AN ABSTRACT OF THE THESIS OF

Nobuya Suzuki for the degree of Master of Science in Wildlife Science presented on February 19, 1992.

Title: Habitat Classification and Characteristics of Small Mammal and Amphibian Communities in Beaver-pond Habitats of the Oregon Coast Range.

Abstract approved: Signature redacted for privacy.
William C. McComb

During 1988-1989, stream habitat variables were compared between beaver-dam sites and unoccupied-stream sites to identify variables that may have been important for beaver (Castor canadensis) in selecting dam sites in the streams of the Drift Creek basin, Lincoln County, Oregon. Increasing valley floor width and grass/sedge cover and decreasing stream width, stream gradient, red alder (Alnus rubra) cover, and shrub cover had positive effects on selection of dam sites. A discriminant function model correctly classified 83 % of beaver-dam sites and 88 % of unoccupied-stream sites with chance-corrected classification rate of 69 % (Kappa statistic).

Applicability of the U.S. Fish and Wildlife Service Habitat Suitability Index (HSI) model for beaver was tested in the basin. HSI-model scores were highly

influenced by the water life requisite and differed between dam sites and unoccupied sites. Scores for the food life requisite did not differ between dam sites and unoccupied sites; food may not be a factor influencing selection of dam sites. The water fluctuation variable was subjective and was not sensitive enough to differentiate dam sites from unoccupied sites. Three geomorphic characteristics (stream width, gradient, and valley floor width) were used in developing a new Habitat Suitability Index (HSI) model for the basin. The HSI model scores produced by the new model were different between dam sites and unoccupied sites.

Capture frequencies of small mammal and amphibian species were compared between beaver-occupied reaches and unoccupied reaches in 5 streams in the Oregon Coast range during the fall of 1989. Species richness, species diversity, and equitability of small mammal and amphibian communities did not differ between occupied and unoccupied reaches. The capture frequency of Microtus spp. was consistently higher at occupied reaches than at unoccupied reaches. None of small mammal and amphibian species had consistently higher or lower capture frequencies at occupied reaches than at unoccupied reaches in each of 5 streams. Inconsistent abundance of small mammal and amphibian species may reflect diverse habitat conditions among occupied reaches.

Habitat Classification and Characteristics of Small Mammal and Amphibian Communities in Beaver-pond Habitats of the Oregon Coast Range

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HABITAT CLASSIFICATION AND CHARACTERISTICS OF SMALL MAMMAL AND AMPHIBIAN COMMUNITIES IN BEAVER-POND HABITATS OF THE OREGON COAST RANGE

CHAPTER I: GENERAL INTRODUCTION

Historically, beaver (Castor canadensis) were found in streams, lakes, and marshes throughout North America from Alaska to northern Mexico (Naiman et al.1988, Anderson 1964). An estimate of beaver populations throughout their range before beaver were being exploited for fur trade was at least 60 million (Seton 1929). Beaver nearly became extinct from North America by 1900, but they have been protected from trapping and reintroduced into their former range (Anderson 1964). Populations have recovered to a current estimate of 6-12 million individuals (Naiman et al. 1988). There are now about 70,000 beaver in Oregon of which half occur in coastal streams (Guthrie and Sedell 1988).

Beaver alter riparian habitats through cutting woody plants and building dams (Naiman et al. 1988). Intense foraging by beaver reduces biomass and changes the structure and composition of riparian forests (Johnston and Naiman 1990). Beaver dams modify stream hydrology, accumulate sediments, and increase wetted surface area of the channel (Gard 1961, Naiman et al. 1986). Streamside areas flooded by beaver become wetland habitats that attract various wildlife species (Beard 1953, Rutherford

1955, Hair et al. 1978).

Excessive beaver populations can sometimes cause economic loss by blocking irrigation ditches, flooding roads, commercial timber lands, and agriculture fields (Grasse and Putnum 1950, Yeager and Hill 1954, Chabreck 1958, Arner 1964, and Maser et al. 1981). On the other hand, wildlife managers can use beaver as a management tool to reduce streambank erosion, to restore riparian vegetation, and to improve stream and streamside habitats for fish and wildlife species (Brayton 1984, Apple 1985, Parker et al. 1985).

Two main objectives of my study were to identify stream habitat variables associated with beaver dams (CHAPTER II) and to compare small mammal and amphibian communities between beaver-occupied and unoccupied riparian habitats of the Oregon Coast range (CHAPTER III).

CHAPTER II: HABITAT CLASSIFICATION MODEL FOR BEAVER IN THE OREGON COAST RANGE

INTRODUCTION

Habitat classification models have been developed to quantify a relationship between selected ecological factors and the potential abundance of beaver or the quality of beaver habitats (Allen 1983, Beier and Barrett 1987). Allen (1983) developed the U.S. Fish and Wildlife Service Habitat Suitability Index (HSI) model for beaver based on habitat-requirement information provided by previous studies and expert opinions. Others have used multivariate statistics to identify physical and vegetative characteristics that seem to influence selection of habitat by beaver (Beier and Barrett 1987), longevity of beaver colonies (Howard and Larson 1985), and density of beaver colonies (Slough and Sadleir 1977, Howard and Larson 1985). Most of these models, except the U.S. Fish and Wildlife Service HSI model, were developed for specific regions of North America.

To my knowledge, no habitat classification models have been developed for beaver in the streams of the Oregon Coast range and the applicability of existing models has not been tested. Habitat classification models help managers to identify potential beaver habitat and to inventory riparian habitat that could be used to enhance populations of beaver and associated fish and wildlife species.

My objectives were: 1) to describe the distribution and abundance of beaver dams in the Drift Creek basin, 2) to describe habitat variables associated with beaver dams in the basin, 3) to develop a habitat classification model for the basin, and 4) to test the applicability of the U.S. Fish and Wildlife HSI model.

STUDY AREA AND METHODS

The Drift Creek basin is located in the western slope of the central Oregon Coast Range, Lincoln County, Oregon (Fig. 1). Drift Creek and its tributaries drain 179 km^2 in area and the elevation of the drainage ranges from sea level to 860 m. Annual temperature averages 10.3 °C and precipitation averages 249.6 cm in the Oregon Coast Range (Franklin and Dyrness 1973).

Red alder (Alnus rubra) and Douglas-fir (Pseudotsuga menziesii) were the most common tree species found throughout the area. Other tree species included western hemlock (Tsuga heterophylla), western redcedar (Thuja plicata), and bigleaf maple (Acer macrophyllum). Salmonberry (Rubus spectabilis) was the dominant understory-shrub species. Other understory vegetation included vine maple (A. circinatum), elderberry (Sambucus racemosa), thimbleberry (R. parviflorus), stinking currant (Ribes bracteosm), huckleberries (Vaccinium spp.), devil's-club (Oplopanax horridum), western swordfern

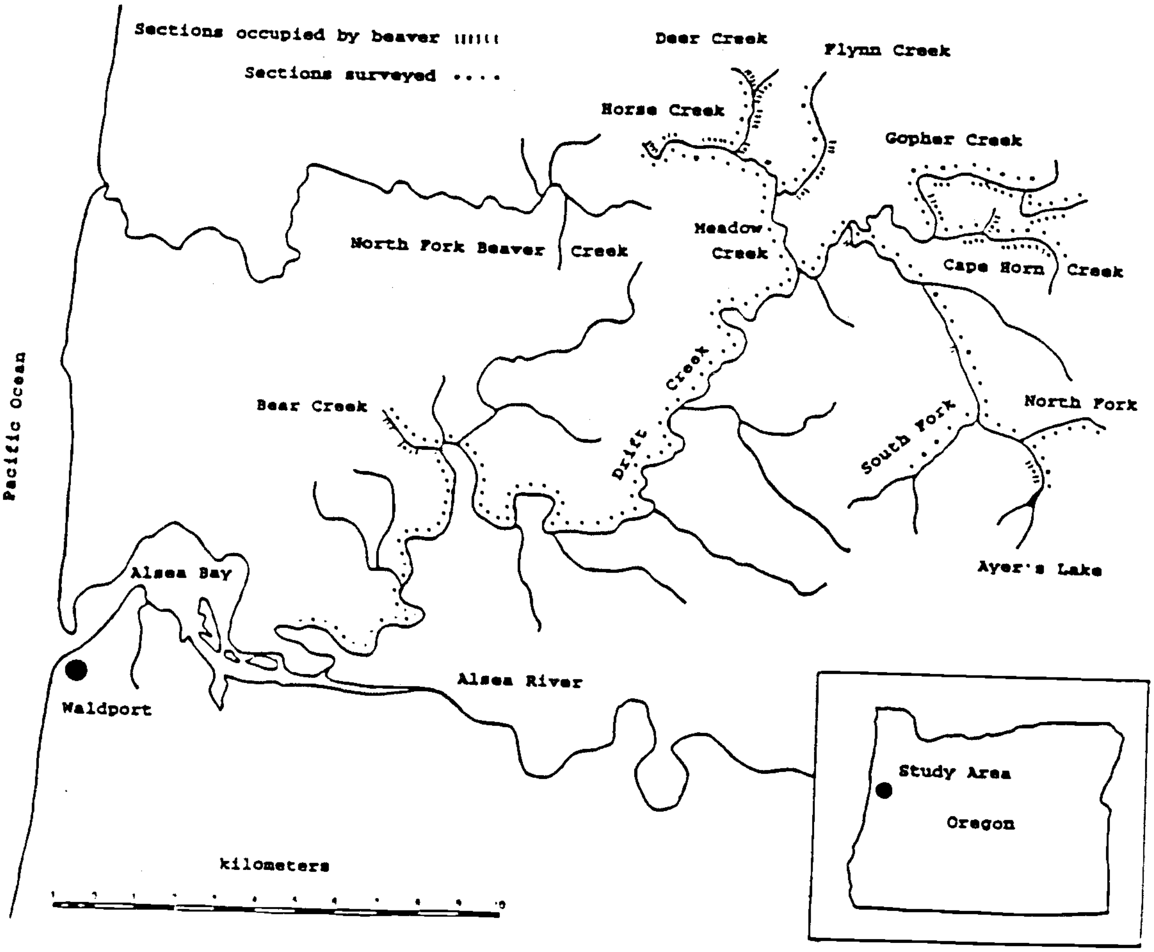


Figure 1. Location of the Drift Creek basin and map showing the stream section surveyed and the stream section occupied by beaver, Lincoln County, Oregon, 1988-1989.

(Polystichum munitum), sedges (Carex spp.), and various forbs and grasses.

In the fall of 1988 and 1989, I walked Cape Horn Creek, Gopher Creek, Deer Creek, Horse Creek, Bear Creek, and Drift Creek below Ayer's Lake and located beaver dams on topographic maps (scale 1:24000). A fish habitat survey conducted by the OSU stream team in the summer of 1988 and 1989 provided additional information on the number of beaver dams and channel geomorphology in the Flynn Creek, South Fork Drift Creek, North Fork Drift Creek, and the Main Stem of Drift Creek. Based on beaver dam locations, each stream was divided into beaver-occupied and beaver-unoccupied sections (Fig. 1).

Nineteen habitat variables, which represent channel geomorphology and percent cover by trees, shrubs, and herbs were measured at 40 randomly selected beaver-dam sites and at 72 randomly selected points within the beaver-unoccupied sections of streams (Table 1). Because few dams were found on the 4th-order and 5th-order sections of Drift Creek, all the sampling points for habitat survey were selected in 1st- to 3rd-order streams. A 20-m radius sampling plot was centered on a randomly assigned stream bank adjacent to the dam. Percent cover of trees and shrubs was estimated within the 20-m radius plot and percent cover of herbaceous vegetation was estimated within a nested 10-m radius plot. Stream width

Table 1. Variables measured at beaver-dam sites and unoccupied sites, Drift Creek Basin, Lincoln County, Oregon, 1988-1989.

Types of variable Variable	Method
Geomorphic	
Stream width (m)	A bank-full width measured immediately below a dam or at a random site with a meter tape.
Stream depth (m)	A bank-full depth, a distance between stream bed and top of bank, measured immediately below a dam or at a random site.
Stream gradient (%)	Average of 20-m upstream and 20-m downstream gradient measured with a clinometer.
Valley floor width (m)	Width of 100-year flood plain measured with a meter tape.
Bank slope (%)	Average percent slope of ground between the channel and a point 20 m away from the channel measured with a clinometer.

Table 1. Continued

Types of variable Variable	Method
Vegetative	
Tree canopy (%)	Ocular estimate of total tree-canopy cover over a 20-m radius plot.
Overstory tree (%)	Ocular estimate of tree-canopy cover > 20 m in height over a 20-m radius plot.
Midstory tree (%)	Ocular estimate of tree-canopy cover (4-20 m in height) over a 20-m radius plot.
Shrub canopy (%)	Ocular estimate of total cover by shrubs (woody stems < 4 m in height) over a 20-m radius plot.
Grass/sedge cover (%)	Ocular estimate of graminoid cover over a 10-m radius plot.
Forb cover (%)	Ocular estimate of forb cover over a 10-m radius plot.
Fern cover (%)	Ocular estimate of fern cover over a 10-m radius plot.
Bare ground (%)	Ocular estimate of bare ground over a 10-m radius plot.

Table 1. Continued

Types of variable Variable	Method
Cover by selected woody species (%)[a]	Ocular estimate of cover of each tree and shrub species over a 20-m radius plot

[a] red alder, Douglas-fir, salmonberry, elderberry, vine maple, stinking currant.

and depth were measured immediately below the dam so that the measurement reflected the original channel characteristics. Habitat variables were examined for normality by normal-probability plot and $\underline{W}$ statistic (SAS Institute Inc. 1988:413). Logarithmic and square root transformations were attempted on all non-normal variables. Non-normal variables, that could not be transformed ($\underline{W} < 0.7$), were excluded from the analyses. Variables were compared between dam sites and unoccupied sites with a Student's $\underline{t}$-test. Linear correlations between all possible pairs of the variables were examined with Pearson's correlation coefficient (Devore and Peck 1986:113).

