). The forests are dominated by *Fraxinus latifolia* (Oregon ash), while the grasslands are mixtures of native and introduced species of grasses (including *Deschampsia cespitosa, Holcus lanatus, Agrostis* spp., *Carex* spp.) and forbs (*Hypericum perforatum, Galium* spp., *Vicia* spp., and others), with shrubs (*Rosa* spp., *Spiraea douglasii*) and trees (*Pyrus* spp., *Crataegus douglasii, Fraxinus latifolia*) scattered throughout.

It has been assumed by Refuge staff that the prairie has remained unplowed as a nearly natural grassland and forest (Franklin, 1972). The near-natural condition of the area, however, has not been confirmed. The RNA has been set aside to provide a baseline site for long-term scientific studies and as a refuge for sensitive biota (Franklin, 1972).

Several unpublished scientific studies have been carried out since the RNA has been established. These include one undertaken in 1971-72 in the southernmost part of the RNA by Moir and Mika (1972), whose objectives were to identify the existing vegetation composition, its relation to the activities of white settlers, its reaction to a burning regime, and to record populations of native prairie plants. A second vegetation study was carried out in 1983 and 1984 in the northernmost part of the RNA by Frenkel and McEvoy (1983), in conjunction with a small mammal study conducted by staff biologist, John Cornely, and Wildlife coop leader, Robert Anthony. In addition, between 1976 and 1990, several prescribed burns have taken place in different portions of the RNA.

GENERAL RESEARCH OBJECTIVES

This research comprises four tasks. The first is to provide an assessment of historical activities affecting the vegetation. To accomplish this task, I searched through various historical records to ascertain how land use has changed since the first land survey was undertaken in 1853.

In particular, I looked for evidence of plowing, grazing and farming.

The second task was to characterize present day vegetation. In accomplishing this task, I assessed vegetation cover by floristically sampling the grassland with randomly placed plots distributed throughout the RNA. Some of these plots have been burned recently prior to sampling, others were burned after the sampling, and still others served as controls. A third task was to relate the present day vegetation to certain general environmental controls independent of burning.

A fourth task was to establish a baseline dataset for future trend analysis of vegetation response to different burning treatments. This analysis will be carried out by future investigators in order to portray the direction vegetation would develop in a wet prairie situation under different burning regimes of different frequency without other human disturbances.

CHAPTER 2: HISTORICAL DESCRIPTION

> *"...Country undulating; soil rich with beautiful solitary oaks and pines interspersed through it and must have a fine effect, but being all burned and not a single blade of grass except on the margins of the rivulets to be seen..."*
>
> (Douglas, 9/27/1826)
> (cited in Johannessen et al. 1971:288)

WILLAMETTE VALLEY VEGETATION

Many changes have occurred in the Willamette Valley since David Douglas, a botanist with the Hudson's Bay Company expedition of 1826, wrote the description above. Interest in documenting the historical character of Willamette Valley vegetation has been prominent since the early 1960s (Habeck, 1961; Thilenius, 1968; Johannessen et al., 1971; Towle, 1982; Boyd, 1986; Boag, 1992). But general studies on the way man has altered the natural environment date from at least the mid-19th century (Bahre, 1991). In most cases, when white settlers entered regions inhabited by indigenous peoples, the landscapes had already been modified by aboriginal occupants to suit their needs (Boag, 1992). In the case of the Willamette Valley, as with many other savanna and prairie regions of the United States, modification was predominately established by periodic fires set by the local Indian tribes to promote growth of preferred plants and trees, and to create favorable habitat for wildlife (Gleason, 1913; Stewart, 1956; Wells, 1970; Boag, 1992).

The oak savanna/dry prairie landscapes encountered by the early settlers have largely disappeared in the Willamette Valley (Thilenius, 1968). Likewise, the wet prairie has been severely reduced in area. Johannessen et al. (1971) identified the major loss of prairie as occurring between 1853 and 1969 due to different land uses such as grazing, crop production, urbanization, draining, and succession to forest. In addition, alien plant species have been introduced and have spread into the prairies.

Towle (1982) identified three woodland types from the Original Land Survey of the mid-1850s: gallery forests along stream courses, isolated groves of oak or fir surrounded by prairie, and more closed forests located on the bordering hillslopes. The dominant species of the gallery forests were, and still are, *Pseudotsuga menziesii* (Douglas-fir), *Fraxinus latifolia* (Oregon ash), *Populus trichocarpa* (black cottonwood), *Salix* sp. (willow) and *Alnus rubra* (red alder). The distance that forest extended from a stream course depended on the size and flooding regime of the stream. Wider forest margins occurred along larger waterways (Towle, 1982). Along the Willamette River the gallery forests occupied widths of 5 to 10 km (Sedell and Frogatt, 1989). The land in the broad valley beyond the floodplain was mainly prairie with individual trees or groves of oak occurring in places. Although both *Quercus garryana* (Oregon white oak) and *P. menziesii* were found on local buttes emergent from the prairies, *P. menziesii* did not invade the poorly drained prairie soils. The moist north-facing slopes of the bordering Coast and Cascade Ranges were dominated by *P. menziesii*, *Acer macrophyllum* (big leaf maple), *Thuja plicata* (western red cedar) and *Tsuga heterophylla* (western hemlock) (Towle, 1982).

The earliest farms were sited at the edge of the prairies (Bowen, 1978; Boag, 1992). The prairies were regarded by early settlers as admirably suited to pioneer agriculture because of their level or gently sloping terrain, and ease in working the soil (Boag, 1992). As timber demands grew over the course of the 19th century, Douglas-fir was harvested. Oak was primarily cut for fire wood and cleared to make agricultural land (Towle, 1982). Livestock such as cattle, swine, sheep and horses was introduced (Bowen, 1978). By 1970 the gallery forest had been narrowed extensively, and open oak woodlands and savanna had mainly disappeared. Fields and pastures were dominant features. Where drier prairie was left unplowed, and with cessation of the annual aboriginal burning and subsequent livestock grazing practices, oak woodland replaced the grassland, and later Douglas-fir forests replaced oak forest. Douglas-fir forests have taken over most open woodlands of the steeper slopes (Towle, 1982).

Although major changes in Willamette Valley vegetation occurred in the 19th century, much of the valley land was not intensively utilized until well into the 20th century (Towle, 1982). Competition from other regions in wheat production increased at the end of the 19th century, reducing the total Willamette Valley acreage in production. Poor drainage, low yields and disease also contributed to abandonment of cultivation. Many fields were left fallow and returned to pasture. Invasion of abandoned fields by oak, ash, and hawthorne, and shrubs such as poison oak and wild rose has occurred (Johannessen et al, 1971). Later in the century, by the 1940s, grass seed production became the major crop in the former wet prairie lands of the valley, favored by the heavier soils and hot dry summers (Towle, 1982). Today, fire is again used as a sanitation treatment of grass seed fields and to remove excess straw (Johannessen et al, 1971; Towle, 1982).

Vegetation composition today within the bounds of the RNA is a mélange of native and introduced species. Although the area suffered many historic disturbances such as fire suppression, grazing, some drainage, and possibly plowing, it has been relatively undisturbed since the early 1960s, except for seasonal flooding by Muddy Creek. The aim of this phase of my study is to identify sources of disturbance which may have occurred since white settlement and the effect these may have had on the landscape and on the plant species and communities.

In this chapter, three questions are addressed:

(1) Has the land now within the RNA been plowed?

(2) What is the burning history of the RNA since the Indian practice stopped?

(3) How has land use affected the vegetation within and surrounding the RNA since settlement?

I used several sources to discover how land use has changed since white settlement in the Willamette Valley in the mid-19th century. These included land survey notes, repeat aerial photography, an interview with prior inhabitants, and previous publications or scientific reports.

LAND SURVEY NOTES

General Land Office surveys, initiated in 1785, are available for all but 19 of the continental United States (Bahre, 1991). They usually contain general descriptions of vegetation found within a section at the time of the surveys and more specifically along section lines and at corners. Usually for each township a plat map is included showing ownership and gross vegetative features. Plat maps together with survey notes are used extensively by researchers to reconstruct the characteristics and distribution of vegetation at the time of survey (Bahre, 1991). Habeck (1961) and Johannessen et al. (1971) employ survey notes and plat maps in their reconstructions of vegetation in the Willamette Valley.

The first land survey for Benton County was executed under contract in 1853. Photographic duplicates of the survey notes are available on microfiche at the Bureau of Land Management offices in Portland, Oregon, and also are on file at the County Surveyor's office in Corvallis, Oregon.

A plat map for each township constructed at the time is also available. The survey notes followed individual township and range specifications, with trees ("witness" or "bearing" trees) being used to locate the four corners of sections and quarter sections. These landmarks were fully described for future recognition by land claimants (Habeck, 1961). Descriptions were made of vegetation and other features encountered while the surveyor walked section lines. Entry into and out of prairie or woodland was noted. Where a stream was encountered, its bearing was noted. In prairies where trees were unavailable, surveyors implanted charred posts and buried these in a pile of soil to mark the corners, or constructed earth or rock mounds to mark intersections. Distances along lines and between objects (usually trees) are measured in chains (1 chain = 66 feet) and links (1 link = 7.22 inches) (Habeck, 1961; Johannessen et al, 1971). More recent surveys do not include these detailed notes.

The RNA lies within Sections 21, 22, 27, and 28 of Township 13 South, Range 5 West (Figure 2, page 16). On January 28 and 29, 1853 this area of the Willamette Valley was surveyed. It was described generally as wet or dry level prairie, with soils in most places "1st and 2nd rate". Features, such as houses belonging to Mahoney and Robert Grimsley and a few isolated oak, ash and willow trees were noted, these being indicated by compass reading and distance from section line corners. Muddy Creek was

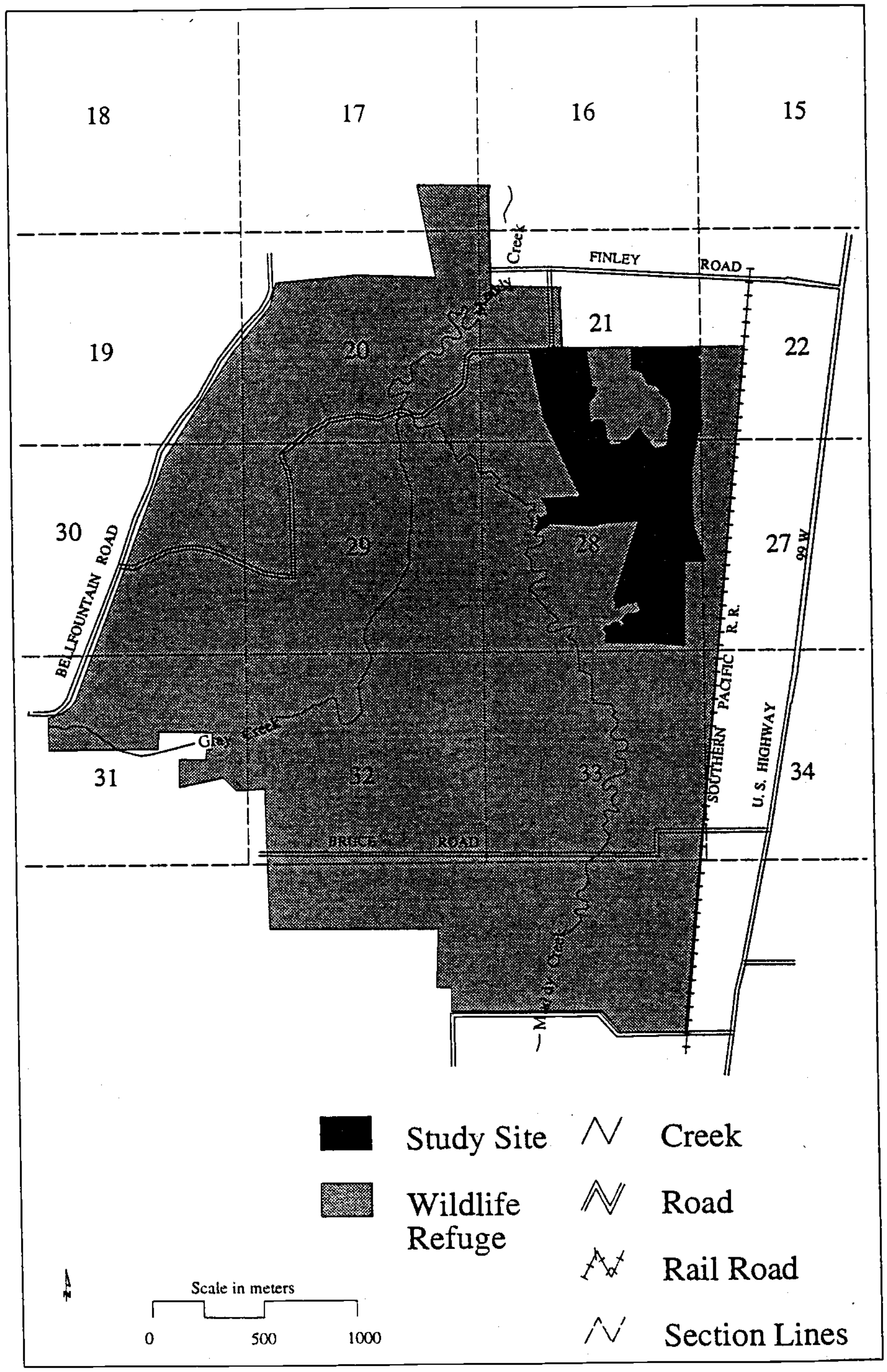

Figure 2. Study site location with respect to Township, Range and Section numbers.

intersected once 43 chains, 12 links (approx. 948 yds.) west along the true line between sections 28 and 33, where the creek was "deep and swift with a NW course." "Thicket" growth was encountered at this point. A second intersection was recorded at 72 chains (approx. 1548 yds.) north along a line between sections 28 and 29, where a few oak and ash trees were found along the creek. Areas of plowed ground were met also but outside of the RNA.

