AN ABSTRACT OF THE THESIS OF

Thaïs E. Perkins for the degree of Master of Science in Forest Science presented on December 11, 2000. Title: The Spatial Distribution of Beaver (*Castor canadensis*) Impoundments and Effects on Plant Community Structure in the Lower Alsea Drainage of the Oregon Coast Range.

Abstract approved: ______________________________
John P. Hayes

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David E. Hibbs

Stream systems in the Pacific Northwest have come to be understood in the absence of beaver (*Castor canadensis*). To understand the effect of beaver upon riparian plant communities, four basins in the lower Alsea drainage were examined to determine the effect of beaver and their impoundments on streamside herbaceous/shrub and forest tree/shrub community composition. The forest tree/shrub transects were located from the water's edge perpendicular to the stream, so that transects included the streamside herbaceous/shrub communities. The streamside herb/shrub communities measured were restricted to the area before the forest understory communities began (the emergent and littoral zones). A comparison was made between beaver impoundments, impoundments caused by factors other than beaver (debris jams), and randomly located unimpounded sites. In the central Oregon Coast Range three sites of each type were chosen per basin in four basins. All sites were topographically similar, generally located in valley widths of 25-30m, on low gradients and streams 2-3m wide. I measured percent cover in the case of

herbs and shrubs, and counted individual trees >15cm dbh. The sites were analyzed using primarily multivariate techniques.

Streamside plant communities around beaver impoundments, consisting of the herbaceous and shrub communities, were different from those around unimpounded sites and debris dams. The differences were attributable to a graminoid-dominated emergent zone present only at beaver impoundment sites, consisting largely of *Salix sitchensis, Juncus effusus, Typha latifolia, Callitriche heterophylla*, and *Lemna minor*. All communities were similar in richness. The communities at debris jam sites and unimpounded sites were not distinct from one another. Communities of the forest zone around beaver impoundments were not distinct from the communities at the other types of sites from the water's edge outward. At beaver impoundment sites, cover of the invasive *Phalaris arundinacea* was inversely correlated with species richness.

I also examined the effect of harvest pattern on impoundment presence. Seven basins in addition to the first four were chosen for presence of beaver and varying amounts of clearcut or young regenerating riparian forest and the relative percentages of stream length impounded in the different forest types calculated. Beaver impoundments were disproportionately associated with stream reaches flanked by clearcuts/ young regenerating stands (80% of available reaches impounded by beaver) over forested reaches (29% impounded) within basins and were correlated over the landscape with basins possessing larger percentages of stream reaches flanked by clearcut/young regenerating stands (r^2=0.30).

I conclude that beaver create a different, although simple, wetland community type that is not encountered elsewhere in the area and that beaver do not dramatically change the riparian forest tree/shrub communities from the water's edge outward. I also conclude that beaver impoundments are associated with reaches flanked by clearcuts/young regenerating stands in the area.

The Spatial Distribution of Beaver (*Castor canadensis*) Impoundments and Effects on Plant Community Structure in the Lower Alsea Drainage of the Oregon Coast Range

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APPROVED:

Co-Major Professor, representing Forest Science

Co-Major Professor, representing Forest Science

Head of Department of Forest Science

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.

Thaïs E. Perkins, Author

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Dedication

This thesis is dedicated to my undergraduate professors

Dr. Donald E. Norris

and

Dr. Glenn Matlack

for their consistent support in the pursuit of the holy grail of biological knowledge

for teaching me the difference between a stick and a potato

and for their reservoirs of humor and goodwill

without which I would not be

in this situation.

The Spatial Distribution of Beaver (*Castor canadensis*) Impoundments and Effects on Plant Community Structure in the Lower Alsea Drainage of the Oregon Coast Range

CHAPTER 1

Beaver (*Castor canadensis*) Impoundments, Effects on Plant Community Structure, and Reed Canarygrass (*Phalaris arundinacea*) in the Pacific Northwest: A Literature Review

Thaïs E. Perkins

Introduction

Ecosystems world-wide are experiencing, under the hand of humankind, a decrease in structural ecosystem complexity. The resurgence of population levels of beaver (*Castor canadensis*) in North America offers the unique opportunity to study a system that is instead increasing in ecosystem structural complexity. This study is centered upon the Oregon Coast Range. Although beaver populations are resurging nationwide (Johnston and Naiman 1990a, c; Snodgrass 1997), the emphasis on management for timber in the Coast Range creates an atmosphere of concern regarding burgeoning beaver population levels. Some, such as those managing for timber production, find the population levels to be high and call for implementing control measures (Mortenson 2000). Others, such as landowners focused upon biodiversity and natural aesthetics, find it to be a cause for celebration. The two conflicting viewpoints result in friction concerning the issue within basins, neighborhoods, and watershed councils.

Beaver populations approached extinction in North America by 1900 (Jenkins and Busher 1979). After near-extinction, the animal was protected, and by the 1920s populations began to return. Nonetheless, since 1834, approximately 195,000-260,000 km^2 of beaver habitat in primitive marshes, swamps, and seasonally flooded bottomlands in the United States have been converted to dry land (Shaw and Fredine 1971). The rate of forested wetland loss in the northern United States is about 300,000 acres annually (Dahl 1997). Much of this was most likely beaver habitat.

Streams in the Oregon Coast Range have come to be understood after these systems were changed by the removal of beaver. Beaver modify stream morphology and hydrology by building dams and cutting wood. These activities retain sediment and organic matter in the channel, create and maintain wetlands, modify nutrient cycling and decomposition dynamics, modify the structure and dynamics of the riparian zone, influence the character of water and materials transported downstream, alter the successional dynamics of riparian communities, and ultimately influence plant and animal community composition and diversity (Naiman 1986; Pollock et al. 1995).

Beaver impact diversity of plant communities at landscape scales (Naiman 1988; Pollock et al. 1998; Johnston and Naiman 1990a, c). The combination of damming and browse behavior results in creation of distinct patches in the landscape. These patches diversify riparian habitats (Johnston 1987; Naiman 1988; Naiman and DeCamps 1997). The impacts that beaver have on their systems have caused them to be deemed "ecosystem engineers" (Lawton and Jones 1995). Beaver are the only animals in North America to affect channel geomorphology and hydraulic conditions to such an extent (Naiman and Rogers 1997).

Beaver Biology

General

The beaver is the sole member of the family Castoridae (Order Rodentia) in North America. *Castor fiber*, the only other member of the genus, is found in Europe, where *C. canadensis* has been introduced and sometimes successfully outcompetes *C. fiber* (Nolet and Rosell 1998). *C. canadensis* occurs in streams, ponds, and margins of large lakes throughout North America except for arctic tundra, peninsular Florida, and southwestern deserts (Jenkins and Busher 1979).

The fundamental family unit is the colony, consisting of 4-8 related individuals (Wheatley 1997a). Colony density generally reaches about 4 colonies/km of stream reaches (range 3-4.6) in montane regions (Jenkins and Busher 1979; Novak 1987). Estimates of dam density (an indicator of colony density) for the Oregon Coast Range include 2.6 dams/km (Suzuki and McComb 1998) and 1.2 dams/km (Leidholdt-Brunner et al. 1992). In Quebec, Canada, Naiman et al. (1986) found a range of 8.6-16 dams/km. Dams in eastern Oregon are few (1dam/7km) but tightly clustered in the basin (McComb et al. 1990). It is difficult to achieve accurate estimates of beaver population density from dam density; however, there are models relating population density to impoundment abundance for Minnesota (Broschart et al. 1990). These models are undeveloped for the Oregon Coast Range, but development of a local model would be useful in estimating populations for this area.

Populations of beaver are expanding at a remarkable rate (Johnston and Naiman 1990a, c; Snodgrass 1997), most likely due to a decrease in trapping. Before European colonization of North America, the beaver population was thought to be between 60-400 million individuals (Seton 1929) whereas the current population is thought to be between 6-12 million (Naiman 1988), or about 10% of the prior population. Less than a one-year closure to trapping is sufficient to increase the density of beaver colonies (McCall 1996).

Habitat suitability studies (Howard and Larson 1985; McComb et al. 1990; Hartman 1996; Barnes and Mallik 1997; Suzuki and McComb 1998) indicate that beaver tend to select wide valley floors with little gradient, streams with silty substrate, and sites with availability of preferred food, although the relative importance of physical factors and food availability varies by region. These factors are consistent for areas as different as the Oregon Coast Range and the eastern Oregon arid region.

Food Preference

Generally, beaver prefer wood from deciduous trees over evergreen for forage (Busher 1996). Beaver prefer aspen or willow for the bulk of their diet when available and when herbaceous plants are limited (Jenkins 1979; Jenkins and Busher 1979; Barnes and Dibble 1986; Naiman 1988; Brunner 1989; Fryxell 1994; Donkor and Fryxell 2000; Ganzhorn 2000). They choose other woody species disproportionately to their prevalence in the plant community (Brunner 1989; Nolet 1994), most likely for nutritional supplement (Nolet 1994). Of all wood cut by beaver in one study in Quebec, conifers accounted for <1% of the wood cut in a study area that was 91% coniferous (Naiman et al. 1986). Preferences for certain trees vary among years, and masting trees may be generally more nutritious than trees in non-mast years over a range of species (Jenkins 1979).

Beavers are less selective in their browse activity when woody material is used for dam construction. It has been speculated that in northern regions beaver annually cut at least a metric ton of wood per colony within approximately 100 m of their pond (Johnston and Naiman 1987), most of which is not eaten. Beaver frequently choose stems based on their size, implicating use in dam-building over ingestion of the wood (Johnston and Naiman 1990b; Barnes and Mallik 1996).

Dispersal

Land managers, concerned about quantities of wood cut by beaver, frequently trap beaver out of basins in the Oregon Coast Range. The tendency of beaver to disperse has become an issue between landowners in basins with mixed ownership. Some landowners contend that beavers disperse onto controlled land (land on which effort has been expended by the landowner to trap out beaver) from uncontrolled land, incurring extra expense (Bhat et. al. 1993).

Dispersal typically occurs around 2 years of age. In a montane-habitat study, 2-year-old beaver were found to move an average of 1.8 km, with the longest dispersal distance recorded being 110 km (Jenkins and Busher 1979). Ranges and dispersal paths tend to follow shorelines (Wheatley 1997a) rather than crossing ridgelines, resulting in long narrow ranges. Dispersing 2-year-olds without a family unit tend to range farther than beaver with family units during the summertime, and males typically move farther than females due to maternal care of beaver kits (Wheatley 1997a, b). Van Deelen (1996) considered wide variation in dispersal dates and settlement to suggest the existence of a summertime subpopulation of transient beavers, unattached to traditional colonies.

Interactions Between Beaver and Other Wildlife

Beaver interact positively with a large range of other animal species, including birds, invertebrates, fish, and other mammals. An increase of beaver impoundments is associated with an increase in waterfowl abundance due to expansion of wetland area (Brown et al. 1996; McCall 1996). In New York, beaver presence in existing wetlands was correlated with an increase in bird species richness (Grover and Bladassarre 1995), most likely due to the encouragement of intermediate cover:water ratios. Ponds in forests provide important habitat for birds. In the coniferous systems of the Northwest even small ponds provide habitat for some songbirds, such as song sparrows or common yellowthroats, which would not normally occur in pure coniferous systems (although these birds also may be common in clearcuts; Csuti et al. 1997) Large ponds provide habitat for mallards and possibly other ducks and grebes. Ponds that are revegetated with shrubs, especially willows, provide unique habitat to many songbirds both during and outside of the breeding season (Csuti et al. 1997). Kingfishers and ducks have been observed at higher elevations in the Coast Range than would have been expected where beaver dams have created suitable habitat (Loegering 1998). In addition, large snags created by flooding are important to the diversity and productivity of mammalian, avian, and insect communities (Maser 1988).

The presence of beaver ponds in the landscape influences invertebrate community structure by replacing running-water taxa with pond taxa, thereby increasing the abundance of collectors and predators, and decreasing the abundance of shredders and scrapers, which ultimately increases diversity over the landscape (McDowell and Naiman 1987; Clifford et al. 1993). Dams support an invertebrate fauna unique to the impoundment, which are generally similar to fauna found on woody debris elsewhere in the stream system (Clifford et al. 1993). Beaver indirectly affect leaf beetles positively (*Chrysomela confluens*) by changing the leaf chemistry of cottonwoods through browsing. A denser concentration of cottonwood defense chemicals enables the beetles to more effectively build up their own analogous defense chemicals (Martinsen 1998).

Beaver are generally thought to have a favorable influence on fish communities, particularly salmonids (Ives 1962; Liedholdt-Brunner et al. 1992; Schlosser and Kallemeyn 2000). By impounding water and creating splash pools (pools creates by the flow of water over a dam), beaver create and maintain over-winter and rearing habitat for juvenile salmon (Liedholdt-Brunner et al. 1992; Nickelson 1992). The presence of impoundments is beneficial to trout in cold environments (Cook 1940) and warm (McRae and Edwards 1994). The presence of dams in watersheds has been shown to increase fish community diversity in the landscape (Hagglund and Sjoberg 1999; Schlosser and Kallemyn 2000), and generally helps to create the spatial habitat variation necessary to support a productive and diverse fish assemblage (Schlosser and Kallemyn 2000). Beaver are also beneficial to other furbearers; river otters select watersheds with the highest proportion of active beaver wetlands and avoid those with no beavers (Dubec and Owen 1990).

Public Attitudes

With an increasing public perception of wild lands as intrinsically valuable apart from their economic use, people have generally begun to view beaver as an important part of the ecosystem instead of as a mere nuisance. In a public-opinion study executed in rural Wyoming, over 45% of all landowners expressed interest in a beaver reintroduction program and in more proactive beaver management. This interest is despite the fact that 89% of all landowners with beaver on their lands reported ‘damage’ while only 51% reported benefits (McKinstry and Anderson 1999).

The perception of beaver primarily as an agent of resource destruction is still pervasive, particularly among those managing for timber production (Spencer 1985; Bhat et al. 1993). Bhat et al. (1993) emphasize the tendency of beaver populations to move from ‘uncontrolled’ areas into ‘controlled’ areas and consider it the responsibility of all landowners in a watershed to keep population levels low. Bhat et al. (1993) ignore the potential for differing value systems within a watershed (some landowners may value habitat and wildlife diversity over the economic pitfalls an active beaver colony may induce on timberlands), but do offer some interesting suggestions in the area of third-party population regulation by state agencies.

Ecological Footprint

Beaver affect the landscape by impounding water and creating sites of sediment collection (Naiman et al. 1988), resulting in the creation of wetlands. The dams retain sediment and organic matter in the channel and modify nutrient cycling and decomposition dynamics, modify the structure of the riparian zone, and ultimately influence the plant and animal community composition (Naiman et al. 1986). The ponds create a discrete set of 3-dimensional boundaries and can be considered “patch bodies” in the riparian matrix (Johnston and Naiman 1987). Beaver have an effect on the relative stability of stream ecosystems. Beaver ponds function as large-mass, slow-turnover components in stream ecosystems. Naiman et al. (1986) state that for this reason, streams with beaver have a high resistance to some types of perturbation.