I used stepwise discriminant analysis to select a combination of variables which best separated dam sites from unoccupied sites. Multicollinearity among the variables was reduced by testing correlated variables ($\underline{r} > 0.6$) separately in a multivariate analysis. All possible combinations of these variables were tested. Linear discriminant function analysis, using the selected combination of variables, was used to develop a habitat classification model. The linear combination of variables that maximized the correct classification level with a linear discriminant analysis was chosen as a final classification model.

The applicability of an existing Habitat Suitability Index (HSI) model was tested in the basin (Allen 1983). The model, which consists of life requisite indices for food and water, produces scores from 0.0 (unsuitable habitat) to 1.0 (optimum habitat). Scores for the HSI model were calculated for each habitat sampling plot and the scores were compared between dam sites and unoccupied sites with a Student's _t_-test.

The original HSI model was modified to improve its performance in the basin by adding variables that the discriminant analysis identified as potentially important in distinguishing between dam-sites and unoccupied sites. Indices that were not sensitive to local conditions were deleted from the model. Using descriptive statistics, I adjusted values of all the indices to meet characteristics of the stream habitat used by beaver in the basin.

RESULTS

Density and Distribution of Beaver Dams

The stream survey covering 65 km of Drift Creek and its tributaries found 170 beaver dams of which 166 dams (98%) were found in 1st- to 3rd-order streams (map scale 1:24000). Only 4 dams (2%) were found in the 4th-order section, and none were found in 5th-order section of Drift Creek. Average stream widths increased from 1st-order tributaries to the 5th-order main stem of the Drift Creek while average stream gradients decreased (Table 2).

Table 2. Comparison of mean (SE) stream widths and stream gradients, and beaver dam density among streams with different orders, Drift Creek Basin, Lincoln County, Oregon, 1988-1989.

Stream order[a]	Width (m)	Gradient (%)	Dams/km
1	3.7(0.1)	3.0(0.3)	4.2
2	4.6(0.1)	3.0(0.3)	4.5
3	6.2(0.2)	1.3(0.1)	1.5
4	14.2(0.2)	1.2(0.1)	0.5
5	26.3(0.3)	0.7(0.1)	0.0

[a] The stream order was determined from the U.S. Geological Survey topographic map (scale 1:24000).

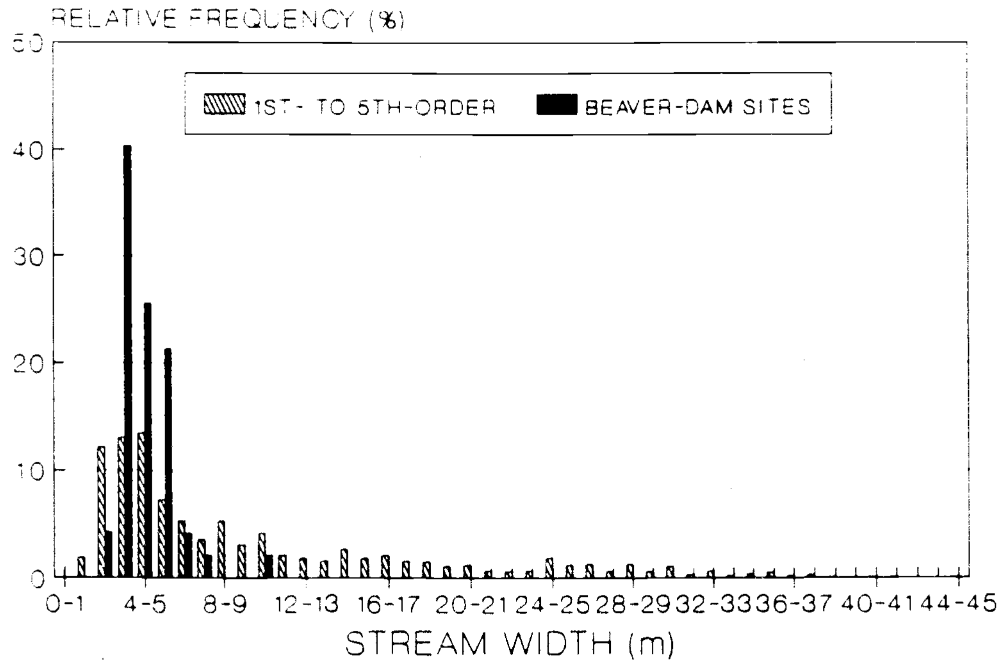


Figure 2. Comparison of relative frequencies of stream widths between 1st- to 5th-order streams and beaver-dam sites in the Drift Creek basin.

Dam density was high in 1st-order and 2nd-order streams and decreased in 3rd-order streams and 4th-order streams (Table 2). The overall dam density was 2.6 dams/km. Widths of streams used by beaver ranged from 2.6 m to 10.0 m, but the widths of the 1st- to 5th-order streams in the basin ranged from 1.0 m to 45.0 m (Fig. 2).

Univariate Comparison of Habitat Variables

Stream gradient and bank slope were lower at dam sites and the valley floor width was wider at dam sites than at unoccupied-stream sites (Table 3). Beaver dam-sites had higher percent coverage by forbs and grasses/sedges and had lower percent coverage by ferns, shrubs, midstory trees, and total tree canopy than unoccupied-stream sites. Red alder, salmonberry, and stinking currant coverages were lower at dam sites than at unoccupied sites. Elderberry cover was higher at dam sites than at unoccupied-stream sites.

Discriminant Analysis

Strong correlations were found between stream width and depth ($\underline{r}$ = + 0.60), valley floor width and bank slope ($\underline{r}$ = - 0.70), shrub cover and salmonberry cover ($\underline{r}$ = + 0.70), and tree-canopy cover and red alder cover ($\underline{r}$ = + 0.92). Correlated variables were tested separately in discriminant analyses. Other variables included in the discriminant analysis were forb cover, fern cover, grass/sedge cover, and Douglas-fir cover.

Table 3. Comparison of mean (SE) habitat variable between the beaver-dam sites and unoccupied-stream sites, Drift Creek Basin, Lincoln County, Oregon, 1988-1989.

Variables	Dam sites (n = 40)	Unoccupied (n = 72)	$P < t$
Stream width (m)	4.1 (0.1)	4.8 (0.2)	0.1192
Stream depth (m)	0.7 (0.0)	0.7 (0.0)	0.2589
Stream gradient (%)	2.2 (0.2)	3.9 (0.4)	0.0007
Valley floor width (m)	32.8 (2.0)	22.7 (1.4)	0.0001
Bank slope (%)	31.8 (2.8)	45.6 (2.8)	0.0015
Tree Canopy (%)	38.8 (2.4)	52.9 (2.3)	0.0001
Overstory tree (%)	22.6 (3.4)	27.8 (2.7)	0.2412
Midstory tree (%)	20.3 (3.1)	29.7 (3.2)	0.0378
Shrub canopy (%)	56.0 (1.6)	65.1 (1.8)	0.0001
Bare ground (%)	9.0 (1.4)	7.6 (1.1)	0.4426
Grass/sedge cover (%)	59.0 (5.0)	25.2 (2.4)	0.0000
Forb cover (%)	45.0 (2.0)	38.9 (1.7)	0.0280
Fern cover (%)	12.5 (1.7)	18.2 (1.4)	0.0138
Red alder (%)	34.5 (2.9)	47.7 (2.8)	0.0030
Douglas-fir (%)	8.0 (1.8)	8.1 (1.4)	0.9802
Salmonberry (%)	46.5 (2.5)	58.2 (1.8)	0.0003
Elderberry (%)	16.0 (2.3)	10.1 (1.3)	0.0468
Vine maple (%)	13.1 (2.1)	14.3 (1.6)	0.6613
Stinking currant (%)	4.9 (2.1)	11.0 (1.5)	0.0039

Three untransformed geomorphic variables (stream width, stream gradient, and valley floor width) and 3 untransformed vegetative variables (total shrub cover, grass/sedge cover, and red alder cover) best separated dam sites from unoccupied sites (Table 4). Increasing valley floor width and grass/sedge cover, and decreasing stream width, stream gradient, red alder cover, and shrub cover had positive effects on dam site selection. The model correctly classified 83 % of beaver dam sites and 88 % of unoccupied stream sites with the chance-corrected classification rate (Kappa statistic) of 69 %.

The linear discriminant function model was:

$$
\begin{aligned}
DF = &+ 0.069 * (\text{valley floor width [m]}) \\
&- 0.364 * (\text{stream gradient [\%]}) \\
&- 0.545 * (\text{stream width [m]}) \\
&- 0.064 * (\text{red alder cover [\%]}) \\
&- 0.098 * (\text{shrub cover [\%]}) \\
&+ 0.024 * (\text{grass/sedge cover [\%]}) \\
&+ 9.167.
\end{aligned}
$$

Using DF = 0 as a dividing point, the discriminant function classified positive values as dam sites and negative values as unoccupied sites. The 3 geomorphic variables, (valley floor width, stream gradient, and stream width) alone correctly classified 83 % of dam sites and 67 % of unoccupied sites with the chance-corrected classification rate (Kappa statistic) of 50 %.

Table 4. Unstandardized and standardized discriminant function coefficients for habitat variables measured at beaver-dam sites and unoccupied sites, Drift Creek Basin, Lincoln County, Oregon, 1988-1989.

Variables	Unstandardized	Standardized	r[a]
Valley floor width (m)	+0.069	+0.855	+0.521
Stream gradient (%)	-0.364	-1.001	-0.414
Stream width (m)	-0.545	-0.960	-0.264
Red alder cover (%)	-0.064	-1.419	-0.394
Shrub cover (%)	-0.098	-1.139	-0.502
Grass/sedge cover (%)	+0.024	+0.594	+0.774
Constant	-9.167		

[a]Correlations between habitat variables and a discriminant function axis.

The linear discriminant function model of geomorphic variables was:

$$
\begin{aligned}
DF = &- 0.484 * (\text{stream width [m]}) \\
&+ 0.060 * (\text{valley floor width [m]}) \\
&- 0.239 * (\text{stream gradient [\%]}) \\
&+ 1.210.
\end{aligned}
$$

Habitat Suitability Index (HSI) Model

Assessment of Original HSI Model

HSI scores of the original model were higher at dam sites than at unoccupied sites (Table 5). However, the original model predicted 95 % (38/40) of dam sites and 78 % (56/72) of unoccupied sites as optimum beaver habitats (HSI score = 1.0, Fig. 3). Index scores (IS) for the food life requisite did not differ between dam sites and unoccupied sites. The model indicated that 98 % (39/40) of dam sites and 93 % (67/72) of unoccupied sites had optimum food supply (IS $\geq$ 1.0). Either the food life requisite variables were not sensitive enough to separate the dam sites from the unoccupied sites or food was not a limiting factor for beaver in selection of their dam sites. The water fluctuation variable was subjective and was not sensitive enough to differentiate dam sites from unoccupied sites. All the sites that I surveyed were on perennial streams and had enough water to keep bank den entrances under the water during the summer low flow,

Table 5. HSI-score means (SE) for the beaver-dam sites and unoccupied-stream sites in the Drift Creek basin, Lincoln County, Oregon, 1988-1989.

Model Indices	Dam sites (n = 40)	Unoccupied (n = 72)	$P < t$
USFW HSI model			
HSI score	0.98 (0.01)	0.91 (0.02)	0.0075
Food life requisite	1.58 (0.04)	1.59 (0.03)	0.8019
Water life requisite	0.99 (0.01)	0.92 (0.02)	0.0054
Stream gradient Index	0.99 (0.01)	0.92 (0.02)	0.0054
New HSI model			
HSI score	0.83 (0.03)	0.38 (0.04)	0.0001
Stream width Index	0.91 (0.02)	0.75 (0.03)	0.0001
Valley floor Index	0.92 (0.03)	0.59 (0.05)	0.0001
Stream gradient Index	0.97 (0.02)	0.79 (0.04)	0.0003

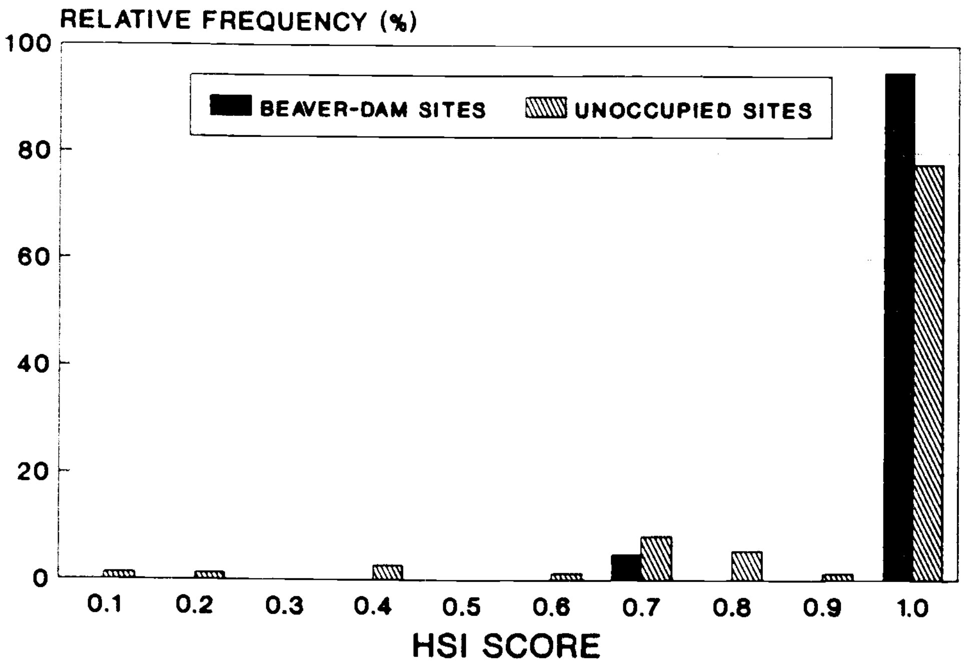


Figure 3. Comparison of HSI score distributions between beaver-dam sites and unoccupied sites in the original HSI model.

therefore, they were classified as having small water fluctuation (IS = 1.0). Because all sites had an optimum level of water fluctuation, index scores for life requisites of water were exactly equal to scores for the stream gradient. Index scores of stream gradient and water life requisites for dam sites were higher than that of unoccupied sites (Table 5). The model indicated that 98 % (39/40) of dam sites and 81 % (58/72) of unoccupied sites had optimum stream characteristics for beaver (IS = 1.0).

