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IN THIS ISSUE

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Ungulate Grazing Relationships with Riparian Restoration: Meadow Creek Experiment

Research at Meadow Creek, part of the Columbia Basin in northeast Oregon, evaluates how ungulate grazing affects stream and riparian restoration for salmonids (Figure 1) and other riparian resources. A unique aspect of this study is understanding the compatibility of improved cattle grazing practices with stream restoration; foundational components include the use of upland (off-stream) water and nutritional supplements, intensive monitoring of cattle riparian use, and herding to uplands. The study also evaluates effects of wild ungulates versus cattle on restoration of riparian vegetation, with initial results pointing to sometimes substantial effects of deer and elk on shrub survival and growth. Research findings will be used in a decision support system to help inform best grazing practices on public allotments in relation to riparian restoration goals.

Figure 1: Meadow Creek provides spawning and rearing habitat for steelhead and rearing habitat for Chinook salmon (in Figure). Photo credit: Daniel Isaak.

StreamNotes is an aquatic and riparian systems publication with the objective of facilitating knowledge transfer from research & development and field-based success stories to on-the-ground application, through technical articles, case studies, and news articles. Stream related topics include hydrology, fluvial geomorphology, aquatic biology, riparian plant ecology, and climatology.

StreamNotes is produced as a service of the U.S. Forest Service National Stream and Aquatic Ecology Center (NSAEC), a technical unit of the Washington Office's Biological and Physical Resources program.

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If you have ideas regarding specific topics or case studies, please email David Levinson at david.levinson@usda.gov

Background

Cattle (*Bos taurus*) grazing is a common land use on public range allotments in the western U.S. where riparian restoration is a major focus for recovery of cold-water fish and other aquatic resources. Thousands of projects have been implemented and billions of dollars invested in restoration for fish recovery. However, less emphasis has been placed on approaches to ensure compatibility of cattle grazing with restoration goals. In addition, elk (*Cervus canadensis*) and mule deer (*Odocoileus hemionus*) co-occupy many public allotments with cattle (Figure 2), and addressing the individual and joint effects of all three ungulate species on riparian restoration can be daunting. In response, we initiated restoration and ungulate research in 2012 at Meadow Creek, a salmonid-bearing stream within the Starkey Experimental Forest and Range (Starkey) in northeast Oregon (Figure 3). Meadow Creek research occurs on a 7-mile reach within Starkey, encompassed by five livestock pastures (5,235 acres) in which grazing practices and effects in relation to restoration is the focus of long-term study (Figure 4).

Figure 2: Cattle, elk, and mule deer co-occupy many public allotments in the western U.S. where grazing and riparian restoration activities require integration to meet management objectives for cold-water fish and other sensitive riparian resources.

