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SELECTION OF IN-STREAM WOOD STRUCTURES BY BEAVER IN THE BEAR RIVER, SOUTHWEST WASHINGTON

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ABSTRACT—Many habitat restoration projects for Pacific salmon (*Oncorhynchus* spp.) have placed wood structures in streams. We observed beaver (*Castor canadensis*) consistently using 3 wood structures placed in the Bear River as foundations for dams, which provided pool habitat for juvenile salmon. Determining why beaver used some structures and not others could help to increase the efficacy of wood placement through use by beaver. We conducted an exploratory study using model selection procedures based on Akaike's information criteria to assess the hypothesis that there were characteristics of the wood structures and their immediate environment that influenced use by beaver. A literature review and field observations were used to develop 7 logistic regression models and the parameters of those models were estimated with data from 55 in-stream wood structures. One model had overwhelming support (Akaike weight = 0.9801) as the best in the set of 7 examined. Variables in that model described both in-stream characteristics (channel confinement; and distance to log jams, deep pools, and beaver bank dens) and riparian conditions (floodplain width and hillside slope). Structures used by beaver were in unconfined channels, farther from other logjams, closer to deep pools and bank dens, in wider floodplains, and with less steep hillsides. The logistic regression model is a resource selection probability function that may be useful in designing wood placement projects if restoration ecologists and managers wish to enlist the services of beaver.

Key words: beaver, *Castor canadensis*, Akaike's information criteria, ecosystem restoration, large woody debris, logit analysis, *Oncorhynchus* spp., Pacific salmon, stream restoration, Washington

Beaver (*Castor canadensis*) activities have substantial influence on both aquatic and riparian ecosystems (Naiman and others 1986; Naiman and others 1988; Pollock and others 1994; Kelsey and West 1998). Ponds and wetlands created by beaver dams provide habitat for a variety of fish and wildlife (Rabe 1970; Renouf 1972; Legeyda and others 1987; Leidholt-Bruner and others 1992; McKinstry and others 2000). However, in many areas beaver populations have been maintained at low levels for decades (Dalquest 1948; Johnson and Chance 1974; Pollock and others 1994), substantially reducing their effects on ecosystem structure and function.

Declines in many stocks of Pacific salmon (*Oncorhynchus* spp.) (Stouder and others 1997) have resulted in numerous assessments of fresh water habitats, identification of limiting factors,

and management programs designed to restore habitat. A common theme among most assessments in forested habitats of the Pacific Northwest is the low number of large logs in the river channel and an associated loss of habitat diversity (NRC 1996; Gregory and Bisson 1997). Large woody debris (LWD) creates high quality habitat for spawning and juvenile salmon (Gregory and Bisson 1997).

Leidholt-Bruner and others (1992) documented the use of beaver ponds by coho salmon (*O. kisutch*) fry in 2 streams in coastal Oregon. They noted that beaver ponds increased coho rearing habitat during late summer and that most beaver dams were destroyed by winter high flows, were associated with logs in the channel, and functioned in similar ways as large woody debris (LWD) in stream channels. They suggested that beaver "represent a

TABLE 1. Abundance and characteristics of beaver (*Castor canadensis*) sign along a 3-km section of the Bear River, Washington, in December 1996.

Feature	Number/km of river	Comments
Bank dens	2	83% with in-channel wood
Dams	3	88% with in-channel wood, 100% breached at high flows
Feeding stations	3	Forage remains: <i>Tsuga heterophylla</i> , <i>Alnus rubra</i> , <i>Rubus spectabilis</i> , <i>Polystichum munitum</i>
Trails	3	To food sources
Scent mounds	1	<i>A. rubra</i> leaves and twigs, mud
Felled trees	7	<i>A. rubra</i> , <i>T. heterophylla</i> , <i>Psuedotsuga menziesii</i> , <i>Rhamnus purshiana</i>

low-cost tool deserving more consideration for stream rehabilitation projects". Reviewing beaver influences on ecosystems, Pollock and others (1994) identified the use of beaver as a key research issue to restore riparian communities.

