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Recent History (1988-2004) of Beaver Dams along Bridge Creek in Central Oregon

Abstract

Bridge Creek is a low-gradient stream in the John Day River basin of eastern Oregon. After decades of grazing, riparian vegetation along a 31.7 km reach was sparse and low in diversity, vegetated floodplains were typically narrow, and the stream was relatively wide and shallow. Cattle grazing within this reach was reduced in 1988, irrigation diversion ditches were replaced with culverts in 1989, and beaver (*Castor canadensis*) trapping was discontinued after 1991. Between 1988 and 2004, we inventoried beaver dams and ponds twice a year and estimated their dimensions. Field notes and photographs were used to document habitat use and better understand the potential role of beaver with regard to channel morphology and riparian plant communities. The annual number of beaver dams present in the study reach ranged from 9 to 103. On average, dams were nearly 8 m in length with ponds extending upstream 26 m. We also found that beaver dams/ponds, over time, typically accumulated sediment, improved conditions for establishment and growth of riparian plants, and altered channels. Dams that breached during periods of high flow often contributed to long-term increases in channel complexity through the formation of new meanders, pools, and riffles. Exposed sediment deposits associated with breached dams provided fresh seedbeds for regeneration of willows (*Salix* spp.), black cottonwood (*Populus balsamifera* ssp. trichocarpa), and other riparian plants. Although portions of the study reach were periodically abandoned by beaver following heavy utilization of streamside vegetation, within a few years dense stands of woody plants normally occupied a larger portion of the floodplain. Observations over a period of 17 yrs indicate that beaver facilitated recovery of riparian vegetation, floodplain functions, and stream channels.

Introduction

Although Beaver (*Castor canadensis*) once ranged across nearly all of North America, fur trapping in the 1700s and 1800s decimated their populations across much of the United States (Hill 1982). With the loss of beaver and their dams along streams in the American west, in conjunction with increasing levels of herbivory from livestock, channel incision and widening often occurred causing drastic reductions in subsurface water storage along floodplains and loss of wetland habitats associated with riparian ecosystems (Fouty 2003). In the Ochoco Mountains of central Oregon, Finley (1937, p. 296) observed that, "with no beaver engineers left to take care of the dams, the ponds disappeared; grassy meadows built up by sub-irrigation died out."

Beaver historically have been identified as destroyers of trees, roads, crops, and habitats (Bump 1941, Yeager and Hill 1954, Hill 1982, Avery 1983, DeByle 1985, Beier and Barrett 1987). More recent studies, however, have established their capability to improve watersheds, stream systems, and habitats (Brayton 1984, Naiman et al. 1988, Wright et al. 2002, Baker and Hill 2003). Even with increasing knowledge regarding the ecological benefits of beaver (Kay 1994, Ringer 1994, Sharps 1996, Wright et al. 2002), public agencies and private landowners were often reluctant to protect them from continued exploitation. This was perhaps due, in part, to damage complaints from landowners that occurred when beaver reoccupied portions of their former range (Hill 1986, Luoma 1996).

In the John Day River basin of central Oregon, the effect of beaver on stream systems was controversial in the late 1980s and thus they were widely trapped. Along Bridge Creek, a tributary of the John Day River, trapping kept populations at relatively low levels since ranchers were apprehensive about potential impacts to crops and irrigation facilities (Freilich et al. 2003). Similarly, various local, state, and federal land managers were concerned that failed beaver dams would contribute to bank damage and riparian impacts, especially where cattle grazed in riparian areas. In light of this controversy, we annually monitored

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beaver dams over a 17-yr period to better understand their potential ecological role with regard to stream and riparian processes.

Study Area

Bridge Creek is a second-order stream that drains 603 km^2 of mostly mixed conifer forest in the Ochoco Mountains, Oregon. Shrub-steppe communities of big sagebrush (*Artemisia tridentata*) and juniper (*Juniperus occidentalis*) frequent lower elevation hillsides.

The portion of Bridge Creek utilized in this study begins downstream from the town of Mitchell at 31.7 river kilometers (rkm) at an elevation of 817 m and continues downstream in a northerly direction to 0.2 rkm (elevation = 466 m), immediately upstream of the confluence with the John Day River. Two segments of private land (8.5-13.7 rkm and 24.1-25.3 rkm), encompassing a total of 6.3 rkm, were excluded from study. The remaining 25.4 rkm of Bridge Creek occur on public land administered by the Bureau of Land Management (BLM).

