Riverine Habitats
23. Riparian Buffer Restoration

DEFINITION

Riparian buffers are vegetated areas adjacent to an inland waterbody that are managed to protect the waterbody from the impacts of surrounding land uses (USFS n.d.). Riparian buffers can consist of a combination of trees, shrubs, and grasses that extend parallel to the banks of the waterbody. Spanning residential, agricultural, industrial, and natural land uses, riparian buffers prevent excess nutrients, sediments, and pollutants from entering the waterbody (Luo et al. 2017). Riparian buffers, generally located on steep slopes, are often installed because of their effectiveness at mitigating erosion compared to stone or concrete banks (Kenwick et al. 2009). Riparian buffers are under threat from invasive species, channelization, overgrazing, conversion to agricultural or urban land uses, and increased wildfire severity (Theobald et al. 2010). Restoring riparian buffers involves regrading stream banks, removing invasive species, installing grade control structures, reconfiguring channels and replanting native species (Laub et al. 2013).

TECHNICAL APPROACH

Restoring riparian buffers involves remediating changes to the soil, hydrology, and geomorphology in and around a riverine system.

1. **Restoring waterway hydromorphology:** The following techniques are commonly used to restore the hydromorphic properties of the stream or river:
    - **Regrading stream banks:** Stream or riverbanks at steep gradients are more prone to erosion and less conducive to vegetation growth. Regrading stream banks involves manipulating the soil to create a flatter slope adjacent to the waterbody, often using heavy machinery. This also typically involves moving the banks back from the waterbody, giving the water more room to flow following heavy precipitation events (Laub et al. 2013).
    - **Invasive species removal:** Riparian buffers are particularly vulnerable to being overtaken by invasive species because they are often sandwiched between developed areas. The dearth of adjacent intact ecosystems aids the proliferation of invasives, primarily herbaceous shrubs and vines (Johnson et al. 2020). Control strategies must be targeted towards individual species, with common control mechanisms including chemical (herbicides), biological (introducing predators), and mechanical (physically removing the plants) controls (USDA n.d.).
    - **Installing grade control structures:** A *grade control structure* is an earthen, wooden, or concrete structure that helps prevent streambed erosion and regulates the velocity of water flow (Cobb and Rainwater 2013). While grade control structures are in the riverbed and not the buffer, they can help riparian restoration by directing water away from eroded banks.

- **Reconfiguring channels:** Many degraded riparian buffers abut channelized streams, where the natural shape of the stream has been straightened. Restoring dynamic channels, which are self-sustained by the processes of sediment transport, creates more resilient riparian buffers that are less likely to erode. To do this, artificial bed substrates must be removed, peak inflows from stormwater drainage systems must be reduced, and riverbanks must be adjusted to restore natural meanders (Vietz et al. 2016).
- **Removing anthropogenic barriers:** Levees line many rivers and streams to keep the water flow within one channel. Because levees are directly adjacent to a river, they occupy the space where a riparian buffer would normally be. Levees have steep slopes and limited vegetation cover, and thus do not support riparian ecological processes (Griggs 2009). Heavy machinery is generally needed to remove levees or other anthropogenic barriers along rivers.
- **Installing natural materials:** To secure banks and mimic natural riparian habitat, boulders and wood are often placed along riverbanks. These abiotic components provide habitat for many amphibian species and help prevent erosion (Norris 1970).

2. **Vegetative restoration:** Once hydromorphic properties of the river or stream have been restored, native species are planted (Figure 1).

   Riparian buffers consist of different zones of flora based on their proximity to the waterbody. Closest to the water is the *emergent zone*, where small, hardy pioneer species should be planted. Next is the *mesic zone*, which is dominated by shrubs and smaller understory trees. Above that is the *xeric zone*, where mature trees are established and provide shade to the other zones (Bair et al. 2021). Outside of the xeric zone is a strip of woody florals and herbaceous forbs, which serve as the first line of defense against runoff (USFS n.d.). Installing plants in riparian buffers can be difficult because of the steep slopes. The following techniques may help:

   - **Wattle fences:** *Wattle fences* are walls of live cuttings built along terraces. The terraces help stabilize the bank until the cuttings develop roots and grow (Polster 2002).
   - **Live bank protection:** Similar to wattle fences, *live bank protection* is a wall of live cuttings that extends along the contours of a stream, preventing erosion (Polster 2002).
   - **Live palisades:** The live palisades technique involves sticking cuttings of larger trees into the ground like posts. The roots will overlap and form a web that will protect the soil (Petrone and Preti 2010).
   - **Live gravel bar staking:** In areas with large gravel deposits, cutting can be wedged in between rocks to help secure the bank. It is important that the cutting reach all the way down into the substrate (Polster 2002).