In summary, it would appear that the vegetation in the RNA at the time of the first land survey was comprised of native plants typical of wet and dry prairie, with isolated oak, ash, and willow trees. Other than major tree species, individual herbaceous and shrub species were not identified as such but may have included several from Nelson's (1919) list from Salem.

REPEAT AERIAL PHOTOGRAPHY

Repeat aerial photography is an effective method to determine change in ground cover over time since it enables coverage of large areas. In this manner patterns and distributions of vegetation can be seen effectively (Bahre, 1991). One difficulty with repeat photographs is that resolution, film type, and scales change between years, making accurate comparisons between years difficult (Bahre, 1991).

Aerial photographs of Benton County from 1936, 1944 and 1948 are available from Benton County Historical Museum, Philomath, Oregon, and the Map Library at the University of Oregon, Eugene, Oregon. Those from 1956, 1963 and 1970 are available from the Museum, and the Map Library at Oregon State University, Corvallis, Oregon. A 1978 aerial photograph is retained at the Agricultural Stabilization and Conservation Service (ASCS) office, and 1983 and 1990 photographs can be found at the County Surveyor's Office, both in Corvallis, Oregon. Other sources may be available also. These historic photographs were studied to see if there was any evidence of plowing or drainage within the RNA site, how vegetation and access routes changed, and if the lenticular-shaped features identified on the 1990 photograph were evident earlier. These lenticular-shaped features appear elevated in the field, and I called them mounds. The way land use varied directly surrounding the RNA over time was also noted.

There were several noticeable changes on the aerial photographs over 54 years of record. A copy of the 1990 photograph is attached as Appendix 1 to aid with the following description. The number of trees in the RNA increased between 1956 and 1970, particularly within the western boundary in the section north of the road. Cattle were withdrawn from the RNA in 1966. Farming use surrounding the RNA increased over time. Fields to the north, east and south were farmed as early as 1936. A field on the northern part of the western boundary was also in use. By 1970, agricultural land use bordering the RNA increased significantly. The field lying along the western boundary mentioned above was extended to the south. The field which is today inset within the northern boundary was developed, as was the one located to the south-west. There was little evidence of ditch and berm construction until 1970 when ditches were dug and soil mounded in the field within the northern boundary. The mounds in the earlier photographs appear scraped or tilled, especially in the northern half of the RNA. This could have been a result of mowing. The bare interiors of these mounds are bounded by a thin dark line, perhaps a hedge of shrubs, or vegetation brushed aside. Shrub invasion on the mounds occurred beginning in the 1956 photograph, with fairly heavy coverage by 1963. There were a few large trees within the RNA in 1936, with little change over the time in question. The number of small trees increased substantially by 1978. The road across the center of the RNA extended over to highway 99W until 1982/3, at which time it was terminated just outside the RNA boundary at some distance from the highway. Trails, probably created by livestock, were common in the earlier photographs but were less obvious by 1970, presumably being overgrown by vegetation. The burns which occurred in September 1983 in three of six plots established for a small mammal study showed up as distinctive pale squares on the 1983 aerial photograph, but were clearer on the 1990 ones, perhaps due to better resolution or timing of the photograph.

OTHER SOURCES

Other sources for assessing changes in the landscape were through personal interview and publications. Locating extant old-time residents of the Refuge proved difficult. I located a couple, Robert (Bobbie) and Virgina Campbell, former manager and residents in the Refuge in the early to mid 1900s, who now reside in Hermiston, Oregon. A second source of local historic information was from a thesis provided by a former interdisciplinary studies student from the University of Oregon (Sekora, 1989).

I interviewed the Campbells in September 1990. Bobbie Campbell was born in 1926 on land that is today located within the Refuge, and lived there until he was 13 or 14 years old. He returned to manage the ranch then owned by Henry Cabell from 1949 until 1963. His father had managed the farm throughout the time Bobbie was not present (pers. comm. Campbell and Campbell, 1992). My interview with the Campbells was directed specifically toward three questions: (1) whether the RNA had been plowed, (2) whether fire had been used in agricultural management, and (3) what was the grazing history.

The Campbells did not know of any fires, accidental or set, within the RNA during the time they worked on Cabell's land although he believed earlier managers may have burned in the RNA. Mr. Campbell believed that plowing occurred on the mounds in the RNA before he or his father managed the ranch, but did not know by whom. He said that the area was grazed by cattle from early in the spring through fall. While the area was still underwater the cattle would graze the mounds first then move to lower ground as water levels fell. He also stated that the "briar" (rose) had increased tremendously since grazing was terminated, which he also considers responsible for the low birdlife and high populations of "varmits". When he was recently visiting the area, he was also surprised by the increase in undergrowth in the woods around Muddy Creek (Campbell and Campbell, 1992).

The thesis by Linda Sekora traced land use changes in the Refuge since white settlement, but focused mainly on historical preservation. She identified original homesteads within the Refuge land, assessed individual structures, and described the state of the land at settlement and its subsequent uses (Sekora, 1989). Homesteads of interest to this study include those of John Fiechter-Archibald Johnson and Jacob Slagle-Samuel Rickard, both established in 1850, and James W. Compton-John Foster-Albert Starr established in 1853, parts of which were incorporated into the RNA.

The John Fiechter-Archibald Johnson homestead, located in sections 20, 21, 28, 29 and 30 (see Figure 2, page 16 for section location), lay along both sides of Muddy Creek. The eastern section of this farmstead is represented within the RNA. It comprised flat floodplain and prairie to the east, and broad gently sloping upland to the west. At the time of first settlement, the general landscape was prairie-savanna, with gallery forest along the creek (Sekora, 1989). Sekora (1989) noted that the vegetation in this eastern section of the Fiechter-Johnson farmstead had remained relatively similar to its original form, except for regrowth in the timbered areas toward the west, which had been logged and grazed, and increase in the riparian forest along the creek. The original service road through the farmstead that she describes, relocated in 1892 and again in 1906, may well be the track running east-west across the center of the RNA today (approximately one mile south of the Finley access road along the northern boundary). In the early 1900s this claim was owned for a short time by Robert S. Hughes, who grazed sheep there (Sekora, 1989).

The James W. Compton-John Foster-Albert Starr farmstead was located in sections 28 and 29 (see Figure 2, page 16), the eastern part of which is today occupied by the south-west corner of the RNA. The land straddles Muddy Creek south of the Fiechter-Johnson land, with low wet prairie soils subject to seasonal flooding. It is comprised of grassland and woodland along banks of the creek. Compton engaged in general farming, whereas Foster both farmed and pastured (Sekora, 1989).

The Jacob Slagle-Samuel Rickard farmstead was located in sections 31, 32, and 33 (see Figure 2, page 16). His land lay to the south of the RNA and was described as gently rolling prairie, with oak openings at higher elevations. Today the landscape is still open, except for dense oak and fir forests on the hillslopes and the expanded gallery forest along Muddy Creek (Sekora, 1989).

At the beginning of the 20th century (1905) the different farmsteads were bought up by the Failing-Cabell estate who administered it until the U.S. Fish and Wildlife Service (USFWS) bought it in 1964. Sekora (1989) generally described the estate as a working ranch and hunting reserve. Cattle were grazed on prairies east of Muddy Creek, while sheep foraged on higher ground until 1946. Pigs were also raised, and, during WWII, turkeys. Fields along Muddy Creek were used to grow dry-land corn for silage, alfafa, hay, sweet clover, oats, barley, hairy vetch, and ryegrass. The land, however, was not highly productive due to poorly drained clay-based soils. Tiling to help drain the land was instigated during the 1940s (during Henry Cabell's time); however, there is no evidence of tiling in the RNA. Fires which often burned out of control were set regularly throughout the grassland regions of the estate by Jess Campbell to remove stubble and control spread of unwanted vegetation. The route traversing the center of the RNA today ceased to be of primary importance by the 1960s (Sekora, 1989).

Since 1966 when the southern portion of the RNA was established, the RNA area has been designated for baseline research and wildlife habitat under the management of the USFWS. The RNA was enlarged in 1986. The surrounding land is still farmed. Fields within the refuge are planted with crops deemed suitable for waterfowl forage, while privately owned farmland surrounding the area produce mainly grass seed.

DISCUSSION

In light of the above information, the questions I posed initially can be addressed. Although I could not determine any evidence of plowing activity throughout the RNA, it appears that some kind of soil disturbance occurred on the higher mound sections. Early aerial photographs show a striped raked appearance signifying some sort of activity. It is possible that this was the result of haying. However, Mr. Campbell thought that tilling had occurred on these sites prior to his or his father's time (early 1900s). One possible means to confirm this activity would be to look for a plow layer within the soil layers. Grazing by cattle is a known disturbance which occurred under the Failing-Cabell estate, and perhaps with earlier settlers. Although a detrimental practice to native prairie in many ways (soil compaction, plant destruction, replacement of native species by aliens, and others), grazing may have deterred spread of rose and other invasive woody species. Mr. Campbell returned to the Refuge in the mid- and late-1980s and was shocked at the amount of "briar" found in the prairie areas. He was convinced that either grazing or burning should be resumed to control the spread of rose.

The burning history can be assessed from Mr. Campbell's memory, previous documents, and recent history. Evidence from cores of specific trees could also be interpreted, if available. After Indian populations were decimated due to disease from white contact, their annual burning practice was terminated. However, early settlers may have ignited accidental fires. No record of fires, however, exists. According to Mr. Campbell, when the different farmsteads were incorporated into the Failing-Cabell Estate at the beginning of the 20th century, fire was again used by managers as a means of controlling unwanted vegetation. For the intervening years (mid-18th century to early 1900s) little is known about the specific use of the land. Introduced species, arriving with the settlers and subsequently, would have become established during these times. When burning resumed within the estate, regular or irregular pasturing by cattle and possibly also sheep became a common disturbance. This pattern of disturbance could lead to several changes in plant species assemblages. Species unable to withstand grazing would be destroyed leaving more resilient species, those which may have been introduced during the non-burn years or under the grazing regime, may have increased. After the USFWS took over the properties, manipulation by fire was irregular. Spread of wild rose particularly has been noted above by Mr. Campbell. Without documentation, spread or decline of other species remains unrecorded.

Aerial photographs give evidence of changes in land use and vegetation within the RNA. Land Use Surveys give descriptions at the time of settlement when wet and dry prairie with some scattered oak, ash and willow trees were the dominant land cover in this area. Gallery forest extended and expanded along Muddy Creek (Frenkel and Heinitz, 1987). According to Sekora (1989), these conditions did not change radically with the early farmers. Details of farming activity are not explicit, however. Early aerial photographs indicate farming had already been established around the RNA prior to 1936, in the north, east, south and north-west. Farming practices would have provided a source of alien species for the RNA. Extension of the field to the north-west and an inset field in the north of the RNA were established by 1970, after the Refuge was formed.

It would appear that the main forms of disturbances since white settlers came into the valley were grazing, sporadic burning, and grain production. There is little evidence to prove or disprove the idea that the RNA is an unplowed tract of derelict prairie. A careful analysis of soil structure needs to be undertaken before this can be established. The production of grain would have provided an inadvertent source of non-native species, while the grazing would have provided the conditions for spread and space for them to invade. The effect of the irregular burning may have controlled spread of some of these species, but may also have enabled alien species to increase at later times. The results of vegetation trend analysis of present day species related to prescribed burning, which will be available from analyses of data collected in subsequent years, may shed further light on the behavior of species of interest, which in turn could be used to interpret historical information on vegetation change.