Stream gradients along the study reach range from 0.5-3%. Streamside vegetation is comprised predominately of willows (*Salix* spp.), with coyote willow (*S. exigua*) being the most common followed by one-color willow (*S. monochroma*), whiplash willow (S. *Lasiandra*), Arroyo willow (*S. Lasiolepis*), and hybrid crack willow (*S. x. rubens*). Other deciduous riparian species included thinleaf alder (*Alnus incana* ssp. *tenufolia*), water birch (*Betula occidentalis*), red-osier dogwood (*Cornus sericea*), and black cottonwood (*Populus balsamifera* ssp. *trichocarpa*).

Most public land within the study reach was acquired by the BLM between 1988 and 1992 during the 256 km^2 Sutton Mountain land exchange. Before the exchange, annual use of the area by domestic cattle and sheep was 4,000 to 5,000 animal unit months (AUMs, where 1 AUM is the amount of forage required by an adult cow and calf for one month). Until the 1950s, there were also about 100 feral horses utilizing an additional 1000 to 1500 AUMs of forage (BLM 1995). In 1988, the Bridge Creek channel was relatively straight, wide, and shallow with limited riparian vegetation and a narrow floodplain.

As the Sutton Mountain land exchange proceeded, season-long grazing along Bridge Creek was gradually reduced. In 1992, riparian areas were excluded from domestic grazing for 5 yrs (BLM 1996). Starting in 1997, and continuing to the present, relatively light winter grazing by cattle occurred between 19.3-24.1 rkm. Currently, the entire Sutton Mountain area is grazed at less than half of its historical use. In addition to changes in grazing management, irrigation ditches were replaced with culverts in 1989, and beaver trapping was discontinued after 1991.

Methods

The BLM completed a general inventory of riparian and channel conditions in the summer of 1988 to help formulate management alternatives along Bridge Creek. We repeated photo points previously established in 1987 at quarter-mile intervals in 1991, 1996, and 1998. We observed vegetation and channels along the study reach, from 1988 to 2004, and recorded observations of changes in vegetation species and composition, channel sinuosity and width, and flow patterns. We also inventoried beaver dams twice each year along the 25.4 rkm of public land. One inventory occurred early each summer to evaluate if springtime flows had affected beaver dams and to observe how dams influenced stream morphology and riparian plant communities. During the fall inventories we estimated the dimensions of existing and newly built dams and evaluated the effects of summer rainfall/runoff events.

We visually estimated the following dimensions of each beaver dam and pond: dam length, pond length (l), maximum pond width (w), maximum pond depth (d). Since maximum pond widths and depths were typically greatest immediately upstream of a given dam, pond surface areas were calculated as $1/2 * l * w$ (area of a triangle) and pond volumes as $1/3 * l * w * d$ (volume of a pyramid). We located and dimensioned 476 dams over the 17 yrs of this study.

Streamflow data were not available for Bridge Creek during the period of this study but were available for the John Day River at Service Creek (drainage area = 13 200 km^2). We used linear regression to evaluate if number of dams along Bridge Creek might be associated with the magnitude of annual peakflow measured at the John Day River gage.