Studies in Maine suggest that a >1 year closure of beaver trapping was sufficient to increase the density of beaver colonies, whereas wetland habitat due to that beaver modification did not begin until 2-3 years post-closure (McCall 1996). This suggests a lag time of around two years between impoundment by beaver and wetland development. In the Oregon Coast Range, where most beaver dams wash out every winter (Maser et al. 1981), only a few beaver dams are strong or extensive enough to withstand the winter floods will have the potential to create long-term wetlands. Beaver, when present, tend to be numerous and have an extensive effect on the riparian corridor. Dams also tend to be numerous, and to cluster within a basin (Jenkins and Busher 1979; Naiman et al 1986; Novak 1987; Johnston and Naiman 1990c; McComb et al. 1990). Over the landscape, beaver flooding has a huge impact on riparian systems. Johnston and Naiman (1990a) suggested that beaver alteration of the landscape in Voyageurs National Park, Minnesota approaches that of humans (0.42% change between 1940-50 opposed to 0.64% alteration of urban encroachment into agricultural land and 0.8% rate of cropland abandonment). The extent of channel alteration has caused beaver to be named an "ecosystem engineer" (Lawton and Jones 1995; Pollock et al. et al. 1995; Clive et al. 1997), defined as "organisms that directly or indirectly control the availability of resources to other organisms by causing physical state changes in biotic or abiotic materials" (Clive et al. 1997).

Dams that are sufficiently large or well-anchored to withstand flooding trap large amounts of sediment. Naiman et al. (1986) showed that a small dam (4-18 m^3) of wood could retain 2000-6500 m^3 of sediment in small-order streams, or 3.2×10^6 m^3 of sediment over the watershed (Naiman et al. 1986). By changing stream channels into ponds, beaver substantially change nutrient dynamics, particularly by increasing nitrogen (Naiman et al. 1986; Johnston and Naiman 1990a; Pinay and Naiman 1991), increasing methane emissions (Pollock et al. 1995; Naiman et al. 1986), creating anoxic water conditions (Snodgrass and Meffe 1998), changing phosphorous availability (Klotz 1998), changing carbon availability (Naiman et al. 1988) and ameliorating stream acidity (Smith et al. 1991). Beaver ponds increase stream temperature sometimes (Cook 1940) but do not always (McRae and Edwards 1994), depending on the type of pond and region studied.

The impacts of beaver impoundments upon stream channels tend to be cyclical. Beaver abandon dams and allow them to fail, resulting in graminoid-dominated riparian meadows. Beaver then may return to the sites, reflooding meadows and re-creating wetlands. Naiman et al. (1988) propose a more complex pattern in boreal forests that may involve the formation of emergent marshes, bogs, and forested wetlands, persisting for centuries without giving way to forests. Beaver colonization and abandonment in New York is a disturbance with a return interval of approximately 10-30 years (Remillard et al. 1987). The return interval for the Oregon Coast Range is unknown.

Impact on Plant Community Structure

Beaver influence plant communities by impounding water and browsing vegetation. Impoundments tend to cause trees to die and encourage development of herbaceous wetland-type communities dominated by graminoids (includes grasses, sedges, and rushes; Naiman et al. 1988; Mitchell and Niering 1993; Feldmann 1995;

McCall 1996). Beaver further cause changes in riparian forest communities by browsing, effectively opening the forest canopy and selecting against some tree species (Kindschy 1985; Barnes and Dibble 1986; Nolet 1994). Reports of the effects of beaver impoundments on plant diversity are mixed, with some reporting an increase of diversity and some a reduction, dependent upon context (Barnes and Dibble 1986; Johnston and Naiman 1990b; Huntly 1991; Pastor and Naiman 1992). In low order streams, beaver create numerous zones of open canopy, large accumulations of detritus and nutrients, an expanded wetted area, and substantial shifts to anaerobic biogeochemical cycles (Naiman et al. 1986).

Impact of Browsing

Beaver change dominance structures of riparian plant communities beyond the edge of the water by shifting community composition towards browse species avoided by beaver (Barnes and Dibble 1986; Johnston and Naiman 1990b; Pastor and Naiman 1992), but the effect of beaver browsing upon the composition of the community is dependent on context. Beaver browsing in areas where preferred forage is common tends to increase diversity in a system, whereas browsing in areas where preferred species are rare tends to decrease diversity (Huntly 1991). Conifers increase in dominance relative to deciduous species in the presence of beaver (Donkor and Fryxell 2000). In a forest dominated by willow in the Netherlands, browsing simplified the tree community composition when beaver satisfied their caloric requirements with *Salix* and obtained their mineral requirements by selecting for other, rarer species (*Corylus* and *Fraxinus* for sodium, *Prunus* and *Populus* for phosphorus; Nolet 1994). In southeastern Oregon, however, beaver browsing encouraged willow regeneration by inducing heightened growth where willow had been overbrowsed by cattle in the summer (Kindschy 1985). Beaver thereby diversified the system by browsing the same tree species as in the Netherlands.

Beaver also may alter plant communities indirectly by altering nutrient availability through browsing, particularly in boreal systems, where nitrogen is limited. Pastor (1988, 1992) suggested that moderate browsing may make a moderately productive system more productive by rapidly cycling nutrients through soil microbes. Johnston and Naiman (1990a) observed nitrogen stocks to triple in the landscape due to the expansion of beaver colonies.

In the Oregon Coast Range, the most abundant woody species are also the species most browsed upon by beaver: salmonberry (*Rubus spectabilis*) and red alder (*Alnus rubrum*). Vine maple (*Acer circinatum*) also was highly selected for by beaver, but is less prevalent (Brunner 1989). Beaver in this area use a large amount of red alder and salmonberry in their dams. Other Oregon studies have found a high correlation between dams and low numbers of red alder and salmonberry (presumably because of browsing), and also with high numbers of grasses/forbs (Suzuki and McComb 1998). The correlation between beaver presence and high numbers of grasses and forbs is usually attributed to impoundment and the subsequent opening of the canopy. However, a study in Sweden found high correlations between the two in areas where beaver did not build dams (Hartman 1996), suggesting an alternate pathway.

Impact of Impoundments

Immediately surrounding the impounded reach, beaver flood the streamside vegetation, cause tree mortality, create of large snags, and encouraging herbaceous vegetation surrounding the pond in the canopy opening (Naiman 1988; Mitchell and Niering 1993; Feldmann 1995; McCall et al. 1996). While flooding causes mortality of some species (such as Douglas-fir and red alder), other species, such as willow, may be encouraged. A study in national parks in the west suggests that the extirpation of beaver from some areas may indirectly negatively impact the resilience of willow to heightened levels of browsing (Singer et al. 1998).

Once abandoned, beaver ponds become graminoid-dominated meadows that resist invasion by the surrounding forest (Naiman et al. 1988; Johnston and Naiman 1990a; Feldmann 1995). The effects of beaver activity on meadowlands can influence vegetation patterns centuries after their extirpation from an area (Neff 1937; Ives 1942; Snodgrass 1997). For wetlands that persist over the long term, rather than simple cycle of pond-meadow-forest, there is a more complex set of pathways involving emergent wetlands, bogs, and forested wetlands (Naiman et al. 1988) resulting in different vegetational communities, sometimes repeatedly cycling between meadows and emergent wetlands without invasion by conifers. Some meadows in the Oregon Coast Range are clearly quite old, with large willow trees, re-sprouts from dam cuttings, anchoring and growing amongst the dams (personal observation). Abandoned meadows next to conifer seed sources can resist reinvasion for at least 70 years (Johnston and Naiman 1990a). Terwilliger and Pastor (1999) suggest that resistance of these meadows to conifer reinvasion is attributable to the lack of ectomycorrhizal fungi in the once-anaerobic soils, implicating small mammals as agents of reinoculation over a long period of time through spores in their fecal matter.

Beaver are ecological engineers that create within a relatively uniform riparian matrix a patch dramatically different in geomorphology, chemistry, and plant community structure. Disturbance theory states that sites with very frequent/intense disturbance or those with very little disturbance create plant communities that are not as rich or diverse as sites with medium-scale disturbance (Pickett and White 1985). Riparian corridors often hold much of the landscapes' diversity due to the array of disturbances (Naiman et al. 1987). Beaver create spatial heterogeneity in riparian landscapes (Pollock et al. 1998; Naiman et al. 1988; Johnston and Naiman 1990a, c), which mediate disturbances at both extremes. Impoundments control the intensity of seasonal flooding in riparian corridors (Johnston and Naiman 1987); in one case a beaver dam failed, releasing 7500 m^3 of water, about 3.5 times the maximum annual discharge for the creek observed over the preceding 23 years, and a downstream beaver wetland attenuated the flood wave peak to 6% of it's upstream peak (Hillman 1998). Beaver also introduce recurrent still-water impoundments in areas that would be lacking in wetlands. Thusly, beaver introduce variation that helps regulate the extremities of riparian disturbances into a medium range of disturbance, increasing the richness and diversity of the plant communities over the landscape (Pollock et al. 1998).

***Phalaris arundinacea* (Reed Canarygrass) in the Pacific Northwest**

Phalaris arundinacea is a common invasive of wetlands, including beaver wetlands, in the Pacific Northwest. It is a coarse, sod-forming cool-season perennial grass, and occurs in a range of moisture conditions from wet to dry. Its best growth occurs on fertile and moist or wet soils. *P. arundinacea* grows perennially from creeping rhizomes, tending to establish dense and highly productive monocultures (Apfelbaum and Sams 1987, Hutchinson 1992). It is highly plastic, in size and shape of inflorescence and overall color. A great genetic variability and variable growth strategies within populations allows it to succeed as an invasive (Morrison and Molofsky, 1998).

The native status of *P. arundinacea* is a subject of debate. The variety present in the Pacific Northwest is probably a mixture of a less invasive North American variety and more invasive European strains (Apfelbaum and Sams 1987; Merigliano and Lesica 1998; Uthus 1999). Regardless, *P. arundinacea* behaves like an invasive in the PNW, tending to establish itself in pure stands impervious to colonization by other herbs or woody species when present. *P. arundinacea* is more likely to be an invasive pest in areas of low species richness and frequent disturbance (Morrison and Molofsky 1998), areas also a good descriptor of beaver impoundments in the Oregon Coast Range. There has been little work concerning effects of *P. arundinacea* on species richness in the PNW, although it has been shown to threaten the endangered *Howellia aquatilis* in western wetlands (Lesica 1997).

There has lately been attention given to efforts to control *P. arundinacea* in wetlands in the PNW out of concern for its invasive nature. Control efforts are usually chemical or mechanical in nature (Apfelbaum and Sams 1987; Hutchinson 1992; Uthus

1999). Little is mentioned about efforts to control *P. arundinacea* through inundation, probably because *P. arundinacea* is known to do well in wet sites (Hutchinson 1992; Rice 1993). Nonetheless, *P. arundinacea* does suffer and sometimes die under inundations persisting more than three days (Rice 1993).

Objectives

Beaver (*Castor canadensis*) impact the landscape in a myriad of ways, ultimately influencing plant and animal community composition and diversity (Naiman et al. 1986; Pollock et al. 1995). The Oregon Coast Range is experiencing resurgence in beaver population levels, as beaver reclaim this part of their historical range. This provides us with the opportunity to study a system that is increasing in landscape complexity as beaver modify riparian areas throughout.

In this study I address the following questions:

> How do beaver affect the herbaceous streamside and forest plant communities of the lower Alsea drainage area in the Oregon Coast Range?
>
> Are modifications of these plant communities by beaver similar to those of impoundments created by coarse wood?
>
> Are beaver impoundments more associated with clearcuts and young regenerating riparian areas than riparian areas flanked by mature forest?

This study addresses several specific questions and associated hypotheses.

Objective 1: Determine effect of beaver damming and browsing behavior on vascular plant species richness and community composition.

Hypothesis 1.1: Vascular plant species richness and community composition differ significantly in the emergent zone among beaver impoundments, impoundments caused by factors other than beaver, and unimpounded streamsides.

Hypothesis 1.2: Vascular plant species richness and community composition in the littoral zone differ significantly among beaver impoundments, impoundments caused by factors other than beaver, and unimpounded streamsides.

Hypothesis 1.3: Vascular plant species richness and community composition associated with beaver impoundments, impoundments caused by factors other than beaver, and unimpounded streamsides differ significantly.

Objective 2: Determine effect of beaver damming and browsing behavior on riparian tree and shrub species richness and community composition.

Hypothesis 2.1: Riparian tree and shrub species richness and community composition associated with beaver impoundments, impoundments caused by factors other than beaver, and unimpounded streamsides differ significantly.

Objective 3: Determine efficacy of aerial photos as a tool in identifying presence of beaver dams in streams in the Oregon Coast Range.

Hypothesis 3.1: Beaver-affected areas are identifiable from aerial photos.

Hypothesis 3.2: Active and inactive beaver dams are not distinguishable from aerial photographs.

Objective 4: Determine the relative use by beaver of riparian stream reaches flanked by clearcut or young regenerating forest, and those flanked by older forest.

Hypothesis 4.1 Beaver use riparian stream reaches flanked by clearcut or young regenerating forest disproportionately over those flanked by older forest.

CHAPTER 2

The Effect of Beaver (*Castor canadensis*) on Plant Community Structure in the Lower Alsea Drainage of the Oregon Coast Range

Thaïs E. Perkins, David E. Hibbs and John P. Hayes

Abstract

Streams in the Oregon Coast Range have come to be understood after removal of beaver (*Castor canadensis*). Beaver are now experiencing resurgence in population levels after their near-extirpation in the early 1900's. To better understand the effect of beaver on riparian plant communities, four basins in the lower Alsea drainage were examined to determine the effect of beaver and their impoundments on composition on streamside herbaceous/shrub and riparian forest tree/shrub communities. A comparison was made between beaver impoundments, impoundments caused by factors other than beaver (debris jams), and randomly located unimpounded sites. In the central Oregon Coast Range three sites of each type were chosen per basin in four basins of the lower Alsea drainage for a total of 36 sites overall. All sites were chosen to be within preferred beaver habitat as defined by Suzuki and McComb (1998). I measured percent cover of herbs and shrubs, and counted individual trees >15cm dbh. The sites were analyzed primarily using Blocked Multi-response Permutation Procedure (MRBP) and Non-metric Multidimensional Scaling ordination (NMS).

All sites were topographically similar and were generally located in valley widths of 25-30m on low gradients and streams 2-3m wide. Beaver sites generally had less cover and plots were closer in height to the in-stream water level (sites were wetter) than other types of sites. Streamside plant communities around beaver impoundments, consisting of herbaceous and shrub communities, were statistically different in composition from the other types of sites. The differences were attributable to a graminoid-dominated emergent zone present only at beaver impoundment sites, consisting largely of *Salix sitchensis,*

Juncus effusus, Typha latifolia, Callitriche heterophylla, and *Lemna minor*. Other graminoids occurring uniquely at beaver sites included *Spargarnium angustifolia*, *Eleocharis ovata*, and *Juncus ensifolius*. All communities were similar in richness. Plant communities at debris jam sites and unimpounded sites were not distinct from one another. Communities of the forest zone around beaver impoundments were not distinct from the communities at other types of sites from the water's edge outward.

Beaver create a different, although simple, wetland community type in the region that is not encountered elsewhere in the area. Beaver do not dramatically change the riparian forest tree/shrub communities in the kinds of areas sampled from the water's edge outward, although the area of open water may be expanded.

Introduction

Streams in the Oregon Coast Range have come to be understood after removal of beaver. Beaver approached extinction in North America by 1900 (Jenkins and Busher 1979). After the near-extinction, the animal was protected, and by the 1920s populations began to rebound. Nonetheless, since 1834, approximately 195,000-260,000 km^2 of beaver habitat in primitive marshes, swamps, and seasonally flooded bottomlands in the United States have been converted to dry land (Shaw and Fredine 1971). Some of the wetland loss in the Pacific Northwest is most likely attributable to eradication of beaver.

Beaver modify stream morphology and hydrology by building dams and cutting wood. These activities retain sediment and organic matter in the channel, create and maintain wetlands, modify nutrient cycling and decomposition dynamics, modify the structure and dynamics of the riparian zone, influence the character of water and materials transported downstream, alter the successional dynamics of riparian communities, and ultimately influence plant and animal community composition and diversity (Naiman et al. 1986; Pollock et al. 1995).

