

IN THIS ISSUE

- Deer Creek: Stage 0 Alluvial Valley Restoration in the Western Cascades of Oregon
- Notices and Technical Tips
- Downstream Warming and Headwater Acidity May Diminish Coldwater Habitat in Southern Appalachian Mountain Streams
- The National Riparian Core Protocol



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Deer Creek: Stage 0 Alluvial Valley Restoration in the Western Cascades of Oregon

Deer Creek shares a common story of degradation in the West. Historic riparian logging and stream “cleaning” reduced channel and floodplain roughness and complexity, facilitating major

geomorphic change during a large flood (in 1964). Following this flood berms were constructed, which channelized and further impaired the stream, creating a primarily single-thread, incised, transport channel with limited floodplain connectivity. The goal of the Deer Creek restoration project was to restore the stream corridor to a complex, dynamic, depositional alluvial valley (Figure 1). A process-based approach was utilized, using a Stage 0 restoration methodology.

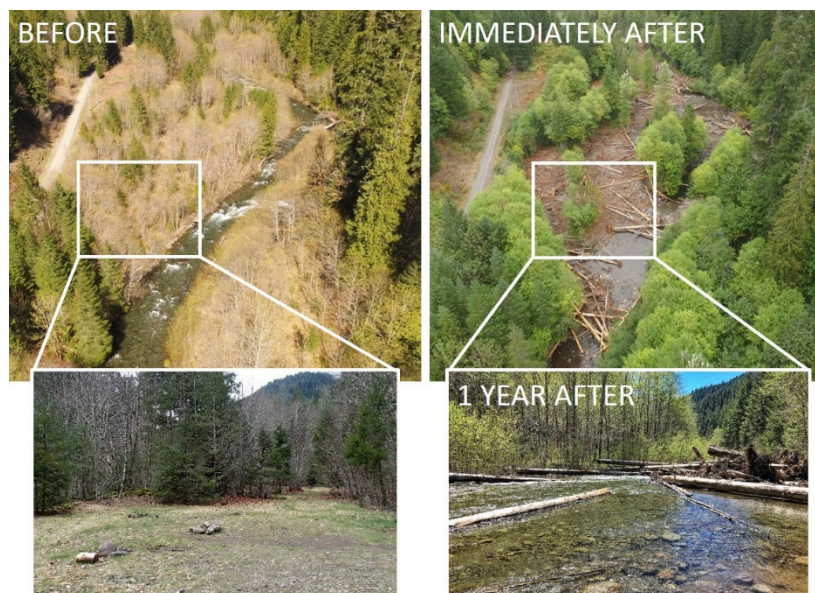


Figure 1: The Deer Creek restoration project, before and after implementation. Shown is an area with substantial berm removal, regrading, and addition of large woody material.

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 climate change.

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Over the past several decades there has been a concerted effort to restore degraded streams and it is now a multi-billion dollar industry (Wohl et al. 2015). For much of this time, stream restoration has been dominated by a *form-based* approach – one that creates a predictable and stable, primarily single-thread channel connected to its floodplain at a particular discharge. This is typically accomplished by reconstructing the channel based on a template derived from a reference reach (e.g., Simon and Hupp 1986, Rosgen 1996). The aim of this approach is to design a channel that maintains equilibrium through effectively balancing pattern, profile, and dimension with a design discharge and the predicted mean annual sediment budget (Lane, 1955; Leopold and Maddock, 1953; Leopold and Wolman, 1957; Leopold et al., 1964; Rosgen, 1996).

As an alternative from this approach, restoration techniques that prioritize process and function over form and embrace more holistic ecosystem processes are being developed (e.g., Kondolf 1998, Roni et al. 2002, Wohl et al. 2005, Bernhardt and Palmer 2007; 2011, Beechie et al. 2010; 2013, Wohl et al. 2015, Booth et al. 2016). In locations where such an approach is possible (given infrastructure), a *process-based* approach to stream restoration addresses the underlying causes of degradation, restores natural processes, and allows the fluvial system to adjust dynamically in response to disturbances or future conditions (Beechie et al. 2010; 2013). In contrast to a form-based approach focused on *stability and predictability*, a process-based approach welcomes *dynamism and variability*, which creates more diverse habitats and a more robust foodweb mosaic (Beechie et al. 2010, 2013).

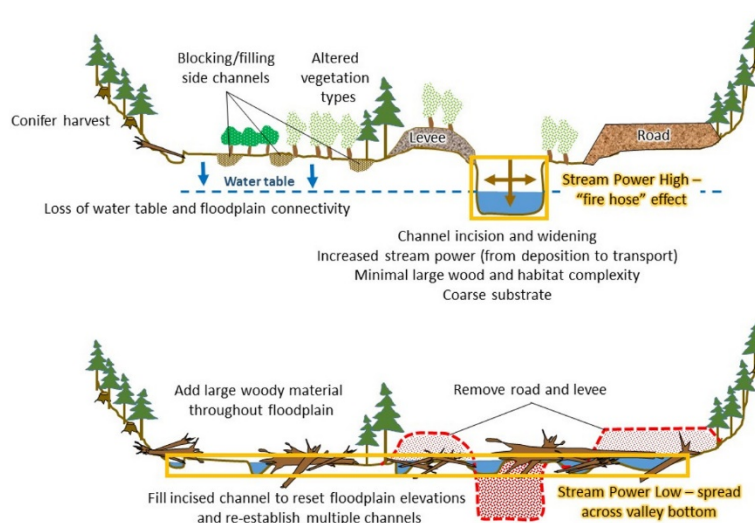


Figure 2: Valley bottom elevation resetting from the cross-section perspective: (1) common impacts to a river and floodplain (top) and (2) Stage 0 restoration actions to reset valley bottom elevations and restore natural river processes (bottom).