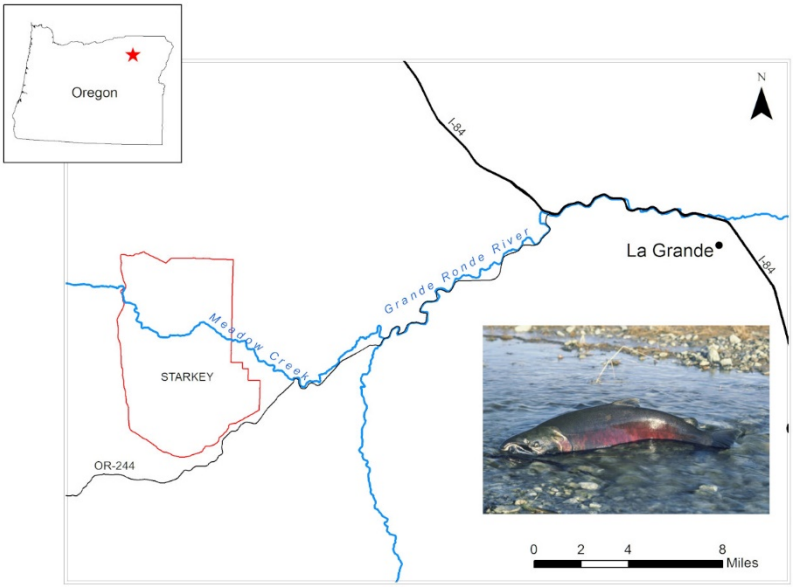

Figure 3: Location of Meadow Creek, tributary to the Grande Ronde River in the Columbia Basin, within the U.S. Forest Service Starkey Experimental Forest and Range (Starkey) in northeast Oregon. Meadow Creek provides spawning and rearing habitat for steelhead (inset) and rearing habitat for Chinook salmon.

Restoration Prescriptions and Benefits

As part of the Columbia Basin, Meadow Creek provides spawning and rearing habitat for Snake River summer steelhead (*Oncorhynchus mykiss*) and rearing habitat for spring/summer Chinook salmon (*Oncorhynchus tshawytscha*). Both salmonid populations are designated as federally-threatened under the Endangered Species Act, with high priority placed on stream and riparian restoration activities for recovery. Meadow Creek typified this restoration need, given its history of long-term degradation from legacy land uses. Splash-dam and railroad logging practices during the 1890s and early 1900s eliminated in-channel woody structures—resulting in widespread elimination of pools for juvenile rearing and gravel for adult spawning by salmonids (Figure 5). Unregulated overgrazing by livestock during the 1800s and early 1900s, followed by conversion of native vegetation to exotic livestock forages in the 1950s, denuded the riparian areas, resulting in an open canopy with little shade—a major problem for a stream system subjected to droughty summers and

high stream temperatures that can approach lethal levels for juvenile salmonids during late summer-early autumn (Justice et al. 2017).

In response, the Wallowa-Whitman National Forest implemented an aggressive program of stream and riparian restoration in Meadow Creek from 2012-2014. Over 60 boulder-tree clusters, each spanning large, channel-width areas, were placed strategically throughout the 7 miles of stream habitat, with locations deemed optimal for local channel geomorphology to achieve maximum scour (Horn et al. 2019). Over 50,000 shrub and conifer seedlings were planted in riparian areas, with planting locations of species based on their drought tolerances in relation to floodplain microsite moisture regimes. Approximately half the deciduous shrub plantings were protected from ungulate grazing with small wire cages (pods), each 4 feet in height and encompassing 4-5 shrubs per pod (Averett et al. 2017).

Large ungulate exclosures, each approximately 1 acre and encompassing the entire stream and riparian width, were established in three of the five livestock pastures following restoration (Figure 4). Exclosures consisted of three types per pasture: (1) complete ungulate exclusion; (2) cattle exclusion; and (3) deer and elk exclusion (Figure 4). Effects on shrub and tree development, and on subsequent changes in canopy cover and other metrics of stream and riparian health, have since been evaluated under these three levels of grazing (complete exclusion; deer and elk effect; cattle effect) and in relation to the cumulative effects from extant grazing by all ungulates under free-ranging conditions in the five pastures.

Results from both the in-channel structural restoration and the riparian plantings yielded beneficial results for salmonids that were