For areas with low gradients and minimal erosion, more conventional techniques such as planting plugs or scattering seeds can be used.

Figure 23.1 Planting sedges and rushes along Kettle Creek, CO

Photo courtesy USFWS Mountain-Prairie

OPERATIONS AND MAINTENANCE

Trash and debris will need to be removed from the restored riparian buffer monthly, and invasive species control may be necessary as well. Mulching and mowing are generally done on an annual basis (Cole et al. 2020). In some cases, erosion may create gullies that need to be filled in, and erosion control measures (revegetating eroded areas, using temporary erosion fences) may be required to prevent the problem from recurring.

FACTORS INFLUENCING SITE SUITABILITY

- ✓ **Adjacent to sources of nutrient pollution including golf courses, agricultural fields, pastures, or residential areas:** One of the primary benefits of riparian buffers is their ability to intercept nutrient pollution before it enters the water. Locating a riparian buffer near a source of nutrient pollution will magnify these benefits (NC DENR 2004).

- ✓ **Water table depth within 3 to 4 ft of the surface:** This water table depth allows plants to access water without becoming waterlogged. This range can be determined by the soil core characteristics (NC DENR 2004).
- ✓ **Sparse or absent woody vegetation:** Sparsely vegetated banks are where riparian buffers are most needed as there is nothing there to protect the river (NC DENR 2004).
- ✓ **Near a body of water that experiences frequent flooding:** Riparian buffers can help absorb excess water before it reaches the waterbody, reducing the amount of water the river must handle. Additionally, the buffer can serve as a part of a floodplain, preventing floodwaters from reaching developed areas.
- ✓ **Banks experiencing significant erosion:** Riparian vegetation helps stabilize eroding banks, protecting property and keeping excess sediment out of the waterbody.
- ✗ **Area that has significant grazing pressure:** High grazing pressure destroys riparian vegetation and limits the success of a restoration project. If a riparian area is adjacent to a grazing pasture, a fence should be installed to protect the buffer vegetation.
- ✗ **Land around the waterbody is constrained by other uses:** In many urban areas, development occurs right up to the river's edge (NC DENR 2004). Moving infrastructure for a riparian restoration project is generally impractical.
- ✗ **Site is seldom wet and handles small amounts of runoff:** In terms of prioritization, sites that are seldom wet and do not handle runoff would limit the benefits a restoration project would yield. While riparian vegetation would not cause any negative environmental impacts at these sites, it is best to choose areas with the greatest need for buffers to maximize scarce resources (Russell et al. 1997).
- ✗ **Channel with an artificial substrate (concrete, brick, and so on) that won't be removed as part of the project:** In many urban streams, the natural bed substrate has been replaced by an artificial riverbed. This alters the hydrology of the stream and is not compatible with a riparian buffer.
- ✗ **Slope greater than 6% (unless being regraded as part of the project):** Plants often struggle to establish themselves on steep slopes. Furthermore, steep slopes are more prone to erosion and degradation (NC DENR 2004).

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?
Riparian Restoration	Guidebook	2004	US Department of Agriculture Forest Service (USFS)	National	Written for technicians restoring riparian ecosystems, this guide overviews the design of riparian restoration projects for areas that are impacted by recreation. Topics covered include pest management, monitoring, planting techniques, and managing human impacts.	✓	✓	✓	—
California Riparian Habitat Restoration Handbook	Guidebook	2009	California Riparian Habitat Joint Venture	Written for California but most of the information is more broadly applicable	This guide puts an emphasis on restoring the hydrology of the river as the key to riparian restoration. The author provides guidance for designing projects in watersheds altered by levees, dams, and logging practices.	✓	✓	✓	—
Riparian Buffer Restoration	Book Chapter	2006	Pennsylvania Department of Environmental Protection	Written for Pennsylvania but most of the information is more broadly applicable	The authors lay out a simple framework for planning and installing riparian restoration projects. With a focus on maintenance, other topics covered include design considerations and planting in developed environments.	✓	✓	—	—
A Field Guide to Riparian Restoration, and Upland and Arroyo Erosion	Guidebook	2021	Watershed Management Group	Arid regions	Erosion is a significant issue in arid regions that receive large downpours, a problem this guide seeks to rectify. The authors describe a variety of techniques to retain water, reduce channel incision, and restore buffers.	✓	✓	—	—