Stage 0

The Channel Evolution Model (Schumm et al., 1984; Simon and Hupp, 1986) has been extensively used to conceptualize how alluvial streams respond to disturbances through a series of morphological adjustments. The broad acceptance of this model has helped propagate an assumption that primarily single-thread streams represent pre-modified conditions, and should be the targeted form for restoration. However, there is growing evidence and recognition that the assumed primarily single-thread, meandering channel does not accurately represent pre-modified conditions in many cases and is not a universally appropriate target morphology for alluvial valley restoration; instead, the pre-modified condition in alluvial valleys was frequently an anastomosing network of channels and wetlands that frequently flooded (Cluer and Thorne, 2013). This anastomosing precursor stage in their Stream Evolution Model is called *Stage 0*, where habitat and ecosystem benefits are thought to be maximized.

In the West Coast states some practitioners, including a core group in the U.S. Forest Service, have been implementing projects that restore alluvial valleys to Stage 0 for more than a decade. In the Pacific Northwest region this approach was initiated when a single-thread, form-based restoration project “failed” following a flood, filling the main channel with sediment and creating a complex, anastomosing system similar to other local less disturbed streams. The practitioners favored the outcome and merged the concept into their subsequent form-based projects by under building channels so they would flood at lower discharges and behave more dynamically. They found, however, that even under built channels frequently remained incised and lacked sufficient floodplain connectivity, retention of gravels and fine sediment, dynamism, and habitat complexity. Subsequently, they took the concept to the next level and started removing all artificial features (i.e. berms and fill material), filling incised channels, nearly leveling valley bottom elevations with no constructed channels, and often adding abundant

large woody material. This concept emulates a large flood and effectively re-sets the valley bottom for full connectivity. It then allows natural fluvial processes to create a Stage 0 anastomosing network of channels and wetlands (Figure 2).

Deer Creek

In the summer of 2016 a 42-acre, 1.6-mile Stage 0 restoration project was implemented on Deer Creek, a mid-order tributary to the upper McKenzie River in the Willamette River Basin. Deer Creek drains about 15,000 acres in the Western Cascades, with typical flows ranging from 10 to 1,000 cfs. In the lower 1.6 miles, Deer Creek flows through an unconfined alluvial valley up to 450 feet wide, at a ~1.8% gradient. Historically, this was a depositional alluvial valley that provided spawning and rearing habitat for spring Chinook salmon and foraging habitat for bull trout. It was also home to cutthroat and rainbow trout, sculpin, and other native species.

During implementation, 200 large trees (24-36" dbh) in nearby upland units were pushed over (to keep the rootwad intact), and broken in half. A total of 450 pieces of large wood were transported to the project area and skidded to placement sites. Following water diversion and fish salvage, berms were pushed into the incised channel with a dozer and excavator (Figure 3). The 450 pieces of wood were placed in logjams and single pieces throughout the valley bottom (Figure 4). An additional 25 large streamside trees (38-63") were pulled over using a truck-mounted yarder to serve as large key pieces (Figure 5). Figure 1 shows an area with significant berm removal, before and after restoration. Although these implementation techniques are relatively aggressive, the benefits are immediate, dramatic, and self-sustaining.



Figure 3: Berm material being pushed into the incised mainstem channel.



Figure 4: Typical logjam construction.

Design

The design approach followed the concepts of Stage 0 restoration. To determine target elevations, we followed a methodology developed by U.S. Forest Service colleagues Paul Powers and Matt Helstab. Using bare earth LiDAR, we first calculated the geomorphic grade line – the best fit trendline of the valley longitudinal profile. From there, we created a relative elevation model using GIS and bare earth

LiDAR, which depicts elevations relative to the geomorphic grade line. Next, we field verified the relic side channels that we sought to re-water at base flow and confirmed that those elevations match the relative elevation model.

Monitoring

Project effectiveness monitoring plans should be based on the objectives of the project. The goal of this project – to restore lower Deer Creek to a complex, dynamic, depositional alluvial valley – was



Figure 5: Large streamside trees pulled over to serve as key pieces.



Figure 6: Sediment size class breaks across valley-wide transects - 5 transects in the untreated reach and a sample of 5 from the treated reach. This depicts visually the difference not only in substrate size, which is much finer in the treated reach, but in substrate diversity and patchiness, which has important ecological implications.

focused on restoring fluvial processes, but the original project objectives instead followed common ones used in form-based restoration, such as increasing pools and large wood per mile, decreasing the D_{50} from cobbles to gravels, and increasing the length of secondary channel habitat. However, such objectives don't capture the scope and complexity of Stage 0 projects; more appropriate objectives should include stronger quantifiable indicators of restored processes, such as sediment storage, channel migration and avulsion, diversity and frequency of geomorphic features, abundance and retention of large wood and organic matter,

and 5 in the untreated reach - during low flow conditions about one year after implementation (September 2017). Across each transect we collected data on large wood abundance and size, and we recorded all breaks in dominant sediment size classes. For each channel encountered across a transect we collected data on wetted width, depth, velocity, large wood, substrate size, geomorphic feature, temperature, and riparian vegetation. The data shows that in the treated reach there is: (1) 800% higher large wood abundance; (2) much greater substrate diversity and patchiness (Figure 6); (3) 143% more wetted area, with the multi-

water table height, wetted area, substrate size class diversity and patchiness, diversity of water velocities, area of cold water refugia, and other biological processes.