Beaver influence plant communities by impounding water and browsing vegetation. Impoundments tend to cause trees to die and encourage development of herbaceous wetland-type communities dominated by graminoids (includes grasses, sedges, and rushes; Naiman et al. 1988; Mitchell and Niering 1993; Feldmann 1995; McCall 1996). The effects of beaver activity on meadowlands can influence vegetation patterns centuries after the extirpation of beaver from an area (Neff 1937; Ives 1942; Snodgrass 1997). For wetlands that persist over the long term, rather than simple cycle of pond-meadow-forest, there is a more complex set of pathways involving emergent wetlands, bogs, and forested wetlands (Naiman et al. 1988) resulting in different plant communities, sometimes repeatedly cycling between meadows and emergent wetlands without invasion by conifers. Some meadows in the Coast Range are clearly quite old, with large willow trees (re-sprouts from dam cuttings) anchoring and growing amongst abandoned dams (personal observation). Abandoned meadows next to conifer seed sources can resist reinvasion for at least 70 years (Johnston and Naiman 1990a).

Beaver further cause changes in the riparian forest communities by browsing, effectively opening the forest canopy and selecting against some tree species (Kindschy 1985; Barnes and Dibble 1986; Nolet 1994). Reports of the effects of beaver impoundments on tree and shrub diversity are mixed, with some reporting an increase of diversity and some a reduction, dependent upon context. Beaver browsing in areas where preferred forage is common tends to increase diversity in a system, whereas browsing in areas where preferred species are rare tends to decrease diversity (Huntly 1991). Evidence of alteration of riparian tree communities focuses mainly upon the tendency of beaver to shift communities towards unpreferred browse species (Barnes and Dibble 1986; Johnston and Naiman 1990b; Pastor and Naiman 1992; Donkor and Fryxell 2000). In the Pacific Northwest, this results in shifts toward conifer-dominated systems, as beaver browse primarily upon Sitka willow (*Salix sitchensis*), red alder (*Alnus rubra*), salmonberry (*Rubus spectabilis*), and vine maple (*Acer circinatum*; Brunner 1989; Suzuki and McComb 1998).

This study is preceded in part by two local studies concerning habitat suitability and associations between beaver pond pool volume and salmon (Suzuki and McComb 1998; Liedholdt-Brunner et al. 1992). In this study I have addressed the following questions: How do beaver affect the herbaceous streamside and forest plant communities of the lower Alsea drainage area in the Oregon Coast Range? Are modifications of these plant communities by beaver similar to those of impoundments created by coarse wood?

Methods

Study Area

The Oregon Coast Range is one the wettest and most vegetatively productive regions in the continental U.S. Heavy precipitation occurs in largely in winter and short summer droughts are ameliorated by frequent marine fogs, particularly in the coastal strip (Franklin and Dyrness 1973). The vegetation is dominated by mesophytic temperate conifer forest dominated by hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*), and western redcedar (*Thuja plicata*). In the immediate coastal strip, which receives reliable summer fog, Sitka spruce (*Picea sitchensis*) is another dominant species. Hardwood species, such as red alder (*Alnus rubra*) and bigleaf maple (*Acer macrophyllum*), are typically minor elements of the forest in terms of biomass, but may be locally abundant near watercourses or in disturbed sites. Understory shrubs form dense undergrowth in many stands. Hazel (*Corylus cornuta*), vine maple (*Acer circinatum*), salmonberry (*Rubus spectabilis*), and various species of huckleberry (*Vaccinium* spp.) are particularly common (Franklin and Dyrness 1973).

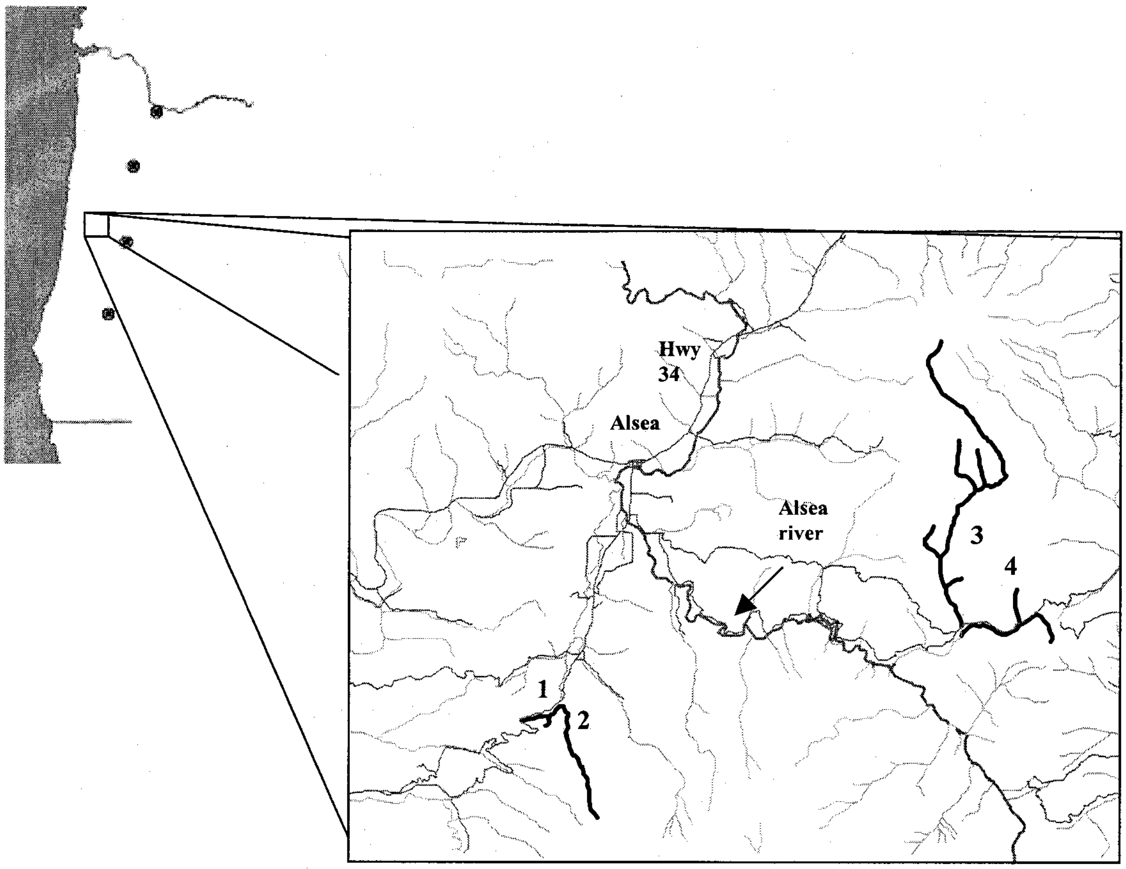
Site Selection

I chose the four basins that fit my selection criteria from a comprehensive pool of third-order basins in the lower Alsea drainage of the Oregon Coast Range (Fig. 2.1). The basins were chosen to have riparian forests old enough to contain a developed understory in the suitable stream reaches (typically > 15 years old). The basins were also chosen to be as close to one another as possible for the purpose of equalizing environmental context.

Within each basin, sampling sites fell into one of three classes based on their impoundment history: dam sites, where active beaver dams were in place and obstructing water; jam sites, where debris jams had effectively blocked the stream; and unimpounded sites, the randomly chosen unimpounded stream locations. These sites are the experimental units upon which the analysis is based.

In order to place unimpounded and jam sites in the same geomorphic context as the impoundment sites, site selection for all site classes was limited to the set of sites typically occupied by beaver as described by the Habitat Suitability Index (HIS) for beaver in the Oregon Coast Range (Suzuki and McComb 1998). Suzuki and McComb (1998) concluded that beaver preferentially located dams in streams with <3% gradient, a stream width of 3-4 m, and valley floors of 25-30m. I limited sampling to areas in third order basins to streams with a <5% gradient and a stream width of <5m.

Figure 2.1: Location of the study basins in the Oregon Coast Range. Dots on map are major Oregon cities (from top to bottom, Portland, Salem, Corvallis, Eugene). Alsea indicates the town, located on Oregon Highway 34. Dark lines represent streams sampled.



Code	Creek
1	Record
2	Swamp
3	Peak
4	Little Peak

Randomization

Within each basin, three impoundments caused by single beaver dams and three impoundments caused by other factors were randomly selected. The number *n* (ranging from 1-10) was chosen from a random number table, and every *n*th impoundment encountered upon walking the drainage was sampled. Within a complex consisting of many dams, impoundments were chosen such that the area studied consisted of the impoundment caused by that dam alone.

Unimpounded sites were chosen by measuring the length in meters of the stream reaches to be studied on a topographic map, then choosing a random 3 or 4-digit number and proceeding that many meters up the stream, reversing downstream when the numbers added up to more than the total stream length. This was repeated three times for each basin. Once the unimpounded site was approximately reached, a 1-digit random number was chosen and used to proceed an exact measured distance upstream of that location.

Dam Categorization

Only three of the surveyed dams were the old, developed impoundments that have the greatest impact on the plant communities. The other two distinct types of dams included in the same category as old dams were new seasonal dams that were small and located on stream reaches flanked by forests that had not been historically impounded, and new dams on open areas with a history of prior beaver impoundment, but which had been abandoned and had experienced a drop in the water level (recolonization dams). Descriptors of dam types are indicated in Appendix 1.

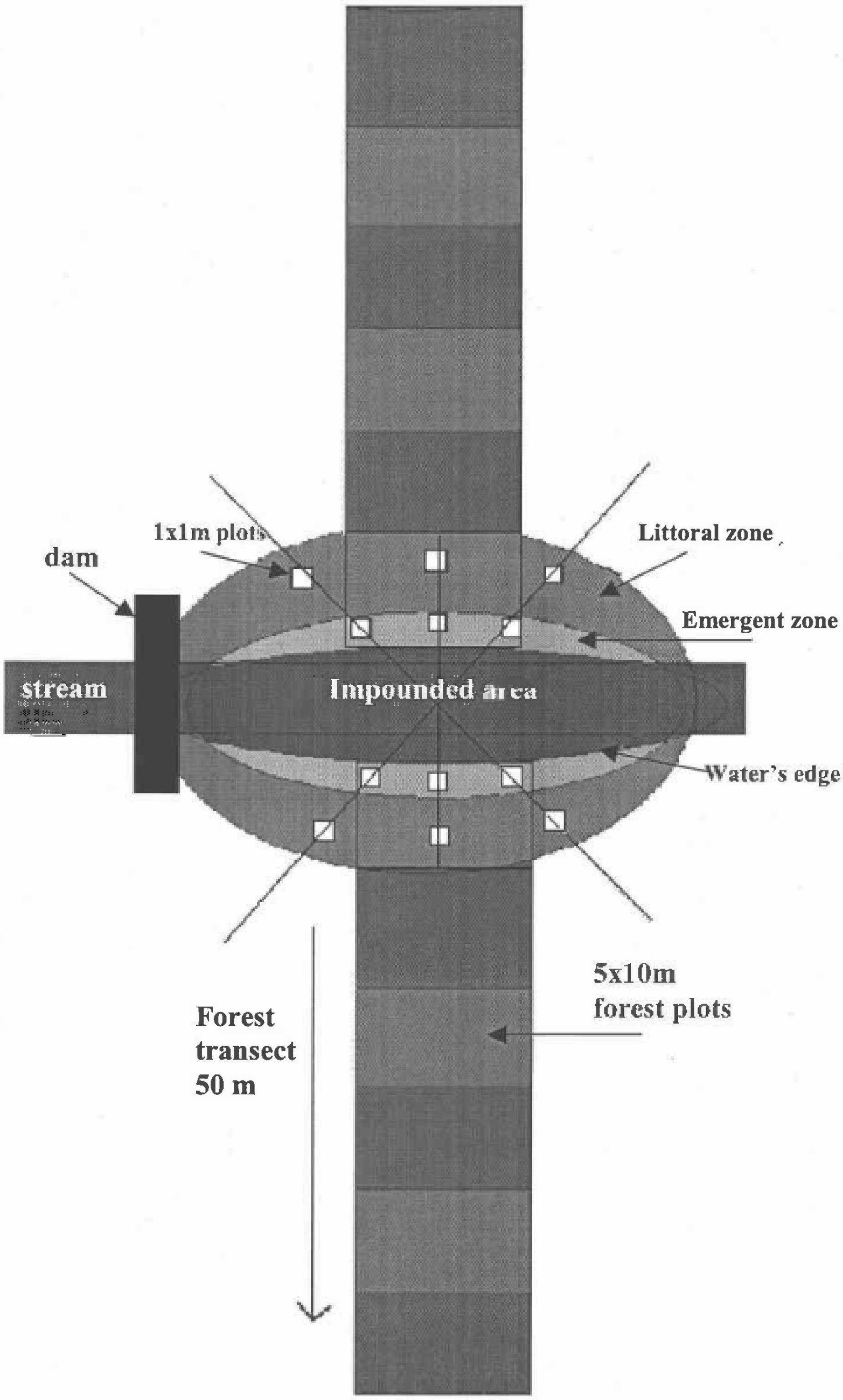
Field Methods

At each site, I measured six variables: stream order, width of valley floor, stream gradient, overstory cover, adjacent forest type, and height of vegetation plot above water level. Gradient (of 50m of stream reach) and overstory cover (at center of site, in 5% increments) were visually estimated for each site; width of valley floor (at dam) and width of stream were measured using meter tape (width of stream for impoundments was measured just downstream of the dam splash pool); and stream order was determined from 7.5' USGS topographical maps.

Streamside Herbaceous/Shrub Sampling

At the site level, transects bisecting the center of the impoundment or stream at 45, 90, and 135 degree angles to the stream were established (Fig. 2.2). Twelve 1x1m plots were located on these transects (six in the emergent zone and six in the littoral zone) in the center of that zone on the transect. The emergent zone was defined as the impounded area occupied by vegetation emerging from the water and the surrounding area normally impounded or wet enough to support emergent-type vegetation. The littoral zone was defined as the area between the emergent zone and the forest edge, and was defined by the presence of a plant community that was neither emergent nor that typical of the forest understory. Unimpounded reaches were frequently forested up to the stream's edge. In this case, the littoral plots were usually placed immediately adjacent to the stream. In these cases, the emergent zone did not exist. Within plots, cover of herbaceous plants and cover of woody shrubs were visually estimated and recorded by species in 5% increments.

Figure 2.2: Sampling schematic at the site level.



Forest Tree/Shrub Sampling

At each site, one 10 x 30m transect extending from the edge of the water into the forest was established on each side perpendicular to the stream and subdivided into six 5 x 10 m plots (Fig. 2.2). Thus, the forested transect included parts of the emergent and littoral zones. I measured cover of shrub species and number of individual trees measuring >15 cm dbh in each plot, as well as distance of the plot from center of impoundment or stream and estimated height of the plot above water level (at plot center).

Analysis

The streamside and forest sampling analysis utilized a balanced randomized block design. Sites were blocked by basin. Within each basin, sampling sites were classified based on their impoundment history (dams, jams, and unimpounded sites as defined above). Comparisons were made among site types. All analyses were conducted using $\alpha = 0.05$.

Environmental Variables

I performed a randomized block analysis of variance (PROC GLM; SAS system software v. 7) to test for differences in environmental variables among site types. All variables but height were measured once in the center of the site, while values for height were averaged across all plots to obtain a site value. I used the model

$$Y_{ij} = \mu + \alpha_i + \beta_j + \alpha_i\beta_j + \varepsilon_{ij}$$

Where μ is the mean response, α_i is the effect of site type *i*, β_j is the effect of block (basin) *j*, α_i β_j is the effect of the interaction between site type and basin, and ε_{ij} is the model error for the treatment *i* in block *j*. All variables were tested for interactions. In the absence of a significant interaction term (all cases except height), variables were analyzed without the interaction term included in the model.

