Voluntary Clean Water Guidance for Agriculture Chapters

A phased approach is being used to develop these guidelines. During the first phase an overview of the guidance was produced along with its initial chapter which examines tillage and residue management practices. Additional chapters not completed though anticipated for inclusion in the overall guidance are listed below. These chapters will be completed in the following several years. Producers who are interested water quality guidance related to practices not yet addressed can contact Ecology's Agriculture and **Water Quality Planner Ron Cummings at ron.cummings@ecy.wa.gov or (360) 407-6600.**

Chapter 1 Cropping Methods: Tillage & Residue Management-Completed (December 2022)

Chapter 2 Cropping Methods: Crop System-***In development***

Chapter 3 Nutrient Management-***In development***

Chapter 4 Pesticide Management-***In development***

Chapter 5 Sediment Control: Soil Stabilization & Sediment Capture (Vegetative) -***In development***

Chapter 6 Sediment Control: Soil Stabilization & Sediment Capture (Structural)-Completed (December 2022)

Chapter 7 Water Management: Irrigation Systems & Management-***In development***

Chapter 8 Water Management: Field Drainage & Drain Tile Management-***In development***

Chapter 9 Water Management-Stormwater Control & Diversion-***In development***

Chapter 10 Livestock Management-Pasture & Rangeland Grazing- **Completed (December 2022)**

Chapter 11 Livestock Management-Animal Confinement, Manure Handling & Storage-***In development***

Chapter 12 Riparian Areas & Surface Water Protection – Completed (December 2022)

Chapter 13 Suites of Recommended Practices-***In development***

This report is available on the Department of Ecology's website at https://apps.ecology.wa.gov/publications/SummaryPages/2010008.html

Chapter 10

Livestock Management: Pasture & Rangeland Grazing

Voluntary Clean Water Guidance for Agriculture

Prepared by:
Washington State Department of Ecology
Water Quality Program

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The Voluntary Clean Water Guidance introduction[1] provides overall goals and objectives, as well as information on how the guidance will be used. Readers are encouraged to read the overall introduction before this chapter.

Introduction

Animal agriculture is an important industry in Washington that contributes significantly to the state's economy and food supply chain. According to the National Agricultural Statistics Services, animal agriculture sales accounted for over 25 percent of the nearly $10 billion in agricultural products sold in Washington. Beef cattle and dairy milk products sales were the leading livestock sectors each generating about $1.1 billion in sales and combining for over 80% of animal product sales (USDA-NASS, 2017). Beef and dairy cattle also account for nearly 90% of the state's livestock. For example, there were approximately 1.14 million head of cattle, 50,000 sheep, 30,000 goats and 50,000 horses in the state in 2020 (USDA-NASS, 2021). Beyond contributing to the state's economy, animal agriculture also supports local jobs and rural economies and provides for a quality of life valued by many.

Washington's livestock industry is a valuable part of state's economy and heritage. However, poor grazing practices cause significant and undesirable impacts to streams, riparian ecosystems and adjacent uplands at the local and landscape scales. These impacts lead to the degradation of riparian vegetation and soils, damage streambanks, and cause long-term changes to natural streams functions and erosion processes which directly and indirectly contribute sediment, bacteria and nutrients to surface waters and reduce shade necessary to keep streams cool. Individually and cumulatively, these impacts and pollutants degrade water quality and cause long-term impairment of aquatic and riparian ecosystems.

Grazing Settings in Washington

In Washington, livestock primarily graze dryland and irrigated pastures, rangelands, forest lands and to a lesser extent they also graze woodlots, haylands, and crop after harvest. Pasture, range and forest lands are diverse landscapes that can provide low-cost forage for all types of domestic livestock plus wildlife. They are also important habitats for many different aquatic and terrestrial wildlife and provide societal benefits such as open space, natural aesthetics and recreational opportunities. Pastures and rangelands occupy over 10 million acres of land in

[1] https://apps.ecology.wa.gov/publications/documents/2010008.pdf

Washington and are located in highly diverse production conditions such as mild, marine influenced areas west of the Cascade Mountains, arid and semi-arid shrub-steppe ecosystems, lowland pastures, forest-grasslands and improved irrigated pastures (http://csanr.wsu.edu/publications-library/livestock/rangelands/).

Generally speaking, pastures are lands used by domesticated livestock for direct consumption through grazing. However, for the purposes of this document, pastures are lands primarily used for the production of domesticated forage plants which are grown specifically for livestock grazing and receive treatment or enhancement to improve forage quality and yields. Pasture lands can be irrigated or non-irrigated and are found throughout the state. In western Washington grazing lands are primarily pastures commonly located in lowland river valleys. East of the Cascade crest, pastures are found on productive lands and other areas such as canyons, river valleys, other drainage ways and marginal cropland with productive soils. Pastures can support a wide variety of small and large livestock such as beef and dairy cattle, sheep, llama, alpacas and goats as well as horses, and are often planted and maintained to suit specific livestock types and grazing systems.

Unlike pastures, rangelands consist mostly of native vegetation that are predominantly grasses, forbs and shrubs. In these environments, trees are often isolated to streamside areas or areas influenced by perennial or intermittent water. Geographically, rangelands in Washington are located east of the Cascadian crest and west of the Rocky Mountains. In general, these are areas of low annual precipitation, ranging from 5 inches in the driest portions of the Columbia Basin to 20-25 inches along the eastern edge of the Basin and in foothills of the surrounding mountains. Temperatures are extreme with hot, dry summers and cold winters and native vegetation is well adapted to these conditions. Beef cow-calf operations are the most common livestock use on Washington rangelands (Harris, 1991).

Ponderosa pine and mixed conifer pine forests are the most commonly grazed forest rangelands in Washington. These forests, often referred to as forested range, grow in semi-arid climates in low to mid-elevation ecosystems. These forests are found along the east slopes of the Cascade Mountains and span the northern and eastern borders of the state stretching as far south as the Blue Mountains. Drier, low elevation and south-facing sites are typically dominated by widely dispersed ponderosa pine with understories composed of grasses, forbs and low shrubs. Ponderosa pine forests of central and eastern Washington are the most commonly grazed forest types due to the abundant forage that can be found in its understory (Harris 1991). At wetter, mid-elevation and north-facing sites, the forest is typically a mix of ponderosa pine, western larch, or Douglas-fir with denser canopies and sparse understories (Belsky et al., 1997). Beef cattle and sheep are the most common domestic livestock that graze forest lands in Washington.

Scope of Guidance

The purpose of this document is to identify best management practices (BMPs) that can be implemented by livestock managers to protect and improve water quality. Best management practices included in this document primarily focus on systems that prevent or reduce water quality pollution. However, in many cases, these practices support additional environmental, animal production and grazing land benefits including improved soil health, increase forage utilization, healthy pastures and rangeland, functional aquatic and semi-aquatic habitats and resilient streams systems.

Definitions as Used in this Document

Continuous grazing - Grazing a particular pasture or management area the entire year including the dormant season.

Deferment - A period of time during the growing season when a management area is not grazed.

Deferred rotation - Deferred rotation involves dividing a management area into two or more units with each unit receiving deferment until seed set every other year. Deferred rotation can be modified to include multiples pastures, but the key feature is that each pasture periodically receives deferment. Common deferment cycles are every two to four years depending on the number of grazing units and forage recovery needs.

Early-season grazing - Grazing that occurs from early April to mid-July.

Grazing system - Planned effort used by grazing managers to produce high quality forage and maximize utilization by grazing livestock while protecting sensitive areas, vegetation and water quality.

Greenline - first vegetation found at the stream edge or slightly below the bankfull stage.

Late- season grazing - Grazing that occurs from September through November.

Mid-season (summer) grazing - Grazing that occurs between mid-July and late September.

Pasture - Pastures are lands comprised primarily of introduced or enhanced native species which are grown specifically for livestock grazing and receive treatment or enhancement to improve forage quality and yields. Pasture differs from rangeland in that vegetation has been primarily planted to provide forage for grazing livestock. Pasture lands may be irrigated or non-irrigated.

Rangeland - Rangelands are lands that consist mostly of native vegetation that are predominantly grasses, forbs and dispersed trees and shrubs. Plant communities can include both native and introduced plants. Rangelands may include grasslands, savannas, shrublands, forests, marshes and meadows.

Rest rotation - Under rest-rotation, larger management units are partitioned into several smaller units and each is grazed in a planned sequence. As part of the rotation, each unit is rested an entire year while the remaining areas are grazed seasonally. The timing of grazing under a rest-rotation strategy varies but grazing units are typically used during the early or late season and that sequence is rotated every year.

Riparian management zone (RMZ) - Land adjacent to surface waters for which management actions are tailored to maintain specific resource objectives, in particular, water quality protection and the provision of aquatic and riparian habitat for fish and wildlife.

Rotation - Scheduled movement of grazing animals from one management unit to another.

Rotational grazing - Rotational grazing is a pasture management system where livestock are allowed to use a portion of a grazing area while the remainder is rested. With rotational grazing, pastures are divided into smaller areas referred to as paddocks and animals are moved from one paddock to the next based the forage conditions in each paddock. This system commonly includes periods of high stocking rates follow by nongrazing periods of rest to allow plant recovery and regrowth. Rotational grazing systems many include a few or numerous paddocks; however, the concept is to have enough paddocks to allow for sufficient rest periods between grazing.

Season-long grazing - Grazing a particular pasture or management area the entire grazing (growing) season.

Site Potential Tree Height (SPTH) - The average maximum height of the tallest dominant trees for a given site class; the index tree age is 200 years, except where shorter-lived trees (such as cottonwoods) are the tallest dominant trees.

BMP Recommendations for Streamside Areas and Adjacent Uplands

The following practices are recommended to protect streamside areas, prevent the generation and discharge of pollutant to surface waters and support healthy upland pastures and rangeland.

- Protect and Restore Riparian Management Zones (RMZ)
- Permanent streamside exclusion fence
- Off-stream water facilities
- Heavy use area stabilization
- Stream crossing (where applicable)
- Emergency water access point (where applicable)
- Grazing management
- Seasonal animal confinement

Riparian Management Zones

Riparian vegetation provides a wide range of functions such as capturing, retaining and transforming pollutants, regulating surface runoff from uplands, inhibiting streambank erosion, providing stream shade, supplying large woody debris and cycling nutrients. Healthy riparian habitats are critical for maintaining healthy streams and water quality. Therefore, it's recommended that riparian areas are established along streams according to Chapter 12, Riparian Management Zone (RMZ) Recommendations. In areas with riparian forest potential, Ecology's preferred option is to have a fully forested RMZ equal to 1 SPTH at 200 years. In ecosystems that do not support the presence of upland trees, it's recommended that native riparian vegetation extent a minimum of 100 feet from the stream. Where it is not feasible to restore full riparian habitat functions it's recommended that landowners select an alternative RMZ configuration outlined in Chapter 12. At a minimum, livestock must be excluded from the core zone of the Riparian Management Zone; however exclusion from the full Riparian Management Zone is preferred.

Permanent Streamside Exclusion Fence

Restricting livestock access to streams and their associated riparian areas or other types of surface waters and providing alternative water sources benefits riparian habitat, streams and water quality, and can also improve livestock productivity, animal health and increase opportunities to improve forage management. Permanent exclusion fencing also supports the implementation of Riparian Management Zones by preventing livestock from entering streams and certain areas within RMZs (at a minimum the core zone of the RMZ) as described in the Riparian Management Zone recommendations, Chapter 12.

Irrigation canals, roadside and field ditches convey significant volumes of water and commonly outlet to streams and can be conduits between grazing areas and streams. Therefore, it's important to ensure that livestock impacts do not occur in or adjacent to these conveyances. To protect water quality, livestock must be excluded at least 25ft from these types of conveyances and include vegetative practices such as filter strips to limit polluted runoff from entering surface waters. Setbacks and vegetative practices widths may be adjusted based on site specific factors.

There is a wide variety of fence types, but the material and construction method chosen must ensure that livestock do not enter restricted areas at any time. Standard post-and-wire fences are suitable as permanent fencing in areas that receive moderate to heavy grazing. For post-and-wire fences, barbed or smooth wire are suitable and electric fence may be included as necessary. Other types of fencing such as woven wire may also be suitable if designed to restrict the size and type of grazing animals. Permanent fencing must be constructed to Natural Resource Conservation Service construction specifications or equivalent standards.

Recommendations and Considerations

- The preferred option is to install permanent fencing to exclude livestock from the entire RMZ.
- At a minimum, permanent fencing must be installed on the upland edge of the core zone and may need to be installed to prevent access to filter strip areas where needed.
- Fencing must, at a minimum, prevent livestock from accessing the core zone.
- Standard post-and-wire fences are suitable as permanent fencing and may include barbed, smooth or electrified smooth wire.
- Other types of fencing may also be suitable if designed to restrict the size and type of grazing animals.
- Fencing must be constructed to Natural Resource Conservation Service specifications or equivalent standards.

Supporting NRCS Field Office Technical Guides: *Fence (382)*

Off-stream Water

A consistent supply of high-quality water is vital to maintaining healthy and productive livestock. Off-stream watering systems create many opportunities to improve forage management and nutrient distribution, increase livestock productivity and protect riparian zones and water quality. Along with fencing, off-stream water is also a key practice commonly used when implementing grazing management systems.

Livestock Water Sources & Drinking Water Quality

Groundwater captured runoff and surface waters such as ponds, lakes, seeps, springs and streams are common water sources used to provide water for livestock and each may have advantages and disadvantages. For example, groundwater quality and quantity can be more reliable and provide the most flexibility when designing a watering system. However, groundwater wells can be costly depending on the local conditions and typically require installing power lines or the use of solar power to operate a pump; although, windmills or gasoline powered pumps or generators may be used in lieu of using solar panels or installing power lines in some situations. Surface waters can be used when in situations where installing groundwater wells isn't feasible or when they provide a reliable and clean source of water. In many situations, an electrical power source is still needed to utilize surface waters; however, gravity-fed systems or mechanical systems such as such as nose, sling or ram pumps may be viable alternatives.

In general, livestock do not need as high of water quality as humans and can drink water of poorer quality though there is a limit. Animals will perform better with higher quality drinking water, and so it's important to consider both the quality and quantity of available water when deciding which water source to use. Supplying the highest water quality water is recommended whenever possible.

Watering Systems

There are a wide range of options to capture, store and deliver water to livestock, and farm level systems often utilize a combination of water sources and systems. Tanks, troughs and ponds are common methods of providing water for livestock, and large watering tanks, separate storage tanks or ponds are often used to store water for future use. Water is typically delivered through mechanical and electric pumps or gravity feed systems.

The choice of systems selected will depend on a variety of factors such as water source, availability of electrical power, pasture layout, required volume of water, season of use, cost, potential for seasonal freezing, reliability, need to store water and producer preferences. While each of these factors will need careful consideration, off-stream water facilities must be designed to provide enough water to meet the daily and seasonal needs of grazing livestock and accommodate the maximum number of animals anticipated to drink at any one time.

The volume of water needed will vary based on the type of animal, age, size, reproductive cycle, environmental conditions and whether livestock water in groups or individually. Consultation with a livestock grazing specialist, knowledgeable contractor or engineer to determine the amount of water needed and to ensure the system design will meet those needs is highly recommended.

Pumps and gravity systems are the two main types of watering systems. Examples of common watering systems include:

- Electric pumps –solar powered or dedicated power source
- Gravity-fed
- Solar pump
- Wind pump
- Hydraulic ram pump
- Nose pump
- Sling pump
- Fuel pumps and generators
- Mobile tanks/hauling water

Water Placement

Access to drinking water is a key factor that affects livestock grazing patterns. Off-stream water has been shown to increase animal distribution and improved forage utilization when properly placed. However, insufficient or poorly placed water developments can limit the use of seasonal pastures and lead to uneven grazing. When developing an off-stream watering systems is important to consider the location and distance between watering sites as these will influence their use and subsequent effect on animal distribution and forage utilization.

Each grazing operation is unique, and the number of water facilities needed and their placement will vary based numerous factors such as the type and number of animals, sources of water used, terrain and watering system chosen. To improve animal distribution and increase grazing uniformity, it's important to limit the distance between grazing areas and watering sites to the maximum extent possible. In arid and semi-arid rangeland locations where forage is typically more dispersed, the distance between water stations may be greater than irrigated pastures or temperate locations. In arid and semi-arid areas its recommended to limit the distance between watering stations to less than 1 km (0.6 mi.) whenever possible, but this distance may need to be reduced on steeper terrain or to meet forage utilization targets. If 1km is not feasible, its recommended to adjust stocking rates to account for a likely reduction in forage utilization beyond 1 km. In temperate areas or on irrigated pastures where forage is more readily available and supports intensive grazing management strategies, shorter distances between water and grazing areas are often needed to improved forage utilization. In these settings, it's recommended to limit the distance between grazing areas and watering locations to 250m (820 ft.) or less whenever possible.

Livestock, especially cattle, prefer flatter, gentler slopes. To be most effective and increase the likelihood of consistent use, its recommended to place off-stream water on slopes less than 10% whenever possible and to limit the vertical distance livestock must travel to access water. Water developments placed on slopes greater than 30% are less likely to be used and should be avoided.

Careful placement of water developments can support improved animal distribution and help alleviate uneven forage utilization. However, water developments may also concentrate disturbances and manure and urine deposition, and lead to the formation of trails. Therefore, it's important to place off-stream water away from riparian areas and any flow paths to surface waters. Off-stream water placement will vary depending on site specific factors but should be placed outside Riparian Management Zones as outlined in Chapter 12 whenever possible. To avoid heavy traffic and forage use near Riparian Management Zones, greater setbacks from Riparian Management Zones are highly recommended.

In situations where it's not feasible to pump water outside the Riparian Management Zone, off-stream water developments may be placed within Riparian Management Zones under the following conditions:

- Off-stream watering facilities must be placed outside the core zone.
- The area adjacent to the watering facility must be stabilized with heavy use are protection that meets NRCS or equivalent design and construction specifications.
- The location of the off-stream watering facility and nearby areas must not be saturated for extended periods during the grazing season.
- The area must not receive significant run-on or have direct or preferential flow paths to surface waters.

- Additional BMPs such as filter strips may be needed down gradient of the water development. Filters strips should be implemented consistent with the Riparian Areas & Surface Water Protection guidance outlined in Chapter 12.

Conditions at every grazing location will be unique and should be carefully considered on a site-specific basis prior to designing and implementing an off-stream watering system. Consultation with a grazing specialist to determine the quantity and location of off-stream water developments is recommended when planning an off-stream water system. A knowledgeable contractor or engineer can also assist in designing a system to fit the needs of each site.

Recommendations and Considerations

- Off-stream water facilities should be located outside Riparian Management Zones whenever possible.
- To limit traffic in or near Riparian Management Zones, its recommended to setback off-stream water facilities from Riparian Management Zones as far as possible. Setbacks of 250m (820 ft.) or greater are preferred when possible.
- The area adjacent to the watering facility must be stabilized with heavy use are protection that meets NRCS or equivalent design and construction specifications.
- When pumping water outside the Riparian Management Zone isn't feasible, watering locations must be outside the core zone. Heavy use area protection must be installed and additional BMPs such as filter strips may be needed down gradient of the water development
- For smaller properties where the Riparian Management Zone overlaps with all or the majority of the grazing area, locate off-stream as far from riparian buffer areas as possible. Water locations must be outside the core zone and include heavy use area protection. Additional BMPs such as filter strips may be needed down gradient of the water development.
- When locating off-stream water facilities, consider how animal traffic may affect nesting birds or wildlife in their reproductive or early life stage.
- Avoid locations where significant run-on is anticipated or areas with flow paths to surface waters.
- Avoid areas that are seasonally flooded or saturated for extended periods of time during the grazing season.
- Locate water facilities in areas with slopes less than 10% and limit the vertical distance livestock must travel to reach water. Avoid locating water developments on slopes greater than 30%.
- Limit the distance between grazing areas and water locations whenever possible.
- Ensure off-stream water facilities can deliver the volume of water needed to meet livestock's daily and season needs.
- Design water facilities to accommodate the maximum number of animals that are anticipated to drink at any one time.

- Implement multiple off-stream water sources to facilitate animal dispersion and improve forage utilization whenever possible or needed.
- Consider using tanks or ponds to store water when using solar pumps or in situations when water supplies may be seasonally limited. When properly located, stored water supplies can be used to gravity feed additional watering stations.
- When a watering system includes an overflow outlet, direct water away from the watering location to prevent the generation of mud and polluted runoff. When possible, overflows should outlet to the stream or within the inner zone to infiltrate.
- Consult with a grazing specialist to determine the number of off-stream water facilities needed and to identify optimal placement.

Supporting NRCS Field Office Technical Guides: *Livestock Pipeline (516), Pond (378), Pumping Plant (533), Spring Development (574), Watering Facility (614), Water Well (642), Heavy Use Area Protection (561)*

Wet Pastures and Sacrifice Areas

Wet and saturated pastures are a common occurrence from late fall through spring in Washington. As soils become wetter, they are less able to withstand livestock traffic. Traffic on wet pastures generates mud and causes soil compaction, erosion and damages the roots and crowns of plants. To limit soil and forage damage within pastures, it is important to take the proper actions to protect pastures during wet periods. Not taking precautions to protect wet pastures can cause excessive damage, reduce forage production and lead to polluted runoff.

A common solution used to prevent negative impacts to pastures and water quality is to establish seasonal sacrifice areas. Sacrifice areas are locations where animals are fenced or penned into a dedicated area for a period of time when grazing can be detrimental to plants, soils and water quality. Sacrifice areas are most commonly used from mid-fall to mid-spring when fields are wet or saturated or when there is no available forage. However, sacrifice areas can also be used late in the grazing season or during periods of drought to avoid damage to recovering plants. These areas may be used to separate animals or care for sick or injured animals as well. The main goals of sacrifice areas are to ensure the majority of grazing lands are rested to stay productive and to prevent negative impacts to water quality.

Sacrifice areas can be improved or unimproved areas depending on the location and site characteristics, and preferences of the operator. Improved sacrifice areas include a footing material such as sand, gravel, wood chips or other wood products such as hogfuel and a geotextile underlayment. Each material has advantages and disadvantage such as cost, life span, suitability and ease of use that should be considered prior to selection. The decision to use an improved or unimproved sacrifice area will be site specific and depend on the goals and needs of the livestock operator. Nevertheless, sacrifice areas must not be a source of water pollution.

Site selection is a key consideration when establishing a sacrifice area especially when the area will be unimproved. Locate sacrifice areas as far as possible from surface waters or conduits to surface waters such as swales, ditches or ephemeral streams. At a minimum, sacrifice areas should be placed outside Riparian Management Zones as outlined in Chapter 12; however, site specific factors may require greater setbacks. When selecting a location, chose elevated areas with good drainage and avoid frequently flood areas, locations that are seasonally saturated or areas that receive significant upland runoff or runoff from adjacent buildings. Additional factors to consider when selecting a location include: slope; potential for preferential flow paths; sacrifice area size, numbers of animals; and the frequency and duration of use. Elevated pads constructed above grade may be used at low lying sites or flood prone locations when necessary.

When site specific factors are likely to cause pollution to reach surface waters, alternative sites should be considered. If alternative sites are not available or if sacrifice areas cannot be located outside of riparian management zones, improved sacrifice areas should be used and additional BMPs may be needed. Improved sacrifice areas should meet NRCS or equivalent design and construction specifications for Heavy Use Area Protection (Field Office Technical Guide 561) and prevent polluted runoff from entering surface waters.

Footing is a critical component of developing a well-drained, durable sacrifice area. Footing materials are used to build up the soil surface to limit compact and facilitate infiltration, decrease mud and runoff, and provide a healthy and comfortable environment for confined livestock. Along with proper siting and footing, livestock should be confined to sacrifice areas using sturdy and safe fences that can reliably contain animals.

It's important to minimize the amount of runoff that enters sacrifice areas. Preventing runoff from entering sacrifice areas will prolong the life of the footing materials, provide a more comfortable environment for livestock, reduce maintenance, facility manure collection and help prevent polluted runoff from leaving the site. Install gutters on animal shelters, barns and sheds and divert roof runoff away from sacrifice areas. Berms, swales and subsurface drains may be used to divert upgradient runoff from sacrifice areas.

Sacrifice areas will need periodic maintenance and manure removal. It's important to periodically inspect sacrifice areas especially after significant precipitation events to ensure the area hasn't become saturated or inundated, that runoff isn't reaching surface waters and that footing material hasn't been eroded. Regular removal and management of manure should also be conducted. Manure accumulations should be stored in a waste storage structure until it can be land applied or proper used or disposed of.

Recommendations and Considerations

- To avoid physical damage to pasture soils, forage and prevent the generation of polluted runoff, rest pastures from approximately mid-fall to early spring.

- Livestock should be removed from pastures before they become excessively wet or saturated or when minimum stubble heights have been reached.
- Wait to start grazing in the spring until adequate forage heights are reached. Forage heights should be twice the recommended residual stubble heights before grazing is allowed.
- Postpone turning out livestock in the spring if pastures are saturated, likely to be damaged or cause polluted runoff to reach surface waters.
- Utilized barns or dedicated sacrifice areas from mid-fall to early spring to avoid damage to pastures and limit negative impacts to surface waters.
- Locate sacrifice areas as far as possible from surface waters and wellheads. At a minimum, sacrifice areas should be located outside Riparian Management Zones as outlined in Chapter 12 whenever possible. A greater setback distance may be needed if the sacrifice areas is likely to contribute polluted runoff to surface waters.
- When property lines or existing structures prohibit the placement of sacrifice areas outside of riparian management zones, sacrifice areas must be improved to include footing materials and additional water diversion and treatment BMPs as appropriate. Adjacent barns or other roofed structures must include gutters and downspouts and runoff from these structures must be diverted away from sacrifice areas and other areas where livestock frequently travel or congregate.
- Divert runoff from sacrifice areas such as runoff from roof, adjacent impervious surface or upgradient slopes.
- Use vegetated filter strips downgradient of sacrifice areas to capture sediment and infiltrate runoff.
- Sacrifice areas may be unimproved if they can be sited, operated and maintained to prevent polluted runoff from entering surface waters.
- When site specific factors are likely to cause pollution to reach surface waters, create improved sacrifice areas that meet NRCS or equivalent design and construction specifications for Heavy Use Area Protection (Field Office Technical Guide 561) and prevent polluted runoff from entering surface waters. Locations with high annual precipitation are more likely to need an improved sacrifice area.
- Perform periodic inspections and maintenance to ensure the sacrifice is performing as designed and runoff from sacrifice areas is not reaching surface waters.
- Routinely manage manure and store accumulated manure in a waste storage structure until it can be land applied, properly used or disposed of.

Supporting NRCS Field Office Technical Guides: *Fence (382), Heavy Use Area Protection (561), Trails and Walkways (575), Waste Storage Facility (313)*

Heavy Use Area Protection

Areas where livestock congregate frequently or for long periods of time such as watering facilities and sacrifice areas often become unstable and are subject to compact, erosion and muddy conditions especially after precipitation or during wet seasons. Heavy use area protection provides a stable, non-eroding surface and is commonly used at off-stream watering facilities and sacrifice areas especially when these sites are likely to become muddy or erode. Heavy use area protection may also be used in other locations such as areas where mineral supplements are provided, supplemental feeding areas and loading corrals. Concrete or compacted gravel are typically used to stabilized areas around off-stream water developments and feeding areas. A variety of footing materials may be used for sacrifice areas including sand, gravel, wood chips or other wood products such as hogfuel.

Recommendations and Considerations

- Size heavy use areas protection to prevent unstable conditions near water facilities.
- Design the foundation and base according to the animal type, traffic frequency and site soil conditions.
- Heavy use area protection areas must be designed and constructed according to NRCS specification or equivalent standards.
- Consult with local NRCS, University Extension or conservation district staff when planning to install heavy use area protection.

Supporting NRCS Field Office Technical Guides: *Heavy Use Area Protection (561), Trails and Walkways (575)*

Stream Crossing & Emergency Water Access Points

Stream crossings are sometimes needed to provide livestock or equipment access to pastures on the other side of a stream without damaging streambanks or the streambed. This practice applies to ephemeral, intermittent and perennial water courses and includes fords, bridges or culvert-type crossings.

Culverts and bridges best suited to prevent disturbances to streambanks and streambeds and should be used in high traffic areas and where fish or large woody debris are expected. Culverts can impede passage of fish and other aquatic organisms and must be sized and installed to prevent obstructions.

Ford crossing are created by stabilizing the streambed with concrete or rock and geosynthetic material. Ford crossing may be suitable for shallow, low velocity watercourses with a gentle sloped streambanks and a firm streambed. Ford crossings are not suitable for high traffic areas with frequent use. Bridges or culverts should be used for in high traffic situations.

Recommendations and Considerations

- Livestock only crossings should be less than 6ft in width and all crossings must be no greater than 30 feet wide as measured from the upstream to downstream end.
- Bridges and culverts must be used for high traffic crossings such those used daily or weekly.
- Ford style crossings are only suitable for low velocity streams with firm streambeds and infrequent use.
- Stream crossing approaches must be limited in width and no wider than 30ft.
- All crossings must include permanent fence to prevent livestock access to riparian areas (see permanent fence requirements).
- Livestock must be excluded from the stream crossing approaches using fence and gates. Exclusion fencing and/or gates must be located on the outer, upland edge of the riparian buffer and filter strip (when a filter strip is required).
- Use of ford crossings for livestock watering is prohibited except for emergencies (see Emergency Water Access Points).
- Any form of work that uses, diverts, obstructs, or changes the natural flow or bed of any fresh water or saltwater of the state, requires a Hydraulic Project Approval (HPA)[2] from the Washington Department of Fish and Wildlife (WDFW). Therefore, all proposed stream crossings must be reviewed by the Washington State Department of Fish and Wildlife prior to installation.
- At a minimum, all stream crossings must designed and installed according to NRCS specifications in accordance with Field Office Technical Guide 578 (Stream Crossing) and any additional requirements that may be required as part of obtaining a HPA from WDFW. Designs that provide the greatest ecological functions are preferred.

Supporting NRCS Field Office Technical Guides: *Stream Crossing (578), Trails and Walkways (575) and Fence (382).*

Emergency Stream Access Points

An emergency access point is a location along a stream where livestock can temporarily access the stream for drinking water purposes. These locations may be needed or desired as a contingency should off-stream water equipment fail or need to be maintained or replaced. However, they must only be used under emergency situations and may not be used as alternatives to permanent off-stream water sources.

Ford style stream crossings may serve as emergency water access points. Where ford style crossings aren't installed or available, temporary access points may be created using gates and

[2] https://www.epermitting.wa.gov/site/alias__resourcecenter/10042/introduction.aspx

fencing to create a narrow lane from upland areas to the stream. Lanes should not be cleared and must maintained native riparian vegetation.

Recommendations and Considerations

- Emergency access points must be no greater than 10 feet wide as measured from the upstream to downstream end.
- Use of emergency access points must be limited to the time needed to repair off-stream watering facilities or move livestock to an alternative location where viable off-stream water is available.
- Access points cannot be used in lieu of installing or maintaining permanent, reliable off-stream watering facilities.
- Riparian vegetation must be maintained in lanes created for emergency water access and clearing is prohibited.
- Lanes should be the shortest distance possible from upland grazing areas to the stream.
- Emergency access locations must be limited in number and geographic extent.

Supporting NRCS Field Office Technical Guides: *Stream Crossing (578), Trails and Walkways (575) and Fence (382).*

Grazing Management & Riparian Management Zones

Riparian Management Zones as outlined in Chapter 12 include streamside buffer areas were agricultural activities including grazing are not allowed. However, agricultural activities including grazing may be allowed within some areas of a Riparian Management Zones.

Most grazing operations in Washington will have grazing areas that include Riparian Management Zones where careful and targeted management measures are needed to ensure Riparian Management Zones are not over-grazed or become sources of pollution. The following sections will describe the goals of grazing management and outline strategies that can be implemented in pasture and rangeland settings. It's important to note that these grazing strategies are not isolated to Riparian Management Zones and are intended to promote animal distribution throughout riparian and upland areas. Improved animal distribution is better for animal production and water quality, and these strategies can be used to help achieve both.

Grazing Management

Grazing management has been shown to decrease pollutants such as sediment, nutrients and bacteria from being transported from upland areas to surface via runoff; however, much of the pollutants entering surface waters originates from areas near streams as of result of livestock congregating in riparian zones (Haan et al., 2010). The availability of water, forage quantity and quality, temperature, topography and availability of shade are the primary factors that determine grazing distribution. Given that riparian areas provide the majority of grazing animal's requirements and are easily accessible, riparian areas are commonly overused by livestock. Congregation within riparian areas, overutilization of riparian vegetation and accessing streams to drink are the primary sources of pollution entering surface waters from grazing lands. Further, congregation in the riparian areas often leads to uneven livestock distribution causing upland forage to be underutilized or left completely ungrazed.

Grazing management strategies attempt to balance forage removal and plant health by adjusting the timing of grazing, stocking rates, duration of grazing and periods of rest to maximize forage utilization while promoting recovery (Swanson et. al, 2015). In doing so, a primary goal is to improve animal distribution on the landscape, and thereby promote even use of palatable, nutritious plant communities while attempting to limit the overuse of forage in sensitive upland and riparian plant communities. The overarching goal of grazing management systems is to help livestock managers better control animal behavior and tendencies to maximize forage potential and utilization while simultaneously promoting pasture and rangeland health.

Management methods used will vary from location to location based on site and regional characteristics and producer's goals, and every grazing strategy will invariably include advantages and disadvantages that must be considered.

Grazing Management Strategies: Overview

Timing, duration, stocking rate and season of use are key factors that must addressed when developing any grazing management plan (DelCurto et al., 2005). The following is a brief description of timing strategies commonly used in the Pacific Northwest along with a discussion of some of their advantages and disadvantages followed by recommendations and additional considerations. Each grazing strategy includes concepts that can be applied to pasture and rangeland settings; although, some are more common to each. For example, early-, mid-, late-, and rest-rotation strategies are commonly used in rangeland settings. Pasture based operations tend to use rotational and season-long grazing system but may incorporate additional strategies as well.

Early Season Grazing

Early season grazing in rangeland areas commonly occurs between April and mid-July in the Pacific Northwest (DelCurto et al., 2005). There is evidence that suggests early season grazing can be an effective management strategy to alter the distribution patterns of cattle when a grazing location includes both riparian and upland vegetation (DelCurto et al., 2000; DelCurto et al., 2005; McInnis, M. L., & McIver, J. D., 2009; Parsons et al., 2003). One potential advantage of early season grazing is the availability of palatable and desirable forages in the uplands along with relatively low daily maximum temperatures. Under these conditions livestock tend to distribute more evenly on the landscape and therefore utilize available forage more uniformly and rely less on riparian area forage (DelCurto et al., 2000; DelCurto et al., 2005; McInnis, M. L., & McIver, J. D., 2009; Parsons et al., 2003). Locations where this strategy is more likely to be successful are those where 1) livestock can be attracted to the uplands by highly desirable, herbaceous forage and warmer temperatures 2) cool and wet conditions in or near riparian areas that discourage loafing and 3) well-drained soils which reduce the possibility of compaction and erosion. These combinations of succulent upland forage and cool temperatures are more likely to facilitate improved livestock distribution and dispersed grazing patterns and facilitate the use of off-stream watering sources.

Early season grazing also includes some potential disadvantages that must be considered. First, because of high soil moisture, riparian areas are more susceptible to physical damage such as soil compaction, dislodging of shallow rooted plants, pugging, streambank sloughing and erosion especially after rainfall or during peak runoff (Marlow & Pogacnik, 1986; DelCurto et al., 2000). Second, early season grazing often coincides with the critical growth period of plants where they are using stored carbohydrates to stimulate leaf growth. Repeated defoliation during spring grazing can delete stored carbohydrates and lead to decreased vigor of desired plants communities and an increase undesirable, less unpalatable species thus reducing a site's grazing potential. Therefore, many rangeland grazing systems that include early-season grazing often include a season of deferment or a year of rest following early season grazing (DelCurto et al., 2005).

With early season grazing, it's important to monitor vegetation quality and quantity within riparian and upland zones as the season progresses and daily ambient temperatures increase. Livestock use of riparian zones has been found to increase as daily ambient temperature increases and upland forage dry matter increases. Leaving livestock in pastures with upland and riparian areas too long can lead to the over-utilization of riparian vegetation and also increase the potential for damage to soil properties and browsing of woody vegetation (DelCurto et al., 2000; DelCurto et al., 2005; Kauffman, et al., 1983; McInnis, M. L., & McIver, J. D., 2009; Parsons et al., 2003). Early season is most compatible with unsaturated riparian areas characterized by coarse to relatively coarse soils with moderate to high infiltration rates.

With careful management, early season grazing can be a beneficial strategy to promote more even utilization of upland and riparian forage. The appropriateness of this strategy will depend on soil characteristics and the potential for saturated soils within the riparian area which must be determined annually on a site-by-site basis. Close monitoring of forage utilization patterns, forage quantity, forage quality and animal distribution patterns is needed to ensure positive outcomes are achieved.

Mid-season (Summer) Grazing

Midseason grazing in the Pacific Northwest occurs from mid-July through late September. Aside from season-long grazing, midseason grazing is mostly likely to be detrimental to riparian vegetation health especially when implemented annually without a deferred or nonuse period.

There are numerous potential disadvantages with the midseason grazing of Riparian Management Zones that must be considered. The most important consideration that must be accounted for is the likely scenario where upland plant maturity coupled with increased air temperature drives livestock to congregate in cooler riparian areas with more succulent vegetation (Kauffman and Krueger, 1984, Kauffman, et al., 1983; McInnis and McIver, 2009). Research has shown that livestock spend more time in riparian zones as ambient temperature increases and prefer riparian forage to upland vegetation once upland forage has matured and increased in dry matter. For these reasons, livestock tend to congregate in riparian areas and overgraze available riparian vegetation which can decrease plant vigor and riparian health (Kauffman and Krueger, 1984, Kauffman, et al., 1983; McInnis and McIver, 2009). Summer grazing is also the most stressful on plant communities because there is less time and moisture to support vegetation growth and replenish energy reserves necessary to sustain plants during dormancy. Additionally, as the palatability of available herbaceous plants decreases, livestock tend to increase browsing of trees and shrubs. This pressure on woody vegetation can suppress growth, prevent the establishment of seedlings leading to non-reproducing, even-aged vegetation communities and ultimately lead to a decrease in the amount of woody species in the riparian area (Kauffman, et al., 1983).

Despite its limitations, midseason grazing may have some potential advantages including the decreased potential for soil compaction due to lower soil moisture, the availability of palatable forage compared with upland areas and sufficient soil moisture to support regrowth following defoliation. Careful management is needed to prevent the degradation riparian areas when conducting midseason grazing. If mid-season grazing is planned in grazing areas that include Riparian Management Zones, the following actions may help prevent riparian area deterioration: 1) low to moderate stocking rates base on the forage potential of the Riparian Management Zone; 2) intensively monitoring forage utilization in the Riparian Management Zone; 3) remove livestock in time to allow vegetation regrowth following grazing; and 4) locate off-stream water upland and outside of Riparian Management Zones. When appropriate and feasible, consider creating a separate pasture within or encompassing the Riparian Management Zone (outside of the core zone) that can be managed specifically to limit the time and duration of mid-season (summer) grazing.

Late Season (Fall) Grazing

Late-season grazing occurs from September through November. In rangeland settings, this often when available upland vegetation is typically very mature and much less palatable than riparian vegetation. For this reason, livestock are commonly drawn to riparian areas during this time and careful management is required. In pasture setting, forage is coming out of semi-dormancy and beginning more rapid regrowth.

There may be some advantages of grazing riparian vegetation during the late season. For example, during this timeframe available vegetation has likely matured and completed its reproductive growth cycle and grazing these plants may have less affect. During the late season, most herbaceous plants have already set seeds, and defoliation will have less impact than early-season grazing. Additionally, soil moisture can be lower prior to the start of fall precipitation which reduces the potential of soil compaction and erosion. Further, with proper temperature and moisture plant regrowth may provide additional forage.

Late season grazing includes disadvantages that must be accounted for and managed. During the late summer and fall, cattle's utilization of woody vegetation often increases because of its increased protein content and palatability compared with herbaceous vegetation (Kauffman and Krueger, 1984, Kauffman, et al., 1983; McInnis and McIver, 2009). If late season temperatures remain high, cool season plants will remain dormant which can lead to overuse of the riparian vegetation including the browsing of woody vegetation. Over-utilization of woody riparian vegetation can reduce plant vigor and survival and reduce the ability of vegetation to perform its riparian functions.

Rest Rotation

Under rest-rotation, larger management units are partitioned into several smaller pastures and each pasture is grazed in a planned sequence. As part of the rotation, each pasture is rested an entire year while the remaining pastures are grazed seasonally based on the number of remaining pastures and herds. The timing of grazing under a rest-rotation strategy varies but pastures are typically grazed either early or late in the season and that sequence is rotated each year the pasture is grazed.

Rest-rotation includes many of the same advantages and disadvantages associated with early and late season grazing; however, the incorporation of a rest period provides a greater opportunity for the vegetation to recover and helps limits the impacts to vegetation that often occurs with repeated grazing. Additionally, rested pastures can also provide forage for emergency use during severe drought years and provides opportunities to implement longer-term pasture and rangeland improvement practices such as reseeding, brush and weed control during scheduled rest periods (Howery et al., 2016).

Some potential disadvantages include the potential for wild herbivores to grazed rested pastures negating some of the benefits of rest. Other disadvantages cited are reduced individual animal performance due to forced animal movements from pasture to pasture, reduction in available acres for grazing on an annual basis and increased stocking density in grazed pastures (Howery et al., 2016).

Season-long Grazing

Season-long grazing is not typically considered a grazing management strategy because it does not attempt to rest any portion of a grazing area for at least part of the growing season. With season-long grazing, stocking rates must be low enough to provide adequate forage during the grazing season. Season-long grazing allows grazing animals the maximum their dietary selectivity throughout the grazing season which can be detrimental to forage health if not properly managed. Conversely, rotation-based systems that restrict livestock from pastures during parts of the growing season may not allow for full utilizations of favored forage. Like rotational grazing systems, its critical to monitor and manage forage height and plant composition within pastures to prevent overgrazing. Season-long grazing is most likely to be successful on flatter areas with shallow groundwater such as wet meadows and pastures with seasonal irrigation or summer precipitation sufficient to provide adequate moisture for forage regrowth and recovery.

Rotational Grazing

Rotational grazing systems are often implemented in lieu of season-long grazing to increase forage utilization and limit undesirable selective grazing. At both small and large scales, livestock selectively graze individual plants, patches and communities. Under rotational grazing, larger management areas are subdivided into smaller pastures where only one section of the total management area is grazed at a time while the remainder is rested. Smaller pastures increase stocking density and rotation allow managers to constrain livestock movement and control the season, frequency and duration of grazing. Collectively, these controls can limit grazing selectivity and help prevent repeated grazing of preferred plants (Bailey and Brown, 2011).

Rotational grazing systems are often implemented in pastures consisting of domesticated forage plants grown specifically for livestock grazing which receive treatment or enhancement to improve forage quality and yields including supplemental irrigation and fertilization. Under these conditions, rotational grazing limit can limit selective grazing, increase forage utilization and reduce the need to mechanically harvest forage. However, in arid and semi-arid rangelands, forage growth is primarily limited by precipitation rather that grazing frequency (Bailey and Brown, 2011) and is typically not conducive to continuous, repeated grazing. For example, when moisture is adequate, rangeland forage is abundant and defoliation levels are typically low. As a result, repeated, intensive defoliation of preferred plants is less likely than in more mesic areas where more consistent precipitation and soil moisture storage allows animals to establish and maintain spatial hierarchies of grazing patterns (Bailey and Brown, 2011). Therefore, management intensive rotational grazing systems are likely less applicable to rangeland settings, and rangeland grazing strategies that focus on limiting grazing of Riparian Management Zones during the summer and fall are likely to be more beneficial than rotational grazing systems (Bailey and Brown, 2011).

As with early-, mid- and late-season strategies, rotational grazing approaches must consider soil conditions within Riparian Management Zones, growth period of forage plants and the potential for degradation of woody riparian vegetation. Further, the length of rest periods must be long enough to avoid progressive, long-term degradation of forage and allow for full recovery of soil hydrologic condition prior to the reoccurrence of livestock grazing (Howery et al., 2016). Given the potential for higher concentrations of livestock, intensive rotational grazing systems may need additional practices to prevent polluted runoff from entering surface waters especially in spring and fall when precipitation and antecedent soil moisture are typically higher.

Stocking Rates and Forage Management

A critical component to any grazing strategy is the development of stocking rates. Stocking rate is generally defined as the number of animals that can be sustained within a specific area of land for a specific amount of time. Stocking rates are highly site specific and will vary depending on the forage type such as native rangeland vegetation, rangeland vegetation with introduced forages or specialize forage mixes used in cultivated pastures, and factors such as weather, climate and soils properties including texture, water holding capacity and depth. No two settings are identical and stocking rates must be developed on a site-specific basis. In general, stocking rates should include knowledge of available forage, type and size grazing animals, consumption rates of grazing animals and length of time grazing is planned.

Forage is the foundation of any grazing system and forage quality and quantity will determine stocking rates and associated animal health and vigor (Fransen et al., 2017). Proper forage management and associated stocking rates are essential for any grazing management system to be successful. Consultation with a grazing or rangeland specialist to develop site specific stocking rates and forage management strategies is highly recommended. Local NRCS, University Extension and conservation district staff can provide resources and assistance with development a grazing management plan that includes appropriate stocking rates and forage management practices. Technical resources such as the Western Oregon and Washington Pasture Calendar (Fransen et al., 2017) and NRCS National Range and Pasture Handbook are also valuable resources that can be used to develop a grazing management plan for pasture and rangeland grazing operations.

Grazing Management Strategies: Recommendations

When properly applied, grazing management systems that incorporate timing, proper stocking rates and forage management can be a valuable tool to help livestock managers better control animal behavior and tendencies, maximize forage potential and utilization, promote pasture and rangeland health and protect water quality. Knowledge of important relationships between grazing timing, forage management and stocking rates is a good first step toward successful grazing management.

Most grazing operations are likely to have pastures or rangeland grazing areas adjacent to streams. Proper grazing management is important on all grazed lands and is especially critical for the protection of water quality and to maintain healthy riparian habitats. For grazing to occur in Riparian Management Zones, operators must develop a grazing management plan that includes specific management measures within Riparian Management Zones. Because of the many benefits these strategies provide to forage and soil health, it’s strongly recommended that livestock managers develop a grazing plan for all upland areas even if they don’t contain streams and riparian areas. This is especially important if upland areas contain other surface waters or conduits to surface waters such as drainage ditches, irrigation canals or swales.

Grazing Management: Minimum Requirements

For grazing to occur in the inner and outer zone of the Riparian Management Zone, we recommend that livestock managers have a grazing management plan that meets the requirements of all applicable grazing management strategies outlined below, and at a minimum, must:

- Identify the season(s) of use for all pasture within Riparian Management Zones.
- Estimate forage availability and utilization rates.
- Develop stocking rates based on available forage types, class and size of animals, estimated utilization rates and duration of grazing.
- Include forage monitoring protocols to evaluate forage utilization during each season of use and assess trends in plant communities over time.
- Set clear and measurable objectives for forage and non-forage plant communities and soil conditions.
- Evaluate the suitability of each site/pasture for livestock grazing.
- Include strategies to facilitate animal distribution and avoid disproportionate grazing of riparian vegetation and prevent browsing of wood vegetation.
- Establish a schedule to rest and rotate pastures to maintain and optimize forage growth and vigor.
- Identify times or seasons when livestock should be removed from pasture such as when pastures are excessively wet, saturated, inundated or when flooding is expected.
- Consider potential impacts to wildlife especially when grazing may overlap with seasonal wildlife uses such as reproduction, rearing and juvenile refuge.

Livestock grazing within Riparian Management Zones must:

- Maintain permanent vegetative cover.
- Prevent bare ground, soil compaction and erosion.
- Maintain riparian vegetation including woody vegetation.
- Limit manure accumulations.
- Not include winter grazing or animal confinement with Riparian Management Zones.
- Not include supplemental feeding within Riparian Management Zones.
- Prevent browsing of woody riparian vegetation.
- Prevent grazing on excessively wet or saturated soils during any season.
- Maintain vegetative cover including post grazing stubble heights of approximately 6 inches in rangeland pastures and approximately 3-4 inches in cultivated pastures.
- Limit forage utilization based on season of use and meet seasonal utilization targets.

Grazing Management Strategies: Minimum Recommendations

Early Season Grazing

Early season grazing typically provides better distribution among riparian and upland plant communities. In many rangeland areas, early season grazing is best followed by rest for the remainder of the grazing season or until fall. If sufficient regrowth occurs, late-season grazing may be appropriate under careful management.

When grazing pastures in the spring (early season):

- Evaluate soils moisture conditions prior to grazing to prevent damage to soils including compact and erosion. Soils with high proportions of clay are likely to be wetter in the spring and are more susceptible to detrimental effects to soil properties from early season grazing.
- Delay grazing when soils are excessively wet or saturated when damage to soils and vegetation is likely.
- Avoid grazing pastures seeded the previous fall until mid-April or until it can pass a 'Pull test'. Graze newly seeded pastures lightly until they become well established. (A pull test is a simple way to see how well newly seeded pastures are established. A pull test is conducted by grabbing a single forage plant and giving is a sharp pull. If the plant is dislodged, the pasture is likely not ready for grazing).
- Remove livestock while forage plants are in a vegetative state.
- Rest pastures on a rotating basis to allow plants to complete reproduction cycles.
- For rangeland areas - limit utilization to approximately 50% and maintain stubble heights of approximately 6 inches
- For cultivated or permanent pastures – maintain stubble heights of approximately 3-4 inches.

Mid-Season Grazing

Grazing in mid to late summer should be managed cautiously as livestock have a strong affinity for riparian areas and tend to concentrate in riparian areas as seasonal temperatures increase.

When grazing the summer (mid-season):

- Monitor forage utilization to prevent browsing of woody vegetation.
- Remove livestock once woody vegetation browsing begins.
- For rangeland areas - limit utilization to approximately 50% and maintain stubble heights of approximately 6 inches
- For cultivated or permanent pastures – maintain stubble heights of approximately 3-4 inches.

Late-Season Grazing

During the late summer and fall, cattle may prefer woody vegetation due to increased protein content and palatability compared with herbaceous vegetation. If late season temperatures remain high, cool season plants will remain dormant which can lead to overuse of the riparian vegetation including browsing of woody vegetation. Time grazing when herbaceous vegetation is readily available, closely monitor forage use and look for any sign of woody vegetation browsing.

When grazing in the late season (fall):

- Monitor forage utilization to prevent browsing of woody vegetation.
- Immediately remove livestock as soon as animals begin to browse woody vegetation.
- Evaluation soil conditions before grazing and stop grazing areas that become excessively wet or when damage to soil and vegetation is predicted.
- For rangeland areas - limit utilization to approximately 30-40% and maintain stubble heights of approximately 6 inches
- For cultivated or permanent pastures – maintain stubble heights of approximately 3-4 inches.

Season Long Grazing

Season long grazing should be limited to situations where animal distribution and use can be strictly controlled, and stubble height requirements can be met. Season-long grazing is most likely to be successful in flatter areas with supplemental irrigation. Season long grazing is generally inappropriate for rangeland grazing.

When conducting season-long grazing:

- Monitor forage utilization to prevent browsing of woody vegetation.
- Remove livestock once woody vegetation browsing begins.
- For rangeland areas - limit utilization to approximately 50% and maintain stubble heights of approximately 6 inches
- For cultivated or permanent pastures – maintain stubble heights of approximately 3-4 inches.

Rotational Grazing

Rotational grazing systems are best suited for pastures with sufficient precipitation or supplemental irrigation to maintain forage growth necessary to support repeated, season-long grazing.

Riparian Management Zones in unirrigated rangelands are not suitable for intensive rotational grazing management and seasonal management strategies such as rest-rotation are recommended.

When using rotational grazing management:

- Assess pastures to ensure sufficient forage quality and quantity is available.
- Improve or renovate pastures as needed.
- Avoid grazing pastures seeded the previous fall until mid-April or until it can pass a 'Pull test'. Graze newly seeded pastures lightly until they become well established. (A pull test is a simple way to see how well newly seeded pastures are established. A pull test is conducted by grabbing a single forage plant and giving is a sharp pull. If the plant is dislodged, the pasture is likely not ready for grazing). When Riparian Management Zones include riparian vegetation, carefully monitor and remove livestock before browsing of wood vegetation begins.
- Evaluation soil conditions before grazing and delay grazing whenever soils are excessively wet or when damage to soil and vegetation is predicted.
- Provide rest periods long enough to avoid progressive, long-term degradation of vegetation and allow full recovery of the soil hydrologic conditions prior to resuming of grazing after resting pastures.
- Maintain stubble heights of approximately 3-4 inches.
- Manage manure accumulations and prevent polluted runoff from entering surface waters especially in spring and fall when precipitation and antecedent soil moisture is typically higher.
- Implement filters strips prior to the grazing season if excessive manure accumulation is anticipated.

Related NRCS Practices

- Fence (NRCS practice code 382)
- Trails and Walkways (NRCS practice code 575)
- Stream Crossing (NRCS practice code 578)
- Watering Facility (NRCS practice code 614)
- Water Well (NRCS practice code 642)
- Spring Development (NRCS practice code 574)
- Pond (NRCS practice code 378)
- Pumping Plant (NRCS practice code 533)
- Livestock Pipeline (NRCS practice code 516)
- Heavy Use Area Protection (NRCS practice code 561)
- Waste Storage Facility (NRCS practice code 313)

Commonly Associated Practices:

- Riparian Management Zones/Riparian Buffers
- Manure storage BMPs
- Confinement area BMPs (e.g., heavy use area protection, gutters and downspouts, stormwater)
- Structural (e.g., sediment control basins) and vegetative (e.g., cover crops, grassed waterways, filter strips) BMPs
- Nutrient management BMPs
- Integrated pest management BMPs
- Irrigation management BMPs

Chapter 10 Appendix Part A: Effectiveness Synthesis (Livestock Management: Pasture & Rangeland Grazing BMPs)

Effectiveness

Purpose and Organization

The purpose of this document is to identify best management practices (BMPs) that can be implemented by livestock managers to protect and improve water quality. A critical step in developing best management practice guidance is to understand the relationship between livestock grazing activities and its effects upon water quality and designated uses of waterbodies. To establish the connection between recommend practices and expected water quality outcomes, this document first describes how livestock grazing activities can affect water quality and stream health, and then outlines BMPs that can be used to reduce or eliminate those impacts. When possible, pollutant reduction values for BMPs are provided. A brief overview of riparian areas and their ecological functions is included because riparian areas are a common location for livestock grazing and are also a key to achieving healthy streams and good water quality.

Best management practices included in this document primarily focus on systems that prevent or reduce water quality pollution. However, in many cases, these practices support additional environmental, animal production and grazing land benefits including improved soil health, increase forage utilization, healthy pastures and rangeland, functional aquatic and semi-aquatic habitats and resilient streams systems.

Grazing Settings in Washington

As covered above in the recommendations section, in Washington livestock primarily graze pastures, rangelands and forest lands and to a lesser extent also graze woodlots, haylands, and croplands. Pasture, range and forest lands are diverse landscapes that can provide forage for beef cattle, dairy cattle, sheep, goats, horses and other types of domestic livestock. They are also important habitats for many different aquatic and terrestrial wildlife and provide societal benefits such as open space, natural aesthetics and recreational opportunities.

Generally speaking, pastures are lands used by domesticated livestock for grazing. However, for the purposes of this document, pastures are lands primarily used for the production of domesticated forage plants which are grown specifically for livestock grazing and receive treatment or enhancement to improve forage quality and yields. Pasture lands can be irrigated or non-irrigated and are found throughout the state. In western Washington grazing lands are primarily pastures commonly located in lowland river valleys. East of the Cascade crest, pastures are found on productive soils in canyons, river valleys and other drainage ways and adjacent to marginal cropland. Pastures can support a wide variety of small and large livestock such as beef and dairy cattle, sheep, llama, alpacas and goats as well as horses, and are often planted and maintained to suit specific livestock types and grazing systems.

Unlike pastures, rangelands consist mostly of native vegetation that are predominantly grasses, forbs and shrubs. In these environments, trees are often isolated to streamside areas or areas influenced by perennial or intermittent water. Geographically, rangelands in Washington are located east of the Cascadian crest and west of the Rocky Mountains. In general, these are areas of low annual precipitation, ranging from 5 inches in the driest portions of the Columbia Basin to 20-25 inches along the eastern edge of the Basin and in foothills of the surrounding mountains. Temperatures are extreme with hot, dry summers and cold winters and native vegetation is well adapted to these conditions. Beef cow-calf operations are the most common livestock use on Washington rangelands (Harris, 1991).

Ponderosa pine and mixed conifer pine forests are the most commonly grazed forest lands in Washington. These forests, often referred to as forested range, grow in semi-arid climates in low to mid-elevation ecosystems. These forests are found along the east slopes of the Cascade Mountains and span the northern and eastern borders of the state stretching as far south as the Blue Mountains. Drier, low elevation and south-facing sites are typically dominated by widely dispersed ponderosa pine with understories composed of grasses, forbs and low shrubs. Ponderosa pine forests of central and eastern Washington are the most commonly grazed forest types due to the abundant forage that can be found in its understory (Harris 1991). At wetter, mid-elevation and north-facing sites, the forest is typically a mix of ponderosa pine, western larch, or Douglas-fir with denser canopies and sparse understories (Belsky et al., 1997). Beef cattle and sheep are the most common domestic livestock that graze forest lands in Washington.

Riparian Areas

Whether pasture, range or forest lands, most grazing locations have lakes, streams, rivers or other types of water bodies in or adjacent to them. Areas adjacent to these water bodies, called riparian areas, are often desirable to livestock and are also critically important for aquatic and terrestrial wildlife and water quality. For these reasons, riparian areas are commonly a focal point for livestock management, and it's therefore important to understand what riparian areas are and why they are important for wildlife and water quality.