Developing a New HSI Model for the Drift Creek Basin

I constructed a new HSI model using the data collected from the Drift Creek basin. Three geomorphic indices (stream gradient index, stream width index, and valley floor index) were included in the new model. I did not include an index of water fluctuation and life-requisite indices of winter food in the new model.

Stream Gradient Index

The U. S. Fish and Wildlife Service HSI model considers stream gradients < 6 % as optimum gradients for dam sites (Allen 1983). In northern California, 91 % of active colonies were found on the streams that had gradient < 2 %, and no beaver dam was reported on the streams that had gradient > 12 % (Beier and Barrett 1987). In the Drift Creek basin, 67 % of beaver dams were found on the streams that had gradient < 3 % (Fig. 4).

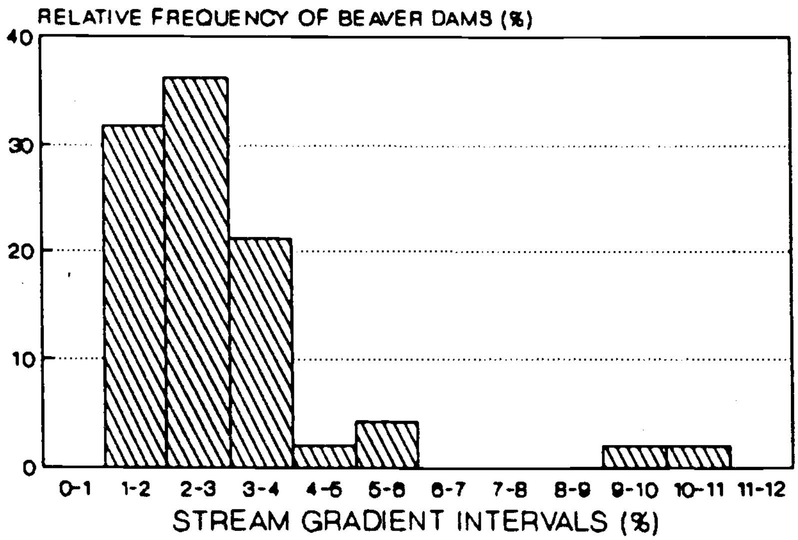


Figure 4. Relative frequency of beaver dams at different stream gradients.

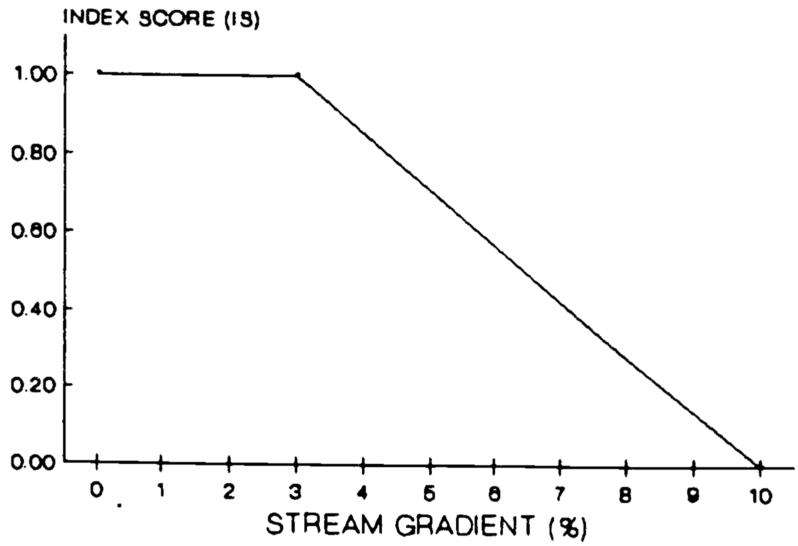


Figure 5. Index scores for stream gradient in the new HSI model.

Frequency of dams decreased as stream gradient increased from 3 % to 10 %. No beaver dams were observed on a stream with a gradient > 10 %. Therefore, stream gradients < 3 % were considered optimum (IS = 1.0) for dam sites and stream gradients > 10 % were considered unsuitable (IS = 0.0) for dam sites in the basin (Fig. 5).

Stream width Index

Howard and Larson (1985) indicated that their classification model should only be applied to streams that had widths < 8 m. I found beaver dams most frequently on the streams 3 - 4 m wide (Fig. 2 and 6). Dam frequency decreased as the streams became wider. No beaver dams were found in the streams that had widths > 10 m or < 2 m. Streams 3 - 4 m wide are considered optimum for dam sites (IS = 1.0, Fig. 7), while stream widths < 2 m or > 10 m are considered unsuitable for dam sites (IS = 0.0).

Valley floor Index

Allen (1983) indicated that streams that had valley floors > 46 m wide provided optimum beaver habitat. In the Drift Creek basin, beaver dams were most frequently found on streams that had valley floors 25 - 30 m wide (Fig 8). Seventy-seven percent of dams were found on streams that had valley floors > 25 m wide. No beaver dams were found on the streams that had valley floors < 10 m wide. Therefore, valley floor widths > 25 m are

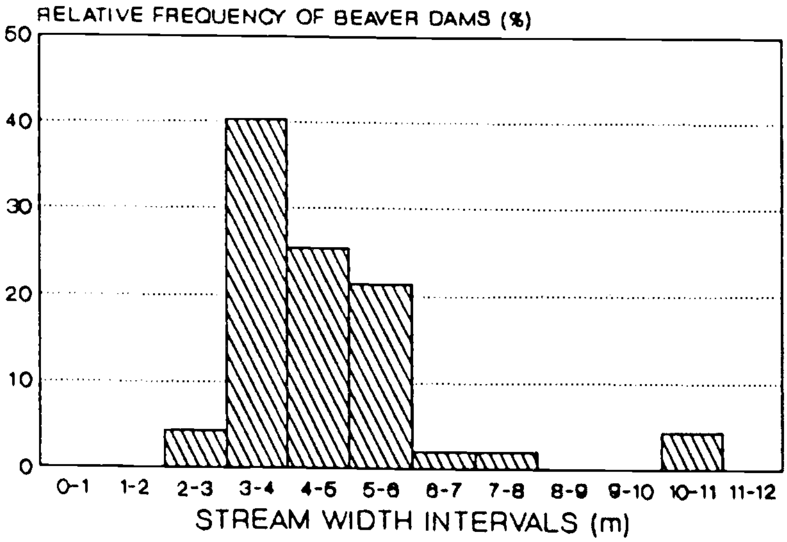


Figure 6. Relative frequency of beaver dams at different stream widths.

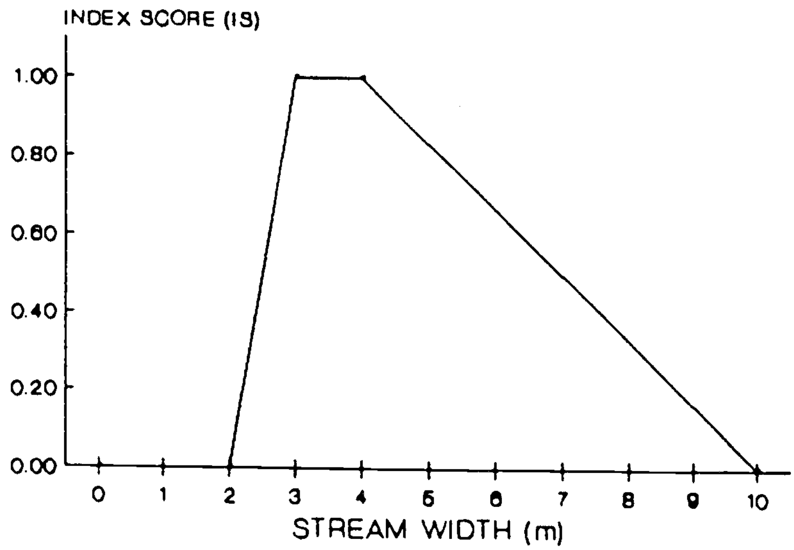


Figure 7. Index score for stream width in the new HSI model.

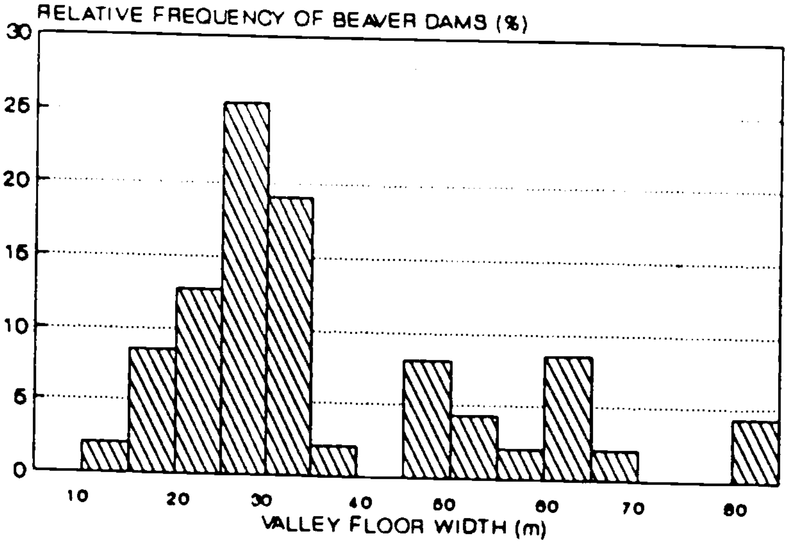


Figure 8. Relative frequency of beaver dams at different valley floor widths.

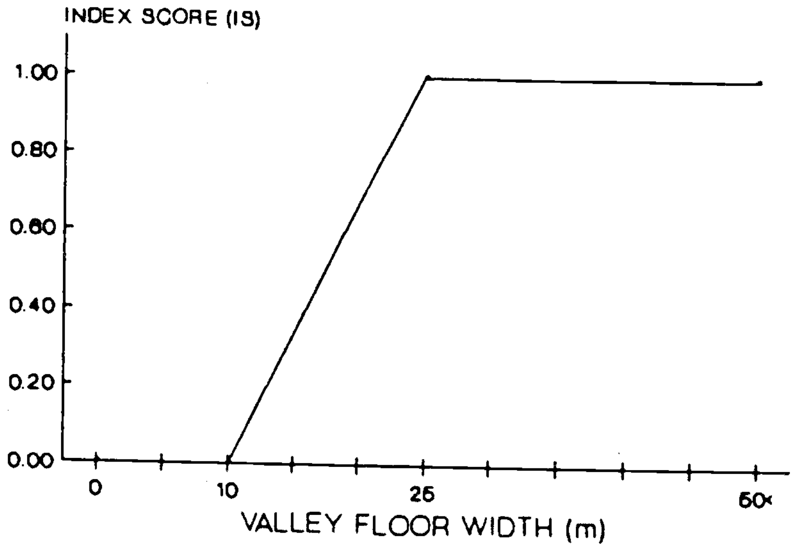


Figure 9. Index scores for valley floor width in the new HSI model.

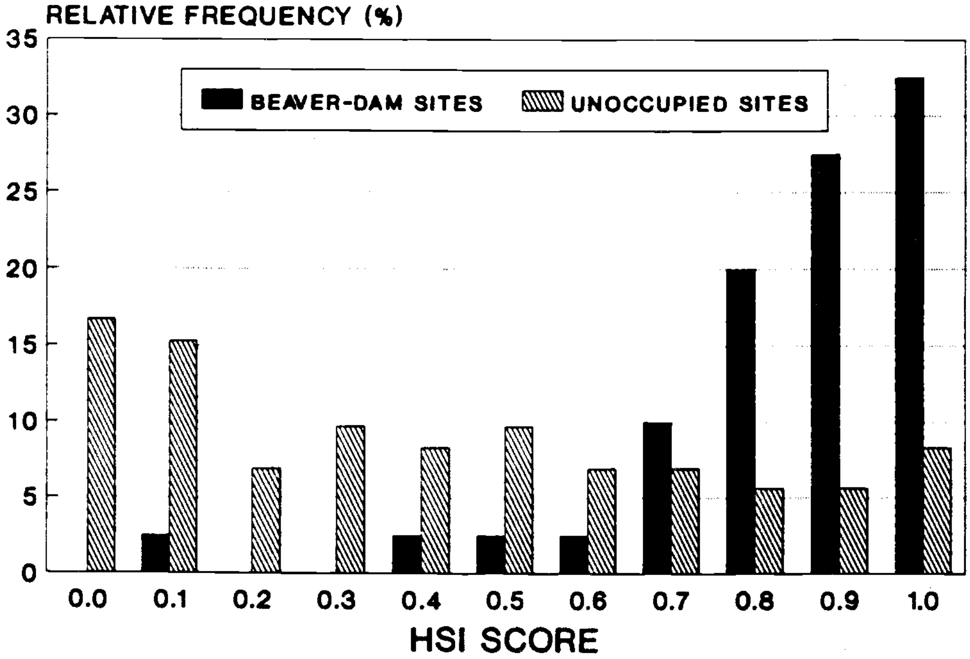


Figure 10. Comparison of HSI score distributions between beaver-dam sites and unoccupied sites in the new HSI model.

considered optimum for beaver dam sites (IS = 1.0, Fig. 9) and valley floor widths < 10 m are considered unsuitable for dam sites (IS = 0.0).

HSI Scores

Based on the limiting factor method (U.S. Fish and Wildlife Service 1981:103-ESM-3-31), a HSI score for a stream site is equal to the lowest index score (IS) obtained for either stream gradient index, stream width index, or valley floor index. The HSI scores produced by the new model were different between the beaver dam sites and the unoccupied sites (Table 5). Differences in distribution of HSI scores between dam sites and unoccupied sites were more obvious in the new model than in the original HSI model (Fig. 3, Fig. 10).