Height and overstory cover did not require transformation to sufficiently fit the assumptions of analysis of variance. Width of valley floor and width of stream required a log transformation. Gradient was visually estimated in the field, and estimates were too imprecise to test for differences within a 5% range. I used a t- test to compare variables that were significantly different between site types in the overall ANOVA model (SAS system software v. 7).

Correlations Among Species

To resolve specific questions of interest concerning *Phalaris* abundance and species richness at dam sites only, I performed a simple linear regression of species richness upon *Phalaris* abundance. (PROC REG; SAS System Software v. 7). *Phalaris* abundance had a normal distribution in beaver impoundment sites, but not in other types of sites, and those could not be transformed to normalcy.

Multivariate Analysis

Blocked Multi-response Permutation Procedure (MRBP) was used along with Non-metric Multidimensional Scaling (NMS) to analyze potential differences in community structure among the three site classes (McCune and Mefford 1999).

MRBP

I used the blocked variant of MRPP, referred to as MRBP, to analyze these data. MRPP (the non-blocked version) is a non-parametric procedure used to test the hypothesis that there is no difference among predefined groups of entities. The general approach of MRPP is to calculate a distance matrix, calculate the average distance in each group, calculate δ such that

$$\delta = \sum_{i=1}^{g} C_i x_i$$

where C_i is the weight based on the number of items in the groups ($C_i = n_i/N_i$ where n_i is the number of items in the group and N_i is the total number of items) for g groups and x_i represents the distance for group i. Then, the probability of a δ this small or smaller is determined (p-value). Effect size is determined by the chance-corrected within-group agreement (A):

$$A = 1 - \frac{\delta}{\mu_\delta} = 1 - \frac{observed\,\delta}{expected\,\delta}$$

The agreement statistic, A, describes within-group homogeneity compared to the random expectation (A=0 indicates that heterogeneity in groups equals expectation by chance). In community ecology, values for A are typically <0.1, even when the observed δ values differ significantly from expected. An A value of >0.3 is fairly high. The advantage of using this procedure over MANOVA or other parametric methods lies in the non-dependence upon classic assumptions such as linearity and normality, which are rarely met by ecological data (McCune and Mefford 1991; Mielke 1984). My data were highly nonlinear and non-normal, making blocked MRPP the logical choice for analyzing this data set.

I used the blocked variant of MRPP (MRBP) to analyze these data. MRBP requires one value per treatment per block, so data are averaged over blocks. Given *b* blocks and *g* treatments, the MRPP statistic is modified to

$$\delta = [g\tbinom{b}{2}]^{-1} \sum_{I=1}^{g} \sum_{j<k} \Delta(x_{ij}, y_{jk})$$

where Δ (x,y) is the distance between points x and y in the p dimensional space. I used the variants of MRPP provided with PC-ORD Software (McCune and Mefford 1991), and both variants were calculated using a Euclidean distance measure without rank-transformation. Groups were defined according to site class (dam, debris jam, or unimpounded site), creating 12 sites per class. Results reported are plots in species space. The primary matrix consists of species abundance (percent cover) for each species in each plot, while the secondary matrix consists of the set of measured environmental variables and site indicators for each plot.

Non-metric Multidimensional Scaling (NMS)

NMS is a method of ordination that is well suited to data that do not meet assumptions of normality and linearity. NMS is fundamentally different in approach than other types of ordination techniquesin that it is based on ranked distances (Kruskal and Wish 1978; Clarke 1993). I used the PC-ORD version of the NMS algorithm with a Sorenson distance measure. I used the scree plot provided in the output to assess dimensionality. All results were based on data sets with rare species (<3 observations) deleted. Data were arcsine-squareroot transformed except for in the case of the emergent and littoral zones combined, in which case they were converted to presence/absence (binary) data.

Results reported are plots in species space. The primary matrix consists of species abundance in analysis of the littoral zone and forest communities, and species presence/absence in analysis of the streamside whole-site analysis, while the secondary matrix consists of the set of measured environmental variables and site indicators. When the emergent and littoral zones are considered as a whole, averaged data (primary data set: species cover) were converted to a binary data set, or presence/absence, to avoid bias due to an uneven distribution of emergent and littoral zones.

Pearson's correlation coefficients were provided between the ordination axes and the individual variables used to construct the axes. R-squared statistics (coefficients of determination between Euclidean distance in the ordination space and a distance matrix based on the main matrix) were calculated to determine percentage of overall variance explained by each axis.

Results

Environmental Variables

The similarity of width of valley floor, width of stream, and stream order among site types (Table 2.1) confirms that all site types were similar in terms of morphological characteristics within the set parameters (Suzuki and McComb 1998). Beaver dam sites were more open (smaller % overstory cover) and wetter (smaller height of plot above water level) than the other types of sites; both characteristics are directly effected by beaver. On the whole, however, all sites were similar.

Overstory cover varied significantly with site type (Table 2.1). Dam sites had less overstory cover than either jam sites or unimpounded sites ($p<0.05$; t-test). Width of stream differed among sites at the 90% level ($p=0.069$). Dams differed from unimpounded sites, but not from jams (impounded streams are smaller).

For the variable height above water, the interaction between site type and basin was significant, so I was unable to test for main effects. Width of valley floor was significantly different among basins but not site types.

Streamside Herbaceous/Shrub Communities

Emergent Zone

Only beaver dam sites possessed emergent zones. This zone supported a unique suite of herbaceous species not found in the littoral zone along with a collection of plants

Table 2.1. Means and standard errors (in parentheses) of stream order, width of valley floor, width of stream, gradient, overstory cover, and height of plot above water level. Categories with same letter are not significantly different in a t-test. Width of valley floor was significantly different among blocks. Height above water interacted significantly with block (basin), and so could not be tested for main effect. Variables without letters were not tested.

Site Type	Stream Order	Width of Valley Floor (m)*	Width of Stream (m)*†	Gradient (%)	Overstory Cover (%)	Height of Plot above Water Level (m)
Dam	2.5 (0.15)	30.9 (3.8)a	2 (0.5) a	1.9 (0.4)	8.5 (8.3) a	0.5 (0.15)
Debris Jam	1.9 (0.16)	23.8 (4.6)a	1.9 (0.4) a	2.7 (0.5)	21.7 (9.7) b	1 (0.12)
Unimpounded Sites	1.9 (0.19)	29.7 (5.9)a	2.7 (0.3) b	3.3 (0.4)	30.9 (12.9) b	0.8 (0.07)

* variable was log-transformed before testing
† Width of stream was significantly different at the 90% level (p=0.069).

that were found elsewhere (Table 2.2). Half of the beaver dams possessed emergent zones; none of the jams or unimpounded sites possessed them.

Littoral Zone

None of the analyses effectively distinguished among site types for the littoral zones. Species richness interacted significantly with basin (block), and I was not able to test for main effects.

MRBP analysis indicated no distinction among the littoral zones of dams and other types of sites. Jams and unimpounded sites were also not distinct (Table 2.3).

A 3-dimensional solution to NMS for the littoral zones of the streamside plots does not indicate site type clustering (Fig 2.3). The axes are not linearly correlated with any of the second matrix variables. However, the second axis is highly correlated with percent cover of *Phalaris arundinacea* ($r = 0.939$). In addition, axis 2 displays a bimodal distribution of overstory cover and a mid-axis peak in species richness. Axis two thereby separates sites of high light into areas of high richness/low *Phalaris* and low richness/high *Phalaris* (Fig 2.4 a-d), suggesting that *Phalaris* abundance may be an important driver of species richness in this system.

Monte Carlo test results indicated that the final stress deviated significantly from what might have been expected by chance ($p<0.019$) The stress vs. iteration plot indicated stability. After 40 iterations for the final solution, the three axes explained 90% of the variance (Axis 1 R^2= 0.07; axis 2 R^2= 0.58; axis 3 R^2=0.24).

Table 2.2. Species characteristic of beaver impoundments. Percent cover values are at sited where the specis was present. Dam communities also include a high number of common riparian species which appear to decrease in importance over time as the wetland develops, and are not listed here.

	Common Name	***Scientific name***	**Frequency Present in Impoundments (%)**	**% Cover (Range)**
Unique to Emergent Zone	Bur-reed	*Sparganium angustifolium*	16	5 (3-7)
	Cattail	*Typha latifolia*	16	8 (9-16.7)
	Common Duckweed	*Lemna minor*	25	14 (8-22)
	Ovate Spikerush	*Eleocharis ovata*	8	1 (1)
	Leafy Pondweed	*Potamogeton* sp.	8	4 (4)
Unique to Beaver Dam sites	Oxeye Daisy	*Leucanthamum vulgare*	8	0.2 (0.2)
	Common Foxglove	*Digitalis purpurea*	25	1 (0.2-2.5)
	Dagger-leaved Rush	*Juncus ensifolius*	25	2 (0.2-6)
	Muskwort	*Chara* sp.	8	1 (1)
	Himilayan Blackberry	*Rubus discolor*	17	11 (3-18)
	Pearly Everlasting	*Anaphalis margaritacea*	8	0.5 (0.5)
	Willow spp.	*Salix* sp.	25	25 (10-38)
>85% Fidelity to Beaver Impoundments	Common Rush	*Juncus effusus*	33	20 (3-46)
	Starwort	*Callitriche heterophylla*	75	6 (0.4-17)
	Small-flowered Bulrush	*Scirpus microcarpus*	25	20(0.4-29)
Other Species of Importance	Reed Canarygrass	*Phalaris arundinacea*	83	52 (1-100)

Table 2.3: Results of blocked and unblocked Multi-response Permutation Procedure for streamside data, littoral vegetative zone.

Analysis	Comparison	A-statistic	P-value
MRBP	3-way comparison among site types	0.023	0.205
	Beaver Impoundments vs. Debris Jam Impoundments	0.057	0.115
	Beaver Impoundments vs. Unimpounded Sites	-0.011	0.580
	Debris Jam Impoundments vs Unimpounded Sites	0.044	0.246

Figure 2.3 Non-metric Multidimensional Scaling ordination of plots in species space for streamside communities (littoral zone only) grouped by site type. Ordination shows no site type clustering.

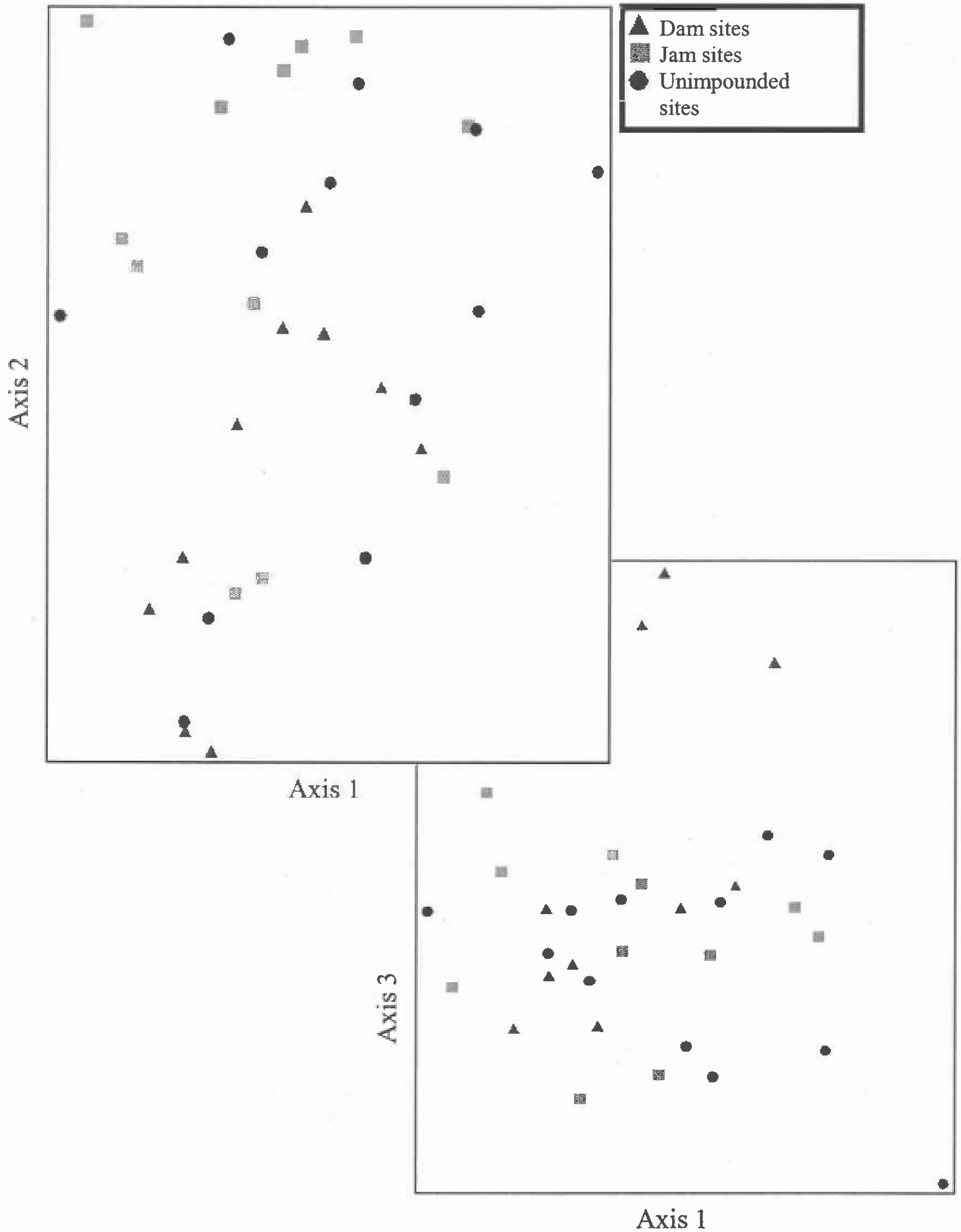
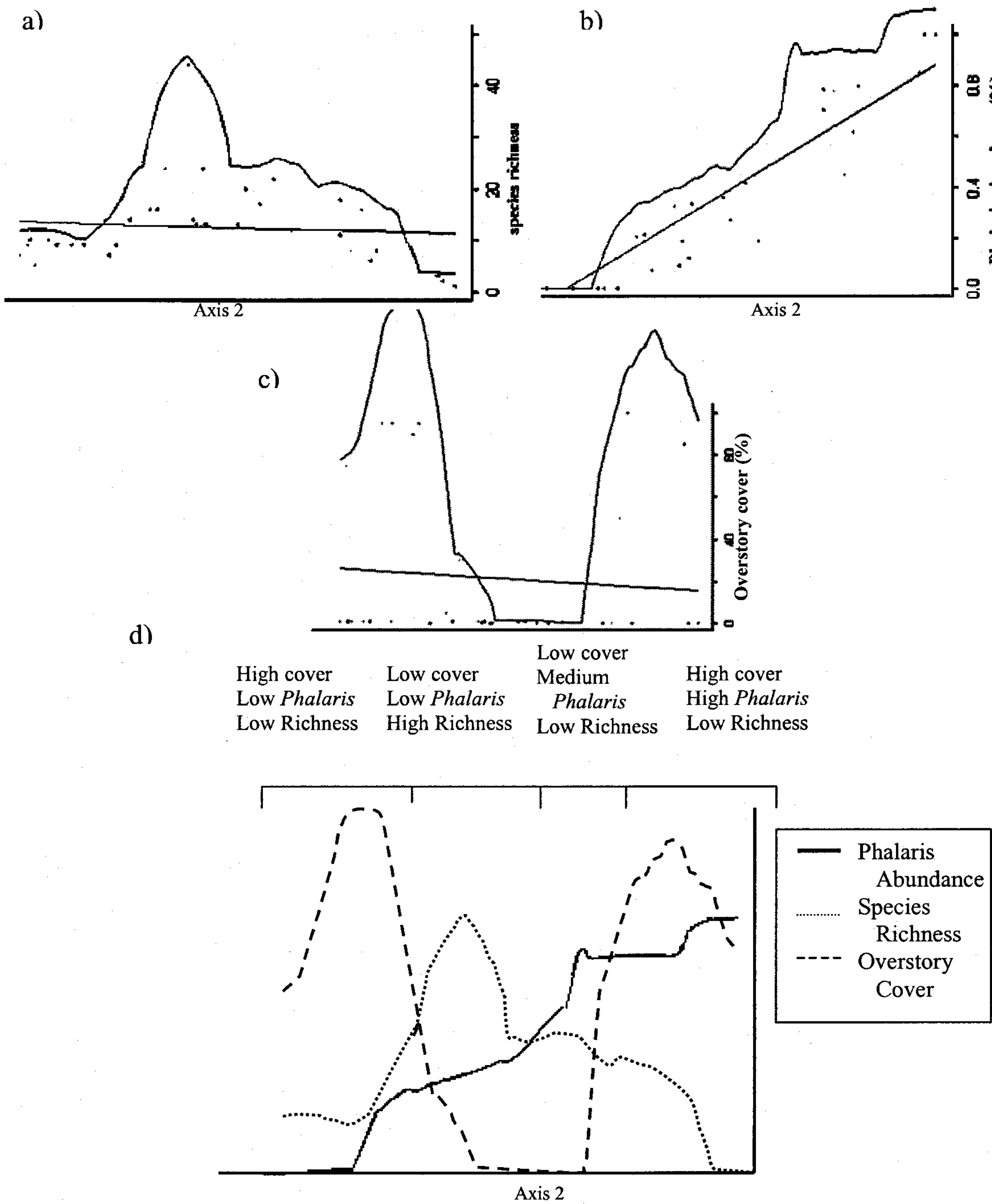