Riparian areas are transitional zones between aquatic and terrestrial ecosystems where the vegetation, soils and microclimate are strongly influenced by the presence of perennial or intermittent water and relatively high-water table. They are areas where surface and subsurface hydrology connects waterbodies with their adjacent uplands and include the active floodplain, riverine wetlands and adjacent uplands that directly contribute organic matter or large wood to the active channel or floodplain (Quinn et al., 2020). Riparian areas are found adjacent to perennial, intermittent, and ephemeral streams, lakes, and estuarine–marine shorelines (NRC, 2002). The physical association with the moisture regime of adjacent waters is an essential part of the structure and functioning of riparian areas.

According to the Washington State Department of Fish and Wildlife, "riparian ecosystems are priority habitats in part because wildlife occurs more often and in greater variety in riparian areas than in any other habitat type" (Quinn et al., 2020). Riparian areas are home to an abundance of animal life, including invertebrates, most amphibian species and many reptiles, the majority of bird species (particularly in the semi-arid West), and many mammal species requiring semiaquatic habitats (NRC, 2002). In healthy landscapes, stream channels, streambanks and the riparian area form a continuous, complex ecosystem commonly referred to as the stream corridor. In these systems, the increased availability of water creates unique microclimate and biotic communities where soils and vegetation are distinctly different from the surrounding uplands which contribute to unique assemblages of plants, soil, animals and aquatic communities (Kauffman, 1984).

Riparian vegetation is a critical component of the environmental landscape. Not only does it shade streams, but it also exerts many important controls over the physical and biological functions of the stream environment (Kauffman and Krueger, 1984) and directly and indirectly influences stream geomorphic processes. Examples of important functions healthy riparian plant communities provide include: streambank protection and channel stabilization, shade and stream temperature control, woody debris, in-stream and terrestrial habitat, nutrient cycling, sediment deposition during overbank flow, capture of sediment and nutrients from upland runoff and nutrient removal from groundwater. The ecological functions that healthy riparian areas provide are vital for maintaining good water quality, biodiversity, fisheries, and wildlife habitat.

A more detailed analysis is found in the Riparian Protection chapter.

Riparian Ecosystem Functions

- Protect stream banks and channels from erosion
- Help maintain stable channels and prevent channel incision or prevent channels from becoming wider and shallower
- Supply small and large wood which contributes to channel complexity and aquatic habitat
- Capture solar energy, provide shade and facilitate microclimate formation which moderates air and water temperature fluctuations
- Provide fish and terrestrial wildlife habit, support biodiversity and maintain food webs
- Intercept, cycle and control the timing and magnitude of nutrient supply to the aquatic environment and are important areas for denitrification processes in shallow groundwater
- Store water to reduce upland flooding and maintain stream flow during dry periods

- Filter and trap pollutants from upland runoff such as sediment, nutrients, pathogens, and metals
- Accommodate channel migration
- Trap sediment during floods
- Carbon storage

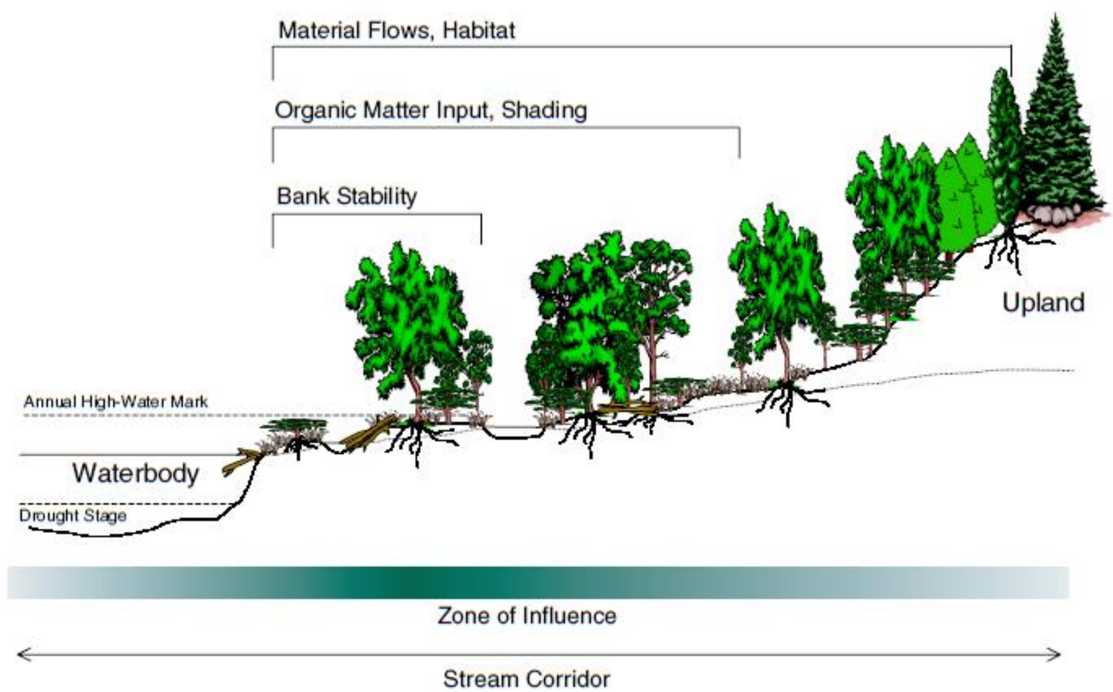

Figure 1: A generalized diagram of the stream corridor (NRC 2002).

The stream corridor includes the active channel and riparian ecosystem. The riparian area does not include the adjacent waterbody (e.g., stream, river, lake) and is a distinct area with soils of higher water availability that provides habitat for plants adapted to these growing conditions. The interaction between various climatic, hydrologic, geomorphic, topographic and biological factors influences the size, characteristics and functions of any given riparian area (NRC 2002).

Riparian Areas and Geomorphology

Stable streambanks are important for maintaining stable channels that retain consistent dimensions, pattern and profile. Healthy riparian areas are vital for maintaining streambank stability as they strongly influence the physical condition of the stream environment and directly and indirectly influence geomorphic processes such as erosion, sediment transport and deposition.

Ultimately, stream erosion processes are controlled by a variety of geomorphic factors such as channel slope, width and depth, stream power, floodplain configuration as well as streambank and riparian vegetation (Tufekcioglu et al., 2012; NRC 2002); however, riparian vegetation directly and indirectly affects all these conditions and has a major influence on how channels dissipate stream energy especially during periods of high flow (NRC, 2002). Healthy riparian plant communities therefore help stabilize streambanks and control the physical shape of river systems and the landforms they create (Simon et al, 2004; Kauffman and Krueger, 1984). In general, riparian vegetation reduces a stream's power by decelerating stream flows through the increased friction between vegetation and flowing water and by disrupting flow paths (Simon et al., 2004).

Streambank stability is directly related to the quality, quantity and diversity of riparian vegetation and native plant communities are generally effective at protecting streambanks from erosion. Streamside vegetation stabilizes banks in multiple ways. First, above ground plant parts such as tree trunks, shrub stems and herbaceous vegetation increase friction by creating a flexible, three-dimensional barrier to streamflow which tends to dampen turbulence and slow velocities at the stream and land interface (NRC, 2002). Second, plant roots and soil organic matter help bind soil particles by creating a complex matrix that has enhanced strength and resistance to erosion (Simon et al., 2004). Third, streamside vegetation increases bank stability by intercepting rainfall that would otherwise infiltrate the banks and also by extracting soil moisture through transpiration; both of these processes enhance the streambanks shear strength and therefore resistance to erosion (Simon et al., 2004; NRC 2002). As a result, streambanks with healthy riparian plant communities can remain relatively stable even during high flows (Simon et al., 2004; NRC, 2002).

Riparian vegetation is clearly understood to play an integral role in reducing the erosive power of streams and rivers and the potential for streambanks to erode or for channels to migrate laterally. Equally important is the fact that the continued growth, establishment and succession of riparian plant communities is essential for maintaining stability and resilience in the face of natural stream processes. Beyond controlling the erosion of streambanks, riparian vegetation also plays an important role in floodplain development. Floodplain vegetation, especially shrubs and herbaceous plants such grasses, sedges and rushes, facilitates fine sediment deposition. In years without floods, riparian vegetation can establish on exposed areas of the floodplain which in-turn creates additional stability and resistance and promotes the vertical accretion of sediment and floodplain vegetation. Consequently, riparian vegetation has a fundamental role in the long-term maintenance of streambanks and the development of floodplain landforms (NRC, 2002).

Why Livestock Congregate in Riparian Areas

Scientific studies indicate that cattle tend to congregate in riparian areas due to the availability of water, greater forage quantity and quality, proximity to higher quality upland grazing sites and microclimatic features such a shade (Kauffman and Krueger, 1984; Trimble and Mendel, 1994).

In a study conducted in the Blue Mountains of eastern Oregon, Roath and Krueger (1982) determined that bluegrass-dominated lowlands provided 81% of the forage consumed by cattle even though it only made up 21% of the total herbaceous biomass within the grazing unit. Further, only 35% of the available land in that grazing unit was utilized and observations of cattle distribution indicated that water was the primary factor in determining cattle use within the grazing area. Kauffman et al. (1983), found that herbaceous dominated streambanks were typically the most heavily utilized forage in a study of cattle grazing impacts on streambanks in northeastern Oregon. Bengeyfield (2007) reported similar animal distribution patterns and noted that upland area forage was seldom grazed to its utilization standard but was often exceeded in the stream bottoms. Further, a study conducted by Platts and Nelson (1985) in a forested watershed in Idaho determined that forage in the streamside area was used at a higher rate than either the immediate range or the overall grazing allotment.

The amount of time livestock spends in or near the aquatic environment varies depending on livestock type, grazing setting or season and available nearby forage supplies and quality. For example, sheep generally prefer slopes and uplands while cattle prefer lowlands and tend to spend a disproportionate amount of time in or near streamside areas than adjacent, drier upland areas (Kauffman and Krueger, 1984; Platts, 1979). This is especially true in arid and semi-arid environments such as Washington's rangelands and ponderosa pine forests where livestock favor riparian areas because they are often a reliable source of succulent forage and drinking water especially in drier seasons (Trimble and Mendel, 1994, Platts, 1979, Kauffman and Krueger, 1984; Belsky et al., 1999, Parson et al., 2003, McInnis and McIver, 2009). When summarizing livestock congregation in the riparian areas, Clary and Webster (1989) stated that seasonal livestock use of riparian areas varies from minimal use in the winter to heavy use in the summer particularly when upland vegetation growth has ceased.

As a result, cattle can preferentially graze riparian areas more heavily than uplands resulting a disproportionate effect on riparian areas. Long-term cumulative effects of riparian grazing involve changes to the structure, composition, and productivity of plant and animal communities (NRC, 2002). This contributes to detrimental effects to stream banks, stream morphology and riparian functions and water quality.

While livestock use of riparian areas will vary depending on many different unique factors for any given location, livestock have been shown to strongly prefer and sometimes rely almost exclusively on riparian areas. The resulting concentration of riparian area use then becomes a key factor in the severity of riparian and water quality impacts commonly associated with riparian grazing.

Livestock Grazing Impacts to Riparian Areas and Water Quality

Site specific impacts of livestock grazing will vary based on many factors such as plant species, density, periods of use or non-use, local plant communities and soil conditions (Beschta et al., 2013). Nevertheless, the negative effects of livestock grazing on riparian areas, stream health and water quality has been well documented, especially in the western United States (Agouridis et al., 2005, O'Callaghan et al., 2019; Beschta et al., 2013) and numerous studies have shown that livestock grazing can cause many undesirable impacts at the local and regional scale (Belsky et al., 1999). In a literature review of livestock influences on stream and riparian ecosystems in the western United States, Belsky et al. (1999) stated that "an extensive literature search did not locate peer-reviewed, empirical papers reporting a positive impact of cattle on riparian areas when those were compared to non-grazed controls". In another review of livestock grazing impacts on stream water quality, Agouridis et al. (2005) reached similar conclusions to Belsky et al. O'Callaghan et al. (2019) concluded that evidence pertaining to impacts in relation to sedimentation, pathogens and riparian vegetation were strong, but stated conclusions related to stream morphology and nutrients was less clear due to inherent variability between and within watersheds. However, the authors drew a similar conclusion to Belsky et al. (1999) stating their review did not find any literature indicating that cattle access to watercourses had a positive impact on the majority of parameters assessed.

Livestock can have numerous and widespread negative effects on riparian plant communities, riparian soils and a variety of hydrologic processes. Stream and riparian damage commonly associated with livestock grazing includes soil compaction and erosion, reduction or elimination of riparian plant communities, and physical modification of streambanks which collectively contributes to changes in channel morphology and watershed hydrology. These conditions along with manure deposition in and directly adjacent to surface waters are major sources of sediment, nutrient and pathogen pollution.

Trampling and grazing of riparian areas also contributes to elevated water temperatures by reducing vegetation and thusly shade, and by reducing stream width/depth ratios making the channel more susceptible to solar radiation. (Agouridis et al., 2005; Belsky et al., 1999; Beschta et al., 2013; Chaney et al., 1991, 1993; Edwards and Canter, 1999; Kauffman and Krueger, 1984; O'Callaghan et al., 2019; Platts, 1979). Furthermore, the combined effects of damage to streambanks, stream channels and riparian areas often creates a cascading effect where conditions continually worsen in response to the initial disturbances. In these circumstances, streambank and riparian vegetation damage often leads to long-term and sometimes irreversible geomorphic responses such as channel bed erosion, channel aggradation (deposition), channel widening and shallowing, channel incision or channel straightening which can in-turn significantly reduce or eliminate riparian vegetation and adjacent upland plant communities.

The following sections discuss livestock grazing effects to the landscape, riparian functions and water quality. Since cattle make up the overwhelmingly highest proportion of livestock in Washington by number and land area grazed, they are the focus of discussion. Nevertheless, much of the information is transferable to other animal types. Because the goal of this document is to identify BMPs that can be implemented at the site level, the focus of the discussion will be on local impacts and water quality. However, its recognized that localized impacts and landscape level changes are inherently related.

Riparian Grazing - Streambank Erosion, Sedimentation & Geomorphic Alteration

The effects of livestock grazing on riparian areas has been the subject of many publications, scientific studies and peer-reviewed journal articles. Numerous studies and literature reviews identify livestock access to streamside areas and riparian grazing as significant causes of streambank erosion, stream sediment loading and negative changes to stream morphology. Further, studies indicate that these impacts result from the direct modification of riparian soils and streambanks, stream channels and the reduction of riparian vegetation and the results of these impacts are interrelated and often compounding (Magilligan and McDowell, 1997; Trimble and Mendel, 1995, Platts, 1979, Belsky et al., 1999; Chaney et al., 1990 and 1993; Kauffman and Krueger, 1984; Trimble and Mendel, 1995, Agouridis et al., 2005; O'Callaghan et al., 2019; Platts, 1979; NRC, 2002). Localized impacts commonly associated with riparian grazing and livestock congregation include: sloughing and eroding streambanks, compacted riparian soils, loss of overhanging banks, wide and shallow channels, lowered water tables, high sediment loads and in-stream turbidity and reduction or loss of stream pool quality and quantity (Bengeyfield, 2007; Chaney et al., 1990 and 1993; Kauffman et al., 1983; Kauffman and Krueger, 1984; Magilligan and McDowell, 1997; Trimble and Mendel, 1995, O'Callaghan et al., 2019; Platts, 1979).

Livestock trampling of soils and vegetation is recognized as a significant cause of erosion within the stream corridor. As livestock move, they exert high pressure incisional and erosive forces on the ground surface which causes soil deformation and soil homogenization (Pietola et al., 2005; Trimble, 1994; O'Callaghan et al., 2019). These forces increase considerable when livestock climb slopes especially during ingress and egress from the stream corridor where the force exerted by hooves can shear off bank material (Trimble & Mendel, 1995).

Trampling has two main effects on riparian soils and vegetation: 1) it removes vegetation, and thereby exposes riparian soil to precipitation and upland runoff and reduces the streambank's resistance to erosional forces of the stream; and 2) it either dislodges soil particles or compacts the soils thus reducing infiltration (Tuffour et al., 2014; Trimble & Mendel, 1995). As discussed in a previous section, these conditions weaken streambanks, decrease resistance to erosion and favor overland flow which also promotes channel erosion. Streams with resilient channel bottoms commonly erode laterally in response to streambank erosion which results in wider and shallower channels. However, streams with softer, unconsolidated substrate experience down-cutting (incision) especially during peak flows. As the channel deepens, flood water detention is lost and water is drained from the floodplain into the channel causing a lowering of the water table which reduces stream baseflows and leads to the drying of the floodplain including riparian soils and wet meadows. Over time, riparian plants can eventually be replaced by upland species that are adapted to drier soils (Belsky et al., 1999).

Riparian Grazing - Soil Conditions

The erosive forces of livestock trampling can significantly affect soils including their productivity, infiltration and water holding capacity, and negative alteration of these properties can lead to other ecological changes.

In a study evaluating the physical effects to soil from livestock grazing, Pietola et al. (2005) found that trampling broke down soil aggregates, reduced porosity and infiltration, and weakened soil structure even at low grazing intensity; and concluded that soils homogenized by trampling are much more susceptible to erosion. Bohn and Buckhouse (1985) indicated that livestock trampling can increase soil compaction, reduce infiltration by grazing protective vegetative and reduce organic matter, and also suggested that compaction and low infiltration rates may interfere with riparian areas functions. Kauffman et al. (2004) also anticipated similar outcomes stating alteration of below-ground structure and riparian zone processes could influence adjacent aquatic ecosystems through changes in root mass, soil structure, infiltration rates and nitrogen turnover rates. While noting the limited research documenting the effects of grazing on riparian soil properties, Bohn and Buckhouse (1985) went on to suggest that soil and water processes in uplands and stream bottoms were similar and had comparable patterns, and also stated that moist riparian soils are generally more vulnerable to compaction because they tend to be wet more often and for longer periods of time than upland soils. This is supported by Tremble and Mendel's (1995) assessment and their conclusion that streambank wetness is a primary factor of erosion vulnerability, and the effects of cattle trampling on streambanks have been found to be significantly correlated with soil moisture.

Bohn and Buckhouse (1985) and Warren et al. (1986) each conducted field studies to evaluate how different cattle grazing systems influence infiltration rates using simulated rainfall. Bohn and Buckhouse evaluated riparian soils and Warrant et al. evaluated pasture soils. Warren et al. determined that infiltration rates were higher and sediment production was lower on plots that were trampled under dry conditions. Bohn and Buckhouse found that an October, late season grazing treatment had lower infiltration rates than its control, and infiltration increased in several control areas where livestock were excluded. Kauffman et al. (2004) evaluated changes to soil properties in wet and dry meadows located in the Blue Mountains of northeastern Oregon and found that soils were less compacted in exclosed sites compared to grazed sites. Soil bulk density was found to be 16% and 32% lower in dry and wet meadows respectively at locations where livestock were excluded. Further, soil pore space and associated water holding capacity and infiltration rates were significantly higher in ungrazed sites vs grazed sites. Ungrazed dry meadows had 6% greater pore space and wet meadows had 12% greater pore space. Additionally, mean infiltration rates within ungrazed sites were found to be 11 times greater in dry meadows and 3 times greater in wet meadows. These findings agree with other study findings that demonstrate livestock grazing can degrade soil structure, reduce infiltration rates and wet soils are more susceptible to compaction.

Riparian Grazing - Streambank Erosion, Sedimentation & Geomorphic Change

Livestock activities in the riparian area such as grazing, loafing and stream ingress and egress have been shown to destabilize streambanks, increased sediment production and are significant sources of sediment transport to surface waters (Zaimes et al., 2019; Tufekcioglu et al., 2012). Streambank erosion, overland flow and bed resuspension are primary sediment pathways associated with livestock activities in the steam corridor and stream sedimentation commonly results from livestock entering streams, direct, mechanical breakdown of banks and indirect streambank erosion associate with degraded riparian soils and vegetation and the consequent reduction in erosion resistance (Trimble, 1994; Trimble and Mendel, 1995; Tufekcioglu et al., 2012). Subsequently, riparian area and stream channel conditions are a major factor that influences sediment loading to surface waters (Bengeyfield, 2007; Zaimes et al., 2019, Trimble and Mendel, 1995; Trimble, 1994).

Trampling along stream channels and its associated effects on riparian soils and vegetation has been shown cause long-term changes to channel morphology such as reductions in stream width/depth ratios and channel incision which contributes to floodplain disconnection and desiccation, loss of flood water detention and reductions in stream baseflow (O'Callaghan et al., 2019, Platts, 1979, Belsky et al., 1999; Chaney et al., 1990 and 1993; Kauffman and Krueger, 1984; Trimble and Mendel, 1995, Agouridis et al., 2005; O'Callaghan et al., 2018; Platts, 1979; NRC, 2002; Magilligan and McDowell, 1997; Trimble and Mendel, 1995). Grazing and trampling of riparian vegetation also directly and indirectly contributes to elevated stream temperatures. Stream temperature is directly affected through the reduction of stream shading resulting from vegetation loss and bank sloughing and is indirectly affected by streambank erosion and sedimentation which causes channels to become wider and shallower-and as a result increases the susceptibility to solar radiation (O'Callaghan et al., 2019; Beschta et al., 2013; Bengeyfield, 2007).

Many studies designed to evaluate livestock effects to riparian areas have found that uncontrolled grazing causes significant streambank erosion, sediment loading and geomorphic alteration. (Trimble, 1994; Bengeyfield, 2007, Platts and Nelson, 1985; Kauffman et al., 1983; Zaimes et al., 2004). Using a series of instream monitoring stations, Bengeyfield (2007) measured suspended sediment in a Montana watershed where livestock grazing, and occasional dispersed recreation were the only land use. The presence of livestock on streambanks was determined to directly introduce sediment to the stream and exposed streambanks to further erosion. Summer grazing was found to cause significant increases to sediment loading and concentration. After the onset of summer grazing sediment loading increased by 157% in low to moderate flow years and 430% in bankfull years. Further, livestock grazing impacts to the stream corridor contributed 2085 tons of sediment to the stream over the eight-year period of the study (1986 to 1993). Stream survey data indicated that the channel morphology had been altered due livestock trampling of stream banks at the majority of locations and trampling had created and perpetuated sources of instream sediment loading.

Kauffman et al. (1983) used steel stakes embedded in streambanks to calculate streambank erosion and found that grazed areas of Catherine Creek in northeastern Oregon had significantly greater streambank losses compared to areas where cattle were excluded. Grazed riparian areas also showed greater disturbance indices and significantly less bank undercuts when compared excluded areas. Zaimes et al. (2004) also used embedded stakes to measure streambank erosion to calculate sediment loading from streambanks. This study found that that continuously grazed horse and cow pastures contributed approximately 256 tons and 1112 tons to the stream respectively over the course of a year with a mean streambank erosion rate of 11.6 inches. Trimble (1994) used stream profiles to measure differences in stream sediment loads between non-grazed and grazed streambanks and found that the uncontrolled grazing caused six times as much gross bank erosion. Areas where livestock entered and exited the stream were found be important sediment sources, and at these locations, trampling formed ramps leading down the stream edge. In a 330m reach, 23 ramps were found ranging from 0.5 to 8m wide. Although cattle continued to use established ramps, they also continued to establish new ramps and enlarge older ones. The only constraint to continued break-down of banks was the presences of trees or large tree roots. Ramps created additional opportunities for erosion, and during the experiment, overland runoff was observed funneling through ramps creating additional erosion. While surface runoff caused ramps to erode, the author further noted that most material removed from ramps was from the stream itself through hydraulic action.

Tufekcioglu et al. (2012) evaluated thirteen cow-calf farms with pastures ranging from 7 to 265ac in size to determine sediment and phosphorus loses from streambank soils under varying stocking rates. Livestock stocking rates were found to be significantly correlated to the percentage of eroded banks lengths and increases in soil bulk density at the top of the bank and adjacent riparian areas. Eroded bank lengths of streamside pastures ranged from 16 to 36% and the sediment loss rates ranged from 93 to 1070 tons/mi per year with an average of 404 tons/mi per year. Cattle grazing, drinking and stream crossing were found to be concentrated on gently inclined banks and other localized channel access points, which increased the susceptibility of the streambanks for further erode. Consistent with similar studies, bank slope and erosion were primarily related to the physical and mechanical impact of livestock on streambanks and erosion rates associated with livestock grazing sites were significant.

Summary

Livestock grazing has been shown to adversely affect riparian habitats, stream hydrology, channel morphology and impair instream water quality and aquatic habitat. Common effects of unrestricted livestock access and use of riparian areas include: increased soil bulk density, increased erosion of riparian soils and streambanks, increased runoff, removal of woody vegetation and over utilization of streamside vegetation. Further, when livestock congregate in riparian areas they often urinate and defecate in or near surface waters and these direct or runoff induced inputs can also contribute excessive nutrients and pathogens loads. These conditions diminish water quality and aquatic habitat and can also contribute to elevated stream temperatures (O'Callaghan et al., 2019, Platts, 1979, Belsky et al., 1999; Chaney et al., 1990 and 1993; Kauffman and Krueger, 1984; Trimble and Mendel, 1995, Agouridis et al., 2005; O'Callaghan et al., 2019; Platts, 1979; NRC, 2002; Magilligan and McDowell, 1997; Trimble and Mendel, 1995). As a result, streams disturbed by livestock grazing are frequently characterized by high sediment yields, elevated bacteria and nutrient loading, wide and shallow channels, lack of overhanging banks, channel incision, and reduced pool quality and quantity.

Riparian Grazing Best Management Practices - Effectiveness Evaluation

The presence of livestock within riparian zones is a common aspect of grazing and can negatively impact the functionality of riparian ecosystems (Malan et al., 2017). Animal grazing behavior is largely influenced by the environment in which animals are located and factors such as water availability, shade, forage quality and quantity, topography and season and these key factors affect grazing area selection and riparian area use (Agouridis et al., 2005; Belsky et al., 1999; Kauffman and Krueger, 1984; Trimble and Mendel, 1994). Given the inherent characteristics of riparian areas and the favorable conditions they often provide, livestock tend to use riparian areas frequently and for extended periods of time when allowed and this behavior is often cited as a primary cause of riparian area degradation and nonpoint source pollution. As a result, BMPs to limit livestock use of riparian areas are often recommended.

The primary goals of limiting livestock use of riparian areas are to prevent degradation of riparian soils, riparian vegetation, stream channels and streambanks as these impacts are known to generate nonpoint source pollution and can lead to negative, long-term changes to channel morphology and riparian ecosystems. In many situations both structural and cultural management practices are recommended to limit livestock use of riparian areas. Three often promoted practices include off-stream watering sources, livestock exclusion fencing and grazing management. In the following sections these practices will be evaluated for their ability to prevent riparian area degradation and nonpoint source pollution. To be considered effective, BMPs should prevent or mitigate against impacts to riparian areas known to generate nonpoint source pollution and limit pollutants such a sediment, nutrients and bacteria. Practices should also support healthy riparian plant communities and their associated ecosystem functions as these are critical for maintaining stable stream systems, maintaining high water quality, keeping water cool, and reducing runoff and associated pollutants from upland areas.

Effectiveness Review: Off-stream Water

Practices intended to modify livestock grazing patterns such as off-stream water have been suggested as a method to draw livestock away from riparian zones and potentially reduce impacts to riparian areas and improve water quality. The primary hypothesis of proposing off-stream water is that livestock at sites with off-stream water will spend less time in riparian areas compared to sites where only the riparian habitat and streams are available (Malan et al., 2017), and this reduction in time spent in streamside areas will limit negative impacts to riparian soils, riparian vegetation, streambanks and instream water quality.

Understanding the effectiveness of off-stream water to alter grazing patterns and limit impacts to riparian areas and water quality requires knowledge of cattle position in relation to the implement BMPs and an evaluation of how altered grazing patterns affect the physical conditions that lead to nonpoint source pollution (Agouridis et al., 2005). A variety of studies have been conducted to evaluate the effectiveness of off-stream water; however, these studies lack a common approach and there doesn't appear to be agreement within the literature for how to best assess the effectiveness off-stream water. For example, some studies focus exclusively on determining the amount of time livestock spend near streams and off-stream watering locations while others include an evaluation of the physical effects that result from altered grazing patterns such as changes to instream water quality, streambank erosion or soil conditions. Further, some studies consider additional factors that may influence off-stream water effectiveness such as off-stream water placement, temperature and humidity during the grazing season, presence or absence of natural riparian area barriers and seasonal differences in upland and riparian forage availability; but consideration of these factors varies. Methods used to track the time livestock spent near watering sources also differed. Earlier studies relied primarily on visual observations while more current studies commonly use GPS tracking devices or a combination of visual observations and GPS technology to determine the amount of time livestock spent in riparian areas or near off-stream water sources.

In addition to differences in study design, observation periods also varied considerably with some occurring over multiple grazing seasons and others only lasting a few days or weeks. Given the limited scope or short timeframes, many of the studies failed to evaluate the effects of off-stream water on riparian conditions such a soils, vegetation or streambanks and instead focused on other indicators such as changes in water source use or riparian and upland forage utilization. As a result, water quality and riparian health outcomes were commonly inferred based on differences in time spent near water sources or other indicators. This variability in research design, timeframes and analysis was highlighted by Agouridis et al. (2005) and Malan et al. (2017) in their reviews of off-stream water studies in which they found few studies that quantitatively assessed the ability of off-stream water provisions to improve water quality or riparian habitat. While there is a substantial array of available research, in aggregate, current studies provide valuable insight into the effectiveness of off-stream water at a variety of scales and settings which is important for developing strategies to protect water quality and improve livestock distribution on the landscape.

As with study design and methods, the results of off-stream water effectiveness studies also vary. For example, a study using GPS collars conducted by Agouridis et al. (2004) found that off-stream water did not affect cattle position preference and did not decrease the amount of time cattle spent along streambanks. However, findings by Sheffield et al. (1997) suggested significant reductions in streambank erosion, nonpoint source pollution and the amount of time livestock spent drinking from the stream. Then again, the conclusions of Sheffield et al. (1997) were inconsistent with Line et al. (2002) which determined that off-stream water alone was not effective at improving water quality.

Studies that track the amount of time livestock spend in streamside zones with and without off-stream water provisions can provide valuable insight into the ability for off-stream water to alter grazing patterns and reduce time livestock spend in riparian areas. In a field study conducted at the University of Kentucky Animal Research Center in Woodford County, Agouridis et al. (2004) used GPS collars to evaluate to the effects of off-stream water and shade on cattle position. The study tested three treatments including 1) a fenced, 30ft wide riparian buffer to exclude cattle from the stream with a 12ft wide stream crossing 2) free stream access 3) free stream access with natural shade from existing old growth tree. Stocking rates remained the same for all treatments and each site had similar characteristics such as soil, existing shade, linear feet of stream frontage and topographical features. Treatment pastures were approximately 2-3 ha (4.9 -7.4 ac) each. To determine cattle position data, a subset of cattle in each pasture were outfitted with GPS collars and their position information was collected every 5 minutes over seven, 18-day periods. The 18-day collection periods spanned spring through fall over two consecutive years (2002-2003). Pasture plots were divided into three zones (riparian, transition and upland) and the position location data within each pasture zone were analyzed to evaluate the effectiveness of BMPs to alter cattle position preferences. Additionally, temperature and humidity measurements were used to calculate a temperature humidity index (THI) for each day within the observation periods to investigate its potential influence on animal behavior.

Examination of the position data found that the treatments did not significantly affect cattle position preferences for either day or night. Analysis of daytime cattle position indicated that the treatments did not differ among the majority of pasture features. Further analysis indicated that season and environmental variations were likely impacting position. When THI was evaluated, it was found to be a better predictor of cattle presence near natural shade; although, a multiple linear regression found that neither THI nor rainfall were significant indicators of cattle position including riparian area use even though there was a substantial linkage between streambank presence and day length. The authors noted that variables such as forage quality and quantity may be better predictors of cattle use of riparian zones. This observation is consistent with other literature which found that cattle frequently concentrated in streamside areas because of access to water, gentler terrain and more abundant and succulent forage. Though off-stream water was not found to be effective at altering cattle use of riparian areas, the authors noted that the inclusion of the alternate shade, pasture improvements and a stream crossing located in the riparian treatment may have impacted effectiveness. The authors further noted that the time effects from this study suggests that the strategic development of cooling features such as shade, wading ponds or misters may influence cattle position.

In a field study conducted in southwest Manitoba, Rawluk et al. (2014) used visual observations and GPS collars to track cattle locations on pastures with off-stream water and pastures with off-stream water and natural barriers to evaluate their ability to limit the amount of time cattle spend in riparian areas. These practices were evaluated at two locations within the same geographic area each with similar forage and weather. Off-stream water was supplied by submersible pumps, solar panels and toughs which were placed 60 -120m (197 - 722ft) from the stream. Study plots ranged from 17.4 to 39.2 ha (43 - 97 ac) and were stocked based on their carrying capacity with approximately 25 cow-calf pairs per treatment area. Streams were not fenced, and natural barriers consisted of fallen trees and branches that were placed across common watering and stream crossing areas to partially exclude cattle and encourage the use of the watering systems. GPS positions of cattle were tracked during three, 28-day periods over a single grazing season. Weather and forage biomass measures were also made to evaluate their potential influence on grazing behavior and water source use. Visual observations were used to record the watering location of cows fitted with GPS collars and were made every five minutes from dawn until dusk over four days within each 28-day evaluation period.

Results from this study found that cattle watered at off-stream locations when available but did not use them consistently or exclusively. When the percentage of time cattle spent in the riparian area with and without natural barriers were compared, the presence of barriers did not consistently limit the use of riparian areas or watering from the stream. During some observation periods cattle spend less time in riparian areas when natural barriers were present; however, in other observation periods cattle spent more time in riparian zones when natural barriers were present. These inconsistent results suggest that additional factors likely influenced animal behavior and may also indicate that barriers used in the study were not large enough to deter cattle from the riparian areas or cattle may have simply moved along the riparian areas to a location without a barrier. Visual observations of water use by collared cows were also mixed and conflicting, and neither off-stream water nor off-stream water with natural barriers consistently limited use of the stream as a preferred watering source. Further analysis of the GPS collar data found the percentage of time cattle spent in the riparian area at each location and treatment site fluctuated between grazing periods and forage availability difference between riparian and upland uplands were likely a major factor that influenced where livestock grazed, congregated and accessed drinking water. Further, cattle use of the riparian areas was also correlated to daily air temperature; and irrespective of the treatment, the percentage of time cattle spent in the riparian area increased as the temperature increased throughout the day. Ultimately the authors found that off-stream water and off-stream water coupled with natural barriers did not consistently decrease watering at streams or the time spent in the riparian areas.

Kaucner et al. (2013) also used GPS collars to assess whether the installation of off-stream water and shade could significantly reduce the interaction of cattle with riparian zones. For this study, cattle behavior of six herds were monitored in twelve experiments which compared controls against treatments during summer and winter of 2007 and 2008. Herds were located at two separate study locations and six trackers were used per herd over four two-week experiments to evaluate cattle behavior prior to treatment and after the implementation of off-stream water, alternative shade and water and shade concurrently. Concrete tanks were used to supply off-stream water and shade was provided via shade cloth support by steel frames. Pasture size differed between study sites with one location having two 1.5 ha (3.7 ac) pastures and the other consisting of a 17 ha (42 ac) and 25 ha (62 ac) pasture. The study sites were located near the towns of Robertson and Goulburn within the Lake Burragorang watershed southeast of Sydney, Australia.

Analysis of the time series data indicated that cattle predominantly moved in groups and collared animals were representative of the herd’s overall movement. When comparing treatments to controls, statistical analysis found significant differences although the magnitudes were small and contradictory to anticipated outcomes at times. In several instances treatments appeared to increase the likelihood of cattle interaction with the riparian zone. Equivalent analysis of near-shade data yielded similar results. Some highly significant differences were found suggesting that livestock were attracted to shade structures, but these trends were small and occasionally opposite of anticipated.

Given the differences in pasture size, the authors estimated the random likelihood of cattle to be found in the riparian zone to be 1.25% and 5% respectively. In comparison, 1.5% and 7.5% the location points were found in the riparian zone for the small and larger paddocks respectively. When frequency was evaluated, there was a 4-fold difference in riparian visit frequency between the smaller and large pastures which was attributed to pasture area. Nonetheless, there were no consistent difference in riparian visit frequency between the controls and treatments. Extended riparian visits (10 minutes or longer) averaged 2-5 occurrences and were slightly shorter within the large pastures. While the riparian area visit frequency between the smaller and paddocks differed significantly, there were no consistent difference between controls and treatments. Overall, the river visit data indicated no cattle preference for or attraction away from the riparian zone in the presence or absence of shade structures and off-stream water.

The authors hypothesized that near-river occurrences might have been influenced by other water-stress factors such as air temperature, solar radiation, percent relative humidity and air speed, and these factors may have overwhelmed the influence of water and shade provisions. Regression analysis of the smaller and larger site data determined that no variable dominated the regression in all three-experiment series. The authors concluded that heat stress had a statistically significant influence cattle position and distance to the riparian area, but the implementation of management measures to modify behavior did not prove successful.

In discussing of the results, the authors highlighted pre-GPS and GPS position plot data from published literature that indicated the tendency of cattle to graze more uniformly with 500-1000m of watering points with grazing intensity commonly the highest within 1 km of a water source in larger pastures. The authors further noted that cattle will often undertake several, longer trips in pursuit of water when an alternative source is not closer. Based on this information and finding from the study, the authors suggested that grazing patterns may be less influenced by off-stream water in pastures. Based on the study and the authors' review of analogous literature, they concluded that cattle drinking behavior in smaller paddocks is not fully understood and the evidence was insufficient to unreservedly recommend off-stream water and shade as a means to protect water quality and riparian areas.

Evaluating the efficacy of water developments can be difficult given the need for continuous monitoring over large, and sometimes very expansive, areas. To overcome some of these challenges, Johnson et al. (2016) used GPS technology to track animal locations over five grazing seasons (2008-2012) to evaluate the relative use of water developments and perennial streams by beef cattle within a rugged and expansion study area in northeastern Oregon. The study areas consisted of three grazing allotments within the Wallowa Whitman National Forest in Baker, Union, and Wallowa counties, Oregon covering 84.0, 46.3 and 39.5 square miles respectively. Allotments varied in elevation from 2,405 ft. to 8,051 ft. and were characterized by rugged mountains and uplands that are deeply dissected by canyons. In this region, elevation in combination with aspect, precipitation, and temperature gradients determines vegetation potential, and the natural vegetation can be described as approximately one third grasslands and two-thirds forest lands. Precipitation across the sites averaged approximately 22.4 inches annually with over half occurring between November and March. Precipitation generally followed the elevation with the driest areas found in the lower reaches of streams draining into the Snake River and the greatest precipitation found in allotments in the Wallowa Mountains.

Each spring, ten randomly selected mature beef cows (10% to 20% of the herd) were selected and fitted with GPS collars which recorded animal positions at five-minute intervals throughout the grazing season. Livestock turn-out dates ranged from April to June. At the end of the grazing season (October or November) cattle were gathered and returned to their home ranches/winter holding areas where GPS collars were removed and returned to project scientists, and the data was downloaded. Comparisons were made between the relative occupancy at water developments versus streamside areas by site and within sites by month and year. Additionally, the use of water developments was contrasted with riparian zone use. Geographic information such as elevation, slope, and aspect, road, vegetation, soils, prior land use activities and aerial and satellite imagery were used in an attempt to identify factors that contribute to use or disuse by season and site.

When the data was viewed in aggregate across the five years of the study, collared cattle were present on 84.6%, 98.6%, and 89.1% of the allotment surface area for Sites 1, 2, and 3, respectively. As stated by the authors, this implied that water from either streams or water developments was available across the majority of the landscape. The percentage of allotment near perennial streams and water developments varied by site. For site 1, 31.8% of the allotment was within 1 km of a perennial stream, 40.7% was within 1 km of a water development and 62% of the allotment was within 1 km of a water source of any kind. For site 2, 30.6% of the allotment was within 1 km of a perennial stream, 70.9% was within 1 km of a water development and 77% of the allotment was within 1 km of a water source of any kind. For site 3, 26.2% of the allotment was within 1 km of a perennial stream, 80.8% was within of a water development and 100% of the allotment was within 1 km of a water source of any kind. Study allotments 1, 2, and 3 contained 44, 41, and 68 water developments respectively. The large number of water developments and their distribution on the landscape are the reasons why 100% of Site 3 was within 1 km of a water source of any type. It was estimated that water developments increased the potential of animal occupancy by 94% to 246%.

Cattle use of water developments and perennial streams varied substantially from site-to-site, month-to-month and year-to-year. In some months cattle watered exclusively from off-stream developments while cattle watered nearly exclusively from perennial streams in other months. For example, the season long average use of perennial streams over the five years of the study ranged from 43.3% to 80.6%, 43.9% to 81.1% and 5.2% to 38.6% for Site 1, Site 2 and Site 3 respectively. Further, within any given year, the monthly percentage use of perennial streams vs. water developments varied significantly as well. For example, in 2008 the monthly average use of perennial streams varied from 3.7% to 88.9%, 58.2% to 92.9% and 0% to 96.1% at Site 1, Site 2 and Site 3 respectively. This month variably of water source use among sites followed a similar pattern over the five years of the study.

Similar to the amount of use, individual water development use by collared cattle also varied considerably with some water developments receiving no use over the five-year study period and others receiving frequent use. At Site 1, which had 44 water developments, 35% of water development positions were found near a single water source (spring with a tank) and 50% of the positions were associated with two water developments. Site 2, with 41 water developments, had a similar pattern with nearly 50% of positions found near two water development. The most dispersed use of water developments occurred at Site 3% which had 68 water developments. There the two most frequented water developments accounted for less than 21% of collared position. Given that cattle tended to rely on a limited number of water developments especially at Site 1 and Site 2, the author's estimate of the potential increase of cattle occupancy within the allotments due to the presence of water developments may not be accurate and animal distribution likely isn't a reflection of the number or distribution of water developments alone. It appears other factors were clearly influencing cattle distribution on the landscape.

Of the 10 most frequently used water developments in the study area, 6 were springs with metal troughs and 4 were ponds. The least used developments were generally higher up elevation gradients sometimes as little as 230 vertical feet. The authors stated that slope gradient, ease of travel and route were obvious factors that play a critical role in determining which water development are selected. In general, water development use was highest in areas where cattle tended to congregate to forage or rest; although, when the number of position counts within 60m of a water development and within 1 km of a development were regressed, this association was weak. According to the authors, the variability of water source use was likely a result of pasture rotation, cattle placement within the allotments, other physical and management factors along with the timing of cattle movement to upland pastures when cattle switched from watering in streams to watering from water developments such as ponds and springs with troughs. Though it's clear these factors inevitably influenced cattle watering behavior, the authors did not assess if or how these factors actually influenced animal watering behavior especially in locations where cattle could freely access perennial streams or water developments.

In review of the cattle GPS data sets in a geographical context, the authors stated that cattle movement and water source use was likely the result of a variety of factors such as management objectives, grazing management plans, prior logging activity, topography, seasonal development and maturation of vegetation and water distribution. This study found that cattle in extensive, rugged grazing allotments used perennials streams frequently and extensively on a monthly and annual basis, but also used water developments frequently or even exclusively at other times. Water source use was also found to depend on a combination of management and physical factors including proximity to surface waters. Ultimately the availability of off-stream water developments in these study areas did not consistently limit the frequency or extended use of perennial streams by cattle as a cattle water source.

In another study conducted in northeast Oregon, McInnis and McIver (2001) tested the hypothesis that providing cattle free choice off-stream water and trace minerals would lessen negative impacts of grazing on riparian vegetation cover and streambank stability compared to pastures without these amenities. The study was conducted on Milk Creek at the Hall Ranch Unit of the Eastern Oregon Agricultural Research Center near Union, Oregon. The study included three replicates of a non-grazed control pasture, grazed pastures with supplemental water and trace mineralized salt and a grazed pasture without supplemental water or salt. Each of the nine pastures were approximately 12 ha (30 acres). Study pastures were sectioned in a manner to represented three different habitats including forest, forest and meadow and meadow. Off-stream water was provided in troughs approximately 1200 feet from the stream and salt supplements were place approximately fifteen feet from the troughs. Ten cow-calf pairs were introduced into each of the six pastures beginning in mid-July of 1996 and 1997 and allowed to graze for 42 consecutive days. The average stocking rate of 0.8 - 0.9ha/AUM (2 ac/AUM) was slightly more than double to stocking rate of the previous 5 years After the second year of grazing, the percentage of stream plots having hoof print, streambank cover and streambank cover and stability were assessed.

Streambanks were examined before and after grazing by walking both sides of the stream and recording streambank cover and stability class within plots defined as the length of a human step (approximately 0.5m). Streambank cover ratings were based the percentage of cover and streambanks were rated as stable or unstable based conditions such as bank breakage, sloughing, bank fracture and bank steepness and cover. Each plot was also examined for the presences of hoof prints defined as a clear impression in vegetation or soil.

The percentage of the streambank plots having hoof prints averaged 0, 26 and 31% in the control, supplemented and non-supplemented pastures and the two treatments were not statistically different.

Neither the streambank cover nor streambank stability differed significantly between the supplemented and non-supplemented pastures. However, when compared to the non-grazed control, providing off-stream water and salt prevented the significant loss of cover observed in non-supplemented pastures. The largest change observed in this study was the significant decrease in the proportion of streambank classified as covered and stable. Both the supplemented and non-supplemented pastures showed significant decreases in the cover-stability class with reductions of 10% and 14% respectively. These decreases we not found to be statistically different, and bank instability was likely the greatest influence on the cover-stability changes. The findings of this study did not validate the hypothesis that free choice supplements would lessen impacts of grazing on cover and streambank stability compared to pastures without these amenities; and ultimately, grazing resulted in a decline in streambank stability, decline in covered-stable streambank class and increased soil erosion potential. Further, grazing at the stocking rate of 0.8 ha/AUM for 42 continuous days after mid-July led to a decrease in streambank stability in both treatment and non-treatment pastures at this site.

Sheffield et al. (1997) evaluated the effectiveness of off-stream water to alter grazing patterns and subsequently improve water quality by installing an off-stream water source along three southwest Virginia spring-fed, first-order streams. The study was conducted at two separate cow-calf operations located in Independence and Floyd, Virginia. Cattle watering behavior, stream erosion and water quality measurements were collected before and after the installations of off-stream water and later compared. During the pre-BMP period (Aug. 1994 through Apr. 1995), cattle had access to a stream in the observed pastures which was their only source of water. After the seven months, water troughs were installed in the pastures and cattle had continued access to streams (post-BMP period: Apr. 1995 through Oct. 1995). A stocking rate of 200 cows and 170 calves on eight pastures totaling 136 ha (336 ac) was used at the Independence site. The Floyd site used a spring-fall grazing rotation with a stocking rate of

150 cows and 30 calves on 187 ha (462 ac). Tall fescue was present in all three test pastures and found to be highly infected by the fungal endophyte.

Cattle watering behavior observations were made on three separate occasions during pre-BMP and post-BMP periods. Pre-BMP watering observations were made on November 22 and December 3 of 1994 and January 10 of 1995. Post-BMP observations were made on June 29, August 22 and September 26 of 1995. Observations were made every 5 minutes (dusk to dawn) from the cab or bed of a parked truck or from the pasture when possible. The number of cattle drinking from the stream or trough, number of cattle within the stream or trough areas, and the percentage of herd grazing were recorded during each time interval. The stream and trough areas were defined as the distance of two adult cow lengths (approximately 4.6 m) from the edge of the water trough and from the center of the stream.

This information was used to determine the cumulative time per animal spent drinking from the stream and cumulative time per cow spent adjacent to the stream.

Streambank erosion was evaluated before and after treatment at the Independence site using 19 pairs of 1 ft. long, 0.5-inch-thick steel stakes. Stakes were randomly place on each side of the stream along straight and meandering portions of the stream channel and were used to measure the cross-sectional distance and distance from the stake to the edge of the streambank. Differences in the distance from the reference stakes to the streambank and stream edge were calculated from the most recent measurement compared to the previous measurement.

Differences in water quality were evaluated before and after off-stream water installation. Due to an insufficient number of samples collected during post-treatment, variations in water quality at the Floyd site were not compared. Water quality samples were taken every two weeks and additional samples were taken during some of the cattle rotation activities. Water quality parameters measured included total suspended solids, nitrate-nitrogen, ammonium, total nitrogen, sediment-bound nitrogen, ortho-phosphate, total phosphorus, sediment-bound phosphorus, fecal coliform, fecal streptococci and total coliform. Samples were collected from the outlet of the stream and expressed in concentration. Nutrient samples were also evaluated in terms of their loading and flow-weighted concentration. Pollutants loads were calculated by multiplying the concentration by the flow volume measured at the time of sampling and the number of days since the last sampling date. The pollutant loadings were then divided by rainfall recorded at the site since the last sampling date in order to remove the effect of variations in rainfall amounts during the pre-and post-BMP periods. If no rain had occurred since the last sampling date, the mass was carried over to the next sampling time where rainfall was recorded.

Changes in cattle behavior and improvements to water quality were reported by the authors and attributed to the implementation of off-stream water. The authors noted significant reductions in the average time each cow spent drinking in the stream and amount of time each cow spent near stream area, 89% and 51% respectively. It's important to note that pre-treatment and post-treatment watering observations were only comparable for one day and the results represent an average across four pastures at two different sites. When the pre-treatment and post treatment times at the Floyd location are compared, the cumulative time spend near the stream area was reduced by 8% and the cumulative time drinking was reduced by 79%. Reductions at the Independence site varies because pre-treatment measurements were only taken on one date (December 1994) while two post-treatment measurements were taken (June and September 1995). As a result, reduction in the cumulative time spend near the stream area was reduced by 72-78% and the cumulative time drinking from the stream was reduced by 91-96%. Water quality changes included a reduction in stream bank erosion (77%) and reductions in flow weighed concentrations of total suspended solids (90%), total nitrogen (8%), ammonium (72%), total phosphorus (65%) and sediment bound phosphorus (43%).

Flow weighted concentrations of nitrate (37%) and orthophosphate (98%) increased and changes to sediment bound nitrogen were negligible. Aside from reductions in total suspended solid, the magnitude of these changes was small. Reductions in fecal coliforms and fecal streptococci were also noted.

Finding from this study suggested significant reductions in the time cattle spent in riparian zones and drinking from the stream along with significant reductions in streambank erosion, nutrients, sediment and fecal coliform bacteria. Under closer examination, it appears the study design and analysis methods may have influenced the outcomes and reported efficacy of the treatment. Especially anomalous was the limited number of watering behavior observations and the use of different seasonal timeframes to determine the effects of off-stream water. Forage availability and daily temperature are known to affect animal behavior and likely influenced grazing patterns and water use. Further, weather, pasture conditions, runoff characteristics and the potential for erosion between the pre and post observation periods were likely very different given the seasons they occurred. Comparing outcomes using different grazing seasons without including controls for each or accounting for additional factors that may have influenced the outcomes is uncommon for these types of studies. Absent control sites or an evaluation of how additional factors may have influenced the outcomes, the comparability of data is limited and changes in water quality and animal behavior cannot be confidently attributed to off-stream water installation alone.

This study highlights the challenges and complexity of evaluating BMP effectiveness and the importance of rigorous study design and comparability among sites. As highlighted by Agouridis et al. (2005), visually identifying animal locations can be difficult and laborious, observers are prone to fatigue and observation periods are often too short to develop confidence in daily behavior patterns. Limitations of this study appears reflects some of the challenges highlighted by Agouridis et al. and are likely reasons why more current studies used GPS collars to track animal behavior over multiple grazing seasons and multiple observation periods with grazing seasons. This study also highlights the importance of including controls, replicates and the value of evaluating change over similar timeframes and conditions.

Numerous field studies have been conducted to evaluate the effectiveness of off-stream water to improve water quality by quantifying the time cattle spend near water sources under different conditions. Inherent to this quantification is the assumption that the amount of time cattle spend in riparian areas is linked to environmental impacts and reducing or eliminating time spent in riparian areas will limit or prevent negative impacts.

Given that off-stream water provisions have been suggested as tool to draw cattle from riparian areas, Malan et al. (2018) conducted a systematic literature review and meta-analysis to assess the effectiveness of off-stream water provisions to reduce the time cattle spend in riparian zones and identify factors that may influence their use.

The authors used a multi-step review process to identify relevant articles for the literature review and meta-analysis. Key search terms such as “off-stream watering points”, “water quality”, “riparian, distribution” and “grazing” were first used to identify papers that made reference to the use or placement of off-stream watering points. The preliminary search yielded 1135 articles which were then screened to determine if the article had sufficient data for a meta-analysis. Based on the second review criteria, a total of 53 articles were reviewed in full leading to an exclusion of 16 articles because they either lacked sufficient information about the use of off-stream watering points to improve riparian health or water quality, had poor scientific quality or were not relevant because they did not include specific information about off-stream watering use. A total of 37 articles were used for the review and seven of the 37 articles had sufficient data for a meta-analysis.

The reviewed studies were conducted in a variety of Koppen climate zones including arid, temperate, continental and tropical. The majority of research was conducted in the United States (n=24) followed by Canada (n=5), Australia (n=4), Brazil (n=2) and New Zealand (n=2). Of the North American studies, the majority of studies were conducted in continental climate zone (55%) followed by temperate (28%) and arid (27%). Of the studies used for the meta-analysis, five of the seven were located in continental climate zones and six of the seven were located in North America. Given that Washington’s climate zones are a mix of temperate, continental and arid climate zones, the majority of the included studies are representative of conditions commonly found in Washington State.

The meta-analysis found some evidence that off-stream water reduced the time spent in riparian zones but with 63.7% variation among studies. The authors noted that factors other than simply providing an off-stream watering points needed to be considered to ensure time spent in riparian areas is reduced. For example, off-stream water at the same distance from waterways yielded both positive and negative results which further indicated that the placement was not the only variable impacting outcomes.

Based on the meta-analysis, the authors concluded that off-stream watering in cold climates, where most of the studies were conducted (n=17), "had little to no effect in reducing the time cattle spent in the riparian zone". In contrast, off-stream water in subtropical and tropical climates seemed to be more effective (n=5). This result suggests that climate may offer a possible explanation for why off-stream water was not very effective at reducing the time cattle spent in riparian zones for the majority of published studies. Since climate likely influence forage quality, THI, water quality and quantity differently, the authors surmised that these factors may explain variations in animal behavior and water source use.

The authors identified seven factors and five sub-factors likely to influence cattle use of off-stream watering points. The primary factors identified included: off-stream watering distance from surface waters, slope, climatic conditions, shade availability, drinking water quality, grazing management, and animal social behavior. The sub-factors were associated with climate and grazing management and included season, temperature humidity index, stocking density, paddock size and shape, and supplement use. Each factor had varying effects on cattle use of off-stream watering and some of the factors appeared to be interdependent.

Analysis of the data suggest that off-stream watering may be more effective in under the following environmental conditions: tropical climates, slope<10%; distance from the stream at either 93–100m or 1100 m; paddock size<20 ha or>140 ha; placed with shade; tropical climates; THI between 60 and 72, good OSWP water quality and good grazing management practices. Furthermore, the authors also stated that the large number of influencing factors and limited data was insufficient to establish off-stream watering guidelines to positively impact water quality.

While off-stream watering itself does not appear to be effective at reducing the time cattle spend in riparian areas in cold climates, factors identified in this journal review may influence the use of off-stream watering and these factors may have some relationship to animal distribution and forage utilization. This information could prove valuable when evaluating structural and management practices to facilitate improved animal distribution and forage utilization.

Conclusion

Providing off-stream water has been suggested as a method to draw livestock away from riparian zones and reduce impacts to riparian areas and improve water quality. The premise is that livestock at sites with off-stream water will spend less time in riparian areas compared to sites where only the riparian habitat and streams are available and this reduction in time spent in streamside areas will limit negative impacts to riparian soils, riparian vegetation, streambanks and instream water quality.

A variety of studies have been conducted to evaluate the effectiveness of off-stream water; however, these studies lack common approaches and methods for tracking livestock use of streams and off-stream water sources. As a result, water quality and riparian health outcomes are commonly inferred based on differences in the time livestock spend near alternative water sources vs. streams.

There is some evidence that off-stream water influences animal watering behavior and distribution on the landscape. However, there is considerable variability in how off-stream water influences the use of riparian areas. For example, some studies found positive outcomes, but others determined that off-stream water had neither a positive nor a negative effect. Further, some studies determined that off-stream water both increased and decreased the time livestock spent in riparian areas within the same study area. While many of these studies were robust and well conducted, it's clear from the research that livestock use of off-stream and instream water sources can be highly variable and many additional factors influence animal watering behavior. Furthermore, these factors were likely affecting the use of available water sources in these studies and the increased use of riparian areas was likely not the result of providing off-stream water.

From the literature reviewed, off-stream water did not consistently or reliably limit the frequency or extended use of riparian areas or the use of streams as a drinking water source. Results suggest that forage quality, forage abundance and relief from heat stress are major factors the influence cattle's use of riparian habitats especially in warm seasons. Therefore, off-stream water developments alone cannot be relied upon to effectively alter livestock distribution to the level required to limit degradation of riparian habitats found in Washington. While off-stream water developments can be a useful managerial practice used to support better animal distribution across the landscape especially in larger pastures and in rangeland settings, they were not found to effectively limit the use of streams or riparian areas or mitigate against impacts to riparian areas commonly associated with livestock grazing.

Effectiveness Review: Exclusion Fence

Livestock grazing within riparian areas has many direct and indirect impacts on water quality and riparian zone integrity. Unrestricted stream access can result in frequent defecation in are near surface water, decreases in riparian vegetation diversity and density, weakening of streambanks, increased riparian soil compaction and unstable stream morphology which collectively contribute pollutants such as sediment, pathogenic bacteria and nutrients to surface waters (Kauffman et al., 2004; Magilligan and McDowell, 1997; Miller et. al, 2010; Nagle and Clifton, 2003; Owens et al., 1996; Ranganath et al. 2009). The primary processes that contribute to livestock-induced water quality pollution are direct defecation to streams, runoff of fecal matter to streams, erosion of streambanks through shearing, erosion of bare or sparsely vegetated soils and resuspension of stream sediment by cattle trampling (Kauffman and Krueger, 1984; Trimble and Mendel, 1995; Belsky et al., 1999).