Alternative HSI model

The abundance of beaver dams relative to the availability of a particular stream gradient, stream width, and valley floor width was considered in developing an alternative HSI model. In this alternative model, valley floor widths > 50 m and stream widths 3 - 5 m were considered optimum for dam sites (Fig. A.1., A.2., A.3., and A.4.). The stream gradient index in the alternative model (Fig. A.5. and A.6.) was identical to the one in the proposed new HSI model (Fig. 5). The HSI scores were determined based on the limiting factor method and were different between dam sites and unoccupied sites

($\underline{P}$ = 0.0001, Fig. A.7.). However, differences in distribution of HSI scores between dam sites and unoccupied sites in the alternative model (Fig. A.7.) were less clear than in the proposed new HSI model (Fig. 10). The mean HSI score of dam sites was lower in the alternative model ($\underline{\bar{X}}$ = 0.65, SE = 0.03; Fig A.7.) than in the proposed new HSI model ($\underline{\bar{X}}$ = 0.83, SE = 0.03; Fig. 10).

Expanding populations of beaver may occupy suboptimal habitat, thus, it may lower the HSI scores of dam sites. When beaver populations are large, the model based on abundance of dams relative to availability of particular stream habitats may not reflect characteristics of stream habitats actually used as dam sites. Therefore, the proposed new HSI model based on the actual frequency distributions of beaver dams seems to perform better than the alternative model in assessing potential dam sites.

DISCUSSION

Density of Beaver Dams in the Basin

Beaver-dam density in the Drift Creek basin (2.6/km) was similar to dam density (2.5/km) previously reported from Kabetogama Peninsula, northern Minnesota (Naiman et al. 1988). Kabetogama Peninsula and the Drift Creek basin are both similar in basin size, and have been influenced by extensive fire and logging practices (Juday 1977, Naiman et al. 1988, Schwartz 1991). In pristine forest streams in Quebec, where trapping has had little effect on beaver populations, beaver dam density was 10 dams/km (Naiman et al. 1986).

Vegetative Characteristics of Beaver Dam Sites

Difference in vegetative variables between dam sites and unoccupied sites may be simply a result of alteration of habitat caused by beaver, therefore, vegetative variables may not reflect the habitat condition when beaver first occupied the stream site (Beier and Barrett 1987). Decreasing red alder cover and shrub cover and increasing grass/sedge cover influenced the discriminant model, but they may not be useful in identifying currently unoccupied sites as potential dam sites.

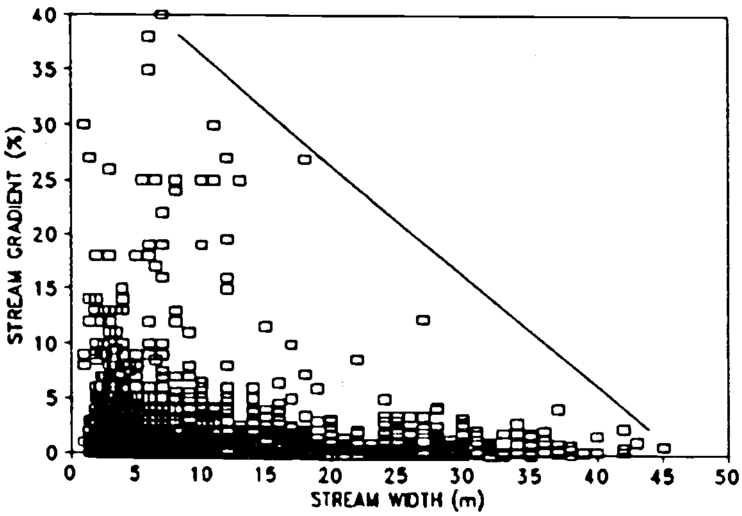
In the Oregon Coast Range, beaver selectively forage on salmonberry, red alder, and vine maple, while avoiding elderberry and thimbleberry (Bruner 1990). Selective foraging of beaver probably reduced the amount of red alder and salmonberry cover and indirectly increased the amount of elderberry cover at dam sites. Johnston and Naiman (1990) and Barnes and Dibble (1988) also indicated that selective foraging of beaver altered species composition of riparian plant communities by removing preferred species and stimulating the growth of avoided species. Abundance of herbaceous vegetation at dam sites was probably a result of removal of tree and shrub cover and increased soil moisture around the beaver pond (Beier and Barrett 1987).

Physical Characteristics of Dam Sites

Physical characteristics of stream habitats were more important factors of dam-site selection than vegetative characteristics (Howard and Larson 1985, Beier and Barrett 1987). I found that decreasing gradients and stream widths and increasing valley floor widths were positively associated with dam-site selection. Beier and Barrett (1987) and Howard and Larson(1985) also indicated that decreasing gradients were positively associated with dam occurrence, but that decreasing stream widths were negatively associated with dam site presence.

Newton's second law defines that force created by an object equals the mass of the object times acceleration of the object (Tilley 1976:23). Downslope force ($\underline{F}$) of a given volume of stream water ($\underline{m}$) on a frictionless stream bed that has a given gradient (θ) is: $\underline{F} = \underline{m} \cdot \underline{g} \cdot \sin\theta$, where $\underline{g}$ is a gravity constant and $\underline{g}.\sin\theta$ is acceleration of stream water. The force acting on a beaver dam is proportional to sine angle of stream gradient (θ) and volume of stream water ($\underline{m}$). Frequency of beaver dams in the Drift Creek basin decreased as stream gradients became steeper or stream widths became wider (Fig. 4 and 6). The force created by stream flow is probably too large for beaver to build or maintain dams on high-gradient streams (>10%) or on wide streams (>10 m) that carry large volume of water per unit length (Fig. 11 and 12).

A



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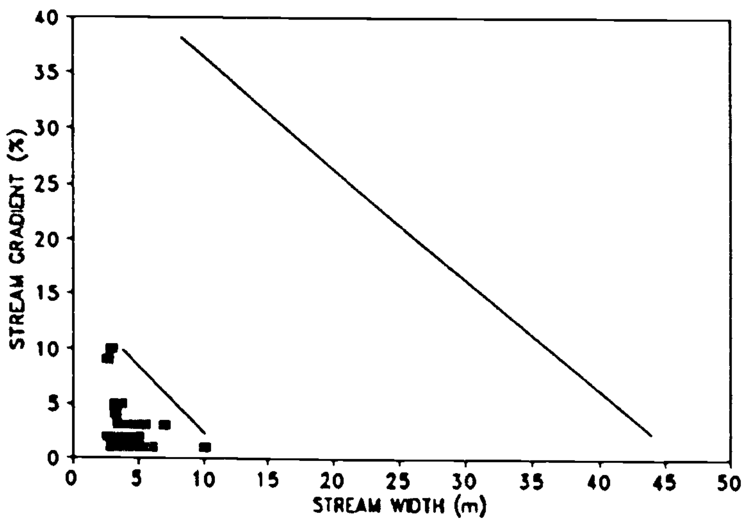

Figure 11. Widths and gradients of 1st- to 5th-order stream sites available for beaver (A) and stream sites actually used by beaver for dam construction (B), Drift Creek Basin, Lincoln County, Oregon, 1988-1989.

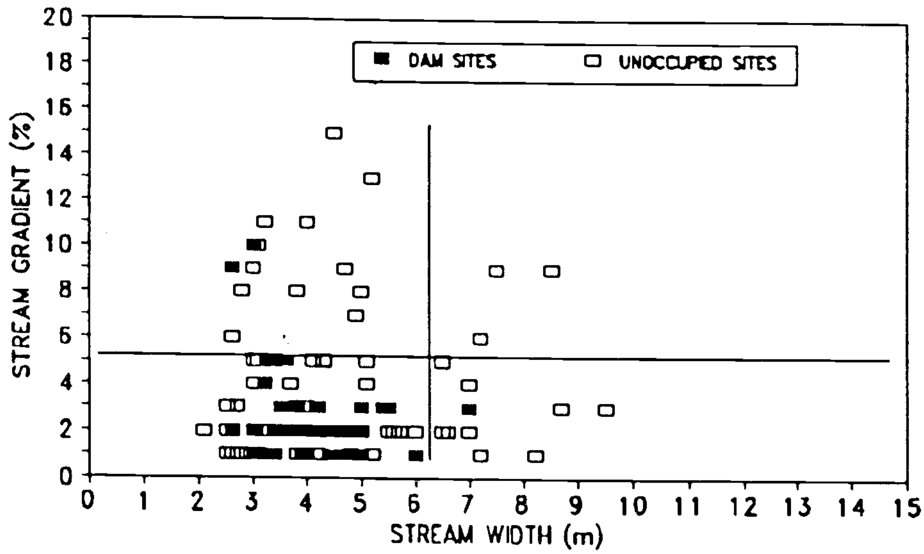

Figure 12. Stream widths and gradients of beaver-dam sites and unoccupied sites in the 1st- to 3rd-order streams, Drift Creek Basin, Lincoln County, Oregon, 1988-1989.

Taylor (1970:142) indicated that flood damage on beaver dams were most evident on slightly steep and undivided stream channel. Bruner (1990) reported that nearly all beaver dams in 4th- and 5th-order coastal streams of Oregon were washed out annually.

Valley floor width is another factor that influenced dam site selection in the basin. Beaver dams that flood a wide valley floor create ponds with large surface area and long perimeter relative to its volume (Johnston and Naiman 1987). During a flood, a series of such ponds effectively store water, as their water tables rise only a few cm, and decrease the peak discharge (Parker et al. 1985). Furthermore, beaver dams significantly reduce velocity of increased discharge flow by spreading the stream flow over wide valley floor (Parker et al. 1985). In contrast, beaver ponds constructed on high-gradient stream with narrow valley floor tend to be small in surface area and perimeter relative to its volume (Johnston and Naiman 1987). During a flood, the water level of such ponds can increase drastically, so the ponds are not effective at reducing peak discharge and flow velocity.

Classification Model and Management Implications

Stream reaches that have low gradients, wide valley floors, and small channel widths provided geomorphologically stable dam sites in the Drift Creek basin. Based on the 3 geomorphic variables (stream width, stream gradient, valley floor width), the new HSI model can be used to evaluate suitability of stream sites as dam sites or the discriminant function model can be used to classify stream sites as either dam sites or unoccupied sites.

Using these models, wildlife managers can inventory suitable beaver dam sites along the streams of the west-central Oregon Coast range. Such information can help increase efficiency of population survey by eliminating unsuitable streams from the survey. This information also may help locating productive fish and waterfowl habitats in small streams. Because beaver activities influence hardwood riparian vegetation, water quality, soil erosion, and aquatic and terrestrial wildlife habitat, managers should consider how land use practices might influence the quality of beaver habitat.

CHAPTER III: CHARACTERISTICS OF SMALL MAMMAL AND AMPHIBIAN COMMUNITIES IN BEAVER-POND HABITATS

INTRODUCTION

Alteration of the riparian habitat by beaver has an impact on abundance and community structure of various aquatic and terrestrial organisms, such as benthic invertebrate communities (McDowell and Naiman 1986), trout (Salmo spp.)(Gard 1961, Call 1966), coho salmon (Oncorhynchus kisutch) (Sanner 1987, Bruner 1990), waterfowl (Beard 1953, Arner 1964, Renouf 1972, Johnson et al. 1975, Brown and Parsons 1979, Ringelman and Longcore 1982), bird communities (Reese and Hair 1976, Hair et al. 1978), and furbearers (Grasse and Putnam 1950, Beard 1953, Rutherford 1955).

Little is known about the community characteristics and abundance of small mammals and amphibians in the habitat altered by beaver. To my knowledge only 1 study has assessed characteristics of small mammal community in the beaver-pond habitat. Medin and Clary (1991) indicated that density and biomass of small mammals at the beaver pond habitat were higher than the adjacent riparian habitat; however, the result was statistically inconclusive. No study has assessed effects of beaver on the community structure and the habitat of amphibians.

Changes in stream hydrology and sedimentation rate caused by beaver dams might have immediate impacts on abundance of amphibian species that use streams and ponds for reproduction. Small mammal species that prefer wetland habitats might benefit from the habitat altered by beaver. On the other hand, beaver herbivory might have negative impact on abundance and habitat quality of those species that are primary associated with dense riparian forests.

The objectives of this study were to: 1) compare abundance and community structure of small mammal and amphibian species between beaver-occupied and beaver-unoccupied habitat, 2) compare habitat variables between beaver-occupied and beaver-unoccupied habitat, 3) assess habitat associations of small mammal and amphibian species.

STUDY AREA AND METHODS

The study was conducted in the western slope of the Oregon Coast Range, Lincoln County, Oregon. The study sites were located on 4 streams in the Drift Creek drainage: Cape Horn Creek, Deer Creek, Horse Creek, Drift Creek below Ayer's Lake (Fig. 13). The fifth site was located in the North Fork Beaver Creek near the Drift Creek drainage. Forest stands at the Ayer's lake and North Fork Beaver Creek sites were young (10-30 years old); the other 3 sites had young stands on 1 side of the stream and mature stands (100-140 years old forest stands) on the other side.