Figure 2.4. Summary of the relationship of overstory cover, Phalaris abundance, and species richness to axis 2 of Non-metric Multidimensional Scaling ordination results for the littoral zone. Figures (a)-(c) are NMS output illustrating the maximums and trends for the given variable on axis 2. Figure (d) illustrates an overlay of figures a-c. Medium and high richness is associated with areas of both low cover and moderate values of *Phalaris,* providing evidence that *Phalaris* cover may be an important driver of species richness in both high and low-light areas. Curves indicate value boundaries, and the general trend.



Whole-Site (emergent and littoral zones combined)

MRBP indicated a medium but significant (at the p=0.058 level) difference between jams and unimpounded sites, and weak but less significant differences between dams and other types of sites (Table 2.4). Between-basin variability was a strong confounding factor in the ability of the analysis to effectively discriminate among site types; basins clustered more effectively than site types (Fig 2.5). Although multivariate analysis indicates no group distinction of littoral zones among site types, when data from emergent zones are averaged into that from littoral zones (and the matrix converted to presence/absence to avoid bias due to uneven samples), the sites cluster (Fig 2.6).

Axis 1 of the 3-dimensional NMS solution is highly correlated with species richness ($r = 0.70$). Axis 2 is correlated with height of plot above water level ($r = 0.58$), suggesting a moisture gradient. Axis 3 is weakly correlated with overstory cover ($r = 0.28$), suggesting a weak light gradient. On these gradients, dams tend to fall to the higher light side of the light gradient, with a fairly even spread on the moisture and species richness gradients (Fig. 2.6). Most sites are on the dry side of the moisture gradient, with the wet half occupied by only three dam sites (SD1, SD2, SD3), two of which are the oldest types of dams that consist entirely of emergent zone. These sites are very low in richness, consisting exclusively of *Phalaris, Salix, Callitriche, Lemna minor,* and *Myostis*.

Table 2.4: Results of blocked and unblocked Multi-response Permutation Procedure for streamside data, emergent and littoral zones combined.

Analysis	Comparison	A-statistic	P-value
MRBP	3-way comparison among site types	0.071	0.029
	Beaver Impoundments vs. Debris Jam Impoundments	0.152	0.058
	Beaver Impoundments vs. Unimpounded Sites	0.086	0.105
	Debris Jam Impoundments vs Unimpounded Sites	0.011	0.386

Figure 2.5 Non-metric Multidimensional Scaling ordination of plots in species space for streamside communities (emergent and littoral zones combined) grouped by basin.

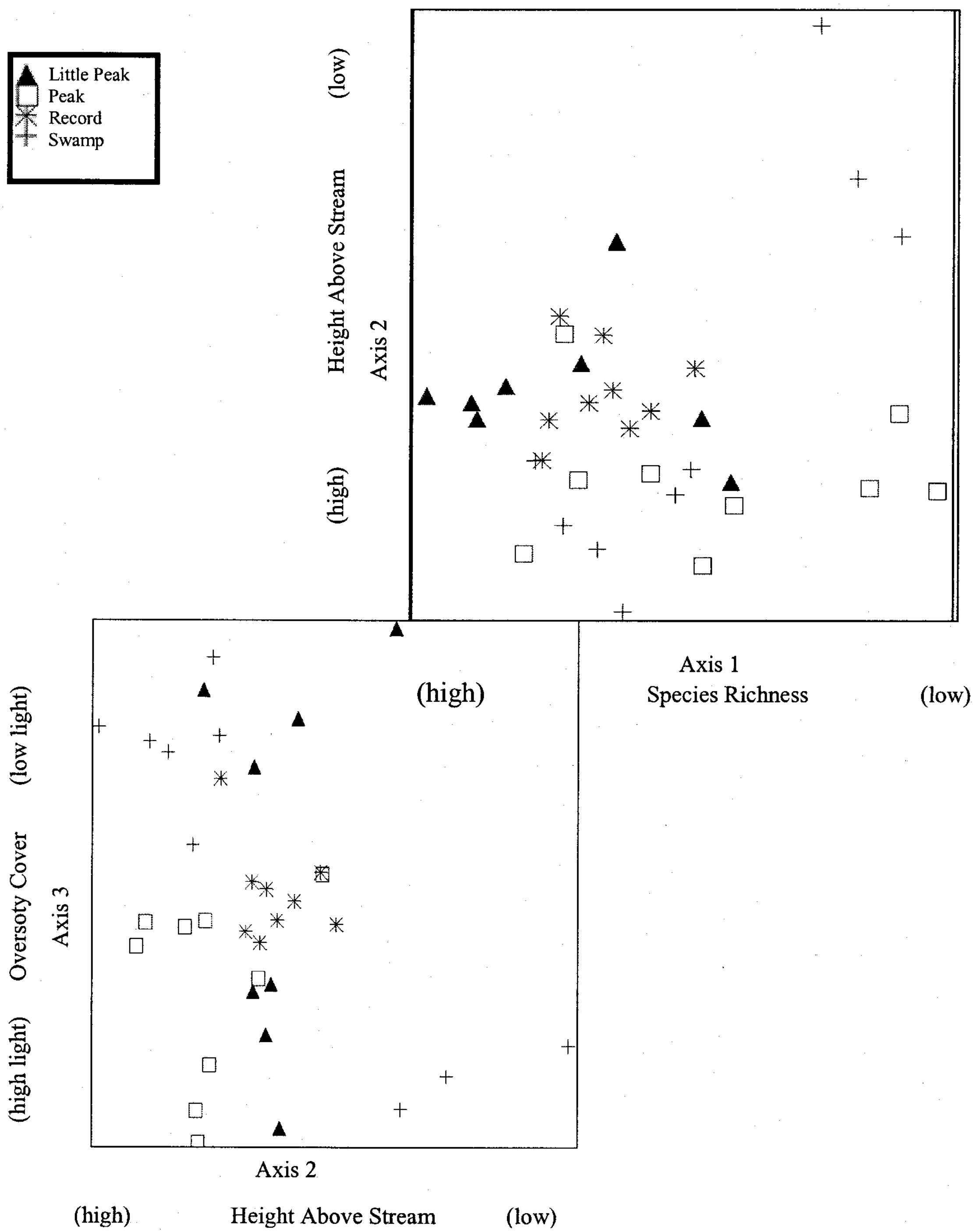
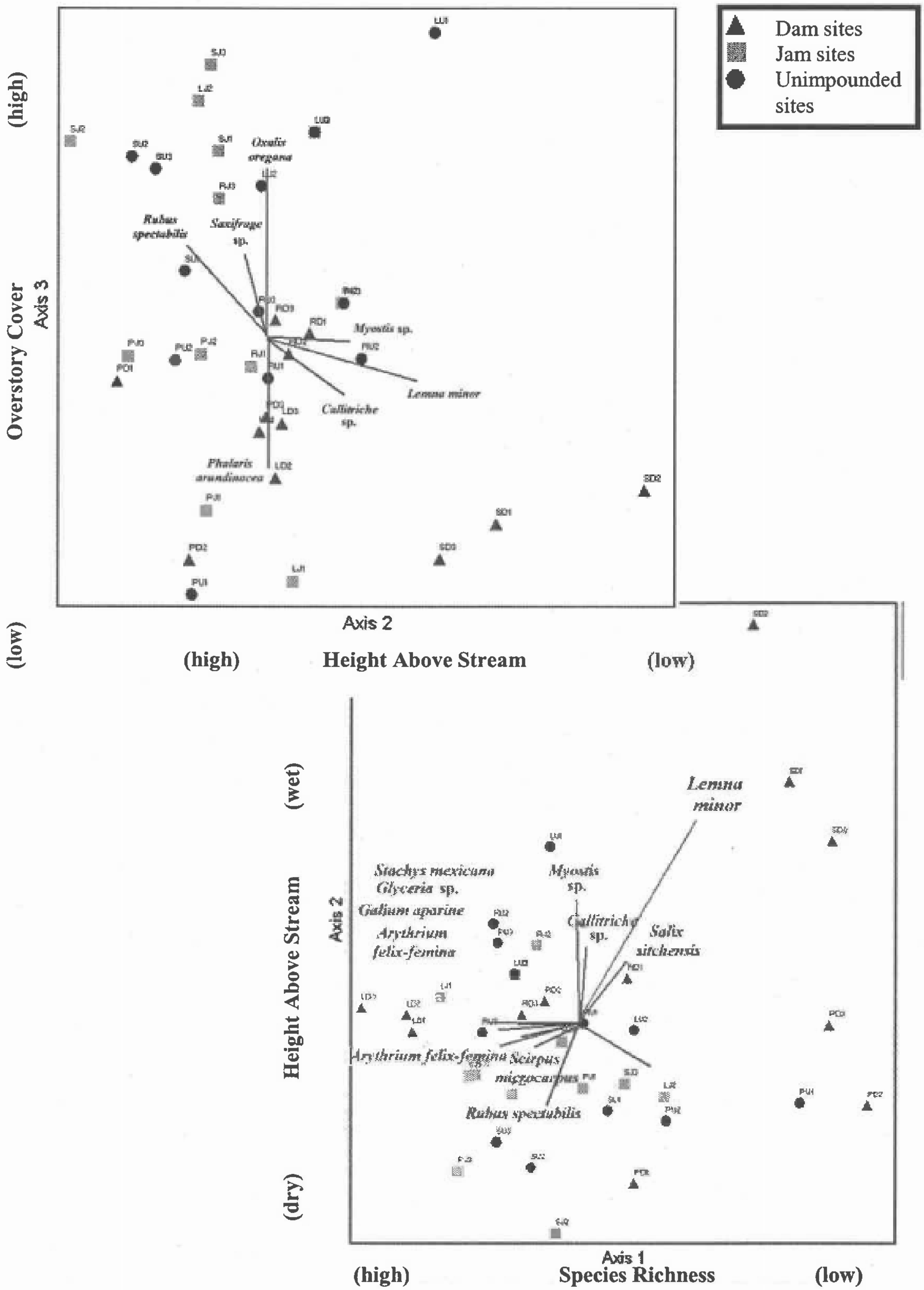


Figure 2.6. Non-metric Multidimensional Scaling ordination of plots in species space for streamside communities (emergent and littoral zones combined) grouped by site type.



Monte Carlo test results indicated that the final stress deviated significantly from what might have been expected by chance ($p<0.019$) The stress vs. iteration plot indicated stability. After 40 iterations for the final solution, the three axes explained 87% of the variance (Axis 1 $R^2= 0.35$; axis2 $R^2= 0.17$; axis 3 $R^2= 0.34$).

Univariate analysis of species richness includes a significant interaction term (richness*block), so I was unable to test for differences in richness. However, mean species richness is very similar for all site types (13.6 for dam sites as opposed to 11.8 for jam and 11.3 for unimpounded sites). Richness for beaver impoundments ranges both higher and lower than the other types of sites (Fig. 2.7) resulting in a similar mean with a larger range. Sample sizes were different in some of the dam sites (4 of 12) due to the presence of an emergent zone. These sites were low in species richness, and differences in sample size do not seem to affect the conclusion that there is no difference in richness means.

Cover of *Phalaris arundinacea* was negatively correlated with species richness for beaver impoundments only ($r = -0.673$). Cover of *Phalaris* explained 45% of the variance in species richness at dam sites ($R^2=0.45$, $p<0.05$; Fig. 2.8). Phalaris had higher average percent cover values for recolonization dams than new or old dams (76%, 26%, and 30%, respectively). While *Phalaris* was not unique to beaver impoundments, it was frequently present (present in 83% of dam sites, as opposed to frequencies of 50% at jam sites and 58% at unimpounded sites; Table 2.2).

Figure 2.7: Relationship of streamside species richness to site type; individual plot values and means. Dam sites have a larger range, but all sites have similar means. Points at same values overlap. Some Dam sites were sampled at 12 points (emergent and littoral zones; solid circles) and some at only 6 (littoral zones only; hollow circles).