CHAPTER 3: FIRE IN WILLAMETTE VALLEY PRAIRIES

> *One of the most striking appearances of the Willamette Valley is the flatness of its Prairies in some instances a dead level for miles in extent - and it becomes a problem of some difficulty to solve how they have been produced. Fire is no doubt the cause of them but the way the forests are growing around them would almost preclude this supposition as but thin belt of wood frequently occurs between extensive ones. Since the country has been in the possession of the whites it is found that the wood is growing up rapidly a stop having been put to the fires so extensively lighted throughout the country every year by the Indians. They are generally lighted in Sept. for the purpose of drying the seed of the [blank] (sunflower) which is then gathered and forms a large portion of their food.*
>
> Wilkes, 1826:53-4
> (cited by Boyd, 1986:71)

Historically, fire has been used by aboriginal peoples as a tool to manipulate vegetation for personal benefit. Some of the more evident reasons for the use of fire are improved game accessibility, improved grazing of game animals, communication, and visibility, and reduction in the threat of uncontrolled fires. In this way, regions of forest and brush have been converted to savanna and open grassland (Vogl, 1974; Anderson, 1990). Indians employed fire deliberately in different regions of North America to encourage certain plants that were of use to them for food and medicine, and to remove cover for game and to attract game to regenerating vegetation (Anderson, 1990; Dorney and Dorney, 1989). It is used today as a management tool to maintain pasture, and also as a means to return some altered systems to their presettlement conditions. The degree of success in the use of fire depends on the physiological response of organisms to fire and the fire regime (Christensen and Burrows, 1986).

THE ROLE OF FIRE

Fire is one form of disturbance prevalent in many environments, especially tall-grass prairie, oak savanna, and conifer-dominated forests in dry summer environments (Anderson, 1990; Vogl, 1974). The specific response of vegetation to fire will depend, amongst other things, on species structure and composition, fuel accumulation, season of burn, climate, and presence of grazing and browsing animals (Anderson, 1990). Fire creates non-vegetated space and releases nutrients readily available for uptake by newly established seedlings. It plays a direct role in processes associated with vegetation succession (Vogl, 1974; Daubenmire, 1968). Nutrient cycling, soil structure, and the stability and dynamics of an ecosystem respond not only to fire but also to season, climate, fuel build-up, fire frequency and intensity, and attributes of the ecosystem itself (Christensen and Burrows, 1986; Vogl, 1974). Species persisting in fire-maintained ecosystems often possess certain attributes which enable their success, such as seed scarification, fire stimulated germination, seed storage in protective structures on plants, mechanisms for fire-stimulated dispersal, bud protection by bark or soil, and vegetative sprouting (Christensen and Burrows, 1986).

Without fire to stimulate their growth, many species would be replaced by others with different attributes.

Frequent fires are believed to favor invading species due to the constant availability of unoccupied space for the establishment of wind-blown seeds common to many invasive plants and also because of enhanced nutrient availability (Christensen and Burrows, 1986; Vogl, 1974). Once established, the new biotic community mainly comprised of invaders may, to some extent, influence the subsequent fire regime, changing its frequency and intensity (Christensen and Burrows, 1986). Repeated burning simplifies stand structure, but may increase species diversity. Native annuals are encouraged by frequent fires. However, the time of year that the fire occurs is important in determining the importance of annuals (Vogl, 1974).

EFFECTS OF FIRE SUPPRESSION

Vegetation response to fire accounts for the persistence of certain ecosystems. Once the fire regime is altered, changes in the vegetation will occur. Fire suppression representing a change in fire regime may lead to replacement of species that have physiological requirements favored by fire, e.g., heat that scarifies or releases seeds. With fewer fires, fuel builds up and may lead to more intense fires. Even those species adapted to less severe fires, for instance thick barked conifers, are not insensitive to a new regime of more intense fire (Christensen and Burrows, 1986).

Other long-term effects of fire suppression are alterations in nutrient pools, increased insect outbreak, reduced unvegetated space, and changes in ecosystem structure, function, and succession. Woody species replace herbs including grasses when the soil and moisture regime can support them. Tree and shrub populations increase along forest edges, expanding the forest (Vogl, 1974).

PRAIRIE RESTORATION

Many prairie restoration projects are underway in North America, initiated by property owners, landscape architects, land managers, consultants and research scientists. One of the largest, underway since the mid-1970s in a mile-square site located above the underground Fermi National Accelerator Laboratory in Batavia, Illinois, is focused on restoration of tallgrass prairie. Beginning with the distribution of a variety of local seeds in one ten-acre plot and increasing the number of plots after a four-year experiment, native tall-grass prairie species have returned to the site. After 15 years the first plot was almost thistle-free. New species appear annually according to their germination time, reaching a total of 125 native grasses and forbs (Mlot, 1990). Other major prairie restoration sites include Konza Prairie Research Natural Area in Kansas (Collins and Wallace, 1990), Osage Hills in

Oklahoma (Madson, 1990), Palmetto Prairie in Florida (Callahan et al., 1990), and the prairie potholes in Iowa (Gladfelter, 1990).

WILLAMETTE VALLEY PRAIRIE RESTORATION

In the Willamette Valley there are several projects aimed at restoring tracts of both wet and dry prairie to their presettlement condition and to protect rare species. Most of these projects are conducted by The Nature Conservancy and by various public agencies. The common strategy in all of these is to re-establish fire regimes characteristic of aboriginal conditions. Until recently, many of these restoration sites were heavily grazed, a land use that severely damaged the original plant communities. Vigorous grasses, such as annual cheat grasses (*Bromus rigidus, B. mollis and B. commutatus*), oatgrass (*Arrhenatherum elatius*), sweet vernalgrass (*Anthoxanthum odoratum*), and hedgehog dogtail (*Cynosurus echinatus*), and perennial forbs and thistles, such as Klamath weed (*Hypericum perforatum*), hairy cat's ear (*Hypochaeris radicata*), bedstraw (*Galium* spp.) and thistle (*Cirsium* spp.), are now abundantly present. Seeds of the prevalent weedy herbs and grasses have been introduced to the valley over the past century.

The objective of these restoration projects is to favor replacement of the alien species by native through reintroduction of fire. It has been assumed by researchers that, without the pressure of grazing and under fire management, native species may successfully compete with aliens and return to their former abundance.

In April 1986, the Oregon Field Office of The Nature Conservancy began monitoring a site at Willow Creek, located within Eugene city limits (Figure 3, page 34). Willow Creek is a seasonally flooded *Deschampsia cespitosa* bottomland prairie, similar to that found in the RNA. At the time The Nature Conservancy began their study, the area was being invaded by ash forest. The vegetation trend was assessed by nested frequency data along six transects. Transects represented two prescribed burning treatments and a control (Acker, 1990).

A preliminary report based on an exploratory analysis of nested frequency data for the three-year period showed that there was little vegetation change. For 56 of the total 76 species-transect combinations possible, no great changes were detected. Frequency differences did not correspond to treatment group, but were well distributed between the various species and life-forms. Two species appeared to be affected by the treatment: *Agrostis* sp. increased in three of the four transects. *Senecio jacobaea* decreased markedly in two transects over the period of observation (Acker, 1990). Abundance of the five most ubiquitous species (*Holcus lanatus, D. cespitosa, Danthonia californica, Agrostis* sp., and *Aster curtus*) did not change significantly from year to year (Acker, 1990).

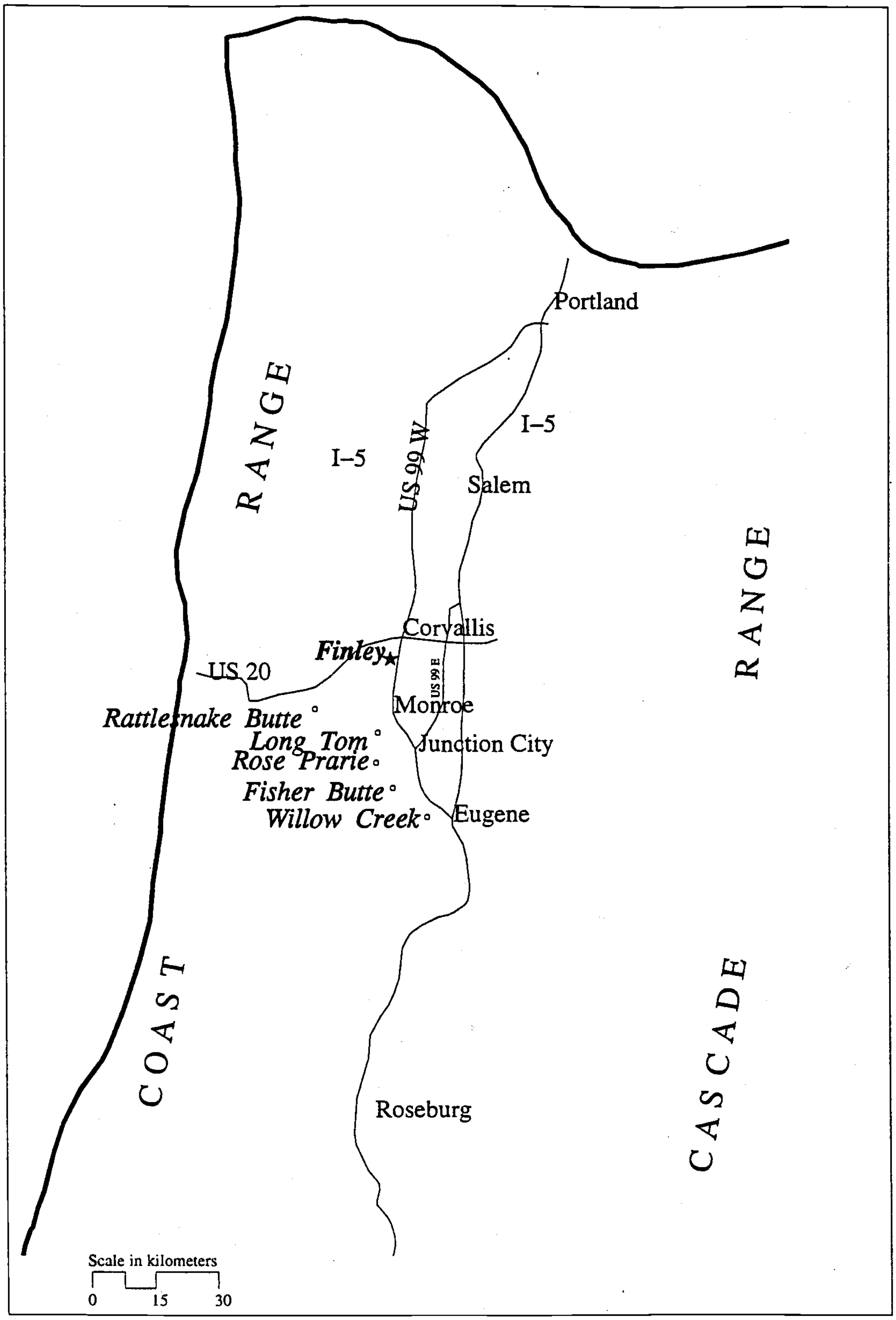

Figure 3. Location of projects within the Willamette Valley.

Acker (1990) also performed multivariate analysis on the dataset in an attempt to learn which are the important components of variability between the samples. Several transects showed little change in native and introduced species, others showed variable changes over time between both groups of species, and one showed a large increase of introduced species (Acker, 1990). A final updated report on the Willow Creek study will not be available until later in 1994 (pers. comm. Dan Salzer, Oregon Field Office, The Nature Conservancy).

A second project undertaken by The Nature Conservancy is on Rattlesnake Butte, a dry prairie remnant located west of Monroe, between Corvallis and Junction City (Figure 3, page 34). This study began in 1988, with a purpose of examining the response of the *Stipa lemmonii-Rhacomitrium canescens* community to reintroduction of fire. Nested frequency data were collected in a split-plot design in six 5 x 11 m plots, each with a specified burn regime. Treatments were no burn (control), one burn in 1988, one burn in 1989, and two annual burns (1988 and 1989). In addition, fifty tussocks of *Stipa lemmonii* were permanently marked, and their basal area and number of flowering culms recorded (Macdonald, undated).