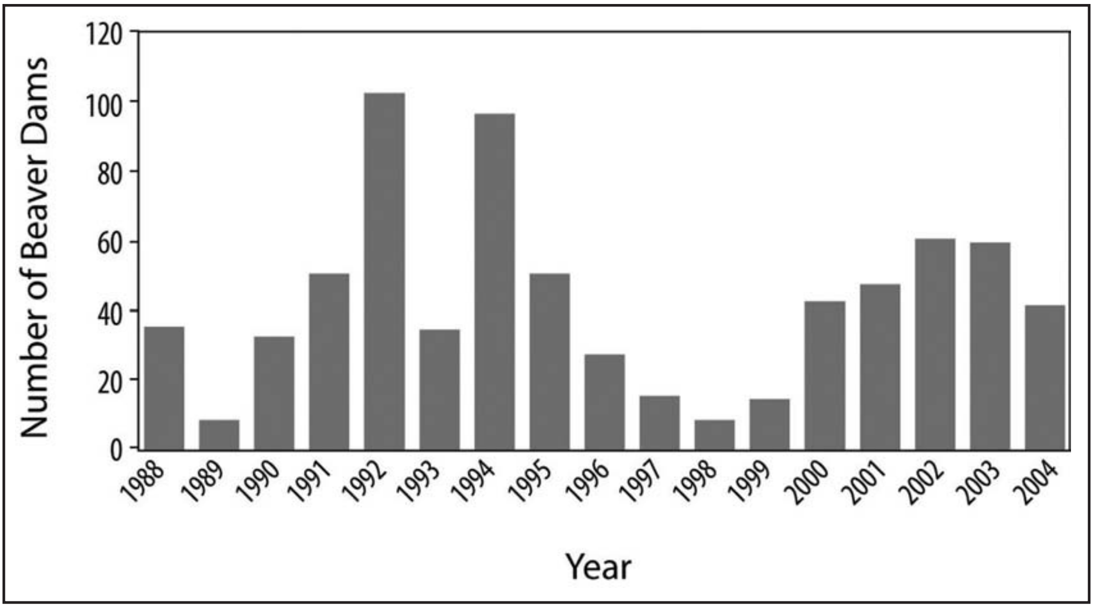

Figure 1. Total number of inventoried beaver dams, by year, along 25.4 km of Bridge Creek in central Oregon.

Results

Observations and photographic evidence indicated that total cover and diversity of riparian vegetation increased over the 17-yr study period, with vegetated riparian zones increasing in width throughout much of the Bridge Creek study reach. These increases began to occur following the initiation of management changes in 1988.

We inventoried 36 beaver dams along Bridge Creek in November of 1988, the 1st yr of the study. In subsequent years, the number of dams inventoried each fall ranged from 9 to 103 (Figure 1). Dams were built from locally obtained materials including stems of woody vegetation, driftwood, forbs, rocks, and mud. Average ($\pm$ SD) dam and pond dimensions were: dam lengths = 8 m ($\pm$6 m), maximum pond widths = 8 m ($\pm$5 m), pond lengths = 26 m ($\pm$18 m), maximum pond depths = 0.8 m ($\pm$ 0.3 m), pond surface areas = 120 m^2 ($\pm$150 m^2), and pond volumes = 80 m^3 ($\pm$130 m^3) (Figure 2). The length of time that dams remained in place varied from <1 to 7 yrs, with a high proportion of dams (i.e., 75%) lasting $\leq$2 yrs.

For most years, snowmelt peakflows (typically occurring during the months of January through May) did not exceed the upper streambanks and few beaver dams were breached or washed out. However, springtime flows covered the floodplain and breached most dams in 1993, 1997, and 1998. Peakflows of the John Day River for these 3 yrs represented the 4th, 2nd, and 1st largest runoff events, respectively, during this study. Linear regression indicated a significant inverse relationship (r = -0.49, P = 0.05) between annual peakflow of the John Day River and number of beaver dams, supporting field observations that indicated fewer dams following the occurrence of high flows.

In the Bridge Creek watershed, runoff from local thunderstorms commonly occurs in late spring and summer. While thunderstorm runoff often breached some beaver dams each year, dams along nearly the entire study reach were breached from summertime high flows in 1995, 1997, and 1998. After 2 yrs of exceptionally high and prolonged flows, only nine dams were recorded in the fall of 1998 (Figure 1). The only year in which dam-breaching thunderstorms did not occur was 1992.

While runoff patterns had a major influence on when beaver dams were built, food availability and physical habitat generally affected their location. When dams were breached and flows remained high during wet years, beaver dispersed along the stream and few dams were constructed. This dispersed population often utilized areas