We explored new monitoring methods and decided to collect data along 23 valley-wide transects - 18 in the project treated reach

thread channels 48% deeper and 38% slower (Figure 7; Figure 8); (4) 130% more gravels, 2000% more fines, 34% less cobbles and 72% less boulders; and (5) 270% more pool and glide habitat, and 79% less riffle habitat.

At this time, the only biological data are redd abundance for rainbow and cutthroat trout and spring Chinook salmon. The rainbow and cutthroat trout redd counts were relatively low in 2017 following implementation (28 total), but have rebounded to relatively high levels in 2018 (82 to date, but spawning surveys are still in progress). No redds were found in the untreated reach in 2017 and only 1 was found in 2018, indicating much poorer spawning habitat. No Chinook redds had been documented in Deer Creek since 1993 and in the fall of 2017 (1 year after implementation) we counted 3 Chinook redds in the project area. The dramatic shift in stream morphology (Figure 9) and habitat provides much higher quality spawning and rearing habitat for fishes and a greater diversity of habitats for invertebrates and other aquatic and riparian communities. These findings are consistent with known habitat and ecosystem benefits found in complex,



Figure 7: Post-restoration condition, with abundant large woody material and diverse habitat types, sediment patches, and velocities.



Figure 8: Slow water habitat now found in re-connected relic channels following implementation.

anastomosing systems (Cluer and Thorne, 2013; Thorp et. al., 2010). Other benefits of the project that aren't described in these data include a dramatic increase in high flow refuge habitat and storage of nutrients and organic material.

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- Paul Powers, Fisheries Biologist, Crescent Ranger District, Deschutes National Forest
- Cari Press, Hydrologist, Sisters Ranger District, Deschutes National Forest
- Johan Hogervorst, Forest Hydrologist, Willamette National Forest Service
- Paul Burns, Fisheries Biologist, Central Coast Ranger District, Siuslaw National Forest

Management Implications

- The practice of process-based Stage 0 restoration is growing and evolving across the western United States, but the scientific framework for learning from these projects is fairly undeveloped. Hence, the practice is experimental and there are substantial scientific opportunities for developing new technology for designing and monitoring Stage 0 restoration projects.
- The methods and metrics used for effectiveness monitoring on Deer Creek show potential for detecting differences in fluvial processes and habitat complexity between treated and untreated reaches, but pre- and post-project comparisons would have provided a richer dataset.
- Although the implementation techniques used on Deer Creek (i.e. berm removal, floodplain regrading, channel filling) are relatively aggressive, the ecological benefits are immediate, dramatic, and self-sustaining.

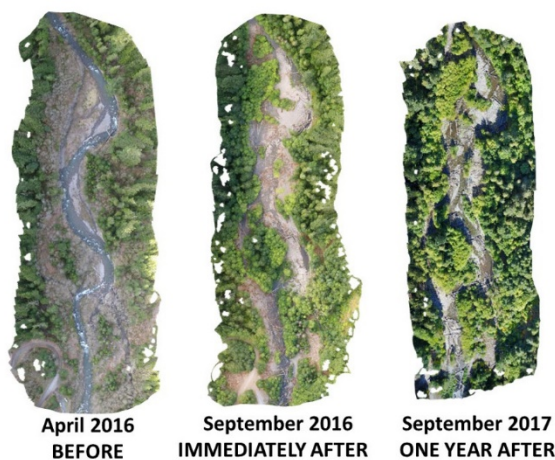


Figure 9 Time series aerial photos of the same area before implementation, immediately after and one year later. The shift from primarily single-thread to an anastomosing network of channels is evident.

- Matt Helstab, Fisheries Biologist, Middle Fork Ranger District, Willamette National Forest

Also appreciation is expressed to our partners at the McKenzie Watershed Council for co-managing this and many other projects; to Mickey Means-Brous, Willamette National Forest Fisheries Technician, for much needed help through implementation; to Nick Grant, Willamette National Forest hydrologist, for helping to develop new monitoring protocol; and to Stephanie Bianco, OSU Graduate Student, for her research on Deer Creek and Stage 0 restoration.

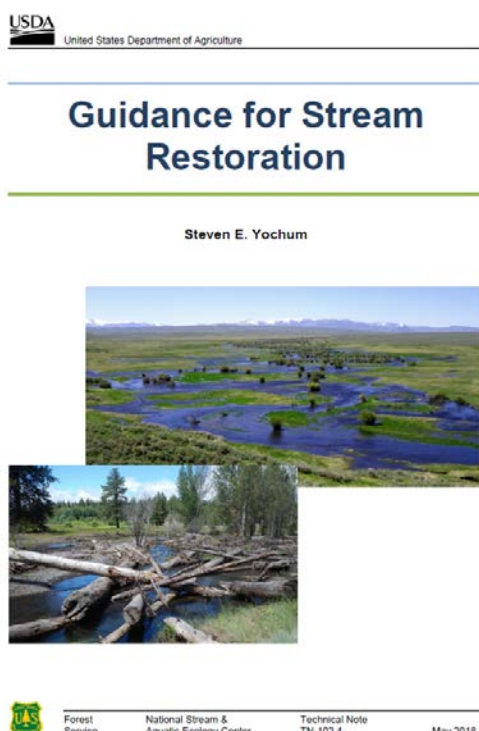
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Notices and Technical Tips

- **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.
- The National Stream and Aquatic Ecology Center has updated the technical note **Guidance for Stream Restoration**. Version TN-102.4, the fourth Forest Service version of this publication, is available for download [here](#).