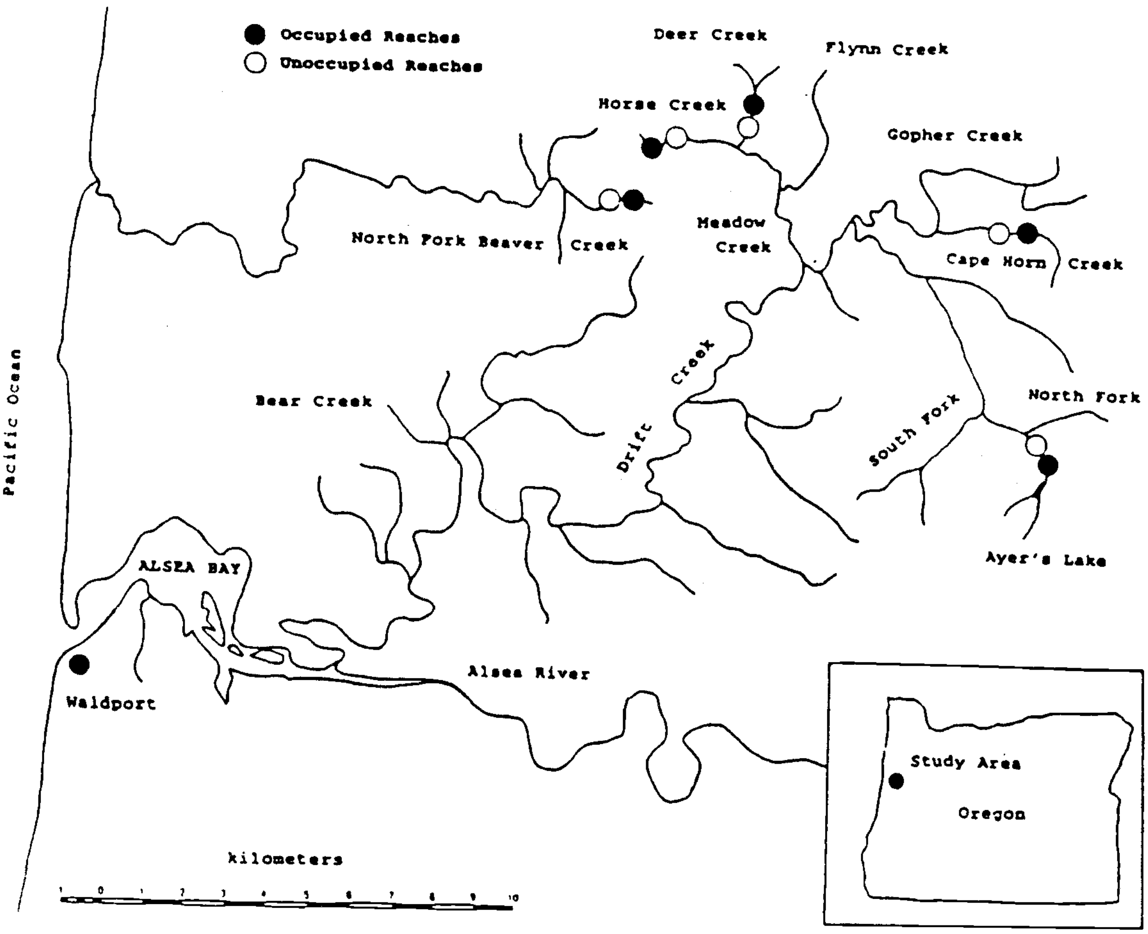

Figure 13. Location of study sites in the Drift Creek drainage and in the North Fork Beaver Creek, Lincoln County, Oregon.

Red alder (Alnus rubra) was the most abundant tree species found along the stream on the study sites. Douglas-fir (Pseudotsuga menziesii) was also abundant but usually found > 30 m away from the stream. Other tree species included western hemlock (Tsuga hetrophylla), western redcedar (Thuja plicata), and bigleaf maple (Acer macrophyllum). Understory vegetation was dominated by salmonberry (Rubus spectabilis). Other understory vegetation included vine maple (A. circinatum), elderberry (Sambucus racemosa), thimbleberry (R. parviflorus), stinking currant (Ribes bracteosm), huckleberries (Vaccinium spp.), devil's-club (Oplopanax horridum), western swordfern (Polystichum munitum), and various species of forbs, grass, and sedges (Carex spp.).

Within each stream, I subjectively selected a pair of beaver-occupied and beaver-unoccupied reaches. Each of the pair were similar in stream order (1st or 2nd order), stream gradient (< 5 %), and forest-stand condition. Within each reach, I established two 180-m streamside transects approximately 8 m from the stream on each side of the stream. I also established a 180-m riparian-fringe transect approximately 20 m from 1 of the streamside transects (Fig. 14). Trapping stations were established every 20 m along each transect. One pitfall trap (double-deep No. 10 tin can) and 2 Museum special traps were placed at each trapping station. The Museum specials were

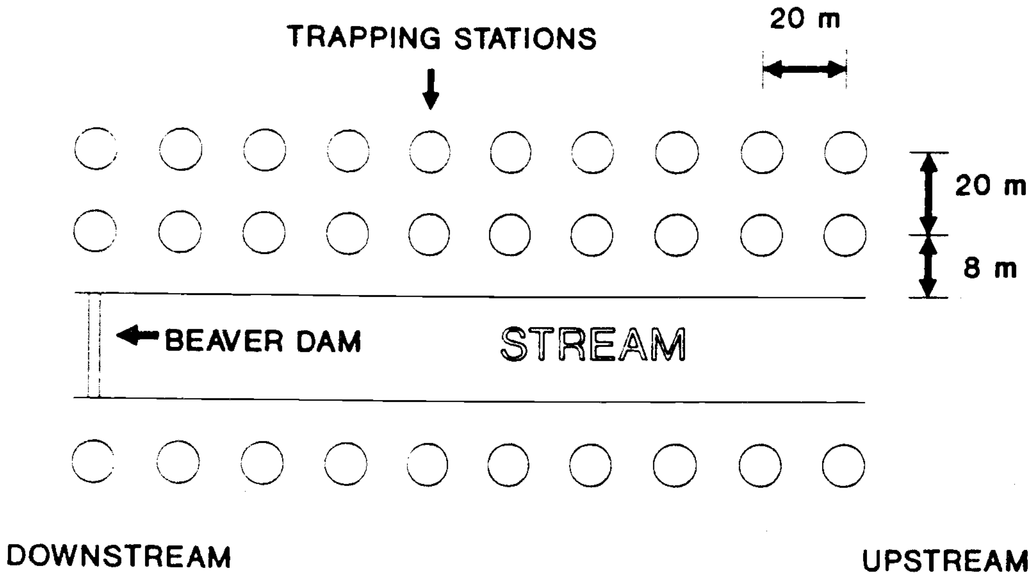

Figure 14. Diagram showing transects and the arrangement of trapping stations used for small mammal and amphibian sampling.

baited with rolled oats and peanut butter. No bait was used in the pitfall traps. The pitfall traps were activated on the second week of September, 1989 and remained open for 30 days. After 30 days of intermission, I reactivated the pitfall traps on the second week of November, 1989 and kept them open for another 30 days. The Museum specials were operated for 3 consecutive days during September, 1989. The pitfall traps were checked weekly and the snap traps were checked daily during the trapping. Twenty-eight habitat variables (Table 6) were measured at a 10-m radius plot centered on each pitfall trap.

I calculated species richness (S = number of species), Shannon-Weaver species diversity index ($H' = -\sum p_i \log p_i$), and an equitability index ($E = H'_{observed} / H'_{max}$) of small mammal and amphibian communities (Brower and Zar 1984:157-160) for each occupied and unoccupied reach. These indices were compared between occupied and unoccupied reaches with Wilcoxon sign-rank tests. I compared capture frequencies for species with $\underline{n} > 20$ captures between occupied reaches and unoccupied reaches with Wilcoxon sign-rank tests. I also used chi-square goodness-of-fit tests (with Yates correction) on capture frequencies of each species pooled across occupied reaches and unoccupied reaches to determine if overall capture frequencies differed from

Table 6. Habitat characteristics measured at trapping stations on beaver-occupied reaches and on unoccupied reaches, Lincoln County, Oregon, 1989.

Variable	Method
Overstory tree (%)	Ocular estimate of tree canopy cover > 20 m in height over a 10-m radius plot.
Midstory tree (%)	Ocular estimate of pole tree (4-20 m) over a 10-m radius plot.
Tall-shrub (%)	Ocular estimate of cover by woody plants in the 1.3 < 4.0 m layer over a 10-m radius plot.
Low-shrub (%)	Ocular estimate of cover by woody plants in the < 1.3 m layer over a 10-m radius plot.
Shrub canopy (%)	A sum of tall-shrub and low-shrub cover
Herb layer (%)	Ocular estimate of total cover by herbaceous plants, including grasses, sedges, ferns, and forbs over a 10-m radius plot.

Table 6. Continued

Variable	Method
Plant cover (%)[a]	Ocular estimate of a selected vegetative cover over a 10-m radius plot.
Bare ground (%)	Ocular estimate of amount of ground with no vegetative cover.
Red alder stem (n/ha)	Number of red alder stems was counted within a 10-m radius plot and converted to per ha densities.
Douglas-fir stem (n/ha)	Number of Douglas-fir stems was counted within a 10-m radius plot and converted to per ha densities.
Number of logs (n/ha)	Number of logs of all sizes as well as number of logs of 3 different diameter classes were counted within a 10-m radius plot and converted to per ha densities.
Total logs (all sizes)	
Small logs (10-19 cm)	
Medium logs (20-49 cm)	
Large logs (>49 cm)	

Table 6. Continued

Variable	Method
Litter depth (mm)	Average depth of leaf litter measured at 5 systematically arranged points (plot center, 5 m to north, south, east, and west of plot center).
Slope (%)	Average of 20-m upslope and 20-m downslope measured with clinometer at a plot center.

[a] Plant-cover variables inclueded cover by red alder, Douglas-fir, salmonberry, vine maple, elderberry, huckleberry, stinking currant, thimbleberry, grasses, sedges, forbs, ferns, and moss.

expected between occupied reaches and unoccupied reaches. For each species, capture frequencies at 5 occupied reaches and 5 unoccupied reaches were tested for homogeneity of variance with a *F*-test. I compared habitat characteristics between beaver-occupied and unoccupied reaches with paired *t*-tests. I used stepwise multiple regression analyses to identify habitat variables that best predicted capture frequencies of small mammal and amphibian species at each transect level.

RESULTS

Habitat Characteristics

Beaver-occupied reaches had lower percent coverage by overall shrubs, shrubs in the > 1.3 m layer, and stinking currants than unoccupied sites (Tables 7 and 8). Percent coverage by grasses, sedges, and elderberry were higher at occupied reaches than at unoccupied reaches. There was only a slight difference in percent coverage by overstory trees between occupied and unoccupied reaches (P = 0.119).

Small Mammal Community

A total 1,531 individuals of 16 species of small mammals was captured in 19,800 trapnights. A total 838 individuals of 16 species of small mammals was captured on beaver-occupied reaches (Table A.1.). A total 693 individuals of 15 species of small mammals was captured on unoccupied reaches (Table A.2.). Deer mice (see Table A.1. for scientific names) comprised of 40 % of the total

Table 7. Comparison of vegetative cover ($\bar{X}$, SE) between beaver-occupied reaches (n = 5) and unoccupied reaches (n = 5) with paired t-tests, 1989, Lincoln County, Oregon.

Cover type (%)	Occupied	Unoccupied	P
Red alder	23.6(4.5)	34.3(9.7)	0.2053
Douglas-fir	12.3(3.2)	9.7(3.4)	0.6644
Salmonberry	42.2(4.3)	54.9(7.6)	0.1681
Vine maple	7.7(3.5)	7.1(1.9)	0.8725
Elderberry	7.6(2.7)	1.8(0.8)	0.0785
Huckleberry	2.0(0.9)	2.1(1.2)	0.8718
Stinking currant	1.3(0.4)	5.4(2.2)	0.0017
Thimbleberry	4.9(2.1)	5.9(3.1)	0.6176
Total shrub	46.3(4.7)	58.2(6.3)	0.0002
Grass	28.1(6.7)	17.0(6.4)	0.0230
Sedge	11.7(4.0)	3.4(1.9)	0.0600
Forb	33.6(3.9)	32.4(5.7)	0.7799
Fern	16.6(3.4)	20.3(5.9)	0.8958
Moss	13.9(3.5)	20.6(2.8)	0.2243
Bare ground	13.0(3.1)	8.5(1.6)	0.1774

Table 8. Comparison of structural elements of habitats ($\underline{\bar{X}}$, SE) between beaver-occupied ($\underline{n}$ = 5) and unoccupied sites ($\underline{n}$ = 5) with paired $\underline{t}$-tests, 1989, Lincoln County, Oregon.

Habitat-structure variables	Occupied	Unoccupied	$\underline{P}$
Overstory tree (%)	22.5(5.2)	35.0(9.4)	0.1119
Midstory tree (%)	24.9(1.9)	24.9(3.9)	0.9900
Tall-shrub (%)[a]	38.2(6.7)	54.4(8.1)	0.0913
Low-shrub (%)[b]	32.5(2.2)	25.9(3.0)	0.2107
Herb layer (%)	58.2(5.0)	52.0(3.9)	0.1009
Litter depth (mm)	27.5(2.7)	31.8(2.3)	0.3230
Red alder (n/ha)[c]	86.8(21.9)	99.7(35.7)	0.5219
Douglas-fir (n/ha)[d]	59.2(13.0)	51.4(21.5)	0.7824
Total logs (n/ha)	130.9(16.0)	158.1(36.9)	0.4108
Small logs (n/ha)	22.3(5.4)	31.4(8.2)	0.2280
Medium logs (n/ha)	82.1(9.1)	95.1(28.1)	0.6534
Large logs (n/ha)	26.5(8.0)	31.6(11.1)	0.4256
Slope (%)	33.8(5.6)	37.2(6.0)	0.6400

[a] Woody plants in the 1.3 m < 4.0 m layer.

[b] Woody plants in the < 1.3 m layer.

[c] Number of red alder stems per 1 ha.

[d] Number of Douglas-fir stems per 1 ha.

captures. Deer mice, Trowbridge's shrews, Pacific shrews, and Pacific jumping mice were present on all beaver-occupied and on all unoccupied reaches.

Species diversity (H'), species richness (S), and equitability (E) of small mammal communities did not differ between occupied and unoccupied reaches (Table 9). The overall capture frequencies of deer mice, Pacific jumping mice, creeping voles, Townsend's voles, long-tailed voles, vagrant shrews, and all species combined were higher at beaver-occupied reaches than at unoccupied reaches (Chi-square goodness-of-fit tests, Table 10, Fig. 15). The overall capture frequency of Trowbridge's shrews was higher at beaver unoccupied reaches than at occupied reaches. None of these trends were consistent among the 5 streams. None of the small mammal species with > 20 captures differed in capture frequencies between beaver-occupied and unoccupied reaches when sites, rather than individual mammal, was considered the independent observation (Wilcoxon sign-rank tests, Table 10). The only exception was the capture frequency of all Microtus species combined being consistently higher at beaver occupied reaches than at unoccupied reaches. Capture frequencies of Pacific jumping mice, creeping voles, Townsend's voles, long-tailed voles, and vagrant shrew, were more variable among the 5 occupied reaches than among 5 unoccupied reaches (F-test, Table 11).