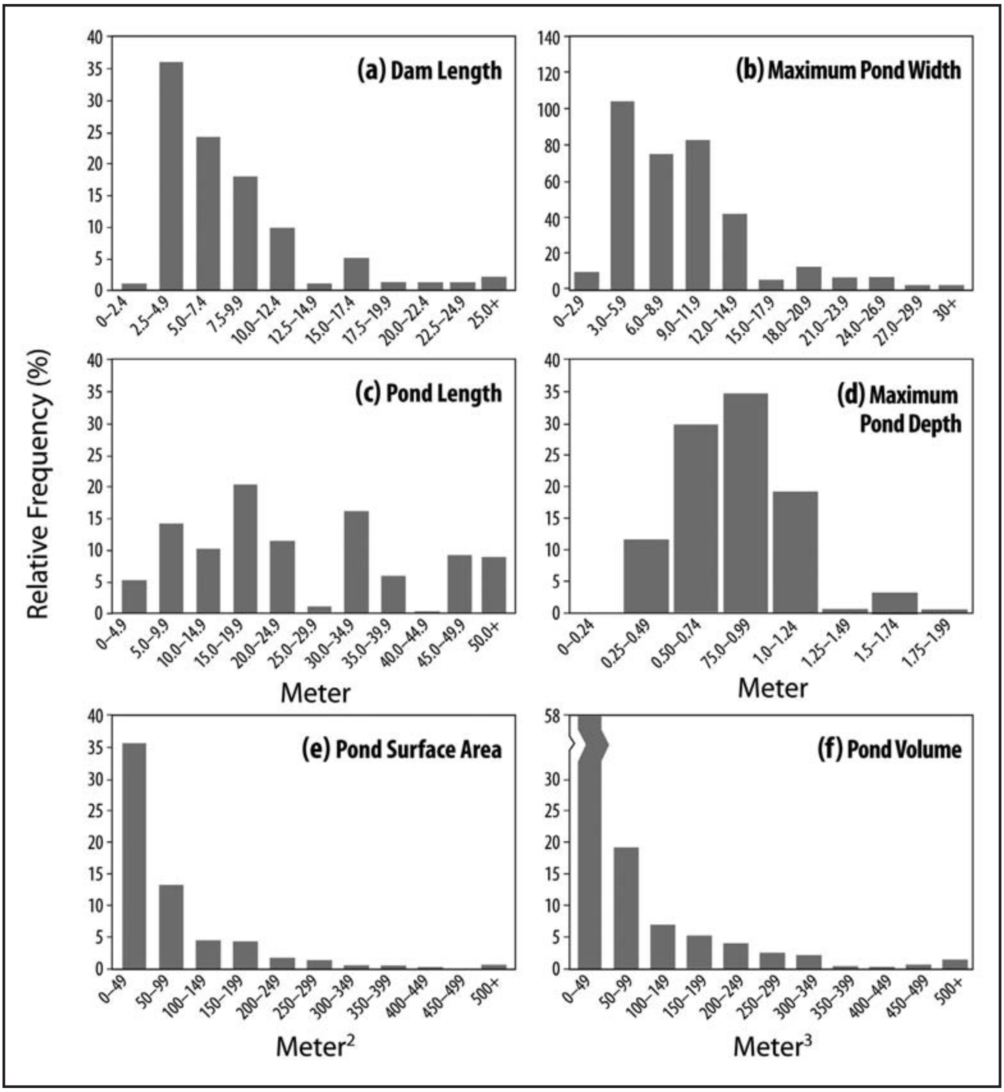

Figure 2. Frequency histograms of a) dam length (m), b) maximum pond width (m), c) pond length (m), d) maximum pond depth (m), e) pond surface area (m^2), and f) pond volume (m^3).

where food resources were relatively low and conditions were not conducive to building dams. In the spring of 1998, a single dam remained following the high winter and spring flows of previous years and, since flows remained relatively high, only eight new ones had been built by fall. Observations of beaver activity (e.g., cutting of willows, building of bank dens, presence of tracks) indicated that they were typically distributed along the entire study reach where they utilized riparian vegetation for food. Since water depths remained relatively deep that summer, beaver were able to live in bank dens dug below the water surface.

It was uncommon for dams that breached during high runoff in the spring/early summer to be immediately rebuilt or replaced. Instead, dam-building typically appeared to begin whenever water levels became too low for beaver to navigate between their den and streamside food sources or when low water levels increased their exposure to predators. Following the normally occurring annual snowmelt peakflow between late April and early June, dam-building increased