One common method of protecting riparian areas is the installation of fencing to exclude livestock from riparian zones. Livestock exclusion fencing a structural source control BMP and does not inherently treat or remove pollutants contained in runoff. From a riparian protection and water quality standpoint, the primary purpose of riparian fencing is to manage the location of livestock and prevent access to the streams and streamside areas which are susceptible to disturbances from livestock grazing; and in doing so, eliminate the deposition of feces in or near streams, trampling and removal of riparian vegetation and degradation of streambanks and riparian soils while simultaneously allowing riparian zones to serve as a means to trap, infiltrate and reduce pollutants in runoff and maintain stable stream morphologic processes.

Numerous studies have been conducted to evaluate the effectiveness of exclusion fencing to improve riparian conditions, stream morphology and water quality. While these studies are designed to test the same hypothesis that streambank fencing will improve water quality, they vary considerably in approach and parameters evaluated to determine effectiveness. For example, some studies focus on instream monitoring results, while others rely on evaluating stream geomorphic and riparian conditions to evaluate change. Given the interrelated nature riparian conditions and their effect on water quality, many studies use a combination of indicators to evaluate the efficacy of exclusion fencing. While these studies can determine the effectiveness of excluding livestock from streamside areas, it's important to note that net changes often depend on many different factors including the geographic setting, previous and current management practices, riparian vegetation and soil conditions and their recovery, stream hydrology and geomorphic conditions and the amount of time riparian areas have been excluded from livestock use. In the majority of situations, exclusion fence effectiveness is about measuring changes in riparian conditions and water quality in response to the removal of disturbances from livestock grazing. As a result, it's generally anticipated that stream fencing will result in some level of positive outcome. The following studies examine exclusion fence effectiveness by examining a variety of improvement indicators.

In a study examining the effects of stream fencing on sediment loss in an Ohio stream located in a watershed used exclusively for grazing, Owens et al. (1996) examined sediment loses before and after steam fencing. The study area was a 69.7 ac watershed used exclusively for grazing. Of the 69.7 acres, 64.2 were used for pasturing Charolais beef cattle. The pasture also included 12.8 ac of woods consisting predominantly of mixed hardwood trees. Beginning in April 1980, a herd of 17 spring-calving beef cattle grazed the entire area all year and were fed supplemental hay elsewhere during the winter months. The herd had access to the entire watershed including a small stream that originated within the study area. Springs and seeps supported year-round flow. From November 9, 1987, through March 31, 1993, cattle were kept out of the stream and the majority of the woodland area via an electric fence. The author found a 57 percent decrease in the average annual flow weighted sediment concentrations and more than a 40 percent decrease in average annual soil loss after exclusion fencing was installed. Further, these decreases were like the result of reduce stream bank cutting rather than the fence area filtering sediment from upland grazing areas.

Line et al. (2003) evaluated the effectiveness of exclusion fencing combined with riparian area planting to reduce pollutant loads to a small North Carolina stream. The study was conducted on 140-acre dairy pasture which was also the major of the study stream's watershed. For the purposes of monitoring, the watershed was divided into an upper pasture (103 acres) that was grazed by 75 to 100 heifers and a lower pasture (37 acres) that was heavily grazed by 50 to 150 adult cows. Livestock had unlimited access to the stream prior to the installation of exclusion fencing. The study included 25 months of water quality monitoring prior to the installation of exclusion fencing. Pre-fencing monitoring found fecal coliform and enterococci levels to be more than 300% greater at a downstream station leaving the study pasture than an upstream monitoring station at the upper most part of the study areas. After fencing the stream, fecal coliform levels decreased by 65.9% and enterococci levels decreased by 57%. Turbidity and suspended sediment levels were also significantly decrease by 49.2% and 60.2% respectively. While, pH, dissolved oxygen, temperature and specific conductivity improved relative to upstream conditions, the changes were not found to be statistically significant.

Miller et al. (2010) found that four to six years of cattle exclusion resulted in multiple positive changes to environmental conditions when compared to an adjacent grazed area. In this study, the authors measured environmental conditions within a cattle-excluded area and adjacent grazed pasture and compared the results. Conditions measured included rangeland health, vegetation health, soil properties and rainfall simulated runoff. The sites for this study were located in the Lower Little Bow watershed in southern Alberta, Canada which is part of the Great Plains of North America. Riparian exclusion areas were established in 2001 and the study was conducted over the course of three years from 2005-2007. Prior to the installation of exclusion fencing the riparian area and adjacent pastures were both grazed. Grazing typically occurred from June to August. Stocking rates were 0.50 animal unit month (AUM) ha-1 (0.2 AUM/acre) from 2001 to 2003 but were later reduced to .40 AUM ha-1 (0.16 AUM/acre) from 2004 to 2007 because of weed problems and overgrazing. The distance from the fence to the river edge ranged from 40-80m. Rangeland health scores, as determined by the Alberta Habitat Management Society, in excluded areas improved 55 to 72%, vegetation cover improved 13-21%, standing litter increased 38-72% and bare soil and soil bulk density decreased 72-93% and 6-8% respectively. After 6 years, the excluded area was categorized as "healthy with problems" while the grazed area was determined to be "unhealthy". Result of monitoring from simulated rainfall showed mixed results. According to the authors, rainfall simulations are useful for relative comparisons of runoffs from different treatments, but value should not be considered representative of true values under natural rainfall or snowmelt. With this caveat, flow-weighted concentrations of TN, TP and TPP were significantly reduced by cattle exclusion in 2007 (19-26%) along with mass loads total suspended solids (41%). Mass load of total nitrogen fractions (TN, TDN, TPN) were significantly lower (21-52%) for cattle excluded areas than grazed areas in 2 of 3 years (2006, 2007). Mass loads of TP (TP, TDP, TPP) were significantly lower (32-43%) in cattle excluded areas in 2006. In 2006 turbidity and pH were significantly greater in excluded areas that grazed areas (2-25%). However, turbidity was greater in grazed areas in 2005 and 2007.

In a study that evaluated the effects of livestock exclusion on stream channel morphology, riparian vegetation and macroinvertebrate communities, Ranganath et al. (2009) used a paired study approach where measurements were taken at stream reaches with and without exclusion practices and these measurements were later compared. The study sites were located in southwestern Virginia and consisted of five, nearly continuous stream reaches with and without livestock exclusion practices. Studies reaches ranged from 117 to 421 meters long and distances between reaches ranged from 217 to 1237 meters. The reaches with livestock access were used by heifer cattle with each location having between 15 and 60 animals. Four of the five excluded reaches ranged from one to 14 years old with one forested, ungrazed reach being at least 50 years old. This study utilized a variety of tools to evaluate geomorphic, riparian vegetation and benthic macroinvertebrate communities. To evaluate stream morphology and quantify physical characteristics of the stream both longitudinal and cross-section surveys were conducted. Longitudinal surveys were used to determine stream gradient, water slope and location of bed features such a pools and riffles, and cross-section profiles were used to quantify channel dimensions and floodplain features and determine bankfull width, depth and width-to-depth ratios. Reach-averaged grain size distribution was determined for each pool with a reach and riffle and embeddedness was estimated within a single riffle at each study reach. Further, the Virginia Department of Environmental Quality Reach Condition Index (RCI) was used to evaluate stream geomorphic conditions and streambank soils were evaluated by measuring soil bulk densities. Riparian vegetation was assessed by cutting all groundcover under a meter high within a 1 m^2 plot. Instream habit was evaluated at each reach using a Rapid Habitat Assessment (RHA). This assessment assigns a score from 0 to 200 based on streambed characteristics, channel morphology, bank structure and riparian area conditions. To assess benthic macroinvertebrate communities, each reach was sampled in mid-June and the end of August in 2006. Samples were taken at three riffles within the middle of each study reach and on the left and right sides of each riffle. The Virginia Department of Environmental Quality (VDEQ) Stream Condition Index (SCI) was used to evaluate the benthic invertebrate assemblages at each reach. The SCI scores range from 1 (severe stress) to 100 (excellent condition). When stream morphology conditions were compared, reaches with livestock exclusion were generally deeper, had lower bankfull width to hydraulic depth ratios and had significantly higher Reach Condition Index scores. However, when bankfull width, sinuosity, large wood debris and overall water surface slope were compared they showed no significant differences. The authors noted mixed results reported in previous studies with some finding significant changes in stream width and depth with livestock access and other concluding that stream depth was not affected. It was further noted that many studies conducted on geomorphic responses to livestock exclusion have determine that bankfull width to depth ratios commonly decrease follow livestock exclusion. When embeddedness and percent fines were compared, they also lacked significant differences; although, substrate size was typically larger in livestock exclusion reaches. The authors believed this lack in statistical difference was likely the result of upstream sediment sources which overshadowed the impacts of local management differences. Riparian vegetation and streambanks soils also show mixed results.

The median amount of groundcover vegetation in excluded reaches was two times greater than grazed reaches. However, soil bulk density measurements were not found to be significantly different and may have been due to low grazing intensities in the study reaches or potentially from rapid recovery from freeze and thaw cycles. When instream habits were evaluated, these was a significant difference in Riparian Habit Assessment scores between grazed and excluded reaches. All scores for grazed reaches were classified to be in poor condition and four of the five excluded reaches at or near a score representing good condition. When riparian habit scores of the study reaches were compared to scores within the ecoregion of the study locations, grazed reaches were at the lower end of the scale and excluded areas were on the high end. Benthic macroinvertebrates were evaluated by testing differences between VDEQ Stream Condition Index scores and components of the index and no significant difference between grazed and excluded sites were found. To this finding, the authors highlight the variability of results in previous studies. Some previous studies determined that livestock exclusion led to increased macroinvertebrate index scores while other studies found no significant differences. Macroinvertebrate assemblages and their responses are greatly influenced by watershed characteristics, land use and subsequent conditions within watersheds such as temperature, flow, discharge, flooding frequency and sediment delivery and stream shading. Also, four of the five study reaches were not likely mature enough to significant increase shading or stream temperature. Additional analysis of watershed characteristics and benthic macroinvertebrate populations within a watershed may have increased the possibility of determining how individual practices influence macroinvertebrate responses. However, according to the authors, the lack of benthic macroinvertebrate responses were likely the result of land use and watershed characteristics rather than localized influences. Additionally, as highlight by the authors, short sections of livestock exclusion aren’t likely to lead to improved biological conditions at a watershed level and watershed-wide efforts to reduce negative impacts to stream from all sources are needed. An evaluation of time-to-recovery found that only the Riparian Condition Index (RCI) displayed a relationship to time. The authors attributed this relationship to the fact that RCI is a qualitative assessment using visual indicators and this type of assessment may lend themselves to showing a rapid response. The authors cited similar results in other studies where the duration of exclusion was not significantly correlated to time meaning that the degrees of channel and geomorphic recover was not directly related to the amount of time livestock were excluded. Given the complex interactions between cattle impacts and the influence of those impact on streambanks, riparian soils and geomorphic responses this is to be expected. However, findings from these studies suggest that parameters or qualitative indices that rely on visual indicator are most likely to indicate change.

Nagle and Clifton (2003) also examined geomorphic adjustments following the elimination of cattle grazing through fencing. To do so, the authors compared stream channel cross sections of grazed stream reaches with a 47-yr. old livestock grazing exclosure along Wickiup Creek in eastern Oregon. The study sites were located in the Malheur National Forest which are characterized by forest slopes and narrow alluvial valleys and open, sagebrush steppe consisting of annual and perennial herbaceous vegetation and sporadic willow and lodgepole pine stands. This study was a follow-up to a previous study conducted in 1986 that found significant and distinct differences in channel morphology between grazed and ungrazed channels. The authors highlighted that the grazed sites had been managed under an increasingly more restrictive deferred grazing system where livestock were only allowed to graze later in the season at varying start and stop times. During the study period, the average grazing days ranged from 16-21 days and included 4 years of complete rest. In 1990, a new forest plan was implemented which essentially removed cattle once they started to graze on riparian plants. The authors noted that the conditions of grazed sites on Wickiup Creek that coincided with the required grazing practice were not typical of area. This study found that some stream channel characteristics of grazed sites improved between 1986 and 1998 although not all were statistically different. However, when compared to the ungrazed reach, grazed reaches showed statistically less improvement than the exclosure site. As the authors highlighted, there are a limited number of studies designed to evaluate stream channel changes under different grazing management practices and many of those studies conducted haven't shown statistically significant differences. Study design, differences in field measurement techniques, site and watershed characteristics, limited the number of reference sites and time required for channels to recovery are some of the reasons for the limited number of studies and lack of statistically significant differences within studies. This article suggests that very limited grazing over a long period of time may lead to some improvements to channel characteristics. Although, in this study area, progressively restrictive grazing approaches had not improved stream characteristics to the level of the ungrazed reach.

Magillian and McDowell (1997) evaluated four stream segments in eastern Oregon where livestock were excluded for more than 14 years and compared channels inside the exclosed areas to adjacent grazed reaches. The results indicate that significant geomorphic changes occurred following the removal of livestock grazing stresses to the riparian area with channel narrowing including bankfull and low flow widths and increased pool area being the dominant response. At all four sites bankfull channel width was lower in the livestock excluded areas than the grazed reaches and the exclosure reaches had more pool areas than grazed reaches. Low flow widths were lower in three of the four exclosures and channels within exclosures were 10 to 20 percent narrower for both low flow and bankfull widths. While many geomorphic properties changed, not all demonstrated recovery and the response in some exclosure was opposite of the authors' hypothesis. For example, in some reaches, stream depth showed the least consistent trend. While bankfull depths were greater in three of the four exclosure, neither low flow depth nor maximum pool deep were consistently great in exclosures than grazed reaches. The authors offered several potential explanations to address this unexpected relationship. First, some variables may be slower to response and 14 years may be an insufficient duration to respond. Second, the geographic settings and local controls with the watershed may dominate the relationships and mask the trends. Third, variables that respond to localized controls may also take longer to recover. As highlighted by the authors, it's important to note that strong differences may exist between the potential for riparian zone recovery and timelines for channel adjustment will vary dramatic, and variation in channel responses is likely due to the different stream conditions and perhaps also the varying approaches for measuring channel attributes. To more accurately assess stream recovery processes, detailed longitudinal studies that capture the conditions at the time exclosures are created followed by monitoring over time may identify specific processes and responses that occur following the removal of the riparian disturbance. These types of studies take a very long time; and therefor, are not commonly conducted.

Unlike other studies that used indicators such as instream monitoring, stream channel measures, soil properties, or riparian condition indices, Batchelor et al. (2015) used repeat photography and digital image analysis to quantitatively assess the effects of eliminating livestock grazing at Hart Mountain National Antelope Refuge in southeastern Oregon 23 years after the removal of cattle. The assessment used 64 photos taken before grazing was removed and compared those to photos take at the same locations 23 years later. The assessment included a qualitative method and a qualitative method using software to insert a digital line transect into the photos for analysis. Accuracy of the digital line intercept method was assessment in the field. The digital line transect method proved to be relatively accurate (91%) suggesting it could be useful tool for quantifying vegetation cover and measuring changes in vegetation cover. The results of the assessment found that channel width and eroding banks decreased significantly (64 and 73% respectively), bare soil reduced 90%, exposed channel decrease by 63% and there was a significant increase in herbaceous (grass, sedge and forb) and willow cover. The study demonstrated that cattle removal can result in dramatic changes in riparian vegetation in semi-arid landscapes and with and without active restoration efforts.

Kauffman et al. (2004) examined how livestock exclosures change belowground ecosystem properties such as total above and below ground biomass, soil properties such as pore space, water holding capacity and associated infiltration rates, soil nitrogen and potential nitrogen mineralization. The study was conducted in the upper reaches of the Middle Fork John Day River in the Blue Mountains of northeastern Oregon. The study evaluated ecosystem properties at 6 floodplain meadow sites each containing wet and dry meadows. 3 sites were areas where livestock had been excluded between 9-18 years and the remaining 3 sites had been continuously managed for cattle grazing. Livestock grazing and hay production had been the dominant land use in the floodplain meadows since the 1800s and the ecological conditions and livestock management of these sites were judged to be representative of region. Livestock removal was found to significantly improve soil hydraulic and riparian vegetation properties. Exclosed sites had significantly higher total below ground biomass, lower bulk density, higher soil pore space and higher infiltration rates when compared to grazed sites. The authors found that livestock removal was an effective approach to ecological restoration and highlighted how greater root mass and improved soil properties could better stabilize streambanks, reduce erosion and dramatically increase soil water storage.

Bohn and Buckhouse (1985) also investigated changes to riparian soil properties in response to the elimination of livestock grazing by evaluating differences in infiltration, sediment production, soil penetrability and bulk density under multiple grazing approaches including no grazing, rest-rotation, season-long, deferred rotation and late season grazing. The study was conducted along Meadow Creek located in the Blue Mountain about 48km southwest of LaGrande, Oregon. At the time of the study, the watershed had been primarily used for logging and heavy livestock grazing since the beginning of the 20th century. The study established test sites under each grazing system and all pastures contained a small control area where livestock were excluded. Measurements were taken at the beginning of the study (1975) and then again at the end of the study period (1981) to compare differences. The stocking rate at each plot was 3.2 ha/AUM (7.9 acres/AUM) and plot sizes ranged from 4 to 73.8 hectares. Animal numbers in each plot varied from 1 to 20 to maintain a stocking rate of 3.2 ha/AUM. Infiltration was determined using a Rocky Mountain infiltrometer which simulated a severe storm event for the area and a ring infiltrometer. Results of the study found that infiltration increased under the simulated storm event in several control exclosures where livestock grazing was eliminated suggesting that recovery from previous heavy grazing had occurred. Rest-rotation grazing appeared to follow similar patterns while infiltration decreased for deferred rotation and season long grazing. Ring infiltrometer data wasn't available for all study plots; however, all test sites had a neutral or negative trend with no grazing having a neutral trend. Given previous grazing practices in the areas and the fact the soil conditions often change slowly, this result may have been expected. Sediment production data was limited but suggests that no grazing had a positive affect while rest-rotation and deferred rotation had a neutral and negative change respectively. Soil penetrability and bulk density data suggested neutral or a negative response under the various management approached. The results of study indicate that no-grazing and rest-rotation resulted in the greatest positive change of measured soil properties.

The effects of livestock exclusion fencing have been assessed through numerous empirical studies. Many of these studies found livestock exclusion fencing to be effective at mitigating direct impacts to streamside areas such as riparian trampling, streambank erosion and streambed disturbance which can result in decreased pollutant loading and improved water quality. To evaluate the responses of sediment, nutrient and fecal indicator bacteria levels to riparian fencing within cattle-grazed lands, Grudzinski et al. (2018) conducted a systematic review of peer-reviewed journal articles that assessed the effectiveness of riparian fencing and summarized the findings of these studies.

To develop a summary of the literature, the authors conducted a systematic, multi-step evaluation of peer-reviewed studies that assessed the effectiveness of riparian fencing within cattle grazed lands. Key search terms were used to identify relevant articles which yielded 478 studies ranging in publication date from 1927 to 2019. The authors then read the title and abstract of each article to identify potentially relevant studies. All potentially relevant studies were then read and articles where research objectives or methodologies did not address the effectiveness of riparian fencing on water quality were eliminated. Studies which included extensive stream restoration were also eliminated because the impact of fencing could not be isolated. Studies that replanted degraded riparian zones or stabilized streambanks degraded by extensive trampling were included as the authors believed these changes should occur naturally upon cattle exclusion. Additionally, studies that provided off-stream water sources or access points to streams were also included as these practices were deemed necessary when exclusion fencing is implemented. Finally, water quality responses were also evaluated by hydrograph timing including baseflow and stormflow conditions.

Twenty-six of the 478 studies identified in the initial literature search were found to be relevant for the review. All the identified studies examined the impacts of fencing on water quality and six also included an evaluation of fencing impacts on parameters related to streambed characteristics. Of the 26 studies, the impact of fencing on sediment was examined in 14 studies, phosphorus in 16 studies, nitrogen in 11 studies, and fecal indicator bacteria in 12 studies. The impacts of fencing on more than one of these parameter categories was examined in fifteen studies and four studies examined impacts on all four parameter categories. In total, the review examined fencing impacts on 88 water quality responses with an average of 3.4 parameters per study. The 26 studies were conducted in three world terrestrial biomes including temperate broadleaf and mixed forests (17), temperate grasslands, savannas and shrublands (7), and temperate coniferous forests (2).

A variety of study designs were used in the reviewed articles including pre–post treatment comparisons, upstream to downstream treatment and comparisons within entire watersheds. Studies varied widely in sampling frequency and duration with some studies sampling multiple times per week and other sampling several times per year. However, most sampled water between weekly and monthly. The duration of studies ranged from less than a year to over a decade. Responses of specific water quality parameters across the studies were grouped into four broad parameter categories including sediment, phosphorus, nitrogen, and fecal indicator bacteria. The sediment category included suspended sediment and deposited streambed sediment. The phosphorus category included total phosphorus, particulate phosphorus, soluble reactive phosphorus, and total phosphorus deposited within the streambed. The nitrogen category included, total nitrogen, nitrate, nitrite, ammonium, ammonia, and total Kjeldahl nitrogen. The fecal indicator bacteria category included E. coli, fecal coliform, fecal enterococci, fecal streptococci and total coliforms.

Fencing effectiveness for each specific parameter was classified as either a “majority improvement”, “minority improvement”, or “no improvement” based on the frequency of statistically significant improvements. Results were classified as a “majority improvement” if a greater than 50% of sites or temporal periods in a study showed significant improvements for a water quality parameter. A result was classified as a “minority improvement” if statistical tests showed a significant improvement in half or less of the analyses, and a “no improvement” determination was made if no statistically significant differences were detected due to fencing.

Of the 26 reviewed studies, 85% (22 of 26) resulted in a “majority improvement” or “minority improvement” in at least one water quality parameter. In general, fencing was most effective at decreasing fecal bacteria and sediment parameters followed by the phosphorus and nitrogen categories. Sediment reductions were found in 79% (11 of 14) of the reviewed studies with 8 of 14 the studies showing “majority improvement”. Fecal indicator bacteria decreases were found in 74% (17 of 23) of the reviewed studies with 15 of 23 demonstrating “majority improvement”. Phosphorus was decreased in 54% (14 of 26) of analyses with 9 of 26 showing “majority improvement”. Nitrogen decreases were less consistent with 36% (9 of 25) of analyses demonstrating improvement and 6 of 25 showing “majority improvement”.

Eight of 20 studies sampled the water column during both baseflow and stormflow conditions, and four compared the effect of fencing during baseflow and stormflow conditions with separate statistical analyses. The other four studies did not separate the analyses by hydrograph. Of the four studies that separated the statistical analyses by hydrograph timing, 21 water responses to fencing were tested and 48% (10 of 21) showed a “majority improvement” during stormflows (phosphorus n = 3; fecal n = 7) and none had “minority improvements”. With the four studies that didn’t separate the statistical analyses by hydrograph, 10 water quality responses were examined with 60% (6 of 10) showing a “majority improvement” (sediment n = 2; phosphorus n = 3; nitrogen n = 1) and 20% (2 of 10) showing a “minority improvement” (phosphorus n = 1; nitrogen n = 1), and 20% (2 of 10) showing no improvement” (nitrogen n = 2). Between the eight studies and corresponding 31 analyses that contained stormflow sampling, 58% (18 of 31) of the water quality responses were improvements. When nitrogen parameters were excluded, improvements occurred in 73% (16 of 22) of the remaining water quality responses and 94% (15 of 16) of these occurrences were “majority improvements”. Generally speaking, studies found more frequent “no improvement” responses for dissolved nutrients i.e. nitrate and soluble phosphorus than for total or particulate nutrients

These findings for dissolved nutrients underscore the interconnected nature of exclusion fencing and streamside buffers as it relates to pollution reduction expectations, and that pollutant attenuation from riparian buffers is inherently associated with the effectiveness of riparian exclusion fencing. To this, the authors highlighted the limited response of nitrogen to exclusion fencing and cited research that found buffers over 50 m were consistently more effective at removing nitrogen than buffers 0–25 m. The lack of buffers 50 m or greater in the reviewed studies may have affected the response of nitrogen to exclusion fencing. Also, most studies included in this review were short-term and studies with a before–after design with “after” samples generally taken immediately following cattle exclusion without a transitional period. While removing cattle from streamside areas is likely to have a more immediate response, it was noted that riparian environments may take extended time to respond to livestock exclusion and as riparian areas mature greater decreases in sediment, nutrient, and fecal bacteria are expected. Further, riparian buffer widths will likely need to vary depending on the parameter category and pollutant reductions sought.

Findings from this literature review are consistent with other studies which reported improvements to riparian conditions and water quality as a result of livestock exclusion fencing. Most studies reviewed in this study (85%) reported instream reductions of sediment, nutrients and fecal indicator bacteria and additional benefits may include the protection of riparian plant species and important wildlife habitat in addition to water quality effects. The impact of fencing varied by parameter and fencing was most found to be most effective at decreasing fecal indicator bacteria and sediment parameters followed by phosphorus and nitrogen parameters. There appears to be less response to dissolved forms of nutrients from riparian fencing and reductions of these pollutants will most likely rely on riparian area vegetation and functions. Lastly, the authors acknowledged the potential for multiple environmental and management variables to influence the impacts of riparian fencing. However, due inconsistent reporting of study designs and statistical outputs within the reviewed articles, only relationships between the water quality parameters and riparian buffer width and stocking rates could be evaluated. Overall, greater riparian widths appeared to result in increased water quality improvement. No relationship between stocking rate and water quality improvement was found.

Conclusion

Riparian fencing is a common best management practice used to manage livestock and prevent access to streams and streamside areas. Numerous studies have been conducted to evaluate the effectiveness of exclusion fencing to reduce livestock-induced impacts to these areas and improve water quality. From the literature reviewed, exclusion fencing was found to consistently improve water quality, riparian conditions, streambanks and stream morphology including the following outcomes:

- Reduction in stream sedimentation and streambank erosion;
- Improved stream channel characteristics including reduced bankfull widths and increased pools;
- Improved riparian conditions including streambed characteristics, channel morphology, bank structure and vegetation cover;
- Reduced sediment, nutrient and bacteria loading; and
- Improved soil properties including reduced bulk density and increased infiltration.

In most situations these positive effects are likely due to the elimination of direct defecation into the stream, reduced runoff of fecal material from adjacent land, reduced erosion of streambanks and riparian soils, prevention of trampling within the stream and the recovery of riparian vegetation in response to the elimination of disturbance pressure from livestock. Though the effectiveness of exclusion fencing is generally positive, it’s also important to note that outcomes from exclusion fencing are likely to vary based on specific factors unique to the location where it is implemented. Further, riparian fencing appears to be less effective at addressing dissolved forms and nutrients; although, this may be a consequence of previous impacts to riparian areas or the lack of healthy and abundant riparian vegetation. Nevertheless, many peer-reviewed articles support the practice of using riparian fencing to recover riparian vegetation and functions and improve water quality.

Effectiveness Review: Grazing Management

Livestock have been found to prefer riparian areas and spend a disproportionate amount of time in these areas compared to uplands. This disproportionate use often leads to negative impacts to riparian stream habitats and water quality typically through tramping and excessive vegetation removal (Bailey, 2004; Clary and Webster, 1989; DelCurto et al., 2005; Kauffman and Krueger, 1984; Trimble and Mendel, 1994). Common effects associated with disproportionate riparian use include streambank erosion, channel aggradation or degradation, channel widening or incision, alteration of streambank morphology and suppression or elimination of riparian plant communities (Belsky et al., 1999; Kauffman et al., 1983; Kauffman and Krueger, 1984; McInnis and McIver, 2009; Parson et al., 2003; Platts, 1979; Trimble and Mendel, 1994).

Historically, grazing management has focused on herbaceous vegetation and optimum use of forage to maximize livestock production (Clary & Webster, 1990; DelCurto et al., 2005).

As a result, previous evaluations of effectiveness often relied on measuring stubble height at the stream edge often referred to as the greenline. However, given the effects commonly associated with riparian grazing, management strategies now often attempt to strike a balance between optimal forage use and protection of sensitive areas especially riparian habitats, and post-grazing assessments often include a variety of forage and streamside condition measurements to evaluate outcomes.

From a water quality, stream and riparian health perspective, the main principle of most grazing strategies is to reduce the amount of time livestock use riparian zones by increasing the uniformity of grazing and protecting sensitive areas by modifying animal behavior or changing attributes of grazed pastures (Bailey, 2004). The hypothesis is that altering the time of use and forage use patterns will significantly reduce or eliminate impacts to streamside conditions and water quality. To do so, grazing management strategies rely on controlling the timing, frequency and duration of grazing activities and often includes seasonal schedules aimed at optimizing livestock distribution and vegetation use patterns (DelCurto et al., 2005).

There are many approaches to grazing management including early-season, late-season, mid-season, continuous-summer, deferred and rest-rotation. Of these, early season, late season and rest-rotation are most likely to be implemented in the Pacific Northwest to alleviate impacts to riparian areas and water quality. A key aspect to these strategies is the concept of deferment where management areas are divided into multiple pastures with each pasture receiving rest during at least part of a grazing season to allow for seed set and avoid grazing during critical times in plant development or when riparian areas are more susceptible to impacts. Under these deferment approaches, pastures are commonly grazed on a rotating basis in either the early season or late season on a scheduled rotation. In some situations, pastures are rested for an entire year in-between pasture rotations which is commonly referred to as rest-rotation.

Deferred grazing management approaches are intended address seasonal preferences for riparian plant species exhibited by livestock and avoid grazing in riparian zones when impacts to riparian vegetation and streamside areas are more likely. Therefore, grazing timing is likely the most critical consideration when attempting to minimize physical impacts to riparian areas and streambanks and limit undesirable changes to the composition, productivity and succession of riparian and upland plant communities (Kauffman et al., 1983; McInnis & McIver, 2009). When selecting a season of use in any particular area including riparian areas, factors such as predicted plant species response, overall impact to plant communities, soil moisture of the site and potential impacts to water quality need to be considered (DelCurto et al., 2005; Marlow & Pogacnik, 1985).

Many studies have been conducted in a variety of settings to evaluate the effectiveness of grazing management strategies to alter livestock vegetation use patterns and minimize impacts to riparian habitats and water quality, and collectively these studies provide valuable insight into the expected outcomes of these approaches. Similar to studies that evaluated the effectiveness of off-stream water and exclusion fence, study designs to evaluate grazing management strategies varied in both approach and indicators used. For example, some studies focused on riparian vegetation responses and other evaluated other indicators such as streambank and riparian soils conditions. Further, many studies tended to focus on measuring post-grazing conditions to evaluate effectiveness and these conditions were often used as proxies for changes to stream habitat conditions and water quality.

In a field study conducted in the foothills of the Wallowa Mountains in northeastern Oregon, Parsons et al. (2009) quantified the effects of early summer and late summer grazing on beef cattle distribution and vegetation utilization pattern within riparian areas and adjacent uplands. To quantify the effects of these season grazing strategies, 52 cow/calf pairs were used to evaluate: 1) early summer grazing (mid-June to mid-July); and 2) late summer grazing (mid-August to mid-September) during the summers of 1998 and 1999. Fencing was used to create nine, 10-15 ha (24.7-37.1 ac) pastures. Each pasture contained about a 260-m (853ft) of stream reach and vegetation within pastures were classified into four vegetation types including gravel bar, riparian grass, riparian sedge/rush, and upland. The nine pastures were separated into three blocks based on vegetation type and the two treatments were randomly assigned to pastures within each block along with a control where no grazing occurred.

An analysis of the data determined that season and time of day significantly affected livestock distribution patterns, and ambient air temperatures were highly correlated with livestock distance from the stream. Cattle were found to express a diurnal pattern in both early and late summer with cattle being furthest from the stream in the early morning and gradually moving closer to the riparian area as the day progressed. Cattle were consistently observed further from the stream at any given hour in early summer than late summer. In early summer, cattle visited riparian areas during late morning hours and then either returned to the uplands or remained near the riparian area during the heat of the day and returned to the uplands in late afternoon. Cattle spent nearly equal time between upland and riparian vegetation types between the hours of 1230 until 1800 during early summer with time spent in riparian areas ranging from 50 to 60%. In late summer, cattle began the day away from the stream but quickly moved closer to the riparian area during the morning hours and congregated in shady areas of the riparian area during the heat of the day until gradually returning to the uplands in late afternoon. Over 90% of the cow observations during late summer were in riparian areas from 1200 to 1700 hours.

Cattle movement data revealed a seasonal effect on grazing activity and the location of grazing. Cattle expressed a distinct trimodal daily grazing pattern during both seasons with discrete peak grazing times during the morning, mid-day and evening. While livestock exhibited a season of use and time of day interaction, the total grazing times did not differ between seasons. When livestock location and grazing activity data were compared, peak mid-day and peak evening grazing occurred between 900 to 1300 hours and 1700 to 2200 respectively in late summer. This coincided with the greatest riparian area occupancy which ranged from 80-100% during the same timeframe. Peak mid-day and peak evening grazing occurred between 1100 to 1300 hours and 1700 to 2200 hours respectively with early summer. During these peak grazing times, riparian occupancy ranged from 20-40% during mid-day grazing and 50-60% during evening grazing. The time spent in the riparian area loafing or grazing was less for early summer grazing compared to late summer grazing. While riparian area use during the early season was significantly less during peak grazing times, cattle still spent measurable time grazing in riparian area especially in the afternoon and early evening.

Vegetation utilization patterns differed between years and season. In 1998 early grazing season utilization levels in riparian and upland vegetation types averaged 31% and 37% use respectively while late summer utilization averaged 42% and 34% use, respectively. In 1999 early grazing season utilization of riparian and upland vegetation types averaged 41% and 40% use, respectively; however, during the late summer grazing season riparian vegetation utilization was disproportionately higher at 55% compared to upland vegetation utilization of 34%. Thus, early summer grazing resulted in nearly equal utilization of upland and riparian vegetation types in both years of the study. This uniform pattern likely reflects more uniform livestock distribution during the early summer grazing period. It's important to note that annual precipitation varied within the study period with 1998 receiving above normal precipitation (500 mm) and 1999 receiving below normal precipitation (264 mm). This measurable difference in annual precipitation could have impacted forage quality and quantity and possibly affected livestock distribution and vegetation utilization patterns. Also, the timing of precipitation can also impact forage quality and quantity. For example, riparian utilization increased in both treatments in 1999 by 30% while upland utilization was nearly unchanged from 1998 to 1999 for early and late season grazing. This increase in riparian utilization suggests that cattle reliance on riparian areas may increase in years with lower-than-average precipitation. During late summer grazing, vegetation immediately adjacent to the streambank edge (green line) was utilized nearly 60% compared to 36% use during the early summer. This again demonstrated the increased reliance on riparian areas with late summer grazing.

Nutrient composition of available forage varied between seasons of use with early summer forage having lower dry matter and fiber and greater crude protein compared with late summer forage. However, there was no difference between upland and riparian area forage composition within seasons. As the grazing season progressed, herbaceous vegetation matured and deteriorated resulting in a decrease in forage quality and an increase in forage dry matter content. The authors noted that previous research found that vegetation quality and quantity played significant roles in determining distribution patterns of cattle. In this study, forage quantity was similar during both season; however, riparian areas had greater forage standing crop than uplands regardless of season which likely influence riparian use. The authors noted that water intake of a given class of cattle is a function of dry matter intake and ambient air temperature. Since ambient air temperatures and dry matter were lower in the early summer, the need for water would also be lower. The authors estimated the difference between early season and late season water needs could be up to 20 liters per animal per day which could increase the dependence on streams for water during late summer.

Parson et al. determined that season affected livestock distribution and the amount of time cattle spent in riparian and upland areas. The amount of time cattle spent in the riparian area was highly correlated to ambient air temperature and increased throughout the day as temperatures increased. As such, cattle spent more time in the riparian area with late summer grazing than the early summer grazing. Mid-day temperatures ranged from 61-66° F and 75-80° F in early summer and late summer, respectively and these temperatures affected cattle distribution. Higher ambient temperatures and greater standing forage in riparian areas during late summer also led to greater riparian forage utilization. Conversely, early season grazing lead to better animal distribution and more even forage utilization. While the amount of time cattle spent in riparian zones was greater with late summer, cattle also relied on the riparian area during the early season spending as much as 50-60% of their time in the riparian zone especially in the afternoon and early evening. Precipitation and subsequent forage availability also appeared to affect forage utilization patterns and the use of riparian forage increased when annual precipitation was lower than average.

Kauffman et al. (1983) also evaluated the influence of season on cattle grazing behavior and riparian area use. In a three-year study the authors compared differences in succession, composition, productivity and structure of riparian plant communities that were ungrazed and plant communities that were grazed under a late season grazing strategy where grazing occurred from late August to mid-September. The study area was located at the Eastern Oregon Agriculture Research Center near the town of Union, Oregon, and included a 50-m by 3-km strip of riparian vegetation adjacent to a stream located in the southwest foothills of the Wallowa Mountains. The study area was part of a 49-ha pasture comprised entirely of plant communities within the riparian zone associated with the stream. Adjacent uplands were dominated by mixed conifer and ponderosa pine habitats. To conduct the study, five livestock exclusion areas were constructed along the stream alternating with grazed portions of the study area. In total, approximately half of the streambank and riparian vegetation within 50 m of the stream was grazed and the other excluded cattle grazing. Grazed and ungrazed areas contained a sufficient number of similar vegetation stands for meaningful comparison. Grazing began about August 25 and continued for 3 to 4 weeks depending on the amount of forage produced and livestock numbers grazing. The stocking rate on the riparian study area was approximately 1.3-l .7 ha/ AUM. The study was conducted over three grazing seasons from 1978 – 1980. Mean precipitation in 1978 and 1980 was higher than average and lower than average in 1979.

The ten most prevalent communities in the riparian zone were intensively sampled using species frequency, standing phytomass and, where appropriate, included shrub density and height measurements. The 10 communities sampled included dry meadow, moist meadow, Kentucky bluegrass-cheatgrass, cheatgrass, Douglas hawthorne/Kentucky bluegrass, snowberry-Wood's rose, gravel bars, ponderosa pine/ Kentucky bluegrass and black cottonwood-mixed conifer. Typically, half of the stands for each community sampled were in grazed areas and the other half of the stands were in ungrazed areas. Estimation of forage utilization was conducted in the fall after cattle were removed and done by an ocular estimate of 10-15 plots in each stand that was sampled for standing phytomass. Stubble heights of key forage species in meadow and Douglas hawthorne communities were estimated by randomly measuring 1 grazed plant per plot.

Analysis of the data found forage utilization patterns varied greatly from community to community and often from stand to stand within particular communities. Dry and moist meadows were most preferred, and cattle utilized these communities more heavily than the other communities. More than 60% of the forage produced in these communities was removed by livestock. In the dry meadow community, Kentucky bluegrass was utilized 55-79% with an average stubble height of 3 to 4 cm. Forb utilization in the dry meadow community was moderate to light. In the moist meadow community, Kentucky bluegrass utilization was moderate to heavy with an estimated utilization of 67-80% and mean stubble heights of 4 to 7 cm. Meadow timothy was utilized at 60-76% with mean stubble heights of 9 cm to 14 cm. The only notable forb utilization in moist meadows was northwest cinquefoil and white clover. In many stands cinquefoil utilization estimates were greater than 70% and white clover was generally utilized at 60% or greater. Douglas hawthorne was also found to be preferred by cattle especially stands with a relatively open canopy. Utilization in Douglas hawthorne stands ranged from 25 -47% with the more open stands of Douglas hawthorne receiving the heaviest utilization. Stubble heights of Kentucky bluegrass in Douglas hawthorne communities were less than 8 cm.

Grazing on gravel bars was light to moderate with less than 40% of the total available forage utilized. Within gravel bars, there was a preference for willows, black cottonwood saplings, and white clover. Plant communities with a dense canopy cover such as black cottonwood, ponderosa pine, and thin leaf alder were less preferred and grazing of these communities was usually less than 20% and always less than 30%. Kentucky bluegrass in forested communities appeared to be less palatable than in meadow communities. Observations in forested communities suggested lower plant densities with fewer tillers per plant but greater leaf blade length compared to those found in meadow or open communities. Lodging, bending over of plant stems near ground level, was more common in communities with an overstory canopy and cattle almost exclusively grazed plants that were not lodged. The cheatgrass community was found to be the least preferred of all communities sampled with late season regrowth being the only detectable forage utilized.

Shrub utilization with the entire riparian ecosystem was neither constant from year to year nor from community to community. Utilization was generally light except in the gravel bar community and on very palatable shrubs. On gravel bars, livestock preferred black cottonwood saplings with a mean utilization rate of 84, 31 and 50% in 1978, 1979, and 1980, respectively. Willow utilization ranged from 27-48%. Utilization on fenced gravel bar communities was always less than 5% for all shrub species and was primarily from big game Cattle utilization of palatable shrubs such as blue elderberry was heavy and often greater than 100% of the current year's growth. Douglas hawthorn shrubs less than 1 m in height were preferred by cattle, particularly in low density stands or as solitary shrubs in meadow communities. Utilization of Douglas hawthorne often exceeded 50% of the current year's growth on many individuals. Douglas hawthorne shrubs exceeding 2m in height were rarely browsed as heavily as the smaller hawthorne shrubs. Snowberry utilization ranged from 9 to 36% in ponderosa pine, snowberry-Wood's rose, and black cottonwood communities. Other shrub species were utilized but typically less than 10%.

Differences in species composition between grazed and ungrazed treatments were evident after 3 years in the moist meadow community. Additionally, phenological and temporal differences were observed with the growing season. For example, in some stands the onset of the growing season, flowering and dormancy is areas where cattle were excluded occurred as much as 2 weeks later in the year compared to grazed areas. Significant increases in mesic or hydric species occurred in some excluded stands of moist meadows. For example, by 1980 lineleaf indian lettuce had a mean frequency of 3% in grazed stands compared to a mean frequency of 16% in areas where cattle were excluded, with a frequency up to 47%. Conversely, significant decreases were apparent in meadow timothy and some forbs within livestock exclusion areas. In grazed stands, meadow timothy frequency ranged from 73-89% for the 3 years of the study. In livestock excluded areas, the frequency of meadow timothy declined significant from 91% in 1978 to 40% in 1980.

Areas more susceptible to trampling damage also experienced changes in species composition with the elimination of grazing. In areas with gravelly, loosely structured soils, cheatgrass dominated the portions of the stand utilized by livestock while quackgrass dominated the excluded area. Quackgrass and cheatgrass are both invasive species known to invade disturbed riparian areas. In the excluded area, perennial and biennial forbs began to colonize the area while areas outside the excluded area were primarily dominated by annuals. Within the gravel bar communities, cottonwood sapling density and height significantly increased in areas of livestock exclusion after 2 years of rest. Mean height of cottonwoods in grazed areas was not significantly different between years and remained 10-12 cm tall. Changes in shrub composition were also observed including increased density and height of willows and black cottonwood in the ungrazed area while the grazed area remained dominated by a low cover of black cottonwoods.

Phytomass is a quantitative estimate of the total mass of plants (above and below ground) within a given area. When impacts of livestock grazing on standing phytomass and productivity were evaluated, the communities with the greatest amount of standing phytomass in the field layer were the communities that exhibited the greatest response to the elimination of grazing. These communities were also most heavily utilized by cattle as forage and primarily located in wet and dry meadows and Douglas hawthorne communities. Despite changes in specific community compositions, no significant differences in total species diversity were found with the timeframe of the study.

Phytomass varied in many communities from year to year in both treatments. Moist meadow followed this pattern and significant differences were found between grazed and ungraze d plots. Mean phytomass was estimated to be the same for both treatments at the beginning of the study. In 1979 mean phytomass was significantly greater in the grazed treatment; however, by 1980 mean phytomass had increased nearly three-fold in and was slightly greater than the grazed treatments but not significantly different. Individual species within moist meadows had different reactions to elimination of grazing but succession towards a more mesic or hydric plant community appeared to be occurring. For example, exotic grasses such as meadow timothy and forbs more attuned to drier environments decreased and were being replaced by native sedges and forbs more attuned to wetter environments.

Annual fluctuations in total standing phytomass in dry meadows were similar to moist meadows. In excluded areas, phytomass was significantly less in 1979 that phytomass measured in 1978 and 1980. In contrast, phytomass in grazed dry meadows remained relatively stable. Phytomass was found to be significantly higher in the ungrazed plots in 1978 and 1980 but there was no difference in 1979. After three years of no grazing, the Douglass hawthorne/Kentucky bluegrass communities in excluded areas had significantly greater phytomass than grazed areas. This increase was mostly attributed to increases in Kentucky bluegrass phytomass. Forest communities showed few changes in standing phytomass and cheatgrass communities showed little response to either treatment.

The effects of grazing on plant community composition and structure were found in vegetation stands were livestock exclusion occurred. After three years, four of ten sampled plant communities displayed significant species composition and productivity differences, and the two meadow and Douglas hawthorne communities had significant differences in standing phytomass. The authors noted that grazing pressure on woody vegetation can prevent the establishment of seedlings often resulting in an even-aged non-reproducing vegetation community. Woody vegetation communities in this setting generally succeed in the following order: black cottonwood sapling communities formed on gravel bars to willow-dominated communities, to thin leaf alder communities followed by mature black cottonwood-mixed conifer communities succeeding thin leaf alder communities. Examination of the woody species composition on willow-cottonwood sapling dominated gravel bars indicated that grazing was likely restricting succession, and this phenomenon was observed at several location where these communities were bisected by exclusion fences at the beginning of the study.

After three years, shrub density and height appeared to be greater in treatments without grazing and thin leaf alder and some willow species were not found in grazed areas of the study. While it was too early to definitely determine if late season grazing negatively impacted the succession of woody vegetation communities and long-term structural diversity of the riparian area, early evidence and observations indicated this was occurring. The authors also noted that late season grazing could increase the likelihood and intensity of shrub utilization within riparian zones, and this would not likely be as severe in upland areas. The primary reason for these expected differences is that late season herbaceous growth in the riparian areas was still succulent and palatable whereas vegetation in the upland generally wasn't. Observations from this study indicated that shrub use by cattle was related to the availability of herbaceous vegetation and palatability of the shrub species. Discernable shrub browsing did not generally begin each year until the later part of the grazing season. Shrub utilization was limited when herbaceous vegetation was available in the riparian zone. The authors noted similar observation made in the Blue Mountains of Oregon where little shrub utilization occurred, with the exception of highly palatable species, when stubble height was 10 cm or greater. When stubble height was further reduced, grazing shifted to less palatable species.

Herbage removal from grazing appeared to be an important factor in altering seasonal phenology of mesic and hydric communities. In grazed areas, flowering for most grasses, sedges and perennial forbs occurred early than excluded areas where most vegetation was still in vegetative form. This was likely due to higher litter density and subsequent lower soil temperature and higher soil moisture in excluded areas. Increased soil moisture from increases in litter was likely an important factor for the increased abundance of mesic/hydric species and the reduction of species more attuned to drier environments in moist meadows with livestock exclusion.

Livestock trampling and trailing was localized to communities with moist or saturated soils susceptible to compaction. The authors noted that communities in these areas with fragile, loosely consolidate gravelly soils are susceptible to physical damage and uprooting. The authors further noted that communities with saturated soils present throughout the grazing period were the only vegetation stands with the potential for severe compaction during late season grazing and the majority of stands had low moisture levels. There was some evidence of recovery from the elimination of grazing on areas with loosely consolidated, gravelly soils. When discussing management implications, the authors noted that some management strategies may be beneficial to some communities and detrimental to others. The study found that late season grazing had major influences on some communities and no detectable influence on others. The authors further noted other research (Kauffman et al. 1982, Kaufman et al. 1983) which found late season grazing to significantly increase streambank erosion and cause significant, short-term decreases in small mammal densities. When discussing forage quality, the authors also noted that riparian vegetation in the late season is generally more palatable and of higher nutritional value than vegetation in the upland community. The authors also noted a study within the same location that found improved dry matter digestibility, improved protein levels, lower lignin and lower acid detergent fiber in diets of heifers grazing the same riparian area during the late season compared to upland vegetation up to 1 month prior.

McInnis and McIver (2009) also conducted a study to evaluate how grazing timing affects cattle distribution and riparian area use. Similar to Parsons et al. (2003), McInnis and McIver evaluated the effects of early summer and late summer grazing; however, their study was designed to evaluate the effects of these strategies on streambank cover and stability. In evaluate how seasonal uses may affect streambanks, a two-year study was conducted at the Eastern Oregon Agriculture Research Center in northeastern Oregon. The study included three replicates of three grazing treatments including early summer grazing, late summer grazing and a non-grazed control. Pastures were established in three blocks along a 2.4 km (1.5 mi) stream reach. Block 1 was forested with ponderosa pine and Douglas hawthorn, Block 2 was mix of forest and meadow and Block 3 was primarily meadow dominated by Kentucky bluegrass, sedges and other dicots. The dominant riparian forages in all blocks were Kentucky bluegrass, sedges, timothy, meadow foxtail and brome. Estimates of stream bank cover and stability were taken before and after each grazing period and forage utilization was measured at the end of the grazing period each year. Stream banks were examined by pacing the entire length of stream on both sides and recording the corresponding stream bank cover and stability class within each plots defined a step length (approximately 0.5 m) taken parallel to the stream. Plot width was about 0.3 m and measurement were taken within the first vegetation at the water's edge or slightly below the bankfull stage which is often referred to as the greenline. Each grazed pasture was approximately 11.5 ha (28.4 ac) and stocked with cow-calf pairs to achieve a mean stocking rate of 0.7 ha per animal unit month (1.7 ac/AUM). The stocking rate ranged from 0.5 to 9.0 ha/AUM (1.2 to 22.2 ac/AUM) with the goal of achieving a moderate grazing intensity that would result in 35% to 50% utilization.

Plots were classified as "covered" if they contained any of the following features: living perennial; vegetation ground cover greater than 50%; roots of deeply-rooted vegetation such as shrubs or sedges covering more than 50% of the stream bank; at least 50% of the stream bank surface covered by rocks of cobble size or larger; or at least 50% of the bank surface covered by logs of 10 cm (3.9 in) diameter or larger. Otherwise, plots were rated "uncovered." Cover estimates were based on visual assessment. Plots were classified as "stable," unless they exhibited any of the following features: blocks of banks broken away and laying in the stream channel adjacent to the bank breakage (bank breakage); bank sloughed into the stream channel (slump); bank cracked and about to move into stream (fracture); or bank uncovered as defined above with an angle visually estimated steeper than 80 degrees from horizontal (vertical bank). Plots exhibiting any of the above-mentioned features were rated "unstable." Each plot was rated according to stream bank cover and stability and was grouped into one of four classes: covered/stable; covered/unstable; uncovered/stable; or uncovered/unstable. A single observer conducted the survey.

An evaluation of streambank cover found that early summer grazing was not statistically differ from non-grazed controls and was significantly less than streambank cover reductions observed with late summer grazing. When streambank stability was evaluated, early summer grazing resulted in a 13% decline in streambank stability while late summer grazing resulted in a 31% decline. Early and late summer grazing resulted in significant effects on cover, stability and cover/stability classes including negative changes in the percentages of the covered/stable, covered/unstable, and uncovered/unstable categories. The greatest change occurred within the covered/stable category which declined 10% during early summer grazing and 28% during late summer. Both early and late summer grazing also resulted in increased percentages of covered/unstable and uncovered/unstable stream banks with the greatest increases resulting from the late summer grazing treatment. Grazing generally resulted in larger changes to streambank stability compared to changes in cover. Declines in bank stability likely contributed to changes in the uncovered/unstable category than did decreases in cover. This is further reflected by the fact that the uncovered/stable category did not change in relation to non-grazed controls while the covered/unstable category declined significantly ($p \leq 0.05$). Slumping was found to have the greatest influence on stream bank instability and accounted for the greatest proportional change. Bank slumping was significantly greater for both treatments when compared to the non-grazed control although slumping was 2.5 times greater in late summer grazing treatment compared to early summer grazing treatment. Bank breakage was also greater in grazed pastures compared to non-grazed controls, but differences between early summer and late summer grazing were not significant. Grazing did not significantly ($p \leq 0.05$) increase the occurrence of bank fracturing or of vertical banks compared to non-grazed controls. Further, the erosion index for both grazing treatments increased significantly compared to the non-grazed control. However, the proportional increase was significantly higher following late summer grazing (1.62x) than early summer grazing. The authors noted that previous work at this location demonstrated that cattle were consistently further from the stream and spend less time near the stream during the early summer than during late summer.

Forage utilization rates as measured at the greenline met the goals of the study and were 37% and 41% for early summer and later summer grazing, respectively. While utilization targets were met, both early and late summer grazing impacted streambanks and caused significant declines in streambank stability. However, late summer grazing reduced bank stability more than twice as much as early summer grazing. To this finding, the authors noted studies documenting use of riparian and upland communities by cattle in the Pacific Northwest which showed a similar seasonal pattern, with upland use declining and riparian use increasing from spring to autumn. This study found no significant difference in cover between early-grazed and non-grazed treatments, but the concentration of cattle in the riparian zone during late summer resulted in a nearly threefold increase in the loss of cover compared to early grazed pastures. As highlighted by the authors, grazing along stream banks can cause as much or more damage to streambanks and riparian habitats through bank alteration than through changes in vegetation biomass. Results from this study demonstrate that grazing during either season caused significant declines in stream bank stability even when forage utilization targets were met. Although, late season grazing reduced bank stability more than twice as much as early season grazing.

Deferred grazing strategies including rest-rotation are common approaches to livestock grazing in rangelands. Understanding how streamside areas respond to rest-rotation grazing strategies is important because selective grazing in conjunction with disproportionate use of riparian areas are often cited as primary causes of riparian habitat deterioration and degraded water quality. To evaluate the effect of rest-rotation on streambank stability and riparian vegetation, Patts and Nelson (1985) conducted a four-year study in central Idaho. In this study, treatment pastures were established in previously ungrazed watersheds and allotments that had been under rest-rotation for 20 years or more. These two approaches allowed the author to investigate the long- and short-term effects of rest-rotation on streambank stability and riparian vegetation. All treatments and controls were studied for at least four years prior to any of the grazing treatments so the results could be comparted to pre-treatment conditions.

Eleven study areas were located in three tributaries of the Salmon River of central Idaho. Climate conditions include snowy, cold winters and significant annual precipitation. Considerable rainfall can occur in this area during the spring, but summers are typically warm and dry. The eleven study areas spanned a variety of settings including meadows within or adjacent to forested areas, dry and wet meadows. All of the study areas were located in Forest Service grazing allotments and the ungrazed locations consisted mainly of productive, grassy valley bottoms.

All study areas, with the exception of one, consisted of a 548.6 m (1800 ft.) reach of stream that were gridded by 181 transects placed at three-meter intervals. The remaining site was 356.8 m (1170 ft.) long and include 120 transects. The central areas of each study location (60 transects) were fenced to create an experimental treatment pasture that could be grazed or rested. Forage use along the streambanks was estimated using qualitative criteria and determined immediately after the grazing season along each transect line from the water's edge to 1.5 m out from the bank edge. The amount of forage used within the adjacent range, defined as being 500 m (1640) from the stream, was determined using Forest Service methods. The amount of forage used by livestock used in grazed plots was determined by comparing ungrazed areas protected by metal cages with surrounding grazed areas. Streambank alteration was evaluated using qualitative criteria that assessed stability, erosion, fish cover, sloughing and if erosion was caused by forces other than stream action.

An evaluation of previously grazed allotments found forage use to differ among streambanks and adjacent rangeland, and streamside vegetation was more heavily used than adjacent rangeland forage on all allotments. On average, streamside forage received 12% greater use than the adjacent pasture in the treatment plots and 8% greater use than the adjacent range in the allotments. According to the authors, if the allotment was managed for moderate intensity (26-50%), the streamside zone could readily sustain heavy grazing at 51-75%. Streamside use in treatment plots, which were stocked to achieve pre-selected forage use, was very different that the allotments. In these test plots, range forage exceeded the use of streamside forage by an average of 12% in all treatments. The authors believed this was an artifact of the small treatment pastures (2.4 – 4.0 acres). The ratio of streamside forage to adjacent range forage which was much greater in the treatment plots than the allotments which lead to reduced grazing of the riparian area.

Grazing timing appeared to influence use of streamside vegetation in the allotments and treatment pastures. Average streamside forage utilization in the allotments was 13% greater than the adjacent rangeland during the late season and 9% greater during the early season grazing. This relationship suggested a tendency for cattle to avoid streamside areas early in the season when soils and vegetation may be wet. Also, in these high elevation meadows, vegetation on the adjacent rangeland is typically lusher during the early grazing season. Use of streamside vegetation within the small treatment pastures was 11% greater than adjacent pasture. Additional factors such as temperature and annual precipitation may have influenced the results but were not include in the study design or analysis.

Differences in streambank alteration between grazed and ungrazed areas began to increase after cattle utilization reached 65-70% and streambank alteration increased relative to ungrazed controls. In some study areas, remission of bank alteration seemed to appear as a result of the rest year, but the authors attributed that observation to regrowth than likely masked some of the bank alteration.

The results of this study determined that rest rotation grazing can lead to the over utilization of forage and damage streambanks and riparian habitat even when adjacent rangeland is receiving acceptable uses as outlined in management plans. Further, after one cycle of a rest-rotation grazing system in the treatment plots, streambank alteration was detectable.

Given that streambanks alteration can occur slowly, the authors were only able to make preliminary interpretations. Longer terms studies that include addition factors such as weather and annual precipitation along with animal distribution information may lead to additional findings.

