Riverine Habitats
21. Beaver Management and Beaver Dam Analogs

DEFINITION

Beavers are large, semiaquatic, herbivorous rodents that reside in the Northern Hemisphere. Only one species of beaver, the North American beaver (*Castor canadensis*), lives in the United States, covering most of the contiguous states (except for Florida, small patches of the Midwest, and the arid Southwest) and southern Alaska (USFS n.d.). Beavers are prominent ecosystem engineers because of their dam-building prowess. Beaver dams alter the hydrology of streams and small rivers, generating a multitude of benefits including filtering pollution, creating wetlands, storing groundwater, preventing floods, and sequestering carbon (Goldfarb 2018). In the pre-Columbian era, there were an estimated 250 million beavers in North America, a number that declined to 100,000 in the early 1900s as a result of intensive trapping (Ortiz and Dello Russo 2021; Goldfarb 2018). Since then, trapping regulations and beaver reintroductions have resulted in an estimated 10 to 15 million beavers living in North America today (Ortiz and Dello Russo 2021; Bardeen 2022). Beaver management refers to a strategy of increasing beaver populations through beaver reintroductions, enhancing beaver habitat, and promoting human–beaver coexistence (Jordan and Fairfax 2022). If an area wants to reap the benefits of beaver dams but does not have any beavers, beaver dam analogs (BDAs) can be built. BDAs are human built structures meant to mimic the design and function of beaver dams (Anabranch Solutions n.d.).

TECHNICAL APPROACH

Beaver Management

Beavers are intelligent animals and can reproduce quickly, which has allowed them to rapidly recolonize much of their former range (Schulte and Müller-Schwarzei 1999). To fully take advantage of the work of these impressive ecosystem engineers, managers can use the following strategies:

- **Beaver reintroductions:** In areas with historic beaver populations but no present-day colonies, a beaver reintroduction program can help improve local riverine processes. *Beaver reintroductions*, also known as *beaver translocations*, are human-facilitated beaver colonizations of a new territory. Before a beaver reintroduction can occur, livestock grazing must be managed to allow enough biomass to grow to provide food for beavers. Planting trees and riparian vegetation to support the beavers may also be necessary (Baker and Hill 2003). Beavers are then usually trapped, quarantined, tagged, and released.

  To avoid disrupting thriving beaver populations, translocation projects often target beaver colonies in urban areas that are generating nuisance complaints and are at risk of being euthanized if not moved. When trapping beavers, a variety of traps can be used, including box traps, suitcase-style traps, and nonlethal cable restraints (Doden et al. 2022). Regulations require beavers to be quarantined in a holding facility for a short period of time to reduce the transmission of disease. During this time beavers should be fed tree cuttings and root vegetables (Campbell-Palmer and Rosell 2015). Beavers can also be fitted with tracking collars to enhance monitoring if desired. Then, beavers should be released at the desired restoration site. While beavers may initially disperse to establish their own territory, over time, their movement will mirror normal beaver activity (Doden et al. 2022).

- **Enhancing beaver habitat:** If human-mediated beaver reintroduction is not feasible, then enhancing beaver habitat can entice beavers to naturally colonize the area. Reducing competition from other herbivores such as cows, elk, and deer will help promote beavers. This can be done by fencing off beaver habitat, killing the other herbivores via population control programs, or reintroducing natural predators such as wolves. Another option is to increase beaver food sources. Beavers like to eat willow and cottonwood trees, which can be planted along rivers. A final option is to reduce beaver predation rates. Humans are by far the main cause of beaver mortality, so more stringent trapping regulations can be implemented to support beaver populations (Pollock et al. 2023).
- **Promoting human–beaver coexistence:** Studies have shown as beaver densities increase, the willingness of residents to take lethal action against beavers increases as well (Siemer et al. 2013). Sources of human–beaver conflict include beavers cutting down commercially valuable timber, flooding properties, and blocking culverts. To reduce tree cutting, installing wire mesh cages around the base of the tree as well as dousing the tree with paint mixed with sand can be effective. For flooding concerns, installing flexible pond levelers or Clemson beaver pond levelers can lower water levels behind a beaver dam. Culvert-protective fencing or replacing a too-small culvert with a properly sized one (also benefitting riverine connectivity) are effective at mitigating conflicts with beavers (Pollock et al. 2023). Furthermore, nonlethal beaver control is much cheaper, saving an average of $229 per site per year (Callahan et al. 2019).