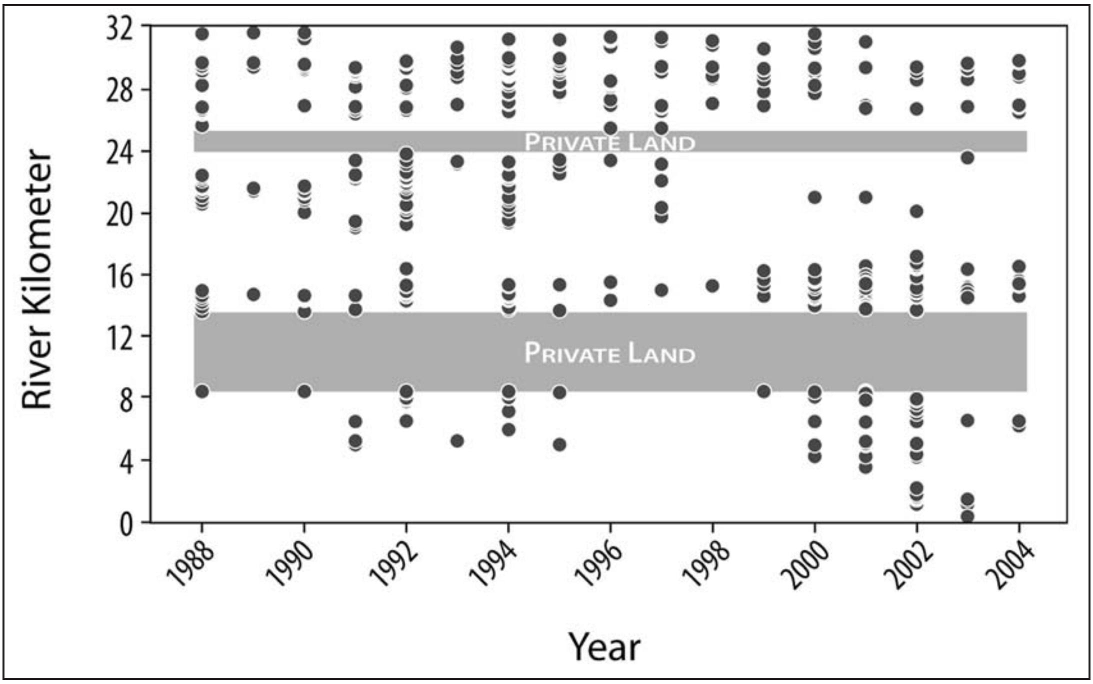

Figure 3. Occurrence of new beaver dams (closed circles) by year and river kilometer (rkm) along the Bridge Creek study reach. Private lands (from 8.5-13.7 rkm and 24.1-25.3 rkm) were not inventoried.

as flow decreased. This temporal pattern of dam construction/reconstruction helped to locally maintain high soil moisture levels along stream banks and floodplains during the summer, moisture crucial locally to the establishment and growth of riparian plant communities. Thus, the temporal and spatial pattern of dam occurrence along the study reach (Figure 3) generally indicated where riparian plant communities most likely benefited from the presence of beaver.

The largest numbers of dams in the study reach were typically found following periods of low streamflow. For example, 63 dams were constructed in the late summer and fall of 1992, bringing the total to 103 since 40 dams remained from the previous 3 yrs when flows remained relatively low. During periods of low summertime flow, beaver often heavily utilized willows adjacent to a pond, then moved upstream to the pond apex and added another dam. Up to four upstream dams in succession were sometimes built over a period of one or more years. When such dams were constructed, downstream dams were abandoned but usually retained their structural integrity for several years if they did not experience high flows. Series of dams in close proximity to each other appeared to be especially effective at spreading floodwaters (Figure 4a), often *via* beaver-made secondary channels, thus forming complex aquatic/riparian habitats. Dams were maintained and often enlarged during dry periods as long as riparian vegetation remained adequate for food.

The spatial distribution of dams (Figure 3) was generally associated with the occurrence of improved riparian plant communities following reductions in livestock grazing and previously abandoned reaches. Thus, dams that had become breached or washed away by high flows were often not replaced if willows were more abundant at other locations. Once a site was abandoned, the previously utilized woody plant communities rapidly recovered within a few years. The germination of willow seeds that fell or washed onto newly exposed alluvial deposits following the loss of a dam typically formed a dense mat of seedlings. Species of the willow normally found along Bridge Creek generally require bare, wet soil within days of seed ripening in the spring (Brinkman 1974). In addition, willows that had been cut almost to the ground grew new stems and beaver-cut portions of willow stems that littered streambanks and alluvial deposits often sprouted.