We became involved in a salmon habitat restoration project on the Bear River in southwestern Washington (Fig. 1) in 1996. In December 1996, a survey of beaver habitat use along a 3-km reach upstream of the restoration reach indicated a high degree of beaver activity associated with in-channel LWD (Table 1). The restoration effort included the placement of LWD (>76 cm diameter at the large end) structures in the river at 13 sites along a 4-km restoration reach, including 3rd- and 4th-order river segments, during July 1997.

During summers, 1997 to 2000, beaver consistently used 3 of the 13 placed LWD structures as anchors for dam construction during summer low flow periods. Juvenile salmon were abundant at the ponds associated with the LWD structures (ADL, unpubl. data). Given the presumed benefits of beaver dams to juvenile salmon and the expressed interest in beaver as a stream restoration agent, we wanted to determine why some LWD structures were used by beavers for dam construction and others were not. Such information could be useful in designing stream restoration projects and increasing the efficacy of placing LWD structures. In this study, we evaluated the research hypothesis that there were explicit characteristics of the LWD structures and their immediate environment that influenced use by beaver.

STUDY AREA

The Bear River flows into south Willapa Bay, draining a 78-km² watershed of the Coast Range (Fig. 1). Elevations range from sea level to 458 m. The majority of the watershed is owned by timber companies, and logging has been the dominant land-use since European settlement. Over 90% of the uplands are in 2nd- or 3rd-growth stands of Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*). Most riparian stands were dominated by red alder (*Alnus rubra*) with a few co-dominant or understory Sitka spruce (*Picea sitchensis*), western redcedar (*Thuja plicata*), and western hemlock. Details of the characteristics of those types of stands are provided by MacCracken (2002). Conifer-dominated riparian stands were composed primarily of Sitka

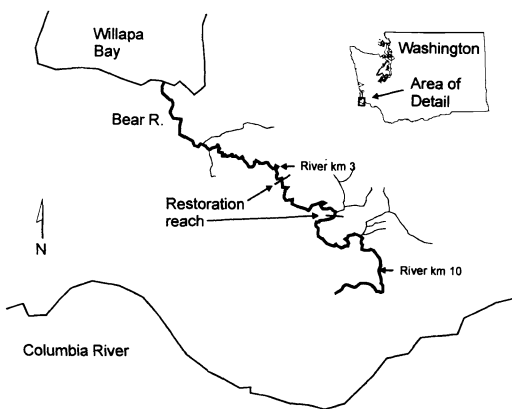


FIGURE 1. The Bear River in southwestern Washington, illustrating the study segment (km 3 to 10) where beaver (*Castor canadensis*) use of large wood structures was sampled in 2000 and the restoration reach where large wood structures were placed in 1997.

spruce and western hemlock. The age of riparian forest stands was unknown, but the adjacent uplands were 20 to 40 y old and it appeared that most of the red alder riparian forests were regenerated during the same time period. However, a 0.8-km segment of the river had a riparian zone of mature (≥ 100 y old) western hemlock-Sitka spruce forest. Herbaceous meadows were also present in the riparian area. The dominant vegetation in those meadows was Merten's sedge (*Carex mertensii*), common rush (*Juncus effusus*), small-flowered bullrush (*Scirpus microcarpus*), Canada thistle (*Cirsium arvense*), and tansy ragwort (*Senecio jacobaea*).

The study area extended from river kilometer 3 (4th-order) to kilometer 10 (3rd-order). Within that area, 49% of the riparian area (30 m on both sides of the channel) was red alder stands, 35% was mixed red alder-conifer stands, 13% was meadow, and 3% was conifer-dominated stands.