Beaver Dam Analogs

BDAs are meant to mimic natural beaver dams in arid or urban areas where beavers struggle to survive (Figure 1).

Like beaver dams, BDAs are engineered to eventually fail after a couple years (Anabranch Solutions n.d.). Additionally, the quantity of BDAs is more important than the quality, as a complex of BDAs can exert a larger influence on a river than one individual dam (Shahverdian et al. 2019). BDAs often attract beavers to colonize the area, where they will maintain and live in human-built dams. Constructing BDAs involves the following steps:

1. **Build up fill material:** A rudimentary wall of fill material should be placed along the river, with the height of the wall not exceeding 1 ft above the water's surface. Fill material can be sourced from the surrounding area and can include logs, stones, mud, and turf (Shahverdian et al. 2019).
2. **Build additional layers:** Next, additional layers of fill material must be added to reinforce the structure. Each successive layer should add around an additional foot of height to the dam until the structure has reached the desired crest elevation (Shahverdian et al. 2019).

Figure 21.1 Beaver dam analog at the North Slope Ochoco Holistic Restoration Project, OR

Photo courtesy NRCS Oregon

3. **Install posts:** Cuttings of midsized trees taken from the surrounding area should then be added to the structure. Posts should be driven into the ground vertically behind the fill material. The top of the post should be approximately 1 ft higher than the crest of the fill material. The number of posts installed is dependent on the level of structural stability desired (Wheaton et al. 2019).
4. **Construct willow mattress:** Weave willow branches into the downstream side of the dam. This will reduce water energy if the dam is overtopped (Shahverdian et al. 2019).
5. **Reinforce dam:** Plug up any leaks in the dam with small pieces of organic material (Shahverdian et al. 2019).

OPERATIONS AND MAINTENANCE

Maintenance activities may include subsequent beaver reintroductions, education and awareness campaigns about the benefits of beavers to help prevent local pushback and/or lethal action against beavers, or repair and maintenance of BDAs as they break down over time.

FACTORS INFLUENCING SITE SUITABILITY

- ✓ **Low gradients:** Stream power is reduced at lower gradients, making it easier for beavers to construct and maintain dams. This also allows beavers to flood a larger area with a smaller dam (Ritter et al. 2020).
- ✓ **Narrow channels:** Narrow channels allow beavers to build more stable dams that can better withstand high seasonal flows (Ritter et al. 2020).
- ✓ **High channel complexity:** Complex channels allow for a greater density of feeding areas as well as providing smaller channels of water that are easier to dam. A complex river morphology also dissipates floodwaters that could compromise the structural integrity of the dam (Scrafford et al. 2018).
- ✓ **High canopy cover of woody riparian vegetation:** Woody vegetation provides beavers with an ample source of both food and building materials for dams. Woody vegetation close to the water also helps beavers avoid predators since they do not have to travel as far to forage (Ritter et al. 2020).
- ✓ **Low-lying areas directly adjacent to the stream:** Low-lying riparian areas allow beavers easy access to foraging space. Additionally, low-lying riparian zones allow beavers to flood a larger area with a smaller dam, resulting in an outsized impact on the riverine system (Ritter et al. 2020).
- ✗ **Heavily incised channels:** Beavers need to access the floodplain to harvest vegetation, and channel incision limits this access (Scamardo and Wohl 2019).
- ✗ **Large rivers:** Beavers typically only live in first- or second-order streams that can be feasibly dammed. Larger rivers have too-deep water and are too wide to support beavers (Scamardo and Wohl 2019).