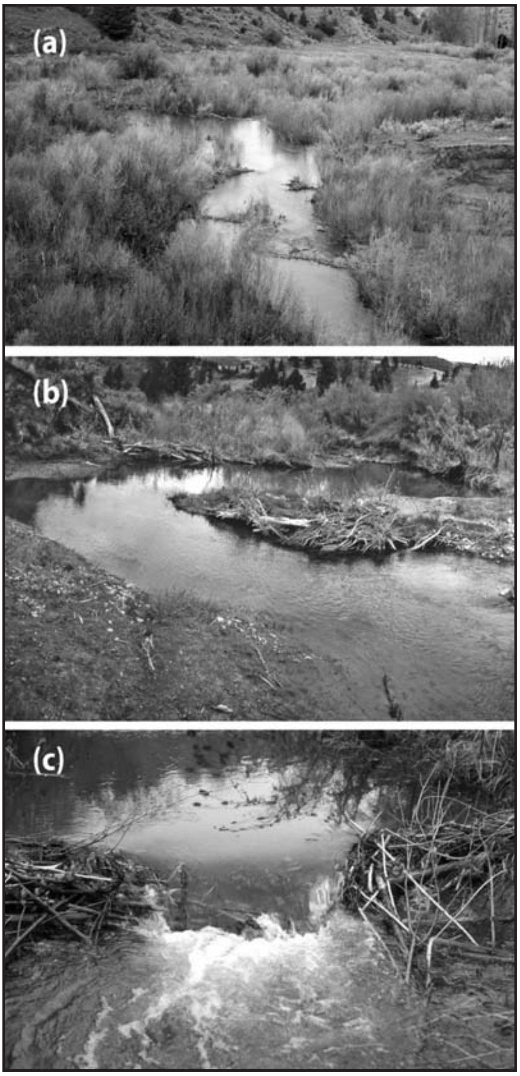

Figure 4. Examples of beaver dam effects: a) general ponding, overbank flows, and an expanded riparian plant community due to multiple dams, b) increased stream sinuosity as a result of a dam breaching on one end, and c) partial breach of dam contributing to pool formation (by scouring) immediately downstream of dam.

Although black cottonwoods and thinleaf alders rarely sprouted from cut branches, they frequently grew from seeds that fell on freshly exposed alluvial deposits. Large sections of the study reach were temporarily abandoned by beaver only to be re-occupied within a few years, following regrowth of the previously utilized riparian vegetation.

When dams washed out, increases in channel sinuosity, hydraulic roughness associated with woody debris and plants, and sediment deposits within former ponds contributed to the formation of complex patterns of pools and riffles (Table 1, Figure 4b, 4c). These beaver-modified reaches developed a diversity of wetland habitats ranging from small shallow marshes vegetated with sedges (*Carex* spp.), rushes (*Juncus* spp.), and cattails (*Typha* sp.) to extensive stands of deciduous woody species. Hence, the morphological and biological effects of beaver dams, which began with their construction and maintenance, usually continued long after the dams were breached or abandoned.

Along most of the study reach, observations indicated that riparian plant communities generally improved (e.g., increased numbers of woody species, height growth, and stem densities) during the course of this study (Figure 5). As these changes occurred beaver began to increasingly occupy the downstream portion of the study reach

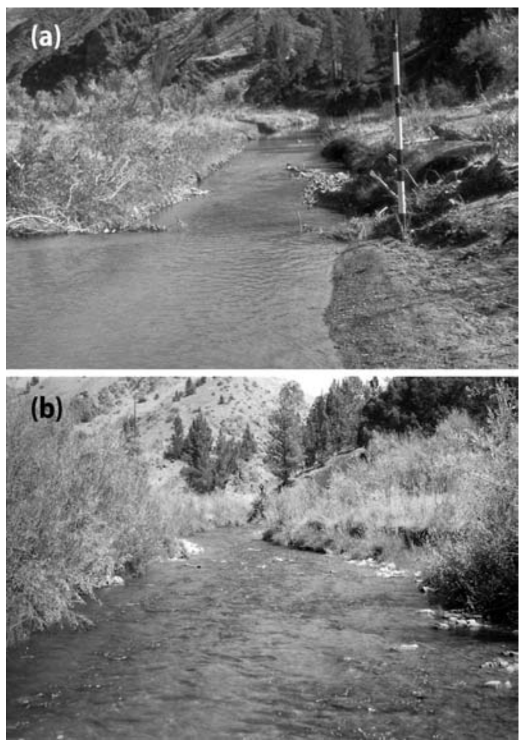

Figure 5. Chronosequence of photographs in a) 1987 and b) 1998 showing improved woody riparian plant communities along streambanks of Bridge Creek.

TABLE 1. The fate of 161 beaver dams from 1988-93 along 25.4 km of Bridge Creek in central Oregon.