To evaluate the relationship between timing of cattle grazing and riparian degradation, Marlow et al. (1987) conducted a four-year study along a small tributary with the Cottonwood Creek watershed in southwestern Montana. The stream and its headwaters are located on the Montana Agricultural Experiment Station's Red Bluff Research Ranch. Cottonwood Creek watershed is approximately 1,360 ha (3360 acres) is characterized by moderate to steep slopes and elevations range from 2,000 m at the headwater spring to 1,400 m where it enters the Madison River

The riparian community was dominated by a mixture of grasses, forbs, sedge and shrubs with an overstory of quaking aspen. The upland communities included a mixture of grass species along with scattered stands of sagebrush interspersed with Rocky Mountain juniper and Wood's rose. The study stream (Cottonwood Creek) is small stream with an average flow of 0.16 m^3/s. The channel substrate consisted of angular gravel, silt, and fine clay and less that 20% of the banks were rock or gravel. Mean daily air temperatures range from 20°C in July and August to -11°C in December. Annual precipitation ranges from 400-500 mm (15.7 – 19.7 in.) and is primarily from snowfall between October and March, rainfall during May and June. Precipitation from July, August, and September contribute less than 20% of the annual total.

A 5.5-ha section of Cottonwood Creek was fenced in the spring of 1981 to create nine paddocks with equal amounts of upland and riparian communities. One paddock served as an ungrazed control and the other eight were grazed sequentially for 14 days each beginning with the paddock furthest downstream. This sequence created eight timeframes including late June grazing, early or late July grazing, early or late August grazing, early or late September grazing, or early October grazing. These times spanned the timeframe of a typically grazing season of the areas. A stocking rate of four yearling cattle per 0.6 ha was established to remove half of annual forage growth.

Channel profile changes, grazing periods, measurement interval, streambank moisture, streamflow, and cattle use-levels were measured to determine the effects of timing of cattle grazing on streambank degradation. Streambank moisture was measured at two points in each paddock when the cattle were introduced to a pasture using a neutron scattering technique. Streambank and channel alterations were monitored by establishing five permanent channel cross-section transects in each paddock. The vertical distance from the level transect line to the channel bed was measured at horizontal intervals of 10 cm at the beginning of the grazing season and immediately after each paddock was grazed. As a result, the time between pre-grazing and post-grazing measurements increased as the grazing season progressed. Differences were summed and the absolute values were used to develop a profile change index for each transect. Streamflow recorders were positioned at three locations along the creek in the grazed area and at the downstream boundary of the ungrazed paddock. Streamflow date from the unit nearest to the treatment paddock were used in comparing streambank and channel changes to streamflow level during that period. Cattle use patterns were based on two, 24-hour observation periods each week in 1982 and 1983 totally 32 observations annually. Feeding and resting activities in the riparian zone or upland were recorded hourly during each observation period. The number of observations in each activity category and location were summed for each grazing period and divided by the total observations to arrive at the percentage of time spent in each zone.

Analysis of the data found a distinct downward trend in channel profile change during the season. The magnitude of change was greatest in early grazing periods (late June through early August) and lowest in early October. Changes occurring from late August to early October were typically greater than the level of change in the ungrazed portion of the same stream; however, they were not significantly different. While channel profile change level declined dramatically in late August each year, variation among channel transects in paddocks grazed in late July, August, and September was great enough to suggest this pattern was continuous.

Cattle use of riparian areas declined from approximately 20% to 10% from late June to early July, but steadily increased to over 60% by late August and remained above 60% for the remainder of the grazing season. Comparison of channel change with cattle use and measurement interval indicated that both use, and interval were closely related to the pattern of change. Alterations in channel profile appeared to decline as the percentage of time cattle spent in the riparian zone or the interval between pre- and post-grazing measurements increased. The negative relationship between cattle use and channel change was puzzling to the authors given previous case studies that suggested high cattle use resulted in altered stream channel profiles. The authors noted the possibility that changes in channel profile during late August, September, early October treatment and the ungrazed control were not detected because the interval between pre-and post-grazing measurements was too long. However, further examination of the type and degree of change that occurred between measurements of individual transects indicated significant changes in all paddocks in all 4 years.

According to the authors, high streamflow during periods of high soil moisture has been suggested to causes severe bank erosion. Higher streamflows were significantly related to the amount of change in the channel profile during 2 of the 4 years of this study. While streamflow appeared to be the major factor in bank erosion, the consistently greater amount of alteration during the early part of the grazing season suggested that either streamflow differed from paddock to paddock, or some other factor was affecting channels during high-flow periods. The authors found it unlikely that flow was the only cause of great bank erosion because there was no significant difference in flow among the five recording locations in three of the four years of observations. Consequently, the presence of cattle during periods of high flow appeared to be the only explanation for the elevated levels of streambank erosion in late June, July, and early August. Given that streamflow generally declines from June to October and streambanks typically become progressively drier, the general lack of significant stream profile change in this study seemed to support the idea that streambank moisture levels at the time of grazing may be correlated to the degree of alteration cattle impacts on streambanks may be seasonal.

The results of this four-year study indicated both streamflow and cattle use were highly correlated with the degree of stream channel profile change. The greatest streambank change occurred during periods of high streamflow and low cattle use. Further statistical analysis of the data indicated that streamflow itself was not a major factor in bank erosion. While not significant in all years, the decline in channel change appeared related to the seasonal trend in soil moisture and cattle grazing. As streambank moisture levels declined, the extent of channel alteration also declined. Channel profiles changes in paddocks grazed after early August when banks had dried were commonly greater than the ungrazed control but were not significantly different ($P < 0.05$). This decline was in sharp contrast to the pattern of cattle use which was the lowest in late June and early July and highest in September and October. Results from this study supports the argument that a combination of high flow, moist streambanks, and cattle use leads to major streambank alteration.

Haan et al. (2010) evaluated the effects grazing management and microclimate on cattle distribution. The primary objectives of this study were to determine the impacts of grazing management and microclimate on cattle use of stream channels, riparian areas, uplands, and shade. A three-year study was conducted from 2005-2007 on six 12.1-ha (30 ac) cool-season grass pastures located at the Iowa State University Rhodes Research farm in central Iowa. The six study pastures were each bisected by a 141 m (463 ft.) stream segment and were grouped into two blocks with each block assigned one of three grazing management treatments including continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR) via riparian fencing and a 4.9 m (16 ft.) wide stream crossing and five-paddock rotational grazing system (RS) with one paddock spanning both sides of the stream and associated riparian zones. Each pasture was stocked with 15 fall-calving Angus cows from mid-May through mid-October. Grazing was not allowed in the fenced riparian areas on either side of the CSR pastures which extended approximately 33 m (108 ft.) from the stream. Riparian paddocks in the RS pastures also extended 33m from the stream in either direction and were 0.91 ha (2.2 ac). Riparian paddocks were grazed until forage height decreased to a minimum of 10 cm (3.9 in.) and were used between 8 and 10 days per year during the study period. Tree cover area was measured in the upland areas and streamside zones which ranged from 1.4% to 13.8% and 3.6% to 23.7% respectively. Pasture with greater streamside zone shade also had greater amounts of shade in the upland areas. To test the effectiveness of off-stream water on cattle distribution, off-stream water tanks were made available to cattle in the CSU and CSR pastures in May, July and September of 2006 and 2007. Water tanks were located on both sides of the stream at a minimum of 240 m (787 ft.) from the stream. Cattle were also provided a mineral supplement adjacent to off-stream watering sites. Pastures did not receive supplement fertilizer during the study period.

Cattle activity and distribution observations were conducted using GPS collars and visual observations. One cow per pasture was fitted with a global positioning system (GPS) for approximately 2 weeks in each month from May through September in 2006 and 2007. Visual observations were conducted from 6:00 a.m. to 6:00 p.m. on two consecutive days in May through September in 2005, 2006 and 2007. Cattle in CSU and CSR pastures did not have access to off-stream water sites during visual observation days or the night prior to visual observations. Cattle distribution information was obtained by a trained observer within each pasture equipped with a hand-held GPS receiver. At 10-min intervals cow herd location, number of cattle present, number of cattle under shade, and the number of observed defecations and urinations were recorded. Cattle location for both visual observation and GPS collar data was defined as within stream (Stream Zone), 0 m to 33 m from the stream edge (Streamside Zone), 33 m to 66 m from the stream edge (Transition Zone), and greater than 66 m from the stream edge (Upland Zone). The Transition Zone included the remainder of the riparian area and the start of the uplands. The Stream Zone was determined by walking the length of the stream with a GPS collar recording position at 30-s intervals. Stream channel was approximately 3 m wide. The Streamside Zone and riparian paddocks were approximately the same with (33m). The Stream Zone, Streamside Zone, Transition Zone, and Upland Zone were 1.1%, 6.1%, 6.1%, and 86.8% of the pasture area, respectively.

Microclimatic measurements including temperature, black globe temperature, wind speed and relative humidity were recorded at 10-minute intervals using a weather station located in the riparian area in the center of the study area. A temperature humidity index (THI), heat load index (HLI) and black globe temperature humidity index (BGTHI) was calculated for every 10-minute measurement. To evaluate the impact of microclimate on cattle distribution and activity, microclimate data were paired with GPS and visual observation date for each observation timeframe. Microclimatic and grazing management effects on cattle occupancy within the Stream, Streamside, Transition and Upland were analyzed along with defecation and urination patterns.

Based on the GPS data, cattle in the CSU pastures spent significantly more time in the Stream and Streamside Zones that the CSR pastures. According to the GPS data, cattle in CSU pastures spent significantly more time in Stream Zones in May, June and August and significantly more time in Streamside Zones in May, June and July and tended to spend more time in August as well. Visual observation data also found that cattle in CSU pastures spent more time in the Stream Zone in all months and these were statistically different in June, July, August and September. Visual observations also found that cattle in CSU spent more time in Streamside Zones that cattle in CSR in all months and these were significantly different. Additionally, during the months of May through August cattle were observed in the Stream or Streamside Zones with the CSU pastures 20% of the time. Differences in cattle use of the Transition and Upland Zones were also observed between grazing management treatments in some months. GPS data found that cattle in CSR pastures spent more time in Transitional Zones than cattle in CSU in May, June, July and August but not September; however, these differences were not statistically significant (P<0.05). Visual observation data determined that cattle in CSR pastures spent more time in Transitional Zones than cattle in CSU in May, June, July, August and September. Statistically differences in Transitional Zone use (visual observations) were not provided by the authors. Upland Zone use in CSR pastures was higher in all months (May – September) for both GPS and visual observations; although, the GPS data was only significantly different in June and the observation data was significantly different in June and August. It's not entirely clear why CSR uplands appeared to be used more but upland shade may have influenced the distribution of cattle within the pastures. Also, the authors noted that pasture with greater streamside zone shade also had greater amounts of shade in the upland areas.

GPS collar data demonstrated that cattle within the CSU treatment were present in Stream and Streamside Zones an average of 1.2% and 10.6% respectively. Stream and Streamside Zones represent 1.1% and 6.1% of the available pasture indicating that cattle tended to favor the Streamside Zone but didn't congregate in the Stream. The authors noted other research which found that cattle used streams channels and floodplain areas of a pasture to a greater extent than the relative areas those zones compare to the total pasture. Given that the CSR (restricted) and Rotational grazing (RS) systems largely prohibited livestock from access streamside areas it is expected that the percentage of time in these areas would be less that the unrestricted treatment. Nevertheless, this study validates the hypothesis that unrestricted access to streams and riparian zone often leads to a disproportionate use of these areas.

In this study, providing cattle with an off-stream water source did not decrease the percentage of time spent in the Stream or Streamside Zone in either the CSU or CSU pastures. The authors guessed that the use of off-stream water may have been affected by the limited time for cattle to acclimate to its availability. Also forage availability during the time when off-stream water was provided was not available but may have influenced its use.

The percentage of observed defecations in each of the pasture zones did not differ from the percent of time spent in each zone. Although, cattle urinated slightly more (83.5%) in Upland Zones that the percent of time spent in this area (82.3%). For the study observations, the authors believed it could be assumed that nutrient and pathogens excreted by grazing cattle would be proportional to the percent of time spent in a given zone.

When the effects of microclimate on cattle distribution were evaluated, it was found that as temperature, BGTemp, THI, BGTHI and HLI increased, the probability of cattle being in the shade increased across the entire range of observation periods in both the CSU and CSR treatments. Grazing management treatments (CSR and CSU) had no effect on the probability of cattle being in the shade. However, there was a statistically significant effect of grazing treatment on the likelihood of cattle being in the shade based on BGTemp, BGTHI and HLI. The greater probability of cattle being in the shade in CSR pastures at higher BGTemp, BGTHI and HLI than CSU pastures was likely the result of cattle having greater access to streams in CSU pastures. Even though cattle in CSR pastures had access to streams that space was restricted to the stream crossing area (14ft wide) and cattle did not appear to loiter in this area. Overall, ambient temperature was superior to the other microclimatic variables in predicting cattle presence in shade.

Increases to temperature, BGTemp, THI, BGTHI and HLI was found to increase the probability of cattle being in the riparian zone in both the CSU and CSR treatments; although, the rate of increase was higher for CSU pastures than CSR pastures. Again, this was likely due to greater access to the stream and riparian areas in the CSU treatment pastures. Off-stream water did not alter the probability of cattle being in the riparian zone of CSU pastures at any Temp, BGTemp or THI. However, there was a for off-stream water to decrease the probability of cattle being in the riparian zone as BGTHI and HLI increase, but this was not statistically significant. Ambient and black globe temperature were found to be superior to other microclimate variable or indices in predicting cattle presence in the riparian zone

Studies have determined the amount of time cattle spend in streams and riparian areas is a commonly a function of temperature, humidity, the need for animals to thermoregulation, access to water for drinking and thermoregulation and forage quantity and quality. Cattle in this study were found to use riparian areas more when they had unrestricted access to them, and ambient temperature and black globe temperature were found to better indicators of cattle presence in streams and riparian areas. Further, the use of fencing and rotational grazing systems included in this study reinforces the need to include structure practice to limit the time cattle spend in streams and riparian areas and highlights the need to limit the use of riparian areas to protect water quality. In this study, fencing with limited access to the stream via a stream crossing was found to reduce the time livestock spent in riparian zones. Given the design of the pasture rotation in this study, cattle in the CSR system were excluded from the majority of surface waters and riparian areas 97% of time and this invariable limited the time spent in riparian areas and influenced the use of upland areas and upland shade. Further, this study found that defecation and urination were commensurate with the time spent in pasture zones.

As highlighted by other research, environmental factors and grazing management are often interdependent and collectively influence the amount of time livestock use streams and riparian areas and effects to riparian areas and water quality. In a study conducted by Nellesen et. al (2011), the authors evaluated the effects of grazing management on streambanks and phosphorus delivery to a surface water. The authors' hypothesis was that managed grazing, as opposed to unrestricted access, would support more stable streambanks and lead to reduced sediment and P losses.

To test the authors' hypothesis, a three-year study was conducted from 2005 to 2007 on six 12.1-ha (30 ac) cool-season grass pastures located at the Iowa State University Rhodes Research farm in central Iowa. The objectives of the study were to quantify the effects of three grazing management systems on net erosion, stream deposition, streambank stability and phosphorus losses from stream banks along a cool-season grass pasture. The six study pastures were each bisected by a 141 m (463 ft.) stream segment and were grouped into two blocks with each block assigned one of three grazing management treatments including continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR) via riparian fencing and a 4.9 m (16 ft.) wide stream crossing and five-paddock rotational grazing system (RS) with one paddock spanning both sides of the stream and associated riparian zones. The CSR pasture also included a 33.5 m (110 ft.) riparian buffer on each side of the stream. Each pasture was stocked with 15 fall-calving Angus cows from mid-May through mid-October. Grazing was not allowed in the fenced riparian areas on either side of the CSR pastures. Riparian paddocks in the RS pastures extended 33m (108 ft.) from the stream in either direction and were 0.91 ha (2.2 ac). Riparian paddocks were grazed until forage height decreased to a minimum of 10 cm (3.9 in.) and were used between 8 and 10 days per year during the study period. Upland paddocks in RS system were 2.78 ha (6.9 ac) and grazed to allow for 50% forage removal in each rotation. Stream stage was monitored from April until November during the study period and grab samples were collected in spring of 2006 under base flow conditions and analyzed for total P, total N and dissolved organic carbon.

Stream stage was monitored from April until November during the study period and grab samples were collected in spring of 2006 under base flow conditions and analyzed for total P, total N and dissolved organic carbon. Sample contained <0.05 mg/L total P, 6.6 mg/L total N and 3.3 mg/L dissolved organic carbon which were found to be similar to values reported for streams flowing though continuously grazed pastures in Iowa. Streambank erosion susceptibility scores using visually scoring during pre-, mid- and post-grazing each year. To quantify the effects of grazing management on sediment and phosphorus loading, transects were established and fiberglass pins were inserted perpendicular to the streambanks at each transect. Exposed pin lengths were measured May to November of each year calculate erosion, deposition and pin activity. If a pin was lost to bank erosion, the total length of the pin was recorded. Deposition was likely due to sediment deposition during high flow, soil falling from upper bank faces and freeze and thawing of bank soils. Pin activity was the absolute value of change in erosion pins, and it was assumed the higher the activity value, the more unstable the system was. Soil samples were collected in the spring of 2006 to characterize bank material. Potential P losses from streambanks were calculated by multiplying the area of the bank, the mean net erosion, bulk density and P concentrations of the bank material.

Since sample samples were collected by soil horizon, estimated of P losses were the sum of losses from each soil horizon.

Total annual rainfall from 2005 to 2007 was 917, 815 and 1100 mm compared to the 30-yr average of 818 mm. Precipitation during the grazing season from 2005 to 2007 was 635, 480, 686 mm while the 30-yr average for this timeframe was 729 mm (28 in.). Lower rainfall during the 2006 grazing season led to fewer and smaller stream flow spikes. Rainfall during the 2007 grazing season was more evenly distributed which resulted in a relatively flat hydrograph.

Streambank erosion and pin activity differed from year to year and measurement period with a given year than amount grazing management. Net bank erosion during the non-grazing season

(November through April) was greater than the grazing season in all three years regardless of grazing management. Net streambank erosion was significantly greater during the non-grazing season compared to the grazing season and erosion tended to occur in the winter. Over the course of the study significant differences among treatments only occurred in July of 2005 and during the non-grazing season of 2007. In July 2005, the net erosion in CSR was less than the CSU and RS pastures. In 2007, net erosion during the non-grazing season was less in the RS treatment than the CSR treatment. Based on the results, the authors stated that cattle grazing management had little effect on streambank erosion and natural process likely had a much greater effect. According to authors, the short amount of time the treatments were in place along with changes in cattle behavior may have influenced the results.

Average pin activity along the study reach followed rainfall patterns and tended to be higher in 2005 and 2005. Similar to average bank erosion, pin activity was greater in the non-grazing season for all three years of the study. To isolate the effects on grazing management on bank erosion, bank deposition and pin activity the data was analyzed with data collected only when cattle were present. Net streambank erosion was not affected by management June through October. However, erosion and deposition activity from June to October was significantly affected by management strategy. Pin activity was the greatest under the CSU management followed by the RS strategy with the lowest under the CSR system. Erosion and deposition were correlated to mean monthly stream stage; however, the correlation between pin activity and reach specific variables were weak. The correlation between net streambank erosion and pin activity was found to be weak; and again, suggested the cattle grazing management strategy had less influence on streambank stability than natural processes.

Trend analysis of monthly erosion and deposition data showed of trend of decreasing erosion in the two RS pasture over the three years of measurement. The authors further noted that there were no negative trends for any of the treatments indicating that bank erosion was not increasing in any of the six pastures. Trend analysis of monthly pin activity showed that pin activity was decreasing, and streambanks were becoming more stable in three of the six treatments including one of each treatment including RS, CSR and CSU. Only one pasture (RS) had a trend of both decreasing bank erosion and increasing stability over the course of the study indicating some response to this management system.

Phosphorus loses during the non-grazing season were greater than the grazing season regardless of grazing management. Mean 3-yr phosphorus losses were lower in CSR pastures than the CSU and RS pastures. Significant differences among treatments occurred in July, September and October of 2005 and November of 2007. In July, phosphorus losses were less in CSR treatments than CSU and RS treatments. However, in September, phosphorus losses were less in the CSR and RS treatments that the CSU treatment. Phosphorus losses in November were less in the RS treatment followed by CSR and CSU. October 2005 was the only measurement period when phosphorus losses from CSU were less than other treatments.

In this study the authors found that streambank erosion and pin activity differed among measurement periods and years more than grazing management treatments. Results were also mixed among treatments and indicators such as net erosion, pin activity, phosphorus loss and streambank stability scores varied from year to year and treatment. For example, trend analysis of erosion and deposition data showed decreasing bank erosion in the two pastures under RS grazing management. Although, mean phosphorus losses were lower in pastures under the CSU and CSR pastures than the RS pastures. Also, significant differences among treatments were only found in four of 21 measurements. In general, CSR and RS appeared to experience less streambank erosion and pin activity, but this was not fully attributable to the grazing system alone. The results of this study suggest that streambank erosion and phosphorus losses to the stream were primarily controlled by geomorphic process at this site. This is shares similarities with Zaimes et al. (2004) which also evaluated streambank erosion in Iowa and found temporal variability in streambank erosion including increase erosion in the non-grazing season likely due to freeze and thaw events.

Timing and duration are two important factors commonly included in a grazing management system. Grazing management strategies often use seasonal schedules to match the timing a grazing with forage quantity and palatability to optimize livestock distribution and vegetation use patterns and limit the overuse of riparian areas and any associated effects. These strategies typically include an estimation of the forage potential of a given area to be grazed and livestock are stocked at differing times and concentration to maximize the use of available forage. Forage availability is site specific and typically estimated in the form of animal unit month (AUM) which is an estimate of the forage required by one animal unit for a month. Because any given grazing location will have a limited forage carry capacity for a given period of time, stocking rates are based on available forage and timeframes for when available forage is expected to be utilized. Generally speaking, when animal stocking rates increase, the amount of time an area can be grazed decreases and vice versa.

Many studies that evaluate grazing management strategies often report stocking rate information; however, very few assess the effects of stocking rates on outcomes. Maloney et al. (1999) assessed the effects of three rangeland management strategies of increasing intensity on instream water temperature and investigated watershed characteristics that influence stream temperatures. Through this study, the authors were able to establish watershed characteristics that affect stream temperature and assess the relationships between those characteristics and summer stream temperatures to determine the influence of increased grazing intensity.

The study was conducted in 12 watersheds within the northern part of the Malheur National Forest located near John Day, Oregon. Study watersheds ranged from 1.2 to 18.1 square kilometers (0.5 to 7.0 square miles) with each watershed predominantly consisting of one or two distinctive ecosystems including fir-spruce, larch, mountain meadow, ponderosa pine, lodgepole pine and Douglas fir. Annual precipitation is this area ranged from 20 to 50 inches with the majority (70%) occurring between November and April as snow. Consequently, the annual hydrograph is dominated by snowmelt that begins in March at lower elevations and mid-May at higher elevations. Peak flow occurs mid-April to early June based on elevation and aspect with flows diminishing through the summer with the lowest flows occurring in August and September. The authors noted that these runoff patterns are similar to those reports for other watersheds in eastern Oregon and Washington. Maximum stream temperatures in the 12 watersheds ranged from 12.5 to 27.8 °C (54.5 to 82.0 °F) with more than 88% percent occurring between July 16 and August 19. Minimum temperatures were similar for all watersheds and ranged from 3.5 to 5.0 °C.

The three range management strategies used in the study included a control with no grazing (strategy A), average stocking rate of 7.7 hectares per animal unit month with grazing management to attain uniform livestock distribution (strategy C) and a stocking rate of 2.8 hectares per animal month with grazing management to emphasize livestock production (strategy D). Multiple grazing management approaches were used to achieve each grazing strategy including deferred rotation, rest-rotation, no-use and season-long use. Four watersheds were used as controls, five were used for strategy C and three were used for strategy D. Strategies were assigned to watershed based on their inclusion in the larger treatment area and strategy D watersheds were in areas selected for their potential for sufficient forage production to support grazing at a stocking rate of 2.8 hectares per animal unit month.

To evaluate the relationship between stream temperature and stream characteristics, maximum and mean weekly stream temperatures were regressed in comparison to stream characteristics to evaluate stream temperature variation. A stepwise regression analysis determined that 67% of the variation in stream temperatures was based on eight factors in declining order: shade, week of year, weekly flow, width, year, travel time, elevation, and aspect. Based on a visual examination of cumulative frequency distribution curves of the percentage of time a temperature was exceeded for individual watersheds and further statistical analysis, the authors identified three distinct watershed groups. Group 1 watersheds had the lowest stream temperatures, greatest mean percentage of shade, greatest 7-day low flow, highest mean elevation, and the shortest mean travel time. All group 1 watershed were control or lower intensity management watersheds. Group 3 watersheds had the highest temperatures, the lowest mean percentage of shade, the lowest 7-day low flow, and the longest mean travel time. All group 2 watersheds were in low or high intensity grazing management. Group 2 watersheds, which included no grazing and low intensity grazing management, were intermediate in temperature response compared to group 1 and 3. When compared to group 3, group 1 was found to be less responsive to sunlight because it had over twice the amount of percent shade.

The effects of range management strategies on stream temperature were observed by not entirely definitive. Maximum hourly and mean weekly temperatures were significantly different among management strategies with strategy D (intensively managed) having significantly greater maximum hourly and mean weekly temperatures that those from strategy A (control). When ecosystems were compared, streams in category C (less intensive) were not significantly different than the no-grazing control or intensively management area (strategy D). In some situations, the dominant ecosystem in the watershed was found to effect mean weekly stream temperatures. Mean weekly stream temperatures were significantly greater for mountain meadow and ponderosa pine than larch/Douglas-fir and fir/spruce ecosystems. Stream temperatures for the lodgepole pine ecosystem were not significantly different from streams of the other ecosystems. Differences among ecosystems were primarily explained by differences in the amount of overstory shade. Overstory shade was greatest for larch/Douglas-fir and fir/spruce ecosystems and least for mountain meadow.

An evaluation of a major tributary in one of the study watersheds found daily maximum stream temperatures to generally increase downstream as shade decreased. One exception occurred between two stream reaches where there was a slight reduction of maximum temperature due to a 26 to 64% increase in shade within these reaches. Statistical analysis found that temperature differences were attributable to differences in stream shade; although, when shade was used as a covariate, the range management was not significant. The author noted that two of the three D strategy (intensively managed) watersheds had areas with mountain meadows and that these areas are highly susceptible to temperature increase from grazing because once streambank vegetation is removed and streambanks are rounded, there is nothing to shade the stream. Further noted by the authors was the nearly 100 years of previous grazing and logging use in the area which likely had a strong influence on stream temperature through the removal of streamside shrubby vegetation and caving of overhanging banks. The authors presumed that more heavily forested areas were likely used less for grazing in the past.

The effects of the tested grazing strategies on stream temperature were not definitive in this study and were likely masked by the strong influence of watershed characteristics and the results of prior grazing management and other activities in the watershed. A phenomenon not uncommon to many areas historically used for grazing. Nevertheless, the authors found that intensively managed grazing sites had significantly higher maximum hourly temperatures and mean weekly temperatures, and all three intensively managed and one moderately managed watershed exceeded temperature standards due to insufficient shade from the lack of riparian vegetation. The authors also found that watersheds with greater than 75% effective shade had maximum hourly stream temperatures within acceptable water quality standard limits which highlights the importance of riparian vegetation to provide shade and prevent streams from reaching lethal levels for cold water trout species and salmonids. According to the authors, of the variables most likely to affect stream temperature, streamside vegetation is probably the most easily manipulated. They suggested maintaining the integrity of riparian zones could be achieved by riparian buffer strips and by more stringent control of animal use of riparian areas.

Studies designed to assess the effectiveness of grazing management systems to limit impacts to riparian areas commonly include an evaluation of forage utilization along with changes to riparian vegetation, soils and streambanks, and these post-grazing conditions are often used as indicators to predict changes to stream conditions. The results of these studies provide value information about the affects streamside grazing associated with various grazing management strategies; however, many do not include additional analysis to evaluate how post grazing conditions affect streams conditions in subsequent years. To help address this gap, Goss and Roper (2018) conducted a study across the Interior Columbia River Basin to describe the relationship between streambank alteration and stubble height measured after the grazing season with stream channel characteristics important to salmonid habitat.

The authors' hypothesis was that these indicators as measured at the end of the growing season were associated with stream habitat conditions the following year. For example, if livestock grazing resulted in excessive streambank alteration or limited vegetation height at the end of the grazing season, then seasonal high flow events between grazing seasons would increase erosion along the disturbed banks and further degrade stream habitat conditions In contrast, if livestock streambank disturbances and above ground vegetation were protect, condition conditions would be either maintained or trend toward improvements.

A common approach to managing livestock use of streamside areas used by Federal land managers such the Forest Service and Bureau of Land Management managers is to set allowable limits of streambank alteration and stubble height, and these indicators are commonly used as surrogates for short-term effects to riparian areas. Streambank alteration is an estimate of how much of the streambank has been disturbed by grazing livestock and stubble height is a measure of the herbaceous material remaining after grazing and is typically measures adjacent to the stream.

For this study, the authors evaluated 153 stream reaches within the Interior Columbia Basin from 2010 to 2012 to determine if these two surrogates of livestock disturbance measured after the vegetative growing season were associated with stream conditions important to salmonids. Livestock disturbances (primarily cattle) were measured on federal land within the Interior Columbia River Basin as part of the PacFish/InFish Biological Opinion Effectiveness Monitoring Program. The stream reaches evaluated selected using a spatially balanced sample of watersheds from across the Interior Columbia River Basin to help ensure that a broad range grazed stream reaches were evaluated. Most monitoring areas were located near low gradient (<4%) stream reaches because cattle generally congregate in gently sloping landscapes. Stream reaches were in allotments where grazing could have occurred from late spring to early fall with specific grazing strategies and intensities determined via Allotment Management Plans.

All stream reaches used in the study had annual indicators of livestock disturbance evaluated at the end of the growing season (mid-September through October), with stream habitat conditions evaluated in the same stream reach the following summer. While grazing was permitted along all evaluated stream reaches, some allotments were rested in the years livestock disturbances were assessed. Approximately 85% of the stream reaches were perennial with many having fish, and represented a broad spectrum of riparian, stream, and watershed conditions grazed by livestock.

Evaluated stream reaches were 110 m long and sampling occurred along the greenline which is the first perennial vegetation that forms along water's edge. Sampling for livestock disturbance generally following the Multiple Indicator Monitoring (MIM) protocol and stubble height was measured within 40 x 50 cm sampling frames. Streambank alteration and stubble height values used in this analysis included the average of all the measurements within the evaluated stream reach. Stream attributes evaluated included width-to-depth ratio, bank angle, percent undercut banks, bank stability, residual pool depth, percent pools, pool-tail fine sediments <2 mm, and wood frequency).

To test their hypothesis, the authors constructed linear regression models that related the outcomes of the streambank alteration and stubble height evaluations to stream habitat conditions measured the following year. Environmental covariates were incorporated into the analysis to account for inherent variability among the stream reaches. For simplicity the authors limited the covariates to bankfull width, reach gradient, and average annual precipitation as these attributes had previous been shown to have strong relationships to stream habitat conditions and not strong correlated to one another.

To better understand the relative magnitude of how livestock disturbances might affect stream conditions, the authors presented the predicted the predicted effects of streambanks disturbance in the context of changes to stream conditions. This was accomplished by comparing the predicted effects of livestock disturbance to stream habitat characteristics at two values commonly used as management standards for streambank alteration (10% and 25%) and stubble height (10 cm and 15 cm) to the expected differences in habitat conditions in dry (0.5 m of precipitation per year) and wet (0.75 m per year) watersheds within the study area.

All the best models for the eight stream habitat attributes included terms where streambank alteration or shorter stubble heights were significantly ($P < 0.1$) related to what would be considered poorer stream habitat conditions for salmonids. While streambank disturbance often explained only a small portion of the total variation, stubble height explained nearly twice as much variability as the covariates model for bank stability. The strength of the associations between livestock disturbance and stream channel characteristics indicated that meaningful biologically change in stream channel conditions could be achieved by reducing livestock disturbance. All the stream habitat models that included stubble height included the polynomial term which suggests a decreasing benefit to stream habitat conditions as stubble heights increased. However, the relationship between stubble height and the stream attributes did not asymptote in the 10–15-cm height range commonly used as standards and stream conditions favored by salmonids continued to improve as stubble height reached approximately 35 cm. Streambank alteration was associated with width-to-depth ratios and pool fines and these relationship were linear meaning increase MIM scores (greater streambank disturbances) lead to increases in pool fine sediment and increased width-to-depth ratios (widening and shallowing).

Measurements of streambank alteration and stubble height in the fall provided insight into stream habitat conditions measured the following year. Increased livestock disturbance, as assessed via streambank alteration and stubble height, was related to stream channel changes through increases in width-to-depth ratios, bank angles, and fine sediment in pool-tails and decreases in undercut banks, bank stability, pool habitat, pool depth, and wood frequency. According to the authors, these changes were expected given previous research of how livestock disturbance affects stream conditions. These results also support previous localized studies that found increased livestock disturbance along streams is related to increases in width-to-depth ratio, streambank angle, fine sediment, decreases in undercut banks, streambank stability, pool habitat and woody material. While the analysis conducted in this study showed results independently for each stream attribute, it's important to note that increasing livestock disturbance negatively affects all of the stream channel characteristics evaluated in this study, and the synergistic adverse effects of livestock disturbance on stream channel characteristics could further affect salmonid densities and survival of all life stages.

Further analysis also determine that five of the six stream habitat conditions were related to stubble including bank angle, undercut banks, bank stability, percent pools, and pool depth which suggests that livestock grazing is altering riparian plant communities in a manner that reduces the streambank's ability to resist high stream flows. Additionally, greater stubble height is likely to lead to greater stream condition outcomes.

Stubble height measured along the greenline has been proposed as an indicator of plant vigor and the presence of livestock, and even proposed as a method to determine impacts to streambanks. The authors noted that stubble height is somewhat redundant with an evaluation of streambank disturbance because stubble height is directly affected by livestock grazing and not subject to environmental conditions. They suggest that management decisions would be better informed when both were evaluated stubble height and streambank disturbance were evaluated. In their analysis of stubble height, the authors identified several stream reaches with short stubble heights but little streambank alteration. These reaches often showed evidence of compaction which made it difficult to detect current-year evidence of disturbance by hooves. In contrast, the authors also identified stream reaches with tall stubble heights and considerable streambank alteration. In these stream reaches, the greenline was often at the level of the water table or there had been recent rainfall. Either of these situations can increase the likelihood of streambank impacts from livestock hooves. The fact that antecedent moisture has been shown to be an important variable affecting streambank alteration likely decreases the strength of the relationship between this livestock disturbance metric and stream habitat conditions.

Based on the result of this study and regression analysis, streambank disturbance and stubble height were associated with stream conditions and meaningful changes in stream conditions would result depending upon how much livestock disturbance is allowed in riparian areas. Additionally, livestock disturbance was found to be as or more important than environmental metrics for several stream attributes. Of the eight stream conditions evaluated, two had linear relationships indicating that continued decreases in streambank alteration would result in continued improvements to stream conditions favored by salmonids, namely reductions in width-to depth ratios and pool tail fines. The relationship between stubble height and the remaining six stream habitat conditions attributes did have curvature but regression analysis suggested that stream conditions favored by cold water fish were more likely to be achieved at values far above values commonly used as stubble height standards such as 10-15 cm. Improvement to stream conditions including bank angles, undercut banks, bank stability, pool habitat, pool depth, and wood frequency would be expected until stubble heights of 35cm of were reached. To these points, the authors believed a more conservative standards stubble height would be prudent until there was sufficient data to justify more liberal standards.

This large-scale study reinforced previous research conducted at smaller scales that found livestock disturbance in riparian areas can negatively affect many stream condition attributes. These finding also highlight the importance of maintaining healthy, vigorous riparian vegetation and preventing streambank alteration as negative impacts to riparian areas have been shown to adversely affect several important stream conditions including those important to salmonids. While this study focused on understanding the relationship between short-term indicators of grazing disturbance and long-term stream conditions, it also highlighted the need for additional work to increase accountability in implementing rangeland standards. The authors found very few Forest Service or BLM units where disturbance streambank standards were set above >25% or stubble height less than 10 cm, yet more than 25% of the stream reaches sampled did not meet these standards. Further, current stubble height standards commonly used were not found to be protective of stream conditions including those favorable to cold water fish species including salmonids. Based on their finding, the authors suggested that implementation of more a conservation standard would be prudent until there is sufficient data to justify the use of current standards commonly used.

Conclusion

Livestock have been found to spend a disproportionate amount of time in riparian areas due to the availability of water, greater forage quantity and quality and microclimate features such a shade, and this disproportionate use has been shown to negatively impact riparian stream habitats and water quality. Grazing management strategies are often proposed as ways to limit the effects of livestock grazing on riparian vegetation, streambanks and water quality. Further, streambank disturbance and stubble height measured at the greenline are commonly used as post-grazing indicators to gauge the result of grazing management.

Management strategies such as early season, late season and rest-rotation grazing attempt to utilize the seasonality of forage availability, ambient air temperature and antecedent soil moisture within riparian areas as a way to address livestock preferences for riparian areas and limit impacts to riparian areas.

An evaluation of grazing management strategies and post-grazing indicators revealed mixed and sometimes competing results. Despite the variability in outcomes, ambient air temperature, availability of palatable forage, access to drinking water and the need for livestock to thermo-regulation were consistently found to affected forage use and animal distribution patterns and appear to be overriding factors. Season and time of day were found to significantly affected livestock distribution patterns, and ambient air temperatures were highly correlated with livestock distance from the stream. As a result, use of riparian areas was found to increased daily and seasonally as temperatures increased. Riparian forage use was also found to increase as upland forage was reduced or as it matured later in the grazing season and became less palatable. Further, post-grazing indicators such as stream disturbance and stubble height were found to be correlated to important stream health characteristics such as width-to-depth ratios, undercut banks, bank stability, and wood frequency. However, commonly used targets for these indicators did not consistently result in conditions that support important stream characteristics representative of healthy streams including those needed by salmonids.

Early season grazing commonly occurs between April and mid-July in the Pacific Northwest (DelCurto et al., 2005). Evidence suggests that early season grazing can alter the distribution patterns of cattle when a grazing location includes both riparian and upland zones and this is due to the availability of palatable and desirable forages in the uplands along with relatively low daily maximum temperatures (DelCurto et al., 2000; DelCurto et al., 2005; McInnis, M. L., & McIver, J. D., 2009; Parsons et al., 2003). Under these conditions livestock tend to distribute more evenly on the landscape and therefore utilize available forage more uniformly and rely less on riparian area forage (DelCurto et al., 2000; DelCurto et al., 2005; McInnis, M. L., & McIver, J. D., 2009; Parsons et al., 2003). While animal distribution in the early season is significantly better than late season grazing, studies found that cattle will continue to use the riparian areas at relatively high rates while grazing in the early season and spend as much as 60% of their time in riparian areas primarily in the afternoon and early evening.

Early season grazing includes some disadvantages that must be considered. First, because of high soil moisture, riparian areas are more susceptible to physical damage such as soil compaction, dislodging of shallow rooted plants, pugging, streambank sloughing and erosion especially after rainfall or during peak runoff (Marlow & Pogacnik, 1986; DelCurto et al., 2000). Evidence shows that a combination of high streamflow, moist streambanks and cattle use commonly leads to significant streambank alteration, and these conditions are most common during the early grazing season. While early season grazing can improve livestock distribution, it was not found to consistently prevent streambank alteration and erosion.

Late-season grazing occurs from September through November when available upland vegetation is typically mature and much less palatable than riparian vegetation. For this reason, livestock are drawn to riparian areas during this timeframe and have been found to spend significantly more time within riparian areas compared to upland areas due to the availability of palatable forage, water and shade. Disproportionate use of riparian areas associated with late season grazing commonly results in significant streambank alteration and erosion despite drier conditions common to this time period. As part of concentrating in riparian zones, late-season grazing also increases the likelihood of woody vegetation browsing which has been shown to negatively impact the succession of woody vegetation communities and long-term structural diversity of the riparian areas. Grazing pressure on woody vegetation can suppress growth, prevent the establishment of seedlings and lead to non-reproducing, even-aged vegetation communities and ultimately lead to a decrease in the number of woody species in riparian areas.

Rest-rotation grazing management is system where pastures are grazed during alternating seasons and include a year of rest where no grazing occurs. Seasons of use often includes early and late season but may also include mid-season or even season-long grazing. Under a rest-rotation system approximately one third of available pastures may be rested annually and rest years are intended to provide an opportunity for grazed areas and vegetation to recovery. Incorporating a year of rest likely has advantages over season-long grazing and may help previously grazed areas recovery and potentially provide forage for emergency use during drought (Howery et al., 2016); however; it may also limit annual forage availability depending on location and climate. While rest rotation may provide longer recovery times, it also includes the inherent advantages and challenges associated with early and late season grazing. For example, early season has been shown to improve animal distribution but also increase streambank erosion. With mid-season, season-long and late season grazing, increased plant maturity within upland areas coupled with increased ambient air temperature commonly results in increased congregation and forage utilization within cooler riparian areas with greater, more succulent vegetation.

Post-grazing indicators including streambank disturbance and stubble height were found to be correlated to important stream health characteristics. Additionally, livestock related disturbances were found to be as or more important than environmental metrics for several stream attributes. These findings support previous research conducted at smaller scales by clearly associating post-grazing impacts to riparian areas with key stream condition attributes critical to maintaining stream health. These findings also highlight the importance of maintaining healthy, vigorous riparian vegetation and preventing streambank alteration.

Stubble height targets of 10-15 cm commonly used by grazing managers appear to indicate when cattle will transition from grazing herbaceous vegetation to palatable woody vegetation; however, this stubble height range was not found to be a good predictor of streambank erosion and currently used targets are not protective of critical stream conditions parameters including those favorable to cold water fish species. Many studies evaluated forage utilization within riparian zones after grazing. In many situations negative impacts to streambanks, riparian soils and riparian vegetation were found even when utilization targets were met. Utilization targets appear to be good measures of impacts and the likelihood of negative trend to forage quality. Although, similar to stubble height, they were not good predictors of impacts to riparian and streambank conditions post-grazing.

In summary, livestock have been found to congregate and spend as disproportionate amount of time in riparian areas, and this behavior is primarily dictated by ambient air temperature, availability of palatable forage, access to drinking water and the need for livestock to thermo-regulation. Deferred grazing strategies such as early season, late season and rest-rotation grazing attempt to utilize the seasonality of forage availability, ambient air temperature and antecedent soil moisture within riparian areas as a way to address livestock preferences for riparian areas and limit impacts to riparian areas and water quality.

Field studies have found that timing within a grazing season will affect animal distribution, amount of time livestock utilize riparian areas and subsequent post-grazing outcomes. However, deferred grazing systems and their reliance on season and forage availability have not been found to fully address the primary factors known to control livestock preferences for riparian areas, and they have not been shown to consistently or reliably prevent impacts to streamside areas and water quality.

While grazing management strategies are limited in their ability to fully protect streamside areas and water quality, they can be useful tools to optimize forage use in upland pastures and pasture with both upland and riparian habitats. All grazing strategies include inherent advantage and disadvantages, and these strategies must be evaluated individually based on local sites conditions such as climate, annual precipitation, forage potential and livestock manager's goals to determine which system is right for any given location.

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Annotated Bibliography

1. Agouridis, C. T., Edwards, D. R., Vanzant, E., Workman, S. R., Koostra, B. K., Bicudo, J. R., ... & Gates, R. S. (2004). Influence of BMPs on cattle position preference. In 2004 ASAE Annual Meeting (p. 1). American Society of Agricultural and Biological Engineers.

The objectives of this research project were to examine the effects of best management practice (BMP) systems on cattle position preference and provide information regarding the effectiveness of alternative management strategies designed to minimize the time cattle graze in riparian areas. The study area was located on the University of Kentucky Animal Research Center in Woodford County, Kentucky. The study tested three treatments including 1) BMPs and a fenced, 30ft wide riparian buffer and a 12ft wide stream crossing, 2) BMPs with free stream access and 3) free stream access and limited BMPs. The "limited BMP" predominantly consisted of natural shade from existing old growth trees. Implemented BMPs included alternative water sources, alternative shade and pasture improvements. Cattle stocking varied but was consistent for all treatments. To determine cattle position data, a subset of cattle in each pasture were outfitted with GPS collars and their position information was collected every 5 minutes over seven, 18-day periods. The 18-day collection periods spanned spring through fall of two consecutive years (2002-2003). Pasture plots were divided into three zones (riparian, transition and upland) and the position location data within each pasture zone were summed. In addition to cattle position information, off-stream water location data was used to evaluate the effectiveness of BMPs in altering cattle position preference. Temperature and humidity were used to calculate a temperature humidity index (THI) for each day of the sampling periods. Forage data was not collected, and therefore rainfall was used to provide insight into potential forage availability. Statistical analyses were performed for each pasture using Sigma Stat. An examination of daytime cattle position indicated that the treatments did not differ for almost all pasture features. Further analysis indicated that season or environmental variations were likely impacting position. When THI was evaluated, it was found to be a more significant predictor of cattle presence near trees which was expected and in line with cited research. The authors cited previous literature which stated, "shade was one of the largest factors contributing to cattle distribution especially during the summer months". Additional statistical analysis found that a 10% increase in day length resulted in a 19% increase in the time cattle spent in the stream or along the streambanks. However, the statistical analysis also predicted this would occur when the day was greater than 17 hours. The authors surmised that other factors beyond day length were affecting cattle presence on streambanks and hypothesized that increased day length was correlated to increased forage consumption and water intake rates. A multiple linear regression determined that neither THI nor rainfall were good indicators of cattle position in the riparian zone even though there was a significant linkage between streambank presence and day length. Variables such as forage quality and quantity were thought to be better predictors of cattle presence within riparian zones. The influence of additional factors on cattle presence in riparian zones is supported by other literature which found that cattle frequently concentrated in streamside areas because of access to water, gentler terrain and more abundant and succulent forage. In this study, the applied treatments did not significantly affect cattle position preferences for either day or night, and the lack of treatment effect findings may have been due to nonparametric data constraints. The authors also suggested that the inclusion of alternate shade, pasture improvement and a stream crossing located in the riparian area may have impacted the effectiveness of the treatments. Nevertheless, the implemented BMP systems were not found to be effective at altering cattle position. The result of this study highlights the importance of shade and its influence on cattle position.

This study was as conducted in a humid, subtropical climate which is not found in Washington. While the climatic conditions were different, factors that influence animal behavior such as day length, forage, temperature and water availability would translate to Washington. Given the forage type and grazing setting, this study would be most analogous to irrigated or non-irrigated pasture lands located in lowland river valleys west of the Cascade crest and cultivated pastures located on productive or marginal cropland and canyons, river valleys and other drainage ways with productive soils planted with forage plants which are grown specifically for livestock grazing and receive treatment or enhancement to improve forage quality and yields.

2. Agouridis, C. T., Workman, S. R., Warner, R. C., & Jennings, G. D. (2005). Livestock grazing management impacts on stream water quality: a review 1. *JAWRA Journal of the American Water Resources Association*, *41*(3), 591-606.

This article is a literature review of grazing best management practices (BMPs) commonly implemented in southern, humid regions of the U.S., and includes additional background information on U.S. animal agricultural statistics. The literature review covered practices such as alternate water sources, alternate shade sources, forage availability, exclusion fencing/riparian buffers, controlled grazing, supplemental feeding and implementation of multiple BMPs in combination. A review of the literature found that most grazing BMP research has been conducted in western and midwestern states. Many of these studies documented the negative impacts of grazing on stream health; although, few examined the effectiveness of BMPs to mitigate these impacts. The authors also noted the limited number of studies conducted to determine the efficacy of comprehensive approaches that integrate multiple BMPs or studies that included pre- and post-BMP monitoring including geomorphic conditions. This literature review recommended that grazing BMP research include monitoring and incorporate geomorphic conditions when evaluating BMP effectiveness and stream health.

3. Batchelor, J. L., Ripple, W. J., Wilson, T. M., & Painter, L. E. (2015). Restoration of riparian areas following the removal of cattle in the northwestern great basin. *Environmental Management, 55*(4), 930-942.

The authors of this article assessed the effects of eliminating livestock grazing at Hart Mountain National Antelope Refuge in southeastern Oregon 23 years after the removal of cattle. The objectives of this study were to: 1) use repeat photography to illustrate riparian vegetation change, 2) use image analysis to quantitatively measure change in vegetation, 3) compare vegetation cover at sites with active and passive restoration and 4) assess the accuracy of using digital line transects. The assessment used 64 photos taken before grazing eliminated and compared those to photos take at the same locations 23 years later. The assessment included a qualitative method and a qualitative method using software to insert a digital line transect into the photos for analysis. Accuracy of the digital line intercept method was assessment in the field. The digital line transect method proved to be relatively accurate (91%) suggesting it could be useful tool for quantifying vegetation cover and measuring changes in vegetation cover. The results of the assessment found that channel width and eroding banks decreased significantly (64 and 73% respectively), bare soil reduced 90%, exposed channel decrease by 63% and there was a significant increase in grass, sedge and forb (herbaceous) cover and willow cover. The study indicated that the removal of cattle can result in dramatic changes in riparian vegetation in semi-arid landscapes and with replanting (passive restoration) or other active restoration efforts. The positive changes to riparian vegetation documented in this study (in semi-arid landscapes) is applicable to many parts of Washington especially areas such as the channel scablands/shrub-steppe ecosystems. This study also provide evidence that passive restoration may be viable option for vegetation reestablishment in semi-arid landscapes.

4. Belsky, A. J., Matzke, A., & Uselman, S. (1999). Survey of livestock influences on stream and riparian ecosystems in the western United States. *Journal of Soil and water Conservation*, *54*(1), 419-431.

The study provides an overview of livestock grazing impacts on stream and riparian ecosystems. The literature review focused on the biological/physical effects of livestock on Western rivers, streams, and associated riparian areas. Findings from comparative studies of grazed versus naturally or historically protected areas are also provided. The study found that livestock grazing negatively affects water quality, seasonal quantity, stream channel morphology, hydrology, riparian zone soils, instream/streambank vegetation, and aquatic/riparian wildlife. Additionally, no positive environmental impacts were found and there is evidence of livestock causing negative impacts at the landscape and regional levels. Specific impacts on nutrient concentrations, presence of bacteria/protozoa, sediment load/turbidity, water temperature, and dissolved oxygen levels are provided. The study analyzes sequential degrading of stream channels due to removal of riparian vegetation by livestock grazing.

5. Bengeyfield, P. (2007). Quantifying the effects of livestock grazing on suspended sediment and stream morphology. *Advancing the Fundamental Sciences*, 85.

This study reviews the impacts of livestock trampling on streambanks and channel functions in the Beaverhead-Deerlodge National Forest in Montana. Researchers used a series of monitoring stations in the forest to quantify suspended sediment from various land uses. Monitoring began in April 1986 and stream surveys were initiated in 1991. The study analyzed suspended sediment production during grazing periods, stream entrenchment, and stream type/functionality. Livestock grazing adversely affects stream channels. Furthermore, sediment loading significantly contributes to the condition of channel and riparian areas. With this, channels in poor condition had more sediment sources. Livestock increased suspended sediment concentrations and loading. Livestock trampling of streambanks also led to an increase in channel entrenchment. The instability along streambanks created by livestock trampling provided sources of sediment for erosion. Finally, rest-rotation grazing is not sufficient to prevent livestock damage to stream banks and consequent increases in sediment.

6. Beschta, R. L., Donahue, D. L., DellaSala, D. A., Rhodes, J. J., Karr, J. R., O'Brien, M. H., ... & Williams, C. D. (2013). Adapting to Climate Change on Western Public Lands: Addressing the Ecological Effects of Domestic, Wild, and Feral Ungulates. *Environmental Management*, *51*, 474-491.

The study assesses historical and contemporary livestock production and its impacts on vegetation, soils, hydrology, and wildlife species composition/abundance since these resources are also impacted by climate change. The study includes information on climate change impacts on different land types, the history/current status of livestock practices in the U.S., ungulate effects and climate change synergies, plant/animal communities in the U.S., soils/biological soil crusts, water/riparian resources, and examples of long-term grazing impacts from livestock on different land types. Generalized climate change effects, heavy ungulate use effects, and their combined effects as stressors to terrestrial/aquatic ecosystems in the western U.S. are provided. The study provides practices to restore ungulate-altered ecosystems and socioeconomic considerations. The authors propose that large areas should become free of use by livestock and feral ungulates to initiate and speed the recovery of affected ecosystems.

7. Bisinger, J. J., Russell, J. R., Morrical, D. G., & Isenhart, T. M. (2014). Pasture size effects on the ability of off-stream water or restricted stream access to alter the spatial/temporal distribution of grazing beef cows. *Journal of Animal Science*, *92*(8), 3650-3658.

The purpose of this study was to evaluate the effects of pasture size, stream access and off-stream water on cow distribution and the amount of time beef cattle spent in or near a perennial stream.

For two grazing seasons (2010 and 2011), the effects of pasture size, stream access and off-stream water were evaluated in six cool-season grass pastures. The study area was located at the Iowa State University Rhodes Research Farm in Chariton, Iowa. Over the course of five, four-week intervals, cattle were assigned to treatments of continuous stocking with unrestricted stream access without off-stream water (U), continuous stocking with unrestricted stream access with off-stream water (UW), or continuous stocking with stream access restricted to a stabilized stream crossing (R). Each treatment was tested on small and large pastures which were 4.0 or 12.1 ha (9.9 or 29.9 acres), respectively. A 141-m (463 ft.) segment of a perennial flowing stream bisected each test pasture. Pastures were not fertilized or mowed for at least six years prior to the study.

To duplicate pasture size treatments in each 4-week timeframe, pasture sizes were changed at 2-week intervals. Cows in small pastures were limited to pasture lowlands by a temporary electric fence which include the streamside area and 2.0 ha on either side of the stream.

Cows in large pastures were allowed access to both the lowlands and uplands which included 4.0 ha on either side of the stream and upland areas of the pasture. By reducing the pasture size and limiting cows to lowlands, the average distance to the stream was reduced compared to large pastures, thereby changing both pasture size and area of pasture distanced from the stream.

For unrestricted access (U) treatments, cows were not allowed access to off-stream water in pastures by installing plywood covers over water tanks. In unrestricted with off-stream water pastures, and off-stream water source was provided via tanks with floats at average distances (mean ± SD) of 129 ± 43.7 m (423 ± 143 ft) and 270 ± 64.3 m (886 ± 211 ft) from the stream in small and large pastures, respectively. In restricted pastures, stream access was limited to a 4.9-m-wide (16 ft) ramp that was stabilized by geo-fabric and crushed rock in the stream and 11.3 m (37 ft) on either side of the stream. Cows were not allowed access to the streamside buffer which extended approximately 33 m on either side of the stream. In 2010, the effects of greater total pasture shade in the riparian zone in the UW treatments than the U treatments seemed to supersede the effects of off-stream water. Therefore, U and UW treatments were switched between pastures with from 2010 to 2011 to evaluate the effects of off-stream water on cow distribution without the effect of shade. Since stream crossings were permanent, it was not possible to re-randomize R pastures in 2011.

Sixty August-calving Angus cows were blocked by age and weight and randomly assigned to large or small pastures with the R, U, or UW treatments. Cattle were place in the corresponding pastures on May 18 in both years, and small and large pastures were stocked with 5 and 15 cows, respectively. Precipitation during the study was 767 mm in 2010 and 278 mm in 2011. During fourth interval in 2011 stream flow was too low to support the needs of cattle; and therefore, data from the fourth interval in 2011 was not included in the statistical analysis. Cows were provided a mineral supplement in feeders located approximately the same distances as the off-stream water sources in all pastures. To monitor the impact of management strategies on forage availability, sward height was measured with a falling plate meter. Measurements were taken at 16 sites within the lowlands and uplands in each pasture at the beginning and end of each 2-wk period in both years. In 2010, forage clipped at a height of 2.5 cm from a 0.25 m^2 areas at 16 sites within the lowlands and uplands of each pasture at the beginning of each 4-wk interval to determine forage nutritional value.

Cow distribution was tracked using Global Positioning System (GPS) receivers and were fitted on two to three cows per pasture and recorded cow position at 10-min intervals, 24 hours per day during each two-week period. At the end of each two-week period, GPS collars were removed, and data was downloaded. To determine cow location in relation to the pasture stream and shade, zones for each feature were created using ArcGIS 10.1. To evaluate microclimate affects, weather data was recorded at 10-min intervals during the grazing season at two weather stations located near the center and west of the study pastures. Weather data collected included ambient temperature, black globe temperature relative humidity, dew point, wind speed and precipitation. A temperature–humidity index, black globe temperature–humidity index and heat load index were calculated for each 10-min intervals.

Based on statistical analysis, the authors determined that temperature provided the model of best fit for the increased probability of cow presence in the stream, riparian, and shade zones. In June 2010, the mean monthly temperature, measured on-site, was 3.5°C higher than the 30-yr average at a weather station in Des Moines, IA (approximately 50 miles from the study location). However, mean monthly temperature in July, August, September and October 2010 were 0.5 to 2.0°C less than the 30-yr average. Similarly, in 2011, the mean monthly temperature in May, June, August, and September were 1.0 to 4.1°C lower than the 30-yr average.

When pasture size and management effects on cow distribution were evaluated, in all treatments there was a greater proportion of cow observations in the stream and riparian area in small pastures compared to larger pastures. The effects of pasture size on cow observations in the stream and riparian zones were greater in interval three (mid-July to early August) than other intervals. While there was no difference in the proportion of cow observations in the stream and riparian area between the unrestricted (U) and unrestricted with off-stream water (UW) in larger pastures, cow in the UW pastures had a great proportion of observations in the stream and riparian area than U pastures. Across all pasture sizes, the proportion of cow observation in the stream and riparian zone in restricted (R) pastures was less than the U and UW pastures.