Table 9. Comparison of species diversity (H′), equitability (E), and richness (S) of small mammal and amphibian communities between beaver-occupied reaches (n = 5) and unoccupied reaches (n = 5) with Wilcoxon sign-rank tests, Lincoln County, Oregon, 1989.

Community Indices	Mean (SE)		P
	Occupied	Unoccupied	
Small mammals			
Species richness (S)	11.0(0.45)	11.0(0.63)	1.000
Species diversity (H′)	1.73(0.11)	1.68(0.12)	1.000
Equitability (E)	0.73(0.04)	0.70(0.05)	0.813
Amphibians			
Species richness (S)	4.6(0.93)	4.8(0.73)	0.893
Species diversity (H′)	1.07(0.17)	1.13(0.19)	0.787
Equitability (E)	0.76(0.03)	0.77(0.10)	0.590

Table 10. Comparison of numbers of small mammal species captured between beaver-occupied (n = 5) and unoccupied reaches (n = 5) with Wilcoxon sign-rank tests, Lincoln County, Oregon, 1989. Chi-square goodness-of-fit tests refer to Figure 15.

	Mean Frequency (SE)		P-value	
Species[a]	Occupied	Unoccupied	Sign-rank[b]	Chi-square
Deer mice	66.8 (18.0)	56.8 (19.1)	0.437	0.044
Pacific jumping mice	19.4 (8.7)	8.0 (2.1)	0.375	0.000
Creeping vole	9.2 (4.3)	3.0 (1.5)	0.375	0.000
Townsend's vole	8.0 (3.0)	2.0 (1.0)	0.250	0.000
Long-tailed vole	4.2 (2.4)	1.6 (0.6)	0.500	0.026
White-footed vole	2.8 (1.2)	4.6 (1.9)	0.750	0.188
Western red-backed vole	1.0 (0.3)	1.8 (1.6)	___	0.422
Trowbridge's shrew	24.4 (4.0)	34.2 (4.4)	0.437	0.016
Vagrant shrew	12.8 (6.6)	2.6 (1.0)	0.375	0.000
Pacific shrew	14.8 (2.9)	18.4 (3.5)	0.312	0.187
Marsh shrew	2.2 (0.9)	3.4 (0.8)	0.750	0.345

Table 10. Continued

Species	Mean Frequency (SE)		P-value	
	Occupied	Unoccupied	Sign-rank	Chi-square
Shrew-mole	0.8 (0.6)	0.6 (0.2)	___	1.000
Townsend's mole	0.6 (0.4)	0.6 (0.4)	___	0.683
Townsend's chipmunk	0.2 (0.2)	0.8 (0.6)	___	0.371
Western pocket gopher	0.2 (0.2)	___	___	1.000
Ermine	0.2 (0.2)	0.4 (0.4)	___	1.000
Microtus species total	21.4 (6.6)	6.6 (1.7)	0.063	0.000
Sorex species total	54.2 (6.4)	58.6 (6.1)	0.750	0.377
All species total	167.6 (25.9)	138.6 (20.9)	0.188	0.000

[a] Refer Table A.1. for the scientific name.

[b] Only species with > 20 captures were tested with Wilcoxon sign-rank tests.

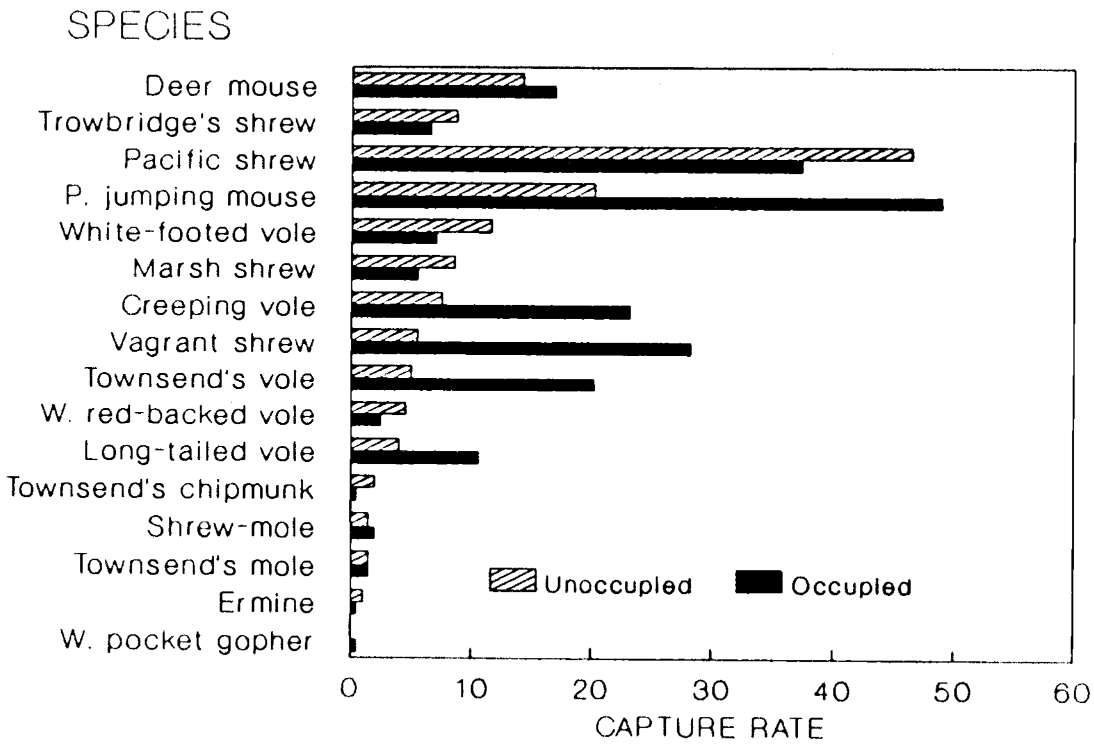

Figure 15. Comparison of overall capture rate of small mammal species between beaver-occupied (n = 5) and unoccupied reaches (n = 5), Lincoln County, Oregon, 1989. The total capture frequencies were converted to the rate of captures/100 trap-nights for deer mice and Trowbridge's shrews and to the rate of captures/1000 trap-nights for other species.

Table 11. Comparison of variance in capture frequencies of small mammal species with > 20 captures between beaver-occupied reaches (n = 5) and unoccupied reaches (n = 5), Lincoln County, Oregon, 1989.

Species[a]	STD[b] Occupied	Unoccupied	F	P-value
Deer mouse	40.25	42.66	1.12	0.9129
Pacific jumping mice	19.47	4.69	17.24	0.0174
Creeping vole	9.71	3.31	8.56	0.0610
Townsend's vole	6.71	2.34	8.18	0.0610
Long-tailed vole	5.35	1.34	15.94	0.0201
White-footed vole	2.77	4.27	2.38	0.4220

Table 11. Continued

Species	STD Occupied	STD Unoccupied	F	P-value
Trowbridge's shrew	8.87	9.76	1.21	0.8590
Pacific shrew	6.53	7.77	1.41	0.7462
Vagrant shrew	14.73	2.30	40.98	0.0034
Marsh shrew	2.04	1.82	1.27	0.8209
Total	58.05	46.62	1.55	0.6813

[a] Refer Table A.1. for the scientific name.

[b] Sample standard deviation.

Amphibian Community

A total 265 individuals of 9 amphibian species was captured in 18,000 trapnights during the study. A total 131 individuals of 9 amphibian species was captured on the beaver-occupied reaches (Table A.3.). A total 133 individuals of 8 amphibian species was captured on unoccupied reaches (Table A.4.). Roughskin newts (see Table A.3. for scientific names) and western redback salamanders comprised 34 % and 29 % of the total captures. Roughskin newts were present on all beaver-occupied and on all unoccupied reaches.

Species diversity (H′), species richness (S), and equitability (E) did not differ between beaver-occupied and unoccupied reaches (Table 9). The overall capture frequencies of roughskin newts and northwestern salamanders were higher at occupied reaches than at unoccupied reaches (Chi-square goodness-of-fit tests, Table 12, Fig. 16). The overall capture frequency of tailed frogs was higher at unoccupied reaches than at occupied reaches. However, none of the amphibian species were consistently more abundant at occupied reaches than at unoccupied reaches (Wilcoxon sign-rank tests, Table 12). The capture frequency of red-legged frogs was more variable at unoccupied reaches than at occupied reaches (Table 13).

Table 12. Comparison of numbers of amphibian species captured between beaver-occupied and unoccupied reaches with Wilcoxon sign-rank tests Lincoln County, Oregon, 1989. Chi-square goodness-of-fit tests refer to Figure 16.

	Mean Frequency (SE)		P-value	
Species[a]	Occupied	Unoccupied	Sign-rank[b]	Chi-square
Roughskin newt	12.2 (3.4)	6.0 (2.2)	0.313	0.002
Western redback salamander	6.6 (2.2)	8.6 (2.3)	0.625	0.302
Olympic salamander	1.8 (0.8)	3.6 (1.6)	0.250	0.124
Red-legged frog	2.0 (1.1)	4.0 (3.0)	0.750	0.100
Tailed frog	0.2 (0.4)	3.8 (3.3)	___	0.000
Northwestern salamander	2.6 (1.3)	0.2 (0.2)	___	0.003
Pacific giant salamander	0.2 (0.2)	0.2 (0.2)	___	0.479
Ensatina	0.6 (0.4)	___	___	0.248
Dunn's salamander	0.2 (0.2)	0.4 (0.4)	___	1.000
Total	26.4 (6.3)	26.8 (4.4)	1.000	0.950

[a] Refer to Table A.3. for the scientific name.

[b] Only species with n > 20 captures were tested with Wilcoxon sign-rank tests.

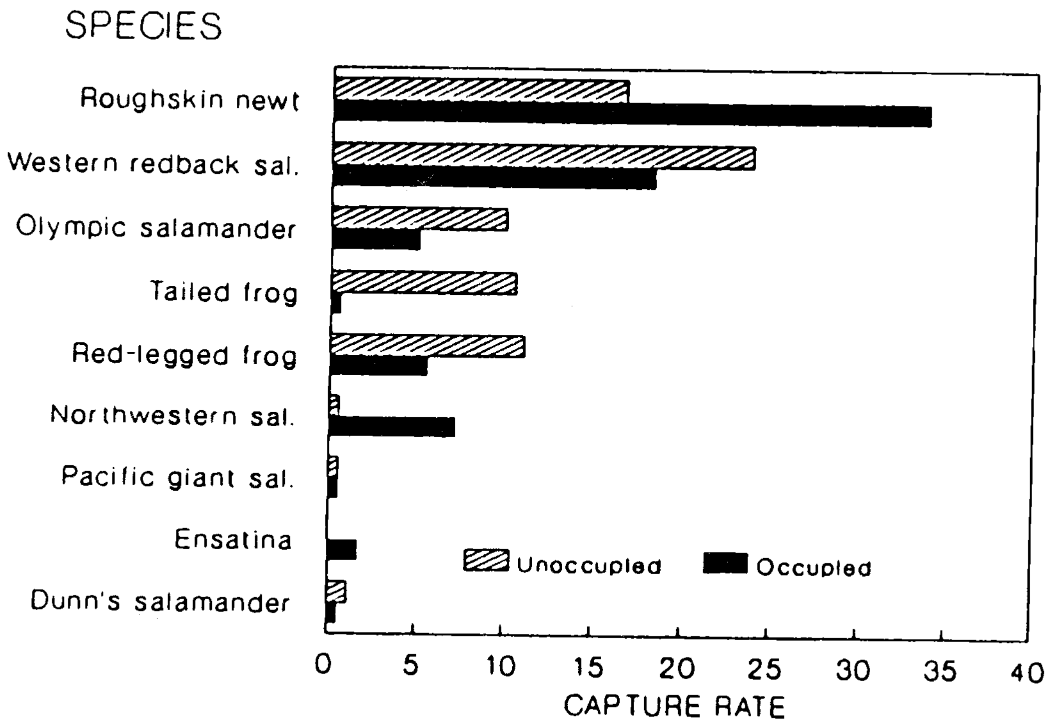

Figure 16. Comparison of overall capture rate of amphibian species between beaver-occupied ($\underline{n}$ = 5) and unoccupied reaches ($\underline{n}$ = 5), Lincoln County, Oregon, 1989. The total capture frequencies of each species were converted to the rate of captures/1000 trap-nights.

Table 13. Comparison of variance in capture frequencies of amphibian species with > 20 captures between beaver-occupied reaches (n = 5) and unoccupied reaches (n = 5), Lincoln County, Oregon, 1989.

Species[a]	STD[b] Occupied	Unoccupied	F	P-value
Roughskin newt	7.19	4.89	2.15	0.4756
Western redback salamander	4.98	5.22	1.10	0.9281
Olympic salamander	1.79	3.51	3.84	0.2205
Red-legged frog	2.54	6.75	7.00	0.0859
Total	14.08	9.76	2.08	0.4954

[a] Refer Table A.3. for the scientific name.

[b] Sample standard deviation.

Habitat Associations

Stepwise multiple regression models predicted capture frequencies for 8 small mammal species and 2 amphibian species (n = 30 transects, multiple R^2 >50 %, Table 14): deer mice (R^2 = 77 %), Pacific jumping mice (R^2 = 72 %), Trowbridge's shrews (R^2 = 62 %), vagrant shrews (R^2 = 54 %), Pacific shrews (R^2 = 53 %), creeping voles (R^2 = 76 %), Townsend's voles (R^2 =51 %), long-tailed voles (R^2 = 77 %), roughskin newts (R^2 = 69 %), and western redback salamanders (R^2 = 52 %).

Capture frequencies of 3 Microtus vole species and deer mice were correlated negatively and the capture frequency of Trowbridge's shrews was correlated positively with overstory tree cover. Capture frequencies of vagrant shrews, creeping voles, Townsend's voles, and Pacific jumping mice were correlated positively with herbaceous vegetation variables: grasses, sedges, and forbs. Capture frequencies of deer mice, Pacific jumping mice, Pacific shrews, creeping voles, and western redback salamander were correlated positively with slope. Capture frequency of Pacific shrews, creeping voles, and roughskin newts were correlated positively with log variables.

Table 14. Habitat variables selected in stepwise regression models for small mammal and amphibian species in 5 streams in the Oregon Coast Range, Lincoln County, Oregon, 1989.