- **Frequent, intense flooding:** Streams that are especially flood-prone will deter beavers as their dams will be destroyed. If a two-year flood is powerful enough to destroy a beaver dam, then restoration should not occur there (Scamardo and Wohl 2019).
- **Noise and light pollution:** Frequent noise and constant light disturbs beavers, making many urban areas unsuitable for beaver habitation. However, this does not mean that beavers should be excluded from urban areas, with beavers thriving in urban parks across the United States (Bailey et al. 2019).
- **Little to no water:** The benefits that beavers provide in arid regions are especially valuable, including their ability to promote aquifer recharge, contribute to arid wetlands, and reduce evaporation rates. However, as rising temperatures and droughts alter the arid landscape, many areas have become unsuitable for beavers. Intermittent streams with little flow are seldom used by beavers (Gibson and Olden 2014). BDAs and rock detention structures are a viable alternative to help restore arid environments.

TOOLS, TRAINING, AND RESOURCES FOR PLANNING AND IMPLEMENTATION

Name and Link	Resource Type	Year	Authors/ Authoring Organization	Geography	Description	Resource Includes: Design/Construction Guidance?	Site Selection?	Monitoring Guidance?	Example Projects?
The Beaver Restoration Guidebook	Guidebook	2023	US Fish and Wildlife Service, US Department of Agriculture Forest Service (USFS), National Oceanic and Atmospheric Administration, University of Saskatchewan	National	This comprehensive guide covers beaver ecology and beaver management strategies. The authors also provide detailed technical guidance on BDAs, urban beaver management, relocating beavers, and managing beaver habitat.	✓	✓	✓	✓
Mimicking and Promoting Wood Accumulation and Beaver Dam Activity with Post-Assisted Log Structures and Beaver Dam Analogues	Book chapter	2019	Utah State University Restoration Consortium	National	Focusing on the technical aspects of building BDAs, this guide walks practitioners through the steps of building a BDA. Filled with helpful diagrams and pictures, the geomorphic and hydrologic implications of beaver management are also discussed.	✓	—	—	✓
Low-Tech Process-Based Restoration of Riverscapes: Design Manual	Guidebook	2019	Utah State University Restoration Consortium	National	This guide explains how beaver management fits into larger river and stream restoration projects. Topics covered include designing BDAs, implementing projects, and restoring river health.	✓	—	✓	✓
Managing for Large Wood and Beaver Dams in Stream Corridors	Guidebook	2019	USFS	National	Beavers are an integral part of stream ecology, but also can create hazards. This helps managers mitigate hazards while maximizing benefits from beavers by analyzing mitigation measures and reintroduction strategies.	✓	✓	✓	✓

Name and Link	Resource Type	Year	Authors/ Authoring Organization	Geography	Description	Resource Includes: Design/Construction Guidance?	Resource Includes: Site Selection?	Resource Includes: Monitoring Guidance?	Resource Includes: Example Projects?
Habitat Considerations at Beaver Restoration Sites: Implications for Beaver Restoration Projects	Journal article	2019	Torrey D. Ritter, Claire N. Gover, and Lance B. McNew	National	The authors analyze environmental factors that make a beaver restoration project successful. By studying wild beaver colonies, the authors recommend ideal sites for beaver habitation.	—	✓	—	—
Beaver (Castor canadensis)	Book Chapter	2003	Bruce W. Baker and Edward P. Hill	National	Providing an overview of beaver ecology and conservation, this chapter is meant for those looking for general information about beavers. Topics covered include habitat requirements, disease, beaver–fish interactions, and the economic value of beavers.	✓	—	—	—
Beaver Restoration Assessment Tool (BRAT)	Model	2013	Utah State University Ecomorphology and Topographic Analysis Laboratory	National	The BRAT model was designed to help restoration practitioners assess the feasibility of beaver management. It predicts where beavers can build dams and potential risks of beaver restoration. A fact sheet is also available.	—	✓	—	—
A Review of Two Novel Water-Tight Beaver Dam Analogs (WTBDA) to Restore Eroded Seasonal Creeks in Drain Tile Zones, to Permanent Beaver Wetlands	Article	2022	The Beaver Institute	National	This guide describes BDAs designs, including a berm and log spillway. The author weighs the tradeoffs between different designs, including management implications and costs.	✓	—	—	✓

LIKELY BENEFITS AND OUTCOMES

Primary objectives for each strategy are highlighted.