The probability of cow presence in the stream and riparian zones increased at a greater rate in 2011 than 2010 in pastures with unrestricted stream access (U) across both pasture sizes. The authors noted that this was likely due to lower average temperature ranges in 2011 than 2010. Within unrestricted pastures (U), as temperature increased the probability of cow presence in the stream and riparian zones increased at greater rates in small pastures compared to larger pastures. When small unrestricted pastures with and without off-stream water were compared, the probability of cows in streams and riparian zones increased at a greater rate within pastures with off-stream water. However, there were no differences in the probability of cow presence in the stream and riparian zones as temperature increased between unrestricted pastures with and without off-stream water. Within large and small pastures, the probability of cow presence in the stream and riparian zones of unrestricted (U) and unrestricted with off-stream water (UW) pastures increased at greater rates over the temperature range that restricted (R) pastures. The probability of cow presence in the stream and riparian areas of small restricted (R) pastures increased at greater rates than large restricted (R) pastures as temperature increased. Additionally, there was no difference between treatments in the probability of cow presence in shade located with the pastures as temperature increased; however, the probability of cow presence in riparian shade in treatments with unrestricted stream access increased at a greater rate in small pastures compared to larger pastures.

The authors noted that previous studies have shown that cows were more often observed in or near streams as ambient temperatures increased. However, relatively few studies have been conducted on to evaluate how pasture size impacts various strategies intended to reduce the time cows spend in or near streams. This study found that as the percentage of total pasture area within 33 m of the stream in pastures with unrestricted access increased, cows were observed more often in and near the stream. Additionally, the probability of cow presence in and within 33 m of the stream increased at a slower rate as temperature increased in larger pastures compared to smaller pastures in this study. The effect of larger pastures on cow distribution was likely resulted from a greater proportion of grazing land being farther from the stream.

Along with increased pasture size, restricting stream access to stabilized crossings also reduced the presence of cows near the pasture stream in small and large pastures. This reduction was likely influenced by the fact that the remainder of the pasture (restricted pastures) was fenced 33 m from the stream and cows could not access the stream or riparian area. Nevertheless, the proportion of cows spending time in the riparian zone in pastures with restricted compared to unrestricted stream access was three times less in small pastures compared to larger pastures. As a result, the authors suggested that restricting stream access to stabilized crossings may be more effective at improving water quality in pastures with a larger proportion of grazing land close to a pasture stream.

When evaluating the influence of forage quality and quantity, the authors noted previous studies where forage quantity and quality in western rangelands influenced cattle grazing behavior and impacts on water quality in pasture streams. In this study, differences in forage sward height within pasture size, management treatment and location may have impacted cow grazing behavior, however, differences in forage quality were inadequate to influence cow distribution. Additionally, differences in sward heights and forage quality between the riparian and upland zones in this study are likely less than rangelands located in the Pacific Northwest due to differences in precipitation and soil types. As with forage quality, off-stream water in this study had no effect on cow distribution. This is similar to the results of similar studies that evaluated the effectiveness of off-stream water to alter grazing behavior and lessen the time spent in streams and riparian areas.

Like other similar studies, as temperature increased, cows were observation near or under shade. In this study, the probability of cows spending time in riparian shade increased at a greater rate in small pastures compared to larger pastures. In addition to management practices and pasture characteristics, annual variability in environmental conditions may also have a significant impact on cattle distribution. Compared to 2010, in 2011 temperatures from mid-July to early August were an average of 2.6°C warmer and the daily temperature range was 10.5°C lower, which corresponded with a 17.4 and 10.0% increase in cow observations in the riparian zone of small and large pastures, respectively. According to the authors, this increase in temperature and reduction in temperature range likely reduced the ability of the cows to cool at night and may have resulted in increased observation of cows in the riparian zone seeking relief from the heat.

This study highlights the influence of temperature on cattle grazing behavior, distribution on the landscape and time spent in streams and riparian areas. In this study, as temperature increased, the probability of cow presence in the stream and riparian zone also increased. Further, pasture size and fencing were found to effect cattle distribution and the time cows spent in stream and riparian zones while off-stream water was not. Unrestricted, small pastures had the highest occurrence of observation in the stream and riparian zone followed by unrestricted, large pastures with restricted pastures having the least observations in stream and riparian areas. It's important to note that the riparian areas for small and large pastures were the same size in this study, and it's unclear if larger pastures with greater riparian areas would lead to the same results. Restricting access to the stream and riparian area inevitably limited the cows' ability to spend time in these areas. In this study, limiting access to the stream and riparian area via a narrow water crossing limited the percent of observations in the stream and riparian zones and this was most effective in larger pastures than smaller pastures.

8. Bohn, C. C., & Buckhouse, J. C. (1985). Some responses of riparian soils to grazing management in northeastern Oregon. Rangeland Ecology & Management/Journal of Range Management Archives, 38(4), 378-381.

In this article Bohn and Buckhouse (1985) evaluated changes in infiltration, sediment production, soil penetrability and bulk density in riparian zones under multiple grazing schemes including no grazing, rest-rotation, season-long, deferred rotation and late season grazing. The study also established test sites under each grazing scheme that were either big game accessible or big game proof. All pastures contained a small control exclosure.

Measurements are taken at the beginning of the study (1975) and then again at the end of the study period (1981) to compare differences. The study was conducted along Meadow Creek located in the Blue Mountain about 48km southwest of LaGrande, Oregon. At the time of the study, the watershed had been primarily used for logging and heavy livestock grazing since the beginning of the 20th century. Soil data was limited for the study sites but were described as interspersed patches of well drained gravelly loam and sandy loam. The stocking rate at each plot was 3.2 ha/AUM (7.9 acres/AUM) which is relatively low. The plot sizes were relatively small for the big game access and late season plots (4-6.2 hectares) while the big game access plots were much larger ranging from 49-73.8 ha.

The number of animals in each plot varied from 1 to 20 to maintain a stocking rate of 3.2 ha/AUM with the big game accessible sites having the largest number of animals. The low stocking rate and limited number of animals on each plot would represent low density, light grazing but likely doesn't represent a typical herd size of grazing operation in the area. Results for infiltration was based on two methods: the first used a Rocky Mountain infiltrometer which simulated a severe storm event for the area and the other used a ring infiltrometer. Results of the study found that infiltration increased under a simulated storm event in several control exclosures suggesting recovery from previous heavy grazing. Rest-rotation grazing appeared to follow similar patterns while infiltration decreased for deferred rotation and season long grazing. Ring infiltrometer data wasn't available for all study plots; however, all sites except for the rest-rotation (game proof site) had a neutral or negative trend with no grazing having a neutral trend. The ring infiltrometer data would be more representative of typical infiltration conditions and the results suggest limited recovery of soil infiltration after 5 years. Given previous grazing practices and the fact the soil conditions change slowly, this result is expected.

Sediment production data was limited but suggests that no grazing had a positive affect while rest-rotation and deferred rotation had a neutral and negative change respectively. Soil penetrability and bulk density data was not available for all sites and treatments, but all tested sites were either neutral or experience a negative response. The limited amount of data for these parameter makes it difficult to make inferences although soil penetrability did decrease in the game access sites. Although, the big game sites also had the largest number of animals. Since the study didn't monitor large game activity it's difficult to determine if or how big game influenced these plots, and the results could be a reflection of the number of livestock and not the influence of big game.

The results of this study indicate that no-grazing and rest-rotation resulted in the greatest positive change of measured soil properties. Given previous grazing practices, it's unclear how changes in stocking rates may have also affected soil properties and this question was not addressed in the study. Other literature has suggested that stocking rates play a significant role in how livestock grazing affects soil property and some authors have suggested that it may be more important that the grazing scheme. The results of this study suggest that low stocking rates coupled with a rest-rotation system (which includes at least one year without grazing) may begin to improve some soil properties after 5 years. Additionally, late season grazing conducted in September had a neutral effect on all soil properties except infiltration under a simulated store event which was positive. Late season grazing conducted in October had a mixed of negative and neutral outcomes. These results are likely representative of soil moisture conditions and the late season results are likely indicative of soil condition changes due to the onset of fall precipitation.

9. Bryant, L. D. (1982). Response of livestock to riparian zone exclusion. *Rangeland Ecology & Management/Journal of Range Management Archives*, *35*(6), 780-785.

The objectives of this study were to determine differences in forage utilization patterns of yearling cattle and cows with calves in pastures containing both riparian and upland mountain range plant communities, evaluate behavioral responses of cattle excluded from the riparian zone by fencing, examine differences in forage use based on cover types on north and south aspects and determine differences in grazing patterns within three grazing periods throughout season.

The study was conducted in the Blue Mountains of northeast Oregon on the Starkey Experimental Forest and Range located approximately 48 km southwest of La Grande, Oregon. This area was typically grazed from mid-June until mid-October by 800 animal units belonging to five permittees. The area used for this study included 345 ha containing a general mix of upland and riparian zones. The vegetation was representative of typical mountainous rangelands of the Blue Mountains. Elevations ranged from 1,067 to 1,524 m and annual precipitation for the area was 50 cm which primary consists as spring and fall rains or winter snow. July and August are commonly the driest months.

The study area consisted of two pastures separated by a stream and riparian zone which was fenced into a corridor. The majority of the riparian zone was fenced except for a small area at the toe of at slope which remained accessible to cattle. The northern pasture was 154 ha on a south aspect, and the southern pasture contained 190.40 ha on a north aspect. The pastures were divided into two zones including a riparian zone (zone 1) and upland zone (zone 2). Not all vegetation in zone 1 was influenced by the stream but other environmental factors characteristic of the riparian zone, such as microclimate, were present. The boundary between zones 1 and 2 was defined by a distinct ecotone between plant community types. Water for livestock was available throughout the south pasture and the north pasture contained two constructed ponds with one located in zone 1 and the other on the ridgetop of zone 2. Two mineral supplements per pasture were placed on the ridgetops of each pasture and located furthest from zone 1. Weather data were available from four stations located near the study area; however only data from two stations located under conifer tree canopy where used.

For this study, the grazing season was divided into three time periods: July 20-August 12 (period 1), August 16-September 9 (period 2) and September 13-October 7 (period 3). Three observation days of six hours each were conducted within each pasture each week. During these observation days, one animal in each pasture wad constantly observed and its location was plotted on an aerial photo at 30-minute intervals. Although plotted locations at 30-minute intervals did not represent all behavior within that timeframe, they were treated as such in the analysis.

On June 30, the north pasture was stocked 10 cows with and the south pasture with 15 yearling heifers. Cattle were rotated between pastures every two week and spent equal time in each pasture. The phenological condition and availability of plants to graze remained relatively equal between rotations. Each class of livestock was given a 2-week adjustment period in each pasture before study observations began. As result, the grazing season was divided into three time periods with 6 observation days occurring every 2 weeks in each pasture. Five cows and 5 yearlings were marked with collars to insure proper identification. One cow and 1 yearling were randomly selected and observed throughout each 6-hour observation day. Observations of cows and yearlings in the separate pastures were made simultaneously. Each animal's location was identified as to plant community type, slope, zone, and distance to water and salt.

Differences in use patterns between time periods by cows and by yearlings and between cows and yearlings was found to be in response to the interaction among the phenological condition of vegetation, grazing preference and climatic changes. Cows and yearlings spent a disproportionate amount of time in the riparian plant communities regardless of pasture aspect from July 20-August 12 (period 1). Yearlings and cows continued use of riparian plant communities from August 16-September 9 (period 2) until they switched and selected upland plant communities from September 13-October 7 (period 3). During period 3, both livestock classes used the upslope communities extensively but selected different plant communities.

Cows with calves grazed the most productive forage areas more widely throughout entire pastures than did the yearlings. While both classes of livestock had a 2-week period to acclimated, the cow had grazed the area in previous years were more familiar with the landscape. This familiarity may have accounted for the wider distribution of cows than yearlings. The authors noted that cows with calves have greater metabolic expenditures than yearlings and greater energy expenditures for due to lactation. This was noted as a potential factor to differences in the use of plant community types by cows and yearlings. By selecting the more productive plant communities, cows were able to fill their greater energy requirement. Conversely, yearling could apparently meet their energy requirement by remaining on gentler terrain.

When discussing forage utilization and weight gains, the authors noted some research found that microclimate effected animal performance and that cattle weight gains in predominantly forested pastures from mid-July to mid-September were greater than those on predominantly grassland pastures. These gains were not solely attributed to the higher nutritional quality of the forage in the forested pastures but were also attributed to the cooler microclimate that allowed animals to graze longer each day. Both cows and yearlings used the timber type plant communities more than the upland grassland plant communities from August 16-September 9 (period 2). According to the authors, in addition to microclimate, grass and grass-like plants at forested sites can have more crude protein and less lignin than those in grassland pastures during this period. In a study also conducted in eastern Oregon rangeland, Parson et al. (2003) did find that upland communities consistently had higher crude protein and less lignin. It appears this phenomenon like varies from location to location and year to year based on many factors including weather and annual precipitation. Nevertheless, upland plant communities may be more palatable and nutritious during the late season (mid-August to mid-September).

When the data from the weather stations were evaluated, it was determined that temperature and humidity measurements were different during the first two time periods (July 20 – September 9). However, there wasn't a difference in mean ambient temperature from September 13-October 7 (period 3) but there was a difference in percent relative humidity.

Environmental conditions were found to affect grazing behavior and time spent in riparian and upland areas. Differences in zone selection (riparian and upland) were found between cows and yearlings; however, during periods of higher mean ambient temperature and lower mean relative humidity on the uplands, both classes moved to the riparian zone regardless of pasture aspect. When the mean ambient temperature decreased and the mean-percent relative humidity increase, both cows and yearlings moved upslope. The authors highlighted that ungulates have few mechanisms by which to control body temperature and typically do one of the following things to cope with excessive heat: accelerate respiration; consume water; restrict movements or rate of movement; (4) seek more comfortable environmental conditions; or perspire through relatively insufficient apocrine sweat glands. And all of these actions tend to reduce the metabolic rate. Based on weather data, the temperature was cooler, and the humidity was higher in the riparian zone from July 20-August 12 (period 1). During this time, both cows and yearlings selected the riparian zone over the upland zone. The authors found that slope than 20%, cooler microclimate, available water, and available forage quantity and quality apparently combined to produce a more desirable situation.

A significant change in both cow and yearling use of plant community types, slope and zones was found during period 2 (August 16-September 9) which was influenced by forage quality and quantity by thundershower activity. On the two occasions when thundershowers produced 1.27 mm and 4.83 mm of precipitation, both cows and yearlings moved from zone 1 to zone II. From September 13-October 7 both classes of livestock largely avoided the riparian zone. In the north pasture, both cows and yearlings avoided the riparian zone. Although, in the south pasture, the yearlings avoided the riparian zone while cows made disproportionately heavy use of zone I. Some of this change could also be attributed to the two thunderstorms that produced 0.5 mm and 2.29 mm of precipitation. From September 13-October 7 (period 3), there were no significant differences in mean ambient temperature between weather stations, but there was a much higher mean percent relative humidity in the riparian zone. Additionally, forage availability was greatly reduced in the riparian zone due to grazing in the riparian zone and the vegetation in the uplands had received little use. While vegetation in the upland zone was cured, precipitation had stimulated regrowth and softened the cured vegetation making it more palatable.

When the effects of slope were evaluated, cows were found to use more upslope plant classes and community types than yearlings. As slope increased, the frequency of use by both livestock classes decreased. Both cows and yearling selected areas with slopes less than 35% in both pastures. Approximately 54% of the north pasture had slopes less than 35% and that area received 85% of the livestock use. In the south pasture, 28% of the area had slopes of less than 35% and that area received 71% of the livestock use. While not explicitly noted by authors, riparian zone inherently has low to gently slopes which would influence the use of lower slope areas and also attraction animals from upland areas especially in seasons with higher temperatures. The authors noted that there doesn't appear to be consistency within the literature about an assumption that young animals such as yearlings use upland area more frequently than cows or cows with calves. This study did not find that younger animals used steeper terrain.

Water was available in the riparian zone and the extreme upper end (zone 2) of the north pasture and throughout the south pasture.

From July 20-August 12 (period 1), the cows remained closer to water than did yearlings. The authors attributed this to the cow's greater need for water due to its size and lactation. From August 16-September 9 (period 2) there was no statistical difference between cows and yearlings in terms of their distance from water. However, their activities and behavior were altered thundershower activity. At the beginning of period 2, cows stayed closer to water and then increased their distance from it. However, yearlings distributed themselves closer to the water than cows and maintained that distance throughout the period. The authors noted that the yearlings were in the pasture before the thundershower activity and the cows were present during the thunderstorms. From September 13-October 7 (period 3), water was ineffective in distributing cows or yearlings. Although there was a difference in how cows and yearling were distributed, they both responded similarly to the progression of the grazing season which was represented by cooler temperatures (which influenced water consumption), fall regrowth, softening of the cured forage, and/or a decrease in lactation production by cows. Water in the upper end of the north pasture wasn't used by cows or yearlings until September 13-October 7 (period 3). The cows were exposed to the upper water source when they were initially introduced to the pasture, but its availability did not attract cows from the riparian area and was not used until after September 13. In fact, the cows were introduced into the pasture The authors future noted that this suggested that water was much less effective in influencing cattle distribution especially in comparison to areas where water is readily available in an already disproportionately attractive riparian zone. This finding is consistent with many contemporary studies that evaluated the effectiveness of off-stream water to alter animal distribution and congregation in riparian zones. Many of these studies reached similar conclusions.

When the effects of salt were evaluated, there was a difference in the way cows and yearlings distributed themselves in relationship to salt, but it was not effective in altering the distribution of either class of animals. The authors concluded that cattle probably chose not to expend the energy necessary to climb out of the canyon bottom to obtain the salt and that cattle used the salt when convenient but did not alter their behavior patterns to obtain it.

Based on one grazing season in the two study pastures, the author found that pasture attributes and environmental conditions likely influenced distributional patterns. Cows and yearlings concentrated their use in the riparian zone especially from July 20-September 9 (periods 1 & 2) and this was a result of cattle seeing comfort (microclimate), energy conservation, availability of succulent vegetation or a combination of these factors. Lower temperatures and higher relative humidity occurred in zone I in time periods I and II. Cows used more plant community types regardless of aspect than did yearlings including a concentration on the productive of these types. Slopes less than 35% were preferred by both classes of cattle regardless of pasture aspects, and cows made more use of steeper slopes in both pastures than yearlings. Salt placement in upper portions of the pastures did not induce cattle to use these areas nor did it reduce cattle concentrations on riparian communities. The authors suggested that further research is needed to determine the effectiveness of water to increase livestock distribution. Since this publication, much more research has been conducted to evaluate the influence of water on animal distribution. While water can help distribute animals across the landscape it has not be found to consistently or reliably reduce the use or reliance of surface waters (streams) as a drinking water source even when off-stream water is readily available.

The authors stated that data suggests cattle use slopes above 35% sparingly. Also, when forage-rich riparian zones are available especially at the bottom of narrow canyons, cattle will often concentrate their activities in these areas. In both situations, careful consideration is needed when preparing a grazing management plan or implementing practices. The authors further recommended that when fencing riparian zones, it's important to exclude livestock in a way to ensure all riparian plant community types are included; and to eliminate livestock concentrations in the riparian zone, it might be better to place the fence on the first flat area above the stream. In this study, temperature and relative humidity in the late season (September 13-October 7) produced a less comfortable environment in canyon bottom riparian zones and more comfortable environments on the up slopes. According to the authors, stocking pastures within riparian zones during the cooler part of the grazing season could lessen cattle impacts. This hypothesis is similar to the concept of early season grazing. Cows with calves used more slope classes and more plant communities than did yearlings. Given these differences, it may be advantageous to stock cows with calves and yearlings together to increase distribution and better forage utilization. However, more studies are needed to test this concept.

This study assessed three distinct timeframes: July 20-August 12 (period 1); August 16-September 9 (period 2); and September 13-October 7 (period 3). These coincide with what is often considered summer (mid-season) grazing, late season grazing and fall grazing. Microclimate and forage availability most influential during the first and second period of this study which is consistent with other studies of this type in this setting (rangelands in eastern Oregon). It appears that fall grazing (period 3) may lessen the use of riparian areas and reliance on surface waters or water sources near riparian zones similar to early season grazing. Again, further research including the effects of fall grazing on riparian vegetation, riparian soils and streambanks is needed.

10. Chaney, E., Elmore, W., & Platts, W. S. (1990). Livestock grazing on western riparian areas. US Environmental Protection Agency.

The guidance was developed to educate livestock operators on how to improve water quality in western rangeland watersheds by controlling livestock grazing. Since the control of nonpoint sources of water pollution is usually with voluntary compliance through nonregulatory programs, this document was intended to give a broad overview of functions and values of western riparian areas, impacts of degraded riparian areas on water quality, and provide case studies to show how livestock grazing can be improved to protect riparian areas.

11. Clawson, J. E. (1993). The use of off-stream water developments and various water gap configurations to modify the watering behavior of grazing cattle. Master's degree thesis.

This study was conducted on 118.7 ha (293 ac) pasture within the Hall Ranch unit of the Eastern Oregon Agricultural Research Center near Union, Oregon. A primary research question of the study was to investigate whether the installation of an off-stream watering trough would reduce the time cattle spent in or around streams.

The study pasture consisted of a mix of coniferous forest and native grass, and the stream was a small perennial stream located on the north side of the pasture. Livestock were partially excluded from the stream and riparian area and approximately 300 feet was left unobstructed and available for cattle to use for drinking, grazing and loafing. Cattle also had unrestricted access to 300ft of a flowing spring (referred to as bottom area). The stream and spring were the only water sources available prior to the installation of a water trough. Cattle continued to have access to the stream section and bottom area after the trough was installed. According to the author, the stream and adjacent banks provided little vegetation but ample shade and water. The bottom area was lush with phreatophytes and other palatable plants. The off-stream water trough was installed approximately 200ft south and up-gradient of the stream and approximately 100ft west of the spring (bottom area). Cattle at the site included seventy heifers, forty cow-calf pairs and three bulls. Calves were treated as individual units because they were difficult to discern from adults in the film and observations. Therefore, 153 cattle were observed.

To evaluate the effects off-stream water on animal behavior, the amount of time cattle spent near watering locations and the riparian area were observed before and after the installation of a watering trough. Prior to the installation of the watering trough, observations were made during daylight hours after cattle were release into the pasture using two SanKyo super eight movie cameras and by personal observation. It was noted by the author that the cameras did not have a complete view of the stream reach during the pre-treatment observation period, and it's presumed this was addressed via supplemental, in-person observations though this wasn't confirmed by the author. After the installation of the watering trough, observations were made dawn to dusk from a small trailer located up-gradient from the watering locations and riparian area using binoculars. Continuous observations were made at one-minute intervals at the trough, stream and bottom areas. Cattle were counted if they within 1.5m of either the streambank or bottom area and within a 12.1-meter square around the trough. A 2ac zone surrounding the trough, stream and bottom area was referred to as the riparian area. Activities of the cattle were recorded at each location and were categorized as drinking, loafing or foraging. The study period spanned three weeks (June 24 – July 15, 1992): two weeks (7 observation dates) prior to installation of the trough and one week after the installation of the watering trough (6 observation dates).

Examination of the time data found that cattle spent less time in the stream after the watering trough was installed. While this is an important finding, the data also suggested a general trend of livestock spending less time in the stream over the course of the pre-treatment observation period. This pattern was not addressed by the author nor was there any analysis to investigate this pattern. The data also showed a significant drop in the use of the bottom area after the installation of the trough. The time cattle spent at the bottom area dropped from a weighted average of 8.3 min/cow/day to 3.9. The trough received 3.8 min/cow/day which was nearly an even split between the bottom area and the off-stream water trough.

The daily data showed that the majority of the use of the bottom area was between the hours of 12:00pm and 6:00 pm. Trough use followed a similar pattern with 93% of its use between 12:00pm and 7:00 pm. While not addressed by the author, it's likely that the relatively close proximity of the bottom area to the trough (100ft) influenced the use of the trough and may be a reason the timing of use and the amount of time spent at the trough and bottom area where nearly the same. This is especially likely given the lush forage available in the bottom area as described by the author.

During the post-treatment period, cattle were found to spend an average of 51.5 min/cow/day in the riparian area (observation were made for 16 hours of each day). Of this time in the riparian area, only 3.5 min/cow/day (6.6%) were spent drinking. When cattle were drinking, 73.5% of the time (2.5 min/cow/day) was at the trough and 23.5% (0.8 min/cow/day) was from the bottom area (flowing spring) and 3% from the stream. Also, the greatest amount of drinking occurred between 12:00 pm and 2:00 pm (51%) and very little drinking occurred before 12:00 pm or after 7:00 pm. The timing of use of the bottom area (12:00pm and 6:00 pm) coincided with the timing of the greatest amount of drinking occurrences (12:00 pm or after 7:00 pm).

When riparian use was evaluated, the majority of use was found to occur between 12:00 pm and 6:00 pm (as with drinking, use of the bottom area) and a majority of this time in the riparian area was spent loafing. While cattle spent more time loafing around the trough than the bottom area, the most time cattle spent loafing was at the stream (60.6% of the time spent in the riparian zone or 28.1 min/cow/day). Further, the bottom area surrounding the spring was utilized most heavily by far, receiving 90% of the foraging use within the 2-ac riparian zone. During the post-treatment period, the stream received no significant grazing use which was likely a result of the streamside area having little vegetation as noted by the author.

The results of this study suggest that cattle will use off-stream watering when provided as an alternative option to surface waters and surface water use by cattle as a drinking water source was reduced after the introduction of an off-stream watering source. However, the results also showed that off-stream water wasn't used exclusively and didn't necessarily limit or reduce the time spent in streamside or riparian zones. The study also demonstrates that cattle will continue to use surface waters for drinking water even when off-stream water is nearby. Additionally, the timing of riparian area use, bottom areas use, drinking and loafing primarily occurred between 12:00 pm and 7:00 pm, and available forage and riparian shade likely influence in the timing and amount of time spent in riparian zone and watering locations. While the results of this study do demonstrate some level of efficacy for off-stream water to alter livestock watering behavior, this study has some limitations when compared to similar types of studies and the study design introduced additional factors that likely influenced the results and were factors that should have been accounted for in the study or analysis.

When compared to similar studies that evaluated the timing of use of watering sources and riparian zone, the timeframe (3 weeks) and number of observations (7 observation days pre-treatment, 7 observation date post-treatment) is relatively short. Also, unlike other research, this study did not utilize separate pastures to measure difference between controls and treatments and did not account for the potential influence of forage utilization prior to the treatment (off-stream water) or account for additional factors such as daily or hourly temperature. Daily and hourly temperature and forage availability are known to influence grazing patterns and use of riparian areas. In this study, livestock were allowed to graze streamside and riparian areas for two weeks prior to the implementation of off-stream water. Two weeks of foraging within and around the riparian zone could have altered forage availability in the riparian zone which could have influence grazing preferences and water source use. Further, livestock were allowed to graze seven additional days after the last pre-treatment observations were made and it's unclear if grazing and watering activities during this time could have influenced the results in any manner. Also, time cattle spent loafing, drinking and grazing were not tracked before and after the installation of off-stream water making it impossible to evaluate if or how these were affected by the treatment.

12. Clary, W. P., & Webster, B. F. (1989). Managing grazing of riparian areas in the intermountain region. *Gen. Tech. Rep. INT-263. Ogden, UT: US Department of Agriculture, Forest Service, Intermountain Research Station. 11 p*, *263*.

This is a guidance document for planning riparian grazing procedures on National Forests. Recommendations in the guidance are not applicable to areas beyond the Intermountain Region of the Forest Service. The riparian grazing management recommendations were developed to reduce nonpoint source pollution in western streams and as suggestions for updated BMPs. The recommendations provided are generic and serve as general criteria for various situations. These recommendations could also be useful for reduction of grazing impacts on other resources in addition to reduction of nonpoint source pollution.

13. Edwards, A. J., & Canter, L. W. (1999). Impact indices for grazing actions. *International Journal of Environmental Studies*, *56*(4), 571-589.

This study highlights negative environmental impacts of livestock grazing on rangelands in the western U.S., identifies techniques and measurements to determine severity of these impacts, and provides indices to summarize environmental data for decision-making. The indices can support identification of vulnerable rangelands, sustainable grazing practices, and mitigation measures. Additionally, the indices can provide evidence to inform decisions for new or renewal grazing permits. The study goes into detail on impacts to vegetation, soil, riparian zones, water quality, and wildlife. Overall, livestock grazing on federal lands damages these aspects which results in the ultimate degradation or loss of wildlife habitat. Some overgrazing impacts may be irreversible, so it is critical to assess land vulnerability. Extant impact indices are especially useful for focusing data collection on factors that are most indicative of negative environmental impacts of grazing. The indices can inform rangeland monitoring, impact predictions, and land permitting/evaluation.

14. Goss, L. M., & Roper, B. B. (2018). The relationship between measures of annual livestock disturbance in western riparian areas and stream conditions important to trout, salmon, and char. Western North American Naturalist, 78(1), 76-91.

Studies designed to assess the effectiveness of grazing management systems to limit impacts to riparian areas commonly include an evaluation of forage utilization along with changes to riparian vegetation, soils and streambanks, and these post-grazing conditions are often used as indicators to predict changes to stream conditions. The results of these studies provide value information about the affects streamside grazing associated with various grazing management strategies; however, many do not include additional analysis to evaluate how post grazing conditions affect streams conditions in subsequent years. To help address this gap, Goss and Roper (2018) conducted a study across the Interior Columbia River Basin to describe the relationship between streambank alteration and stubble height measured after the grazing season with stream channel characteristics important to salmonid habitat.

The authors' hypothesis was that these indicators as measured at the end of the growing season were associated with stream habitat conditions the following year. For example, if livestock grazing resulted in excessive streambank alteration or limited vegetation height at the end of the grazing season, then seasonal high flow events between grazing seasons would increase erosion along the disturbed banks and further degrade stream habitat conditions In contrast, if livestock streambank disturbances and above ground vegetation were protected, condition conditions would be either maintained or trend toward improvements.

A common approach to managing livestock use of streamside areas used by Federal land managers such the Forest Service and Bureau of Land Management managers is to set allowable limits of streambank alteration and stubble height, and these indicators are commonly used as surrogates for short-term effects to riparian areas. Streambank alteration is an estimate of how much of the streambank has been disturbed by grazing livestock and stubble height is a measure of the herbaceous material remaining after grazing and is typically measures adjacent to the stream.

For this study, the authors evaluated 153 stream reaches within the Interior Columbia Basin from 2010 to 2012 to determine if these two surrogates of livestock disturbance measured after the vegetative growing season were associated with stream conditions important to salmonids. Livestock disturbances (primarily cattle) were measured on federal land within the Interior Columbia River Basin as part of the PacFish/InFish Biological Opinion Effectiveness Monitoring Program. The stream reaches evaluated selected using a spatially balanced sample of watersheds from across the Interior Columbia River Basin to help ensure that a broad range grazed stream reaches were evaluated. Most monitoring areas were located near low gradient (<4%) stream reaches because cattle generally congregate in gently sloping landscapes. Stream reaches were in allotments where grazing could have occurred from late spring to early fall with specific grazing strategies and intensities determined via Allotment Management Plans.

All stream reaches used in the study had annual indicators of livestock disturbance evaluated at the end of the growing season (mid-September through October), with stream habitat conditions evaluated in the same stream reach the following summer. While grazing was permitted along all evaluated stream reaches, some allotments were rested in the years livestock disturbances were assessed. Approximately 85% of the stream reaches were perennial with many having fish, and represented a broad spectrum of riparian, stream, and watershed conditions grazed by livestock.

Evaluated stream reaches were 110 m long and sampling occurred along the greenline which is the first perennial vegetation that forms along water's edge. Sampling for livestock disturbance generally following the Multiple Indicator Monitoring (MIM) protocol and stubble height was measured within 40 x 50 cm sampling frames. Streambank alteration and stubble height values used in this analysis included the average of all the measurements within the evaluated stream reach. Stream attributes evaluated included width-to-depth ratio, bank angle, percent undercut banks, bank stability, residual pool depth, percent pools, pool-tail fine sediments <2 mm, and wood frequency).

To test their hypothesis, the authors constructed a linear regression model that related the outcomes of the streambank alteration and stubble height evaluations to stream habitat conditions measured the following year. Environmental covariates were incorporated into the analysis to account for inherent variability among the stream reaches. For simplicity the authors limited the covariates to bankfull width, reach gradient, and average annual precipitation as these attributes had previous been shown to have strong relationships to stream habitat conditions and not strong correlated to one another.

To better understand the relative magnitude of how livestock disturbances might affect stream conditions, the authors presented the predicted the predicted effects of streambanks disturbance in the context of changes to stream conditions. This was accomplished by comparing the predicted effects of livestock disturbance to stream habitat characteristics at two values commonly used as management standards for streambank alteration (10% and 25%) and stubble height (10 cm and 15 cm) to the expected differences in habitat conditions in dry (0.5 m of precipitation per year) and wet (0.75 m per year) watersheds within the study area.

All the best models for the eight stream habitat attributes included terms where streambank alteration or shorter stubble heights were significantly ($P < 0.1$) related to what would be considered poorer stream habitat conditions for salmonids. While streambank disturbance often explained only a small portion of the total variation, stubble height explained nearly twice as much variability as the covariates model for bank stability. The strength of the associations between livestock disturbance and stream channel characteristics indicated that meaningful biologically change in stream channel conditions could be achieved by reducing livestock disturbance. All the stream habitat models that included stubble height included the polynomial term which suggests a decreasing benefit to stream habitat conditions as stubble heights increased. However, the relationship between stubble height and the stream attributes did not asymptote in the 10–15-cm height range commonly used as standards and stream conditions favored by salmonids continued to improve as stubble height reached approximately 35 cm. Streambank alteration was associated with width-to-depth ratios and pool fines and these relationship were linear meaning increase MIM scores (greater streambank disturbances) lead to increases in pool fine sediment and increased width-to-depth ratios (widening and shallowing).

Measurements of streambank alteration and stubble height in the fall provided insight into stream habitat conditions measured the following year. Increased livestock disturbance, as assessed via streambank alteration and stubble height, was related to stream channel changes through increases in width-to-depth ratios, bank angles, and fine sediment in pool-tails and decreases in undercut banks, bank stability, pool habitat, pool depth, and wood frequency. According to the authors, these changes were expected given previous research of how livestock disturbance affects stream conditions. These results also support previous localized studies that found increased livestock disturbance along streams is related to increases in width-to-depth ratio, streambank angle, fine sediment, decreases in undercut banks, streambank stability, pool habitat and woody material. While the analysis conducted in this study showed results independently for each stream attribute, it's important to note that increasing livestock disturbance negatively affects all of the stream channel characteristics evaluated in this study, and the synergistic adverse effects of livestock disturbance on stream channel characteristics could further affect salmonid densities and survival of all life stages.

Further analysis also determine that five of the six stream habitat conditions were related to stubble including bank angle, undercut banks, bank stability, percent pools, and pool depth which suggests that livestock grazing is altering riparian plant communities in a manner that reduces the streambank's ability to resist high stream flows. Additionally, greater stubble height is likely to lead to greater stream condition outcomes.

Stubble height measured along the greenline has been proposed as an indicator of plant vigor and the presence of livestock, and even proposed as a method to determine impacts to streambanks. The authors noted that stubble height is somewhat redundant with an evaluation of streambank disturbance because stubble height is directly affected by livestock grazing and not subject to environmental conditions. They suggest that management decisions would be better informed when both were evaluated stubble height and streambank disturbance were evaluated. In their analysis of stubble height, the authors identified several stream reaches with short stubble heights but little streambank alteration. These reaches often showed evidence of compaction which made it difficult to detect current-year evidence of disturbance by hooves. In contrast, the authors also identified stream reaches with tall stubble heights and considerable streambank alteration. In these stream reaches, the greenline was often at the level of the water table or there had been recent rainfall. Either of these situations can increase the likelihood of streambank impacts from livestock hooves. The fact that antecedent moisture has been shown to be an important variable affecting streambank alteration likely decreases the strength of the relationship between this livestock disturbance metric and stream habitat conditions.

Based on the result of this study and regression analysis, streambank disturbance and stubble height were associated with stream conditions and meaningful changes in stream conditions would result depending upon how much livestock disturbance is allowed in riparian areas. Additionally, livestock disturbance was found to be as or more important than environmental metrics for several stream attributes. Of the eight stream conditions evaluated, two had linear relationships indicating that continued decreases in streambank alteration would result in continued improvements to stream conditions favored by salmonids, namely reductions in width-to depth ratios and pool tail fines. The relationship between stubble height and the remaining six stream habitat conditions attributes did have curvature but regression analysis suggested that stream conditions favored by cold water fish were more likely to be achieved at values far above values commonly used as stubble height standards such as 10-15 cm. Improvement to stream conditions including bank angles, undercut banks, bank stability, pool habitat, pool depth, and wood frequency would be expected until stubble heights of 35cm of were reached. To these points, the authors believed a more conservative standards stubble height would be prudent until there was sufficient data to justify more liberal standards.

This large-scale study reinforced previous research conducted at smaller scales that found livestock disturbance in riparian areas can negatively affect many stream condition attributes. These finding also highlight the importance of maintaining healthy, vigorous riparian vegetation and preventing streambank alteration as negative impacts to riparian areas have been shown to adversely affect several important stream conditions including those important to salmonids. While this study focused on understanding the relationship between short-term indicators of grazing disturbance and long-term stream conditions, it also highlighted the need for additional work to increase accountability in implementing rangeland standards. The authors found very few Forest Service or BLM units where disturbance streambank standards were set above >25% or stubble height less than 10 cm, yet more than 25% of the stream reaches sampled did not meet these standards. Further, current stubble height standards commonly used were not found to be protective of stream conditions including those favorable to cold water fish species including salmonids. Based on their finding, the authors believed that implementation of more conservation standard would be prudent until there is sufficient data to justify the use of current standards commonly used.

15. Gregory N. Nagle & Caty F. Clifton (2003) Channel Changes Over 12 Years on Grazed and Ungrazed Reaches of Wickiup Creek in Eastern Oregon, Physical Geography, 24:1, 77-95

In this study, Nagle and Clifton compared stream channel cross sections of grazed stream reaches with a 47-yr. old livestock grazing exclosure along Wickiup Creek in eastern Oregon. The study sites were located in the Malheur National Forest which characterized by forest slopes and narrow alluvial valleys and open, sagebrush steppe consisting of annual and perennial herbaceous vegetation and sporadic willow and lodgepole pine stands. The setting of this study would translate to similar ecoregions in Washington state especially forested rangelands east of the Cascade Crest. This study was a follow-up to a previous study conducted in 1986 that found significant and distinct differences in channel morphology between grazed and ungrazed channels. The authors highlighted that the grazed sites had been managed under an increasingly more restrictive deferred grazing system where livestock were only allowed to graze later in the season at varying start and stop times. During the study period, the average grazing days ranged from 16-21 days and included 4 years of complete rest. In 1990, a new forest plan was implemented which essentially removed cattle once they started to graze on riparian plants. The authors noted that the conditions of grazed sites on Wickiup Creek that coincided with the required grazing practice were not typical of area.

This study found that some stream channel characteristics of grazed sites improved between 1986 and 1998 although not all were statistically different. However, when compared to the ungrazed reach, grazed reaches were statistically different (less improvement) than the exclosure site. As the authors highlight, there are a limited number of studies designed to evaluate stream channel changes under different grazing management practices and many of those studies conducted haven't shown statistically significant differences. Study design, differences in field measurement techniques, site and watershed characteristics, limited number of reference sites and time required for channel to recovery are some of the reasons for the limited number of studies and lack of statistically significant differences. This article suggests that very limited grazing over a long period of time may lead to some improvements to channel characteristics. Although, in this study area, progressively restrictive grazing approaches had not improved stream characteristics to the level of the ungrazed reach.

16. Grudzinski, B., K. Fritz, W. Dodds. 2020. Does riparian fencing protect stream water quality in cattle-grazed lands? Environmental Management, 66: 121 – 135.

This article provided a literature review of the effectiveness of riparian fencing within cattle-grazed lands and response to stream sediment, nutrient, and fecal indicator bacteria levels. To develop a summary of the literature, the authors conducted a systematic, multi-step evaluation of peer-reviewed studies that assessed the effectiveness of riparian fencing within cattle grazed lands. Key search terms were used to identify relevant articles which yielded 478 studies ranging in publication date from 1927 to 2019. The authors then read the title and abstract of each article to identify potentially relevant studies. All potentially relevant studies were then read and articles where research objectives or methodologies did not address the effectiveness of riparian fencing on water quality were eliminated. Studies which included extensive stream restoration were not included because the impact of fencing could not be isolated. Studies that replanted degraded riparian zones or stabilized streambanks degraded by extensive trampling were included as the authors believed these changes should occur naturally upon cattle exclusion. Additionally, studies that provided off-stream water sources or access points to streams were also included as these practices were deemed necessary when exclusion fencing is implemented. Finally, water quality responses were also evaluated by hydrograph timing i.e. baseflow vs stormflow conditions.

Twenty-six of the 478 studies identified in the initial literature search were found to be relevant for the review. All the identified studies examined the impacts of fencing on water quality and six also included an evaluation of fencing impacts on parameters related to streambed characteristics. Of the 26 studies, the impact of fencing on sediment was examined in 14 studies, phosphorus in 16 studies, nitrogen in 11 studies, and fecal indicator bacteria in 12 studies. The impacts of fencing on more than one of these parameter categories was examined in fifteen studies and four studies examined impacts on all four parameter categories. In total, the review examined fencing impacts on 88 water quality responses with an average of 3.4 parameters per study. The 26 studies were conducted in three (of 12) world terrestrial biomes including temperate broadleaf and mixed forests (17 studies), temperate grasslands, savannas and shrublands (seven studies), and temperate conifer forests (two studies).

The effects of fencing on water quality were empirically assessed through a variety of study designs including pre–post treatment comparisons, upstream to downstream treatment and comparisons within entire watersheds. Studies varied widely in sampling frequency and duration with some studies sampling multiple times per week and other sampling several times per year. However, most sampled water between weekly and monthly time scales. The duration of studies ranged from less than a year to over a decade.

Responses of specific water quality parameters across the studies were grouped into four broad parameter categories including sediment, phosphorus, nitrogen, and fecal indicator bacteria. The sediment included suspended sediment and deposited streambed sediment. The phosphorus category included total phosphorus, particulate phosphorus, soluble reactive phosphorus, and total phosphorus deposited within the streambed. The nitrogen category included, total nitrogen, nitrate, nitrite, ammonium, ammonia, and total Kjeldahl nitrogen. The fecal indicator bacteria category included E. coli, fecal coliform, fecal enterococci, fecal strep, and total coliforms. The authors acknowledged that combining parameters into broader categories could mask some water quality responses to fencing such as difference in particulate vs. dissolved nutrients. However, based on the limited number of studies for some parameters, the authors determined they could not draw conclusions at finer levels.

Fencing effectiveness for each specific parameter was classified as either a “majority improvement”, “minority improvement”, or “no improvement” based on the frequency of statistically significant improvements. Results were classified as a “majority improvement” if a majority (>50%) of sites and/or temporal periods in a study showed significant improvements for a water quality parameter. A result was classified as a “minority improvement” if statistical tests showed a significant improvement in half or less of the analyses (<50 but >0%). A “no improvement” determination was made if no statistically significant differences were detected due to fencing (0% of statistical tests detected significant water quality improvements).

As part of the statistical analysis, the authors examined the relationships between potential covariates such as buffer width and water quality responses when sufficient data was available. Due to limited reporting of many covariates (e.g., cattle breed, manure application) or uniformity across studies (e.g., grazing season), the relationships of covariates on impact to water quality could not be determined beyond stocking rates and riparian buffer widths.

Of the 26 reviewed studies, 85% (22 of 26) resulted in a “majority improvement” or “minority improvement” in at least one water quality parameter. The largest responses in water quality to riparian fencing occurred with fecal bacteria and sediment parameters while nutrients experienced the least responses. Sediment reductions were found in 79% (11 of 14) of the reviewed studies with 8 of 14 the studies showing “majority improvement”. Fecal indicator bacteria decreases were found in 74% (17 of 23) of the reviewed studies with 15 of 23 demonstrating “majority improvement”. Phosphorus was decreased in 54% (14 of 26) of analyses with 9 of 26 showing "majority improvement". Nitrogen decreases were less consistent with 36% (9 of 25) of analyses demonstrating improvement and 6 of 25 showing a "majority improvement".

Eight of 20 studies sampled the water column during both baseflow and stormflow conditions and four of those studies compared the effect of fencing during baseflow and stormflow conditions with separate statistical analyses. The other four studies did not separate the analyses by hydrograph. Of the four studies that separated the statistical analyses by hydrograph timing, 21 water responses to fencing were tested and 48% (10 of 21) showed a "majority improvement" during stormflows (phosphorus n = 3; fecal n = 7) and none had "minority improvements". With the four studies that didn't separate the statistical analyses by hydrograph, 10 water quality responses were examined with 60% (6 of 10) showing a "majority improvement" (sediment n = 2; phosphorus n = 3; nitrogen n = 1) and 20% (2 of 10) showing a "minority improvement" (phosphorus n = 1; nitrogen n = 1), and 20% (2 of 10) showing no improvement" (nitrogen n = 2). Between the eight studies and corresponding 31 analyses that contained stormflow sampling, 58% (18 of 31) of the water quality responses were improvements. When nitrogen parameters were excluded, improvements occurred in 73% (16 of 22) of the remaining water quality responses and 94% (15 of 16) of these occurrences were "majority improvements".

The authors noted that there are many potential environmental and management related variables that could influence the impacts of riparian fencing. Although, in this study, the authors were unable to evaluate the impact of many of these additional variables because of inconsistent reporting of study designs and statistical outputs within the reviewed article. Nevertheless, the authors were able to examine the relationship across all parameters and riparian buffer width (n = 31) and stocking rates (n = 34). Overall, a greater riparian width appeared to improve water quality. For the reviewed articles, there was no relationship between stocking rate and water quality improvement.

Most studies reviewed in this study (85%) reported in stream reductions of sediment, nutrients and fecal indicator bacteria as a result of fencing. Establishing buffer widths greater than 5–10 m appeared to increase the likelihood of water quality improvements. The impact of fencing varied by parameter and fencing was most found to be most effective at decreasing fecal indicator bacteria and sediment parameters followed by phosphorus and nitrogen parameters. This is predictable since fencing cattle from streams decreases direct defecation and associated fecal inputs and eliminated streambank trampling with decreases streambank trampling and in-channel disturbances. Overall, the reviewed studies reported less phosphorus reductions. Nitrogen benefits were less frequent and consistency and appeared to benefit the least during storm events. The authors cited buffer research which found riparian buffers over 50 m were consistently more effective at removing nitrogen than buffers 0–25 m, and this was highlighted as factor that may have affected nitrogen removal efficacy of fencing and associated buffers. Generally speaking, studies found more frequent "no improvement" responses for dissolved nutrients (nitrate and soluble phosphorus) than for total or particulate nutrients.

This further highlights the interconnected nature of exclusion fencing and streamside vegetation (buffers) as it relates to pollution reductions associated to riparian area fencing.

In review of the literature, the authors highlighted gaps in the current research and offered suggestions to improve future research. For example, the small number of studies that differentiated between storm and baseflow conditions limited the author's ability to make conclusions about the water quality benefits during storms even though the data was promising. Most studies included in the review were short-term and studies with a before–after design with "after" samples generally taken immediately following cattle exclusion without a transitional period. While removing cattle from streamside areas is likely to have a more immediate response, it was noted that riparian environments may take extended time to respond to livestock exclusion and as riparian areas mature greater decreases in sediment, nutrient, and fecal bacteria are expected. For these reasons the authors recommended longer-term studies that also measure ecosystem responses. Response of other grazing livestock (e.g., sheep, goats, etc.) is a significant unknown.

Based on the 26 studies evaluated in this study within the biomes represented, the authors found that most studies identified positive impacts from riparian exclusion fencing. Fencing appeared to be most effective in reducing sediment and fecal bacteria and additional benefits may include the protection of riparian plant species and important wildlife habitat in addition to water quality effects.

17. Haan, M. M., Russell, J. R., Davis, J. D., & Morrical, D. G. (2010). Grazing management and microclimate effects on cattle distribution relative to a cool season pasture stream. *Rangeland ecology & management*, *63*(5), 572-580.

The objectives of this study were to determine the impacts of grazing management and microclimate on cattle use of stream channels, riparian areas, uplands, and shade. A three-year (2005-2007) study was conducted on six 12.1-ha (30 ac) cool-season grass pastures located at the Iowa State University Rhodes Research farm in central Iowa. The six study pastures were each bisected by a 141 m (463 ft.) stream segment and were grouped into two blocks with each block assigned one of three grazing management treatments including continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR) via riparian fencing and a 4.9 m (16 ft.) wide stream crossing and five-paddock rotational grazing system (RS) with one paddock spanning both sides of the stream and associated riparian zones. Each pasture was stocked with 15 fall-calving Angus cows from mid-May through mid-October. Grazing was not allowed in the fenced riparian areas on either side of the CSR pastures which extended approximately 33 m (108 ft.) from the stream. Riparian paddocks in the RS pastures also extended 33m from the stream in either direction and were 0.91 ha (2.2 ac). Riparian paddocks were grazed until forage height decreased to a minimum of 10 cm (3.9 in.) and were used between 8 and 10 days per year during the study period. Upland paddocks in RS system were 2.78 ha (6.9 ac) and grazed to allow for 50% forage removal in each rotation. Tree cover area was measured in the upland areas and streamside zones which ranged from 1.4% to 13.8% and 3.6% to 23.7% respectively. Pasture with greater streamside zone shade also had greater amounts of shade in the upland areas. To test the effectiveness of off-stream water on cattle distribution, off-stream water tanks were made available to cattle in the CSU and CSR pastures in May, July and September of 2006 and 2007. Water tanks were located on both sides of the stream at a minimum of 240 m (787 ft.) from the stream. Cattle were also provided a mineral supplement adjacent to off-stream watering sites. Pastures did not receive supplement fertilizer during the study period.

Cattle activity and distribution observations were conducted using GPS collars and visual observations. One cow per pasture was fitted with a global positioning system (GPS) for approximately 2 weeks in each month from May through September in 2006 and 2007. Visual observations were conducted from 6:00 a.m. to 6:00 p.m. on two consecutive days in May through September in 2005, 2006 and 2007. Cattle in CSU and CSR pastures did not have access to off-stream water sites during visual observation days or the night prior to visual observations. Cattle distribution information was obtained by a trained observer within each pasture equipped with a hand-held GPS receiver. If the herd split into subgroups, the observer remained with the group that included the cow fitted with the GPS collar. At 10-min intervals cow herd location, number of cattle present, number of cattle under shade, and the number of observed defecations and urinations were recorded. Cattle location for both visual observation and GPS collar data was defined as within stream (Stream Zone), 0 m to 33 m from the stream edge (Streamside Zone), 33 m to 66 m from the stream edge (Transition Zone), and greater than 66 m from the stream edge (Upland Zone). The Transition Zone included the remainder of the riparian area and the start of the uplands. The Stream Zone was determined by walking the length of the stream with a GPS collar recording position at 30-s intervals. Stream channel was approximately 3 m wide. The Streamside Zone and riparian paddocks were approximately the same with (33m). The Stream Zone, Streamside Zone, Transition Zone, and Upland Zone were 1.1%, 6.1%, 6.1%, and 86.8% of the pasture area, respectively.

Microclimatic measurements including temperature, black globe temperature, wind speed and relative humidity were recorded at 10-minute intervals using a weather station located in the riparian area in the center of the study area. A temperature humidity index (THI), heat load index (HLI) and black globe temperature humidity index (BGTHI) was calculated for every 10-minute measurement. To evaluate the impact of microclimate on cattle distribution and activity, microclimate data were paired with GPS and visual observation date for each observation timeframe. Microclimatic and grazing management effects on cattle occupancy within the Stream, Streamside, Transition and Upland were analyzed along with defecation and urination patterns.

Based on the GPS data, cattle in the CSU pastures spent significantly more time in the Stream and Streamside Zones that the CSR pastures. According to the GPS data, cattle in CSU pastures spent significantly more time in Stream Zones in May, June and August and significantly more time in Streamside Zones in May, June and July and tended to spend more time in August as well. Visual observation data also found that cattle in CSU pastures spent more time in the Stream Zone in all months and these were statistically different in June, July, August and

September. Visual observations also found that cattle in CSU spent more time in Streamside Zones that cattle in CSR in all months and these were significantly different. Additionally, during the months of May through August cattle were observed in the Stream or Streamside Zones with the CSU pastures 20% of the time. Differences in cattle use of the Transition and Upland Zones were also observed between grazing management treatments in some months. GPS data found that cattle in CSR pastures spent more time in Transitional Zones than cattle in CSU in May, June, July and August but not September; however, these differences were not statistically significant ($P<0.05$). Visual observation data determined that cattle in CSR pastures spent more time in Transitional Zones than cattle in CSU in May, June, July, August and September. Statistically differences in Transitional Zone use (visual observations) were not provided by the authors. Upland Zone use in CSR pastures was higher in all months (May – September) for both GPS and visual observations; although, the GPS data was only significantly different in June and the observation data was significantly different in June and August. It's not entirely clear why CSR uplands appeared to be used more but upland shade may have influenced the distribution of cattle within the pastures. Also, the authors noted that pasture with greater streamside zone shade also had greater amounts of shade in the upland areas.

GPS collar data demonstrated that cattle within the CSU treatment were present in Stream and Streamside Zones an average of 1.2% and 10.6% respectively. Stream and Streamside Zones represent 1.1% and 6.1% of the available pasture indicating that cattle tended to favor the Streamside Zone but didn't congregate in the Stream. The authors noted other research which found that cattle used streams channels and floodplain areas of a pasture to a greater extent than the relative areas those zones compare to the total pasture. Given that the CSR (restricted) and Rotational grazing (RS) systems largely prohibited livestock from access streamside areas it is expected that the percentage of time in these areas would be less that the unrestricted treatment. Nevertheless, this study validates the hypothesis that unrestricted access to streams and riparian zone often leads to a disproportionate use of these areas.

In this study, providing cattle with an off-stream water source did not decrease the percentage of time spent in the Stream or Streamside Zone in either the CSU or CSU pastures. The authors guessed that the use of off-stream water may have been affected by the limited time for cattle to acclimate to its availability. Also forage availability during the time when off-stream water was provided was not available but may have influenced its use.

The percentage of observed defecations in each of the pasture zones did not differ from the percent of time spent in each zone. Although, cattle urinated slightly more (83.5%) in Upland Zones that the percent of time spent in this area (82.3%). For the study observations, the authors believed it could be assumed that nutrient and pathogens excreted by grazing cattle would be proportional to the percent of time spent in a given zone.

When the effects of microclimate on cattle distribution were evaluated, it was found that as temperature, BGTemp, THI, BGTHI and HLI increased, the probability of cattle being in the shade increased across the entire range of observation periods in both the CSU and CSR treatments. Grazing management treatments (CSR and CSU) had no effect on the probability of cattle being in the shade. However, there was a statistically significant effect of grazing treatment on the likelihood of cattle being in the shade based on BGTemp, BGTHI and HLI. The greater probability of cattle being in the shade in CSR pastures at higher BGTemp, BGTHI and HLI than CSU pastures was likely a result of cattle having greater access to streams in CSU pastures. Even though cattle in CSR pastures had access to streams that space was restricted to the stream crossing area (14ft wide) and cattle did not appear to loiter in this area. Overall, ambient temperature was superior to the other microclimatic variables in predicting cattle presence in shade.

Increases to temperature, BGTemp, THI, BGTHI and HLI was found to increase the probability of cattle being in the riparian zone in both the CSU and CSR treatments; although, the rate of increase was higher for CSU pastures than CSR pastures. Again, this was likely due to greater access to the stream and riparian areas in the CSU treatment pastures. Off-stream water did not alter the probability of cattle being in the riparian zone of CSU pastures at any Temp, BGTemp or THI. However, there was a for off-stream water to decrease the probability of cattle being in the riparian zone as BGTHI and HLI increase, but this was not statistically significant. Ambient and black globe temperature were found to be superior to other microclimate variable or indices in predicting cattle presence in the riparian zone. According to the authors the finding that ambient temperature was a better predictor of cattle presence in shade was contrary to other studies which found equations that considered multiple microclimatic factors to be better indicators.

The amount of time cattle spend in streams and riparian areas is a function of forage availability and quality, water availability, microclimatic factors such as temperature and humidity and management. Cattle in this study were found to use riparian areas more when they had unrestricted access to them, and ambient temperature and black globe temperature were found to better indicators of cattle presence in streams and riparian areas. Further, the use of fencing and rotational grazing systems included in this study reinforces the need to include structure practice to limit the time cattle spend in streams and riparian areas and highlights the need to limit the use of riparian areas to protect water quality. In this study fencing with limited access to the stream (crossing) was found to reduce the time livestock spent in riparian zones. While not explicitly stated by the authors, livestock in CSR pastures excluded cattle from the majority of surface waters and riparian areas (97%) and this invariable limited the time spent in riparian areas and influenced the use of upland areas and upland shade. Further, this study found that defecation and urination were commensurate with the time spent in pasture zones. This also reinforces the need to limit the time spent in or near surface waters.

18. Harris, G. A. (1991). Grazing lands of Washington State. *Rangelands (USA)*.

Grazing on Washington land is valuable to generating livestock products in the state. Other uses of pasture and rangeland add value to grazing land resources including wildlife, big game, water, recreation, and open spaces. The study gives an overview of Washington's unique topography, grazing land conditions and resources, vegetation associations, and range conditions across ecological sites. Attitudes/goals of private and public land managers are supportive of restoration/maintenance of Washington's rangeland resources. Although, finding economic practices to implement continues to be a challenge. While Washington's range livestock industry is successful, individual farms face economic struggles to invest in range improvements. With this, range renovation programs that are dependent on private resources will be slow to complete. There continues to be a need for strengthening land rehabilitation programs given invasive vegetation. Establishing noxious weeds, loss of valuable forage species, and loss of irreplaceable soil are critical to rehabilitating rangelands. A unified state and federal program are necessary for focusing economic assistance on local rehabilitation. Extension programs for rangelands, technical assistance, and research are also needed to promote land rehabilitation.

19. Jellison, B., Emme, T., & Cundy, T. (2007). Response of Prairie Stream Riparian Buffers to Livestock Exclusion and Short-Duration Grazing in Northeast Wyoming–A Pre-and Post-Photographic Comparison. *Wyoming Game and Fish Department, Sheridan Regional Office*.