Different species responded differently to the burning regimes. *Aira caryophyllea* and *B. mollis* responded by increasing, and *Cynosurus echinatus* by decreasing, more in the plots burned in 1988 and 1988/89 than they did in the plots burned in 1989 and controls. *Festuca* sp. decreased in overall density across all treatments and the control. There was an overall significant net decrease in the percent frequency of *R. canescens* across all burned and control plots in the 1988 and 1988/89 treatments but not in the 1989 treatment. There was an overall increase in the density, basal area, and number of flowering culms of tagged *S. lemmonii* from 1988 to 1991. Mortality rate of *S. lemmonii* varied over the three year period from 18% in the control, 6% in the 1988 burn treatment, 31% in the 1989 burn treatment and 28% in the 1988/1989 burn treatment; however, these differences were not significant (Macdonald, undated).

Boone Kauffman, Kathy Connelly, and Karen Finley, Oregon State University, have been studying three bottomland prairie sites east of Fern Ridge Reservoir (Connelly and Kauffman, 1991; Wilson et al., 1993). Sites were: Fisher Butte, Rose Prairie, and Long Tom (Figure 3, page 34). *Phalaris arundinacea* (reed canarygrass) is a major invader of the wettest areas in these sites (Wilson et al., 1993). Plots were located in all three study sites in areas experiencing two burns, one burn, and no burn (control). Plant communities were inventoried along 30 m transects using percent cover and nested frequency methods. Detailed measurements were collected on individual plants of *L. bradshawii* and *E. decumbens* (Connelly and Kauffman, 1991; Wilson et al., 1993). Measurements of fuel and fire characteristics were made also (Connelly and Kauffman, 1991).

Community sampling results are not available at the time of writing (Connelly and Kauffman, 1991). The PC-ORD program (McCune, 1990) was used to calculate species richness from cover and frequency data (Wilson et al., 1993). This analysis at Fisher Butte identified a *Rosa nutkana/D. cespitosa-Juncus nevadensis* (ROSNUT/DESCES-JUNNEV) community and a *D. cespitosa-D. californica* (DESCES-DANCAL) community. *D. cespitosa, D. californica, Madia glomerata,* and *Grindelia integrifolia* were found to be the dominant native species, and *H. lanatus* the dominant non-native species, in both communities. Table 1 (page 38) identifies the dominant native and dominant non-native species for each community.

At Rose Prairie, three plant communities were differentiated: a *R. nutkana/A. odoratum* (ROSNUT/ANTODO) community, a *D. cespitosa-D. californica* (DESCES-DANCAL) community, and a *Vaccinium caespitosum* (VACCAE) community. Overall, the site was drier than Fisher Butte, and had more non-native species (Wilson et al., 1993). Table 2 (page 39) identifies the dominant native and dominant non-native species for each community.

Fire effects on overall cover and diversity of both native and non-native species was inconsistent and inconclusive. In the ROSNUT/ANTODO community at Rose Prairie, native species increased in number in the burned

Table 1. Native and non-native dominant species by community at Fisher Butte (after Wilson et al., 1993).

	ROSNUT/DESCES-JUNNEV community	DESCES-DANCAL community
Dominant native species	*Deschampsia cespitosa* *Danthonia californica* *Madia glomerata* *Grindelia integrifolia* *Carex* spp. *Juncus nevadensis* *Agrostis exarata* *Rosa nutkana* *Cardamine pendulifora* *Galium* spp. *Beckmannia syzigachne* *Boisduvalia* sp. *Brodiaea coronaria* *Eleocharis acicularis* *Epilobium* spp. *Microseris gracilis* *Veronica scutellata* *Eryngium petiolatum*	*Deschampsia cespitosa* *Danthonia californica* *Madia glomerata* *Grindelia integrifolia* *Aster chilensis var. hallii* *Eriophyllum lanatum* *Microseris laciniata* *Prunella vulgaris* *Sisyrinchium angustifolium*
Dominant non-native species	*Holcus lanatus* *Mentha pulegium* *Briza minor* *Centaurium umbellatum* *Hypericum perforatum* *Briza minor* *Centaurium umbellatum* *Hypericum perforatum*	*Holcus lanatus* *Agrostis spp* *Centaurium umbellatum* *Hypericum perforatum* *Briza minor* *Hypochaeris radicata* *Leontodon nudicaulis* *Anthoxanthum odoratum*

plots and declined in the unburned plots. Non-native annual, biennial, and perennial forbs increased 2-3 fold in the burn plots, but remained less common in unburned plots. Native tree and shrub cover increased in the burned plots of the ROSNUT/DESCES-DANCAL community at Fisher Butte, remaining unchanged where not burned. Native perennial graminoids increased in the burned plots of the DESCES-DANCAL community at Rose Prairie after two burn treatments, but did not increase in unburned plots. There was up to 2.1% cover of non-native graminoids in the burned plots, while almost none occurred in the unburned control plots (Wilson et al., 1993).

Table 2. Native and non-native dominant species by community at Rose Prairie (after Wilson et al., 1993).

	ROSNUT-ANTODO community	DESCES-DANCAL community	VACCAE community
Dominant native species	*Lotus purshiana* *Heterocodon rariflorum* *D. californica*	*D. cespitosa* *D. californica* *Panicum occidentale* *Eriophyllum lanatum* *G. integrifolia* *Camassia quamash* *Centunculus minimum* *Centaurium muhlenbergii* *Microseris laciniata* *Juncus tenuis* *J. nevadensis*	Same as DESCES-DANCAL community, and *V. caespitosum* *A. curtus* *Carex* spp. *Lotus formosissimus* *Prunella vulgaris* *Sisyrinchium angustifolium* *Viola adunca* *A. chilensis* var. *hallii* *Brodiaea coronaria* *Comandra umbellata* *Fragaria virginiana* *Horkelia congesta* *R. nutkana*
Dominant non-native species	*A. odoratum* *H. perforatum* *H. lanatus* *Plantago lanceolata* *R. nutkana*(?native) *Rumex acetosella* *B. minor* *Cerastium viscosum* *L. nudicaulis* *Myosotis discolor* *Parentucellia viscosa* *Seneceo jacobaea* *Galium parisiense*	*Agrostis tenuis* *A. odoratum* *H. radicatam* *L. nudicaulis*	*A. tenuis* *A. odoratum* *H. radicatam* *L. nudicaulis* *H. perforatum* *B. minor*

Flowering and seed production of *L. bradshawii* increased dramatically (as much as seven-fold) in burn treatment plants relative to the control. Similarly, umbel and umbellet production were enhanced. Height and crown diameter appeared to be little affected by burning. Highest mortality occurred in the twice-burned treatment at one location, and the control treatment at a second. Changes in plant density were variable (Connelly and Kauffman, 1991; Wilson et al., 1993).

Plant height growth and flowering of *E. decumbens* was adversely impacted by the first burn. Flower production appeared to be stimulated following the second burn. Crown growth was positively affected after two years of burning, and mortality rates were greater in burn treatment plots compared to controls. Density increased dramatically in burn treatment plots over time (Connelly and Kauffman, 1991; Wilson et al., 1993).

VEGETATION STUDIES AT THE FINLEY RNA

Several studies employing fire to manipulate the vegetation have been undertaken within the RNA since the early 1970s. Figure 4 (page 41) summarizes these different studies.

In 1971, William Moir and Peter Mika studied the RNA vegetation in order to (1) establish the present vegetation composition, (2) relate this to the history of the Anglo settlers' activities in the valley, (3) determine effects of initiation of a burning program, and (4) establish the extent of native prairie plants within the RNA. From aerial photographs, they identified ovate "islands" within the RNA, to which three plant communities were related. The communities were: *R. eglanteria* (ROSEGL) at the centers of the ovate islands, *Poa pratensis-Agrostis exarata* (POAPRA-AGREXA) along the margins of the islands, and *D. cespitosa* (DESCES) in the areas between the islands and their margins. Moir and Mike sampled herbaceous vegetation with

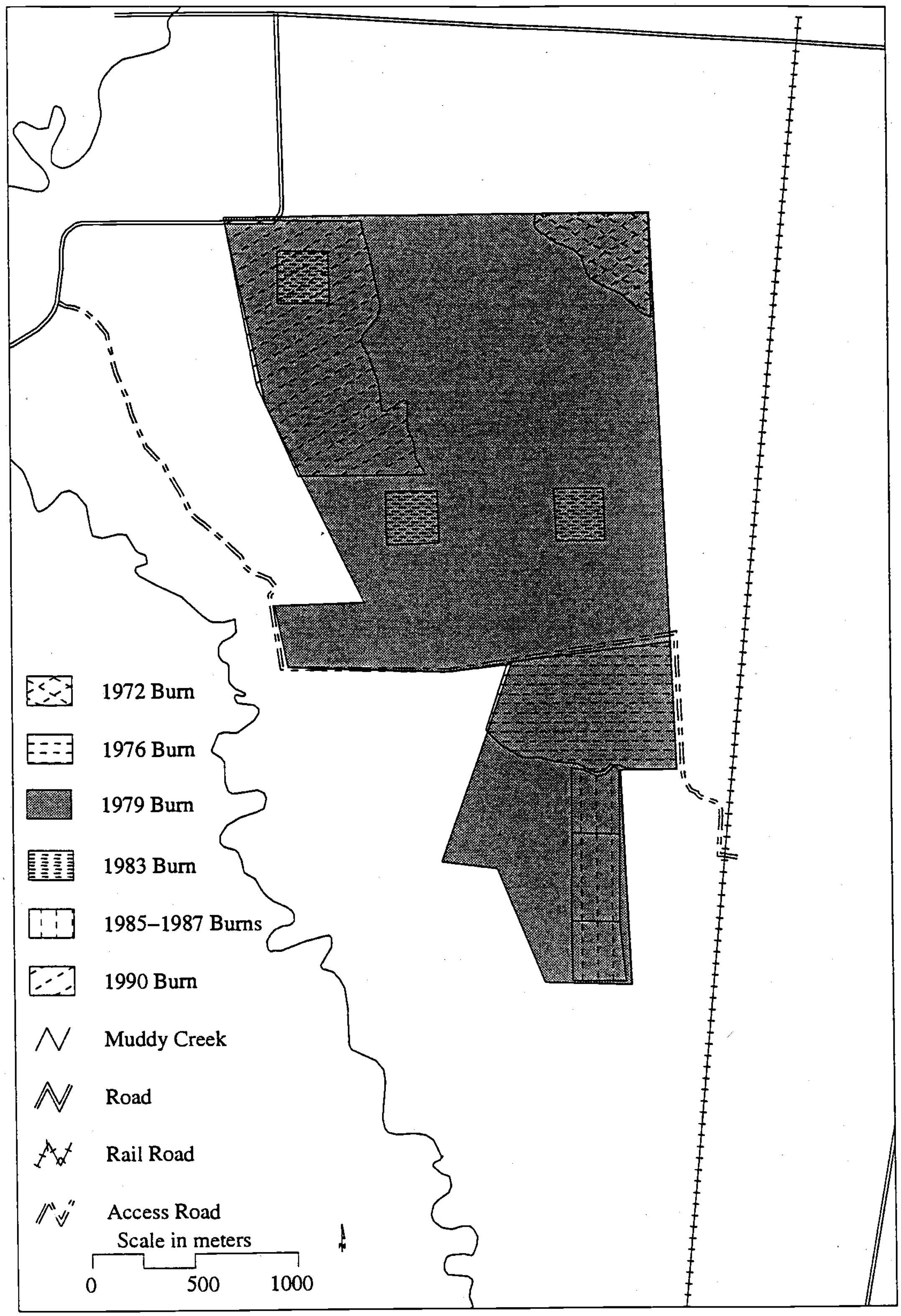

Figure 4. Approximate locations of projects and burn sites within the RNA (Frenkel and McEvoy, 1985.)

fifty 25 x 50 cm Daubenmire plots along two transects at 50.4 m intervals in the DESCES and POAPRA-AGREXA community types, and assessed cover and frequency of all but minor vascular plant species. They employed line-point transect sampling to describe composition of shrub cover within the ROSEGL communities along 25 m-long transects. They also estimated above-ground biomass in the DESCES and POAPRA-AGREXA communities by clipping and harvesting (Moir and Mika, 1972).

In the DESCES community, Moir and Mika found other codominant grasses: *H. lanatus, Poa ampla*(?), *Juncus spp., D. californica* and *Bromus japonicus*(?). In slight depressions within these communities, *Hordeum brachyantherum, Beckmannia syzigachne*, and *Alopecurus geniculatus* became dominant. The forb, *Veronica scutellata*, was reported "sometimes conspicuous". In spring, *Camassia* spp., *Montia linearis* and *Eleocharis acicularis*, were prominent; in autumn *Aster chilensis* and *Madia* spp. were common (Moir and Mika, 1972).