Climate Threat Reduction

- **Drought mitigation:** Beavers can turn intermittent washes into perennial streams by spreading out runoff flow over longer periods of time. By pooling water, beavers can increase groundwater storage and aquifer recharge. Surface water preserved by beaver dams and retained during droughts allows for farmers to continue irrigating their crops (Moore and McEvoy 2022).
- **Reduced flooding:** Beaver dams are highly effective at attenuating floodwaters. When excess water flows encounter a beaver dam, the water is pushed out laterally into the floodplain, protecting downstream communities. This increases flood lag times, distributing the amount of water that a river handles over a long period of time (Puttock et al. 2021).
- **Carbon storage and sequestration:** As ecosystem engineers, beavers promote carbon sequestration by creating peatlands and other inland wetlands that function as large carbon sinks. Furthermore, beaver dams trap sediments that increase the carbon density in the soil. Beaver-modified landscapes also promote additional plant growth, facilitating the storage of carbon in woody biomass (Johnston 2014).
- **Reduced wildfire risk:** Beaver dams store water in the surrounding environment, providing water to riparian vegetation during times of drought. During wildfires, beaver-occupied riparian areas exhibited increased fire resistance compared to beaverless streams. This creates refuges for plants and animals during fires (Fairfax and Whittle 2020).
- **Heat mitigation:** During heat waves, beaver dams help keep the water temperature of streams cooler. The increased water storage from dams resulted in decreased stream temperatures, reducing mortality rates for aquatic organisms (Dittbrenner et al. 2022). Furthermore, beavers and BDAs result in lower air temperatures. Beaver dams provide water to support increased vegetative cover, which has a cooling effect on the environment (Pearce et al. 2021).

Social and Economic

- **Aquifer recharge:** Beaver dams increase the residence time for water pooling behind the dam, facilitating percolation into aquifers. Beaver dams also push water into riparian areas, increasing the surface area covered by water, allowing more water exchange points with the aquifer. Additionally, beaver dams can reduce the rate of water table drawdown during dry seasons by increasing water flows to riparian areas. The community of vegetation created by these wet conditions reduces evapotranspiration rates, allowing plants to store surplus water (Westbrook et al. 2006).
- **Resilient fisheries:** Beaver dams provide a multitude of benefits for fish, including the creation of more complex habitats, enhancing overwintering habitat, providing

cover from predators, increasing invertebrate productivity, and creating a temperature refuge. All these factors contribute to higher fish growth rates and greater fish health (Kemp et al. 2012).

- **Jobs:** For most aspects of beaver restoration, workers will have to be hired to perform the restoration activities, stimulating the local economy.
- **Mental health and well-being:** Beaver restoration improves greenspace, boosting residents' mental health and psychological well-being.
- **Tourism:** Beaver reintroductions have been shown to increase local tourism. Businesses created to support wildlife tourism help diversify the local economy and an influx of wildlife watchers may increase visitation to parks (Auster et al. 2020).
- **Cultural values:** Beavers are enigmatic animals that are intertwined with human cultural traditions. Restoring beavers to their historical range will facilitate an increased understanding of beavers (Thompson et al. 2021).
- **Reduced erosion:** Streambed erosion occurs when sediment is transported away faster than new sediment is deposited. While beaver dams may cause lateral erosion of streambanks as a result of the widening of the watercourse, this results in more sediment entering the stream, reducing streambed erosion. The beaver dam then stops the sediment from traveling downstream, nourishing the streambed with sediment (Pollock et al. 2014).

Ecological

- **Supports wildlife:** Beavers create a diversity of wetland habitats, increasing habitat for wetland species and rewet wetlands that were anthropogenically drained, allowing for the restoration of the ecosystem services these wetlands provide. Beaver dams also create wetlands at diverse successional stages, with older beaver dams hosting mature wetlands while newly built dams support emerging wetlands (Bush et al. 2019). Periodic flooding behind beaver dams creates a mosaic of habitats. Wetlands, ponds, meanders, fens, and off channels are all created by beaver dams, creating habitat for flora and fauna that rely on these special conditions for survival (Sundell et al. 2021).
- **Enhanced biodiversity:** Beavers create a wide variety of habitats, increasing the number of organisms that can live in a certain area. An increase in the diversity of birds and invertebrates has been seen in streams after beavers moved in (Hood et al. 2021; Nummi and Holopainen 2020). Beavers also increase fish biodiversity as they create a spectrum of deep-to-shallow channels, which support more fish species (Smith and Mather 2013). While it could be assumed that beavers degrade riparian areas because of their use of riparian vegetation, beaver presence actually improves riparian health. Beavers slow down water flow, reducing erosion of riparian areas. Water pooled behind beaver dams helps the water table rise, allowing riparian plants better access to water. Additionally, beavers remove more established upland trees, helping riparian plants get established themselves (Pollock et al. 2023).
- **Improved water quality:** Beaver dams capture sediment and excess nutrients behind them, improving water quality downriver. Beaver engineering also reduces