This document is a series of pre- and post- photographs of locations where livestock exclusion was implemented. The photo sites are located in northern Johnson and western Sheridan Counties in northeastern Wyoming within the Northwestern Great Plains ecoregion. Photographs were taken prior to livestock exclusion and then 5 years later at the same location and times (within 4 days). The photo-monitoring was conducted at eleven prairie streams in watershed consisting of predominantly erosive silt and clay loams. While there may not be an equivalent ecoregion in Washington, alluvial valleys with deep sediment would respond to abusive grazing practices is similar ways. This document didn't include any technical analysis or studies to measure vegetation changes over time. However, photo document is an effective way to identify significant changes in vegetation cover and type and also identify some stream channel adjustments. The changes documented in this report are similar to the finding of Batchelor et al., 2015 which found decreases in exposed channels, significant increases in herbaceous cover and reductions in eroding banks and channel width. The rapid recovery and establishment of riparian vegetation captured in this report is consistent with empirical studies and is when grazing pressure and trampling is eliminated from the riparian zone. Some phots in the report suggest channel adjustments including reductions in width and depth ratios. Riparian vegetation is known to stabilize streambanks, increase roughness and flow resistance and facilitate sediment which leads to narrower change widths. Additionally, stream systems with sufficient sediment loading are likely to experience more rapid change adjustments following livestock exclusion that systems will limit sediment loading. This report alluded to channel adjustment that occurred at some sites which is likely a reflection of increase riparian vegetation and sufficient sediment loads give the soil types of the watersheds the sited were evaluated.

20. Johnson, D. E., Clark, P. E., Larson, L. L., Wilson, K. D., Louhaichi, M., Freeburg, T., & Williams, J. (2016). Cattle use of off-stream water developments across a northeastern Oregon landscape. *Journal of Soil and Water Conservation*, *71*(6), 494-502.

The primary objectives of this study were to: 1) assess the influence of water-development locations on broad-scale cattle distribution patterns; 2) examine the timing and intensity of cattle use near water developments; 3) investigate the relative impact of off-stream water development on riparian use by cattle; 4) evaluate the characteristics of water developments receiving the greatest and least amount of cattle use.

As noted by the authors, evaluating the efficacy of water developments can be difficult given the need for continuous monitoring over large, and sometimes very expansive, areas. To overcome some of these challenges, the authors used global positioning system (GPS) technology to track animal locations over five grazing seasons (2008-2012) to evaluate the relative use of water developments and perennial streams by beef cattle within a rugged and expansion study area in northeastern Oregon.

The study areas for this research consisted of three grazing allotments within the Wallowa Whitman National Forest in Baker, Union, and Wallowa counties, Oregon. The three study allotments were extensive with sites 1, 2 & 3 covering 84.0, 46.3 and 39.5 square miles respectively. All three study sites were enclosed in a rectangular area of approximately 29.2 miles (east/west) by 71.5 miles (north/south). The three grazing allotments varied in elevation from 2,405 ft. to 8,051 ft. and were characterized by rugged mountains and uplands that are deeply dissected by canyons. Two of the study areas (Site 1 and Site 2) were located on the southwest slopes of the Wallowa Mountains. The third study area (Site 3) was located at the northern extent of the Wallowa Mountains. In this region, elevation in combination with aspect, precipitation, and temperature gradients determines vegetation potential, and the natural vegetation can be described as approximately one third grasslands and two-thirds forest lands. Precipitation across the sites averaged approximately 22.4 in annually with over half occurring between November and March. Precipitation generally followed the elevation with the driest areas found in the lower reaches of streams draining into the Snake River and the greatest precipitation found in allotments in the Wallowa Mountains. Of the three study sites, Site 1 was the wettest and coolest and driest and warmest was site 3.

Each spring, ten randomly selected mature beef cows (10% to 20% of the herd) were selected and fitted with GPS collars which recorded animal positions at five-minute intervals throughout the grazing season. Livestock turn-out dates ranged from April to June. At the end of the grazing season (October or November) cattle were gathered and returned to their home ranches/winter holding areas where GPS collars were removed and returned to project scientists, and the data was downloaded.

Cattle occupancy around water developments and perennial streams were determined using 60 m (196.9 ft) buffers. A 60 m buffer was selected by the authors because it was presumed to take longer than five minutes for an animal to travel across the buffer to the water source, drink and loaf for four minutes, and exit. Comparisons were made between the relative occupancy at water developments versus streamside areas by site and within sites by month and year. Additionally, the use of water developments was contrasted with riparian zone use. Geographic information such as elevation, slope, and aspect, road, vegetation, soils, prior land use activities and aerial and satellite imagery were used in an attempt to identify factors that contribute to use or disuse by season and site. Estimates of the land area available for grazing with access to water were also made. To do this, the authors used GIS software to create a 1 km (0.62 mi) buffer along streams and off-stream water sources. The authors also used this information to determine the land area (acres) of the overlap between the two. A 1 km buffer was used because previous research that 0.8 to 1.2 km (0.5 to 0.7 mi) was the ideal distance between watering points on the Starkey Experimental Range in northeast Oregon. The authors also noted that no off-stream water developments were within 197 m (646.3 ft.) of perennial streams on any of the study allotments. Since collared animals were selected at random and did not receive special herd management, it was assumed that the spatial behavior of collared cattle was representative of their subgroup. Subgroups typically consisted of 5 to 15 herd mates and calves, as well as the entire herd.

This study was largely descriptive in nature and meant to provide information about how livestock interact with water developments on mountainous landscapes.

When the data was viewed in aggregate across the five years of the study, collared cattle were present on 84.6%, 98.6%, and 89.1% of the allotment surface area for Sites 1, 2, and 3, respectively. As stated by the authors, this implied that water from either streams or water developments was available across the majority of the landscape. Further, it was estimated that water developments increased the potential of animal occupancy by 94% to 246%. Areas not occupied by collared cattle were typically very steep, very rocky, or both. For site 1, 31.8% of the allotment was within 1 km of a perennial stream, 40.7% was within 1 km of a water development and 62% of the allotment was within 1 km of a water source of any kind. For site 2, 30.6% of the allotment was within 1 km of a perennial stream, 70.9% was within of a water development and 77% of the allotment was within 1 km of a water source of any kind. For site 3, 26.2% of the allotment was within 1 km of a perennial stream, 80.8% was within of a water development and 100% of the allotment was within 1 km of a water source of any kind. Sites 1, 2, and 3 had 44, 41, and 68 water developments respectively. The large number of water developments and their distribution on the landscape are the reasons why 100% of Site 3 was within 1 km of a water source of any type.

Cattle use of water developments and perennial streams varied substantially from site-to-site, month-to-month, and year-to-year; and in some months, cattle watered exclusively from off-stream developments while in other months cattle watered nearly exclusively from streams. As an example of the year-to-year variability, the season long average use of perennial streams over the five years of the study ranged from 43.3% to 80.6%, 43.9% to 81.1% and 5.2% to 38.6% for Site1, Site 2 and Site 3 respectively. Further, within any given year, the monthly percentage use of perennial streams vs. water developments varied significantly as well. For example, in 2008 the monthly average use of perennial streams varied from 3.7% to 88.9%, 58.2% to 92.9% and 0% to 96.1% at Site 1, Site 2 and Site 3 respectively. This month variably among sites followed a similar pattern over the five years of the study.

Similar to the amount of use, individual water development use by collared cattle also varied considerably with some water developments receiving no use over the five-year study period and other used frequently. For example, when position data was evaluated on a monthly basis, there were no recorded positions within 60m of a water development on Site 1 during June 2008 and 2011 and on Site 3 in April 2009 and 2011. The highest level of water development use on Site 1 was August and October of 2012. For Sites 2 and 3, August and September 2011 and June and July 2008 were months with the highest water development use respectively. At Site 1, which had 44 water developments, 35% of water development positions were found near a single water source (spring with a tank) and 50% of the positions were associated with two water developments. Site 2 (41 water developments) had a similar pattern with nearly 50% of positions found near two water development. The most dispersed use of water developments occurred at Site 3% (68 water developments) where the two most frequented water developments accounted for less than 21% of collared position. Given that cattle tended to rely on a limited number of water developments especially at Site 1 and Site 2, the author's estimate of the potential increase of cattle occupancy within the allotments due to the presence of water developments may not be accurate or a reflection of the number or distribution of water developments and other factors clearly influenced cattle distribution on the landscape. Although this doesn't necessarily minimize the utility of having additional water developments as they still may be used for short periods when grazing other areas or when transitioning between pastures.

In general, water development use was highest in areas where cattle tended to congregate to forage or rest; however, when the number of counts within 60m of a water development and counts within 1 km of a development were regressed, this association was weak. According to the authors, the variability of water source use was likely a result of pasture rotation, cattle placement within the allotments, other physical and management factors and the timing of cattle movement to upland pastures (within allotments) when cattle switched from watering in streams to watering from water developments such as ponds and springs with troughs. Though it's clear these factors inevitably influenced cattle watering behavior, the authors did not assess if or how these factors actually influenced animal watering behavior especially in locations where cattle could freely access perennial streams or water developments. Of the 10 most frequently used water developments in the study area, 6 were springs with metal troughs and 4 were ponds. The least used developments were generally higher up elevation gradients sometimes as little as 229.7 vertical feet. The authors stated that slope gradient, ease of travel and route were obvious factors that play a critical role in determining which water development are selected.

One of the stated goals of this study was to investigate the relative impact of off-stream water development on riparian use by cattle. Unfortunately, this research goal wasn't fully addressed. Percentages of use where provided; however, the influence of off-stream water developments on perennial stream and riparian area use was not fully assessed. Further, neither riparian nor streamside conditions were assessed to determine if the amount of time cattle spent in these areas resulted in any negative impacts to these areas.

This study would have further benefitted from an examination of the types and number of watering sources available with allotments during any given month and an evaluation of how these factors did or did not affect water source use. For example, did cattle rely on perennial streams because there were no other water sources? Or were water developments used more in some pastures despite the presence of a perennial stream? Further discussion and analysis could have helped explain livestock's exclusive use of perennial streams as water sources in some cases and little or no perennial stream use in other situations. It would have also help determine the influence of water developments on the use of perennial streams. To further illustrate, Site 1 had the largest buffer overlap area between perennial streams and water development. These grazing areas would presumably allow livestock to easily drink from off-stream water developments or perennial streams. Yet, Site 1 had the highest percentage of perennial stream use of the three sites when averaged over the study period. Although, Site 1 also had the greatest number of perennial streams within on the allotment. It's unclear from this study if livestock preferred drinking from perennial streams when alternatives were available or if off-stream water developments successfully limited the amount of time spent in buffer areas along perennial streams. Since there were no water developments within 197 m (646.3 ft.) of perennial streams, it would have been beneficial to understand if this distance (or greater) limited the use of perennial streams or not.

This study demonstrates that in extensive, rugged grazing allotments cattle will commonly use perennials streams extensively on a monthly or annual basis but will also use water developments frequently or even exclusively in some situations as well. Use of water sources can be highly variable and often depends on a combination of management and physical factors such as proximity to surface waters, grazing management strategies, seasonal development and maturation of vegetation and water distribution. Water developments can also be a useful managerial strategy to support wider use of grazing areas, but careful placement is required to improve the likelihood that cattle will find and use these water sources. Further, the availability of off-stream water developments did not consistently limit the frequency or extended use of perennial streams as a cattle water source in this study area.

The geographic setting, vegetation and precipitation characteristics of this study is similar to many grazing settings commonly found in Washington and would be most analogous to the east-slope of the Cascade Mountains, northern border with Canada and eastern border with Idaho stretching from Canada to the Blue Mountain at the Oregon border. The vegetation in these areas commonly consist of a mix of lowland grasslands and upland forestland and tend to similar factor that influence vegetation potential.

21. Kaucner, C. E., Whiffin, V., Ray, J., Gilmour, M., Ashbolt, N. J., Stuetz, R., & Roser, D. J. (2013). Can off-river water and shade provision reduce cattle intrusion into drinking water catchment riparian zones? Agricultural Water Management, 130, 69-78.

The primary aim of this study was to assess whether off-stream water and shading could significantly reduce the interaction of cattle with riparian zones in a temperate Australian watershed. To do this, the behavior of 2 herds was evaluated using GPS collars.

Cattle movements were tracked over four 2-week experiments with the following treatments: (1) an initial, no-treatment baseline; (2) off-stream water only; (3) alternative shade only; (4) off-stream water and shade. The two study sites were selected within the Lake Burragorang watershed. The sites were located 5 and 2 km respectively from the towns of Goulburn (34◦48 S, 149◦40 E) and Robertson (34◦36 S, 150◦36 E). Annual rainfall differed markedly between Goulburn and Robertson sites (530 versus 960 mm respectively), but grazing was a historical practice at both locations. The 59 ha Goulburn site was split into 17 ha (northern) and 25 ha (southern) pastures. Sowing occurred prior to project and so stocking rates were kept slightly less than normally practiced on the property (20, 3 to 6 yr.-old Devan cattle and approximately 1.4 animal unit/ha). Twelve medium-sized Murray Grey beef cattle raised at the Robertson site. Supplementary feeding occurred during winter or when pasture growth was slow, allowing a higher stocking density of 11 animal units/ha. Off-stream water and shade were installed in each paddock. For shade, metal frames were erected to support shade cloth (90% reduction and 3.7 square meters per animal) which was in-line with industry recommendations.

Two experiment series were conducted at the Robertson site. One series was conducted during the Austral winter (25 July 2007–19 September 2007) and the other during the Austral Summer/Autumn (27 February 2008–17 April 2008). Only one experiment series was conducted at the Goulburn site (November 2007–23 January 2008/Austral spring-summer) due to equipment acquisition delays.

Cattle movements were tracked over four, 2-week long experiments including: an initial non-intervention baseline measurement period, followed by three controls with treatment experiments. The four experiments comprised of: (1) characterization of cattle behavior in the absence of any treatment; (2) off-stream water only; (3) alternative shade only; (4) water and shade concurrently. The duration of the experiments reflected animal ethic requirements that cattle be collared two or less months. The study was initially planned to include dedicated ‘treatment’ and ‘control’ paddocks; however, preliminary analysis of the Robertson 1 data suggested differences in cattle movement between the paddocks. To minimize this variance, source, treatment and control paddocks were switched halfway during the Goulburn 1 and Robertson 2 series meaning that each treatment was applied in either the north or south paddock for one week after which the treatments were reversed.

In both the treatment and control experiments, herds utilized the entire available paddocks but in a partially random and partially clumped pattern. Analysis of the time series data indicated that cattle predominantly moved in groups and collared animals were representative of the herd’s overall movement. Cattle also periodically took rapid, short duration visits to the riparian area. When comparing treatments to controls, statistical analysis found highly significant differences although the magnitudes were small. In multiple instances the treatments appeared to actually increase the likelihood of cattle presence in the riparian zone. Equivalent analysis of near-water and near-shade data yielded similar results. There were some highly significant difference and suggestions that livestock were attracted to shade structures. However, the trends were small at best and occasionally the opposite of anticipated outcome.

Given the size of the Goulburn and Robertson paddocks, the authors estimated the random likelihood of cattle to be found in the riparian zone to be 1.25% and 5% respectively. In comparison, 1.5% and 7.5% the location points were found in the riparian zone for the Gouldburn and Robertson paddocks respectively. When frequency was evaluated, treatment and controls were significantly different; however, the trends were inconsistent and the magnitude small. There was a 4-fold difference in riparian visit frequency between the Robertson and Goulburn site likely due to paddock size. However, there were no consistent difference in riparian visit frequency between the controls and treatments. Overall, the river visit data indicated no cattle preference for or attraction away from the riparian zone in the presence or absence of shade structures and off-stream water.

Extended riparian visits (10 minutes or longer) averaged 2-5 occurrences and were slightly shorter at the larger Goulburn sites. While the visit frequency between the smaller Robertson and larger Goulburn paddocks differed significantly, there were no consistent difference between controls and treatments.

The authors hypothesized that near-river occurrences might have been influenced by other water-stress factors such as air temperature, solar radiation, % relative humidity and air speed, and these factors may have overwhelmed the influence of water and shade provisions. Regression analysis of the Goulburn and Robertson site data determined that no variable dominated the regression in all three-experiment series. The authors concluded that heat stress had a statistically significant influence cattle position and distance to the riparian area/river, but the implementation of management measures (practices) to modify behavior did not prove successful.

According to the authors, pre-GPS data indicates that cattle tend to uniformly graze an area (piosphere) several hundred to thousands of meters from there water sources, and this occurs at small or large pastures when watering point are few; and more recent data using position plots supported the hypothesis that grazing tends to be more uniform within 500-1000m of watering points. Further, cattle show preferences for watery areas, gullies and shade within piospheres. For larger pastures, grazing intensity is commonly the highest within 1 km of the water source and significantly tapers off at further distances. When water is further afield, cattle will undertake several, longer trips in pursuit of water when an alternative source is not closer. For these reasons, the authors suggested that grazing patterns may be less influenced by off-stream water in smaller grazing areas (<10-20 ha or 25-49ac). The authors discussed other research that reported improvements following the installation of off-stream water and determined that the results of those studies did not convincingly contract their hypothesis that cattle grazing patterns reflect water stress and that stress may be less influential in smaller grazing areas.

Some of the control versus treatment comparisons found statistically significant tendencies for cattle to spend more time in the riparian zone with off-stream water and shade provisions. Based on the study and the authors' review of analogous literature, they concluded that cattle drinking behavior in smaller paddocks is not fully understood and the evidence appeared insufficient for unreservedly recommending off-stream water and shade for the protection of water quality and riparian buffers.

22. Kauffman, J. B., Krueger, W. C., & Vavra, M. (1983). Effects of late season cattle grazing on riparian plant communities. *Rangeland Ecology & Management/Journal of Range Management Archives*, *36*(6), 685-691.

Objectives of this study were to compare differences in succession, composition, productivity and structure of riparian plant communities that were ungrazed and plant communities that were grazed under a late season grazing strategy (late August- mid September). The study area was located on the Eastern Oregon Agriculture Research Center near the town of Union, Oregon. The study area was a 50-m by 3-km strip of riparian vegetation adjacent to Catherine Creek located in the southwest foothills of the Wallowa Mountains. The study area was part of a 49-ha pasture comprised wholly of plant communities within the riparian zone associated with Catherine Creek. Adjacent uplands were dominated by mixed conifer and ponderosa pine habitats. The study area elevation was approximately 1,030 m, and the annual precipitation was 60 cm. Precipitation for 1979 was lower than average and mean precipitation for 1978 and 1980 was higher than average.

To conduct the study, five livestock exclosures (locations where livestock grazing was eliminated) were constructed along the stream alternating with grazed portions of the study area. Exclosures were constructed to minimize alterations to normal livestock movements. In total, approximately half of the streambank and riparian vegetation within 50 m of the stream was excluded from grazing. Grazed and ungrazed areas contained a sufficient number of similar vegetation stands for meaningful comparison. Grazing began about August 25 and continued for 3 to 4 weeks depending on the amount of forage produced and livestock numbers grazing. The stocking rate on the riparian study area was approximately 1.3-l .7 ha/ AUM. The study was conducted over three grazing seasons from 1978 – 1980. Mean precipitation in 1978 and 1980 was higher than average and lower than average in 1979.

The ten most prevalent communities in the riparian zone were intensively sampled using species frequency, standing phytomass and, where appropriate, included shrub density and height measurements. The 10 communities sampled included dry meadow, moist meadow, Kentucky bluegrass-cheatgrass, cheatgrass, Douglas hawthorne/ Kentucky bluegrass, snowberry-Wood's rose, gravel bars, ponderosa pine/ Kentucky bluegrass and black cottonwood-mixed conifer.

At the onset of the study in 1978, representative stands were stratified by visual observation with respect to species composition, standing phytomass, and structure. Stands found to be significantly different from the others sampled were omitted for further comparisons. Within each selected stand, transects were randomly established and plots were measured at 1/2-m intervals. A 1/4 m quadrat was used for frequency measurements with a 1 / 16-m nested plot used to determine frequency for the prominent species. Frequency was based on 30 plots per vegetation stand with 6-18 stands of each community measured. Typically, half of the stands for each community sampled were in grazed areas and the other half of the stands were in ungrazed areas. Frequency was determined during late June to early July which coincided with times when most perennial species were in an identifiable phenological state and the highest seasonal species diversity for most plant communities. Shrub density, height and composition was measured using transects of 10, 1-m plots, permanently established in 30 vegetation stands. Density and height measurements were recorded for all shrub species with a rooting stem base occurring completely within the plot. Given the rhizomatous nature of many of the woody species, density estimates were recorded as rooting stem density and not as individual plant density. Standing phytomass was determined using a 1/4-m plot. Three stands of each community in both grazed and ungrazed areas were measured by clipping 10 plots in each stand for a total of 30 plots in each community for each treatment. Plots were clipped in late July to mid-August just prior to the onset of grazing. All forbs and graminoids were clipped at the stem base within the plot, oven dried, and then weighed to obtain individual species dry weight estimates. Estimation of utilization was conducted in the fall after cattle were removed and done by an ocular estimate of 10-15 plots in each stand that was sampled for standing phytomass. Stubble heights of key forage species in meadow and Douglas hawthorne communities were estimated by randomly measuring 1 grazed plant per plot.

From the statistical analysis conducted, utilization patterns were found to vary greatly from community to community and often from stand to stand within particular communities. Dry and moist meadows were most preferred, and cattle utilized these communities more heavily than the other communities. More than 60% of the forage produced in these communities was removed by livestock. In the dry meadow community, Kentucky bluegrass was utilized 55-79% with an average stubble height of 3 to 4 cm. Forb utilization in the dry meadow community was moderate to light, with utilization estimates of 33% of 1979, and 15% in 1978 and 1980.

In the moist meadow community, Kentucky bluegrass was moderate to heavy with an estimated utilization of 67-80% and mean stubble heights of 4 to 7 cm. Meadow timothy was utilized at 60-76% with a mean stubble height of 9 cm to 14 cm. The only notable forb utilization in moist meadows was of northwest cinquefoil and white clover. In many stands cinquefoil utilization estimates were greater than 70% and white clover was generally utilized at 60% or greater. Douglas hawthorne was also found to be preferred by cattle especially stands with a relatively open canopy. Utilization in Douglas hawthorne stands ranged from 25 -47% with the more open stands of Douglas hawthorne receiving the heaviest utilization. Stubble heights of Kentucky bluegrass in Douglas hawthorne communities were less than 8 cm.

Utilization on gravel bars was light to moderate with less than 40% of the total available forage utilized. A preference for willows, black cottonwood saplings, and white clover was observed. Utilization of plant communities with a dense canopy cover such as black cottonwood, ponderosa pine, and thin leaf alder was light and usually less than 20% and always less than 30%.

Kentucky bluegrass in forested communities appeared to be less palatable than in meadow communities. Observations in forested communities suggested lower plant densities with fewer tillers per plant but greater leaf blade length compared to those found in meadow or open communities. Lodging (bending over of plant stems near ground level) was more common in communities with an overstory canopy. Utilization occurred almost exclusively on plants that were not lodged. The cheatgrass community was found to be the least preferred of all communities sampled with late season regrowth being the only detectable forage utilized. Utilization in 1978 was 14% and less that 2% of the total available standing phytomass was utilized in 1979 or 1980.

Shrub utilization with the entire riparian ecosystem was neither constant from year to year nor from community to community. Utilization was generally light except in the gravel bar community and on very palatable shrubs. On gravel bars, livestock preferred black cottonwood saplings with a mean utilization rate of 84, 31 and 50% in 1978, 1979, and 1980, respectively. Willow utilization ranged from 27-48%. Utilization on fenced gravel bar communities was always less than 5% for all shrub species and was primarily from big game Cattle utilization of palatable shrubs such as blue elderberry was heavy and often greater than 100% of the current year's growth. Douglas hawthorn shrubs less than 1 m in height were preferred by cattle, particularly in low density stands or as solitary shrubs in meadow communities. Utilization of Douglas hawthorne often exceeded 50% of the current year's growth on many individuals. Douglas hawthorne shrubs exceeding 2m in height were rarely browsed as heavily as the smaller hawthorne shrubs. Snowberry utilization ranged from 9 to 36% in ponderosa pine, snowberry-Wood's rose, and black cottonwood communities. Other shrub species were utilized less than 10%. Precipitation and subsequently forage production was lower in 1979 than 1978 or 1980, and shrub utilization for all shrub species was lower in 1979 than 1978 or 1980.

Differences in species composition between grazed and ungrazed treatments were evident after 3 years in the moist meadow community. Additionally, phenological and temporal differences were observed with the growing season. For example, in some stands the onset of the growing season, flowering and dormancy is areas where cattle were excluded occurred as much as 2 weeks later in the year compared to grazed areas. Significant increases in mesic/ hydric species such as lineleaf indian lettuce, willow weeds and sedges occurred in some excluded stands of moist meadows. For example, by 1980 lineleaf indian lettuce had a mean frequency of 3% in grazed stands compared to a mean frequency of 16% in areas where cattle were excluded, with a frequency up to 47%. Conversely, significant decreases were apparent in meadow timothy and some forbs with the livestock exclosures. In grazed stands, meadow timothy frequency ranged from 73-89% for the 3 years of the study. In exclosures, the frequency of meadow timothy declined significant from 91% in 1978 to 40% in 1980.

Areas more susceptible to trampling damage also experienced changes in species composition with the elimination of grazing. In areas with gravelly, loosely structured soils, cheatgrass dominated the portions of the stand utilized by livestock while quackgrass dominated the excluded area. (Quackgrass is an invasive perennial weed that can rapidly establish in moist, disturbed environments.) In the excluded area, perennial and biennial forbs began to colonize the area while areas outside the exclosure were primarily dominated by annuals.

A well-developed litter layer is forming in the exclosed area. Within the gravel bar communities, cottonwood sapling density and height significantly increased in areas of livestock exclusion after 2 years of rest. Mean height of cottonwoods in grazed areas was not significantly different between years and remained 10-12 cm tall. Changes in shrub composition were also observed including increased density and height of willows and black cottonwood in the ungrazed area while the grazed area remained dominated by a low cover of black cottonwoods.

When impacts of livestock grazing on standing phytomass and productivity were evaluated, the communities with the greatest amount of standing phytomass in the field layer were the communities that exhibited the greatest response to the elimination of grazing. These communities were also most heavily utilized by cattle as forage (primarily wet and dry meadows and Douglas hawthorne communities). Even with some changes in specific compositions, there was no significant difference in total species diversity within the timeframe of the study.

Phytomass varied in many communities from year to year in both treatments. Moist meadow followed this pattern and significant differences were found between grazed and ungrazed plots. Mean phytomass was estimated to be the same for both treatments at the beginning of the study. In 1979 mean phytomass was significantly greater in the grazed treatment; however, mean phytomass dramatically increased in 1980 (nearly three-fold) and was slightly greater than the grazed treatments but not significantly different. Individual species within moist meadows had different reactions to elimination of grazing, and without grazing, it appeared that succession towards a more mesic/ hydric plant community was occurring. For example, exotic grasses such as meadow timothy and forbs more attuned to drier environments decreased and were being replaced by native sedges and forbs more attuned to wetter environments.

Annual fluctuations in total standing phytomass in dry meadows were similar to moist meadows. In excluded areas, phytomass was significantly less in 1979 (precipitation was less than average) than 1978 and 1980. In contrast, phytomass in grazed dry meadows remained relatively stable. Phytomass was found to be significantly higher in the ungrazed plots in 1978 and 1980 but there was no difference in 1979. After three years of no grazing, the Douglass hawthorne/Kentucky bluegrass communities in excluded areas had significantly greater phytomass than grazed areas. This increase was attribute to increases in Kentucky bluegrass phytomass. Forest communities showed few changes in standing phytomass. Cheatgrass communities showed little response to the different treatments.

The effects of grazing on plant community composition were found in vegetation stands were a change in species composition in excluded areas occurred. The authors noted that grazing can open up vegetation and create niches for plants to establish. Additionally, grazing pressure on woody vegetation can prevent the establishment of seedling resulting in an even-aged non-reproducing vegetation community. Woody vegetation communities in this setting generally succeed in the following order: black cottonwood sapling communities formed on gravel bars to willow-dominated communities, to thin leaf alder communities followed by mature black cottonwood-mixed conifer communities succeeding thin leaf alder communities. Examination of the woody species composition on willow-cottonwood sapling dominated gravel bars indicated that grazing was likely restricting succession, and this phenomenon was observed at several locations where these communities were bisected by exclusion fences at the beginning of the study. After three years, shrub density and height appeared to be greater in treatments without grazing and thin leaf alder and some willow species were not found in grazed areas of the study. While it was too early to definitely determine if late season grazing negatively impacted the succession of woody vegetation communities and long-term structural diversity of the riparian area, early evidence and observations indicated this was occurring.

The authors noted that late season grazing could increase the likelihood and intensity of shrub utilization within riparian zones, and this would not likely be as severe in upland (non-riparian) areas.

The primary reason for these expected differences is that late season herbaceous growth in the riparian areas was still succulent and palatable whereas vegetation in the upland generally wasn't. Observation from this study indicated that shrub use by cattle was related to the availability of herbaceous vegetation and palatability of the shrub species. Also, discernable shrub browsing did not generally begin each year until the later part of the grazing season. When herbaceous vegetation was available in the riparian zone, shrub utilization was limited. The authors noted that this observation was similar to observations in the Blue Mountains of Oregon where little shrub utilization occurred, except with highly palatable species, when stubble height was 10 cm or greater. When stubble height was further reduced, grazing shifted to less palatable species.

Herbage removal from grazing appeared to be an important factor in altering seasonal phenology of mesic/hydric communities. In grazed areas, flowering for most grasses, sedges and perennial forbs occurred early than excluded areas where most vegetation was still in vegetative form. This was likely due to higher litter density and subsequent lower soil temperature and higher soil moisture in excluded areas. Increased soil moisture from increases in litter was likely an important factor for the increased abundance of mesic/hydric species and the reduction of species more attuned to drier environments in moist meadows with livestock exclusion.

Livestock trampling and trailing was localized to communities with moist or saturated soils susceptible to compaction. The authors noted that communities in these areas, with fragile, loosely consolidate gravelly soils, are susceptible to physical damage and uprooting. The authors further noted that communities with saturated soils present throughout the grazing period were the only vegetation stands with the potential for severe compaction during late season grazing and the majority of stands had low moisture levels. However, there was some evidence of recovery from the elimination of grazing on areas with loosely consolidated, gravelly soils.

When discussing management implications, the authors noted that management strategies may be beneficial to some communities and detrimental to others. The study found that late season grazing had major influences on some communities and no detectable influence on others. The authors further noted other research (Kauffman et al. 1982, Kaufman et al. 1983) that found later season grazing to significantly increase streambank erosion and cause significant, short-term decreases in small mammal densities.

When discussing forage quality, the authors also noted that riparian vegetation in the late season is generally more palatable and of higher nutritional value than vegetation in the upland community. It was also noted that a study within the same location found improved dry matter digestibility, improved protein levels, lower lignin and lower acid detergent fiber in diets of heifers grazing the same riparian area during the late season (August – early September) compared to upland vegetation up to 1 month preceding this period. Daily intake rates were also greater in the riparian zone than upland pastures either before or after the August – early September timeframe.

23. Kauffman, J. B., & Krueger, W. C. (1984). Livestock impacts on riparian ecosystems and streamside management implications... a review. *Rangeland Ecology & Management/Journal of Range Management Archives*, *37*(5), 430-438.

The study gives an overview of how riparian zones are impacted by livestock and the importance of preserving riparian/stream ecosystems. Riparian zones are valuable to wildlife and cattle across the Pacific Northwest were found to have a strong preference for riparian zones. The study explores livestock riparian relationships in more detail and provides considerations for livestock-riparian management as well as impacts of livestock on instream ecology. Recognizing and understanding impacts on riparian zones from previous and current land use practices is essential to streamside land planning. With this, public grazing lands should be managed on a multiple use basis that recognizes the biological potential of various ecological zones. Furthermore, management strategies that recognize resource values should be designed to maintain or restore the integrity of riparian communities.

24. Kauffman, J. B., Thorpe, A. S., & Brookshire, E. J. (2004). Livestock Exclusion and Belowground Ecosystem Responses in Riparian Meadows of Eastern Oregon. *Ecological Applications*, 1671-1679.

This study examined how livestock exclosures change belowground ecosystem properties such as total above and below ground biomass, soil properties such as pore space, water holding capacity and associated infiltration rates, soil nitrogen and potential nitrogen mineralization. Implications for watershed management are also discussed. The study was conducted in the upper reaches of the Middle Fork John Day River in the Blue Mountains of northeastern Oregon. The study evaluated ecosystem properties at 6 floodplain meadow sites each containing wet and dry meadows. 3 sites were areas where livestock had been excluded between 9-18 years and the remaining 3 sites had been continuously managed for cattle grazing. Livestock grazing and hay production had been the dominant land use in the floodplain meadows since the 1800s and the ecological conditions and livestock management of these sites were judged to be representative of region. Livestock removal was found to significantly improvements to soil hydraulic and vegetation properties. For example, exclosed sites had significantly higher total below ground biomass, lower bulk density, higher soil pore space and higher infiltration rates when compared to grazed sites. The authors found that livestock removal was an effective approach to ecological restoration and highlighted how greater root mass and improved soil properties could better stabilize streambanks, reduce erosion and dramatically increase soil water storage. While the results of this study are clear and demonstrate improvements to riparian ecosystem properties that can result from livestock exclusion from riparian areas, it wasn't designed to evaluate how stocking rates affected ecosystem properties within each treatment site. This study is applicable to wet and dry meadow locations in Washington state especially in rangeland and forested ranges east of the Cascade Crest. Furthermore, this study highlights the need to consider additional ecosystem properties beyond aboveground vegetation when evaluate livestock impacts to riparian areas and when developing any grazing approach.

25. Line, D. E. (2003). Changes in a Stream's Physical and Biological Conditions Following Livestock Exclusion. Transactions of the ASAE, 46(2), 287-293.

This study was designed to evaluate changes in physical water quality parameters and fecal coliform and enterococci bacteria levels that resulted from the installation of livestock exclusion fencing in a dairy cow pasture. The effects on water quality from the implementation of an alternative water supply without exclusion fencing and a culvert style stream crossing were also evaluated. The study was conducted on a small stream in the Long Creek watershed located in southwestern North Carolina. The study included 2.25 years of water quality monitoring prior to the installation of exclusion fencing. Prior to the installation of exclusion fencing, fecal coliform and enterococci levels were more than 300% greater at a downstream monitoring location compared to an upstream station. After fencing, fecal coliform levels decreased by 65.9% and enterococci levels decreased by 57%. Turbidity and suspended sediment levels were also significantly reduced. While, pH, dissolved oxygen, temperature and specific conductivity improved relative to upstream conditions, the changes were not statistically significant. Off-stream watering without fencing was not found to be effective at improving water quality. The culvert style stream crossing was believed to enhance the effectiveness of the livestock exclusion fence and buffer created by the exclusion fencing. In other studies, and literature reviews, livestock exclusion fencing has been shown to improve riparian soil conditions and facilitate the recovery of degraded riparian vegetation and altered stream channels. This study provides water quality specific information that can be used to establish best management practice recommendations that protect or improve streambanks, natural riparian vegetation and functions and instream water quality. The location of this study is not completely analogous to all grazing settings in Washington State especially as it relates to regional climate. However, the study site likely shares attributes of many cow dairy, heifer replacement and beef cattle operations found east of the Cascade Crest. For example, most western Washington livestock operations have pastures that are grazed from spring through fall and many of these pastures are adjacent to surface waters with and without livestock exclusion fencing. Also, the study location and many western Washington counties have similar annual rainfall, and each location typically has livestock grazing properties situated in lowland watersheds with moderate to low slopes where facilities and pastures are adjacent to smaller, low-order streams. Additionally, the pollutants, pollutant sources and transport mechanisms are the identical. The climates of central and eastern Washington are different from the study site. However, many of the site attributes such as pastures without and without fencing, livestock access to low-order streams and pollutant sources and transport mechanisms are very similar or if not the same.

26. Magilligan, F. J., & McDowell, P. F. (1997). Stream Channel Adjustments Following Elimination of Cattle Grazing 1. *JAWRA Journal of the American Water Resources Association*, *33*(4), 867-878.

This article examines geomorphic adjustment following the elimination of cattle grazing through fencing. For the study, the authors evaluated four stream segments in eastern Oregon where livestock were excluded for more than 14 years and compared channels inside the exclosed areas to adjacent grazed reaches. The results indicate that significant geomorphic changes occur following the removal of livestock grazing stresses to the riparian area with channel narrowing (bankfull and low flow widths) and increased pool area being the dominant response. While most geomorphic properties changed, not all properties demonstrated recovery and the response in some reaches was opposite of what was hypothesized. The authors provided geomorphological mechanisms to explain width reductions and the increase in pool areas. The authors also provided factors that may influence or limit stream channel adjustments such as time required for change to occur and local controls such as stream gradient, availability of course and fine sediment, tributary influences, channel bed substrate, riparian vegetation and riparian vegetation recovery. The article found that some channel adjustment (improvements) can occur within 14 years, but other variables may take longer. Additionally, the authors highlighted to lack of long-term term studies to evaluate stream morphology changes and provided some possible reasons for the lack of strong consistency in observed channel response found in the literature.

27. Malan, J. A. C., Flint, N., Jackson, E. L., Irving, A. D., & Swain, D. L. (2018). Offstream watering points for cattle: protecting riparian ecosystems and improving water quality? Agriculture, Ecosystems & Environment, 256, 144-152.

In this article the authors conducted a literature review to identify key factors that influence how cattle use off-stream watering points and also conducted a meta-analysis to determine if OSWPs are an effective best management practice to reduce the time cattle spend in riparian zones. A multi-step review process was used to identify relevant articles for the literature review and meta-analysis. Key search terms such as "off-stream watering points", "water quality", "riparian, distribution" and "grazing" were first used to identify papers that made reference to the use or placement of off-stream watering points. Identified papers (n=1135) were screened a second time to determine if the article had sufficient data for a meta-analysis.

Based on the second review criteria, a total of 53 articles were reviewed in full leading to the an exclusion of 16 articles because they either lacked sufficient information about the use of off-stream watering points to improve riparian health or water quality (n=11), had poor scientific quality (n=3) or were not relevant because they did not include specific information about off-stream watering use (n=2). A total of 37 articles were used for the review and seven of the 37 articles had sufficient data for a meta-analysis.

The reviewed studies were conducted in a variety of Koppen climate zones i.e., dry (arid and semi-arid), temperate (warm/mild), continental and tropical/sub-tropical. Studies conducted in temperate, arid/semi-arid and continental zones are most analogous to condition founds in Washington State. The majority of research was conducted in the United States (n=24) followed by Canada (n=5), Australia (n=4), Brazil (n=2) and New Zealand (n=2). Of the North American studies, the majority of studies were conducted in continental climate zone (n=16) followed by temperate (n=8) and arid (n=6). Five of the seven studies used for the meta-analysis were located in continental climate zones. Washington contains a mixed of temperate, continental and arid climate zone, and studies conducted in these environments are most analogous to conditions founds in Washington State.

From the 37 articles reviewed, the authors identified seven factors and 5 sub-factors that may influence cattle use of off-stream watering points. The primary factors identified included: off-stream watering distance from stream, slope, climatic conditions, shade availability, drinking water quality, grazing management, and animal social behavior. The sub-factors were associated with climate (season and temperature humidity index) and grazing management (stocking density, paddock size and shape, and supplements/mineral licks). Each factor had varying effects on cattle use of off-stream watering and some of the factors appeared to be interdependent.

The meta-analysis in this article found some evidence that off-stream watering did reduce the time cattle spent in riparian areas, however with significant variation (63.7%). The authors noted that factors other than simply providing an off-stream watering points needed to be considered to ensure time spent in riparian areas is reduced. For example, off-stream water at the same distance from waterways yielded both positive and negative results which further indicated that the placement (distance from stream) was not the only variable impacting outcomes.

Based on the meta-analysis, the authors concluded that off-stream watering in cold climates "had little to no effect in reducing the time cattle spent in the riparian zone". Additionally, the overall effect of off-stream watering was an increase in time cattle spent in the riparian area. The authors did however suggest that off-stream watering may be more effective in temperate/subtropical climates and could help reduce the time cattle spend in riparian areas under the following environmental conditions: slope<10%; distance from the stream at either 93–100m or 1100 m; paddock size<20 ha or>140 ha; placed with shade; THI between 60 and 72, good OSWP water quality and good grazing management practices.

With that, the authors also stated that the large number of influencing factors and limited data was insufficient to establish off-stream watering guidelines to positively impact water quality.

While off-stream watering itself doesn't appear to be effective at reducing the time cattle spend in riparian areas in cold climates, factors identified in this journal review may influence the use of off-stream watering and these factors may have some relationship to animal distribution and forage utilization. This information could prove valuable when evaluating structural and management practices to facilitate improved animal distribution and forage utilization.

28. Maloney, S. B., Tiedemann, A. R., Higgins, D. A., Quigley, T. M., & Marx, D. B. (1999). Influence of Stream Characteristics and Grazing Intensity on Stream Temperatures in Eastern Oregon.

The objectives of this study were to assess the effects of three rangeland management strategies of increasing intensity on instream water temperature and evaluate watershed characteristics that influence stream temperatures. To do so, the authors established summer temperature characteristics of the study watersheds, assessed the relationships between stream characteristics and summer temperatures and determined the influence of increasing intensity of range management strategies on summer stream temperature.

The study was conducted in 12 watersheds within the northern part of the Malheur National Forest located near John Day, Oregon. Study watersheds ranged from 1.2 to 18.1 square kilometers (0.5 to 7.0 square miles) with each watershed predominantly consisting of one or two distinctive ecosystems including fir/spruce, larch, mountain meadow, ponderosa pine, lodgepole pine and Douglas fir. The three range management strategies used in the study included a control (no grazing), average stocking rate of 7.7 hectares per animal unit month with grazing management to attain uniform livestock distribution (strategy C) and a stocking rate of 2.8 hectares per animal month with grazing management to emphasize livestock production (strategy D). Multiple grazing management approaches were used to achieve each grazing strategy including deferred rotation, rest-rotation, no-use and season-long use. Four watersheds were used as controls, five were used for strategy C and three were used for strategy D. Strategies were assigned to watershed based on their inclusion in the larger treatment area and strategy D watershed were in areas selected for their potential for sufficient forage production to support grazing at a stocking rate of 2.8 hectares per animal unit month.

Data from a nearby location (Austin, OR) indicated that the study area receives 20 to 50 inches of precipitation with the majority (70%) occurring between November and April as snow. The mean temperature in July was 16.7 ^{o}C (62.1^{o}F). The annual hydrograph is dominated by snowmelt that begins in March at lower elevations and mid-May at higher elevations. Peak flow occurs mid-April to early June based on elevation and aspect with flows diminishing through the summer with the lowest flows occurring in August and September.

The authors noted that these runoff patterns are similar to those reports for other watersheds in eastern Oregon and Washington.

Stream temperatures were continuously recorded at the mouth of each watershed during the summer months from 1978 to 1984. Watershed streams were also divided into reaches to determine stream characteristics including percentage of shade, aspect and gradient. Following data collection, analysis was conducted to determine the relationship between stream temperature, watershed characteristics and rangeland management strategy. Additionally, multiple regression analysis was used to determine the amount of variation in stream temperature due to stream characteristics, air temperature and cloud cover.

Maximum stream temperatures in the 12 watersheds ranged from 12.5 to 27.8 ^{o}C (54.5 to 82.0 ^{o}F). Minimum temperatures were similar for all watersheds and ranged from 3.5 to 5.0 ^{o}C. Maximum weekly temperatures ranged from 10.9 to 17.8 ^{o}C. The date of maximum temperatures varied from year to year, but more than 88 percent were observed July 16 to August 19.

To evaluate the relationship between stream temperature and stream characteristics, maximum and mean weekly stream temperatures were regressed in comparison to stream characteristics to evaluate stream temperature variation. The author's best model from stepwise regression analysis explained 67 percent of the variation in stream temperatures based on eight factors in declining order: shade, week, weekly flow, width, year, travel time, elevation, and aspect. Based on a visual examination of cumulative frequency distribution curves of the percentage of time a temperature was exceeded for individual watersheds and further statistical analysis, the authors identified three groups of watersheds. Group 1 watersheds had the lowest temperatures, the highest mean percentage of shade, the highest 7-day low flow, the highest mean elevation, and the shortest mean travel time. All group 1 watershed were control or lower intensity management watersheds. Group 3 watersheds had the highest temperatures, the lowest mean percentage of shade, the lowest 7-day low flow, and the longest mean travel time. All group 2 watersheds were in low or high intensity grazing management. Group 2 watersheds (control and low intensity grazing management) were intermediate in temperature response compared to group 1 and 3. When compared to group 3, group 1 was found to be less responsive to light because it had over twice the amount of percent shade.

The effects of range management strategies on stream temperature were observed by not entirely definitive. Maximum hourly and mean weekly temperatures were significantly different among management strategies with strategy D (intensively managed) having significantly greater maximum hourly and mean weekly temperatures that those from strategy A (control). Streams in category C were not significantly different that strategy A or D. In some situations, the dominant ecosystem in the watershed was found to effect mean weekly stream temperatures. Mean weekly stream temperatures were significantly greater for mountain meadow and ponderosa pine than larch/Douglas-fir and fir/spruce ecosystems. Stream temperatures for the lodgepole pine ecosystem were not significantly different from streams of the other ecosystems. Differences among ecosystems were primarily explained by differences in the amount of overstory shade. Overstory shade was greatest for larch/Douglas-fir and fir/spruce ecosystems and least for mountain meadow. When stream temperatures were evaluated in one of the twelve watersheds (Caribou Creek), daily maximum stream temperature generally increased downstream as shade decreased with the exception of a slight reduction of maximum temperature with the increase of shade (26-64 percent) between reaches 3 and 1. Statistical analysis found that temperature differences were attributable to differences in stream shade; although, when shade was used as a covariate, the range management was not significant. The author noted that two of the three D strategy watersheds had areas with mountain meadows and that these areas are highly susceptible to temperature increase from grazing because once streambank vegetation is removed, and streambanks are rounded there is nothing to shade the stream. Further noted by the authors was the nearly 100 years of grazing use and logging in the area which likely had a strong influence on stream temperature through the removal of streamside shrubby vegetation and caving of overhanging banks. The authors also speculated that more heavily forested areas probably received less previous grazing use, and the strong influence of watershed characteristics likely masked the effects of range management strategy.

The effects of the tested grazing strategies on stream temperature were not definitive in this study which were likely was due to the strong influence of watershed characteristics and the consequences of prior grazing management and other activities in the watershed. Nevertheless, the authors found that intensively managed grazing sites had significantly higher maximum hourly temperatures and mean weekly temperatures, and all three intensively managed and one moderately managed watershed exceeded temperature standards due to insufficient shade from the lack of riparian vegetation. The authors also found that watersheds with greater than 75 percent effective shade had maximum hourly stream temperatures within acceptable limits which was highlighted by the authors when the emphasize the importance of riparian vegetation to provide shade and prevent stream from reaching lethal levels for trout and salmon (chinook). The authors concluded maintaining the integrity of riparian zones could be achieved by using buffer strips and by more stringent control of animal use of riparian areas. Also, of the variables affecting stream temperature, streamside vegetation is probably the most easily manipulated.

29. Marlow, C. B., Pogacnik, T. M., & Quinsey, S. D. (1987). Streambank stability and cattle grazing in southwestern Montana. Journal of Soil and Water Conservation, 42(4), 291-296.

To evaluate the relationship between timing of cattle grazing and riparian degradation, Marlow et al. (1987) conducted a four-year study along a small tributary with the Cottonwood Creek watershed in southwestern Montana. The stream and its headwaters are located on the Montana Agricultural Experiment Station’s Red Bluff Research Ranch. Cottonwood Creek watershed is approximately 1,360 ha (3360 acres) is characterized by moderate to steep slopes and elevations range from 2,000 m at the headwater spring to 1,400 m where it enters the Madison River.

The riparian community was dominated by a mixture of grasses, forbs, sedge and shrubs with an overstory of quaking aspen. The upland communities included a mixture of grass species along with scattered stands of sagebrush interspersed with Rocky Mountain juniper and Wood's rose. The study stream (Cottonwood Creek) is small stream with an average flow of 0.16 m3/s. The channel substrate consisted of angular gravel, silt, and fine clay and less that 20% of the banks were rock or gravel. Mean daily air temperatures range from 20°C in July and August to -11°C in December. Annual precipitation ranges from 400-500 mm (15.7 – 19.7 in.) and is primarily from snowfall between October and March, rainfall during May and June. Precipitation from July, August, and September contribute less than 20% of the annual total.

A 5.5-ha section of Cottonwood Creek was fenced in the spring of 1981 to create nine paddocks with equal amounts of upland and riparian communities. One paddock served as an ungrazed control and the other eight were grazed sequentially for 14 days each beginning with the paddock furthest downstream. This sequence created eight timeframes including late June grazing, early or late July grazing, early or late August grazing, early or late September grazing, or early October grazing. These times spanned the timeframe of a typically grazing season of the areas. A stocking rate of four yearling cattle per 0.6 ha was established to remove half of annual forage growth.

Channel profile changes, grazing periods, measurement interval, streambank moisture, streamflow, and cattle use-levels were measured to determine the effects of timing of cattle grazing on streambank degradation. Streambank moisture was measured at two points in each paddock when the cattle were introduced to a pasture using a neutron scattering technique. Streambank and channel alterations were monitored by establishing five permanent channel cross-section transects in each paddock. The vertical distance from the level transect line to the channel bed was measured at horizontal intervals of 10 cm at the beginning of the grazing season and immediately after each paddock was grazed. As a result, the time between pre-grazing and post-grazing measurements increased as the grazing season progressed. Differences were summed and the absolute values were used to develop a profile change index for each transect. Streamflow recorders were positioned at three locations along the creek in the grazed area and at the downstream boundary of the ungrazed paddock. Streamflow date from the unit nearest to the treatment paddock were used in comparing streambank and channel changes to streamflow level during that period. Cattle use patterns were based on two, 24-hour observation periods each week in 1982 and 1983 totally 32 observations annually. Feeding and resting activities in the riparian zone or upland were recorded hourly during each observation period. The number of observations in each activity category and location were summed for each grazing period and divided by the total observations to arrive at the percentage of time spent in each zone.

Analysis of the data found a distinct downward trend in channel profile change during the season. The magnitude of change was greatest in early grazing periods (late June through early August) and lowest in early October. Changes occurring from late August to early October were typically greater than the level of change in the ungrazed portion of the same stream; however, they were not significantly different. While channel profile change level declined dramatically in late August each year, variation among channel transects in paddocks grazed in late July, August, and September was great enough to suggest this pattern was continuous.

Cattle use of riparian areas declined from approximately 20% to 10% from late June to early July, but steadily increased to over 60% by late August and remained above 60% for the remainder of the grazing season. Comparison of channel change with cattle use and measurement interval indicated that both use, and interval were closely related to the pattern of change. Alterations in channel profile appeared to decline as the percentage of time cattle spent in the riparian zone or the interval between pre- and post-grazing measurements increased. The negative relationship between cattle use and channel change was puzzling to the authors given previous case studies that suggested high cattle use resulted in altered stream channel profiles. The authors noted the possibility that changes in channel profile during late August, September, early October treatment and the ungrazed control were not detected because the interval between pre-and post-grazing measurements was too long. However, further examination of the type and degree of change that occurred between measurements of individual transects indicated significant changes in all paddocks in all 4 years.

According to the authors, high streamflow during periods of high soil moisture has been suggested to causes severe bank erosion. Higher stream flows were significantly related to the amount of change in the channel profile during 2 of the 4 years of this study. While streamflow appeared to be the major factor in bank erosion, the consistently greater amount of alteration during the early part of the grazing season suggested that either streamflow differed from paddock to paddock, or some other factor was affecting channels during high-flow periods. The authors found it unlikely that flow was the only cause of great bank erosion because there was no significant difference in flow among the five recording locations in three of the four years of observations. Consequently, the presence of cattle during periods of high flow appeared to be the only explanation for the elevated levels of streambank erosion in late June, July, and early August. Given that streamflow generally declines from June to October and streambanks typically become progressively drier, the general lack of significant stream profile change in this study seemed to support the idea that streambank moisture levels at the time of grazing may be correlated to the degree of alteration cattle impacts on streambanks may be seasonal.

The results of this four-year study indicated both streamflow and cattle use were highly correlated with the degree of stream channel profile change. The greatest streambank change occurred during periods of high streamflow and low cattle use. Further statistical analysis of the data indicated that streamflow itself was not a major factor in bank erosion. While not significant in all years, the decline in channel change appeared related to the seasonal trend in soil moisture and cattle grazing. As streambank moisture levels declined, the extent of channel alteration also declined. Channel profiles changes in paddocks grazed after early August when banks had dried commonly greater than the ungrazed control but were not significantly different ($P < 0.05$). This decline was in sharp contrast to the pattern of cattle use which was the lowest in late June and early July and highest in September and October.

Results from this study supports the argument that a combination of high flow, moist streambanks, and cattle use leads to major streambank alteration.

30. McInnis, M. L., & McIver, J. (2001). Influence of off-stream supplements on streambanks of riparian pastures. Rangeland Ecology & Management/Journal of Range Management Archives, 54(6), 648-652.

For this study, the authors tested the hypothesis that providing cattle free choice off-stream water and trace minerals would lessen negative impacts of grazing on riparian vegetation cover and streambank stability compared to pasture without these amenities. The study was conducted on Milk Creek at the Hall Ranch Unit of the Eastern Oregon Agricultural Research Center near Union, Oregon. The study included three replicates of 3 grazing strategies including 1) non-grazed control 2) grazed with supplemental water and trace mineralized salt and 3) grazed without supplemental water or salt. Nine pastures of approximately 12 ha (30 acres) were established in three blocks along Milk Creek. The blocks were established because they represented different habits including 1) forest 2) forest and meadow and 3) primarily meadow. The three treatments were randomly assigned to the pastures in each block. Off-stream water was provided in troughs approximately 1200 ft. from the stream and salt supplements were place about 15 ft. from the troughs. For the grazing treatments, 10 cow-calf pairs were introduced into each of the 6 pastures for 42 consecutive days beginning in mid-July 1996 and 1997. The average stocking rate of 0.8-0.9 AUM/ha was slightly more than double to stocking rate of the previous 5 years. Following cattle removal after the second year of grazing, the percent of stream plots having hoof print, streambank cover and streambank cover and stability were assessed. Neither the streambank cover nor streambank stability differed significantly between the supplemented and non-supplemented pastures; however, there was a trend for the supplemented pasture to have lower hoof prints. Also, when compared to the non-grazed control, providing off-stream water and salt prevented the significant loss of cover observed in non-supplemented pastures. The largest change observed in this study was the significant decrease in the proportion of streambank classified as covered and stable. Both the supplemented and non-supplemented pastures showed significant decreases in the cover/stability class with 10% and 14% reductions respectively. These reductions in cover/stability were not found to be significantly different and bank instability likely had the greatest influence on the cover/stability changes. Ultimately, grazing resulted in a decline in streambank stability, decline in covered/stable streambank class and increased soil erosion potential. The degree that livestock are attracted to riparian areas can vary depending on a variety of factors such as topography, vegetation, weather, forage quality and quantity. This study could have benefited from additional analysis to consider the three grazing blocks and the associated environmental factors that could have also influenced cattle position. Nevertheless, the finding of this study did not validate the hypothesis that free choice supplements would less impacts of grazing on cover and streambank stability compared to pastures without these amenities. Furthermore, grazing at the stocking rate and duration of the study (0.8 ha/AUM and 42 continuous days after mid-July) led to a decrease in streambank stability.

31. McInnis, M. L., & McIver, J. D. (2009). Timing of cattle grazing alters impacts on stream banks in an Oregon mountain watershed. Journal of Soil and Water Conservation, 64(6), 394-399.

Studies indicate that cattle tend to congregate in riparian areas due to the availability of water, greater forage quality and quantity, proximity to higher quality upland grazing sites and microclimatic features such a shade. The timing of grazing can also affect the use of riparian areas and subsequent effects on streambanks. The purpose of this study was to test the hypothesis that early summer grazing (28 days; mid-June to mid-July) would have less impact on stream bank cover and stability compared to late summer grazing (28 days; mid-August to mid-September).

To test the author's hypothesis, a two-year study was conducted at the Eastern Oregon Agriculture Research Center in northeastern Oregon where three replications of three grazing treatments were examined including: (1) non-grazed, (2) early summer grazing, and (3) late summer grazing. The pastures were established in three blocks along a 2.4 km (1.5 mi) stream reach (Milk Creek) within the study area. Block 1 was forested with ponderosa pine and Douglas hawthorn, Block 2 was mix of forest and meadow and Block 3 was primarily meadow dominated by Kentucky bluegrass, sedges and other dicots. The dominant riparian forages in all blocks were Kentucky bluegrass, sedges, timothy, meadow foxtail and brome. Each grazed pasture (approximately 11.5 ha [28.4 ac]) was stocked with cow-calf pairs for a mean stocking rate of 0.7 ha per animal unit month (AUM–1) (1.7 ac AUM–1) (range 0.5 to 9.0 ha AUM–1 [1.2 to 22.2 ac AUM–1]) to achieve moderate grazing intensity of 35% to 50% utilization. Three grazing treatments were randomly assigned to pastures within each block beginning in 1998 and remained the same in 1999. This study site is similar and analogous to forested range settings found in central and eastern Washington.

Estimates of stream bank cover and stability were taken before and after each grazing period and forage utilization was measured at the end of the grazing period. The mean forage utilization over the two-year study was 37% (ranged 31% to 40%) in early-grazed pastures and 41% (ranged 34% to 55%) in late-grazed pasture. Stream banks were examined by pacing the entire length of Milk Creek on both sides and recording the appropriate stream bank cover and stability class within plots defined lengthwise as a step (about 0.5 m [20 in]) taken parallel to the stream. Plot width were about 0.3 m (12 in) and within the greenline (the first vegetation at the water's edge or slightly below the bankfull stage). The number of plots with hoof prints were tallied to establish a frequency (number of plots with hoof prints ÷ total number of plots examined.