Abstract: A great deal of effort has been devoted to developing guidance for stream restoration. The available resources are diverse, reflecting the wide ranging approaches used and expertise required to develop effective stream restoration projects. To help practitioners sort through the extensive information, this technical note has been developed to provide a guide to the available guidance. The document structure is primarily a series of short literature reviews followed by a hyperlinked reference list for readers to find more information on each topic. The primary topics incorporated into this guidance include general methods, an overview of stream processes and restoration, case studies, data compilation, preliminary assessments, and field data collection. Analysis methods and tools, and planning and design guidance for specific restoration features are also provided. This technical note is a bibliographic repository of information available to assist professionals with the process of planning, analyzing, and designing stream restoration projects.

- The Forest Service Stream and Riparian Restoration Network has created a **new webinar series**, with the first held on May 22 (*Applying ecological stream restoration standards to mountain meadow restorations in California*, by Karen Pope and Matthew Johnson). The webinars are recorded, with these recordings and the schedule available on the internal [Forest Service SharePoint page](#).
- Using a blend of citizen science and traditional research, a new approach has been developed to monitor intermittent streams: the [Stream Tracker](#) tool. This effort combines citizen science to monitor where and when water is flowing, a sensor network, and remote sensing. "Every large river is fed by smaller streams that only flow after large rain storms or snowmelt. While these streams look dry and lifeless much of the time, they often support diverse aquatic life when they flow. By improving our understanding of these streams, we can help improve streamflow forecasting to predict water supply and flood risk. Better maps of small streams can also aid land use planning, habitat assessments, and wetland delineation."

Downstream Warming and Headwater Acidity May Diminish Coldwater Habitat in Southern Appalachian Mountain Streams

The distribution of stream-dwelling coldwater species is constrained by temperature, water chemistry, and habitat fragmentation. In the southern Appalachian Mountains region, many watersheds are vulnerable to both elevated stream water temperatures and stream acidification caused by atmospherically deposited acidifying compounds. The combined effect of stream acidification and thermal habitat loss presents a conundrum for watershed managers tasked with identifying suitable habitats for obligate coldwater species (e.g., Brook Trout [*Salvelinus fontinalis*]) which exist at the southern-most extent of their range in this region. In general, low-order, higher-elevation streams are most susceptible to acidification; in the absence of adequate buffering capacity, otherwise suitable habitat is rendered uninhabitable in the headwaters of susceptible streams. In contrast, downstream thermal habitat for coldwater species becomes less suitable (i.e., warmer) as elevation decreases. When these scenarios overlap, suitable habitat is 'squeezed' from the top down by acidification and the bottom up by warming temperature, thus increasing the vulnerability of coldwater species to climate change. This effect is detailed in a [PLOS One article](#) (McDonnell et al. 2015).

We analyzed the spatial distribution of stream water Acid Neutralizing Capacity (ANC) in relation to

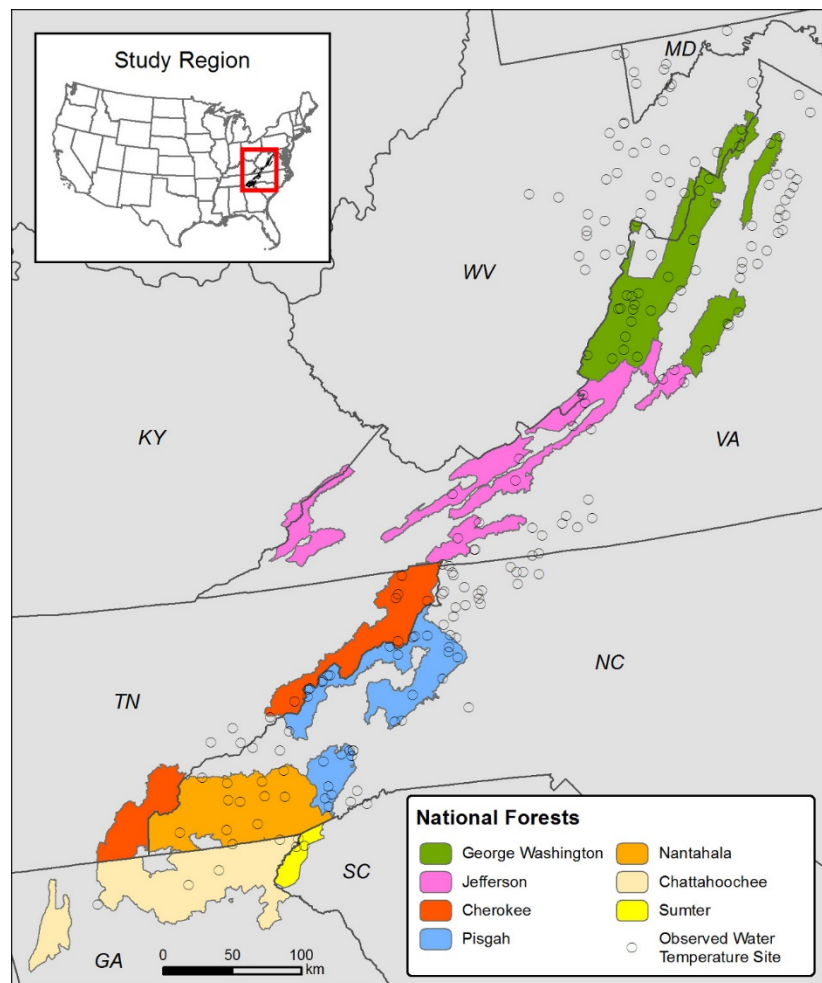


Figure 10: National Forest proclamation boundaries within the Southern Appalachian Mountains and locations of contemporaneous water and air temperature monitoring sites.

contemporary and projected future stream water temperatures across a range of public and private forestland within the proclamation boundaries of seven southeastern national forests (Figure 10).