METHODS

Information-theoretic Approach

We used the information-theoretic approach proposed by Burnham and Anderson (2002) to address our research hypothesis, which emphasizes specifying a set of candidate models that represent hypotheses about the research question and selection of a model (or set of models) for making inferences from the data. Candidate models are often a subset of a global model, specified prior to data collection, and based on relevant findings in the scientific literature and investigator experience and expertise. The model parameters are estimated from empirical data, providing an estimate of the maximum point of the likelihood function, which is used in model selection. The model selection tool (Akaike's information criteria, AIC) incorporates these 3 important features: 1) the principle of parsimony (the tradeoff between model complexity and interpretability); 2) Kullback-Leibler information theory (Kullback and Leibler 1951), which is a measure of information lost when a model is used to approximate reality; and 3) maximum likelihood statistics (Akaike 1973). Akaike weights (the relative likelihood of the models) are used to rank models, to estimate variable importance, and to derive model averaged inferences. Model un-

certainty can be high when several models are equivalent as the best model. In such cases, model-averaged predictions, parameter estimates, and associated measures of precision are more reliable than estimates based on the single best model (Burnham and Anderson 2002).

Model Specification

We used binary logistic regression as the statistical model in this study (Hosmer and Lemeshow 1989). The response variable for all candidate models was dichotomous: 1 for LWD structures used by beaver for dams and 0 for those not used. The choice of explanatory (independent) variables included in each *a priori* candidate model was based on a literature review of beaver habitat use and field observations we made from 1996 to 2000. We found 5 published studies that estimated beaver habitat use (Slough and Sadlier 1977; Howard and Larson 1985; Beier and Barrett 1987; McComb and others 1990; Leidholt-Bruner and others 1992), but only studies by McComb and others (1990) and Leidholt-Bruner and others (1992) were conducted in the Pacific Northwest. Furthermore, Leidholt-Bruner and others (1992) was most relevant as their study area was in the Coast Range of Oregon, about 233 km S of ours. The 5 studies identified 14 variables that were important correlates with beaver habitat use. Those were stream width, gradient, and depth; presence of logjams, tributaries, and debris slides; percent slope of valley hillsides or stream banks; composition of the riparian community; soil drainage class; floodplain width; land use; watershed size; and ground cover. Nine of the 14 variables were judged relevant to our study, particularly those identified by Leidholt-Bruner and others (1992), and those that were found to be important in ≥ 2 studies. The 9 variables were stream width (WID), gradient (GRA), and depth (DEP); composition of the riparian community (VEG); floodplain width (FPW); percent slope of valley hill sides (SLP); and the proximity of logjams (JAM), tributaries (TRB), and debris slides (DSL). Land use and size of the watershed were not considered in this study because they did not vary over our study area. Furthermore, the soil drainage classification system of Howard and Larson (1985) was not applicable to our study

area, and ground cover was synonymous with riparian community composition.

In addition to the literature, our observations suggested 4 additional variables that may influence beaver use of LWD structures. Those were distance to a bank den (DEN) and deep pool (POL), channel confinement (a confined channel has little or no floodplain [CON]), and LWD structure height above the water (HIT). Thus, 13 variables comprised the global model while candidate models consisted of different combinations of those variables.

Seven models were specified that represented competing hypotheses about the importance of river channel, riparian area, and LWD characteristics as well as the applicability of the published literature and the accuracy of our field observations. Model g_1 (WID, DEP, GRA, VEG, SLP, FPW, JAM, TRB, DSL) represented the hypothesis that the published literature is relevant and that null hypothesis testing correctly identified variables "universally" important in habitat selection by beaver. Model g_2 (DEN, POL, JAM, CON) indicated that most of the literature results were not applicable to our study area, and that our informal observations of beaver activity were the most accurate. Model g_3 (FPW, DEN, POL, JAM, CON, SLP) combined the results of Leidholt-Bruner and others (1992) with some of our field observations. Model g_4 (FPW, DEN, POL, CON) is similarly based, but indicated that proximity to other log jams and slope of hillsides were unimportant. We reasoned that a relatively high density of logjams would reduce the need to construct a dam, and that differences in hillside slopes were not great enough to influence use by beaver. Models g_5 (DEN, HIT), g_6 (DEN), and g_7 (HIT) are based solely on field observations and represent the hypotheses that distance to a bank den and height of the LWD structure above the water were the most influential characteristics.