Name and Link	Resource Type	Year	Authors/ Authoring Organization	Geography	Description	Resource Includes: Design/Construction Guidance?	Site Selection?	Monitoring Guidance?	Example Projects?
Guidelines and Protocols for Monitoring Riparian Forest Restoration Projects	Guidebook	2011	New Mexico Forest and Watershed Restoration Institute	Southwest United States	This guide details the process of monitoring riparian restoration projects. The authors explain the reasoning behind monitoring, what to monitor, and monitoring techniques.	—	—	✓	—
Restoring Riparian Ecosystems	Book chapter	2020	Washington Department of Fish and Wildlife	Pacific Northwest	This chapter of a larger management manual covers riparian restoration, outlining suggested riparian restoration techniques. Additional topics include monitoring strategies, adaptive management, and regulatory considerations.	✓	✓	✓	—
Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers	Guidebook	1998	USDA	Designed for the Chesapeake Bay watershed but most of the information is more broadly applicable	This guide goes through a variety of factors that need to be taken into consideration when restoring a riparian buffer, including soil quality, buffer width and streamside stabilization. The authors describe the relationship between riparian buffers and their surrounding land uses, including forestry, agriculture, and urban development.	✓	✓	—	—
Case Studies of Riparian and Watershed Restoration in the Southwestern United States—Principles, Challenges, and Successes	Guidebook	2017	US Geological Survey (USGS)	Southwest United States	Spanning restoration techniques and a variety of case studies, this guide catalogs the challenges and successes of riparian restoration in the Southwest United States. By exemplifying the lessons learned from each project, the authors aggregate collective knowledge on riparian restoration.	✓	✓	—	✓

GRAY INFRASTRUCTURE ALTERNATIVES

Riparian buffer restoration can be an alternative to gray infrastructure approaches that address riverine flooding (levee and dike systems) or urban runoff (stormwater drainage systems). The ability of a riparian buffer restoration project to replace or supplement these gray infrastructure approach depends strongly on the project's location and whether it is designed to create the necessary outcomes. Certain environmental conditions may require gray infrastructure rather than riparian buffer restoration. See the gray infrastructure alternative tables in Section 1 for a comparison of riparian buffer restoration to these alternatives.

LIKELY BENEFITS AND OUTCOMES

Climate Threat Reduction

Primary objectives for each strategy are highlighted.

- **Reduced flooding:** During high-volume precipitation events, riparian buffers help absorb increased runoff flows into the ground before they reach the river. This reduces the volume of water the river must handle, limiting downstream flooding. Furthermore, riparian zones can attenuate excess floodwaters if a river exceeds its bank, mitigating damage to nearby properties (Hawes and Smith 2005).
- **Heat mitigation:** Riparian zones can help mitigate heat waves by decreasing both air and water temperature. Water temperature is decreased as it slows while traversing the riparian buffer before it enters the primary waterbody. Air temperature is reduced by the dense canopy cover in riparian zones (Somers et al. 2013).
- **Drought mitigation:** Riparian buffers can mitigate drought by recharging aquifers. Riparian areas slow down runoff; buffer vegetation increases soil infiltration capacity, allowing for surplus runoff to percolate into aquifers (Singh et al. 2021).
- **Carbon storage and sequestration:** Riparian buffers contain a diverse array of vegetation, from climax community trees to pioneer grasses, all of which absorb CO_2 from the atmosphere (Vidon et al. 2019).

Social and Economic

- **Reduced erosion:** Riparian buffers can help reduce erosion by providing vegetation to stabilize steep banks and prevent topsoil from entering streams (Nakao and Sohngen 2000). Furthermore, riparian buffers can provide valuable flood protection, limiting the amount of soil loss that occurs in nearby areas (Hawes and Smith 2005).
- **Mental health and well-being:** Riparian buffers can function as valuable waterfront greenspace, increasing residents' mental health and psychological well-being.
- **Cultural values:** Restoring riparian buffers can increase residents' appreciation and admiration of the local ecosystem.
- **Jobs:** Contractors will need to be hired to implement the restoration, boosting the local economy.