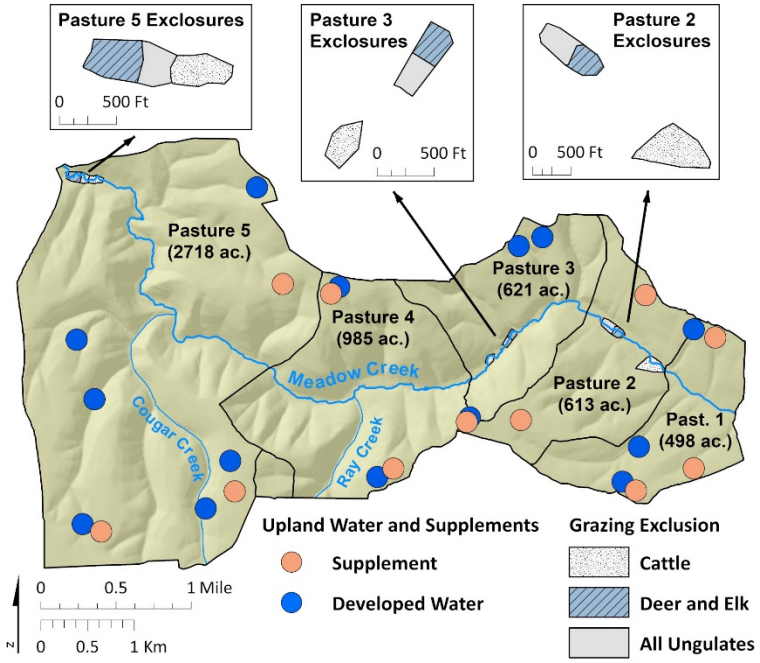

Figure 4: The five livestock pastures encompassing 7 miles of Meadow Creek and locations of upland water and upland nutritional supplement sites. Three types of ungulate exclosures were established in Pastures 2, 3, and 5: (1) cattle exclusion; (2) deer and elk exclusion and (3) all ungulate exclusion. Each exclosure type is approximately 1 acre in size and encompasses the entire stream channel and riparian area. Grazing effects associated with each exclosure type are further evaluated in relation to extant grazing by all ungulates in pasture areas outside these large exclosures.

Figure 5: Meadow Creek before restoration (top left), lacking in-stream structures and shrub-tree canopy, in contrast to in-stream structures added in 2013 (top right), resulting in a substantial increase in pool and gravel areas and beaver presence by 2019 (aerial view, bottom).

immediate and biologically meaningful. By early summer 2014, pool area for juvenile rearing and gravel area for adult spawning had increased substantially in response to increased scour associated with the restoration structures following high spring flows (Figure 5). The increased pool area resulted in higher juvenile salmonid use of new pools, and abundance increased by >50% in Meadow Creek from 2014-2016 compared to reference streams not undergoing restoration (Horn et al. 2019).

Growth and survival of planted shrubs also increased substantially with ungulate protection during the first two years after restoration (Averett et al. 2017) but was severely diminished in areas unprotected from wild ungulates (Figure 6). Ungulate protection provided by the large, 1-acre ungulate exclosures also attracted beaver in response to increased growth and stature of nutritious shrubs as a key food source. Beaver recolonization was their first documented use of this reach following a ~25-year absence, likely in response to shrub enhancements, combined with deep pools provided by the stream restoration features. By 2019, these continued habitat improvements were dramatic and obvious (Figure 5), and over 25 beaver dams were present along the 7 miles of stream.

Evaluation of Ungulate Effects and Grazing Practices

Conventional grazing practices on public allotments typically follow a set schedule of cattle rotation to and from a given pasture. Daily to weekly monitoring of riparian use and timely herding to uplands or a new pasture, with use of range riding, often is appropriate to prevent riparian overuse and meet restoration objectives. In addition to range riding, riparian restoration can benefit from a larger set of integrated grazing practices. At Meadow Creek, improved grazing practices under formal evaluation include the use of small pastures; upland water; upland nutritional supplementation; short grazing periods per pasture; weekly monitoring of ecological indicators; moderate stocking rates; deferred rotation; early-season grazing; compressed late-season grazing (early departure when necessary); regular (multiple times per week) monitoring of cattle presence in the riparian area; and prompt herding of cattle to uplands or a new pasture as deemed appropriate based on management indicators. Practices