the speed of water flow, reducing suspended sediment in the water and limiting the transportation of nutrient pollution (Brazier et al. 2021). Large amounts of nutrients are stored in beaver ponds. Beavers also reduce the canopy cover in the area, facilitating plant growth and nutrient uptake from the plants which cuts nutrient runoff into waterbodies. Beavers also promote conditions ideal for denitrifying bacteria, facilitating denitrification. This is especially valuable for watersheds overloaded with nutrients from agricultural runoff (Brazier et al. 2021).

- **Increased primary productivity:** Beaver ponds increase the availability of nutrients and allow more sunlight to penetrate the water's surface, allowing primary producers to thrive. This results in an increase of primary consumers (who eat the primary producers) and creates a greater food supply for larger fish and mammals (Pollock et al. 2023).

BARRIERS AND SOLUTIONS FOR PRACTITIONERS

Common Barriers

Several barriers are common across many of the nature-based solutions strategies; these are described in more detail in Section 1 of the Roadmap. Additional notes about the barriers specific to beaver management and beaver analogs are included here.

- **Expense:** While beaver translocations can be relatively inexpensive, building a BDA can be quite costly (The WYldlife Fund n.d.). It can cost up to $30,000 to build a BDA, which also need frequent upkeep unless beavers move in and take over the maintenance duties (Sorflaten 2022).
- **Capacity**
- **Public opinion:** Many residents feel threatened by the presence of beavers, regardless of if threats are real or perceived. Ensuring that local stakeholders are supportive of beaver restoration efforts is critical for a successful project, as residents can easily trap the beavers, derailing the project. Research has shown that proactive engagement, appropriate communication, and shared decision-making can increase community buy in (Auster et al. 2021).
- **Conflict with other land uses**
- **Regulation:** Permitting for both BDAs and beaver translocation are complex processes given the varying levels of regulation across states. For BDAs, permits are required from multiple agencies, including the US Army Corps of Engineers, the state fish and wildlife authority, and local authorities, depending on the project jurisdiction. Additional permits will be needed if an endangered species is impacted, and the National Environmental Policy Act applies to any project on federal land or using federal money (Davee et al. 2019). Beaver translocation policies vary from state to state; the practice is illegal in some states.
- **Lack of effectiveness data**

Economic

- **Impact on timber harvest:** Beavers cut down commercially valuable trees for their dams. Flooding from beaver dams can also induce rot and disease on timber, reducing its quality and value. A single beaver dam can flood thousands of acres of low-lying forest, making it inaccessible to tree-harvesting machinery. A cost-benefit analysis of a beaver control program in Mississippi estimated that the program saved between $25 million and $57 million in timber harvest (Shwiff et al. 2011). However, alternatives to beaver trapping exist, including protecting trees with mesh and paint (Pollock et al. 2023).
- **Infrastructure damage:** Beavers can burrow through levees and roads, compromising their structural integrity and necessitating costly repairs (Taylor et al. 2017).

Community

- **Flooding:** While beavers are highly effective at attenuating floodwaters downstream, beavers create ponds directly behind their dams, flooding a previously dry area. This can be mitigated with flexible ponds levelers or Clemson beaver pond levelers (Pollock et al. 2023). Additionally, if a beaver dam experiences a sudden failure, then infrastructure downstream is at risk. Beaver dam failures have led to human fatalities and the destruction of roads, airports, and buildings (Taylor et al. 2017).
- **Disease:** Giardiasis, also called *beaver fever*, is an intestinal disease caused by a tiny parasite called *Giardia*. Humans can contract giardiasis from a variety of sources, including exposure to feces of other humans or animals or water contaminated with feces. Beavers are frequently blamed for giardiasis because of a few prominent outbreaks that have originated from beavers. However, transmission between humans is more common. Good hand hygiene and water treatment are solutions to giardiasis, meaning that disease risks shouldn't hinder beaver restoration (Rozell 2021).