In the POAPRA-AGREXA community, dominance varied with season. *P. pratensis* and *Carex* spp. were common in spring, *H. lanatus, Festuca idahoensis*, and *Poa compressa* were dominants in early June, *and A. exarata* in late June. Forbs included *Delphinium ochroleucum (= D. pavonaceum)*, *Plantago lanceolata, Geranium dissectum, Daucus carota, Epilobium paniculatum, Achillea millefolium, Rumex acetosella*, and

Sisyrinchium bellum (= *S. angustifolium*), *S. jacobaea*, *Madia* spp., and *A. chilensis* (Moir and Mika, 1972).

Ovate islands were dominated by a ROSEGL community, "with several comparatively minor species." *Spiraea douglasii* occurred in "conspicuous circular patches at occasional sites in the DESCES community" (Moir and Mika, 1972).

Peak standing herbage from the DESCES and POAPRA-AGREXA communities averaged 530 and 323 grams/m^2 respectively and were comparable to estimates from other similar highly productive prairie communities in North America (Moir and Mika, 1972).

Frenkel and McEvoy studied the RNA in July and August 1983 and 1984 (Figure 4, page 41) to (1) determine species composition, cover and biomass in burned and unburned plots prior to a prescribed burn, (2) characterize plant communities in the study area, and (3) compare burned plant communities to unburned (Frenkel and McEvoy, 1983). The vegetation monitoring was initiated to complement an assessment of small mammal populations. Six 4-ha square (10 acre) permanent macroplots were established by Refuge personnel and vegetation cover sampled in 50 1-m square microplots in each 10-acre plot. Percent cover and species composition were estimated at 5% canopy cover intervals. Biomass data was collected in late August by clipping all vegetation and leaf litter in ten 50 x 100 cm microplots. Three randomly chosen 10-acre plots were burned in

September; the remaining three served as controls (Frenkel and McEvoy, 1983).

The dominant species included *Rosa* spp., *H. lanatus, D. cespitosa, Epilobium glandulosum, Agrostis spp., Carex unilateralis, Veronica scutellata, Galium trifidum* and *S. douglasii* var *douglasii*. Raw dry weight of the biomass was tabulated but not analyzed. Five communities were identified prior to burning by TWINSPAN classification: *Symphoricarpos albus/Geranium dissectum, Agrostis alba/H. perforatum/Parentucellia viscosa/Centaurium umbellatum, D. cespitosa/Carex lanuginosa, D. cespitosa/Alepocurus geniculatus/Carex unilateralis*, and *S. douglasii*. DECORANA ordination helped ascertain potential environmental relationships. Although the *Spiraea* community was distinctive from other communities, no environmental interpretation was put forth (Frenkel and McEvoy, 1985).

Monitoring of the same plots continued in 1984 after prescribed fire treatment, employing the same methods. Comparisons of species cover between burned and unburned plots were to be made. Postburn vegetation was not analyzed. Biomass was collected in clip plots adjacent to those clipped in 1983. Analysis to determine statistical differences of total peak biomass between the burned and unburned plots, and between different years for the unburned control plots, however, was not completed. Table 3, page 45, lists the change in abundances of the ten most common species between the two years (Frenkel and McEvoy, 1985).

Table 3. Change in abundance of ten most dominant species between 1983/1984 (after Frenkel and McEvoy, 1985).

Species Name	1984 %	1983 %
Holcus lanatus	87.3	80.0
Rosa spp.	86.1	92.3
Myosotis laxa	57.8	41.4
Deschampsia cespitosa	54.4	57.5
Epilobium spp.	53.3	34.9
Agrostis alba	40.5	33.7
Parentucellia viscosa	36.8	16.1
Hypericum perforatum	36.0	31.0
Veronica scutellata	33.1	27.3
Agrostis exarata	29.2	21.1

A general program of prescribed burning was carried out by John Cornely, Finley staff biologist, between 1985 and 1987 in the southeastern part of the RNA (Space 4 today). This program has not been documented, but apparently no vegetation data were collected. Based on phone contact, the area presently identified as "Space 4" was divided south-to-north into thirds, the southern third burned 1985, 1986, and 1987. The central third burned in 1985 and 1986, and the northern third burned in 1985 only (Figure 4, page 41).

In addition to the above research projects, several deliberate and one accidental manipulations of the area with fire have taken place. A small triangular area in the north-east corner was burned in 1972. A 25-acre area centrally located in the southern part of the RNA was burned in 1976. In 1979, an escaped agricultural fire burned almost the entire prairie (Frenkel and McEvoy, 1983). In August 1990, a prescribed burn was undertaken as part of an effort by USFWS personnel to restore presettlement vegetation in the northwest part of the RNA to control invading species, particularly non-native rose species (Figure 4, page 41). Vegetation data collection is a part of the present research.

CHAPTER 4: METHODS

"Although species may be added to communities, they are not committed in their evolution to particular communities. Most species occur in a range of communities in which they interact with different combinations of other species.... Species change their associations with other species in evolutionary time. A community observed in the present includes species of diverse histories in different other communities."

Whittaker, 1975

SAMPLING METHODS

Approach

The RNA is a 210 ha tract of mostly wet prairie with some forest located in the south-west corner. The prairie is partially flooded annually by Muddy Creek from November to April depending on precipitation, and is closed to the public during this time to protect overwintering waterfowl. A few large ash trees are scattered within the prairie, and an occasional oak is found in the peripheral fields. Hawthorn and adventive fruit trees have invaded in places.

My overall objective is to document the progress in restoring RNA vegetation to its state at the time of anglo-European settlement, around 1840. Since fire had been used historically by the Kalapuya Indians throughout the valley, reintroduction of fire was proposed by Refuge personnel as a means of re-establishing historic vegetation. The proper frequency of burning must therefore be determined in order that an effective regime be administered.

I divided the RNA into three treatment blocks: (1) an area to be burned annually, (2) an area subjected to burns every two or three years, and (3) an unburned control area. The different areas designated for these treatments were delineated on a recent (1990) large scale (1:5100) aerial photograph after consulting with Refuge staff regarding logistics of experimental burns. Since a 28-ha area in the north part of the RNA had been burned by Refuge personnel in September 1990, this became the parcel to be subject to an annual burn treatment (Space 1). A second parcel, having similar physical and vegetation structure to the annual burn parcel, was chosen to represent the control (Space 2). This area was known to have burned in 1979 along with the entire RNA. A third parcel, to be subject to a three year burn treatment, was also similar to the control and annual burn area. This third parcel was divided into two sub-areas. One sub-area had not had an intensive fire history (Space 3). The other had a more extensive history of burning (Space 4). Figure 5 (page 49) shows locations of these parcels. The parcels are hereafter referred to as spaces.

The aerial photograph was also examined to identify significant features of the RNA (Appendix 1). It was obvious that a pattern of large lenticular shrubby areas ("mounds") were imbedded in a matrix of lower-growing more herbaceous vegetation ("intermounds"). Field comparisons were made to verify these features. Based on early spring observation, the lower intermound areas remain saturated beyond the wet season, into May or early June. Thus, due to heavier materials separating out ahead of lighter sediments,

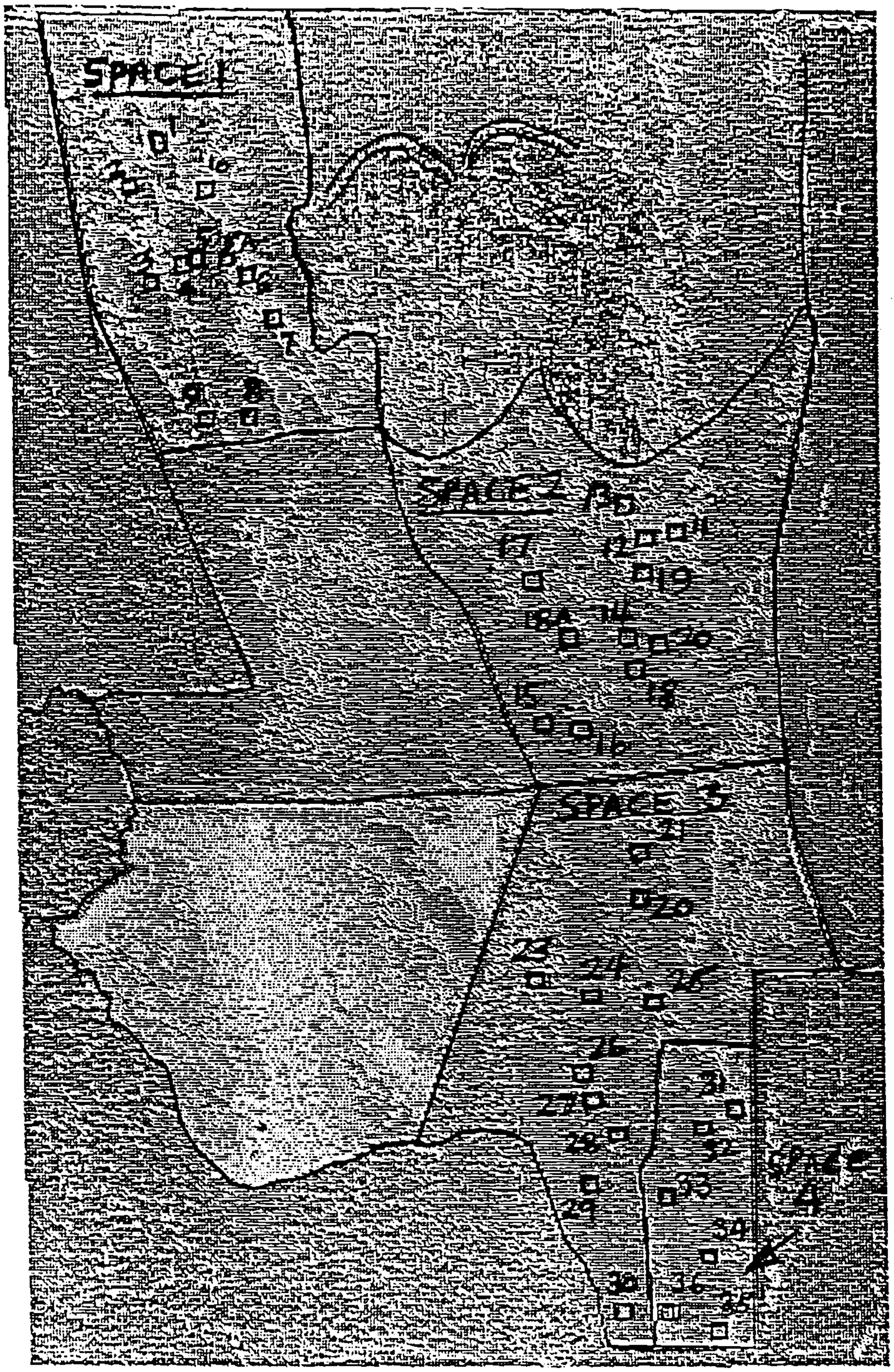

Figure 5. Location of spaces within the RNA showing macroplot sites (refer also to aerial photograph attached as Appendix 1).

the soil texture of the intermounds would be of a finer nature than that of the mounds.

Sampling Systems

To adequately reflect the variability in the vegetation, I established a sampling system with ten, 25 x 25 meter (m) macroplots, distributed randomly but equally among mounds or intermounds within each of the three treatments in Spaces 1, 2 and 3. I allocated six plots to Space 4, three on mounds and three on intermounds (Figure 5, page 49). I used the 1990 aerial photograph to locate macroplots within each space. To randomly locate macroplots, I overlaid a grid of numbered dots scaled at 25 m intervals on the air photograph. I excluded dots located within 25 m of the RNA boundary, trails and ditches, and mound-intermound interfaces. I generated random numbers for remaining dots, and randomly located on the image and in the field 36 macroplots. Eighteen plots were located randomly on what I judged to be mounds and 18 on intermounds. Plots 1 to 10 occurred in Space 1, 11 to 20 in Space 2, 21 to 30 in Space 3, and 31 to 36 in Space 4.

For floristic sampling, microplots were randomly located in each of the 36 macroplots in a stratified fashion. I divided each macroplot into 25 5 x 5 m squares, each of which I subdivided into 1 x 1 m^2 microplot positions. Using computer-generated random numbers, I selected 25 of these 1 m^2 microplot positions for the vegetation survey, as illustrated in Figure 6 (page 52). Stratified random microplots therefore sampled the entire macroplot in a representative fashion. I chose the stratified sampling method to prevent clustering of samples within the macroplots, and to optimize the estimates of vegetation coverage and species frequency for all species present.

FIELD METHODS

Vegetation

I located the 36 randomly selected macroplots in the field relative to identifiable landmark features (such as prominent trees) seen on the aerial photograph, using the compass bearing and distance of the NW corner of the macroplot from this feature, and transferring this information to the field. This proved to be very difficult. I drove six-foot iron angle posts into the soil to mark the NW and SW corners of each macroplot and wired numbered metal tags to each post for field identification in subsequent years.