We developed multiple linear regression models based on stream temperature measurements from 231 sites within the southern Appalachian Mountains using 32 independent variables representing aspects of climate, hydrogeomorphology, lithology, soil texture, vegetation, and solar radiation to explain variation in July Mean Daily Maximum Stream Temperature (JMMST). The JMMST threshold represented the

upper limits of the preferred temperature range for the coldwater species guild, including salmonid (e.g., Brook Trout) and cottid (e.g., Mottled Sculpin [*Cottus bairdi*] and Slimy Sculpin [*C. cognatus*]) fishes. The ANC threshold - $ANC < 50 \mu\text{eq/L}$ - was selected based on evidence of substantial negative biological effects on stream macroinvertebrate and fish species. We estimated the extent of potential habitat loss by comparing the current length of suitable coldwater habitat with likely habitat length associated with air temperature increases of 2 and 4 °C and summarized changes in the length of suitable stream habitat.

Contemporary stream temperature and Acid Neutralizing Capacity

Our models suggested that the amount of stream habitat currently available for coldwater species is moderate to low as a percentage of total stream length across the southern Appalachian Mountains (Table 1). Biological impairment for acid-sensitive species occurs in all national forests included in this study, with the exception of the Sumter where no stream reaches were predicted to have ANC <50 µeq/L. Stream reaches that both exceeded the temperature threshold and fell below the ANC threshold were rare, accounting for only 2% of the total stream length. Consequently, most stream reaches predicted to have low ANC (<50 µeq/L) occurred in locations with otherwise suitable thermal habitat. Assuming that ANC <50 µeq/L renders this habitat inhospitable for acid-sensitive aquatic species, low ANC precludes use of approximately 16% of the length of suitable thermal habitat for coldwater species within each national forest. In general, JMMST is strongly correlated with elevation ($r^2 = 0.92$). The highest elevations occur in the southern portion of the region – North Carolina’s Pisgah and Nantahala National Forests contained the most coldwater habitat (approximately 4000 km

each) and greatest percentage of total stream length (nearly 50%) – where elevation tends to override the influence of latitude and increased solar radiation inputs.

Habitat loss from stream warming

The amount of suitable stream habitat for acid-sensitive coldwater species is predicted to decrease as air temperature increases across all southern Appalachian Mountain national forests (Figure 11). With a 2 °C increase in July maximum daily air temperature, mean stream temperature will increase 0.76 °C above contemporary JMMST, resulting in a 6% reduction in current stream length within each national forest. A 4 °C increase in maximum daily air temperature likely will result in a mean stream temperature increase of 1.52 °C above contemporary JMMST, and a consequent 10% reduction in total stream length. These changes in stream temperature and thermal habitat loss incorporate the predictions of the logistic regression model that we used to classify stream reaches as having either low or high sensitivity to air temperature. We also estimated that approximately 27% of the stream network has low sensitivity to air temperature, and we therefore assumed no stream temperature warming in those reaches in

response to increases in maximum daily air temperature.

For the majority of national forests, the largest reductions in stream length having suitable thermal habitat occurred in response to a 2 °C increase in maximum daily air temperature (Figure 12). Losses of suitable thermal habitat corresponding with air temperature increases between 2 and 4 °C are approximately half of those predicted for air temperature increases of 2 °C above contemporary conditions. Losses of thermal habitat on the Pisgah and Nantahala National Forests, which are expected to experience the greatest overall reductions in suitable thermal habitat, are exceptions to this pattern. Thermal habitat losses associated with a 2 °C increase in maximum daily air temperature will approach 900 km, or approximately 10% of total stream length within each national forest; the additional habitat loss as maximum daily air temperature approaches 4 °C increases to 1600 km or 21 and 18% of the total stream length in the Pisgah and Nantahala National Forests, respectively. In general, the effect of incremental stream warming is a contraction of suitable thermal habitat towards low-order headwater locations and a shift in the distribution of coldwater species from lower to higher elevations, as well as a decrease in

Table 1: Stream length and percentage of total stream length that was predicted to be too warm (> 20 °C) during July, too acidic (ANC < 50 µeq/L), or suitable (ANC > 50 µeq/L and T < 20 °C) for sensitive species.

National Forest	Stream Length (km and %)				Suitable Habitat
	Total	temp> 20 °C	ANC < 50 µeq/L	Temp > 20 °C & ANC <50 µeq/L	
George Washington	12,090	11,009 (91.1)	939 (7.8)	546 (4.5)	687 (5.7)
Jefferson	10,856	7,363 (67.8)	1,168 (10.8)	389 (3.6)	2,714 (25.0)
Cherokee	11,183	7,881 (70.5)	798 (7.1)	191 (1.7)	2,695 (24.1)
Pisgah	8,004	4,100 (51.2)	568 (7.1)	79 (1.0)	3,415 (42.7)
Nantahala	8,978	4,906 (54.6)	728 (8.1)	34 (0.4)	3,378 (37.6)
Chattahoochee	9,017	7,877 (87.4)	42 (0.5)	2 (0.0)	1,101 (12.2)
Sumter	906	881 (97.2)	0 (0.0)	0 (0.0)	25 (2.8)
Total	61,035	44,017 (72.8)	4,243 (7.0)	1,241 (2.2)	14,015 (22.4)