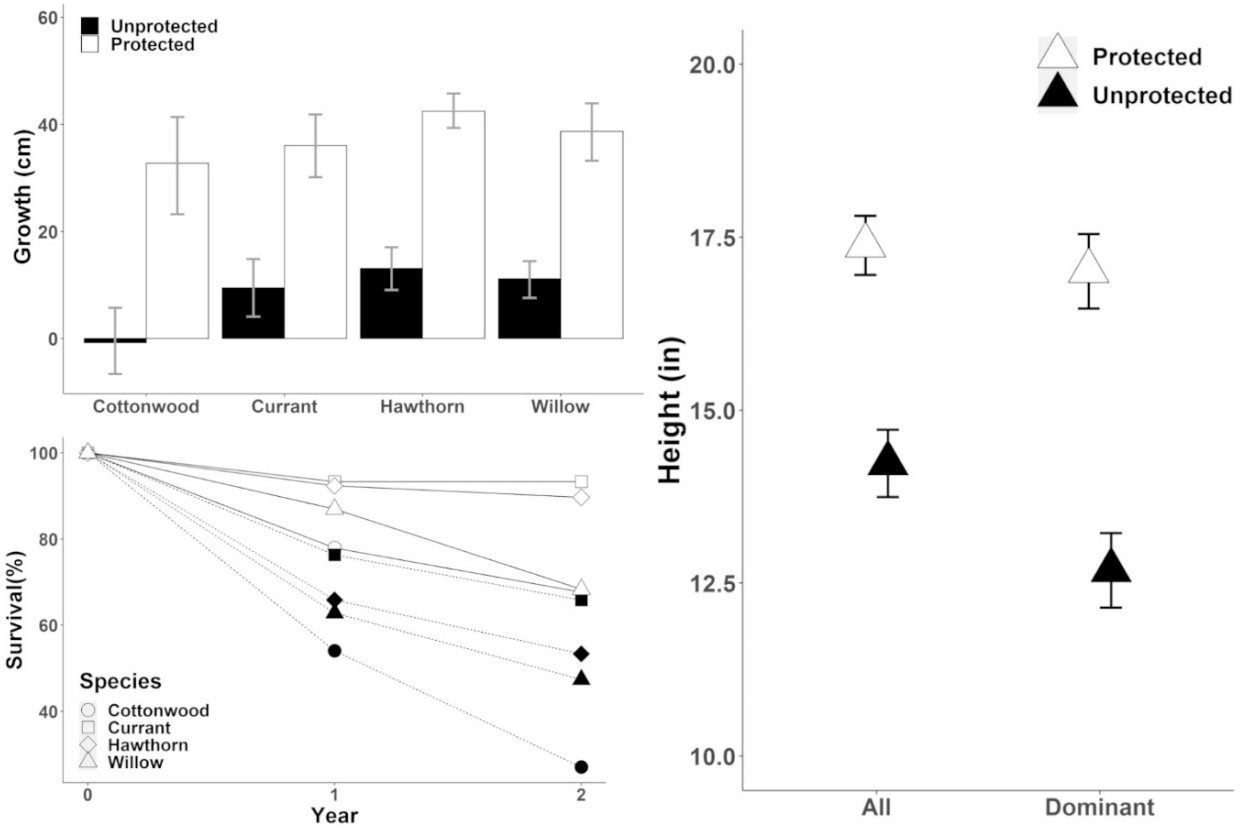

Figure 6: Elk and deer reduced growth and survival of riparian shrubs during the first two years after planting, in the absence of cattle (left panels, from Averett et al. 2017) and substantially reduced greenline stubble height (right), the latter often solely attributed to cattle (from Averett et al. 2018).

are designed to maintain cattle distribution primarily in uplands while allowing limited grazing use in riparian areas compatible with restoration.

A myriad of social, economic, and ecological responses to the grazing practices, and different types of ungulate riparian exclusion, are under evaluation. Economic responses include cattle performance (weight gain) and grazing time (number days of grazing/pasture) in relation to monetary investments in range riding, off-stream water, and supplements. Social science responses focus on understanding the willingness of livestock operators to adopt grazing practices found to be economically and ecologically effective. Ecological responses include trends in riparian shrub and tree restoration to increase stream shading and mediate high summer stream temperatures to enhance survival of juvenile salmonids, particularly in response to climate change; responses of native bees that depend on flowering plant food sources that compose major items of ungulate diets; compliance with, and efficacy of, contemporary ecological indicators of stubble height, streambank alteration, and woody browse use, now implemented or considered in management of ungulates in relation to riparian use on public allotments; and over 150 additional stream and riparian metrics of fisheries health and hydrologic regime.