To locate microplots accurately within the macroplots, I extended 30-meter tapes along two legs of each macroplot. I laid down a metric stadia rod sequentially at each five-meter increment along the western boundary during surveying to aid in locating each microplot in the 5 x 5 m strata.

Sampling started June 24, 1991, in Space 1 and followed the schedule shown in Table 4 (page 53). I identified

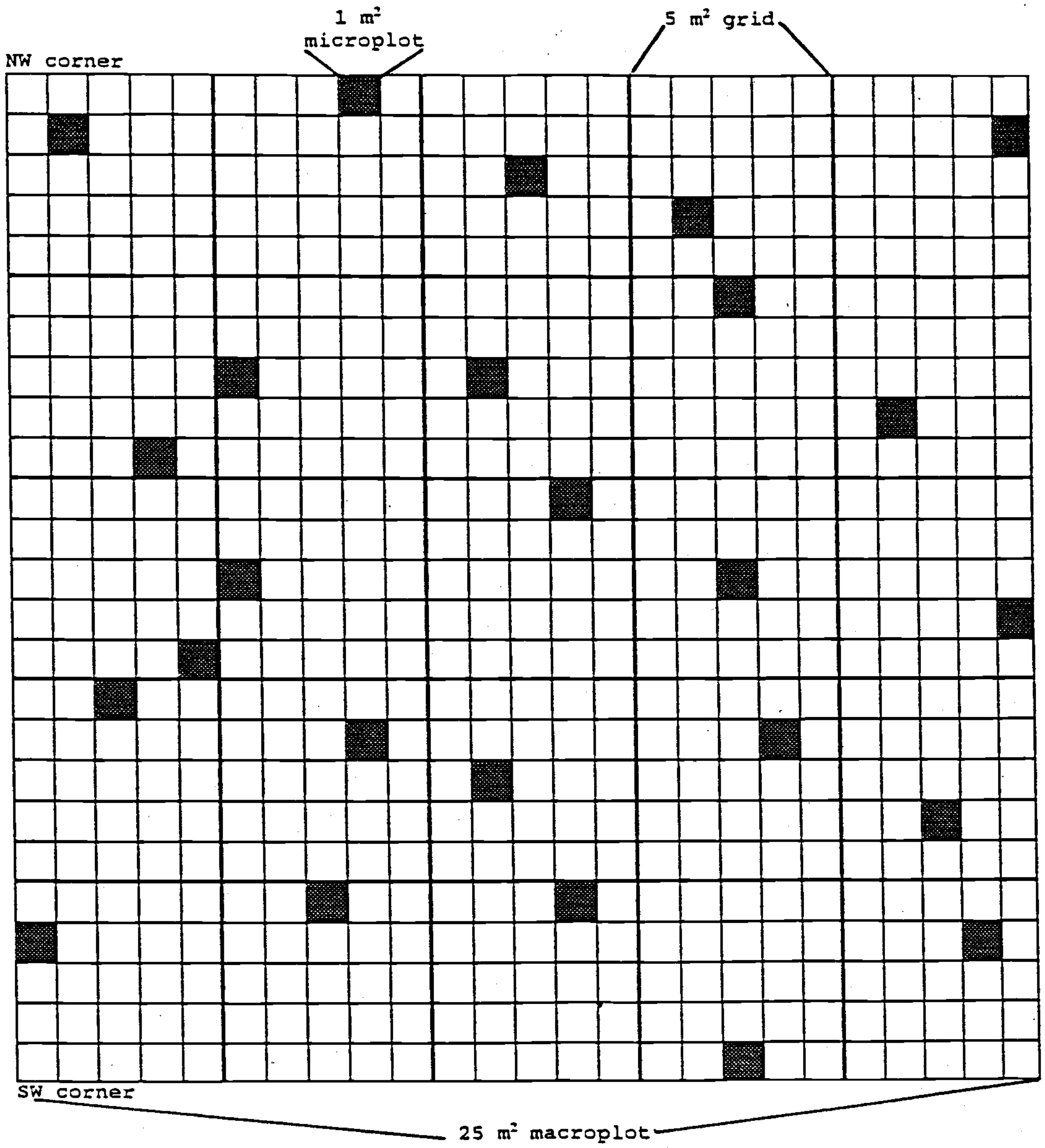

Figure 6. An example of stratified sampling within a 25 m^2 macroplot showing location of nested quadrats within a 5 m grid.

species with the assistance of Hitchcock and Cronquist, 1973 in the field and office. I recorded all non-seedling plant

Table 4. Sampling schedule.

Date (1991)	Macroplot
Monday 6/24	1, start 2
Tuesday 6/25	2, 3
Wednesday 6/26	4, 5
Thursday 6/27	6, start 7
Friday 6/28	7, start 5A
Monday 7/01	8, 9
Tuesday 7/02	10
Wednesday 7/03	31, 32
Friday 7/05	33, start 34
Tuesday 7/09	34, 35, 36
Wednesday 7/10	30, 29, start 28
Thursday 7/11	28, 27, start 26
Friday 7/12	26, 25
Monday 7/15	24
Tuesday 7/16	23, 22
Wednesday 7/17	21, 16, 15
Thursday 7/18	18A, 17
Friday 7/19	20, 19
Monday 7/22	11, 12, 13
Tuesday 7/23	18, 14

species in each meter-square microplot using two measures of vegetation: presence/absence in three quadrat sizes (0.01, 0.10, and 1.0 m^2) and estimate of cover in the 1.0 m^2 quadrat. Collection of presence/absence data followed the nested frequency method of Winward and Martinez, 1983. Species presence/ absence was recorded in each nested unit for future trend analysis. Species canopy cover was recorded in the 1 x 1 m quadrat by cover class (Table 5, page 54).

Table 5. Cover classes and analytical cover values.

Field Classes		Midpoint %Cover	Pseudospecies Cut Levels 1	Pseudospecies Cut Levels 2	
1	<1%	0	0	0	<4%
2	1- 5%	3	0	5	5- 9%
3	6- 10%	8	5	10	10-15%
4	11- 25%	18	10	16	16-20%
5	26- 50%	38	25	21	21-30%
6	51- 75%	63	50	31	31-40%
7	76-100%	88	75	41	41-60%
				61	>61%

For nested frequency, if a plant species were found in the smallest unit, I awarded it a score of 1 in the field data form. Since presence/absence plots were nested, a species present in the smallest size plot was automatically represented in the next two larger nested units. If it was absent in the smallest unit, but present in the middle unit, I allocated it a score of 2, thus automatically confirming it as present in the third. If the species was only recorded in the largest unit, it received a score of 3. If it was not represented in any of the units, it scored zero.

A total of 900 meter-square microplots was sampled. For analytical purposes, however, there were 36 plots each sampled randomly by 25 microplots.

Additional Field Studies

In addition to the floristic survey, I undertook two further projects during the field season: preliminary terrain surveying and fire temperature assessment. Results from these studies are included in Chapter 5. I also attempted mapping the RNA boundary and plot locations using a Global Positioning System (GPS), surveying for rare plants, and carrying out a preliminary soil analysis. The data for these last three projects were incomplete, not analyzed, and are not presented. However, in order that a better comprehension of the vegetation structure within the RNA be ascertained, I strongly recommend that they become a focus of future studies.

Terrain Surveying

Because of the apparent differences in wetness between the drier shrubby areas and wetter graminoid communities, I surveyed relative elevations along five transects. This project was carried out in early September. I selected five transects, each crossing several mound/intermound interfaces, throughout the four spaces to measure and characterize terrain undulations. Relative elevations along each transect were recorded, as well as distances and macroplots traversed (if any). No true height-above-sea-level was determined. Surveying was to third order accuracy using an optical automatic level and stadia rod.

Fire Temperature Assessment

Spaces 1, 3 and 4 were burned by USFWS personnel in September 1991 as part of their efforts to restore native prairie vegetation in the RNA. In order to measure the intensity of the burn as it passed over individual macroplots, I inserted one or two graded temperature chips in the soil in each microplot in Spaces 1, 3 and 4 in late August, totalling thirty-five chips. To each 4 x 6 cm chip consisting of asbestos felt to which a thin sheet of mica was stapled, I applied ten 0.5 cm wide strips of temperature sensitive paint in order of degree of meltability (with temperature ranges from 38°C to 427°C [100°F to 800°F])(after Fenner and Bentley, 1960; Cole et al., 1992). I placed the temperature chips within 50 cm of the NW and SW posts, exposing approximately 1 cm above the soil surface. Approximately 4 cm was below the soil surface. I retrieved thirty chips in late September after the burn measuring the depth at which the different paints were melted. In addition to the temperature estimates, I assessed the intensity of fire visually in each macroplot after the burn, according to a seven-point scale:

0 = no evidence of burning
1 = slight burn, no soil charring
2 = some soil charring (<50% of macroplot area)
3 = >50% charring
4 = completely charred, <50% woody stems killed and herbage consumed
5 = severe burn, >50% woody stems killed and herbage consumed
6 = 100% woody stems killed and herbage consumed.

ANALYTICAL METHODS

Data Analysis

The need to detect change in species abundance over time is essential to assess the effect of the two prescribed burning treatments. I used the nested frequency technique to provide baseline data for monitoring treatment response trends for future sampling. Compared with other methods for trend determination (repeat measurements of cover, production, and density), nested frequency sampling is considered highly sensitive, providing a high degree of precision and stability over time in relatively homogeneous vegetation (Smith et al., 1986). It provides pertinent information on the presence and absence of a species, and is measured objectively (i.e., presence or absence), easily, and rapidly (Smith et al., 1986). However, use of a single plot size as opposed to a nest of sizes to assess all species regardless of their abundance can result in exclusion of some species or estimation of 100% frequencies of other species which are very abundant (Winward and Martinez, 1983). Appropriate frequency values should range from 50 to 86% for the most abundant species to permit estimates of successional change. By using the nested quadrat with three different sized plots, the ability to detect the most sensitive frequency values for each species is tripled, and a choice exists for the ultimate quadrat size. A species occuring in greater abundances requires a small plot to adequately detect changes (Smith et al., 1987).

A second type of data analysis was used to classify the RNA vegetation and relate vegetation to environmental factors. For this purpose, several multivariate programs were used. As part of this task, I estimated the degree of similarity between macroplots, assessed abundances of the different species, and floristically classified them. I used the canopy cover class estimates (Table 5, page 54) in the meter-square microplots for basic data collection (Daubenmire, 1957). The choice of cover classes was to save field time in evaluating species composition in 900 microplots. While canopy cover estimates increased the efficiency of sampling, it did so at a cost possibly of more accurate quantitative or qualitative estimates. It is, however, considered a reasonably objective estimate of the cover of the species (Oksanen, 1976).

Data Preparation

Raw field data were tabulated by computer using Lotus 1-2-3 and Quattro-Pro spread sheet programs. Species frequency matrices were analyzed in this form for each quadrat size. Cover data matrices were first converted from spreadsheet matrices into ASCII files to be read by the Cornell University Ecology Program COMPOSE (generating "condensed format"), then altered into "compact format" for the PC-ORD system (McCune, 1991). Seven cover classes were converted to percent midpoint cover (Table 5, page 54). I then standardized these by an arc-sine square root transformation. I chose this transformation to reduce influence of midrange cover values.

Vegetation Analysis

Vegetation analysis considered species abundance differences between identified mounds and intermounds and the effects of a treatment (burning) on species composition. While data used for this study serves as baseline data for future studies as the prescribed burning program is carried out in forthcoming years, I was able to address several questions in the vegetation analysis as follows:

(1) What are the main plant communities within the RNA, based on species composition? How is each community characterized in terms of the dominant species and key species for community identification?

(2) Does the vegetation differ between mound and intermound micro-landforms? If so, what are the major plant communities of each? Do more "weedy" (non-native alien) species occur in the mounds?

(3) Does the vegetation differ between all four spaces, especially between the three treatments (annual burn, triennial burn, control)? If so, what are the differences and how are they related to recent disturbances?

(4) How do the macroplots differ with respect to a frequency-weighted average wetland index based on the National List of Plant Species that Occur in Wetlands?

(5) What are the percent frequencies of each species within each nested plot size?