Number (%) of dams	Observations
30 (19%)	These dams washed away completely, usually during periods of high flows.
61 (38%)	These dams breached on an end where flows would typically begin to erode the streambank adjacent to the dam and eventually form a new meander around the end of the dam. The remaining portion of a dam would accumulate sediment deposits on its upstream and downstream sides. Coyote willows (*Salix exigua*) growing on the dam would spread roots into the surrounding sand and gravel further stabilizing deposited alluvium.
51 (32%)	These dams breached in the center while both ends of the original dam remained well-anchored along each bank. The remnant dam sections constricted flow and would eventually create an upstream riffle and a downstream pool. These deflectors became stabilized by vegetation and often remained for many years before they were gradually buried by sediment deposits or were undercut. Alluvial deposits usually formed along streambanks upstream and downstream of the former dam.
14 (9%)	These dams remained intact over time while the original pond simply filled with sediment. Water continued to flow over or around these dams, sometimes creating deep plunge pools immediately downstream of a dam. After a few years a channel would reestablish either by cutting through the dam, washing it out completely or by cutting around an end of the dam leaving a large proportion of the deposited sediment in place. A riffle/pool sequence formed where the dam was cut in the center or a new meander formed when the channel cut around the end of the dam.
2 (1%)	The top portion of these dams washed away leaving woody material and rocks embedded along the channel bottom. In these cases the channel became a broad riffle at the former dam site with a shallow pool formed immediately downstream of the original structure.
3 (2%)	A large dam was constructed downstream from an existing dam thus causing the original structure to be inundated by the new pond. The older dam would be partially dismantled and some of the materials would be incorporated into the new dam. The pond associated with the new dam contained relatively large amounts of woody debris and rocks that formed a complex aquatic habitat.

(Figure 3) where habitat was initially marginal for their use.

Discussion

Along Bridge Creek, as is perhaps the case for other low-gradient mountain streams where beaver have a significant presence, the building of dams and the ponding of water is part of a complex process that helps to shape and maintain the character of riparian plant communities, floodplains, and channels. But efforts by beaver to maintain conditions necessary for their survival (e.g., ecosystem engineering) often brings them into conflict with certain land uses. For some portions of Bridge Creek, the channel historically had been straightened and armored with large rocks to accommodate roads. At other locations, instream fords were periodically constructed so that farmers and ranchers could access fields or grazing lands with vehicles and equipment. Thus, there were landowner concerns that increased beaver activity might adversely affect these structures as well as block irrigation ditches, thereby causing additional impacts to streams and riparian plant communities which had been extensively grazed by livestock for over 100 yrs.

The historical development and maintenance of irrigation systems along Bridge Creek had resulted in a management strategy that emphasized the removal of beaver and their dams. Before the change from private to public ownership along Bridge Creek, which occurred in stages between 1988 and 1992, beaver were routinely trapped. Trapping of beaver subsided as the transfer of land from private to public occurred and in 1992 such activities were banned along the entire stream and beaver dams were no longer removed on publicly acquired lands. In the fall of 1988 there were only 36 active beaver ponds along the Bridge Creek study reach, by1992 the number had increased to 103 (Figure 3).

During the Sutton Mountain land exchange, acquisition of land by the federal government started near Mitchell in 1988 and proceeded downstream when the lower 3 km of Bridge Creek were acquired in 1992. Thus, by the time of the last acquisitions along the lower portions of the stream, upper reaches were already undergoing change. As soon as the beaver population was allowed to fluctuate without significant human interference, a pattern of use became increasingly evident. Dams were initially built in locations where woody riparian plant species, primarily willows, were available for food and dam construction in this recovering system only to be subsequently abandoned when food resources were locally depleted. A similar pattern was observed by Hall (1960).

In 1988, coyote willow was the dominant woody riparian species throughout the study reach, especially downstream of rkm 8. Since then, other species of willow, thinleaf alder, water birch, red-osier dogwood, and black cottonwood were increasingly observed throughout the study reach. Although coyote willow is still the most prevalent deciduous woody species within the study reach, it is no longer dominant in many locations and is no longer the only woody species in the lower 8 rkm. Similarly, Wright et al. (2002) found that wetlands created in areas where beaver have built dams may support vegetation not found elsewhere in the riparian community, thus increasing species richness.