- **Agriculture and timber yields:** Riparian buffers help increase yields in nearby agricultural areas by providing habitat for pollinators, providing habitat for predators that help to control pests, decomposing dead organic material, and reintegrating nutrients back into the soil (Luke et al. 2019).
- **Resilient fisheries:** The presence of an established riparian buffer helps regulate the transfer of solar energy, organic materials, and inorganic materials in between terrestrial and aquatic environments, improving the conditions in which fish live and thus their health. For example, the leaf litter created by riparian vegetation improves fish habitat quality and diversity. Furthermore, when riparian buffers hinder excess nutrients from entering waterbodies, they increase the rate of fish survival (Pusey and Arthington 2003).
- **Increased property values:** Riverfront properties with riparian buffers have higher values than similar properties without (Bin et al. 2009).

Ecological

- **Improved water quality:** Riparian buffers are highly effective at intercepting excess nutrients and sediment runoff before they enter waterbodies, preserving local water quality (Anbumozhi et al. 2005; Mankin et al. 2007). Wider buffers are more effective at preventing pollutants from reaching water bodies (Ortiz-Reyes and Anex 2018). Furthermore, riparian zones help limit additional sources of sediment pollution by preventing stream banks from eroding.
- **Enhanced biodiversity:** Riparian buffers have been shown to increase biodiversity because they conserve vital habitat, especially for animals that use both terrestrial and aquatic environments at different stages in their life cycles. Buffers of 50 m can support a sufficient amount of biodiversity for most species while buffers of at least 150 m are needed to maintain bird biodiversity (Lind et al. 2019).
- **Supports wildlife:** Riparian buffers create a wide variety of riverine habitats by modifying light penetration into water, depositing woody debris, altering water flow, and protruding vegetative root masses into the water. This allows for a greater diversity of species to thrive in the same aquatic region. The canopy of a riparian buffer also moderates the transition of solar energy into the water, resulting in fewer temperature fluctuations. Consistent temperature helps a greater number of aquatic organisms thrive (Pusey and Arthington 2003).
- **Increased habitat connectivity:** Riparian buffers mirror the long and narrow morphology of the rivers they surround, meaning that they can connect distant fragments of habitat. This fosters increased species diversity, genetic diversity within species and migratory pathways (Naiman and Décamps 1997).

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 riparian buffer restoration are included here.

- **Expense**
- **Capacity**
- **Public opinion:** While floods can increase community awareness about their vulnerability without riparian buffers, a catastrophic flood soon after a riparian restoration process has commenced can sour public opinion towards the project. Although mature buffers can attenuate floodwaters, severe floods can kill young plantings before they can make a significant impact on the environment (Thomson and Pepperdine 2003).
- **Conflict with other land uses:** Successful riparian buffers are generally around 100 m wide (50 m on each side of the waterbody), meaning that significant areas of land will have to be converted from their former uses (Santelmann et al. 2001). Riparian buffers are often adjacent to grazing areas. Riparian areas cannot tolerate intense grazing pressure and the waste of grazing animals often adds excess nutrients to the waterbody, heightening the risk of eutrophication (Sovell et al. 2000). Riparian buffers also take up the space directly along the water's edge, meaning that development cannot occur there. This is problematic for many industries that need direct access to water.
- **Regulation:** Many streams in the United States, especially in arid regions, are intermittent or ephemeral. However, these channels still need riparian buffers because they are acutely prone to erosion when they are inundated by heavy rains. In light of the recent Supreme Court ruling in *Sackett v. Environmental Protection Agency,* Clean Water Act protections no longer apply to most of these waterbodies (Turrentine 2023).
- **Lack of effectiveness data**

Community

- **Overuse by visitors:** In frequently visited areas, there is a tendency for visitors to informally expand trails and campsites into riparian areas. Heavy foot traffic and trash is detrimental to riparian buffers, meaning that projects in areas with high visitation often need to be fenced (Eubanks 2004).