I addressed the first three questions by analyzing the cover data aggregated into 36 macroplots employing three multivariate approaches. Vegetation was first classified by

TWINSPAN, a classification system displaying samples and species in a two-way table in their determined groupings. This program is included in the Cornell Ecology Program developed by Mark O. Hill (Hill, 1979). I used a non-parametric procedure, Multi-response Permutation Procedures (MRPP), to test for differences between groups. I used Non-metric Multidimensional Scaling (NMS) as an ordination procedure, that is also non-parametric and suited to analyzing non-normal data. Non-parametric procedures were used because of the non-linear relationships between variables and the non-normal distribution of the data (many zeros in the matrix). These programs are included in a package PC-ORD developed by Bruce McCune (McCune, 1991).

I chose TWINSPAN to classify the data primarily because of its effective tabular display of the groupings. It is a two-way indicator species analysis, classifying species as well as samples, and employs an hierarchical, polythetic, divisive methodology (Hill, 1979). The matrix tabular display approximates the final product of the Braun-Blanquet classification. The ordered two-way tables are constructed through the identification of differential species. Samples are classified first based on attributes of the species, followed by classification of the species which are based on the structure of the samples (Hill, 1979).

In TWINSPAN, I first ran the complete data set, with 36 macroplots and 108 species choosing seven cut levels corresponding to mid-point cover percentages (Table 5, page

54, column 3). All other parameters of the program were set to the program defaults, that is a maximum of six levels of divisions, each with a minimum group size of five. I then removed from the original dataset those species occurring in fewer than four macroplots and with abundances under 5% (24 species), and reran the program. In this second run I selected eight cut levels, emphasizing lower percentages to better reflect those species with lower abundances (Table 5, page 54, column 4). All other settings remained the same. A total of 84 species (199 pseudospecies) was entered into the program. I used this second run for analysis.

The MRPP, a non-parametric form of discriminant analysis, is provided in the PC-ORD package, along with the NMS ordination program (McCune, 1991). Species with less than 4% average cover or occurring in less than three macroplots were discarded (17 species), leaving 91 species for analysis.

The permutation test was used to test the validity of the TWINSPAN classification instead of other statistical tests because it does not require assumptions such as a normal distribution of the variables or homogeneity of variances which can seldom be met in practice (Biondini et al., 1985). It tests the significance of differences in the average distances between groups of objects (Zimmerman et al., 1985). In running this program, I chose the city-block distance measure (1-[2W/A+B], where W represents the shared distributional area of both samples A and B, A represents the space occupied by A alone and B that of B alone). I weighted groups according to their size ($C_i = n_i/(\text{sum of})n_i$, recommended by Mielke, where C_i is the weight applied to each item in group *i* and n_i is the number of items in group *i*)(McCune, 1991).

The MRPP statistic (delta, δ) represents a linear combination of weighted average within-group city-block distance measures for the number of groups being tested. The smaller the value of δ, the more concentrated the objects within each group (Zimmerman et al., 1985). Hypothesis testing making use of δ can be performed, where the null hypothesis, H_o, implies a random allocation of the groups with little clustering, and H_A implies a clustering into groups (Berry et al., 1980). The P value is derived through a permutation argument (assignment of all objects to groups in all possible arrangements), so no distributional requirements are made. For an observed statistic, the P value is the probability of finding another δ as low or lower than the observed δ. If the observed permutation into which the groups fall is unusual (low probability value), the null hypothesis is rejected, indicating a difference in their structure (Zimmerman et al., 1985).

The NMS ordination procedure is also contained in PCORD. It follows the model devised by Mather (1976), with the central computational algorithm (steepest descent minimization to find minimum stress) based on Kruskal (1964) and McCune (1991). I selected the NMS over other ordination procedures because of its focus on ranking sampling units according to their dissimilarities (Ludwig and Reynolds, 1988). Parametric ordinations such as principal components analysis assume linearity in arranging these non-linear relationships along the underlying environmental gradients, resulting in hard-to-interpret arched or spiral ordinations (Ludwig and Reynolds, 1988). NMS endeavors to minimize the linear constraint by ordering measures of dissimilarity and distance between plots monotonically rather than using their actual values (Greig-Smith, 1983).

The principal methodology of the NMS is to find a rank order agreement between distances of sample units in species space and their dissimilarities in variable space while reducing dimensionality of their structure (Kenkel and Orloci, 1986). It seeks by trial and error an arrangement in which distances or dissimilarities in the original data increase monotonically with the ordinated interstand distances. Diversion from monotonicity is called "stress." Stands are initially placed either along a prespecified number of ordination axes or from a previous ordination (Greig-Smith, 1983). In this study, I employed Bray Curtis ordinations from PC-Ord as starting coordinates after runs with randomly generated starting coordinates identified the number of major dimensions in the data. The Bray Curtis procedure involves selection of two endpoints within the data, with the positioning of the remaining samples along an axis according to their similarities with the chosen endpoints. In its original form a third endpoint to locate the second axis is selected as that which is farthest from the first X-axis, i.e., that stand which is equidistant from both primary endpoints (Ludwig and Reynolds, 1988). The PC-ORD version of the Bray Curtis technique does not identify the third endpoint in this way. BCORD "perpendicularizes" successive axes by basing them on residual distance matrices rather than on the original distance matrix (McCune, 1991). As many as nine axes can be computed on the PC-ORD version of the model.

Using random coordinates in the NMS model and the maximum number of dimensions (six), the amount of "stress" was reduced to 5.15 from 55.02 (Figure 7, page 65). As can be seen, the largest reduction occurred between the first axis and the second, from 55.02 to 15.69, with a further reduction to 7.52 in the third dimension, followed by very small reductions thereon. The last four dimension reductions were considered inconsequential. For this reason, I based my interpretation on two axes only. The per cent of variance amounted to 50.43%. It has been shown that NMS may distort structure if more dimensions than necessary are used (Kenkel and Orloci, 1986). Thereafter, I used three axes on the Bray Curtis model, and two on the NMS model. The coordinates provided by the Bray Curtis runs did not vary with added axes, i.e., axes 1 and 2 were the same regardless if more than two were run.

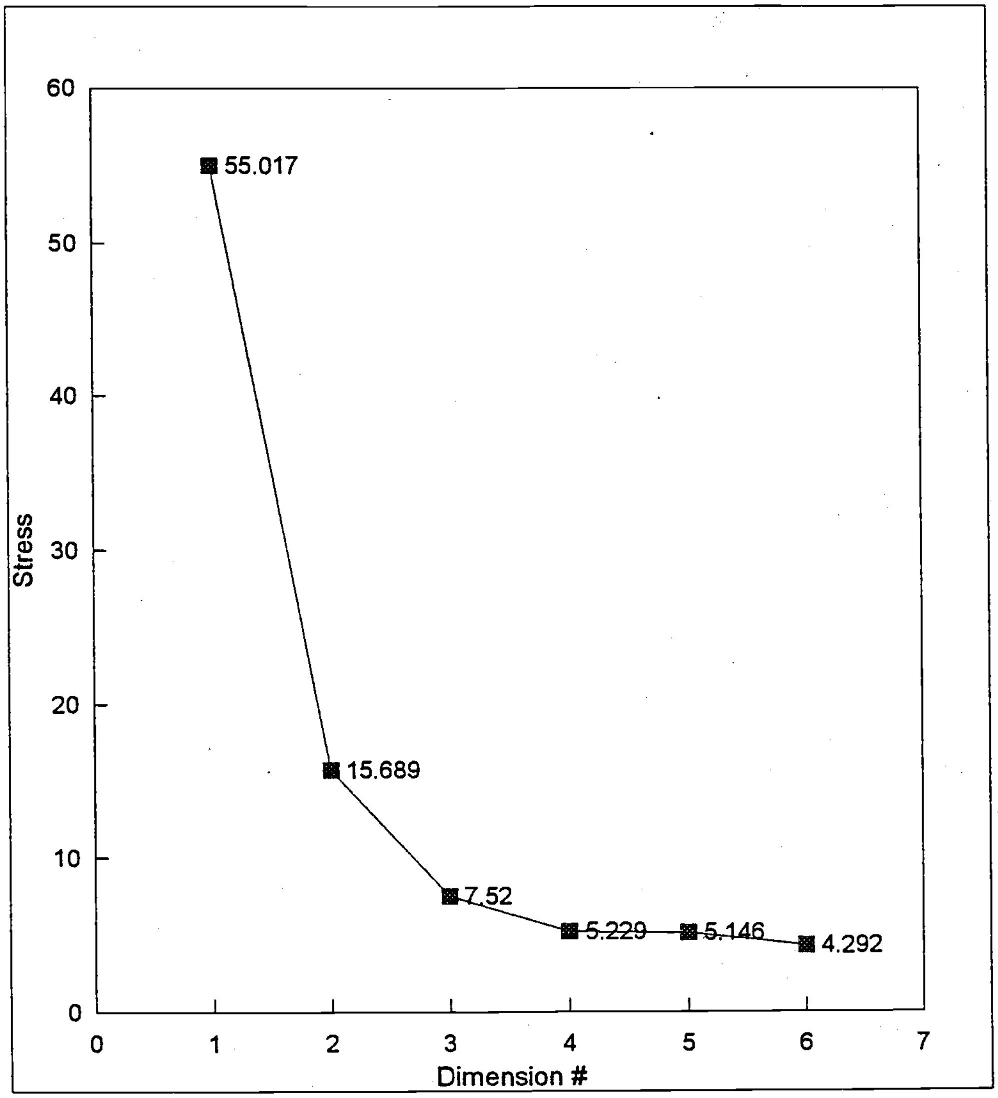

Figure 7. NMS stress values (using standardized data.)

To address question 4, a wetness index was developed for each macroplot based on wetland indices of individual species as given in the National List of Plant Species That Occur in Wetlands: Oregon, 1988 for habitat requirements of individual species (Reed, 1980). Plant species have different tolerance of soil moisture. Plants are rated according to their moisture tolerance in five categories ranging from obligates to upland (non-wetland) in the national wetland plant list. Table 6 shows the categories and the arbitrary numerical rating given in this study.

Table 6. Categories and numerical ratings according to the National List of Plant Species that Occur in Wetlands for habitat requirements of individual plant species.

Category	Wetland Weighting Factor
Obligate Wet	1
Facultative Wet	2
Facultative	3
Facultative Dry	4
Upland	5

Upland species do not appear in the list and an unlisted species is assumed to be an upland species. A wetland index was given for each macroplot in which the species wetland index was weighted by frequency according to the equation on page 67. This index follows the procedure of Wentworth et al., 1988. Wetland indexes vary in my study from 1.6 to 4.5 where an index of 3.0 indicates that a plot is neutral with respect to wetland affiliation. Indexes less than 3.0

indicate wetland associated conditions. The formula is as follows:

$$W_j = \frac{\sum I_{ij} E_i}{\sum I_{ij}} P$$

where W_j = Wetland Index for plot j
I_{ij} = Frequency of the ith species in plot j
E_i = Wetland Weighting Factor for the ith species (Table 6, page 66)
P = Number of species in plot j

To address question 5, I used nested frequency data to assess species trend. The number of occurrences of each species within each quadrat size within the set of three nested quadrats is determined and percent frequencies calculated. Data were processed from all 36 macroplots using a program developed especially for this purpose by Dan Salzer, vegetation analyst for The Nature Conservancy, Oregon Field Office. Most abundant species, and those associated with the intermounds or mounds, could be identified, and the best fit quadrat size, 0.01 m^2, 0.10 m^2, or 1.00 m^2, for each species was generated to measure change in successive years. For a trend to be assessed, the percent frequency for best fit should lie between 20 - 80% (Winward and Martinez, 1983). In addition, an average percent species frequency for intermounds and mounds by space was calculated.

CHAPTER 5: RESULTS

"It is not clear that any characteristic of communities is selected for as such. Diversity increases by the addition of species to communities, not by selection of richer communities over poorer ones. The rates at which species are added are influenced by the kinds of environmental stresses affecting the species of different taxonomic groups."

Whittaker, 1975

FLORISTIC CONVENTIONS AND NOMENCLATURE

I have used capitalized acronyms to designate species names throughout this thesis. Because several programs required six letter acronyms, rather than use the standard acronyms in Garrison et al (1976), I developed my own using the first three letters of the genus epithet and the first three letters of the species epithet. Species encountered and discussed in my thesis and their epithets appear alphabetically in Appendix 2 together with their acronyms, nativity, and major life form. To standardize nomenclature, I used Hitchcock and Cronquist (1973) throughout my study.