Plots were classified "covered" if they contained any of the following features: (1) living perennial vegetation ground cover greater than 50%, or (2) roots of deeply-rooted vegetation such as shrubs or sedges covering more than 50% of the stream bank, or (3) at least 50% of the stream bank surface covered by rocks of cobble size or larger, or (4) at least 50% of the bank surface covered by logs of 10 cm (3.9 in) diameter or larger. Otherwise, plots were rated "uncovered." Cover estimates were based on visual assessment. Plots were classified "stable," unless they exhibited any of the following features: (1) blocks of banks broken away and laying in the stream channel adjacent to the bank breakage (bank breakage), (2) bank sloughed into the stream channel (slump), (3) bank cracked and about to move into stream (fracture), or (4) bank uncovered as defined above with an angle visually estimated steeper than 80 degrees from horizontal (vertical bank). Plots exhibiting any of the above-mentioned features were rated "unstable." Each plot (step) was rated according to stream bank cover and stability and was grouped into one of four classes: (1) covered/stable, (2) covered/unstable, (3) uncovered/stable, or (4) uncovered/unstable. A single observer conducted the survey. Each parameter was analyzed using multifactor analysis of variance (ANOVA).

An evaluation of streambank cover found that early grazing (-3%) did not differ from non-grazed controls and was significantly less than the reduction (8%) in cover observed following late summer grazing. Streambank stability declined as a result of early season (-13%) and late season grazing (31%) though the decline in late season grazing was considerably greater. There were significant treatment effects on cover, stability and cover/stability classes including negative changes in percentages of the covered/stable, covered/unstable, and uncovered/unstable categories. The greatest change was in the covered/stable category, which declined 10% during early summer grazing and 28% during late summer. Grazing also resulted in increased percentages of covered/unstable and uncovered/unstable stream banks in each category with the greatest increase resulting from the late summer grazing treatment. There were proportionally larger changes in streambank stability comparted to cover that resulted from grazing. As a result, declines in bank stability likely contributed more to change in the uncovered/unstable category than did decreases in cover. This is further reflected by the fact that the uncovered/stable category did not change in relation to non-grazed controls, while the covered/unstable category declined significantly ($p \leq 0.05$). The stream bank instability class that contributed most to the proportional change was slumping which was significantly greater for both treatments when compared to the non-grazed control. Although slumping was 2.5 times greater in late summer grazing compared to early summer grazing. Bank breakage was greater in grazed pastures than non-grazed controls, but differences due to timing of grazing were not significant ($p \leq 0.05$). Grazing did not significantly ($p \leq 0.05$) increase the occurrence of bank fracturing or of vertical banks compared to non-grazed controls. These observations coincide with two-year forage utilization rates of 37% in early-grazed pastures and 41% in late-grazed pasture.

The erosion index for both grazing treatments increased significantly compared to the non--grazed control. However, the proportional increase was significantly higher following late summer grazing (1.62x) than early summer grazing. The authors noted that previous work at this location demonstrated that cattle were consistently further from the stream and spend less time near the stream during the early summer than during late summer. The authors also noted conflicting results of studies that evaluated the effects on morphology from early and late season grazing. Neither grazing system clearly reduced impacts to geomorphology.

In this study, there were no significant difference in cover between early-grazed and non-grazed treatments, but the concentration of cattle in the riparian zone during late summer resulted in a near threefold increase in the loss of cover compared to early-grazed pastures. As highlighted by the authors, grazing along stream banks can cause as much or more damage to stream and riparian habitats through bank alteration as through changes in vegetation biomass. Results from this study demonstrate that grazing during either season caused significant declines in stream bank stability even when forage utilization targets were met. Although, late season grazing reduced bank stability more than twice as much as early season grazing.

32. Miller, J. J., Chanasyk, D. S., Curtis, T., & Willms, W. D. (2010). Influence of streambank fencing on the environmental quality of cattle-excluded pastures. Journal of Environmental Quality, 39(3), 991-1000.

The objective of this study was to determine if 4-6 years of riparian fencing would result in improved environmental conditions within a livestock-excluded area compared to an adjacent grazed area. To do so, the authors measured environmental conditions within a cattle-excluded area and adjacent grazed pasture and compared the results. Conditions measured included rangeland health, vegetation health, soil properties and rainfall simulated runoff. The sites for this study were located in the Lower Little Bow watershed in southern Alberta, Canada which is part of the Great Plains of North America. Riparian exclusion areas were established in 2001 and the study was conducted over the course of three years from 2005-2007. Prior to the installation of exclusion fencing the riparian area and adjacent pastures were both grazed. Grazing typically occurred from June – August. Stocking rates were 0.50 animal unit month (AUM) ha-1 from 2001 to 2003 but were later reduced to .40 AUM ha-1 from 2004 to 2007 because of weed problems and overgrazing. The distance from the fence to the river edge ranged from 40-80m. The study site vegetation was primarily grass communities dominated by wheat grass and needle-and-thread grass. Underlying soils were moderately drained loam consisting of medium to moderately coarse fluvial material.

This study found that cattle exclusion resulted in many positive changes to environment conditions. Rangeland health scores improved (55 to 72%) and vegetation cover (13-21%) and standing litter increased (38-72%). After 6 years, the excluded area was categorized as "healthy with problems" while the grazed area was determined to be "unhealthy". Bare soil and soil bulk density decreased 72-93% and 6-8% respectively in the excluded area. Under simulated rainfall the authors did not find significant differences in runoff depth in 2005 (wet year) but did find significant reductions in runoff depth in the excluded area in 2006 and 2007 (21-31%). Flow-weighted concentrations of TN, TP and TPP were significantly reduced by cattle exclusion in 2007 (19-26%). Mass loads of total suspended solids were also significant reduced in 2007 (41%). Mass load of TN fractions (TN, TDN, TPN) were significantly lower (21-52%) for cattle excluded areas than grazed areas in 2 of 3 years (2006, 2007). Mass loads of TP (TP, TDP, TPP) were significantly lower (32-43%) in cattle excluded areas in 2006. In 2006 turbidity and pH were significantly greater in excluded areas that grazed areas (2-25%). However, turbidity was greater in grazed areas in 2005 and 2007.

Surface soil sampling indicated that the cattle excluded pasture was generally not enriched in nutrients when compared to the grazed pasture. The authors suggested this may have been the result of low stocking rates and the relatively short period of cattle exclusion. Some researchers have found higher amounts of water-soluble and labile P in cattle-excluded pastures and have suggested that excluded areas may be a source of P runoff. This study did not find this to be the case. The authors suggested that additional research is needed to evaluate nutrient dynamics, loss and uptake difference between grazed and livestock excluded riparian areas.

The authors ultimately attributed improved environmental conditions in the excluded area to decreased runoff and greater infiltration that resulted from increased vegetation cover and standing litter and decreased bare soil and lower compaction/soil bulk density. These results demonstrate that rangeland health, vegetation and soil properties can begin to recovery after 4-6 years after livestock exclusion. Furthermore, livestock exclusion can be an effective approach to reducing nonpoint source pollution from grazed riparian areas.

33. National Research Council. 2002. *Riparian Areas: Functions and Strategies for Management*. Washington, DC: The National Academies Press. https://doi.org/10.17226/10327.

This guidance contributes to the growing recognition of the similarities in wetland and riparian area functions and the differences in their legal protections. The report is intended to raise awareness of riparian areas and their ecological values. Since riparian areas contribute to a significant proportion of biological/physical functions, riparian function restoration is essential to water quality and habitat preservation.

34. Nellesen, S., Kovar, J., Haan, M., & Russell, J. (2011). Grazing management effects on stream bank erosion and phosphorus delivery to a pasture stream. Canadian Journal of Soil Science, 91(3), 385-395.

The objectives of this study were to determine the impacts of grazing management on streambank erosion, streambank stability and phosphorus losses. The author's hypothesis was that managed grazing, as opposed to unrestricted access, would support more stable streambanks and lead to reduced sediment and phosphorus losses. The specific objectives were to quantify the effects of three grazing management systems on net erosion/deposition, streambank stability and phosphorus losses from stream banks along Willow Creek in south central Iowa.

To test the authors' hypothesis, a three-year (2005-2007) study was conducted on six 12.1-ha (30 ac) cool-season grass pastures located at the Iowa State University Rhodes Research farm in central Iowa. The six study pastures were each bisected by a 141 m (463 ft.) stream segment and were grouped into two blocks with each block assigned one of three grazing management treatments including continuous stocking with unrestricted stream access (CSU), continuous stocking with restricted stream access (CSR) via riparian fencing and a 4.9 m (16 ft.) wide stream crossing and five-paddock rotational grazing system (RS) with one paddock spanning both sides of the stream and associated riparian zones. The CSR pasture also included a 33.5 m (110 ft.) riparian buffer on each side of the stream. Each pasture was stocked with 15 fall-calving Angus cows from mid-May through mid-October. Grazing was not allowed in the fenced riparian areas on either side of the CSR pastures. Riparian paddocks in the RS pastures extended 33m (108 ft.) from the stream in either direction and were 0.91 ha (2.2 ac). Riparian paddocks were grazed until forage height decreased to a minimum of 10 cm (3.9 in.) and were used between 8 and 10 days per year during the study period. Upland paddocks in RS system were 2.78 ha (6.9 ac) and grazed to allow for 50% forage removal in each rotation.

Stream stage was monitored from April until November during the study period and grab samples were collected in spring of 2006 under base flow conditions and analyzed for total phosphorus, total N and dissolved organic carbon. Sample contained <0.05 mg/L total phosphorus, 6.6 mg/L total N and 3.3 mg/L dissolved organic carbon which were found to be similar to values reported for streams flowing though continuously grazed pastures in Iowa. Streambank erosion susceptibility scores using visually scoring during pre-, mid- and post-grazing each year. To quantify the effects of grazing management on sediment and phosphorus loading, transects were established and fiberglass pins were inserted perpendicular to the streambanks at each transect. Exposed pin length was measured May to November of each year calculate erosion, deposition and pin activity. If a pin was lost to bank erosion, the total length of the pin was recorded. Deposition was likely due to sediment deposition during high flow, soil falling from upper bank faces and freeze and thawing of bank soils. Pin activity was the absolute value of the change in pin erosion, and it was assumed the higher the activity value, the more unstable the system was. Soil samples were collected in the spring of 2006 to characterize bank material. Potential phosphorus losses from streambanks were calculated by multiplying the area of the bank, the mean net erosion, bulk density and phosphorus concentrations of the bank material. Since sample samples were collected by soil horizon, estimated of P losses were the sum of losses from each soil horizon.

Total annual rainfall from 2005 to 2007 was 917, 815 and 1100 mm compared to the 30-yr average of 818 mm. Precipitation during the grazing season from 2005 to 2007 was 635, 480, 686 mm while the 30-yr average for this timeframe was 729 mm (28 in.). Lower rainfall during the 2006 grazing season led to fewer and smaller stream flow spikes. Rainfall during the 2007 grazing season was more evenly distributed which resulted in a relatively flat hydrograph.

Streambank slope scores did not differ among grazing treatments or sampling period amount sampling periods or treatment. Vegetative cover scores found that continuous, unrestricted grazing (CSU) had more bare soil along the banks and scores were affected by cattle grazing and bank sloughing. Bank stability scores were higher in CSU pasture than CSR and CSU pastures which indicated great instability. Streambank erosion susceptibility scores tended to be higher (greater potential for erosion) in 2005 and were great in CSU pastures than either CSR or RS in 2006 and 2007. In 2007, erosion susceptibility scores also decreased during the grazing season but there was no treatment by period interaction effect.

Streambank erosion and pin activity differed from year to year and measurement period with a given year than amount grazing management. Net bank erosion during the non-grazing season (November through April) was greater than the grazing season in all three years regardless of grazing management. Net streambank erosion was significantly greater during the non-grazing season compared to the grazing season and erosion tended to occur in the winter. Over the course of the study significant differences among treatments only occurred in July of 2005 and during the non-grazing season of 2007. In July 2005, the net erosion in CSR was less than the CSU and RS pastures. In 2007, net erosion during the non-grazing season was less in the RS treatment than the CSR treatment. Based on the results, the authors stated that cattle grazing management had little effect on streambank erosion and natural process likely had a much greater effect. According to authors, the short amount of time the treatments were in place along with changes in cattle behavior may have influenced the results.

Average pin activity along the study reach followed rainfall patterns and tended to be higher in 2005 and 2005. Similar to average bank erosion, pin activity was greater in the non-grazing season for all three years of the study. To isolate the effects on grazing management on bank erosion, bank deposition and pin activity the data was analyzed with data collected only when cattle were present. Net streambank erosion was not affected by management June through October. However, erosion and deposition activity from June to October was significantly affected by management strategy. Pin activity was the greatest under the CSU management followed by the RS strategy with the lowest under the CSR system. Erosion and deposition were correlated to mean monthly stream stage; however, the correlation between pin activity and reach specific variables were weak. The correlation between net streambank erosion and pin activity was found to be weak; and again, suggested the cattle grazing management strategy had less influence on streambank stability than natural processes. Trend analysis of monthly erosion and deposition data showed of trend of decreasing erosion in the two RS pasture over the three years of measurement. The authors further noted that there were no negative trends for any of the treatments indicating that bank erosion was not increasing in any of the six pastures. Trend analysis of monthly pin activity showed that pin activity was decreasing, and streambanks were becoming more stable in three of the six treatments including one of each treatment including RS, CSR and CSU. Only one pasture (RS) had a trend of both decreasing bank erosion and increasing stability over the course of the study indicating some response to this management system. Phosphorus loses during the non-grazing season were greater than the grazing season regardless of grazing management. Mean 3-yr phosphorus losses were lower in CSR pastures than the CSU and RS pastures. Significant differences among treatments occurred in July, September and October of 2005 and November of 2007. In July, phosphorus losses were less in CSR treatments than CSU and RS treatments. However, in September, phosphorus losses were less in the CSR and RS treatments that the CSU treatment. Phosphorus losses in November were less in the RS treatment followed by CSR and CSU. October 2005 was the only measurement period when phosphorus losses from CSU were less than other treatments.

In this study the authors found that streambank erosion and pin activity (as an indicator of bank stability) differed among measurement periods and years more than grazing management treatments. Results were also mixed among treatments and indicators such as net erosion, pin activity, phosphorus loss and streambank stability scores varied from year to year. For example, trend analysis of erosion/deposition data showed decreasing bank erosion in the two pastures under RS grazing management. Additionally, mean phosphorus losses were lower in pastures under the CSU and CSR pastures than the RS pastures; although, significant differences among treatments were only found in four of 21 measurements. In general, CSR and RS appeared to experience less streambank erosion and pin activity, but this was not fully attributable to the grazing system alone. The results of this study suggest that streambank erosion and phosphorus losses to the stream were primarily controlled by geomorphic process at this site. Further, this study could not determine if the RS was more, less or equivalent to the CSR system.

35. O'Callaghan, P., Kelly-Quinn, M., Jennings, E., Antunes, P., O'Sullivan, M., Fenton, O., & Huallachain, D. O. (2019). The environmental impact of cattle access to watercourses: A review. *Journal of environmental quality*, *48*(2), 340-351.

The study assesses impacts of diffuse pollutants and point source pollution on stream morphology, streambed sediment, in-stream and sediment nutrients, microbial contamination, and aquatic biota. Authors propose mitigation measures to reduce the amount of time that cattle spend on riparian margins and watercourses. The study specifically seeks to explore how direct cattle access to waterways can impact streams, what mitigation measures are effective, and divergent results on the effect of cattle access. This study found knowledge gaps in relation to the impact of cattle grazing on certain freshwater parameters, but there is evidence for the benefits of excluding cattle from riparian areas. The study did not find any other research which indicated cattle access to riparian areas had positive impacts for most parameters. Additionally, there are gaps in research on real-time impacts of livestock grazing on freshwater conditions and more research is needed to understand temporal and spatial recovery following mitigation efforts to reduce livestock grazing. A greater understanding of the impact of cattle on riparian areas can help inform policymaking.

36. Owens, L. B., Edwards, W. M., & Van Keuren, R. W. (1996). Sediment losses from a pastured watershed before and after stream fencing. *Journal of Soil and Water Conservation*, *51*(1), 90–94. Pell, A. N..

This study investigated differences in total soil loss from a grazed watershed managed under a year-round grazing with and without stream fencing. The study was conducted at the North Appalachian Experimental Watershed near Coshocton, Ohio. The study area was a 69.7 ac watershed used exclusively for grazing. Of the 69.7 acres, 64.2 were used for pasturing Charolais beef cattle. The pasture also included 12.8 ac of woods consisting predominantly of mixed hardwood trees. Beginning in April 1980, a herd of 17 spring-calving beef cattle grazed the entire area all year and were fed supplemental hay elsewhere during the winter months. The herd had access to the entire watershed including a small stream that originated within the study area. Springs and seeps supported year-round flow. From November 9, 1987, through March 31, 1993 cattle were kept out of the stream and the majority of the woodland area via an electric fence.

The stream was equipped with a weir to determine surface runoff and continuous sampler to measure suspended sediment. Precipitation was measure via a standard rain gauge and corrected to estimate “true” precipitation. Because the base flow was routinely low, the automatic sampler was set to sample storm runoff only. Sediment concentrations were determined by dried sediment weight resulting from vacuum filtration.

Average annual precipitation during the post-fencing period was slightly lower than the unfenced period. Monthly average didn’t vary greatly and most of the differences resulted from less precipitation from August through November. While there was variation is precipitation within the study period, they were not statistically different. Similar to annual precipitation, storm flows did not have consistent, large differences between study periods with the exception of the winter months (December through March). The largest difference was the result of a precipitation event in December 1990 (fenced period) of ten inches which was the record high for the area. This even led to subsequent high stormwater flows for the month of December.

Fencing cattle away from the stream produced an overall decrease in sediment transport and sediment concentrations in stormwater runoff. Even with the monthly peak stormwater

When annual soil loss before and after stream fencing was compared, the average annual soil loss was 40% lower after cattle were fenced from the stream, and this reduction in soil loss resulted in a nearly 60% reduction in average stormwater sediment concentrations.

37. Parsons, C. T., Momont, P. A., Delcurto, T., McInnis, M., & Porath, M. L. (2003). Cattle distribution patterns and vegetation use in mountain riparian areas. Rangeland Ecology & Management/Journal of Range Management Archives, 56(4), 334-341.

The objective of this study was to quantify the effects of early summer and late summer grazing on beef cattle distribution and vegetation utilization patterns within riparian areas and adjacent uplands in northeastern Oregon. The authors’ hypothesis was that livestock grazing distribution and forage utilization patterns would be more uniform during early summer and riparian areas would receive disproportionately more use than uplands during late summer.

The study was conducted within a 109-ha area of the Eastern Oregon Agricultural Research Center's Hall Ranch located in the foothills of the Wallowa Mountains in northeastern Oregon. Study site elevation was approximately 1,015-m with annual precipitation averaging 350-mm which typically occur between October and June. These conditions commonly result in dry summers and limited potential for vegetative re-growth from July through September. The study site consisted of riparian meadows and adjacent uplands bordering Milk Creek, a tributary of Catherine Creek in the Grande Ronde River watershed.

To quantify the effects of early and late summer grazing, 52 cow/calf pairs were used to evaluate 1) early summer grazing (mid-June to mid-July), and 2) late summer grazing (mid-August to mid-September) during the summers of 1998 and 1999.

Fencing was used to create nine, 10-15 ha (24.7-37.1 ac) pastures. Within each pasture, vegetation was classified into 4 vegetation types: gravel bar, riparian grass, riparian sedge/rush, and upland. Gravel bar vegetation were located within the riparian area and appeared to be remnants of past stream channels. Riparian vegetation was located within the floodplain. Riparian grass vegetation included Kentucky bluegrass, brome, meadow foxtail, timothy, rushes, sedges and a variety of forbs. Riparian sedge/rush vegetation was located within the riparian grass communities but were distinguished by greater than 50% sedges and/or rushes by weight. The overstory of woody species included hawthorn, ponderosa pine, snowberry, black cottonwood and rose. Upland vegetation consisted of a mix of grassed, a variety of forbs, patches of shrubs. Most of upland areas of the sites had an overstory of ponderosa pine with open areas though some were open and lacking a woody overstory. Green line vegetation was considered the vegetation located immediately on the streambanks edge.

Each pasture contained about a 260-m (853ft) reach of Milk Creek. The nine pastures were separated into three blocks based on based on vegetation type and two treatments were randomly assigned to pastures within each block including early summer grazing (mid-June to mid-July), late summer (mid-August to mid-September) and a control where no grazing occurred. Each pasture within a block had similar proportions of the four vegetation types and all cows had equal access to all areas of their assigned pasture. Cows used on early summer pastures were also used on late summer pastures. All cows used in this study had previous exposure to similar grazing areas as yearling heifers. Based on dry matter (DM) production estimates from previous years, pastures were stocked to achieve 50% relative herbaceous vegetation utilization after 28-days of grazing, with resulting stocking density of 1.7 AU/ha (1.1 AU/ac).

Visual observations and vibracorders were used to monitor hourly livestock distribution and grazing behavior patterns. Visual observations were collected during the second and third week of each season of use over two, 4-day periods. During these times cow location, cow activity and ambient air temperatures were monitored throughout the daylight hours (0600 to 1900 hours). Livestock activities were categorized as grazing, loafing/resting or drinking. Location information was recorded on aerial photos and later transcribed to a geographical information system for the study area. Daily observations for early summer and late summer grazing average 252and 242 respectively. Vibracorders used to measure grazing times during both years of the study and were placed on six randomly selected cows per block, per observation period for a total of 72 total vibracorder recordings. These devices can record up and down movements and be used to provide an estimate of grazing and resting times. Vibracorder recordings were read as minutes/hour and hours/day spent grazing.

Relative herbaceous vegetation utilization was measured at the end of each season immediately after the removal of cattle. Vegetation utilization was visually estimated using 0.25 m^2 plots every 7.5 m beginning at the stream and outward (perpendicular) on 6 equally spaced transects within each pasture resulting in an average of 387 utilization estimates per pasture. At each observation point a utilization class was assigned including: 0 = 0 percent utilization, 1 =

1 to 25 percent utilization, 2 = 26 to 50 percent utilization, 3 = 51 to 75 percent utilization, and 4 = 76 to 100 percent utilization). Remaining herbaceous stubble height was measured and vegetation type recorded. Stubble height was measured by placing a ruler at the furthest edge of the 0.25 m2 frame and measuring the height of the remaining forage to the nearest cm. Fresh fecal deposits located within 1-m of the stream's edge were at the end of each grazing season.

To evaluate forage nutrient composition, 20 randomly clipped plots (0.25 m^2) were obtained from each grazed pasture the end of the third week of each season of use. Of the 20 plots, 10 were from the riparian areas and 10 were from the upland area. Samples were dry matter (DM), Kjeldahl nitrogen 1 crude protein, acid detergent fiber, neutral detergent fiber, lignin, and in situ dry matter disappearance (ISDMD).

The data was statistically analyzed after the end of the study period and season of use was found to significantly affect livestock distribution patterns throughout the study. Cattle were consistently observed further from the stream at any given hour in early summer than late summer. Ambient air temperatures were highly correlated with livestock distances from the stream in early and late summer with cows being observed closer to the stream when ambient air temperatures were higher. The movement from upland areas to riparian areas also differed by season.

The season of use and time of day interaction was found to be statistically significant, and this interaction affected the use of various vegetation types. In early summer, cattle visited riparian areas during late morning hours and then either returned to the uplands or remained around the riparian area during the heat of the day, later returning to the uplands around late-afternoon. In late summer, cattle began the day away from the stream, but quickly moved closer to the riparian area during the morning hours and congregated in shady areas of the riparian area during the heat of the day, and then gradually returned to the uplands around late afternoon. During early summer, cattle spent nearly an equal proportion of time in upland and riparian vegetation types between the hours of 1230 until 1800 with time spent in riparian areas ranging from 50 to 60%. In late summer, cattle started out their day in upland vegetation types but rapidly moved into riparian vegetation types after 0800 hours. They spent the remainder of the day in the riparian vegetation types gradually returning to upland areas during late afternoon/early evening. Over 90% of the cow observations during late summer were in riparian areas from 1200 to 1700 hours. During early summer 50 to 60 percent of observations were in riparian areas during the same time period. Early season temperatures between the hours 1200 and 1900 ranged from 61 to 66-degree Fahrenheit while temperature during the same time period in the late season ranged from 75 to 80 degrees Fahrenheit.

Vibracorder data also demonstrated that season of use also affected cattle grazing activity. Cattle expressed a distinct trimodal daily grazing pattern during both seasons with discrete peak grazing times during the morning, mid-day and evening. While livestock exhibited a season of use and time of day interaction, the total grazing times did not differ between seasons. Cattle grazed an average 584 minutes/day (9 hours and 34 minutes) and

574 minutes/day (9 hours and 34 minutes) during the early and late seasons, respectively. Observational data showed that daylight cow activity was not affected by season of use. Grazing accounted for 65% of the time, loafing/resting accounted for 34% of the time and drinking occupied 1% of the daylight activities during both seasons of use.

When livestock observation data and vibracorder data were compare, peak mid-day grazing occurred from 1200 to 1400 hours in late summer which coincided with the highest riparian area occupancy. This illustrated the potential for increased riparian vegetation utilization by cattle during the heat of the day in late summer. Peak riparian occupancy within early season pasture occurred between 1200 and 1800 hours. In this time span, early season mid-day grazing was declining but was also followed by a period of steadily increasing grazing activity. However, the percentage of observations in the riparian area was 35 to 40% in the early season pastures. Based on the plot of minutes per hour grazing vs. time of day, it appears morning and mid-day occurred earlier in the early season plots than the late season plot. The timing of evening grazing was approximately the same for each season of use.

Vegetation utilization patterns differed between years. In 1998 early grazing season utilization levels in riparian and upland vegetation types averaged 31% and 37% use respectively while late summer utilization averaged 42% and 34% use, respectively. In 1999 early grazing season utilization of riparian and upland vegetation types averaged 41% and 40% use, respectively; however, during the late summer grazing season riparian vegetation utilization was disproportionately higher at 55% compared to upland vegetation utilization of 34%. Thus, early summer grazing resulted in nearly equal utilization of upland and riparian vegetation types in both years of the study. This uniform pattern likely reflects more uniform livestock distribution during the early summer grazing period. It's important to note that annual precipitation varied within the study period with 1998 receiving above normal precipitation (500 mm) and 1999 receiving below normal precipitation (264 mm). Also, the area received dramatically more rain in May of 1998. This measurable difference in annual precipitation could have impacted forage quality and quantity and possibly affected livestock distribution and vegetation utilization patterns. Also, the timing of precipitation can also impact forage quality and quantity. For example, riparian utilization increased in both treatments (earlier and late season grazing) in 1999 by a factor of 1.3 while upland utilization was nearly unchanged from 1998 to 1999 for early and late season grazing. This increase in riparian utilization suggests that cattle reliance on riparian areas may increase in years with lower-than-average precipitation. During late summer grazing, green line utilization was nearly 60% use compared to 36% use during the early summer. This again demonstrated the increased potential for riparian area degradation in late summer.

Stubble height differed between years and between seasons of use except for greenline and gravel bar vegetation. However, stubble height did not exhibit a season of use a season by year interaction. Post grazing stubble height followed the vegetation utilization estimates with increasing vegetation utilization resulting in decreased stubble height.

Although, the magnitude of difference was less with the stubble height measurements which could have been due to differing plant phenologies and seasons.

Nutrient composition of available forage varied between seasons of use with early summer forage having lower DM and fiber (ADF, NDF and lignin) and greater crude protein and in situ dry matter disappearance (ISDMD) compared with late summer forage. However, there was no difference between upland and riparian area forage composition within seasons. As the grazing season progressed, herbaceous vegetation matured and deteriorated resulting in a decrease in forage quality and an increase in forage dry matter (DM) content. The authors noted that previous research had shown that vegetation quality and quantity played significant roles in determining distribution patterns of cattle. In this study, forage quantity was similar during both season; however, riparian areas had greater forage standing crop than uplands regardless of season.

The authors noted that water intake of a given class of cattle is a function of dry matter intake and ambient air temperature. Since ambient air temperatures and dry matter were lower in the early summer, the need for water would also be lower. The authors estimated the difference between early season and late season water needs could be up to 20 liters per animal per day which could increase the dependence of streams for water. Fresh fecal deposits within 1-m of the stream were similar between early summer and late summer averaging 13 and 28, respectively.

This study found that early season grazing lead to better animal distribution and forage utilization. The amount of time livestock spent in the riparian area was correlated to ambient air temperature; and as such, cattle spent more time in the riparian area in late summer than the early summer. While the amount of time cattle spent in riparian zones was greater with late season grazing, cattle also relied on the riparian area and spent 50-60% of their time from 1300 to 1800 in the riparian zone. Mid-day temperatures during the early season ranged from 61-66^{o} F and 75-80^{o} F in late season. While not addressed in this study, mid-summer (mid-July to mid-August) temperatures would presumably increase the use of available shade including riparian areas. Further, mid-day temperatures between 75-80^{o} F and greater standing forage in riparian areas increased the time spent in riparian areas and riparian forge utilization. Additionally, riparian forage utilization increased in the year (1999) when annual precipitation was lower than average which may suggest that cattle will rely on riparian areas more in years with lower-than-average precipitation.

38. Pietola, L., Horn, R., & Yli-Halla, M. (2005). Effects of trampling by cattle on the hydraulic and mechanical properties of soil. *Soil and tillage research*, *82*(1), 99-108.

The study assessed the effects of trampling by cattle on the physical parameters of different pasture site types. Site types included (1) grass with no visible trampling; (2) pasture with some trampling; (3) vicinity of a drinking site with some signs of penetrated hooves; and (4) a drinking site with totally homogenized surface soil and destroyed vegetation. There was a significant difference in water infiltration between trampled and non-trampled soils, although grazing intensity was low. When trampling occurred for longer time periods in a soil with high clay content, infiltration was only 10-15% of that in non-trampled pastures. Beside soil compaction, the demonstrated potential for water repellency of the studied sites evidently delayed water infiltration into the dry soil surface. This should also be taken under consideration when risks of runoff are estimated. Results showed even a low intensity of grazing will reduce infiltration and hence increase susceptibility to erosion at the drinking sites. Overall, water infiltration into a heavy clay/sandy loam was severely restricted by cattle trampling and the surface of trampled heavy clay soil lost strength due to dynamic kneading effects with high water contents. Therefore, soils that have been homogenized by trampling are much more susceptible to erosion.

39. Platts, W. S. (1979). Livestock grazing and riparian/stream ecosystems. In *Abstracts of papers presented at the... annual meeting of the American Society of Range Management. American Society of Range Management*.

The study assesses impacts of livestock grazing on streams and potential solutions to mitigate impacts. Findings include that (1) solutions to grazing impacts are not as clear and easily available; (2) solutions can be drawn from multiple disciplines; (3) past studies focused on identifying problems and offered few solutions; and (4) more research is needed to support agencies' management of streamside environments. The article gives an overview of the history of livestock grazing along with grazing impacts on fishery needs, riparian vegetation, species in stream channels, and water quality. Ultimately, livestock grazing affects all components of aquatic systems and can alter, reduce, or eliminate streamside vegetation. Documenting and evaluating livestock grazing impacts is challenging since natural events can cause similar impacts. However, livestock grazing can result in micro-changes to the environment that accumulate overtime. With this, streamside environments should be considered as separate management systems, so they receive the necessary attention from landowners. In the past, landowners haven't implemented sufficient practices to preserve streamside environments which has resulted in deteriorating conditions. Therefore, landowners and experts across other disciplines are recommended to come together to determine feasible solutions.

40. Platts, W. S., & Nelson, R. L. (1985). Impacts of rest-rotation grazing on stream banks in forested watersheds in Idaho. *North American Journal of Fisheries Management*, *5*(4), 547-556.

Platts and Nelson evaluated the effects of rest-rotation grazing along three tributaries of the Salmon River in Idaho. Under rest-rotation, a grazing area is partitioned into several pastures and each pasture is grazed in sequence. As part of the rotation, each pasture is rested at least one year, and no grazing occurred. The timing of grazing under a rest-rotation strategy varies but pastures are typically grazed either early or late in the season and that sequence is rotated each year the pasture is grazed. Deferred grazing is a common livestock grazing strategy in rangeland in forest rangeland; however, there doesn't appear to be consensus in the literature as to whether it leads to increased forage quality and quantity while simultaneously preventing deterioration of riparian vegetation, streambanks and riparian soils. The authors highlighted studies that found no stream-side improvements under a rest-rotation grazing approach. The authors also expressed concern about the lack of definitive guidance to meet both forage and riparian protection needs. Selective grazing and livestock preference for riparian areas was highlighted as an overriding factor that likely influences the efficacy of rest-rotation grazing and may be a primary reason for why riparian areas haven't experience the same level of improvement as rangelands as a whole have experienced since the 1930s. Livestock's preference for riparian areas and riparian grazing impacts to riparian conditions have been documented and cited in other literature related to livestock grazing. Any grazing strategy designed to protect water quality, aquatic habitat and fish needs must also account for impacts to riparian vegetation, streambanks, channel alteration and riparian soils. This study found rest-rotation resulted in higher forage use in streamside areas than adjacent range or the overall grazing allotment. Streambank alteration also occurred soon after cattle were allowed ungrazed meadows. The authors determined that their studies suggest that it may be impossible to optimize all riparian areas uses simultaneously.

41. Quinn, T., K.L. Krueger, and G.F. Wilhere. 2020. Introduction. Page 5 *in* T. Quinn, G.F. Wilhere, and K.L. Krueger, technical editors. Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications. Habitat Program, Washington Department of Fish and Wildlife, Olympia. https://wdfw.wa.gov/sites/default/files/publications/01987/wdfw01987.pdf

This document on Priority Habitats and Species was developed to support the Washington Department of Fish and Wildlife's mission to preserve, protect, and perpetuate the state's fish, wildlife, and ecosystems while providing sustainable recreational and commercial opportunities. The document provides insights on key ecological functions of riparian areas, how riparian areas/watersheds affect freshwater habitats, and how human activities affect the capacity of riparian areas/watersheds to provide habitats in rivers and streams. The guidance goes into more detail on riparian ecosystem management, watershed management, and protection/restoration recommendations. Chapters in the guidance focus on stream morphology impacts, different types of disturbances, use of instream wood, land use impacts, and pollutant/nutrient dynamics.

42. Ranganath, S. C., Hession, W. C., & Wynn, T. M. (2009). Livestock exclusion influences on riparian vegetation, channel morphology, and benthic macroinvertebrate assemblages. *Journal of Soil and Water Conservation*, *64*(1), 33–42. doi:10.2489/jswc.64.1.33

The goal of this research was to assess changes to stream channel morphology, riparian vegetation and macroinvertebrate communities over time resulting from livestock exclusion, and to evaluate the time needed to improved channel morphology and benthic communities once exclusion projects were implemented. To do so, the authors used a paired study approach where measurements were taken at stream reaches with and without exclusion practices and these measurements were later compared. The study sites were located in southwestern Virginia and consisted of five, nearly contiguous stream reaches with and without livestock exclusion practices. Studies reaches ranged from 117 to 421 meters long and distances between reaches ranged from 217 to 1237 meters. The reaches with livestock access were used by heifer cattle with each location having between 15 and 60 animals. Four of the five excluded reaches ranged from one to 14 years old with one forested, ungrazed reach being at least 50 years old.

This study utilized a variety of tools to evaluate geomorphic, riparian vegetation and benthic macroinvertebrate communities. To evaluate stream morphology and quantify physical characteristics of the stream both longitudinal and cross-section surveys were conducted. Longitudinal surveys were used to determine stream gradient, water slope and location of bed features such a pools and riffles, and cross-section profiles were used to quantify channel dimensions and floodplain features and determine bankfull width, depth and width-to-depth ratios. Reach-averaged grain size distribution was determined for each pool with a reach and riffle and embeddedness was estimated within a single riffle at each study reach. Further, the Virginia Department of Environmental Quality Reach Condition Index (RCI) was used to evaluate stream geomorphic conditions and streambank soils were evaluated by measuring soil bulk densities.

Riparian vegetation was assessed by cutting all groundcover under a meter high within a 1 m^2 plot. Instream habit was evaluated at each reach using a Rapid Habitat Assessment (RHA). This assessment assigns a score from 0 to 200 based on streambed characteristics, channel morphology, bank structure and riparian area conditions. To assess benthic macroinvertebrate communities, each reach was sampled in mid-June and the end of August in 2006. Samples were taken at three riffles within the middle of each study reach and on the left and right sides of each riffle. The Virginia Department of Environmental Quality (VDEQ) Stream Condition Index (SCI) was used to evaluate the benthic invertebrate assemblages at each reach. The SCI scores range from 1 (severe stress) to 100 (excellent condition).

When stream morphology conditions were compared, reaches with livestock exclusion were generally deeper, had lower bankfull width to hydraulic depth ratios and had significantly higher Reach Condition Index scores. However, when bankfull width, sinuosity, large wood debris and overall water surface slope were compared they showed no significant differences. The authors noted mixed results reported in previous studies with some finding significant changes in stream width and depth with livestock access and other concluding that stream depth was not affected. It was further noted that many studies conducted on geomorphic responses to livestock exclusion have determine that bankfull width to depth ratios commonly decrease follow livestock exclusion. When embeddedness and percent fines were compared, they also lacked significant differences; although, substrate size was typically larger in livestock exclusion reaches. The authors believed this lack in statistical difference was likely the result of upstream sediment sources which overshadowed the impacts of local management differences.

Riparian vegetation and streambanks soils also show mixed results. The median amount of groundcover vegetation in excluded reaches was two times greater than grazed reaches. Soil bulk density measurements were not found to be significantly different which may have been due to low grazing intensities in the study reaches or rapid recovery from freeze and thaw cycles.

When instream habits were evaluated, these was a significant difference in Riparian Habit Assessment scores between grazed and excluded reaches. All scores for grazed reaches were classified to be in poor condition and four of the five excluded reaches at or near a score representing good condition. When riparian habit scores of the study reaches were compared to scores within the ecoregion of the study locations, grazed reaches were the lower end of the scale and excluded areas were on the high end.

Benthic macroinvertebrates were evaluated by testing differences between VDEQ Stream Condition Index scores and components of the index and no significant difference between grazed and excluded sites were found. To this finding, the authors highlight the variability of results in previous studies. Some previous studies determined that livestock exclusion led to increased macroinvertebrate index scores while other studies found no significant differences. Macroinvertebrate assemblages and their responses are greatly influenced by watershed characteristics, land use and subsequent conditions within watersheds such as temperature, flow, discharge, flooding frequency and sediment delivery and stream shading. Also, four of the five study reaches were not likely mature enough to significant increase shading or stream temperature. Additional analysis of watershed characteristics and benthic macroinvertebrate populations within a watershed may have increased the possibility of determining how individual practices influence macroinvertebrate responses. However, according to the authors, the lack of benthic macroinvertebrate responses was likely the result of land use and watershed characteristics rather than localized influences. Additionally, short sections of livestock exclusion aren't likely to lead to improved biological conditions at a watershed level and watershed-wide efforts to reduce negative impacts to stream from all sources are needed.

An evaluation of time-to-recovery found that only the Riparian Condition Index (RCI) displayed a relationship to time. The authors attributed this relationship to the fact that RCI is a qualitative assessment using visual indicators and these types of assessment may lend themselves to showing a rapid response. The authors cited similar results in other studies where the duration of exclusion was not significantly correlated to time meaning that the degrees of channel and geomorphic recover was not directly related to the amount of time livestock were excluded. Given the complex interactions between cattle impacts and the influence of those impact on streambanks, riparian soils and geomorphic responses this is to be expected. However, findings from this study suggest that parameters or qualitative indices that rely on visual indicator are most likely to indicate change.

43. Rawluk, A. A., Crow, G., Legesse, G., Veira, D. M., Bullock, P. R., González, L. A., ... & Ominski, K. H. (2014). Off-stream watering systems and partial barriers as a strategy to maximize cattle production and minimize time spent in the riparian area. Animals, 4(4), 670-692.

The objectives of this research were to evaluate if off-stream watering (OSW) and off-stream watering with natural barriers as a partial exclusion method would reduce the amount of time cattle spend in riparian areas. Additionally, this study evaluated the effects of OSW and OSW with barriers on watering behavior and animal performance as determined by weight gain. The study was conducted at two sites in southwest Manitoba, Canada: one site near the town of Killarney on the Pembina River and the second near the town of Souris on Plum Creek. The criteria for selected pastures at each site included: (1) continuously grazed (mid-June/early July to early September); (2) comprised largely of native or tame species, with similar forage types; (3) similar carrying capacity and stocking density (approximately 25 cow/calf pairs); (4) adjacent to a stream which flowed for the duration of the trial; (5) pre-existing perimeter fencing around the pasture and no exclusion fencing along the stream or riparian area.

The study was conducted over three, 28-day periods during a single grazing season. Three treatments were evaluated at each site including: (1) no OSW/no barrier (1CONT); (2) OSW with barrier (2BARR); (3) OSW without a barrier (3NOBARR). The OSW consisted of a submersible pump, solar panel and battery, storage tank and tough. At each site, OSW was located north of the stream.

At the Killarney site, OSW was located approximately 60 m from the stream in 2BARR and 120m in 3NOBARR. At the Souris site, the OSW was located approximately 95 m from the stream in 2BARR and approximately 105 m from the stream in 3NOBARR. Mineral supplements were placed within 25m of the OSW locations and OSW was located to intercept the main flow of animal traffic. For pastures treated with natural barriers, deadfall (fallen tree and branches) was placed across common watering and crossing areas on the north side of the stream. The natural barriers were created to encourage use of the watering systems but not completely exclude cattle from the riparian area. The riparian area was not fenced, and the stream size allowed for cattle to cross from one side to the other.

At each location a sample of cows in treatments 2BARR and 3NOBARR were fitted with GPS collars to monitor their location throughout the pasture. The distribution of animals was monitored over three 28-day periods during the grazing season. To identify when cattle were in the riparian area, GIS software was used to establish a 10m buffer on either side of the stream measured from the center of the stream. An 8m buffer was created around the off-stream watering location to determine use. Visual observations were also conducted to record the watering location of cows fitted with GPS collars in treatment pastures. Observations were recorded every five minutes from dawn until dusk over four days of each 28-day period. Observational data was not collected at night. Watering activity was recorded when cattle were in any of the following locations: stream (in stream or within one body length of the stream, approximately 2 m), riparian area (within five body lengths of the stream, approximately 10 m), or OSW (within four body lengths of the OSW, approximately 8 m).

Daily weather data was collected to evaluate whether climatic conditions influenced watering and animal distribution. Ambient temperature, relative humidity and precipitation were recorded hourly. Temperature and humidity data were used to calculate a temperature humidity index on days cattle were fitted with GPS collars and these calculated indices were averaged into three-hour blocks of time. Forage biomass measurements were taken in randomly placed locations in the riparian and upland. Forage availability was sampled at the beginning of each grazing period. Animal performance was determined by evaluating cow and calf weights. Animals were weighed on the first day of each 28-day grazing period.

The time cattle spent in the riparian zone varied between treatments and sites. For example, at the Killarney site, cattle in 2BARR spent less time (statistically different) in the riparian zone than 3NOBARR during the 1st and 3rd, 28-day periods. The time spent in the riparian area during the 2nd period were similar and not significantly different. While the presence of OSW and barriers likely influenced cattle position, forage biomass of the riparian area during these periods likely influenced time spent in the riparian area as well. For example, 3NOBARR had 2.0x and 1.4x more riparian forage biomass than 2 BARR in the 1st and 3rd periods respectively. Additionally, there was a significantly more (3.7x more) forage biomass in the riparian area than the upland area during 2nd period in treatment 2BARR. Conversely, the upland forage biomass for 3NOBARR during this same period (2nd) was greater than the riparian forage biomass although not statistically different.

At the Souris site, cattle in 2BARR spent significantly more time in the riparian area than 3NOBARR during the 1st period, less in the 2nd period and a similar amount of time in the 3rd period. Riparian forage biomass in 2BARR was 1.5x greater than 3NOBARR during the first period and was 0.9x less in the 2nd and 3rd periods. Similar to the Killarney sites, its likely riparian forage biomass along with OSW and barriers influenced time spent in the riparian area at the Souris site. For example, a comparison of upland and riparian biomass found significantly greater forage in the riparian area than the upland in 2BARR and 3NOBARR during Period 2, as well as 3NOBARR in Period 3. Also, the amount of forage biomass available in the upland pasture decreased as the grazing season progressed in 3NOBARR, while forage biomass increased in 2BARR.

Despite inconsistent results among sites, the authors noted that cattle in 3NOBARR spent a greater proportion of time in the riparian area in all three periods than 2BARR at the Killarney site which suggests some level of efficacy of natural barriers coupled with off-stream watering. However, without GPS data from the 1CONT pastures it was not possible to conclusively determine if OSW was successful at decreasing the amount of time cattle spent in the riparian zone. The authors highlighted the discrepancy between the Killarney and Souris sites and noted that the Souris 3NOBARR site was 49% larger than the 2BARR pasture, and the 2BARR pasture had 51% more upland biomass. It was also noted that cattle at the Souris site spent less overall time in the riparian area than at the Killarney site. Variation in pasture size, biomass availability and cattle use of supplemental pastures were suggested to have influenced animal behavior and contributed to discrepancies between the two sites.

Data from each cow fitted with a GPS collar at each site, treatment and period were grouped into eight, 3-hr time block for analysis (0001h to 0300 h, 0301 to 0600h, etc.). The percentage of time cattle spent in the riparian area in each 3-hour time block fluctuated between grazing periods. However, regardless of the presence of natural barriers, a general trend was apparent: the percentage of time cattle spent in the riparian area was limited during the night and early morning (0001 h to 0600 h), increased throughout the late morning (0901 h to 1200 h), remained high throughout the afternoon, and decreased again during the evening (2101 h to 2400 h). According to the authors, this trend is similar to reported results from other studies and followed a similar pattern to observed daily temperature – as temperature increased during the day so did the percentage of time cattle spent in the riparian area.

Seasonal effects on cattle distribution were found at both sites; however, they didn't follow similar pattern. At the Killarney site, cattle were found to spend more time in the riparian area during the first two grazing periods, and the percentage of time spent cattle spent within the riparian area in 2BARR and 3NOBARR declined as the grazing season progressed. The authors surmised his was because cattle spent more time in the riparian area in the first two periods, potentially grazing riparian vegetation heavily which required cattle to move into the upland pasture in search of more vegetation as the season progressed. At the Souris site, time spent in the riparian area did not decline as the season progressed for both treatments (3NOBARR and 2BARR). The time cattle spent in the riparian area at 3NOBARR increased from period 1 to period 2 and then declined from period 2 to period 3. The pattern was opposite in 2BARR. The authors could not conclusively explain the unusual pattern at the Souris site but speculated that cattle may have spent more time in supplemental pastures allowing for recovery of the main pastures.

Visual observations of water use by collared cows over four days also had mixed results. "At the Killarney site, 100%, 93%, and 100% of observed watering events for the collared cows in 2BARR occurred at the OSW in Periods 1, 2, and 3, respectively. In 3NOBARR, 50%, 38%, and 40% of observed watering events for collared cows occurred at the OSW in Periods 1, 2, and 3, respectively. At the Souris site, 85%, 31%, and 7% of observed watering events for the collared cows in 2BARR occurred at the OSW in Periods 1, 2, and 3, respectively. In 3NOBARR, 44%, 33%, and 0% of observed watering events for collared cows occurred at the OSW in Periods 1, 2, and 3, respectively." These results demonstrate that cattle used off-stream watering locations, but the availability of an alternative water source did not decrease watering at the stream or time spent in the riparian area. The authors noted that the use of off-stream watering is likely influenced by proximity, and that the distances of off-stream watering from the stream and the lack of off-stream watering on the south side of the stream may have influenced the continued use of the stream for watering.

Average temperature-humidity index values were calculated for each day of the grazing period to evaluate if temperature and humidity affected cattle use of the riparian area. Calculated THI values were not consistently higher than established risk levels and no correlations between THI and riparian area use were made. However, animal use of the riparian area was correlated to temperature and livestock were found to spend more time in the riparian area as the day progressed and air temperature increases. Further, the authors noted that night cooling has been demonstrated to be a means of dissipating heat accumulated during the day. Cattle in this study experienced night cooling at both locations and the cooling was believed to influence riparian area use and potentially less reliance on midday cooling.

This suggests that cattle located in areas with less night cooling and higher THI may be more likely to rely on riparian areas for cooling during the day.

The authors evaluated animal performance between all three controls. Calf weight gain at each site was followed linear increase pattern at both sites and treatments. Cow weights mostly increased during the first 28-day period and then leveled off during the subsequent periods. The primary exception was the Souris Site. Cows at the Souris, 3NOBARR site experienced a slight decline in weight. According to the authors "the positive differences in weight gain between 2BARR cows and 1CONT cows, and the negative differences between 3NOBARR cows and 1CONT suggest the presence of the OSW had an impact on weight gain. However, as the variation in weights was no longer apparent as the season progressed the observed differences in weight gain cannot be only attributed to the OSW". Furthermore, the author noted that the study results indicated that OSW may improve weight gains but that these improvements aren't consistent throughout the grazing season. The presence of an OSW may act in favor of animal performance in some instances, but other factors such as management, available forage and temperature also impact gain.

Results from this study indicate that cattle watered at OSW when available, but they did not use the OSW exclusively. Also, when comparing the percentage of time that cattle spent in the riparian area with or without barriers, the presence of the natural barriers did not consistently prevent cattle from watering at the stream though the data did suggest some efficacy of the barriers on deterring cattle from the riparian area. As noted by the authors, it's also important to consider the feasibility of natural barriers and whether they are cost effective. For example, natural barriers, particularly fallen trees, may not be feasible in areas of with sparsely forested riparian areas such as arid areas or wet meadows. Also, the economic implications such as the time required to build and maintain these structures should be considered to evaluate if the cost of building and maintaining them actually offsets the benefit of using inexpensive materials.

44. Roath, L. R., & Krueger, W. C. (1982). Cattle grazing and behavior on a forested range in the southern Blue Mountains of Oregon, vegetation types. *Rangeland Ecology & Management/Journal of Range Management Archives*, *35*(3), 332-338.

The study analyzed environmental and topographic parameters across the Blue Mountains of Oregon to establish impacts of cattle behavioral response. Researchers specifically examined forage use, cattle distribution, herd social structure, and cattle activities. Findings included that water and vegetation type were influenced cattle grazing areas and degree of use. Additionally, vertical distance above water was critical to vegetation utilization on steeper slopes. Time of day and humidity also impacted cattle activity. Understanding how cattle use ranges and why the prefer certain land over others is valuable information for developing management plans for gazing on mountainous ranges. Additionally, landowners should consider the impacts of cattle returning to their home ranges. Livestock operators could potentially train cattle to new areas that were under-utilized. Overall, manipulating cattle should be consistent with other factors that influence grazing distribution (e.g., water availability). With this, trail building and other practices could be implemented to better control livestock grazing.

45. Sheffield, R. E., Mostaghimi, S., Vaughan, D. H., Collins Jr, E. R., & Allen, V. G. (1997). Off-stream water sources for grazing cattle as a stream bank stabilization and water quality BMP. Transactions of the ASAE, 40(3), 595-604.

The goals of this study were to (1) compare the behavior of cattle using streams as a primary water source to those which had access to streams as well as off-stream water; (2) estimate and compare streambank erosion in pastures when off-stream was available and when it wasn't; and (3) estimate and compare nutrients and fecal coliform bacteria concentrations from pasture with and without off-stream water.

This study was conducted on three pastures at two separate cow-calf operations in southwest Virginia. One study pasture was located in Independence Virginia on the River Ridge Farm and two additional pastures were located in Floyd Virginia on the Bender Farm. The River Ridge Farm produced Brahama-Angus calves using a high stocking rate of 200 cows and 170 calves on eight pastures totaling 136 ha (336 ac). The Bender Farm used a spring-fall grazing rotation with a stocking rate of 150 cows and 30 calves on 187 ha (462 ac). Tall fescue present in all three test pastures were found to be highly infected by the fungal endophyte. As noted by the authors, ingestion of endophyte infected tall fescue can cause fescue toxicosis which can cause the temperature of cattle to elevate and potentially increase the likelihood of cattle to wallow in mud or stand in surface waters in the hotter parts of the day.

For this study, the pre-BMP period was from August 1994 through April 1995 and the post-BMP period was from April 1995 through October 1995. During the first seven months of the study, cattle had access to access to a stream in the observed pastures. After the first seven months, watering stations were installed, and cattle also continued to have access to streams. The streams used for drinking water were first order, spring-fed waterways.

Three day-long observations of cattle behavior were conducted during the pre and post treatment period. Cow location observations were made every 5 minutes (dusk to dawn) from the cab or bed of a parked truck or from the pasture when possible. The number of cattle drinking from the stream or trough, number of cattle within the stream or trough areas, and the percentage of herd grazing were recorded during each time interval. Observation notes about the extent of the area along the stream used by the cattle, size of groups watering together, distance the cattle traveled to water in relation to grazing area, closest stream or trough location, and the behavior of age/sex groups within the herd were also made. The stream and trough areas were defined as the distance of two adult cow lengths (approximately 4.6 m) from the edge of the water trough and from the center of the stream. Pre and post comparisons of time cattle spent in the riparian zone and drinking from the stream were made by averaging the data for all the sites over the three observations dates.

Streambank erosion was only evaluated at the River Ridge Farm before and after treatment using 19 pairs of 1 ft. long, 0.5-inch-thick steel stakes. Stakes were randomly place on each side of the stream along straight and meandering portions of the stream channel. Stakes were used to measure the cross-sectional distance and distance from the stake to the edge of the streambank. Difference in the distance from the reference stakes to the streambank and stream edge were calculated from the most recent measurement compared to the previous measurement. Measurements of the location of the streambank edge were only allowed to increase through time. If the most recent measure of the streambank was closer to the stream, then the previous value was substituted. Pre and post treatment water quality variations were evaluated at the River Ridge site as well.

This study suggested significant reductions in the time cattle spent in riparian zones and drinking from the stream. Further, the study suggests significant reductions in streambank erosion and nutrients, sediment and fecal coliform bacteria. However, under closer examination, the study design and analysis methods likely influenced the study outcomes, and the purported efficacy of the treatment should be carefully considered. For example, the control and treatment data were collected in mid-winter and mid-summer respectively. Also, pre and post treatments monitoring only spanned one day and considered only four pastures, and only two of the pastures were observed pre and post treatment. Differences in forage availability and daily temperature are known to affect animal behavior and likely influenced grazing patterns and water use. However, these factors were not considered in the study and comparing results from different seasons is uncommon for these types of studies. Without evaluating the effects of season on animal behavior, erosion and runoff, the comparability of site-specific data is limited.

The time cattle spent in riparian zones and drinking from the stream where not compared between sites but were averaged among sites to establish an average among all pastures and sites. Averaging the data in this way suggested reductions in the time cattle spent in riparian area or watering in the stream. However, when the South Bender and River Ridge sites are compared, they demonstrate conflicting results. For the South Bender site, the pre and post time spent near the stream were nearly the same suggesting no response due to the presence of off-stream water. Further, the cumulative time cattle spent in the riparian area at the South Bender on August 29 site was 3.7x higher than observed times at the River Ridge site on June 29 and 4.4x higher than observations made at the River Ridge site on September 26. The authors suggested this may have been a consequence of pasture conditions and that decreased forage availability within the main grazing area may have forced the cattle to seek vegetation within the stream corridor. Despite this hypothesis, averaging times among sites implies BMP effectiveness at the South Bender site and this is not supported by the data. Instead, the results are mixed and consistent. When data from the River Ridge site is considered, it suggests that off-stream water reduced the time cattle spent in the riparian area and time spent drinking from the stream. Although, the observation periods for the pre and post treatments were very different with the pre-treatment observations made on December 2 and post treatment measurements made on June 29 and September 26. The difference in observation periods and factors that may have influenced differences found between the treatment periods were not addressed.

This study determined that off-stream water led to reductions in stream erosion at the River Ridge site. While only one site was evaluated, the authors suggest some level of effectiveness of off-stream water to reduce erosion. With that, additional consideration is needed. Most importantly, the seasonal timeframes for comparing pre and post treatment data are measurably different (pre-BMP period: Aug. 1994 through Apr. 1995, post-BMP period: April 1995 through October 1995), and conditions likely to affect animal behavior, runoff characteristics and potential for erosion are not comparable. The study did not address this issue. Absent an evaluation of the effects of these factor son outcomes, the reduction in streambank erosion cannot be solely attributed to post-BMP implementation.

Results from this study also suggest that off-steam water led to significant reductions in sediment, nutrients and pathogens and reductions were attributed to significant reductions in stream bank erosion. As highlighted, the streambank erosion cannot be attributed solely to off-stream water implementation as the observation periods varied significantly in temperature, precipitation, vegetation cover, vegetation vigor, and all these factors likely influenced erosion, runoff and sediment adsorbed and runoff off induced pollution. Differences in the observation periods and differing conditions may have influenced the study results were not accounted for. Thusly, comparing water quality results between pre and post treatments is problematic, and the conclusions likely have limited validity. This issue was partly addressed by the authors when discussing the significant increase in nitrate concentrations after off-stream watering was installation by highlighting the increased mean air temperature during the post-BMP period. Increases in soil temperature affects the mineralization of organic nitrogen to nitrate and is one example of the influence of season. More importantly, the authors highlighted the many limitations of this study stating "the implementation of the conclusions drawn from this study are limited by several factors. First, the study was conducted for a relatively short time of about 14 months. Seasonal variation of cattle behavior, rainfall patterns, and runoff nutrient concentrations may significantly alter the conclusions drawn from this study if data were collected for longer durations".

This study and results highlight the complexity of evaluating BMP effectiveness and the importance of good study design and comparability among sites. Also, as highlighted by Agouridis et al. (2005), visually identifying animal location can be difficult and laborious, observers are prone to fatigue and observation periods are often too short to develop confidence in daily behavior patterns. The results of this study are likely a reflection of the challenges highlighted by Agouridis et al. and likely reasons subsequent studies have used GPS collar to track animal behavior over multiple grazing seasons and multiple observation periods with grazing seasons. This study also highlights the importance of including controls, replicates and the value of evaluating change over similar timeframes and conditions.