Data Collection

Data on the use of LWD structures by beaver and the 13 variables identified above were collected during August to September 2000. We conducted a complete census of all LWD structures in the study reach. Thus, the logistic regression models are resource selection probability functions that should be useful in pre-

dicting use of LWD structures by beaver (Manly and others 2002).

Stream width, to the nearest 0.1 m, was estimated 1 to 2 m upstream of each LWD structure by stretching a measuring tape across the channel at the ordinary high water mark (OHWM) on each bank (the point where terrestrial vegetation was established). Stream depth (channel bottom to the OHWM) was measured at the deepest point of the channel where stream width was estimated. Stream gradient (%) was measured with a clinometer between the LWD structure and a maximum of 50 m upstream or the farthest point where the structure could still be seen if <50 m upstream. The distance to the nearest logjam, tributary, debris slide, bank den, and deep pool (≥ 1 m deep) was measured from the LWD structure upstream (following the channel) to the nearest meter with a measuring tape, hip chain, or by pacing, up to 100 m. Height of the LWD structure above the water was measured from the OHWM to the bottom of the structure at the point where the structure was highest above the OHWM. Floodplain width, to the nearest meter, was measured 1 to 2 m upstream of the LWD structure from the OHWM to the toe of the hill slope on each bank. Hillside slope was measured from the toe of the slope, to a maximum of 50 m upslope or to the point just before visibility was lost. Channel confinement immediately above the structure was recorded as confined (1) or not (0). Riparian vegetation was recorded as hardwood forest (1), herbaceous meadow (2), hardwood/conifer forest (3), or conifer forest (4) based on the dominant vegetation ($\geq 51\%$ cover) upstream of the LWD structure for 50 m on each bank. For models that included CON and VEG, CON (1) and VEG (4) were set as the "standard" conditions (Manly and others 2002).

Data Analysis

Prior to estimating model parameters, the explanatory data set was reduced by estimating all pair-wise correlations and dropping 1 variable of a pair that had $r \geq 0.7$. The variable retained in the analyses had low ($r \leq 0.6$) correlation with other variables and better ecological interpretation.

The logit regression procedure of SYSTAT (Wilkins 1997), with the quasi-maximum likelihood adjustment of the covariance matrix,

TABLE 2. McFadden's s-rho² (ρ^2), prediction success (%), log maximum likelihood estimate [$\log(\mathcal{L})$], number of estimated parameters (K), Akaike's information criteria (AIC_c), rescaled AIC_c (Δ_i), Akaike weights (w_i), and evidence ratios (w_3/w_i) for logistic regression models relating the characteristics of 55 large wood structures and their immediate environment to their use as beaver (*Castor canadensis*) dam foundations in the Bear River, Washington.

Model	ρ^2	%	$\log(\mathcal{L})$	K	AIC_c	Δ_i	w_i	w_3/w_i
g_3	0.87	97	-2.4700	7	21.3224	0.0000	0.9801	—
g_2	0.49	89	-9.6843	5	30.5931	9.2207	0.0095	103
g_5	0.34	88	-12.4181	3	31.3062	9.9838	0.0067	146
g_4	0.41	86	-11.2465	5	33.7169	12.3945	0.0020	490
g_6	0.21	84	-15.0253	2	34.2957	12.9733	0.0015	653
g_1	1.00	100	-0.0000	12	34.4286	13.1065	0.0001	9803
g_7	0.05	81	-18.0447	2	40.3294	19.0070	0.0001	9803
Global	1.00	100	-0.0000	16	45.9487	25.6263	0.0000	—