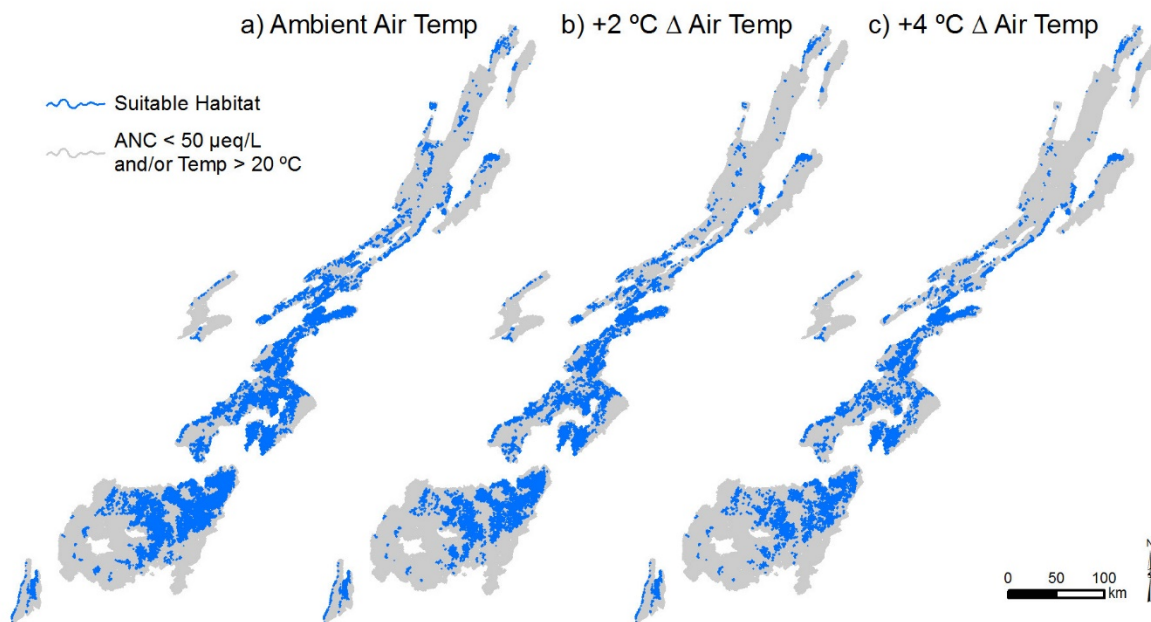


Figure 11: Locations of suitable (blue) and unsuitable (gray; ANC < 50 µeq/L and/or temperature > 20 °C) stream habitat under a) current conditions and future increases of b) 2 °C and c) 4 °C.

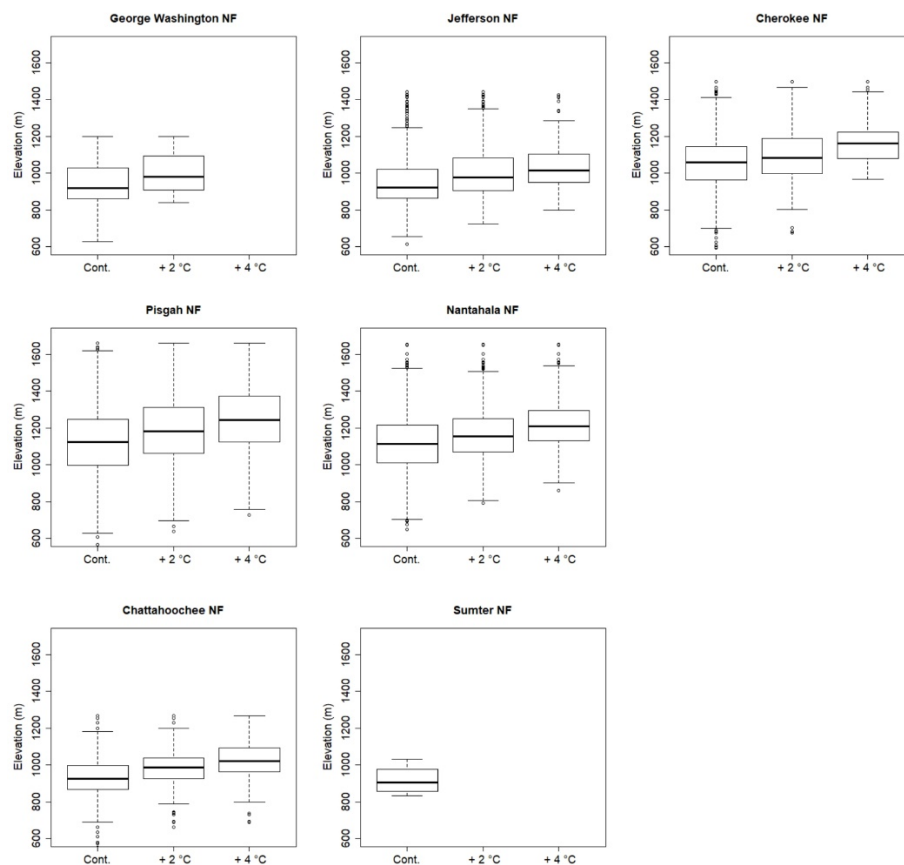


Figure 12: Distribution of watershed elevations associated with individual stream segments considered to be suitable habitat for coldwater acid-sensitive species under a) contemporary, b) +2 °C, and c) +4 °C mean daily air temperature.

habitat connectivity. The combined effect of low ANC and stream warming is to restrict suitable habitat for acid-sensitive coldwater species to an ever narrowing band of mid-elevation stream reaches within stream networks.