Ecological

- **Beaver movement:** Once beavers are translocated, they do not stay put, with most beavers moving around 10 km from their release site. Movement is often attributed to beavers looking for a mate, suitable habitat, and their own territory; beaver movement is highly variable based on the availability of suitable habitat. The majority of beaver movement occurs within 60 days of release, as beavers rarely migrate after they have established their territory and built a dam. Therefore, it is not certain that beavers will live in the desired restoration area (Doden et al. 2022).
- **Lack of dam building:** Beavers do not always build dams, and may instead opt to build lodges, canals, or burrows. Ecologically, this means that the benefits of beavers as ecosystem engineers may not be realized, since these benefits are associated with habitat creation via dam building. Building BDAs is a way to overcome this barrier (Pollock et al. 2023).
- **Overgrazing:** Due to the dearth of predators across America, grazing species such as moose, elk, and deer are well above their historic densities. These grazing species significantly impact riparian areas, preventing woody riparian vegetation from maturing. This is an issue for beavers because they rely on mature trees close to the water for dam building. Fencing off beaver habitat is a potential solution (Kay 1994).

EXAMPLE PROJECTS

Name and Link	Location	Leading Organizations	Techniques Used	Size, acres	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Magnuson Park Constructed Wetland System Beaver Restoration	Seattle, WA	Seattle Parks and Recreation, Berger Partnership	Habitat enhancement, Clemson beaver pond leveler	12.1	14.2 million	6	A team converted a military airfield into a wetland complex with the expectation that beavers would colonize the site. Soon after, a colony of beavers arrived and further modified the wetland via dam building.	No	When the beaver dams flooded walking trails, Clemson beaver pond levelers were used to control water levels.
Zuni Beaver Restoration	Zuni Reservation, NM	Pueblo of Zuni Fish and Wildlife Department	Beaver translocation, invasive species removal, grazing management	Not provided	17 million	10	To restore a local watershed, the Zuni Tribe translocated 23 beavers. Invasive species removal, reducing grazing pressure, and reshaping channelized watercourses were also completed.	Drought	Isolated instances occurred where beavers died in traps from drowning or predation. This was reduced by checking snares daily.
Methow Beaver Project	Okanogan-Wenatchee National Forest, WA	**Bureau of Reclamation, US Fish and Wildlife Service (USFWS),** USFS, Washington Department of Ecology, Washington Department of Fish and Wildlife	Beaver translocation	Not provided	Not provided	15 (ongoing)	Beavers are translocated from areas where they are deemed nuisances to streams within the natural forest. The driving force behind the project has been to restore salmon fisheries, which have been impacted by declining snowpack runoff.	Drought	The project maintains a beaver solutions hotline where they help address human–beaver conflicts.

Name and Link	Location	Leading Organizations	Techniques Used	Size, acres	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Cucumber Gulch Beaver Restoration	Breckenridge, CO	Town of Breckenridge, Breckenridge Ski Area	Habitat restoration, sediment removal, BDA construction, beaver translocation	2.4	Not provided	3	A ski resort significantly altered the local hydrology, with artificial snowmelt overwhelming the watershed and causing beavers to leave the area. Workers built BDAs, restored wetland hydrology, and removed excess sediment.	Flood protection	Extensive monitoring has shown that the project was a success, with natural migrants joining translocated beavers at the site and maintaining the BDAs.
Thompson Creek Beaver Restoration	Newman Lake, WA	**USFWS,** The Lands Council, Spokane Conservation District, Gonzaga University	BDA construction	65	Not provided	3	To restore Thompson Creek, the team designed and built more than 18 BDAs. This also helped restore the floodplain surrounding Thompson Creek.	No	Thompson Creek was a major source of phosphorus pollution for Newman Lake, which had issues with harmful algae blooms. Previous efforts to reduce the pollution had failed. The team then turned to BDAs, which slowed phosphorus flow.

Bolding indicates DOI affiliates.

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