was used to estimate the parameters of all models. The fit of the global model, as well as the subset of models, was assessed with McFadden's Rho-squared statistic (analogous to r^2 in linear regression) and the accuracy of model predictions (Steinberg and Colla 1997). The log of the maximum likelihood estimate for each model, used in calculating AIC_c , was provided by the SYSTAT output. Because the number of LWD structures sampled (n) was small relative to the number of parameters (K) in the global model ($n/K < 40$), a small sample derivative of AIC_c (AIC_{ci}) was calculated for each model. The model with the smallest AIC_c estimate is considered the best approximating model and the AIC_c estimates were re-scaled as simple differences ($\Delta_i = AIC_{ci} - \min AIC_c$). In addition, the "Akaike weight" (w_i) for each model was calculated. The w_i are interpreted as the relative likelihood (probability) of the model as the best in the set (Burnham and Anderson 2002). Evidence ratios (Burnham and Anderson 2002) based on the w_i were calculated for all models, relative to the model with the greatest w_i . The Δ_i , w_i , and evidence ratios provided a weight of evidence as to the model(s) with greatest support as the best. The relative importance of individual variables included in the best model(s) was estimated by summing the w_i 's across all possible variable combinations (or a balanced subset, if that criterion resulted in ≥ 100 models) for that set of variables (Burnham and Anderson 2002).

RESULTS

Data were gathered from 55 LWD structures over the 7 km of river surveyed. Twelve of the 55 structures were placed as part of the resto-

ration project, and 3 of the 12 were consistently used by beaver as foundations for dams. Beaver also used 3 of the remaining 43 natural LWD structures.

The global model fit the data, and prediction success was high (Table 2). Model g_3 had the greatest weight of evidence (smallest AIC_c , greatest w_i , and a very large evidence ratio for the 2nd best model, g_2) as the best in the set. The weight of evidence in support of the other 6 models was relatively weak (Table 2). Model g_3 was clearly superior to the others, model uncertainty was low, and the conditional parameter estimates and measures of precision from that model were relatively accurate, precluding the need for model averaging (see Burnham and Anderson 2002). According to this model, use of LWD structures by beaver was inversely related to the slope of valley hillsides and distance to a bank den, and positively related to unconfined river channels, distance to a log jam, distance to a deep pool, and the width of the floodplain (Table 3). Model g_3 also fit the data well and overall predictions of the model were very accurate (Table 2).

To estimate variable importance, there were 64 possible unique combinations of the 6 variables in model g_3 , and each variable occurred in 28 models. The sum of the w_i 's across each model containing a particular variable indicated that CON, JAM, SLP, and POL were the most important (Table 3). All LWD structures used by beaver were in unconfined channels, whereas the majority of structures not used were located in confined channels (Table 4). In addition, LWD structures used by beaver were farther from log jams than unused structures, in valleys of slightly lower hill slopes, closer to

TABLE 3. The logistic regression model coefficients (β_i), standard errors ($s_{\bar{x}}$), and summed Akaike weights (Σw_i) for 6 explanatory variables of the Kullback-Leibler best model (g_3) for large wood structures used by beaver (*Castor canadensis*) in the Bear River, Washington.

Variable	β_i^a	$s_{\bar{x}}^a$	Σw_i^b
Channel confinement (CON)	53.198	12.694	0.9999
Logjam proximity (JAM)	1.031	0.230	0.9995
Hillside slope (SLP)	-0.493	0.197	0.8353
Deep pool proximity (POL)	0.129	0.054	0.8136
Floodplain width (FPW)	0.011	0.046	0.4254
Bank den proximity (DEN)	-0.096	0.026	0.2180
Constant ^a	-48.804	13.532	

^a From model g_3 .

^b Each variable was in 28 of 64 models.

deep pools, in wider floodplains, and closer to a bank den (Table 4). The contradiction between the sign of the coefficient for POL (+) in model g_3 and the actual relationship with use by beaver (inverse) is likely a result of the relatively large negative coefficient for the constant in the model (Table 3). The constant accounts for the majority of the inverse trend in the model, leaving little to none assigned to the other variables (H Stauffer, Humboldt State University, Arcata, CA, pers. comm.).

DISCUSSION

Channel confinement was 1 of the most important variables influencing the probability of

use of LWD by beaver; all used structures were in unconfined channels (Table 4). Water velocity in confined channels is greater, increasing the probability of dam breaching, and confined channels have narrow floodplains, limiting the width of a potential beaver impoundment. Although preference for LWD in unconfined channels was strong, 18 structures in unconfined channels were not used, suggesting that other factors were also important.