Indicators of Stream and Riparian Grazing Effects

Streambank alteration (percentage of the streambank covered by ungulate hoof prints) is assumed to indicate the potential for grazing to destabilize the streambank and introduce stream sediments. Woody browse use (percentage of current year's shrub leaders browsed by ungulates for shrubs within 3-ft of greenline) is considered an index of the degree to which ungulates may limit the growth and stature of shrubs to achieve a tree-like prominence for stream shading, habitat for wildlife (e.g., food for beaver) and other desirable riparian functions. Greenline stubble height (measured as the height of key herbaceous ungulate forages along the greenline) is a traditional measure of grazing use that provides a general indication of overall riparian grazing pressure. Streambank alteration <20%, woody browse use <40%, and greenline stubble height >6 inches are levels often assumed to indicate neutral riparian grazing effects over time (U.S. Forest Service 2016).

Results on the effectiveness of Multiple Indicator Monitoring (MIM) metrics as grazing management indicators are not yet available, but near-term research has provided interesting and useful findings related to the degree that cattle versus wild ungulates contribute to each metric. To date, our key findings include:

- Greenline stubble height can be substantially reduced by wild ungulates (Figure 6), with cumulative effects from all ungulates often attributed solely to cattle. Moderate stocking densities of cattle can often reduce stubble height more than high densities of wild ungulates.
- All three management indicators are correlated (Figure 7), but streambank alteration appears to be almost solely associated with cattle. Substantial woody browse use by deer and elk can occur after cattle leave a riparian pasture, confounding compliance with woody browse use during cattle grazing.
- MIM triggers that prompt cattle to be moved to a new pasture can be delayed with effective use of range riding, combined

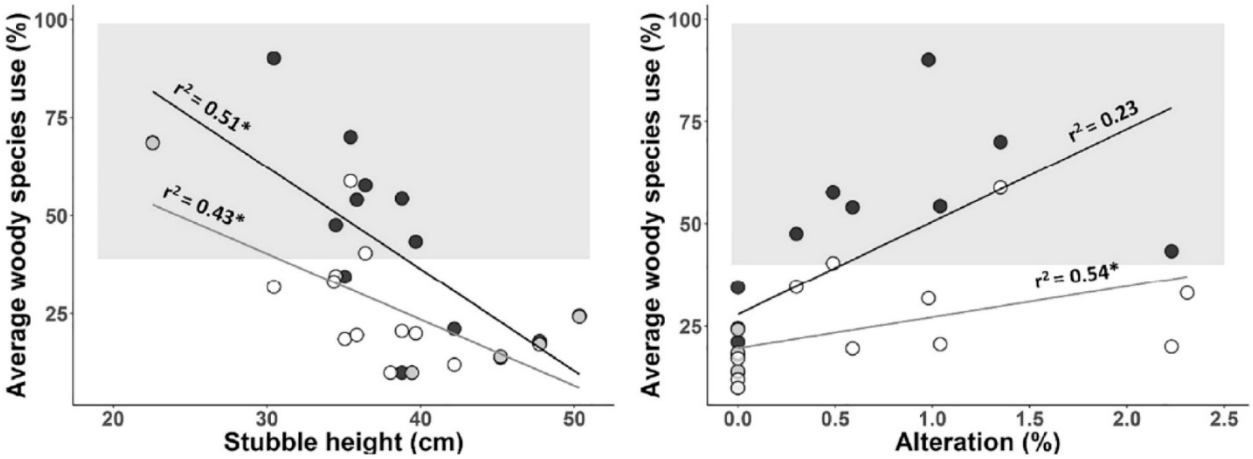

Figure 7: Stubble height, streambank alteration, and woody species use by ungulates along the greenline (streamside) of the riparian zone are correlated (from Averett et al. 2018). Gray shaded area represents woody browse use over 40%, often set as a threshold not to be exceeded for riparian grazing management (see Averett et al. 2018).

with off-stream water and nutritional supplements, in maintaining cattle in uplands when more gentle slopes encompass water and supplement sites.