Species	Habitat variables[a]	Standardized coefficients	R^{2b}
Deer mouse	Overstory tree	-0.270	0.77
	Ferns	-0.474	
	Slope	+0.454	
	Salmonberry	-0.386	
	Vine maple	+0.308	
	Thimbleberry	-0.569	
	Litter depth	+0.328	
Pacific jumping mouse	Sedges	+0.791	0.72
	Forbs	+0.743	
	Slope	+0.647	
	Salmonberry	-0.989	
	Elderberry	-0.427	
	Douglas-fir stem	-0.544	
	Litter depth	+0.436	

Table 14. continued

Species	Habitat variables	Standardized Coefficients	R^2
Vagrant shrew	Grasses	+0.491	0.54
	Sedges	+0.536	
Trowbridge's shrew	Overstory tree	+0.237	0.62
	Midstory tree	+0.364	
	Sedges	-0.633	
	Vine maple	-0.399	
	Elderberry	-0.310	
	Litter depth	-0.599	
Pacific shrew	Midstory tree	+1.103	0.53
	Ferns	+0.388	
	Slope	+0.671	
	Elderberry	-0.577	
	Douglas-fir stem	-1.351	
	Number of logs	+0.435	
	Litter depth	-0.451	

Table 14. continued

Species	Habitat Variables	Standardized Coefficients	R^2
Creeping vole	Overstory tree	-0.721	0.76
	Low-shrubs	-0.471	
	Grasses	+0.972	
	Forbs	+0.423	
	Slope	+0.460	
	Thimbleberry	-0.302	
	Douglas-fir stem	+0.308	
	Small logs	+0.438	
Townsend's vole	Overstory tree	-0.274	0.51
	Grasses	+0.374	
	Sedges	+0.391	
Long-tailed vole	Overstory tree	-0.966	0.77
	Moss	-0.452	
	Salmonberry	-0.424	
	Thimbleberry	-0.558	

Table 14. continued

Species	Habitat variables	Standardized Coefficients	R^2
Roughskin newt	Red alder	-0.456	0.69
	Sedges	-0.258	
	Elderberry	+0.970	
	Number of logs	+0.285	
Western redback salamander	Low-shrubs	-0.409	0.52
	Slope	+0.467	
	Thimbleberry	+0.506	
	Litter depth	-0.512	

[a] Refer to Table 6. for detailed description.

[b] Coefficient of multiple determination.

DISCUSSION

Microhabitat Associations of Small Mammal and Amphibian Species

Creeping vole

The capture frequency of creeping voles was correlated negatively with coverage by overstory tree, by thimbleberry, and by low-shrubs in the < 1.3 m layer and correlated positively with coverage by grasses and by forbs, number of Douglas-fir stems, and number of small logs. Forest openings with mixture of dense grasses and forbs characterized the habitat of creeping voles, consistent with description from previous studies (Goerts 1964, Gashwiler 1970, Sullivan 1981, and Doyle 1990). Creeping voles mainly consume forbs and grasses and occasionally consume hypogeous fungi; consequently, these voles become abundant in areas where herbaceous diet is available (Maser et al. 1978).

Townsend's vole

The capture frequencies of Townsend's voles were correlated positively with coverage by grasses and sedges and correlated negatively with coverage by overstory trees. Townsend's voles consume various species of herbs, including sedges, false dandelion (Agoseris spp.), and buttercups (Ranunculus spp.)(Maser et al. 1981:209). The streamside habitat with dense grasses and sedges is the primary habitat of these voles (Goerts 1964).

Long-tailed vole

The capture frequencies of long-tailed voles were correlated negatively with coverage by overstory trees, moss, salmonberry, and thimbleberry. Although grassland and sedge marshes are the primary habitat of long-tailed voles, they can be found in other type of habitats when small grassy patches were available (Getz 1985:292-293). Beck and Anthony (1971) indicated long-tailed voles inhabited in shrub dominant habitats in eastern Washington, whereas montane voles (M. montanus) inhabited in grass dominant habitats. Diet of long-tailed voles are not well known, except long-tailed voles are herbivores (Maser et al. 1981:210). Long-tailed voles may have more flexible habitat requirements than creeping voles and Townsend's voles, that have strong association with coverage by grasses and sedges.

Vagrant shrew

The capture frequencies of vagrant shrews were correlated positively with coverage by grasses and sedges. Vagrant shrews were inhabitants of grassy streamside habitats and they are often sympatric with Townsend's voles (Hooven et al. 1975). These shrews use runways of voles and eat various invertebrates, such as insect larvae, slugs, and snails (Whitaker and Maser 1976).

Trowbridge's shrew

The capture frequencies of Trowbridge's shrews were correlated positively with coverage by overstory tree and by midstory tree and correlated negatively with coverage by sedges, vine maple, and elderberry and with litter depth. Trowbridge's shrews are primary associated with forest habitats and they are less abundant in forest clearings and wet meadows (Jameson 1955). In western Oregon, Maser and Franklin (1974) indicated that these shrews were most often captured in the alder/salmonberry community. Trowbridge's shrews consume wide varieties of invertebrates (Jameson 1955, Whitaker and Maser 1976) as well as plant seeds (Jameson 1955).

Pacific shrew

The capture frequencies of Pacific shrews were correlated negatively with the number of Douglas-fir stems, coverage by elderberry, and litter depth and correlated positively with coverage by midstory trees and by ferns, slope, and the number of logs. Red alder pole stands with dense fern cover and abundance of logs characterized the habitat of Pacific shrews in my study sites. Maser et al. (1981:53) similarly described Pacific shrews as more often found in alder/salmonberry, riparian alder, and skunkcabbage marsh habitats than in the conifer dominant habitats. These shrews have association with protective cover, such as logs (Maser et al. 1981:54).

They eat various invertebrates, insect larvae and occasionally eat small amphibians, vegetation, and fungi (Whitaker and Maser 1976).

Pacific jumping mouse

The capture frequencies of Pacific jumping mice were correlated negatively with coverage by salmonberry, elderberry, and the number of Douglas-fir stems and positively with coverage by sedges and forbs, slope, and litter depth. Pacific jumping mice mainly consume grass seeds and inhabit in grassy, wet habitats (Ingles 1965:304). Dense herbaceous vegetation along the stream provided suitable habitats for Pacific jumping mice.

Deer mouse

The frequencies of deer mice were correlated positively with slope, litter depth, and coverage by vine maple; and negatively with coverage by overstory trees, thimbleberry, salmonberry and ferns. Maser et al.(1981:183) indicated that deer mice occur at all habitat types along the Oregon Coast range. Deer mice are usually more abundant in the habitat modified by logging (Gunther et al. 1983, Cross 1985) or a combination of logging and slash burning (Black and Hooven 1974, Gashwiler 1970, Hooven and Black 1976) than the climax forest habitat. Deer mice eat various plant seeds, fruits, invertebrates, and underground fungi (Maser et al. 1981:183).

Western redback salamander

The capture frequencies of western redback salamanders were correlated positively with slope and coverage by thimbleberry and negatively with litter depth and coverage by low-shrub cover in the < 1.3 m layer. Corn and Bury (1991) indicated western redback salamanders were associated with capture sites that had steep slope and large amount of ground covered by rock. Western redback salamanders are adapted to the terrestrial environment and are not strongly associated with streams and ponds (Green and Campbell 1984). They are commonly found in dry coniferous forests and talus slopes (Nussbaum et al. 1983:109). In the riparian habitat of the Oregon Coast range, dry hillside dominated by thimbleberry seems to characterize the habitat of western redback salamanders.

Roughskin newt

The capture frequencies of roughskin newts were correlated negatively with coverage by red alder and by sedges and correlated positively with coverage by elderberry and total number of logs. Similarly, Green and Campbell (1984) indicated that roughskin newts were commonly found in open woodlands with large amount of deadfall and litter. Roughskin newts also require slow-flowing streams, ponds, and swamps for reproduction (Green and Campbell 1984, Nussbaum 1983:113).

Potential Effects of Habitat Alteration on the Abundance of Small Mammals and Amphibians

In the Oregon coastal streams, beaver most often cut small stems (2-9 cm in diameter) of red alder, salmonberry, and vine maple (Bruner 1990). This selective nature of beaver herbivory probably decreased cover of preferred shrub species, especially in the >1.3 m layer. Such selection may indirectly stimulate the growth of unbrowsed species, such as elderberry. Johnston and Naiman (1990) and Barnes and Dibble (1988) indicated that selective foraging of beaver altered species composition of riparian plant communities by removing preferred species and stimulating the growth of avoided species. Grass and sedge cover was increased in response to removal of shade and increased soil moisture at occupied reaches (Taylor 1970, Beier and Barrett 1987).

Consistently high capture frequencies of _Microtus_ vole species at occupied reaches were probably a response of _Microtus_ to dense cover by grasses and by sedges and presence of standing water. Graminoid vegetation, which provides essential food and cover, and moisture conditions are the factors influencing distributions and abundance of _Microtus_ species (Getz 1985:288).

Creeping voles (Doyle 1990), Townsend's voles (Hooven et al. 1975), long-tailed voles (Maser et al. 1981:210), vagrant shrews (Hooven et al. 1975), and Pacific jumping mice (Ingles 1965:304) are often associated with herbaceous streamside vegetation. Consequently, some beaver occupied reaches seemed to be highly productive sites for these small mammal species. However, the abundance of these species was highly variable among occupied reaches.

The overall capture frequencies of deer mice were also higher at occupied reaches than at unoccupied reaches. Although deer mice are found in wide variety of habitats (Maser et al. 1981:183), they often become more abundant in early seral stage habitats than in old forests (Gashwiler 1970, Black and Hooven 1974, Hooven and Black 1976, Gunther et al. 1983, Cross 1985). Some of the occupied reaches probably contained patches of early successional habitats that were suitable for deer mice.

In contrast, Trowbridge's shrews had lower overall capture frequencies at occupied reaches than at unoccupied reaches probably because they were primarily associated with forest and they require dense protective cover (Maser et al. 1981:61).

Northwestern salamanders and roughskin newts are known to breed in ponds, swamps, lakes, or slow-flowing streams in woodlands (Nussbaum et al. 1983:49, Green and Campbell 1984, Bury and Corn 1988). These species probably use beaver ponds for reproduction hence they had higher overall capture frequencies at occupied than at unoccupied reaches.

Tailed frogs are well adapted to cold and fast-flowing streams within forested areas (Green and Campbell 1984, Nussbaum et al. 1983:146). Higher temperature and increased siltation have negative effects on their habitat quality (Nussbaum et al. 1983:150). Slow stream flow and reduced canopy cover at occupied reaches might create stream habitat conditions unsuitable for tailed frogs.

None of capture frequencies of amphibian and small mammal species were consistently higher or lower at 5 occupied reaches than at 5 unoccupied reaches. Inconsistency found in abundance of small mammal and amphibian species probably is an indication of the variability among beaver-occupied reaches.

Taylor (1970) indicated the amount of silt deposition and aquatic primary production were highly variable among ponds. Vegetation types associated with occupied reaches are also variable because of differences in successional stages of ponds, herbivory, hydrology, and preimpoundment vegetation among occupied reaches (Naiman et al. 1988). In California, there are at least 4 general successional stages of beaver ponds: unsilted ponds, shallow sedge-marsh, grass-sedge meadow, and dry grass meadow (Taylor 1970). In boreal forest, 32 different wetland vegetation types are associated with beaver ponds and general successional stages of ponds include emergent marsh, bogs, forested wetlands, and open water ponds (Naiman et al. 1988).

Habitat conditions of beaver-occupied reaches are altered through time and space, as a result, any ecological features of beaver-pond habitats do not stay spatially constant (Naiman et al. 1988). On a localized scale during a short period of time, there were no differences in small mammal and amphibian community structures between occupied reaches and unoccupied reaches. On a scale of entire drainage basin or in a long period of time, combination of beaver occupied reaches with different ecological conditions might contribute to produce diversity of habitats and associated wildlife species. Further study is necessary to understand effects of beaver habitat alteration on small mammal and amphibian communities over long temporal and large spatial scales.