McComb et al. (1990) observed that stream gradient was the most significant predictor of dam location in the Long Creek Basin of eastern Oregon where gradients ranged upward to 12%. They found dams only on reaches with gradients of 1.5-4.0%. Since most of the Bridge Creek study reach falls within this range, other factors such as stream depth, flow volume, and food availability likely affected the spatial distribution of beaver dams. For example, locations with wide floodplains and low gradients appeared to be preferred building sites for dams as these areas provided greater amounts of desired plants. These sites also represented locations where the erosive energy associated with high flows could be more easily dispersed by vegetation and where dams remained intact for up to 7 yrs.

Beaver sometimes built dams in straight channels with narrow floodplains, thereby diverting flow against steep stream banks. Over time, these banks eroded laterally allowing for a widening of the local floodplain and an increase in the area available for the establishment of riparian plant communities. Breached beaver dams in these reaches also created additional sinuosity, pool-riffle sequences, and increased amounts of instream woody debris.

The maintenance of pond levels during periods of low streamflow can increase hyporheic flow along channels (Lowry 1993, Sharps 1996). The construction of dams also contributes to increased water tables and flooding of adjacent floodplains that may have otherwise become too dry to support riparian vegetation (Westbrook et al. 2006). Such effects are especially important during low water years when beaver dams were able to maintain extensive wetted areas along floodplains.

We rarely observed elk using any portion of Bridge Creek prior to about 1995. However, elk were increasingly observed in the later years of this study, particularly downstream of 16.1 rkm. Relatively high elk use occurred in 2001 between 14.5 and 19.3 rkm but did not appear to adversely affect riparian plant communities or discourage beaver from building dams.

While beaver continued dam-building activity in the reaches grazed by elk, they seldom built dams in the reach between 19.3 and 24.1 rkm after cattle grazing was reinstated in 1997 (Figure 3). This reduced dam-building occurred even though riparian vegetation along the cattle-grazed reach has generally increased over time and comprises a high density of woody species. Observations indicated that beaver activity (other than dam construction) was generally higher along this reach than in the remainder of the study area. While the reason for a lack of dam construction is not known, one possible explanation is that pools had become deeper and more numerous in this reach, allowing beaver to live in the creek without the need for dams. This hypothesis is supported by the fact that a somewhat narrower and deeper channel between 19.3 and 24.1 rkm developed following the rain-on-snow runoff event that caused widespread flooding in January of 1997. As high flows during the January runoff cut into adjacent terraces, floodplains along the lower portion of the study reach increased their lateral dimensions by more than 15 m and, in subsequent years, riparian vegetation rapidly colonized these newly exposed alluvial surfaces.

Several factors likely contributed to the initiation of riparian plant community recovery along Bridge Creek, including a ban on beaver trapping, improved irrigation systems, and altered grazing patterns perhaps being the most important. For example, the use of culverts to convey water to irrigated fields prevented erosion to banks and riparian areas that once occurred regularly when beaver dammed irrigation ditches. The removal of cattle grazing for several years allowed for increased growth and establishment of riparian plants. Furthermore, when cattle grazing was reintroduced to Bridge Creek, it was seasonally controlled (winter only), spatially limited (only 4.8 rkm out of a total of 25.4 rkm on public land), and at the relatively low intensity of less than 100 AUMs.

Various studies have shown that grazing by livestock along streams occupied by beaver can significantly reduce the availability of riparian vegetation to beaver for food and dam-building (Munther 1981, Jungwirth et al. 2005). Where grazing by livestock or native ungulates is extensive, riparian plant communities may be greatly impacted (Dieter and McCabe 1989, Kay 1994, Dobkin et al. 2002, Fouty 2003) and, without sufficient food, beaver eventually may be excluded. In turn, the loss of beaver can have important ecological consequences to other species. For example, studies in eastern and western Oregon (Bruner 1990, Talabere 2002) have shown that beaver dams/ponds provide important rearing habitat for native and anadromous fish. Similarly, a review of published studies by Pollock et al. (2003) found that the hydrologic and geomorphic effects of beaver dams generally enhanced stream habitat quality for fish.

In conclusion, the management concern that an increased beaver presence would contribute to the degradation of a riparian/aquatic system along a stream that had previously experienced multiple decades of heavy grazing was not supported by this study. Instead, results indicated that beaver had positive ecological effects and assisted in riparian plant community recovery along Bridge Creek, a low-gradient mountain stream in central Oregon. Beaver dams, whether functioning or breached and in combination with a variable natural flow regime, resulted in increased area and diversity of riparian plant communities and more complex channels during the nearly two decades of this study, thus contributing to the ecological recovery of riparian and aquatic habitats.

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