Habitat suitability for acid-sensitive coldwater species

Headwater streams typically provide the coldest available habitat within stream networks and are often perceived as potential climate refugia for coldwater species. The relative mobility of many aquatic species can enable populations to track changes in thermal habitat, provided that constraints associated with stream size, steepness, or other barriers do not limit upstream movement. Range shifts towards headwaters have been observed in some fish populations in response to warming. However, our analysis of spatial patterns of stream acidification and temperature in the southern Appalachian Mountains suggests that species' distributional shifts to colder, higher elevation habitats can be constrained by acidification of headwater streams. Headwater acidity is expected to persist in some watersheds for decades, even with substantial reductions in atmospheric deposition of sulfate and nitrate. Low rates of mineral base cation weathering combined with release from the soil of previously adsorbed sulfate are the primary causes of this expected delayed recovery of stream ANC conditions. Consequently, managers will need to continue consideration of stream ANC as a potentially important limiting factor for aquatic species in addition to the expected impacts of increasing air temperature on stream water.

Although air temperature-elevation relationships are common surrogates for stream temperature

when projecting the potential effects of climate warming on stream ecosystems, a variety of local controls are known to alter relationships between air and stream temperature. Stream temperature forecasts that assume direct correspondence with air temperature tend to overestimate the extent of thermal habitat loss. This occurs mostly because of variability in riparian shading and groundwater contributions among stream watersheds. Consequently, we attempted to account for spatial variation in stream temperature sensitivity by directly modeling the sensitivity of JMMST to changes in maximum daily air temperature. We observed considerable spatial variation in the sensitivity of stream temperature to increases in air temperature. The mean predicted July maximum stream temperature increase associated with the 4 °C increase in July mean maximum daily air temperature was approximately 1.7 °C (i.e., mean stream temperature increase per unit increase in air temperature = 0.42°C). However, paired air and stream temperature records for the study area indicated statistical independence between air and stream temperature at some sites, and a nearly one-to-one relationship at others.

A key finding of our analysis is that there is little spatial overlap in streams that are either too acidic or too warm for sensitive aquatic species. Thus, over much of the southern Appalachian Mountains, habitat loss from acidification and stream warming will be additive rather than compensatory. In many areas of the region suitable habitat for acid- and thermally sensitive species will shift to the middle portion of current coldwater reaches that occur below headwaters with low ANC, and above low elevation reaches where JMMST will likely exceed 20 °C. With increases in air temperature, stream warming is

predicted to progress upstream, causing the elimination of coldwater habitat in some branches of the stream network, or encroaching on reaches that are suitably cold but that have low ANC. Thus, with stream warming, we predict an incremental contraction in the extent of mid-elevation stream reaches with both adequate ANC and suitable stream temperature for coldwater species. Suitable stream habitat under ambient July mean maximum daily air temperature was estimated to be 23% (14,015 km) of total stream length (61,034 km), with a range of 2 – 68% among ranger districts. Reductions in suitable habitat with a future increase in July mean maximum daily air temperature of 2 °C ranged from zero to 85% among ranger districts, representing a 27% reduction (3716 km) in total suitable stream length across all ranger districts, with four ranger districts losing more than 300 km of thermally suitable stream length. Losses associated with a 4 °C increase in July mean maximum daily air temperature ranged from zero to more than 90% among ranger districts, which translates to 42% reduction (5,847 km) of suitable stream length under ambient conditions.

Efforts to improve understanding of geologic and geomorphic factors directly associated with groundwater contributions to base flow will improve future climate change assessments. Nevertheless, our approach was useful for identifying many portions of the southern Appalachian Mountains where stream temperature is not likely to be sensitive to atmospheric warming.

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Management Implications

- Climate-induced stream warming and headwater stream acidity represent a significant dual challenge to maintaining suitable habitat for coldwater species in the Southern Appalachian Mountains, where species' distributional shifts to colder, higher elevation habitats in response to stream warming may be complicated and constrained by acidification of headwater streams.
- The potential extent of habitat loss from the collective influence of stream warming and stream acidity warrants additional effort to reduce uncertainty in the prediction of spatial patterns of acid neutralizing capacity and stream temperature.
- Our results identify areas where managers must consider both stream temperature and stream acidification in developing climate change adaptation plans. Such spatially explicit results will be useful for restoration planning, which may include fish stocking, liming to reduce stream water acidity, and riparian canopy enhancement.



The National Riparian Core Protocol – a Roadmap for Riparian Vegetation Monitoring along Wadeable Streams

Wadeable streams can serve as effective indicators of watershed health as they exhibit signs of impairment and natural variability in larger landscape and watershed processes (Whigham et al. 2012). Across the United States, wadeable streams are abundant relative to other stream types and have been estimated to comprise 90% of perennial stream and river miles (USEPA 2006). While these wadeable streams and their associated riparian ecosystems are common across some landscapes, this abundance doesn't always equate to high-quality ecosystems. For example, in 2006, the Environmental Protection Agency (EPA) found that 41.9% of the United States' wadeable streams were in poor condition (USEPA 2006) while Macfarlane et al. (2017) found that 62% of Utah's wadeable streams have degraded or altered riparian vegetation. Two common stressors that impair U.S. streams are riparian disturbance and vegetation alteration, impacting 25.5% and 19.3% of U.S. streams respectively (USEPA 2006). Additional studies have identified myriad other threats to wadeable streams' riparian ecosystems (Theobald et al. 2010, Poff et al. 2011).