- MIM triggers are often met quickly in riparian pastures where adjacent uplands have steep slopes or unreliable off-stream water, conditions not likely to hold cattle in uplands predictably, regardless of range riding effort, and may require riparian grazing exclusion.
- Stream restoration increased pool area for juvenile salmonid rearing and gravel area for adult salmonid spawning in reaches within and outside areas of ungulate exclusion, and protection from ungulate grazing increased riparian shrub growth and survival following restoration.
- Beaver recolonized the Meadow Creek reach following restoration treatments and have contributed to herbivory of enhancement plantings following a ~25-year absence. Shrub enhancements associated with areas of ungulate exclusion were used as new sources of forage by beaver.
- Future Meadow Creek research will evaluate the use of virtual fencing exclusion—based on use of telemetry collars worn by cattle that have auditory and sensory cue capacity to exclude animals from designated areas. Cue activation first provides an auditory warning followed by electric stimuli as cattle approach the area electronically marked for exclusion. This technology is new and currently undergoing initial testing on cattle by Oregon State University and USDA Agricultural Research Service at other sites in eastern Oregon. Exclusion areas can be established temporarily and strategically in specific riparian areas where other approaches may not be feasible or as economical.

Grazing and other Riparian Resources

Several other responses to restoration and levels of grazing at Meadow Creek have been evaluated, with sometimes surprising results. A study of native bee communities documented more than 220 species, with different bees active at different times of the growing season (DeBano et al. 2016). Behavioral observations and molecular analyses of pollen collected from foraging bees showed that some bees prefer certain species of flowers, and preferences vary from month to month (Roof et al. 2018). In spring, when most available flowering plants are small annuals, many of the shrubs planted in riparian restoration play key roles as food sources for early-season bees. Data collection on native bee responses to cattle versus deer and elk grazing is complete and analyses are underway. One notable finding is the high overlap of plant species in the diets of the three ungulates with plants used by native bees for food, demonstrating the far-reaching interactions of ungulates with other flora and fauna and their habitats (Figure 8). Small mammal communities also differed across sampling sites, reflecting legacy effects from past grazing management. Small mammal richness and abundance were lowest in areas where native riparian vegetation was converted to exotic grasses in the early 1950s for livestock forage, particularly in sites dominated by meadow foxtail (*Alopecurus pratensis*). Exotic grasses still dominate these riparian areas, with little change in the herbaceous plant community composition and structure for nearly 70 years.

Stream temperature modeling that ties shade provided by riparian restoration with climate change projections has also been a part of Meadow Creek studies. Using modeled scenarios of vegetation and climate change, Wood (2017) documented the value of riparian restoration along Meadow Creek in reducing days above lethal stream temperature thresholds for salmonids. Justice et al. (2017) also projected future stream temperature dynamics in relation to climate change, including mitigations of different levels of stream shading. Results from both studies point to the importance of grazing management that allows survival