46. Simon, A., Bennett, S. J., & Neary, V. S. (2004). Riparian Vegetation and Fluvial Geomorphology: Problems and Opportunities. *Riparian Vegetation and Fluvial Geomorphology*, *8*, 1-10.

This study focuses on how riparian vegetation influences various processes in geomorphology and affects the magnitude/distribution of important hydrologic, hydraulic, and geotechnical factors in river environments. With this, riparian vegetation can potentially improve or worsen processes that affect stream morphology and understanding these impacts is essential to understanding stream channel hydraulics, sediment transport, and morphology. The study analyzes flow resistance, velocity, turbulence, bank erosion, as well as large woody debris and river restoration. Overall, understanding interactions between riparian vegetation and geomorphology is necessary for analyzing alluvial channels. Quantifying these relationships is beneficial to informing erosion-control and stream restoration activities.

47. Tiedemann, A. R., Higgins, D. A., Quigley, T. M., Sanderson, H. R., & Bohn, C. C. (1988). Bacterial water quality responses to four grazing strategies—comparisons with Oregon standards (Vol. 17, No. 3, pp. 492-498). American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

The main objective of this study was to determine how different cattle grazing strategies effected fecal coliform concentrations and compare those concentrations to Oregon's water quality standards. Another objective of the study was to identify bacterial sources (livestock and wildlife) by comparing the ratio of fecal coliform and fecal streptococcus concentrations.

The study was conducted in watersheds located in the northern part of the Malheur National Forest near John Day, Oregon. Study sites where a combination of USFS and USDA grazing allotments and private lands. The grazing strategies evaluated included A) no grazing B) grazing without management to promote uniform livestock distribution C) grazing management to attain uniform distribution via fencing and water developments and D) intensive grazing to maximize livestock production including uniform distribution and improved forage with practice such as seeding, fertilization and forest thinning. 13 samples were collected at each site from July 3 to September 25 to establish mean FC levels and a rolling geometric mean. Concentrations of FS were used for calculating FC/FS ratios to determine the bacterial source.

The geometric mean FC counts had the following pattern A<C<B<D; however only the lower values for A and C were statistically different. In a longer-term study conducted by the authors in the same area (6 years) the FC counts were significantly different and followed the same pattern of A<C<B<D. Strategy A watershed and all but one strategy C watersheds had FC levels less than 10 FC/100ml.

When comparing FC counts to the Oregon water quality standards, two D strategies violated the water quality standards (the third D strategy was not grazed during the study period). One strategy C (containing streamside meadow) approached a violation of the standard but declined rapidly after the removal of cattle. The authors stated the difference in the physical and vegetation characteristics of the watershed played a major role in the degree of FC contamination. For example, all strategy D watersheds had prominent meadows adjacent to the stream and the one strategy C watershed with elevated FC had a "stringer" meadow next to the stream. The authors surmised that cattle frequently concentrated in the meadows along the stream because of water, gentler terrain and more abundant and succulent forage, and stated that the actual number of animals in a watershed is probably not as important as watershed characteristics.

The effects of cattle presence and their previous presence was not found to have a statistically significant effect on FC concentration; however, a comparison of means found a nine-fold greater FC counts when cattle were present than when they were not. Comparison of the three grazing strategies was most prevalent for strategy D which had counts of 27, 269 and 155 per 100ml for cattle not present, cattle present and cattle previously present, respectively. Average FC counts after cattle removal were 60% less than when cattle were present. Differences were not significantly different due to variability, but the authors concluded that comparisons reinforced conclusions from their long-term study that FC levels can remain elevated up to 9 months after animals are removed from a watershed.

For FC/FS ratios, the majority of strategy A, B and C watersheds samples had FC/FS ratio less than 0.04 which was presumed to indicate that wildlife were the primary bacterial source. Cattle appeared to be the main sources of bacteria in D strategy watersheds with FC/FS ratios between 1.2-0.08. It's important to note that prior to this study (1988), the ratio of FC to FS had been proposed as a way to determine bacterial sources in lakes and streams where lower ratios indicate wildlife and high ratios indicate cattle or human sources. However, attempts to use FC/FS ratios to determine bacterial sources have not been consistently successful. Confounding factors include, but are not limited to, the requirement for sampling to occur soon after manure deposition (within 24 hours), differing fecal bacteria die off rates and difficulties of distinguishing fecal streptococci in wastes from fecal streptococci that are naturally present in soil and water. As a consequence, streams with naturally higher FS would have lower FC/FS ratios suggesting wildlife as the source. Varying die-off rated could also skew results to suggest cattle or wildlife. Given advances in other, more accurate analytical techniques and the variability of this approach, it's not currently considered a preferred or reliable approach. While the evaluation of FC/FS ratios may provide limited information, this study was able to evaluate instream FC concentrations under differing grazing strategies and also show differences is FC counts based on whether livestock were present, absent or previously present. Additional information about each grazing strategies and additional analysis of factors of each strategy to affects or could have affected FC counts would have provide additional value.

48. Trimble, S. W. (1994). Erosional effects of cattle on streambanks in Tennessee, USA. *Earth surface processes and landforms*, *19*(5), 451-464.

The study assesses how cattle grazing and other factors contribute to streambank erosion. A key finding is that the impacts of cattle on streambank erosion are challenging to isolate given the impacts from other factors in the Central Basin of Tennessee. However, results showed that uncontrolled cattle grazing caused roughly six times as much gross bank erosion in comparison to protected land. This erosion was due to the breakdown of banks from cattle trampling, rather than by removal of bank vegetation by grazing. The study provides insights on inexpensive control structures to reduce bank erosion. For example, low dams could mitigate both mechanical damage and streambank erosion. Overall, this study provides a geomorphically short-term view of cattle grazing on streambanks. More research over longer time periods is needed to understand impacts on grazed and un-grazed areas along streambanks.

49. Trimble, S. W., & Mendel, A. C. (1995). The cow as a geomorphic agent—a critical review. *Geomorphology*, *13*(1-4), 233-253.

The study found evidence that heavy grazing by cattle compacts soil, reduces infiltration, increases runoff, and increases erosion and sediment yield. Alternatively, light and moderate grazing have less significant impacts. In riparian zones, grazing was found to decrease erosional resistance. Recommendations provided in the study include that future studies should be framed within the hydroclimatological, edaphic and geomorphological dimensions of the areas being studied so that controlling variables can be isolated. This is especially critical for studying differences in semi-arid and humid environments. Overall, empirical studies and deterministic modeling can be useful for understanding grazing impacts on geomorphology.

50. Tuffour, H. O., Bonsu, M., & Khalid, A. A. (2014). Assessment of soil degradation due to compaction resulting from cattle grazing using infiltration parameters. *International Journal of Scientific Research in Environmental Sciences*, *2*(4), 139.

The purpose of this study was to investigate how cattle grazing contributes to soil degradation. Ungrazed and grazed fields were used for the study and soil texture, moisture content, bulk density, total porosity and aeration were observed. Excess rainfall was found to cause instant ponding and/or runoff on both fields. Cattle hooves affected various soil characteristics through surface compaction. Even though cattle in this study grazed for a shorter time period, results still showed significant impacts on soil properties and infiltration parameters. Overall, the study found that cattle grazing was harmful to soil structure and infiltration due to soil compaction. With this, infiltration parameters are useful for evaluating soil degradation due to cattle grazing.

51. Tufekcioglu, M., Isenhart, T. M., Schultz, R. C., Bear, D. A., Kovar, J. L., & Russell, J. R. (2012). Stream bank erosion as a source of sediment and phosphorus in grazed pastures of the Rathbun Lake Watershed in southern Iowa, United States. *Journal of Soil and Water Conservation*, *67*(6), 545-555.

This study was intended to determine the sediment and phosphorus losses from stream bank soils under varying cattle grazing rates to understand factors that impact stream bank erosion in southern Iowa. The study area was 13 cow-calf farms and over three years, stream bank erosion rates were estimated using an erosion pin method. Results showed that the length of severely eroded streambanks and soil compaction of riparian areas in pastures were positively related to grazing rates. With this, the use of riparian areas for grazing can negatively impact the integrity of major source areas. However, the impacts of livestock grazing can be reduced through best management practices. Additionally, nutrient losses from stream banks and riparian areas can be reduced with better management. Stream size, morphology, and hydrologic characteristics of streams are important causative factors that drive sediment flux and could mask the impacts of improved livestock grazing management in riparian areas.

52. Zaimes, G. N., Schultz, R. C., & Isenhart, T. M. (2004). Stream bank erosion adjacent to riparian forest buffers, row-crop fields, and continuously grazed pastures along Bear Creek in central Iowa. *Journal of Soil and Water Conservation*, *59*(1), 19-27.

The study assessed how row-crop agriculture, grazing, and stream channelization accelerated stream bank erosion and increased sediment load. The study area included riparian forest buffers, row-crop fields, and continuously grazed pastures in central Iowa over one year. Results showed that row-crop fields had the greatest stream bank erosion rate and total soil losses whereas riparian forest buffers had the lowest erosion rates and soil losses. The study gives background information on stream bank erosion trends across seasons and typical consequences of episodic stream bank erosion patterns. Even though stream bank erosion varies, land use impacts erosion rates, total bank eroding lengths, and soil losses. Riparian forest buffer vegetation was found to reduce stream bank erosion and could be implemented along row-crop fields and grazed pastures. Overall, sustainable land use management should include sustained/minimal stream bank erosion and riparian forest buffers can effectively accomplish this goal.

53. Zaimes, G. N., Tufekcioglu, M., & Schultz, R. C. (2019). Riparian land-use impacts on stream bank and gully erosion in agricultural watersheds: What we have learned. *Water*, *11*(7), 1343.

This literature review focused on different studies conducted on streams in Iowa to understand riparian land-use impacts on stream banks, gullies, and other riparian sediment sources. Specific riparian land uses that were investigated were riparian forest buffers, grass filters, rotational/continuous pastures, pastures with fencing along streams, and row-cropped fields. Results showed that maintaining vegetation in riparian areas and excluding livestock grazing from streams resulted in stable stream banks and gullies. Additionally, cattle loafing areas and stream access points were found to be important sediment sources. With this, riparian vegetation can be a sustainable and cost-effective conservation practice to reduce sediment in streams and help maintain watersheds in agricultural production. Overall, the literature review supported findings that overgrazed pastures with access to stream channels and row-cropped fields significantly contribute to nonpoint sediment in water from stream bank and gully erosion. Therefore, conservation measures should account for spatial and temporal soil erosion variability and target areas that produce the most sediment to maximize effectiveness of these measures.

Chapter 10 Appendix Part B: Implementation Considerations (Livestock Management: Pasture & Rangeland Grazing BMPs)

Introduction

This section describes factors related to the implementation of pasture and rangeland grazing best management practices in Washington state (WA). It focuses on factors that apply at the parcel level and is meant to support decision making as producers to move towards implementing conservation and clean water practices for pasture and rangeland. General information is provided below on costs and benefits along with discussion of the barriers and incentives for adoption of each practice. The *Implementation Information Synthesis* provided for each practice provides specific information for implementation. Information was gathered through literature review and interviews with conservation districts and other practitioners.

Range and pasture lands are diverse but refers to land where the primary vegetation is herbaceous plants and disperse trees and shrubs. The land provides forage for beef cattle, dairy cattle, sheep, goats, horses and other types of domestic livestock. The primary economic outputs of this land include livestock production but there can also be wildlife and recreation values. According to NRCS Washington, these lands provide ecosystem services, such as clean water, wildlife and fish habitat, and recreation opportunities. As of 2021, Washington state had nearly 1.2 million heads of cattle (USDA 2021). These cattle are raised both for beef production and for dairy production and are raised across diverse production conditions that occur across the state. Poor management of these livestock can lead to impaired water and air quality and contribute to the spread of noxious weeds.

This chapter focuses on three practices that can limit time spent by livestock in the stream and riparian areas leading to water quality benefits:

1. **Livestock exclusion fencing:** a practice where permanent fence is installed to prohibit livestock from accessing streams and critical areas not intended for grazing. Common types of exclusion fencing include; barbed, high tensile, board or electric wire.
2. **Off-stream watering**: a management practice to disperse livestock and reduce livestock impact to riparian and aquatic habitats (Johnson et al. 2016). Off-stream watering provides an alternatives source of drinking water or alternate method of access water to substitute for direct use of streams, irrigation canals or other water conveyances. Water can be delivered through a combination of pumps, pipes, troughs, and tanks sourced from wells, streams, spring developments, ponds, or rainwater catchment systems.

3. **Stream crossings:** stabilized areas or structures constructed across a stream to provide a travel way for livestock. Stream crossing should be located in areas where the streambed is stable or where grade control can be provided to create a stable condition.

This chapter also provides information on implementing grazing management strategies. Strategies can include early-season, late-season, mid-season, continuous-summer, deferred and rest-rotation. The three most commonly used strategies in the Pacific Northwest for alleviating pressure on riparian areas and water quality within rangeland settings are early-season, late-season and rest-rotation. As such, these are the three strategies focused on in this guidance. In pasture settings, rotational grazing is the most commonly used grazing strategy but concepts from early-, late- and rest rotation may be used as well. One of the most important factors driving the decision between grazing management strategies is timing, because they address seasonal preferences for riparian plant species and avoid grazing impacts when negative impacts are most likely.

It is well understood by practitioners and producers alike that all of these BMPs are highly site-specific and rely on producer knowledge of their own land. As such, this guidance attempts to acknowledge the various ways the practices can be implemented to support a producers goals for their operation (Boie 2013). The chapter also includes a list of relevant cost-share programs that can financially and technically support producers.

Livestock Exclusion Fencing

Livestock exclusion fencing is a practice where permanent fence is installed to prohibit livestock from accessing streams and critical areas not intended for grazing. Common types of exclusion fencing include barbed, high tensile, board or electric wire. Exclusion fencing is effective at reducing nutrient loads and allowing damaged and highly used riparian areas to repair.

Benefits and Costs Associated with Livestock Exclusion Fencing

Exclusion fencing is beneficial in settings where grazing lands, riparian areas and water quality are likely to be negatively impacted by poor grazing distribution, congregation in riparian zones, improper timing of grazing and inadequate rest and recovery periods. All of these factors can impact the water quality of streams. Restricting cattle access to the riparian area can help limit conditions that cause pollution. Additionally, increased vegetative cover by reducing trampling and plant removal reduces the opportunity for encroachment of noxious and invasive weeds.

There are a number of additional benefits to utilizing exclusion fencing. Restricting access by livestock to the stream can lead to better health outcomes and increased weight of cattle (Zeckoski et al. 2007). Producers in Virginia found their cattle had reduced instances of foot rot, pink, eye, scours, and mastitis. Additionally, one producer in the same study noted that risk of cattle drowning was reduced by excluding them from the stream. Another benefit noted in Zeckoski et al. found it was easier to gather the herd for veterinary visits, and to locate or isolate individual animals when fencing was utilized within a rotational grazing system. In

Washington state, exclusion fencing in combination with off-stream watering has been found to lead to better livestock dispersion through their range and in turn, the animals are healthier and require less supplemental feed during the year (ECY 2018). Reducing the amount of supplemental feeding can lower production costs.

There are two associated costs with exclusion fencing: installation and maintenance. Maintenance includes the regular checking of fence quality, fence replacement after flooding or fallen trees, riparian buffer vegetation management, and opportunity cost of the land in the buffer area lost to production (Zeckoski et al. 2007). However, costs gained through the weight gain of the cattle has been found offset the costs of the fencing itself in some cases (Zeckoski et al. 2007). In a model of eastern Oregon grazelands, fencing was less expensive that other practices to improve grazing distribution while it also increased profits for farmers through increased weight of cattle and calves (Tanaka et al. 2007).

Barriers to Implementation

A significant barrier to exclusion fencing, depending on the scale of livestock grazing and the size of the area of production, is there can be high upfront installation costs and subsequent maintenance costs (Malan 2018). The area between the fence and the stream could also be considered lost forage area (DelCurto 1999). Although in some cases excluding cattle from the stream reduces noxious weed growth in the riparian area, growth of noxious weeds is cited by producers as a negative aspect of exclusion fencing (Boie 2013). As weeds grow behind the fence, they can potentially move into the grazing area (Zeckoski et al. 2007). To reduce the amount of weed growth, mechanical removal or spot spraying may be needed.

Table 1: Implementation factors for exclusion fencing

Considerations	Details
Capital Cost	• Costs include equipment installation, labor, materials, and mobilization. • Detailed information on costs under a number of different scenarios can be found in NRCS guidance[3]. • In general, according to NRCS, under different scenarios barbed/smooth wire fence can cost $5.43 to $7.64 per foot. Woven wire fencing costs $6.76 per foot, and electric wire is estimated to cost $3.08 per foot. • Under heavy use scenarios where livestock pressure on the fence is expected, permanent installation of fencing would require heavy grade material, raising the cost to $9.03 per foot of fencing. • Fencing for sacrifice are winter feeding areas may be higher.

[3] https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download/?cid=NRCSEPRD1855299&ext=pdf

Considerations	Details
Operational and maintenance requirements and costs	• *Maintenance Requirements:* Regular inspections after storms and other disturbance events including tree/limb removal, repair or replacement of loose or broken materials or, gates, repair of eroded areas as necessary and, repair of replacement of markers or other safety and control features (NRCS 2022).
Technical requirements	• If a producer chooses to install fencing themselves, they may need to rent or buy a post-hole digger implement for a tractor. The alternative is to hire a contractor.
Lifespan	• The lifespan of fencing will depend on the type of fencing installed and the frequency of maintenance. According to NRCS the lifespan of different types of electric fencing can range from 17 – 33 years, whereas non-electric fencing ranges from 19 – 40 years.
Land area requirements	• At a minimum, Ecology recommends livestock fence be placed at the edge of the core zone but encourages exclusion from the entire RMZ. The land area requirements vary based on the type of stream-see Chapter 12.
Other implementation factors	• Exclusion fencing inherently limits cattle access to a water source, and as such, must be implemented with the placement of alternative off stream water sources. • For ease of maintenance purposes, NRCS recommends avoiding as much irregular terrain as possible (NRCS, n.d.). It is also important to consider soil erosion potential and feasibility of fence construction when planning fencing on steep or irregular terrain. ○ State and local laws may impact locations of boundary fences (NRCS, n.d.)
Resources	Associated NRCS practices (Field Office Technical Guides) include: • Fence (382)[4]

Off-stream watering

Adoption of Off-Stream Watering Practices in Washington State

Off-stream watering practices are often implemented to manage grazing distribution, improve vegetation of with pastures and rangeland, and reduce or eliminate the presence of livestock in streams and riparian areas. Limiting the time livestock spends in streams and riparian areas can improve water quality and the health of the riparian area. Water development in upland areas that lack water is often a key factor in reducing livestock concentrations in riparian areas. Where feasible, water development can be achieved by installing solar, hydraulic ram, or

[4] https://efotg.sc.egov.usda.gov/#/state/WA

conventional pumps; developing springs, seeps, wells, or guzzlers; and piping water to several troughs once collected. Even within riparian areas or riparian pastures, water developments, ponds, or troughs can reduce streambank trampling damage (Malan 2018).

As mentioned above, off-stream watering is required when exclusion fencing is implemented. Unrestricted livestock access to streams has been found to negatively impact water quality. Also, when provided access, cattle deposited approximately 10% of their waste in streams. Properly placed alternative water sources can reduce the amount of time cattle spend in riparian zones and in turn reduce defecation adjacent to streams.

Off-stream watering can take on a wide range of sizes, shapes, and materials depending on the needs of the livestock and producers. Water is delivered using a combination of pumps, pipes, troughs, and tanks with common water sources being wells, streams, and springs. The watering point itself can be permanent or temporary and can be made of a range of materials including tires, lumber, or concrete. Common delivery systems include:

- Mobile tanks/hauling water
- Electric pump (connected to a grid) and well
- Gravity fed systems
- Solar pumps
- Wind pumps
- Hydraulic ram pumps
- Nose pumps (i.e., pasture pump/livestock powered)
- Sling pump (likely uncommonly used
- Gas power pump (likely uncommonly used)

Systems designed for off-stream water in Washington state are highly site dependent and rely on producer's knowledge of their land, animal behavior, and producer preferences. Oftentimes, different delivery systems are combined to fit the needs of producers. For example, in an implementation interview with Conservation Districts, it is common to install shallow wells utilizing a solar array to pump water into a tank, which is then gravity fed down to a trough. Efficiency and ease of use/access is a priority for implementing the practice, and it is common for troughs to be placed near existing heavy use areas (See Chapter 12) or between two paddocks so it can be accessed by cattle continuously across grazing areas. If there is no existing heavy use area, it is recommended to implement the practice in concert with off-stream watering. There are a number of ways for producers in Washington to implement off-stream water and there is no one-size-fits all option.

Benefits and Costs Associated with Off-Stream Watering

Off-stream watering can lead to a range of benefits to the environment and producers. Lack of available drinking water sources can restrict land use by livestock and strategically placing watering locations can disperse cattle across a wider range of land and reduce pressure on riparian areas (Johnsen et al. 2016). Not only can providing off-stream water lead to water quality benefits, such as reduced *E. coli* loading in streams (Wagner et al. 2013), but it can also improve the health of cattle through delivery of clean water. In a study on the use of off-stream watering, cattle gained up to 9% more weight as compared to those who had direct access to streams (Brewner 2008). A study in northeastern Oregon found that increased weight of cattle utilizing off-stream water led to an increased annual net return to ranchers of $4,500 to $11,000 depending on cattle prices at the time and precipitation levels (Stillings et al. 2003). In this same study, cattle grazing was dispersed more broadly across upland areas which led to reduced purchasing of feed from other sources, lowering input costs. Costs gained through weight increases of livestock and reduced costs of inputs are often a driving consideration for producers who choose to implement off-stream watering.

Barriers and Incentives to Implementing Off-Stream Water

In some cases, off-stream water can lead to concentration of disturbance in areas outside of the riparian area since cattle congregate nearby. When deciding where to implement an off-stream watering point, producers should avoid creating new problems, such as excess soil erosion or vegetation and habitat impacts (Malan 2018). A frequently cited incentive of off-stream watering is increased profits for producers. In a model of eastern Oregon grazelands, off-stream water development was less expensive that other practices to improve grazing distribution while increasing profits for farmers through increased weight of cattle and calves (Tanaka et al. 2007).

Table 2: Implementation Factors for Off-Stream Watering

Considerations	Details
Capital Cost	• Livestock Pipeline (according to NRCS guidance) • *Equipment installation*: $1.63 per 12-inch-wide x 48-inch depth – including equipment and labor for trenching and backfilling • General labor: $31.73 per hour • *Materials*: $2.34 per pound of PVS pressure rated pipe priced by weight of materials w/ diameters less than 18 inches, • *Mobilization/medium equipment*: $262.88 each per equipment with 70-150 HP or typical weights between 14,000 and 30,000 lbs. • Nose pumps • *Cost of Nose Pumps:* Range from approximately $400-$1700. The low estimate is for a basic nose pump and the high-end estimate is for frost-resistant nose pumps available. • Trough • *Tanks*: Small (14-16 gallon) portable tanks with float valves cost $100-$150 each. ◦ *Delivery Method in Remote Areas*: Solar and wind systems to deliver water generally cost between $1,500 and $4,000 (https://extension.missouri.edu/publications/eq380)
Operational and maintenance requirements and costs	• *Maintenance requirements:* Cleaning, repair, replacement of damaged components (e.g., leaks, site erosion, damage to associated fencing, heavy use areas), ensuring adequate inflow and outflow, and winterizing (NRCS 2014) and checking the performance of the automatic water level device, if present (NRCS 2021). Outlet pipes, if being used, should be checked to ensure they are functioning and not causing erosion. • If winterizing: Must drain supply pipes, empty tanks, or ensure that float valves will not be damaged by ice (NRCS 2021). ◦ If a portable trough is used: There must be a plan to move the trough, along with monitoring the condition of the vegetation in the area (NRCS 2014).
Technical requirements	• Off-stream water placement may require knowledge of where and when livestock graze across landscapes. Placing off-stream water in frequently used areas or near established roads can increased frequency of use by cattle (Johnson et al. 2016). • To limit traffic near the RMZ, setbacks of 250 meters feet or greater are preferred. For small properties, locate off-stream water as far from the riparian buffer as possible.

Considerations	Details
	• Research suggests that forage utilization is significant reduced once the horizontal distance to water is above 1.6 km. In rangeland settings, its to recommend limit the horizontal distance to water to 1 km or less. Further reducing the horizontal distance to water in rough terrain or steep topography may be necessary. In pasture situations, it is recommended to limit the horizontal distance to water as must as possible. 250 m or less is best whenever possible. One trough is suggested for every 50-75 cattle (Malan et al. 2018). • If using a nose pump, one nose pump to every 20-35 cattle, depending on the manufacturer specifications. • Cattle on steep slopes spent less time in riparian areas. Grades of <10% more favorable for placement of OSWPs (Malan et al. 2018; Bailey et al. 2006).
Lifespan	• NRCS (2014) states the life expectancy of a water source is at minimum 10 years and can be longer with proper maintenance.
Land area requirements	• Water development may be most necessary in: • Upland areas where there is a lack of water (USDA 1997). • All land uses where there is a need for a watering facility for livestock or wildlife, where there is a source of water that is adequate in quantity and quality for the purpose, and where soils and topography are suitable for a facility (NRCS 2021).
Other implementation factors	• Inclusion of mineral salts and supplements within 5m of OSWP may attract cattle to underutilized areas and reduce time cattle spend in the riparian area (McInnis and McIver 2001). • Shape of the off-stream watering point may influence frequency of use but studies on shapes have mixed results (Malan 2018). • Accessibility via moderate terrain or by established roads may improve use (Johnson et al. 2016). • Creating shade and locating rubbing posts and oilers nearby may augment water development and help reduce the time livestock spend in riparian areas (USDA 1997) • Some sites may require watering ramps to stabilize use areas, specifically for ponds. • A Hydraulic Project Approval (HPA) from the Washington Department of Fish and Wildlife (WDFW) may be required when installing off-stream water systems that withdraw water directly from streams. Consultation with WDFW about the need for a HPA prior to the installation of these types of systems is recommended. The HPA application can be accessed online.

Considerations	Details
	• Local permits may be required for electrical systems associated with off-stream watering systems.
Resources	Associated NRCS practices (Field Office Technical Guides) include: • Livestock pipeline (516)[5] • Pond (378)[6] • Pumping plant (533)[7] • Spring development (574)[8] • Watering well (642)[9] • Water facility (614)[10]

Stream Crossing

Adoption of Stream Crossing Practices in Washington State

Stream crossings are practices designed to assist livestock with safely traversing a stream or creek in order to access additional pastures or other livestock rearing facilities while reducing impacts to the stream channel, streambanks and riparian vegetation. Three common stream crossing types include bridges, fords (hardened and stabilized streambed) and culverts. Stream crossings are applied to improve water quality by reducing sediment, nutrient, or organic loading to a stream and reduce streambank and streambed erosion. The practice can be applied to all land uses where an ephemeral, intermittent or perennial stream exists, controlled access from one side of the stream to the other side is necessary to reduce or eliminate environmental degradation, and where soils, geology, fluvial geomorphology and topography are suitable for construction of a stream crossing.

Permitting for Stream Crossing in Washington State

Hardened crossings are commonly used in Washington State. Any hydraulic project in the state of Washington requires permits from Washington Department of Fish and Wildlife. Larger order streams would call for USACE or associated county permits. Local permits may also be required. Permits may be required for alterations, repairs, maintenance, enlargements, and removals of bridges, culverts, and low water crossings.

5 https://efotg.sc.egov.usda.gov/api/CPSFile/28787/516_WA_CPS_Livestock_Pipeline_2021
6 https://efotg.sc.egov.usda.gov/api/CPSFile/17935/378_WA_CPS_Pond_2020
7 https://efotg.sc.egov.usda.gov/api/CPSFile/28806/533_WA_CPS_Pumping_Plant_2021
8 https://efotg.sc.egov.usda.gov/api/CPSFile/33581/574_WA_CPS_Spring_Development_2022
9 https://efotg.sc.egov.usda.gov/api/CPSFile/28660/642_WA_CPS_Water_Well_2021
10 https://efotg.sc.egov.usda.gov/api/CPSFile/28913/614_WA_CPS_Watering_Facility_2021

State Permit Requirements

The Revised Code of Washington (RCW) 77.55 requires that any work that uses, diverts, obstructs, or changes the natural flow of fresh or salt water obtains a Hydraulic Project Approval (HPA) from the Washington Department of Fish and Wildlife. This includes projects that involve any construction, repair, or replacement of any structure crossing a stream, river, or any body of water regardless of the location. It is also required for moving large woody debris in a stream. This ensures that fish and aquatic habitats are protected.

The HPA permit process is free can take 45 days after the receipt of a complete application package. The HPA application can be accessed online.[11] Permit applications are submitted to the Aquatic Protection Permitting System (APPS)[12] and applications are reviewed in Olympia for completeness under RCW 77.55.021. To be complete, the HPA must include:

- General plans for project
- Complete plans and specifications for the proposed construction or work within the mean higher high-water line in salt water or within the ordinary high-water line in fresh water
- Complete plans and specs for the proper protection of fish life.
- Notice of compliance with any applicable requirements of the State Environmental Policy Act (SEPA).
- Applications for streamlined processing of fish habitat enhancement projects must additionally include a copy of the Joint Aquatic Resource Permit Application JARPA[13], the fish habitat enhancement project application form (an attachment to JARPA), and proof of sponsorship of the project.

Once the application is accepted, a habitat biologist reviews and processes applications within APPS. The design must meet all Washington Administrative Code (WAC) 220-660-190 requirements. The stream being constructed on is fish bearing, there are a lot more requirements to consider. Helpful resources to better understand the HPA process include the Governor's Office for Regulatory Innovation and Assistance Permit Handbook[14] and WDFW's Complete Water Crossing Design Guidelines manual.[15]

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[11] https://wdfw.wa.gov/licenses/environmental/hpa
[12] https://www.govonlinesaas.com/WA/WDFW/Public/Client/WA_WDFW/Shared/Pages/Main/Login.aspx
[13] https://www.epermitting.wa.gov/site/alias__resourcecenter/jarpa/9983/jarpa.aspx
[14] https://apps.oria.wa.gov/permithandbook/permitdetail/25
[15] https://d3n8a8pro7vhmx.cloudfront.net/yyccares/pages/20/attachments/original/1498653408/Washington_State_wdfw01501.pdf?1498653408

Federal

Projects that involve filling or dredging materials for development such as stabilizing a streambank, water resource projects such as dams or levees, infrastructure developments such as highways and airports, and mining projects require a permit under [Section 404][16] of the Clean Water Act (CWA). This is regulated by the U.S Army Corps of Engineers (USACE). USACE has jurisdiction over any work below the ordinary high-water mark. Typically, landowners will need to seek a Nationwide Permit (NWP) if there are more than minimal environmental impacts. If a NWP is needed, a submission of a Pre-Construction Notification (PCN) will need to be sent to the USACE prior to construction. There are different permits for different activities, such as maintenance or bank stabilization. See appendix D of User's [Guide for Nationwide Permits in WA State][17] for a list of nationwide permits.

Local

Local permits may be required as well to build stream crossings. It is best to contact or research your local county to ensure these requirements are met. For example, Whatcom County WA provides a checklist[18] before construction of a private bridge. A Whatcom County Land Disturbance permit, or Private Bridge Permit may be required if the bridge was not reviewed by the county engineer.

Local governments participating in the National Flood Insurance Program (NFIP) administered by the Federal Emergency Management Agency (FEMA) must review proposed projects to determine if they are in the 100-year floodplain. If projects are in this zone, they require a Floodplain Development Permit, issued by the City or County government. The cost of this permit will vary depending on local governments. Development includes, but is not limited to, any man-made changes including structures, dredging, filling, paving, excavating, drilling. For more information, see the Office for Regulatory and Innovation and Assistance website[19] on Floodplain Development Permits.

Benefits and Costs Associated with Stream Crossings

There are a number of benefits associated with implementing stream crossings. Having an establish stream crossing can reduce pollutant loads in streams, reduce erosion along the stream bank, and promote cattle grazing in upland areas as opposed to the riparian zone resulting in more uniform grazing. Some of the benefits for producers include providing livestock access to all pastures on a producer's land, providing access to grazing fields that are

[16] https://www.epa.gov/cwa-404/permit-program-under-cwa-section-404
[17] https://wsdot.wa.gov/sites/default/files/2021-10/Env-perm-CorpsNWPUsersGuide.pdf
[18] https://www.whatcomcounty.us/DocumentCenter/View/1135/Private-Bridge-Permit-Review-Checklist-PDF
[19] https://apps.oria.wa.gov/permithandbook/permitdetail/47

difficult to access, improving health of cattle by preventing them from spending time in the mud, cleaner water, and control of where the cattle cross (NRCS 2009).

The cost of implementing stream crossings is largely influenced by how the crossing is built and the width of the stream. Other factors influencing the costs include the grading of the stream banks and bottom, the material used, and any fencing installed to guide livestock to the crossing.

The cost of implementing stream crossings is largely influenced by how the crossing is built, the width of the stream, and how the crossing will be utilized. Other factors influencing the costs include the grading of the stream banks and bottom, the material used, and any fencing installed to guide livestock to the crossing. Costs will vary by design, such as bridges or culverts. When choosing a design, it is important to consider the stream's ability to move floodwaters, installation and replacement costs, annual maintenance costs, organism passage effectiveness, and structure lifespans. Costs need to take into account not only building costs, but future replacement and repair costs as well. (USDA).[20]

Barriers and Incentives of Stream Crossing

A potential barrier to implementing stream crossing is acquiring the necessary state or federal approval or permits. However, if landowners work with NRCS to develop implementation plans, the permitting process can be streamlined. According to Washington state law (RCW 77.55[21]), structures utilized for crossing over fish bearing streams also require a Hydraulic Project Approval (HPA), which is provided through the Washington Department of Fish and Wildlife.

There are a number of programs that incentivize the implementation of BMPs such as stream crossings. NRCS Conservation Stewardship Program[22] is a voluntary program that enables producers to gain free technical assistance from NRCS. The CSP can also provide financial assistance in completing projects on producer-owned land. In order to be eligible, producers need to meet Adjusted Gross Income requirements and have a Farm Tract Number with FSA. Land already enrolled in USDA Farm Bill programs, such as CRP and some easement programs, may not be eligible. CSP enhancements include stream crossing, in particular, strategies to reduce the number of stream crossings on a producer's land to assist grazing and reduce the amount of erosion along a stream. Improvements noted by the CSP participants include improved cattle gains per acre, decreased inputs, and better resilience to weather extremes.

[20] https://deq.nd.gov/publications/WQ/3_WM/NPS/SWCBinder/Rangeland/Stream_Cross_Final.pdf
[21] https://apps.leg.wa.gov/rcw/default.aspx?cite=77.55
[22] https://www.nrcs.usda.gov/wps/portal/nrcs/main/wa/programs/financial/csp/

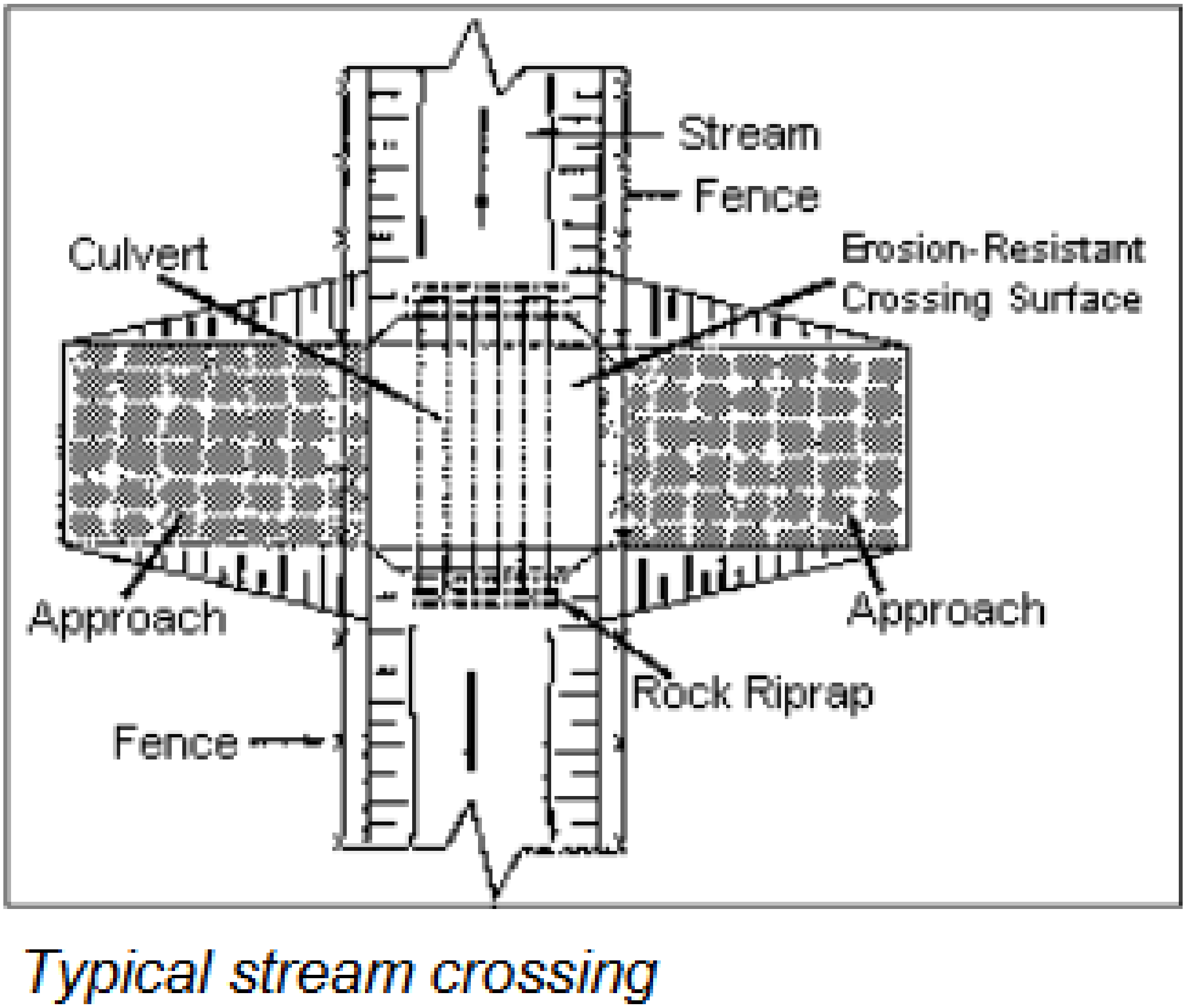

Figure 2: Typical stream crossing cross section ***Source: NRCS 2009***

Table 3: Implementation Factors for Stream Crossing

Considerations	Details
Capital Cost	• *Hard Armor Crossing:* According to NRCS Guidance, a low water crossing utilizing hard armor would cost $25.06 per square foot, and a low water crossing utilizing prefabricated products (i.e., precast concrete blocks, geocells, pavers, and gabions) would cost $27.04 per square foot. • *Culverts and Bridges:* If the use of culverts and/or bridges is necessary, the cost is significantly higher. Culverts should only be used in areas where there are hydrologic needs, not aquatic organism needs. However, bridges may need to be built if the producer is hoping to also utilize the stream crossing for heavy equipment access. If culverts/bridges are utilized, the cost can range from $495.12 per square foot to $2,632.33 per square foot, dependent on the expected uses of the crossing and materials used.
Operational and maintenance requirements and costs	• If installed correctly, very little maintenance should be needed. Some maintenance actions include checking the crossing after storms for erosion on the banks and streambed, repairing eroded areas, and checking any associated livestock fencing.
Technical requirements	• A livestock only crossing should be no less than 6 feet wide, and no more than 30 feet wide, as measured from the upstream end to the downstream end of the crossing, not including the side slopes. • Side slope cuts and spills should be stable for the channel materials involved. The side slops should be no steeper than 2 horizontal to 1 vertical (2:1). Rock cuts or fills should be no steeper than 1.5 horizontal to 1 vertical (1.5:1). • Must be installed in a location where the streambed is stable or where the streambed can be stabilized (NRCS 578). • The main aspect of building a sturdy stream crossing is ensuring the slope of the banks of the stream on each side are firm. This includes making the banks flat enough for livestock or equipment to move safely down the bank, protecting banks with gravel laid over filter fabric, and making the streambed firm enough for cows and equipment to cross without causing ruts. In some cases, such as in gravel or bedrock streams, additional streambed preparation may not be needed (NRCS 2009).
Lifespan	• 20 years according to Texas A&M University [23]
Land area requirements	• Any associated fencing to guide cattle to stream may block grazing areas.

[23] https://agrilifeextension.tamu.edu/library/ranching/reducing-bacteria-stream-crossing/

Considerations	Details
Other implementation factors	• NRCS recommends vegetating highly disturbed areas as soon as practical after construction of a stream crossing in line with CPS Critical Area Planting (Code 342) or CPS Heavy Use Area Protection (Code 561). • Streambank soil bioengineering practices and other streambank stabilization measures should follow practices set out by CPS Streambank and Shoreline Protection (Code 580) where appropriate (NRCS 2018). • Approaches and descent grades should be no steeper than 4:1 (NRCS 2018). • Stream crossings should not be placed where the channel grade or alignment changes abruptly, excessive seepage or instability is evident, overfalls exist, where large tributaries enter the stream, or within 300 feet of known spawning areas of listed species. • It is easiest to install stream crossings during the driest time of the year to avoid issues with mud and erosion.
Resources	Associated NRCS practices (Field Office Technical Guides) include: • Stream Crossing (578)[24] • Heavy Use Area Code (561)

Grazing Management Strategies

Adoption of Grazing Management Strategies in Washington State

There are a number of different grazing management strategies that can be applied in different rangeland and pasture settings, including early-season, late-season, mid-season, continuous-summer, deferred, rest-rotation and rotational grazing. The most commonly applied grazing management strategies within rangeland settings in the Pacific Northwest are early-season, late-season and rest rotation. In pasture settings, rotational grazing is the most commonly used grazing strategy but concepts from early-, late- and rest rotation may be used as well.

Early-season grazing commonly occurs between April and mid-July whereas late-season grazing occurs from September through November. Rest-rotation grazing management is a system where pastures are grazed during alternating seasons, including a year of rest where no grazing occurs. Approximately 1/3 of available pastures can be rest annually. These rest years allow for grazed areas and vegetation to recover. Deferred grazing strategies, including rest-rotation, are commonly applied in rangeland settings more appropriate in Eastern Washington. The remainder of the season, livestock may be in sacrifice areas or grazing in other pastures.

[24] https://efotg.sc.egov.usda.gov/api/CPSFile/18846/578_WA_CPS_Stream_Crossing_2018

Wet Pastures and Sacrifice Areas

Wet pastures and sacrifice areas are often utilized along with grazing management strategies to limit livestock grazing from mid-fall to early spring (approximately November to March). These sacrifice areas typically utilize a small enclosure, such as a paddock, corral, or pen. The location of sacrifice areas should be on high enough ground to improve drainage and prevent ponding. The location is recommended to be near a barn or manure storage to facilitate maintenance and care of the livestock. The sacrifice areas should be located so it avoids drainage to streams and other water sources and can include a vegetated buffer strip around it to increase filtering of pollutants before they leave the area.

Proper sizing of the sacrifice area is essential and will be determined by the number of livestock being managed and the amount of land available. Lining can be from a number of materials, including hogfuel, gravel and sand, and geotextile fabric. Hogfuel represents the cheapest option and geotextile fabric the most expensive. If hogfuel is being used alone, it is recommended to use small sized hogfuel to more easily remove manure and it should be 18" to 24" in depth. Gravel and sand is more long lasting than hogfuel, and should be at a depth of 8" to 12". Gravel and sand can be trampled and can sink into the soil if applied directly and will need to be replaced periodically. Geotextile fabric can be used with other footings to improve drainage. A common footing application is a layer of geotextile fabric, 6" of gravel, 6" of sand, and topped with hogfuel. For more information on implementing a wet pasture or sacrifice area, see the Washington University Extension. (WSU-Pasture Sacrifice Areas[25])

Benefits and Costs Associated with Grazing Management Strategies

Beyond improved water quality, implementing well-suited grazing management strategies for a given pasture or rangeland forage can lead to healthier pastures and producer better quality and greater quantities of forage. Reduction in weed infestations through improved soil health can also lead to higher quality forage. As a result, the grazing season can lengthen, increase the health of animals, and reduce the cost of supplemental feed. Producers in Wisconsin saw increases in net income per cow through implementing rest-rotation grazing systems and dairy farmers saw an increase in net income for milk (Undersander et al., 2002). In general, grazing management strategies can lead to more drought resistant lands, which is particularly important for eastern Washington, through increased soil health. Rest-rotation can also provide opportunities to implement relatively long-term rangeland improvement practices (e.g., reseeding, brush control) during scheduled rest periods, and rested pastures can provide emergency forage during severe drought years. (Howery et al., 2000). Rest-rotation practices are particularly desirable because they can be designed based on a producer's specific needs and can allow more control over the timing and intensity of forage grazed by cattle.

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[25] https://extension.wsu.edu/clark/naturalresources/smallacreageprogram/pasture-sacrifice-areas/

A common perception is that rest-rotation systems require more time to move cattle, but this is only true in cases where the system is not designed properly. If the paddock is designed efficiently, a study in Wisconsin found that after milking, moving cattle only averaged 15 minutes per day in contract to feeding hay and silage in confinement, which can take 20 minutes to one hour (Undersander et al. 2002).

Barriers and Incentives of Grazing Management Strategies

There are few barriers to implementing appropriate grazing management strategies to a producer's land. However, in some cases, rested pasture may attract elk, deer, and other herbivores which can ultimately reduce the positive impacts of the rest rotation system to the pasture (Howery et al. 2000). Additionally, individual animal performance may decrease due to the required, forced animal movement from one area to another. Lastly, with increased stocking density, there can be a reduction in dietary selectivity by animals. To reduce this negative impact on dietary selectivity, producers should size their areas being utilized for rest-rotation based on current and future stocking rates (Howery et al. 2000).

Strategies also have unique disadvantages, and it is important to consider the desired outcomes for producers in concert with the weaknesses of practices. Because early-season grazing occurs during wetter months, it is more likely to alter riparian soils through soil compaction, dislodging of shallow rooted plants, and erosion, among other things. This is particularly true during rainfall or peak runoff (Marlow & Pogacnik 1986; DelCurto et al. 2000). If a producer is undergoing riparian buffer planting or streamside restoration, early-season grazing may not align with the producer's intended goals. Similarly, late season grazing occurs during months where upland vegetation is more mature and less palatable than riparian vegetation which can also lead to overutilization of riparian vegetation and negatively impact soils or cause erosion.

Rest-rotation may limit grazing options depending on the location and climate of a producer's land, and has similar barriers and limitations associated with early- and late-season grazing in terms of potential impact to streambanks and erosion. Additionally, rest-rotation grazing requires more fencing be constructed, more water sources and access to shade for each paddock, and, if not designed properly, it requires more time to move cattle.

Table 4: Implementation Factors for Grazing Strategies

Considerations	Details
Capital Cost	• Associated fencing with paddocks (see costs for fencing types in topic 1): Fencing can be permanent or temporary, depending on the goals of the producer. • Associated watering sources of paddocks (see costs for off-stream watering): Watering sources could be permanent or temporary depending on the goals of the producer.
Operational and maintenance requirements and costs	• Rotational grazing: WSU extension[26] recommends mowing and harrowing recently grazed areas to promote pasture grass regrowth during recovery period. It also promotes the plants to produce more leaves and fewer stems, producing thicker, hardy grass stand. Also, can control weed species. • Harrowing (dragging) pasture after grazing breaks up manure and evenly distributes the nutrients in the manure. Prevents grass from being smothered and can control parasite growth in manure piles. • Monitoring of pasture and rangeland areas to ensure that management practices are accomplishing goals for the land and for the livestock (See Howery et al. 2000; USDA 2017).
Technical requirements	• Balancing stocking rate with forage availability is key and failing to do so can lead to over or under grazing. Determining stocking rate includes collecting information on overall pasture production and balancing the animal numbers with available forage. Assistance in determining stocking rate can be given by local NRCS offices (Grazing Management and Soil Health[27]).
Lifespan	• N/A
Land area requirements	• In rest rotation, the land area requirements are determined by paddock size. Paddock size is determined by the number of animals, time of year, grazing duration, and quality of available forage.
Other implementation factors	• When setting up a **rotational grazing system**, producers should consider the following factors. • *Goal setting* (i.e., What are you trying to achieve? How intensive do you want management to be?) and *Resource Availability* (i.e., How much capital is available to invest? Do you have sufficient pasture to implement the practice?)

[26] https://extension.wsu.edu/clark/naturalresources/smallacreageprogram/pasture-grazing-management/
[27] https://www.nrcs.usda.gov/sites/default/files/2022-09/Grazing%20Management_SoilHealth_1.pdf

Considerations	Details
	• *Length period of rest and length of grazing periods*: This will be driven by the forage availability and productivity. • *Fencing:* Determining the type of fencing required and whether you can utilize existing fencing to reduce costs. • *Lanes and Laneways:* Plan laneways (if required) to withstand wear and tear. Lanes should be as narrow as possible (6’ to 8’ wide for cattle or 14’ to 18’ for cattle and machinery). • *Design a paddock system:* The paddock layout will be tailored to a producer’s land and can be gradually changed form a continuous to rotational system if needed. Design of paddocks will include considering existing fencing, permanent buildings, water sources, and forage availability. • *Evaluating and improving the grazing system:* If a producer intends to improve the system over time and optimize forage further, it is necessary to consider the animals behavior and the health of the pasture in the current system before making changes. • *Drought*: In some cases, producers may want to have a paddock dedicated for use in drought conditions. This paddock should consist of drought resistant forage (i.e., warm season grasses). In general, during drought periods, more stubble should be left across paddocks after grazing which may then require a supplement feeding source.

Cost-Share Programs

Cost share programs assist farmers by providing federal and state funding to lower or eliminate costs of implementing conservation practices. Practices covered by programs vary but can include exclusion fencing, planting buffers along streams, rotating livestock, or developing manure management plans. Many cost-share programs also provide technical assistance, often by local specialists to help farmers design and implement practices. Below are some relevant cost share programs that may assist producers in Washington state implement pasture and rangeland BMPs:

Conservation Reserve Program (CRP): CRP is an overarching, federal cost-share program. Applicants are selected by a bidding system and enrollment is open January 4th to February 12th. Bids are scored by Environmental Benefits Index factors and ranked against other applications. The six factors are wildlife habitat benefits, water quality benefits, on-farm benefits for reducing erosion, benefits that will likely endure beyond the contract period, air quality benefits from reduced wind erosion, and cost. Two additional programs fall under CRP: CREP and Continuous CRP.

Continuous CRP – Continuous CRP is a more specialized federal cost-share program than CRP. Applicants are automatically accepted if they meet the requirements. and enrollment is open as long as acres are available. It focuses on environmentally sensitive land. The signup can be found here.[28] There are several enrollment opportunities within CRP:

- Clean Lakes, Estuaries, and Rivers (CLEAR) Initiative[29]
  This cost-share program works to reduce sediment, nutrient, and harmful algal blooms in water by encouraging clean water practices in agriculture. This can include installing riparian buffers and wetland restoration.
- Clean Lakes, Estuaries, and Rivers 30 Pilot (CLEAR30 Pilot)[30]
  Certain water quality practices enrolled under continuous CRP or CREP have contracts that ended September 30, 2022. These may be offered now in CLEAR30.
- Conservation Reserve Enhancement Program (CREP)[31]
  CREP is a joint state and federal initiative, which can provide additional incentives such as higher cost-share reimbursement rates. CREP is administered federally by the Farm Service Agency (FSA) and at state-level by State Conservation Commission (SCC), and at local level by conservation districts. Farmers are compensated for voluntarily planting a buffer zone of native vegetation along salmon-bearing streams. The contract renews typically on a 10-to-15-year basis. The program pays for costs of the project and manages oversite and maintenance for five years to ensure survival of vegetation. Landowners are paid rent for the acreage they restore and a monetary bonus for enrolling in the program. See here for step-by-step roles and responsibilities[32] and resources on technical information.[33]

- State Acres for Wildlife Enhancement (SAFE)[34]
  This is a part of Continuous CRP and is implemented in cooperation with WDFW. Landowners voluntarily receive rental payments, establish and maintenance cost-share and incentive payments in return for entering a contract to provide specific wildlife habitat as part of five specific projects.

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[28] https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/crp-continuous-enrollment/index
[29] https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/Conservation/PDF/clear_fact_sheet_05-05-22.pdf
[30] https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/fsa-clear30_factsheet.pdf
[31] https://www.scc.wa.gov/conservation-reserve-enhancement-program
[32] https://uploads-ssl.webflow.com/5faf8a950cdaa224e61edad9/61c26ac5f9e8f1beb93d4fe6_CREP%20Step%20by%20step_121021.pdf
[33] https://www.scc.wa.gov/cd/for-crep-technicians
[34] https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/archived-fact-sheets/state_acres_wildlife_enhancement_init_jul2015.pdf

- Transition Incentives Program TIP:[35] This program provides two CRP annual rental payments to a retired or retiring owner or operator of land under an expiring CRP contract.
- Debt for Nature:[36] This is a program available to people with Farm Service Agency (FSA) loans on environmentally sensitive land. Individuals may qualify for cancellation of a portion of FSA loans in exchange for a conservation contract with a 10, 30, or 50-year term.

Natural Resource Conservation Service:[37] NRCS administers several of cost share programs for farmers and ranchers to implement conservation activities including:

- Environmental Quality Incentives Program (EQUIP)[38]
  - NRCS works with producers to develop conservation practices and activities and offers free technical assistance. NRCS provides financial assistance for specific practices and some farmers qualify for advance payment. They also offer conservation innovation grants.[39]
- Conservation Stewardship Program (CSP):[40] These are five-year contracts with opportunities for renewal. NRCS offers annual payments for implementing and maintaining conservation practices. You can also select a suite of enhancements and receive higher payment rates. This program covers conservation practices relate to cleaner air and water, healthier soil, and better wildlife habitat

Sustainable Farms and Fields (SFF) grant program:[41] Farmers and ranchers may receive free services and financial assistance to cover costs of eligible projects, equipment, and other expenses. Examples of projects include planting trees/shrubs, managing manure storage, purchasing animal feed, or shared-use equipment. Conservation districts and other public entities help implement this program.

Local Cost-Share Programs

In addition to federal programs there are local cost-sharing programs such as King County Cost Sharing.[42] For this program, applications are approved by King County. Livestock must be present on the property and a Farm Management Plan must be on file. The applicant can have up to $5,000.00 for projects including buffer fencing, cross fencing, gutters, manure management, machinery rental, pasture seed, pasture renovation, stream crossings, livestock watering systems, buffer re-vegetation, confinement areas/heavy use protection areas, clean

[35] https://www.fsa.usda.gov/programs-and-services/conservation-programs/transition-incentives/index
[36] https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/FactSheets/archived-fact-sheets/debtfornature07.pdf
[37] https://www.farmers.gov/your-business/livestock
[38] https://www.nrcs.usda.gov/programs-initiatives/eqip-environmental-quality-incentives
[39] https://cig.sc.egov.usda.gov/?utm_source=nrcs-cig&utm_medium=site&utm_campaign=obv-redirect
[40] https://www.nrcs.usda.gov/programs-initiatives/csp-conservation-stewardship-program
[41] https://www.scc.wa.gov/sff
[42] https://kingcounty.gov/services/environment/water-and-land/agriculture/bmp-cost-sharing-guidelines.aspx

water diversion, and more. The King County Livestock Program can be called for more information at 206-477-4810.

There are a number of local cost-share programs available through state conservation districts. Below is a list of Washington State Conservation District cost-share programs where more information can be found tailored to specific areas:

- Benton County Soil and Water Conservation District[43]
- Central Klicktitat Conservation District[44]
- Franklin Conservation District[45]
- King Conservation District [46] - Landowner Incentive Program
- Kittitas County Conservation District[47] – Small Projects Cost Share Program – funds 4-8 projects per year.
- Lincoln County Conservation District[48]
- Mason County Conservation District[49]
- North Yakima Conservation District[50] – Voluntary Stewardship Program
- Okanogan Conservation District:[51] Irrigation Efficiencies Grant Program and Save Water Save Energy Program
- Pierce Conservation District[52]
- San Juan Islands Conservation District[53]
- Skagit Conservation District[54]
- Snohomish Conservation District[55]
- South Yakima Conservation District[56] – Livestock/Dairy Cost Share Program and Direct Cost-Share Program
- Spokane County Conservation District[57] – Voluntary Stewardship Program

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[43] https://www.soilandwater.org/about-available-programs-and-assistance
[44] https://ckcd.org/programs/cost-share-assistance/
[45] https://www.franklincd.org/livestock
[46] https://kingcd.org/programs/better-backyards/landowner-incentive-program/
[47] https://www.kccd.net/programs
[48] https://www.lincolncd.com/cost-shares
[49] https://www.masoncd.org/farmassistance.html
[50] https://northyakimacd.wordpress.com/projects-and-program/voluntary-stewardship-program-vsp/
[51] https://www.okanogancd.org/cost-share
[52] https://www.piercecd.org/609/Farm-Improvement-Financial-Assistance
[53] https://www.sanjuanislandscd.org/cost-share-program
[54] https:// https://www.skagitcd.org/
[55] https://snohomishcd.org/cost-share-basics
[56] https://sites.google.com/a/sycd.us/south-yakima-cd/livestock-dairy-cost-share-program
[57] https://www.spokanecd.org/departments/small-acreage/voluntary-stewardship/

- Thurston County Conservation District[58] – Voluntary Stewardship Program
- Whidbey Island Conservation District[59] – federal and state assistance guidance

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[58] https://www.thurstoncd.com/working-lands/vsp/

[59] https://www.whidbeycd.org/cost-share.html

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