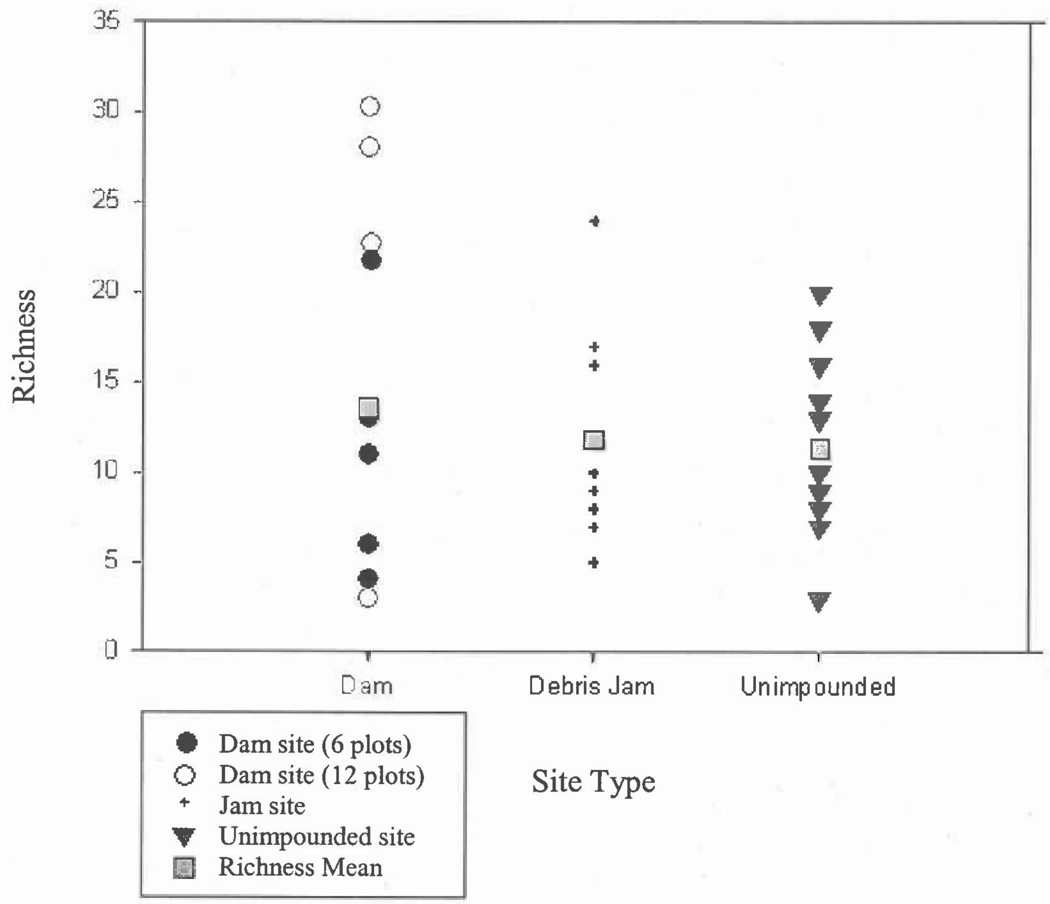
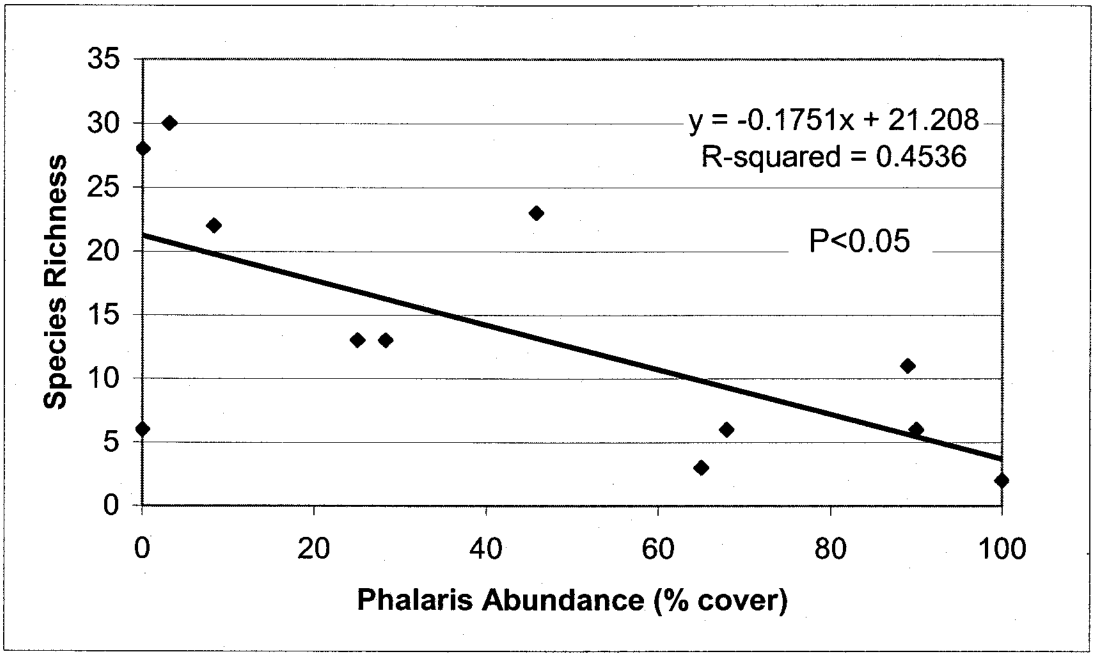


Figure 2.8. Relationship of species richness and *Phalaris* abundance for dam sites.



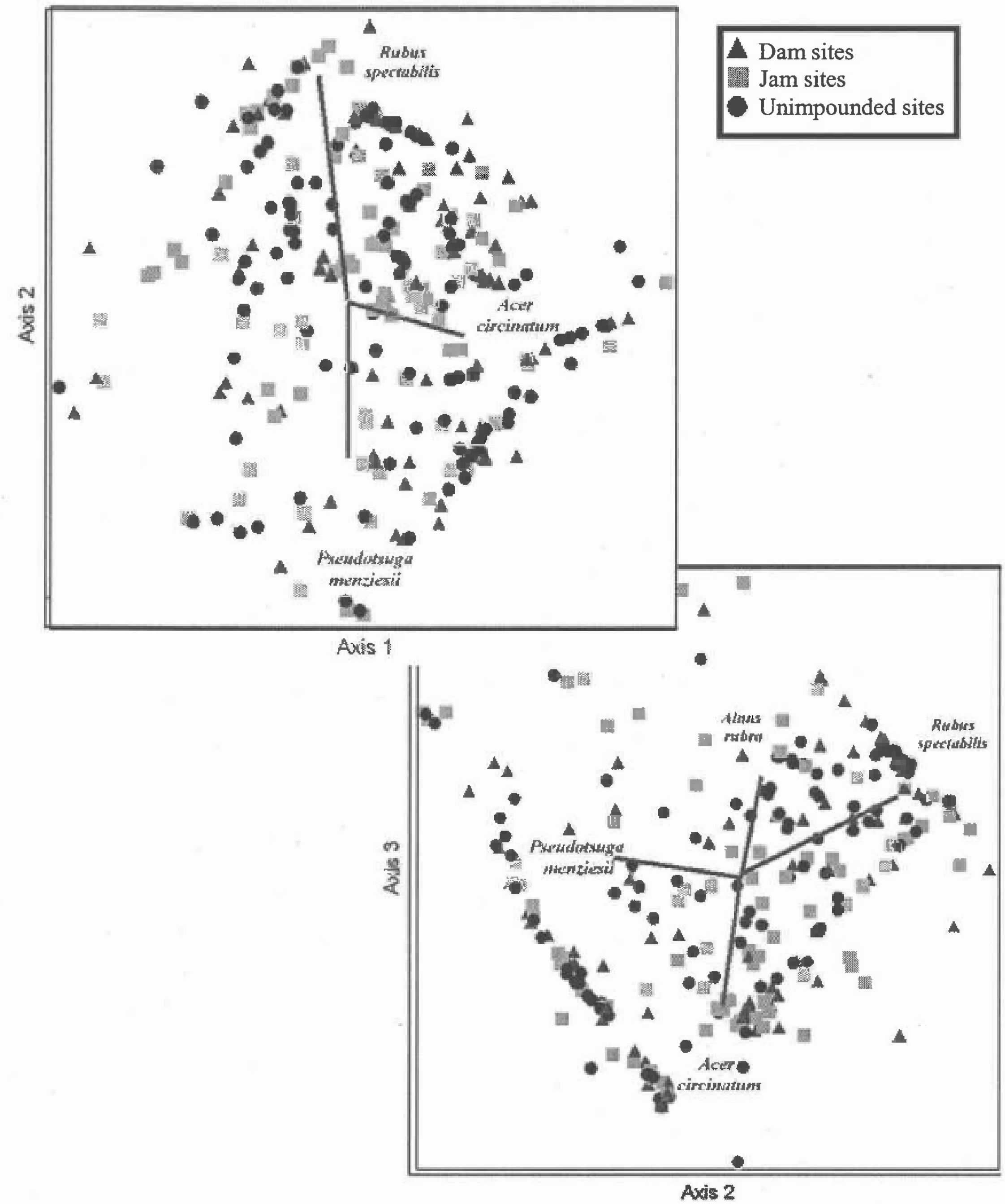
Riparian Forest Zone Communities

There was no significant difference in mean species richness in the forest tree and shrub communities among site types (F=1.25; p=0.316). MRBP analysis indicated a significant difference in community composition between dam and jam sites, but the small A-value suggests the difference is biologically meaningless (A=0.005, p=0.028). All other comparisons were non-significant.

Because of a preponderance of zeros in this data set and a small number of dimensions, it was difficult to create randomly shuffled data sets for a Monte Carlo comparison. This caused PC-ORD to fail to create a solution. Therefore, it was necessary to forego the random runs in this analysis. I am, however, still confident in a low-stress solution after examining the stress vs. iteration number plot provided with PC-ORD. The axes explained a total of 80% of the variation (Axis 1 R^2=0.22; Axis 2 R^2= 0.38; Axis 3 R^2=0.20; Fig 2.9)

NMS indicated no clustering of site types on any axis (plots in species space; Fig 2.9). Axis two is correlated with *Pseudotsuga menziesii* stem count (r = -0.649) and also slightly with height above water (r = -0.194).

Figure 2.9: Non-metric Multidimensional Scaling ordination of plots in species space for the riparian forest zone. Axes are not correlated with observed environmental variables, with the exception of Axis 2 (with distance, -0.196).



Discussion

Streamside Herbaceous Zone

Beaver activity initiates development of a plant community adjacent to the stream that is different in quality from debris jam impoundments and unimpounded sites. Beaver sites consisted of wetland type communities with a developed graminoid contingent (Table 2.2). The differences are most apparent in the addition of the emergent zone, a unique feature of dam sites. Of the eight dam sites, emergent zones of varying sizes were present at six. In the most developed cases (three cases), the emergent zone filled the entire valley floor and covered more than 2500 m^2.

The area immediately surrounding around the emergent zone (the littoral zone), by contrast, does not differ greatly among types of sites. Emergent zones have a disproportionate effect on the character of beaver sites, creating a distinction in whole-site multivariate analysis despite their relatively small size. The tendency of beaver impoundments to create these types of wetland communities has been noted consistently in the literature (Bilby 1980; Naiman et. al. 1986; Naiman et al. 1988; Johnston and Naiman 1990a; Mitchell and Niering 1993; Feldmann 1995; Brown et al. 1996; McCall et al. 1996), though it has rarely been quantified (Feldmann 1995). I have found no other to do so in the Pacific Northwest.

The emergent communities in beaver impoundments found in the Coast Range are simple. They are dominated by cattails (*Typha latifolia*), spreading rush (*Juncus effusus*), starwort (*Callitriche heterophylla*), duckweed (*Lemna minor*) and Sitka willow (*Salix* *sitchensis*). Never were debris jams observed to create the kind of consistent still-water environment necessary to support these communities. Others have also been unable to find impoundments created by large wood (Lombard 1997). Most large wood that I observed to span the channel had been used by beaver as a base for dam construction, and so could not be included in the study. Maser (1981) found most dams in the Coast Range to wash out every winter. Many dams I sampled looked too weak to withstand the winter, but dams built around pieces of large wood may be sturdier. It is possible that an increase in large wood in Coast Range streams will increase the number of resilient beaver dams, and therefore wetland habitat.

The only place I saw *Salix* (willow) and most rushes, and the only sites supporting wetland-type plant communities, were beaver impoundments. Beaver has a particularly close association with *Salix*. Beaver prefer willow over most woody species for browse, with the exception of aspen (Jenkins and Busher 1979; Barnes and Dibble 1986; Naiman 1988; Donkor and Fryxell 2000; Ganzhorn 2000). Beaver use, unlike livestock use, encourages growth of *Salix* (Kindschy 1985). It has been suggested that extirpation of beaver from willow-rich areas may negatively impact the ability of willow to withstand other kinds of browsing (Singer 1998). Beaver and willow each benefit the other, and the presence of beaver in the landscape of the Oregon Coast Range seems to help maintain willow populations.

Beaver impoundments encompass a greater range in species richness (on average similar) than jam or unimpounded sites, depending on the extent of invasion by *Phalaris arundinacea*. In South Carolina (Feldmann 1995) beaver increased species richness and diversity within stream channels, and changed the species composition to graminoid-dominated wetland communities. These results are similar to my own. With a decrease in the extent of *Phalaris* invasion the dam sites may be richer on average than the other types of sites.

At dam sites, high *Phalaris* abundance parallels, and presumably causes (Lesica 1997; Morrison and Molofsky 1998; Uthus 1999), a marked reduction in species richness (Fig 2.8). Jams and unimpounded areas tended to contain less *Phalaris* per site when present and a lower overall frequency of invasion. This is may be due to a reduced risk of invasion by the grass in the other types of sites; dam sites had a wide range of *Phalaris* abundance levels while only a few of the other types of sites had high levels of *Phalaris*. *Phalaris* was most abundant at recolonization dams (new dams in areas previously colonized by beaver), perhaps because abandonment had caused the water table to drop in the past, allowing *Phalaris* to aggressively colonize the area. *Phalaris* suffers and sometimes dies under inundations persisting more than three days (Rice 1993). Newer dams may not have raised water levels sufficiently to impact the grass.

Phalaris is known to be more likely to be invasive in areas of low species richness and frequent disturbance (Morrison and Molofsky 1998). Beaver impoundments in the Coast Range, with their inherently low species richness and repetitive cycle of abandonment and recolonization, provide an appropriate environment for *Phalaris* colonization (Hutchinson 1992). There are few studies in the Pacific Northwest or elsewhere concerning the impact of *Phalaris* upon species richness and diversity (Lesica 1997), an area in which more research is needed.

In the absence of *Phalaris* invasion, beaver impoundments present a wetland community unique to the area. By creating distinct wetland patches in a relatively homogenous riparian forest community landscape, beaver increase landscape habitat heterogeneity (Naiman et al. 1988; Pollock et al. 1998; Johnston and Naiman 1990 a, c), and provide a habitat type that is unique and highly important to wildlife (Csuti et al. 1997; McDowell and Naiman 1987; Smith et al. 1981; Clifford et al.1993) and fish (Liedholdt-Brunner et al. 1992; Schlosser and Kallemyn 2000). Apart from wetlands created by beaver, I found no wetlands in my study area. The inclusion of this community type in the relatively simple Coast Range community matrix increases landscape heterogeneity in the region.

Riparian Forest Zone

Results from multivariate analyses did not show clustering of site types; I found no difference in tree and shrub communities around the three types of sites. Either beaver are altering the riparian zone through browsing and the sampling and analysis fail to reveal this, or beaver are not significantly altering tree and shrub communities. The communities I sampled are simple, and a shift away from a beaver-preferred species, towards an avoided species, or indiscriminate removal of many trees near impoundments should have been significant enough to be detected. I therefore conclude that beaver are not altering the communities in a significant way past the water's edge in this area, although they affect the position of the waterline.

This is a surprising result for several reasons, most strikingly the preponderance of anecdotal reports of beaver taking out large numbers of trees (particularly planted ones that have reached a certain size), and the cultural perception of beaver as destructors of large swaths of riparian trees. I was unable to find peer-reviewed papers documenting this kind of activity, except for one comment by Naiman et al. (1988) that, where the riparian zone consists of deciduous trees preferred by beaver (i.e. *Populus tremuloides* or *Salix* sp.), the riparian zone may be "virtually clear-cut". Many prior studies in other regions have noted a subtle shift in composition toward avoided browse species, frequently a move towards conifer dominance (Barnes and Dibble 1986; Johnston and Naiman 1990b; Pastor and Naiman 1992; Nolet 1994; Donkor and Fryxell 2000).

Secondly, beaver tend to impound large amounts if not all of the floodplain, typically dominated in the Oregon Coast Range by red alder (Nierenberg and Hibbs 2000). My riparian transects began at the water's edge. One might to find conifer-dominated areas at the edge of the water around beaver impoundments where the typically red alder-dominated floodplain has been impounded. In the floodplains around the other types of sites one might expect to find red alder near the water. The tendency of beaver to select against conifer in their browsing (Brunner 1989; Busher 1996; Suzuki and McComb 1998) should only enhance the distinction.

However, as *Pseudotsuga menziesii* is the dominant tree in the region, one should not expect to find much of a difference upslope in conifer dominance. In no analysis was I able to perceive a difference in community structure beyond the edge of the water. This suggests that despite of the dramatic change in the streamside herbaceous communities, there may be little effect of beaver colonies on the surrounding *P. menziesii* density beyond the edge of the water. Historically, of course, impoundment removed what *P. menziesii* was present on the floodplain. If one were to consider a time before beaver, then one might imagine that *P. menziesii* had grown near to the stream in many cases.