The distance to the next logjam was essentially tied with channel confinement as an important variable (Table 3). As this distance increased, the probability of the LWD structure being used by beaver increased. This suggests

TABLE 4. Mean and standard error ($s_{\bar{x}}$) or proportions for characteristics of 55 large wood structures and their immediate environment, used and not used by beaver (*Castor canadensis*) for dam construction in the Bear River, southwest Washington.

Variable	Used ($n = 6$)	Not used ($n = 49$)
Channel confinement (%)		
No	100	37
Yes	0	63
Logjam proximity (m)	52 (22)	14 (5)
Hillside slope (%)	28 (6)	30 (2)
Deep pool proximity (m)	46 (17)	64 (6)
Floodplain width (m)	41 (18)	23 (4)
Bank den proximity (m)	57 (14)	95 (3)
Channel depth (cm)	104 (14)	85 (15)
Channel gradient (%)	1 (0)	1 (0)
Height of structure above water (m)	0.1 (0.1)	0.2 (0.04)
Riparian vegetation (%)		
Hardwood	17	59
Herbaceous	83	0
Hardwood/conifer	0	19
Conifer	0	1
Debris slide proximity (m)	>100	>100
Tributary proximity (m)	84 (11)	81 (5)
Channel width (m)	13 (1)	9 (1)

that the clumping of structures may influence use by beaver. Consistent with our hypothesis, beaver may benefit more from the time and energy expended to construct a dam in reaches of low LWD density if areas of high LWD density provide numerous deep pools, more potential den and feeding sites, and greater cover. In contrast, the longitudinal distribution of LWD in a river is dynamic and influenced by the size of the wood relative to channel width (Harmon and others 1986; Bilby and Bisson 1998; Keim and others 2000). As stream order increases, LWD tends to be more clumped and is often deposited in areas where the wood is completely out of the water at low flows. This suggests that in areas of high LWD density most of the structures may be unsuitable for dam construction.

The slope of the valley hillsides was also important and inversely related to beaver use of a LWD structure. Although the average difference was only 2%, steeper slopes may exponentially increase movement costs for foraging and the collection of material for dam construction.

Although used structures were actually closer to deep pools than unused structures (Table 4), the probability of LWD use based on model g_3 increased as distance to a deep pool increased. This discrepancy between the model coefficient and the data has been explained previously and model prediction success was high despite this anomaly (Table 2). Deep pool was an important variable in the model (Table 3) and deep pools provide escape cover and most bank dens were also located in deep pools.

Floodplain width and distance to a bank den were also included in g_3 , but their importance was relatively low compared to other variables. However, wider floodplains would be associated with unconfined channels, greater width of the pool behind a dam, and slower water velocities. The negative relationship between use of a structure and distance to a bank den indicates that the probability of use increases if beaver are established close by, and there may be a threshold distance from a den at which an impoundment has little benefit.

The small number of LWD structures used by beaver could be due to several reasons. First, only 6 structures may have had the right combination of channel and riparian characteristics. For example, channel confinement was 1 of the most important variables, and all LWD

structures used by beaver were located in unconfined channels, whereas nearly equal numbers of structures were in both channel types (24 in unconfined and 31 in confined, Table 4). However, structures in unconfined channels that were not used were closer to other logjams, farther from bank dens, and had relatively narrow floodplains.

In contrast, another possible reason for the low use of LWD structures may be that current beaver populations in the Bear River are below the watershed carrying capacity and, therefore, because beaver did not occur in all areas, all suitable structures were not used. Commercial and damage control trapping of beaver has occurred in the watershed for decades, likely limiting population growth. However, those activities ceased in 1997 when public access was restricted, and no damage control removals have occurred. Although casual observations indicated that the beaver population was increasing, we have no information on population density or watershed carrying capacity. However, dams averaged 1336 m ($s_x = 710$) apart and there was little sign of beaver activity in the intervening reaches.