In any vegetation study dealing with a large number of species in a region where disturbance is common, plant identification poses a problem. In this study, identification of the rose species was uncertain. Many collected plants keyed most closely to *Rosa eglanteria*, others to *R. nutkana*, and still others to *R. pisocarpa*. Possible hybridization is occurring. I elected to refer to rose throughout the thesis as *R. eglanteria* (ROSEGL). Likewise, I had problems in identifying *Agrostis alba* and

A. tenuis. Hybridization between the taxa or other *Agrostis* entities may be occurring. I chose to report a single species, *A. tenuis* (AGRTEN). The two *Madia* species may have been confounded because sampling mostly predated bolting after which both leaf characteristics and flower heads become more apparent. Several *Carex* species may have been misidentified. I am certain about the identification of *C. densa* (CARDEN), *C. lanuginosa* (CARLAN), *Carex tumulicola* (CARTUM), and *C. unilateralis* (CARUNI). Identification of the other *Caricies* is more problematic and our samples are being worked on by the Oregon State University Carex Working Group. I have retained the problematic field identifications for *C. deweyana* (CARDEW), *C. feta* (CARFET), *C. pratensis* (CARPRA), and *C. siccata* (CARSIC), but misidentification of these taxa should not introduce major problems in analysis. I also encountered difficulties in identifying *Juncus* species and *Epilobium* species.

The total flora found in my macroplots consisted of 108 species. A number of other species were encountered when I walked about the RNA but these were not recorded. Probably the total RNA flora consists of 170 species. Distribution of species among major life forms within the macroplots is 4 trees, 5 shrubs, and 99 herbs and dwarf shrubs. Of the latter group I encountered 21 Graminae, 9 other graminoids, and 69 forbs. Relative to the life cycle, there were 65 perennials/biennials (including trees, shrubs, and herbs) and 43 annuals (all herbs). Of nativity, 70 were indigenous and 38 were aliens. From these general statistics the macroplot flora, which is representative of the RNA flora, can be seen as dominantly herbaceous and native.

VEGETATION

RNA vegetation character mostly follows the flora. The RNA plant cover consists of a combination of herbaceous vegetation dominated by a mix of graminoids and forbs interspersed with dense shrub cover. ROSEGL exhibited strong dominance with a mean cover of 41.0% in 36 macroplots (39.4% in the intermounds and 42.5% in the mounds). The second most dominant species was HYPPER. While the overall mean cover was 13.0% in 31 macroplots, the intermounds had less than 1% cover whereas the mounds had over 25% cover. Other prominent herbaceous species, with mean cover between 2.5% and 10%, included HOLLAN, DESCES, AGREXA, MYOLAX, GALAPA, EPIPAN, VERSCU, PARVIS, PLASCO, MADGLO, and TRIDUB. Dominance of these taxa is shown in Table 7 (page 71) along with their percent frequency. A total of 79 species each had a mean cover less than 1% over all 36 macroplots. The average number of species per 25 x 25 macroplot was 37.0 (range 29 to 48). Appendix 3 gives a row-column summary of the percentage midpoint data.

Classification

I classified vegetation by TWINSPAN using cut levels of 0, 5, 10, 16, 21, 31, 41, and 61, to get a tabular display that best approximated cover class values. Figure 8 (page

Table 7. Distribution of % cover and % frequency of the 13 most common species in 36 macroplots in the RNA.

Species	% Cover	% Frequency
ROSEGL	40.96	95.4
HYPPER	13.04	49.9
HOLLAN	8.72	74.6
DESCES	8.03	37.0
GALAPA	7.81	47.6
AGRTEN	5.20	47.7
MYOLAX	3.50	36.9
EPIPAN	4.33	51.8
VERSCU	4.89	32.2
PARVIS	2.54	32.1
PLASCO	3.79	29.0
MADGLO	2.55	28.9
TRIDUB	2.63	20.9

72) shows the TWINSPAN classification to the third level. At the first level macroplots separate into the mound and intermound habitats which had been evident in the air photographs, although 19 intermounds and 17 mounds (as opposed to 18 of each) were identified. Macroplot 2, thought to be sited on a mound in the air photograph, classified as an intermound; GPS verification of plot location carried out in August 1994 places it in an intermound location. However, I treated the plot as a mound plot in my analysis. Macroplots 5, 8, 35 and 36 are borderline plots at the first level of classification. The MRPP results testing whether a difference exists between groups (IM and M) verifies this classification ($T = -17.92$, $p = 0.000$). Indicator species in the first division are shown in bold in Figure 8.

			MOUNDS				INTERMOUNDS				
			33233122	1112	1		33	13	2212222	111	
			24903524	4781	6	3458	56	21601	76733805	9129	
78	105-	SHEARV	11521154	--11	1	----	--	-----	--------	----	111111
77	104-	CIRARV	---1-251	----	-	----	--	-----	--------	----	111111
74	65--	VICHIR	-1122112	----	1	----	-1	-----	--------	----	111111
71	102-	CONNYC	31542211	----	-	----	--	-----	--------	1---	111111
75	68--	FRAVIR	-1-1-1--	---1	-	----	--	-----	--------	----	111110
2	03--	SYMALB	15----11	1-11	-	1---	--	-----	--------	----	111110
76	70--	DAUCAR	1---31--	1--1	-	----	1-	-----	--------	----	11110
67	89--	ACHMIL	11211111	1-11	-	-11-	-1	-----	--------	---1	11110
63	85--	BROELE	1--111--	11--	-	---1	--	-----	--------	--1-	11110
61	82--	SIDCAM	-1122111	3111	-	11--	--	-----	--------	----	11110
52	73--	GERPUS	11112211	1111	1	1111	--	1----	--------	----	111011
41	59--	LOTMIC	11--1---	----	-	--1-	--	-----	--------	----	111011
65	87--	STECAL	-----11-	2-21	1	-11-	--	-----	------1-	----	111010
59	80--	RUMACE	111--1-1	1111	-	-111	--	1----	--------	----	111010
46	64--	VICSAT	1-111111	1111	-	1211	-1	-----	--------	----	111010
62	84--	LUPBIC	-1--1---	----	-	1-11	--	-----	--------	----	11100
60	81--	PLECON	-----1--	111-	-	2-1-	--	1----	--------	----	11100
50	71--	PLALAN	--1-----	1-11	1	-111	--	-----	--------	----	11100
17	27--	AIRCAL	-1--1---	-1--	-	1111	--	-1---	--------	----	11100
80	109-	ANTSCA	---1--1-	-1--	-	----	--	-----	------1-	----	11011
55	76--	CIRVUL	11122122	1111	1	1--1	11	-1---	--------	-11-	11011
45	63--	VICTET	1-11-312	1-2-	1	----	-1	2----	2-----1-	---1	11011
27	45--	HYPPER	63666566	7567	6	1111	21	111-1	1--1-111	-111	11011
79	106-	TREERI	--1--1--	-111	-	----	-1	-----	--------	----	11010
49	69--	VERPER	-111-1-1	1111	1	-11-	1-	-----	-----1--	----	11010
38	56--	MADSAT	111-1111	1111	1	1111	1-	11-1-	--------	----	11010
12	17--	POAPRA	11111111	-111	1	1-11	11	1-1--	--------	----	11010
84	42--	CARTUM	211111-1	1122	1	1111	11	1---1	---1----	-11-	11001
43	61--	TRIDUB	11112-11	1111	1	4353	11	121--	1-------	----	11001
85	91--	RUMCRI	-----1--	----	1	-1--	--	-----	--------	1---	11000
69	92--	SENJAC	-----1--	----	1	-1--	--	-----	1-------	----	11000
30	48--	GALAPA	63535222	1114	4	3455	21	12-11	-----+--	1---	11000
19	33--	ANTARI	--------	----	-	4112	1-	-----	-------1	----	11000
54	75--	RANOCC	-----1--	-1--	-	-1-1	--	-11--	--------	----	101
40	58--	LOTPUR	11------	-1-1	1	2112	11	11-1-	--------	-111	101
8	13--	AGRTEN	22111111	1112	1	1222	34	23123	421111111	11-1	101
3	05--	CRADOU	-----1--	1-11	2	1-1-	--	---1-	-1----1-	---1	101
64	86--	BROHYD	-1----1-	11--	1	--1-	--	-----	1-1---1-	--1-	10011
53	74--	CAMQUA	11--1---	111-	-	1111	--	-1-1-	11-11---	1---	10011
51	72--	CERARV	11111111	1121	1	1111	11	11---	-11-111-	----	10011
68	90--	ERILAN	-11-1---	--11	-	-1-1	11	-----	--------	--11	100101
44	62--	POTGRA	1-11111-	1112	1	1111	23	1-1--	-1---11-	--1-	100101
48	67--	PERGAI	11111111	1111	1	1111	11	11111	11-1--1-	-1-1	100100
36	54--	PARVIS	22-11111	1211	1	1123	23	11111	1--11111	-111	100100
4	06--	FRALAT	-------1	1---	-	----	--	1----	---1----	----	100100
83	38--	CARDEW	111-2-1-	-2-1	1	----	11	---1-	1---11-1	111-	10001
81	110-	CENUMB	11--11-1	1111	1	----	12	----1	---1-111	--1-	10001
33	51--	EPIPAN	33212221	2322	2	----	22	-1-11	-1111111	1122	10001
82	113-	LATSPH	----1--1	----	-	----	11	-----	--------	----	10000
72	18--	BROCOM	11111111	1-1-	1	----	11	-----	-11-1111	---1	10000
73	24--	ARRELA	-11--1--	1--1	-	----	11	-----	---11-1-	-111	0111
18	30--	ALOGEN	1-1111-1	---1	-	-11-	--	11111	1-111-1-	11--	0111
14	23--	POASCA	1--1----	---1	-	----	--	-1-1-	----11--	1---	0111
58	79--	ORTHIS	--------	-11-	-	-11-	1-	-11--	--------	1---	0110
39	57--	MADGLO	111-1111	1111	3	1111	11	11111	11121222	-1-2	0110
1	01--	ROSEGL	52687787	8777	7	4577	66	25458	57877777	1636	0110
66	88--	GNAPAL	-----1--	----	-	-11-	--	--1--	-----1--	1-1-	0100
56	77--	PRUVUL	--------	----	1	1111	1-	-1-1-	11---1-1	----	0100
15	25--	DANCAL	1-------	----	-	1--1	11	---1-	1----1--	---1	0100
10	15--	BRIMIN	--------	----	1	-111	11	111-1	1----111	----	0100
23	37--	CARDEN	-------1	----	-	1---	-1	1-11-	--1---11	-1--	00111
22	36--	JUNBUF	--------	----	-	11--	--	11111	1------1	----	00111
57	78--	CLAAMO	-1------	1---	1	1111	--	11111	11111111	-111	00110
42	60--	MICGRA	--------	----	1	-1-1	11	11111	1-11111-	1-11	00110
34	52--	BOIDEN	--------	1---	-	--11	1-	--121	111111--	-1-1	00110
25	40--	CARLAN	--------	----	-	-11-	--	11---	111-11--	----	00110
32	50--	EPIGLA	--------	-11-	1	1111	11	11121	22111121	1111	001011
20	34--	JUNTEN	--------	-1--	1	1111	11	11111	11111111	1322	001011
5	10--	HOLLAN	11211222	1311	2	1212	32	23224	21331345	1335	001011
47	66--	MIMGUT	--------	-1--	-	----	--	-1---	-11----1	----	001010
31	49--	EPIWAT	-----111	1111	1	-111	--	11-11	11131122	1211	001010
29	47--	GALTRI	--------	313-	-	---1	--	-1111	12111111	1111	001010
28	46--	MYOLAX	11111111	1111	1	1111	11	11111	56312111	1111	001010
24	39--	CARFET	--11----	---1	1	----	11	--1--	-11-1-11	1---	001010
35	53--	VERSCU	--1----1	1-11	1	-1-1	--	11111	43533214	-242	00100
13	19--	FESARU	--------	-1--	-	----	--	-----	1-----11	-1--	00100
26	44--	CARUNI	--------	----	1	---1	1-	--111	11111111	3111	00011
9	14--	BECSYZ	--------	----	1	-1-1	1-	11111	-1111111	411-	00011
6	11--	DESCES	----1-1-	-1-1	1	11-1	23	11233	11253542	1676	00011
70	101-	DOWELE	-----1--	----	-	----	--	-----	-1--111-	11--	00010
21	35--	JUNOXY	--------	----	-	----	-1	11111	1213311-	1111	00010
16	26--	PHAARU	--------	----	-	----	--	-----	1221----	----	00010
11	16--	HORBRA	--------	----	-	----	--	1-11-	112-22-1	111-	00010
37	55--	PLASCO	--------	----	1	-2-1	11	24462	11111211	1111	0000
			00000000	0000	0	0000	11	11111	11111111	1111	
			00000000	0000	1	1111	00	00000	11111111	1111	
			00000000	1111	0	1111	00	11111	00000000	1111	
			00111111					01111	00011111		
			000111						00011		

Figure 8. TWINSPAN two-way table output.