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APPENDIX

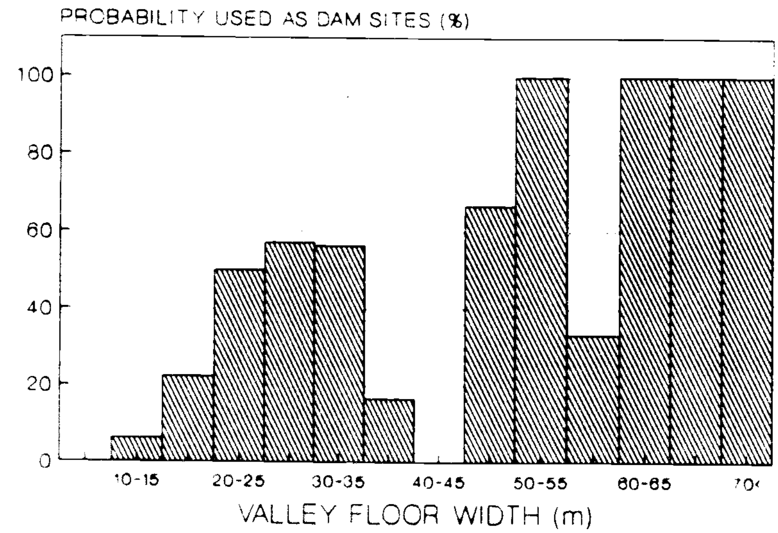

Figure A.1. **Proportion of available valley floor widths used as dam sites.**

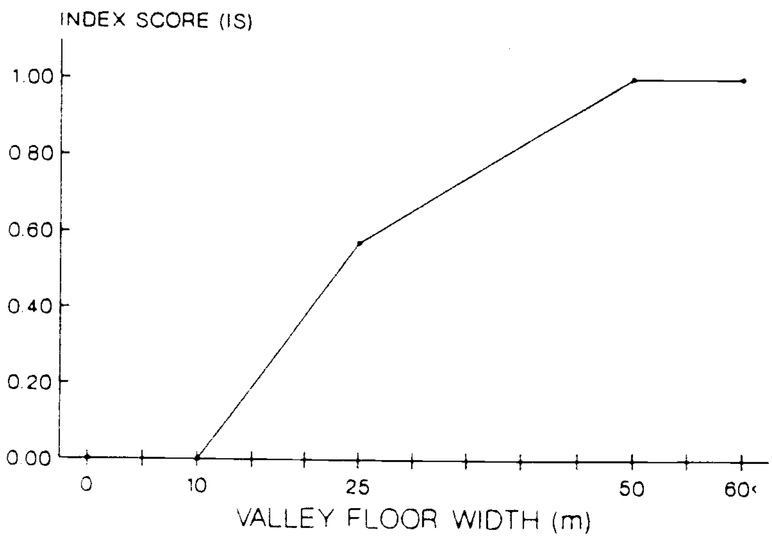

Figure A.2. **Index scores for valley floor width in the alternative HSI model.**

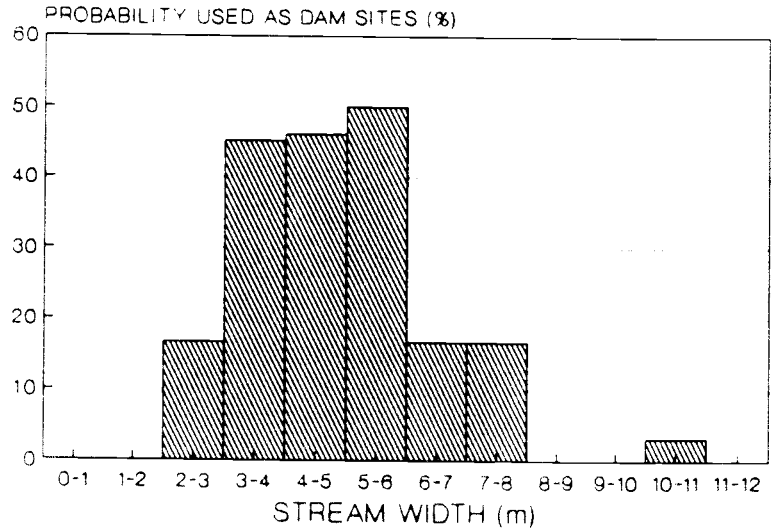

Figure A.3. Proportion of available stream widths used as dam sites.

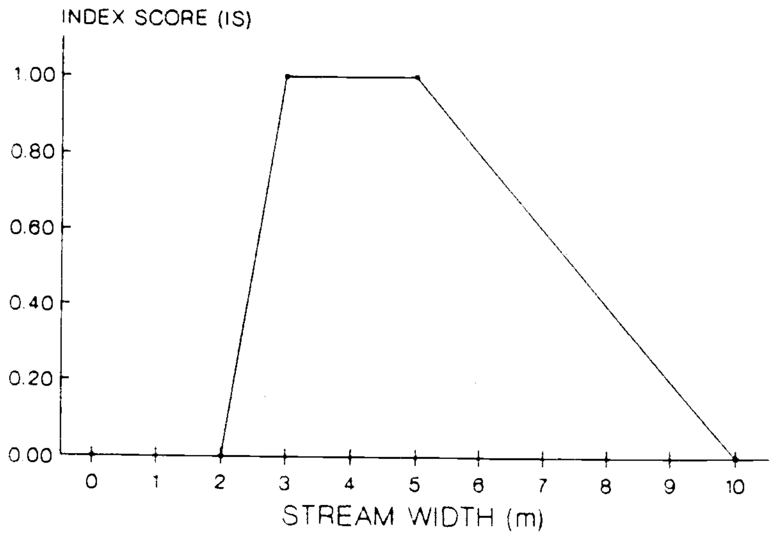

Figure A.4. Index scores for stream width in the alternative HSI model.

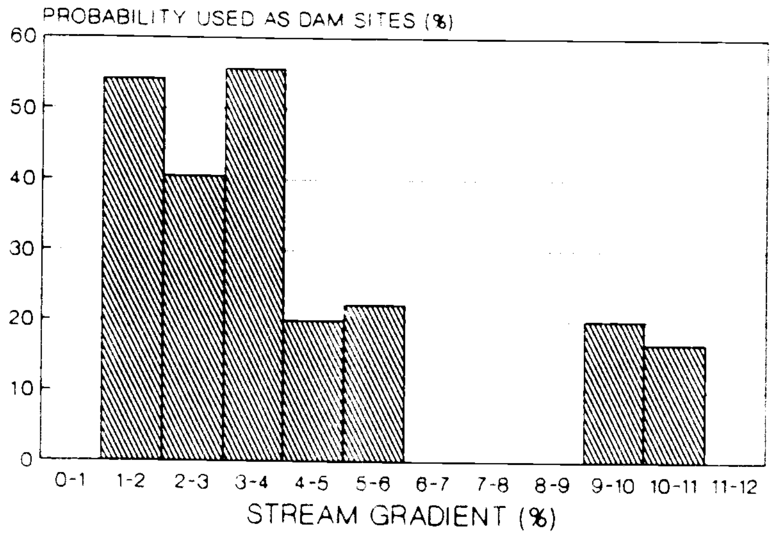

Figure A.5. Proportion of available stream gradients used as dam sites.

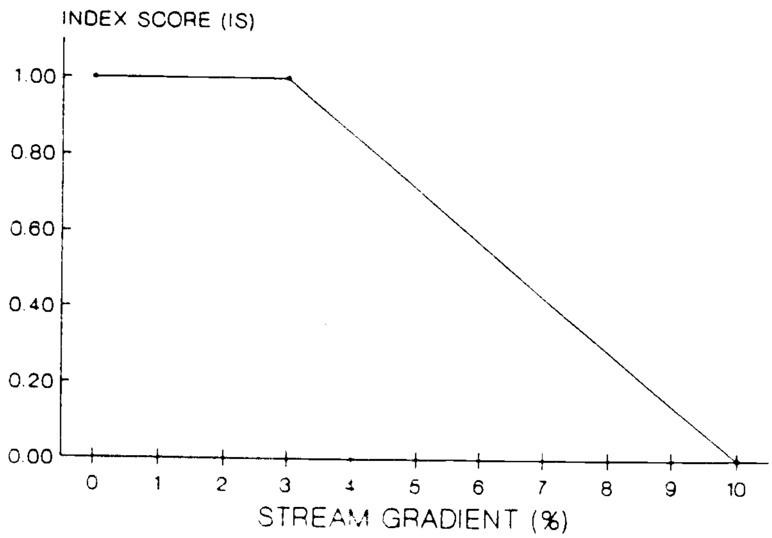

Figure A.6. Index scores for stream gradient in the alternative HSI model.

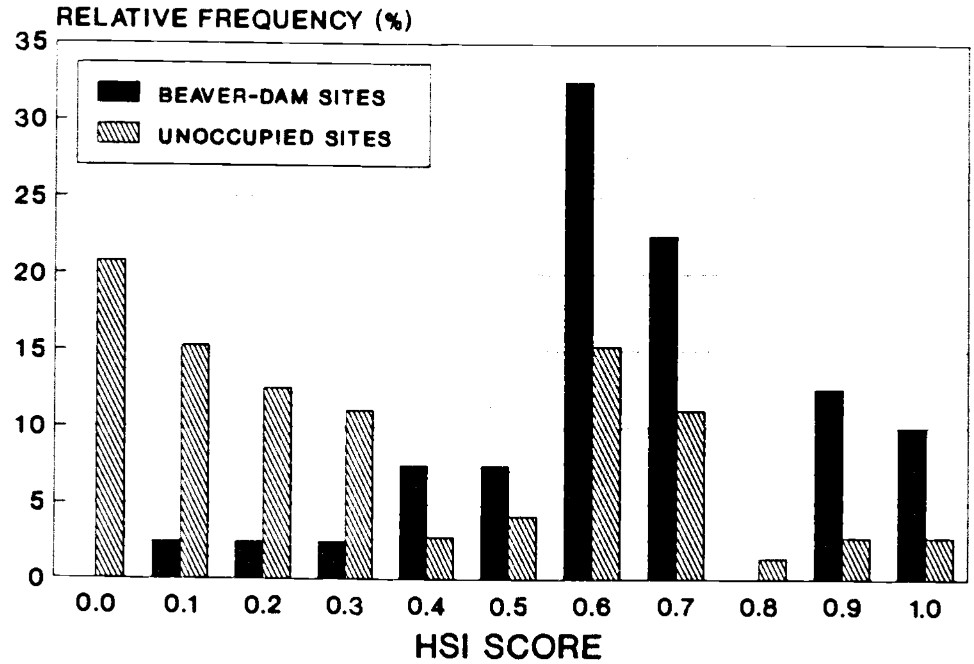

Figure A.7. Comparison of HSI score distributions between beaver-dam sites and unoccupied sites in the alternative HSI model.

Table A.1. Capture frequencies of small mammal species in streamside habitats ($\underline{n}$ = 5) occupied by beaver, Lincoln County, Oregon, 1989.

Species	Streams[a]					Total
	AL	BC	CC	DC	HC	
Deer mouse (*Peromyscus maniculatus*)	51	71	119	10	83	334
Pacific jumping mice (*Zapus trinotatus*)	10	48	31	5	3	97
Creeping vole (*Microtus oregoni*)	5	7	26	1	7	46
Townsend's vole (*Microtus townsendii*)	5	7	19	8	1	40
Long-tailed vole (*Microtus longicaudus*)	_	13	_	5	3	21
White-footed vole (*Phenacomys albipes*)	5	_	_	6	3	14
Western red-backed vole (*Clethrionomys californicus*)	_	1	1	1	2	5
Trowbridge's shrew (*Sorex trowbridgii*)	40	19	19	23	21	122
Pacific shrew (*Sorex pacificus*)	16	18	6	23	11	74

Table A.1. Continued

Species	Streams AL	BC	CC	DC	HC	Total
Vagrant shrew (*Sorex vagrans*)	3	2	35	21	3	64
Marsh shrew (*Sorex bendirii*)	4	_	_	3	4	11
Shrew-mole (*Neurotrichus gibbsii*)	_	1	_	3	_	4
Townsend's mole (*Scapanus townsendii*)	1	2	_	_	_	3
Townsend' chipmunk (*Tamias townsendii*)	_	_	_	_	1	1
Western pocket gopher (*Thomomys mazama*)	_	_	1	_	_	1
Ermine (*Mustela elminea*)	_	_	1	_	_	1
Total	140	189	258	109	142	838

[a] AL=Drift Creek near Ayer's Lake, BC=North Fork Beaver Creek, CC=Cape Horn Creek, DC=Deer Creek, HC=Horse Creek.

Table A.2. Capture frequencies of small mammal species in streamside habitats ($\underline{n}$ = 5) without the influence of beaver, Lincoln County, Oregon, 1989.

	Streams[b]					
Species[a]	AL	BC	CC	DC	HC	Total
Deer mouse	25	34	129	34	61	283
Pacific jumping mice	5	6	13	13	3	40
Creeping vole	–	–	4	8	3	15
Townsend's vole	6	–	1	2	1	10
Long-tailed vole	3	1	–	1	3	8
White-footed vole	3	4	12	3	1	23
Western red-backed vole	8	–	–	–	1	9
Trowbridge's shrew	24	50	29	34	34	171
Pacific shrew	8	28	19	14	23	92
Vagrant shrew	6	–	1	3	3	13
Marsh shrew	4	1	6	3	3	17

Table A.2. Continued

Species	Streams AL	BC	CC	DC	HC	Total
Shrew-mole	1	—	1	1	—	3
Townsend's mole	—	2	—	—	1	3
Townsend' chipmunk	—	—	1	—	3	4
Western pocket gopher	—	—	—	—	—	—
Ermine	—	2	—	—	—	2
Total	93	128	216	116	140	693

[a] See Table A.1. for scientific names

[b] AL=Drift Creek near Ayer's Lake, BC=North Fork Beaver Creek, CC=Cape Horn Creek, DC=Deer Creek, HC=Horse Creek.

Table A.3. Capture frequencies of amphibian species in streamside habitats ($\underline{n}$ = 5) occupied by beaver, Lincoln County, Oregon, 1989.

Species	Streams[a]					Total
	AL	BC	CC	DC	HC	
Roughskin newt (*Taricha granulosa*)	12	13	21	1	14	61
Western redback salamander (*Plethodon vehiculum*)	14	6	7	_	6	33
Olympic salamander (*Rhyacotriton olympicus*)	_	2	4	3	_	9
Tailed frog (*Ascaphus truei*)	_	_	1	_	_	1
Red-legged frog (*Rana aurora*)	_	6	1	_	3	10
Northwestern salamander (*Ambystoma gracile*)	_	2	7	_	4	13

Table A.3. Continued.

Species	Steams					Total
	AL	BC	CC	DC	HC	
Pacific giant salamander (*Dicamptodon ensatus*)	1	—	—	—	—	1
Ensatina (*Ensatina eschscholtzi*)	—	—	2	—	1	3
Dunn's salamander (*Plethodon dunni*)	—	1	—	—	—	1
Total	27	30	43	4	28	132

[a] AL=Drift Creek near Ayer's Lake, BC=North Fork Beaver Creek, CC=Cape Horn Creek, DC=Deer Creek, HC=Horse Creek.

Table A.4. Capture frequencies of amphibian species in streamside habitats ($\underline{n}$ = 5) without the influence of beaver, Lincoln County, Oregon, 1989.

Species[a]	Streams[b]					Total
	AL	BC	CC	DC	HC	
Roughskin newt	13	9	4	1	3	30
Western redback salamander	11	16	7	2	7	43
Olympic salamander	_	7	7	4	_	18
Tailed frog	_	7	4	6	1	19
Red-legged frog	_	2	1	1	16	20
Northwestern salamander	_	_	_	_	1	1
Pacific giant salamander	_	_	_	_	1	1
Ensatina	_	_	_	_	_	0
Dunn's salamander	_	_	2	_	_	2
Total	24	41	25	14	29	133

[a] See Table A.3. for scientific names.

[b] AL=Drift Creek near Ayer's Lake, BC=North Fork Beaver Creek, CC=Cape Horn Creek, DC=Deer Creek, HC=Horse Creek.