The pools created by beaver dams during low flow periods provide a number of benefits to other organisms and alter the structure and function of impounded reaches (Naiman and others 1986, Naiman and others 1988, Pollock and others 1994, Kelsey and West 1998). Beaver may benefit by maintaining deep water at bank dens, increasing the amount of escape cover, and increasing secure access to floodplain and hillsides for foraging and collection of dam building materials. Salmon, particularly coho fry, benefit from increases in the amount and quality of rearing habitat. This includes decreases in fast water (Bisson and others 1988; Leidholt-Bruner and others 1992), retention of organic matter and increased productivity (Naiman and others 1986), development of water temperature strata where optimum conditions can be exploited, and inundated floodplains that provide food, cover, and off-channel habitats. These functions could be extremely important to the production of coho smolts from the system as low flow periods in the summer can reduce habitat volume (Ziemer and Lisle 1998). Low flows result in increased fish density in pools, increased vulnerability to

predation, and increased competition for food and space.

In addition to the above, beaver dams that persist through several high flow events or those that are not completely destroyed provide fry with off-channel areas to escape fast water and premature flushing down river (Sedell and others 1990; Leidholt-Bruner and others 1992). Our general observations indicated that dams in the Bear River that had LWD structures as a foundation tended to survive the first 2 to 3 high flow events. In addition, when breached, only portions associated with the thalweg (the low flow channel) were completely lost, thus extending the presence and amount of slow water refugia. Dams not associated with LWD were constructed exclusively in shallow riffles or the tail of glides and pools, were typically <0.3 m tall, were often abandoned prior to completely spanning the channel, and were completely swept away with the 1st high flow event in the fall.

The placement of LWD structures as a stream restoration tool can be expensive; the cost was \$4046/structure in this project. Given the potential benefits of beaver dams to salmon fry, restoration ecologists may be able to increase the efficacy of some placed LWD structures through designs that will increase the likelihood of beaver use. Results of this study indicate that logs placed to encourage the development of beaver dams should be in unconfined channels, >50 m from other structures, with adjacent hill slopes <28%, and <50 m from a deep pool and bank den (Table 4). Furthermore, model g_3 can be used to predict the probability that a LWD structure will be used by beaver (Manly and others 2002). However, even though the prediction success of the model was high, it should be tested with an independent data set.

Biologists that have promoted the role of beaver in stream restoration have suggested increasing beaver densities or maintaining populations at high densities (Leidholt-Bruner and others 1992). However, Pollock and others (1994) recognized the importance of fluctuating beaver populations and the role of beaver abandonment and colonization of river segments on the structure and function of aquatic systems. This suggests that maintaining high densities of beaver may be impractical, or possibly counter-productive. Furthermore, our

study provides information on the characteristics of LWD structures that appear to elicit dam construction; we do not know if LWD placement influences beaver colonization rates.

In most watersheds, beaver populations are probably lower than those prior to European settlement and may have been held at low levels for decades by commercial trapping and damage control programs (NRC 1996). Beier and Barrett (1987) suggested that the enumeration of active and inactive beaver colonies could be used to estimate the total number of potential colonies in a watershed. Estimates of watershed carrying capacity will help to develop realistic goals and expectations for the role of beaver in a stream restoration project. However, basic research on beaver population dynamics, movements, dispersal, colonization patterns, and habitat use is needed to refine those goals and expectations.

Regardless, in many watersheds that are managed primarily for timber production, such as the Bear River, maximizing beaver populations may not be practical given the potential for conflicts with reforestation efforts and road maintenance. Similar conflicts arise in agricultural, suburban, and urban areas. However, the practice of placing LWD structures that encourages use by beaver may be a means to optimize the trade-off between maximizing the benefits of beaver activities to aquatic systems, and conflicts with intensive land use.

This study was largely exploratory, retrospective, and lacked replication. As such, extrapolation of the findings to other watersheds should be done with caution. Past stream restoration projects with placed LWD structures could be used to confirm our results and test model g_3 . In addition, future projects could easily be designed to test the applicability of our results.

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