Finally, one may expect to find abandoned beaver meadows that have created an unimpounded no-tree zone between the stream and the edge of the forest. I observed these meadows to be plentiful within my study reaches. Since I made no effort to restrict my sampling of debris jam and unimpounded reaches to areas devoid of old beaver meadows (meadows made up large portions of riparian areas in basins with a large beaver presence), the difference was not picked up by the analysis.

Beaver contribute a unique (and the only) wetland plant community and wildlife habitat to the lower Alsea drainage of the Oregon Coast Range. Unrestricted beaver activity will assist landowners who would like to create, maintain, or mitigate wetlands on their land in streams where beaver tend to build dams. Beaver will use wood provided to them in the absence of suitable riparian vegetation (Pollock et al. 2000), trapping sediment and helping to stabilize bank structure. Beaver impact little area beyond the edge of the impoundment, although impoundments may sometimes cover extensive areas; the main browse effects are usually within 30m of the water's edge (Liedholt-Brunner et al. 1992) with the farthest browsing effort centered on more rare, nutritionally profitable plants (Suzuki and McComb 1998; Brunner 1989; Nolet 1994). This area is within the Riparian Management Areas (RMAs) set by the Oregon Department of Forestry regulations for private lands and the RMAs set by the Northwest Forest Plan for federal lands (USDA and USDI, 1994), the two primary landowner types in this study area (Stanfield 2001). Land managers that wish to manage for plant and wildlife diversity in addition to timber should consider relinquishing active beaver areas to animal use instead of undergoing time-consuming and usually expensive (Bhat et al. 1993) efforts to control beaver.

CHAPTER 3

The Relationship Between Impoundment Presence and Clearcuts/Young Even-Aged Forest Stands in the Lower Alsea Drainage of the Oregon Coast Range

Thaïs E. Perkins, David E. Hibbs and John P. Hayes

Abstract

The recent population expansion of beaver (*Castor canadensis*) in the Oregon Coast Range has been a subject of concern to those who manage land for timber harvesting. I examined the effect of harvest pattern on impoundment presence. Eleven basins were chosen for beaver presence and varying amounts of clearcut or young regenerating riparian forest and the relative percentages of stream length impounded in the different forest types calculated. Beaver impoundments were disproportionately associated with clearcut stream reaches (80% of available reaches impounded) over forested reaches (29%) within basins. Impoundment abundance was correlated over the landscape with basins possessing larger percentages of stream reaches flanked by clearcut/young regenerating forest (R^2=0.30). I conclude that beaver impoundments are associated with clearcut reaches in the area.

Introduction

The Oregon Coast Range is experiencing resurgence in beaver population levels, as beaver reclaim this part of their historical range. Populations are expanding at a remarkable rate nationwide (Johnston and Naiman 1990a, c; Snodgrass 1997), most likely due to a decrease in trapping. Before European colonization of North America, the beaver population was thought to be between 60-400 million individuals (Seton 1929) whereas the current population is thought to be between 6-12 million (Naiman et al. 1988), or about 10% of the prior population.

Beaver (*Castor canadensis*) impact the landscape in a myriad of ways, ultimately influencing plant and animal community composition and enhancing diversity (Naiman et al. 1986; Pollock et al. 1995). Benefits of beaver to stream systems include sediment trapping (Naiman et al. 1986), enhanced trout and salmon habitat (McRae and Edwards 1994; Liedholdt-Brunner et al. 1992; Schlosser and Kallemyn 2000), and an increase in riparian heterogeneity (Johnston and Naiman 1987; Naiman et al. 1986; Lawton and Jones 1995; Pollock et al. 1995; Clive et al. 1997).

Alteration of riparian tree communities by beaver manifests mainly in the tendency of beaver to shift communities towards unpreferred browse species (Barnes and Dibble 1986; Johnston and Naiman 1990b; Pastor and Naiman 1992; Donkor and Fryxell 2000). In the Pacific Northwest, this results in a shift towards conifer-dominated systems, as beaver browse primarily upon willow (*Salix sitchensis*), red alder (*Alnus rubra*), salmonberry (*Rubus spectabilis*) and vine maple (*Acer circinatum*; Brunner 1989; Suzuki and McComb 1998). Nonetheless, the cultural perception of beaver primarily as an agent of resource destruction (namely as a threat to young conifers) is pervasive, particularly among private timber industrial landowners (Spencer 1985; Bhat et al. 1993; Mortenson 2000). There is a large emphasis upon the need for population control within watersheds in which timber harvesting is taking place (Bhat et al. 1993).

While doing field work for a study addressing plant communities behind beaver impoundments in the Oregon Coast Range, I noticed large, abandoned dams in forested stream reaches that were in close proximity to very new dams in clearcut reaches, or reaches surrounded by very young regenerating forest. These observations prompted a study to determine whether beaver impoundments may be more associated with clearcuts and young regenerating riparian areas than riparian areas flanked by mature forest.

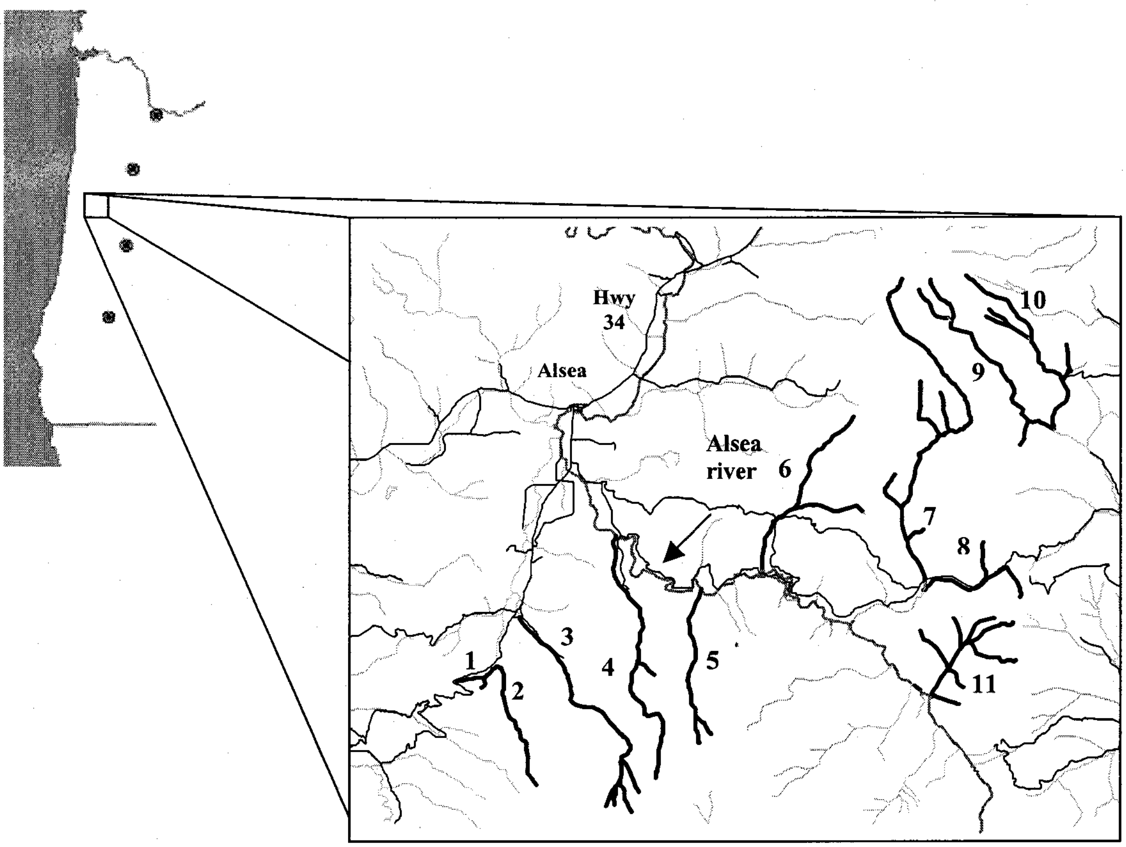
Aerial photography has sometimes been used as a tool for studying riparian change due to beaver, and in the instances where scientists have employed it, they have found it to be a useful tool (Johnston and Naiman 1990; Robel and Lloyd 1993; Snodgrass 1997). Where beaver build dams and lodges, the resultant patches are easily seen from the air (Johnston and Naiman 1990), although in areas where beaver do not build dams (i.e. coastlines) little beaver impact can be seen (Robel and Lloyd 1993).

Methods

I chose 11 third-order basins (Fig. 3.1) in close proximity to one another to determine beaver presence and to represent an array of streamside forest conditions (clearcut, young, and mature). Forests old enough to have a developed understory (typically more than 15 years old) were considered mature forests for the purposes of this study. In each, I identified beaver-affected areas on aerial photographs (defined as openings attributable to an impoundment history) along all reaches similar to those identified as typically used by beaver in Suzuki and McComb (1998; see chapter 1). Identification of beaver-affected areas was ground-checked.

The aerial photographs containing the sample reaches were imported into ArcView and four attributed measured: length of stream surrounded by mature forest,

Figure 3.1: Location of the study basins in the Oregon Coast Range. Alsea indicates the town, located on Oregon Highway 34. Dots on large map are major Oregon cities (from top to bottom, Portland, Salem, Corvallis, Eugene). Dark lines represent streams sampled.



Code	Creek
1	Record
2	Swamp
3	Tobe
4	Rock
5	Bummer
6	Trout
7	Peak
8	L. Peak
9	Oliver
10	Rickard
11	Miller

length of stream with one or both sides flanked by clearcuts or recently installed plantations, length of stream affected by beaver in the forested reaches, and length of stream affected by beaver in the clearcuts and recently installed plantations.

Analysis

Accuracy

My assistant and I identified areas on the aerial photographs we thought to be beaver-affected, and ground checked for accuracy. I estimated stream length thought to be beaver-affected on the maps and areas actually beaver-affected using ArcView and compared them to create accuracy measurements. Although all basins with beaver dams were walked (and basins with no beaver sampled to ensure absence of beaver), use of aerial photographs enabled us to approximate stream lengths easily.

Impoundment Association

Measurements of length of stream obtained from the photographs were converted into percentages of total length of stream for clearcut, forest, beaver-affected clearcut reaches and beaver-affected forested reaches. Reaches were considered beaver-affected if they were actively impounded. The estimated relative quantity of impounded reaches among basins (percentage of the total basin affected by beaver) was regressed upon percentage of the stream reaches in the basin flanked by clearcut or young forest.

Results

Accuracy

Ground-truthing showed complete accuracy in identifying openings attributable to beaver impoundment history (since all openings of that kind were due to impoundment history, either active impoundments or meadows), but we were unable to distinguish between active impoundments and non-active meadows unless open water was readily visible. New dams were not visible on the photographs. Therefore, more meters of stream length were actually impounded than were identifiable from photographs (59% accuracy identifying all impoundments).

Impoundment Association

Beaver had an affinity for clearcuts within a basin in this region. Beaver actively impounded 80% of all available clearcut stream lengths, while only 29% of the suitable reaches were impounded in forested areas (percentages are from averaged meters across all drainages; Fig. 3.2). Swamp creek was the only creek in which beaver used more of the forested reaches than the clearcut reaches. It is worth noting that the harvested stands in that basin are quite recent, looking to be less than 2 years old.

Among basins, beaver used more of the stream reaches in more extensively cut basins than in basins that were not as extensively cut (R^2=0.30; p=0.08; Fig 3.3). One basin (Bummer Creek) was an outlier, at 57% cut and no beaver impoundments. Without Bummer Creek, the r^2 explains 55% of the variation and is significant at the 99% level (p=0.01).

Figure 3.2: Relative abundance of stream reach types among study basins containing beaver. Streams containing no beaver are not included (Oliver, Tobe, and Bummer Cr.)

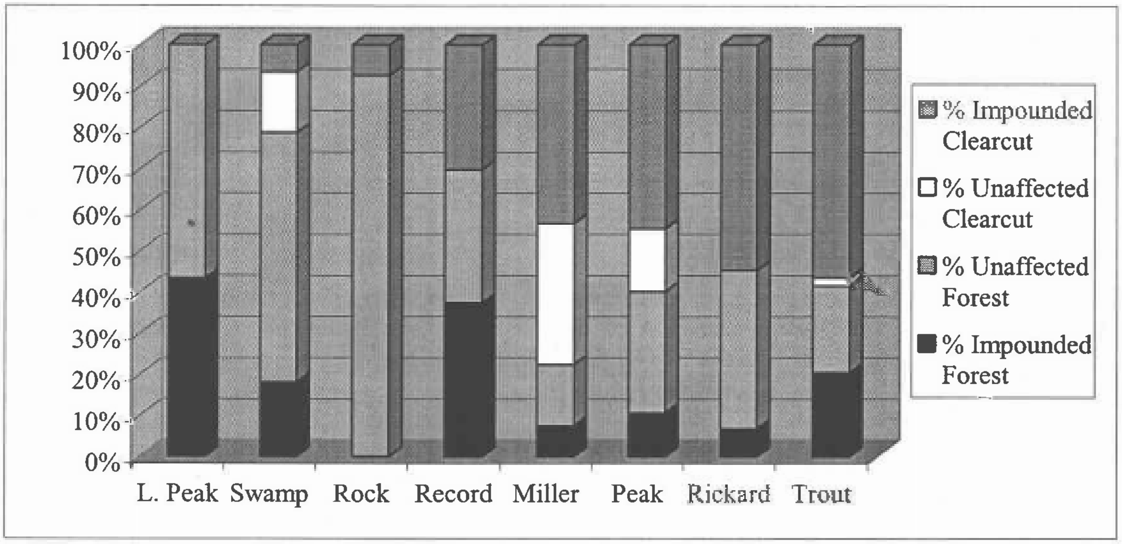
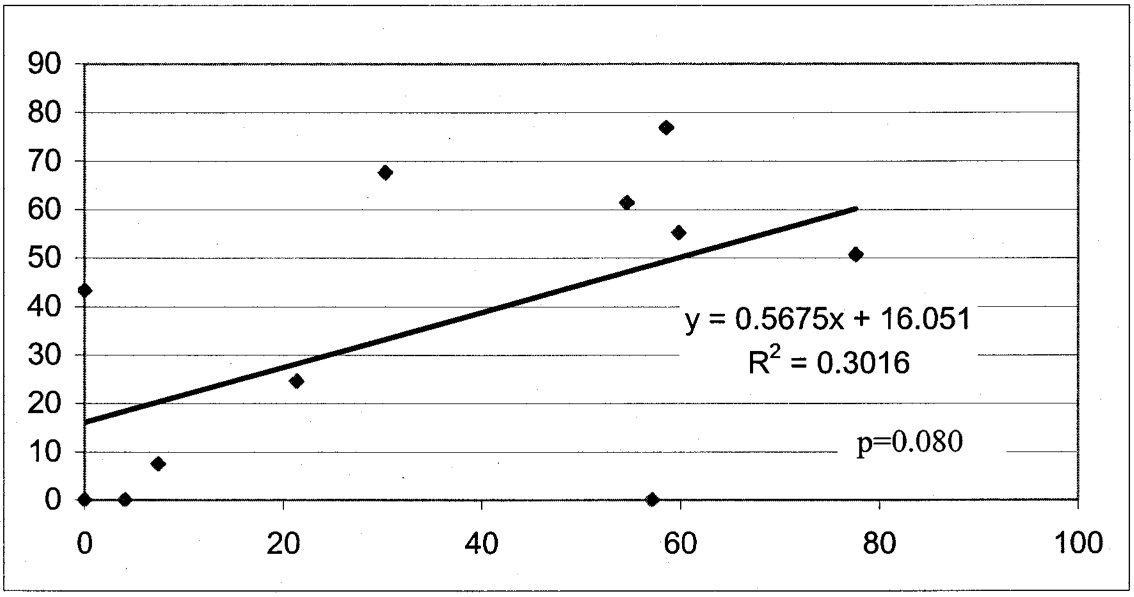


Figure 3.3: Relationship of available stream length impounded to percent of stream length adjacent to clearcut for 11 basins in the lower Alsea drainage and adjacent area.