Ecological

- **Invasive species:** Invasive species plague riparian areas and invasive species management must be a part of routine maintenance and monitoring for any restoration project. Communities of invasive species can coexist with each other in riparian buffers, amplifying the problem (Harms and Hiebert 2006).
- **Release of in-stream sediment stores:** Polluted sediments from previous poor land use management often build up in streams (Greenwood et al. 2012). The restoration of riparian buffers has the ability to release these sediment stores, which can be mitigated by dredging or the use of fine-sediment suction devices (McKergow et al. 2016).

EXAMPLE PROJECTS

Name and Link	Location	Leading Organizations	Techniques Used	Size	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Granite Camp Riparian Restoration	Grand Canyon National Park, AZ	**National Park Service (NPS),** Grand Canyon Association	Invasive species removal via mechanical control, installing native vegetation via planting poles and seeding	2 acres	104,500	1 year	Granite Camp is a remote backcountry camp in Grand Canyon National Park along the Colorado River. Volunteers removed invasive tamarisk trees and replaced them with a variety of native species, including willows and cottonwoods.	Inland flooding	The backcountry setting was particularly difficult to work in because plantings had to be flown in by helicopter and transplanted using hand tools because of a wilderness designation limiting the presence of power tools.
Canyon de Chelly Riparian Restoration Project	Canyon de Chelly National Monument, AZ	**NPS,** Navajo Nation	Invasive species removal	800 acres	NA	10 months	Invasive tamarisk and Russian olive trees caused significant channel incision and erosion while also adding to the fuel load in a fire-prone, arid region. The invasive trees were removed using a backhoe. To allow the newly restored areas to recover, fences were installed to keep out grazing animals.	Drought, wildfires	The cut-stump method was found to be the most cost-effective method of removing invasive shrubs and trees.

Name and Link	Location	Leading Organizations	Techniques Used	Size	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Las Vegas Wash Restoration Project	Clark County, NV	Southern Nevada Watershed Authority, **US Bureau of Reclamation**	Invasive species removal, native plant installation, building grade control structures	1,400 acres	125 million	13 years	To reduce the erosion and sedimentation of the Las Vegas Wash, workers built grade control structures to slow down the water in this ephemeral channel. A host of invasive species were removed and replaced with native vegetation to stabilize the banks.	Inland flooding, drought	Supplemental irrigation was needed to support plants in this arid region.
Fourmile Creek Fish Passage Restoration Project	Klamath County, OR	**US Fish and Wildlife Service, USGS,** US Department of Agriculture Forest Service (USFS), Klamath Bird Observatory	Debris removal, removing anthropogenic barriers, restoring historic channels, large wood and boulder placement	2 acres	172, 763	5 years	To divert a channel through its original riparian habitat, workers removed gradient barriers and debris. Large wood and boulders were also used to mimic natural riparian habitat.	No	Removing debris was critical to reducing sediment buildup plaguing the stream.
Beaver Creek Restoration Project	Helena -Lewis and Clark National Forest, MT	USFS; Montana Fish, Wildlife and Parks; Trout Unlimited	Installing natural materials, seeding native plants, planting native trees, constructing pools	1.2 creek miles	462,590	3 years	Volunteers helped restore the riparian zone around Beaver Creek by creating natural meanders with large wood and constructed pools. Native plants were also reseeded.	Drought	Significant alterations to the topography had to be made to restore the natural hydrology.

Name and Link	Location	Leading Organizations	Techniques Used	Size	Cost, $	Duration	Project Description	Climate Threats Targeted	Lessons Learned or Adaptive Management
Wild Mile Restoration Project	Chicago, IL	City of Chicago, Urban Rivers	Dechannelization, revegetation, installing aeration waterfalls, removing armored shoreline defenses	17 acres	1.4 million	Ongoing	In an industrial section of Chicago, workers are restoring riparian areas along the Chicago River by removing armored shoreline defenses and replacing them with native riparian vegetation. Aeration waterfalls will help increase dissolved oxygen levels for fish.	Inland flooding	Creating a gradual transition from land to water in the riparian zone is a challenge in an urban environment.
Dolores River Restoration Partnership	Eastern Utah and western Colorado	**Bureau of Land Management,** The Nature Conservancy, The Walton Family Foundation	Invasive species removal using biocontrol, chemical treatment and mechanical control; planting native vegetation	1,140 acres	1.26 million	6 years	Invasive species were removed along the banks of the Dolores River using a plethora of different methods. Native flora were then planted	Drought	A variety of invasive species treatment was found to be most effective when used in combination

Bolding indicates DOI affiliates.

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