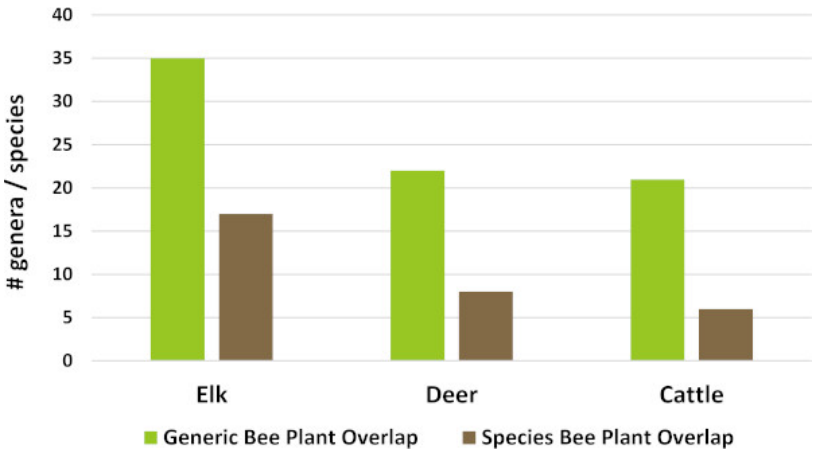

Figure 8: Overlap of plant species in ungulate diets, summarized from published literature, that also serve as significant floral resources for native bees at Meadow Creek. Overlap is summarized at the genus and species levels for bees (from Table 5, DeBano et al. 2016).

and growth of trees and shrubs to offset climate change effects that could otherwise elevate late summer-autumn stream temperatures to lethal levels for juvenile salmonids.

Management Implications

- Results from Meadow Creek research are intended for management applications on public range allotments to help integrate grazing approaches compatible with riparian restoration.
- Scientists and managers are developing a decision support system (DSS) to evaluate grazing practices and conditions that may limit compatibility with riparian restoration, and to identify more effective approaches.
- An effective DSS could further address the function and condition of grazing systems, levels of riparian grazing use, and many additional factors to help meet restoration goals.
- Landscape evaluation tools such as a DSS, based on Meadow Creek results and follow-on validation studies, have high potential to help support riparian restoration success on public allotments in the western U.S., an issue of growing importance as restoration projects become more extensive and comprehensive in approach.

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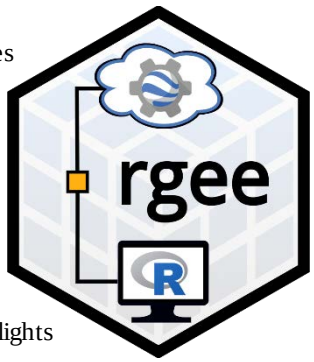
Notices and Technical Tips

- **Direct technical assistance from applied scientists at the National Stream and Aquatic Ecology Center** is available to help Forest Service field practitioners with managing and restoring streams and riparian corridors. The technical expertise of the Center includes hydrology, fluvial geomorphology, riparian plant ecology, aquatic ecology, climatology, and engineering. If you would like to discuss a specific stream-related resource problem and (if needed) arrange a field visit, please contact a scientist at the Center or David Levinson, the NSAEC program manager.



- **Google Earth Engine for R**: The R package rgee is a relatively new tool that provides access to the Google Earth Engine (GEE) cloud-based platform from within R. Previously, it was typical for the massive remote sensing datasets and cloud computing offered by GEE to be accessed using the Code Editor, which requires JavaScript coding, or the Python GEE API. For intermediate to advanced users of R, or those looking to further their skills, the rgee package is an excellent alternative. The package is well documented online, with numerous examples, function descriptions, setup instructions, and hints and tips available.
- **New research on floodplain storage** highlights the importance of floodplains in storing water, solutes, sediment, and organic matter. This Q & A with the author highlights floodplain restoration conducted on the Willamette National Forest (Figure 9).
- **Beaver-Related Restoration** (BRR) is the topic of a 2021 overview article in the Journal Bioscience. This article dives into a thorough discussion of the topic *de jour* and provides a healthy perspective, concluding that, "Ultimately, what makes BRR so exciting and challenging are one and the same—the prospect of restoring nature with nature." And nature is messy. The authors urge that BRR practitioners consider this fact when laying out project objectives. To aid in this, they put forward a framework that links beaver-related restoration tactics to commonly expected outcomes.

Figure 9: The restored floodplain of the South Fork McKenzie River in Oregon, USA following the Holiday Farm Fire in 2020. Credit: Kate Meyer, USDA Forest Service.

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