Discussion

Recent aerial photographs can be used effectively to pinpoint some kinds of areas affected by beaver. Older, developed wetlands and abandoned meadows are observable on the photographs, but were not readily distinguished from one another before ground-truthing. So, ground-truthing is important when the two types must be distinguished. New dams that were not yet causing openings in the forest canopy could not be seen at all. In studies that are concerned with impoundments that are having an extensive effect on plant community structure, and in historical studies, aerial photographs can be quite useful (Johnston and Naiman 1990; Robel and Lloyd 1993; Snodgrass 1997; Remillard et al. 1987).

This study shows that beaver impoundments are correlated with clearcuts and young plantations in this area, for which there may be several possible explanations. First, beaver impoundments and recently cut reaches may both be preferentially located in low-gradient valley bottoms with silty substrates and narrow streams. Beaver are known to be associated with such areas, which are also areas with good road access and easily logged conditions. Correlation between recently cut stands and the topographic preferences of beaver (low gradient valley floors) in this area is unknown.

Alternately, beaver may be preferentially trapped out of older forested reaches by landowners. Landowners managing lands for timber production trap beaver from recently planted stands to protect seedlings (Brayton 1984; Mortenson 2000). It makes less sense that they might preferentially trap from older stands, although this strategy would make sense if implemented as part of an attempt to keep a metapopulation controlled over the landscape. The Coast Range is a complex matrix of ownership and land uses, and it is difficult to make conjectures about trapping frequency.

Finally, beaver may have stripped older stream reaches of browse and dam-building material, or material may just be easier to find in recently cut reaches. Beaver may be attracted and relocating to recently cut stream reaches. Dams in these areas looked to be most likely seasonal or year-old dams, constructed more recently than the area was cut, though we did not formally age the dams. The riparian areas I observed in reaches flanked by clearcuts or very young stands generally resembled the same kind of riparian conditions beaver create: open riparian areas with little shade and an abundance of herbaceous stems for summer feeding (Naiman et al. 1986; Naiman et al. 1988; Johnston and Naiman 1990b). Hardwood tree regeneration and shrubs that beaver prefer in the Coast Range were also plentiful in the regenerating clearcut sites I observed. In habitat suitability studies, silty substrate and food availability are two of the three most-cited parameters correlated with beaver (the third being wide valley floor with little gradient; Howard and Larson 1985; McComb et al. 1990; Hartman 1996; Barnes and Mallik 1997; Suzuki and McComb 1998).

Field observations of the type prompting this section of the analysis- namely old, developed dam networks that have been abandoned in close proximity to many new dams in cleared areas- seems is inconsistent with the hypothesis that landowners are trapping over the landscape to control metapopulations. Abandoned dams in older forests and fresh dams in recently cut reaches were twice found in close proximity on land owned by the same landowner.

A key ecological function of beaver in this system historically results not from the creation of new impoundments, which frequently do little to change the plant communities for 2 years or more (McCall 1996), but rather from the maintenance of old, developed wetlands (Chapter 1; Naiman et al. 1986; Naiman et al. 1988; Pollock et al. 1995). As beaver populations have begun to reclaim the Coast Range, they are encountering a system of land management quite different from their historical experience. Even-aged forest management in this region is quite pervasive; at least 39% of the land area in the Alsea Basin has been harvested so in approximately the last 3 decades (25% by private industry, 14% by the Bureau of Land Management; Garman 1999, Stanfield 2000). The Coast Range is a rapidly shifting mosaic of forest conditions. If beaver are relocating in response to the mosaic, the disturbance regime (abandonment and recolonization) will be altered as well.

Abandoned ponds have noticeably higher abundances of *Phalaris*, which I observed to occur frequently in pure stands at old beaver meadow sites (see Chapter 1). *Phalaris* then inhibits recolonization of those clearings by any other species (see Chapter 1; Lesica 1997; Uthus 1999). There is doubt in the literature that re-impoundment will control *Phalaris* (Morrison and Molofsky 1999; Uthus 1999), although some believe that it may be a means of control (Hutchinson 1992). *Phalaris* has been found to suffer and sometimes die following three consecutive days of complete impoundment (Rice 1993). I found several new dams (including one quite large one that had backed up quite a bit of water and impounded some *Phalaris*) in streams surrounded by pure *Phalaris* stands, indicating that beaver will recolonize invaded areas. However, whether the impoundments will control *Phalaris* invasion well enough for native plant communities to reassert themselves is unknown. These factors, namely the impact of relocation on disturbance intervals and the greater amounts of Phalaris in recolonization dams compared to established ones, may affect the ability of beaver to fulfill their keystone role within the ecosystem.

Beaver are known to contribute a unique (the only) wetland plant community and wildlife habitat to the Oregon Coast Range (see Chapter 1). Beaver have also been found to impact little area beyond the edge of the impoundment, although impoundments may sometimes cover extensive areas (see Chapter 1); the main browse effects are usually within 30 m of the water's edge (Liedholt-Brunner et al. 1992). Land managers that wish to manage for plant and wildlife diversity in addition to timber should consider relinquishing active beaver areas to animal use instead of undergoing time-consuming and usually expensive (Bhat et al. 1993) beaver control efforts.

SUMMARY

Beaver impoundments create a type of herbaceous/shrub community adjacent to the stream that is different in quality, if not richness, from debris jam impoundments and unimpounded sites. Beaver sites as a whole consisted of wetland type communities with a developed graminoid contingent. The differences are most apparent in the addition of the emergent zone, a unique feature of dam sites. Beaver impoundments are both more and less rich in species (on average similar) than jam or unimpounded sites (depending on the extent of invasion by *Phalaris arundinacea).* At dam sites, increases in *Phalaris* abundance parallel and presumably cause (Lesica 1997; Morrison and Molofsky 1998; Uthus 1999) a marked reduction in species richness.

Beaver impoundments are disproportionately associated with stream reaches flanked by clearcut or young stands in this area. These are the same kinds of reaches in which beaver populations are controlled by land managers out of concern for browse impacts on young conifers. I found no difference in tree and shrub communities around the three types of sites; beaver are not altering the communities in a significant way past the water's edge in this area, although they affect the positioning of the water's edge. Land managers that wish to manage for plant and wildlife diversity in addition to timber should consider relinquishing active beaver areas to animal use instead of undergoing time-consuming and usually expensive (Bhat 1993) beaver control efforts.

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APPENDICES

Appendix 1 : Area of impoundment types and vegetative zones. E:L is ratio of emergent zone area to littoral zone area. Dam codes refer to impoundment history (N=new (1-2 years); O=old; R=recolonization). Empty cell means data is unavailable.

Beaver Impoundments				
Basin/Site Number	Impounded area (m^2)	Emergent Zone Area (m^2)	Dam Code	E:L
L.Peak 1	9.9	24.44	N	1:2
L.Peak 2	1	.	N	0:1
L.Peak 3	1122	1122	O	6:1
Peak 1	16	.	R	0:1
Peak 2	16	.	R	0:1
Peak 3	12	.	R	0:1
Record 1	165.6	2502	R	88:1
Record 2	1.4	.	N	0:1
Record 3	4.8	.	N	0:1
Swamp 1	714	715	O	1:0
Swamp 2	.	.	O	1:0
Swamp 3	18	36	N	0:1

Appendix 2: Species list by site type.

Common Name	*Scientific name*	% ABUNDANCE of species in given type Dam	Jam	Unimpounded	FREQUENCY of PLOTS in which spp was present Dam	Jam	Unimpounded
Forest Communities							
Sitka willow	*Salix sitchensis*	100	0	0	4	0	0
Thimbleberry	*Rubus parviflorus/leucodermis*	91	0	9	5	0	1
Dull Oregon Grape	*Mahonia nervosa*	77	0	23	11	0	4
Cascara	*Rhamnus purshiana*	60	21	19	10	4	2
Red Elderberry	*Sambucus racemosa*	54	22	23	16	10	9
Red Alder	*Alnus rubra*	44	19	37	29	17	27
Big Leaf Maple	*Acer macrophyllum*	42	38	20	25	22	12
Stink Currant	*Ribes bracteosum*	40	47	13	5	4	1
Red huckleberry	*Vaccinium parvifolium*	36	33	31	15	10	11
Douglas-fir	*Pseudotsuga menziesii*	32	33	35	25	30	35
Vining Maple	*Acer circinatum*	31	37	32	59	55	57
Indian Plum	*Omleria cerasiformis*	31	56	12	6	9	3
Salmonberry	*Rubus spectabilis*	28	36	36	69	74	62
Red Cedar	*Thuja plicata*	25	45	29	6	12	7
Beaked Hazelnut	*Crylus cornuta*	24	40	36	26	32	30
Rose	*Rosa* sp.	24	60	15	1	1	1
Salal	*Gaultheria shallon*	21	68	11	5	14	5
Oceanspray	*Holodiscus discolor*	17	51	32	5	11	8
Trailing blackberry	*Rubus ursinus*	0	13	87	0	1	3
Red Elderberry	*Sambucus racemosa*	0	66	34	0	3	1
Devil's Club	*Oplopanax horridus*	0	100	0	0	2	0
Common Snowberry/ Waxberry	*Symphoricarpus albus*	0	100	0	0	1	0
Streamside Communities							
Common foxglove	*Digitalis purpurea*	100	0	0	25	0	0
Dagger-leaved rush	*juncus ensifolius*	100	0	0	25	0	0
Common Duckweed	*Lemna minor*	100	0	0	25	0	0
Sitka willow	*Salix sitchensis*	100	0	0	25	0	0
Himilayan Blackberry	*Rubus discolor*	100	0	0	17	0	0
Bur-reed	*Sparganium angustifolium*	100	0	0	17	0	0
Cattail	*Typha latifolia*	100	0	0	17	0	0
Oxeye Daisy	*Leucanthamum vulgare*	100	0	0	8	0	0
Muskwort	*Chara* sp.	100	0	0	8	0	0
Ovate Spikerush	*Eleocharis ovata*	100	0	0	8	0	0
Pearly Everlasting	*Anaphalis margaritacea*	100	0	0	8	0	0
Leafy pondweed	*Potamogeton* sp.	100	0	0	8	0	0
Common rush	*Juncus effusus*	96	4	0	42	8	0
Starwort	*Callitriche heterophylla*	89	1	10	75	8	8
Small-flowered Bulrush	*Scirpus microcarpus*	88	12	0	25	8	0
Cascara	*Rhamnus purshiana*	80	20	0	17	8	0
Willow weed	*Polygonum douglasii*	75	25	0	33	25	0

Canada Thistle	*Circeum arvense*	69	31	0	17	17	0
Crisp sandwort	*Stellaria crispa*	67	21	12	50	42	25
Forget-me-not	*Myostis* sp.	65	11	24	33	8	17
Wild ginger	*Asarum cadatum*	64	16	20	25	8	8
American brooklime	*Veronica beccabunga*	55	9	36	25	17	25
Reed Canary Grass	*Phalaris arundinacea*	50	22	29	83	50	58
Red Alder	*Alnus rubra*	38	62	0	25	17	0
Water parsley	*Oenanthe sarmentosa*	38	40	23	50	33	58
Yellow monkeyflower	*Mimulus guttatus*	33	5	63	33	8	8
Vining Maple	*Acer circinatum*	26	39	35	25	25	25
Cow Parsnip	*Heracleum lanatum*	25	0	75	8	0	8
Muskflower	*Mimulus moschatus*	23	27	51	33	50	33
Cleavers	*Galium aparine*	22	43	35	50	58	50
Ladyfern	*Athyrium felix-femina*	21	34	45	50	25	42
Mexican hedgenettle	*Stachys mexicana*	18	45	37	33	58	50
Horsetail	*Equisetum*	17	73	9	17	33	25
Stinging nettles	*Urtica dioica*	17	15	67	33	25	42
Curled Dock	*Rumex crispus*	16	0	84	8	0	17
Trailing blackberry	*Rubus ursinus*	15	62	22	25	17	33
Bracken Fern	*Pteridium aquilinum*	14	31	56	17	25	33
Glyceria	*Glyceria*	9	51	40	42	50	33
Candyflower	*Claytonia sibirica*	8	58	33	17	50	33
Redwood sorrel	*Oxalis oregena*	7	32	61	25	67	83
Salmonberry	*Rubus spectabilis*	7	63	30	42	83	83
Saxifrage	*Saxifrage* sp.	3	65	32	58	75	75
Water-carpet	*Chrysosplenium* sp.	3	97	0	8	8	0
Sword fern	*Polystichm munitum*	2	32	66	25	33	25
Bleeding Heart	*Dicentra formosa*	1	5	93	8	17	17
Enchanters nightshade	*Circaea alpina*	0	27	73	0	17	42
Little buttercup	*Ranunculus uncinatus*	0	0	100	0	0	17
Red Elderberry	*Sambucus racemosa*	0	9	91	0	8	17
False Lily-of-the-valley	*Maianthemum dilatatum*	0	37	63	0	8	17
Agrostis	*Agrostis spp.*	0	100	0	0	8	0
Ryegrass	*Lolium perenne*	0	100	0	0	8	0
Big Mans' Foot	*Marah oregana*	0	0	100	0	0	8
European Bittersweet	*Solanum dulcamara*	0	0	100	0	0	8
Luzula	*Luzula spp.*	0	100	0	0	8	0
Maidenhair fern	*Adiantum pedatum*	0	100	0	0	8	0
Oceanspray	*Holodiscus discolor*	0	100	0	0	8	0
Pacific Waterleaf	*Hydrophyllum tenupis*	0	0	100	0	0	8
Poa	*Poa* sp.	0	0	100	0	0	8
Salal	*Gaultheria shallon*	0	100	0	0	8	0
Star-flowered False Solomon's seal	*Smilacina stellata*	0	100	0	0	8	0
Stink Currant	*Ribes bracteosum*	0	100	0	0	8	0

Appendix 3 : Lengths of stream impounded by Beaver by riparian forest type.

Stream	Unaffected Forest (m)	Impounded Forest (m)	Unaffected Clearcut (m)	Impounded Clearcut (m)	Total (m)
Rock	3577	0	0	288	3865
Swamp	2040	606	497	220	3363
Record	683	789	0	637	2109
Rickard	1020	179	0	1444	2643
Trout	1013	984	102	2717	4816
Peak	1251	449	646	1884	4230
Miller	350	173	802	1012	2337
Average	1419.14	454.29	292.43	1171.71	3337.57
Bummer	1871	0	2494	0	4365
Oliver	3678	0	0	0	3678
L. Peak	1287	981	0	0	2268
Tobe	4447	0	189	0	4636

Stream	% Impounded Forest	% Unaffected Forest	% Impounded Clearcut	% Unaffected Clearcut
Rock	0.00	1.00	1.00	0.00
Swamp	0.23	0.77	0.31	0.69
Record	0.54	0.46	1.00	0.00
Rickard	0.15	0.85	1.00	0.00
Trout	0.49	0.51	0.96	0.04
Peak	0.26	0.74	0.74	0.26
Miller	0.33	0.67	0.56	0.44
Average	0.29	0.71	0.80	0.20
Bummer	0.00	1.00	0.00	1.00
Oliver	0.00	--	--	1.00
L. Peak	0.43	0.57	--	--
Tobe	0.00	1.00	0.00	1.00