Based on their abundance and susceptibility to disturbance, wadeable streams and their riparian ecosystems have historically been monitored by U.S. land and water management agencies. While the EPA's wadeable streams assessment (USEPA 2006) provided a systematic, nationwide inventory of stream condition and catalog of relevant threats, it was predicated on land management agencies' histories of monitoring wetland,

floodplain, and riparian systems to meet resource conservation, restoration, and planning objectives (USEPA 2009, Lanigan 2010, Burton et al. 2011, Cooper and Merritt 2012, PIBO EM 2012, Dickard et al. 2015, Bureau of Land Management 2017).

In this tradition, the U.S. Forest Service released the National Riparian Core Protocol (Merritt et al. 2017; NRCP) to present a flexible framework for evaluating riparian vegetation and associated habitat parameters along wadeable streams. The full National Riparian Core Protocol is available online as [General Technical Report RMRS-GTR-367](#).

The National Riparian Core Protocol (NRCP) is overlain on agencies' riparian monitoring traditions and is designed to assist in monitoring riparian vegetation and associated stream properties accurately, quantitatively, and consistently. Historically many agencies, including the Forest Service, developed individual protocols for monitoring different regions' wetland, riparian, or stream habitats. Individual resource specialists such as foresters, rangeland managers, hydrologists, and botanists had to either select their agencies' existing protocols for system-wide monitoring or design their own protocol for project monitoring. In many cases, these protocols were designed for specific applications, but were not always easily repurposed to new applications, scales, and questions.

The NRCP was designed to present an open-ended protocol for resource specialists that assimilated numerous riparian scientists' expertise and experience. This protocol presents a road map to guide scientists through the various steps of question-driven riparian monitoring (Figure 13). It leads resource specialists through identifying and stratifying sample

sites based on valley types, collecting herbaceous and woody vegetation data, identifying where vegetation occurs along the channel, and summarizing channel attributes. The NRCP is not intended to replace or compete with existing agency-wide protocols but guide the monitoring of riparian ecosystem status and trend.

Resource specialists can consult with the NRCP (and forthcoming Riparian Technical Guide) after they have defined a specific resource question that monitoring can help them answer but before they have selected sites and reaches. By consulting with the NRCP before designing or selecting an existing protocol, resource specialists can select the appropriate vegetation and channel attributes that will allow them to answer their specific questions and blend their approach with other appropriate techniques for measuring channel and vegetation attributes.

Thus far, various iterations of the protocol have been applied to identify the downstream effects of water diversion on riparian vegetation in the Routt National Forest (Caskey et al. 2015). The protocol is also being used to assess riparian vegetation pre- and post-stream channel restoration on the Routt National Forest. This approach will allow the Forest to assess the ecological return on investment from physical and hydrological restoration. Beta tests of the protocol have also been completed in the White Mountain National Forest (VT), the Green Mountain National Forest (VT), the Allegheny National Forest (PA), and the San Juan National Forest (CO).

We encourage Forest Service staff to consult with and consider using attributes of the NRCP when designing question-based monitoring to support their programmatic needs. Technical

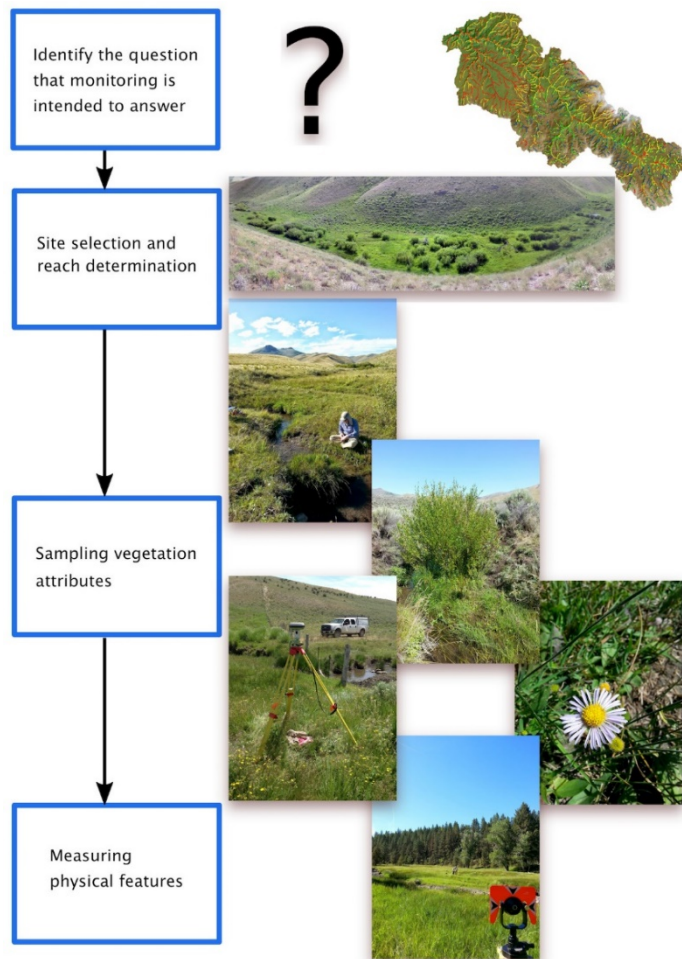


Figure 13: Schematic of the steps outlined in the National Riparian Core Protocol: identifying a research question, selecting sites, sampling vegetation attributes, and measuring stream physical parameters.

assistance in the implementation of the protocol is available through the [National Stream and Aquatic Ecology Center](#) as are NRCP monitoring field kits which include iPads for quickly and electronically logging data, laser measuring instruments, and a durable, field copy of the NRCP.

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