Article

Development of Riparian and Groundwater-Dependent Ecosystem Assessments for National Forests in the Western U.S.

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Abstract: In 2012, the U.S. Department of Agriculture adopted a new planning rule that outlined a process for developing, amending, and revising land management plans for the 155 National Forests, 20 National Grasslands, and one Tallgrass Prairie managed by the U.S. Forest Service. The rule outlines a framework with three phases: assessment, development/amendment/revision, and monitoring. We are assisting National Forests in the western U.S. with the first phase by completing a series of assessments of riparian and groundwater-dependent ecosystems. Here, we describe our methods and the lessons learned over the course of conducting assessments for seven National Forests. Per the requirements of the planning rule, we conduct a rapid assessment of ecological integrity that uses existing data to evaluate drivers, stressors, structure, function, composition, and connectivity. We have collaborated with National Forests, state agencies, and other research groups to obtain datasets representing various wetland landscape features. Our work supports the plan revision process, from assessment through plan approval, and informs future forest and project planning for the restoration and maintenance of structure, function, composition, and connectivity. We developed our assessment methods in collaboration with resource managers at the National Forest and regional level to ensure useful end products such as published technical reports, literature reviews, photo libraries, or collections of datasets related to riparian and groundwater-dependent ecosystems. Our approach and lessons learned throughout the process are relevant to other resource management planning applications, analyses of landscape condition, as well as assessments of other ecosystems, such as forests or grasslands.

Keywords: 2012 planning rule; key ecosystem characteristic; natural range of variation; U.S. Forest Service; decision making

1. Introduction

The U.S. Forest Service (USFS) stewards 193 million acres of forests, grasslands, and prairies within the National Forest System. The National Forest Management Act (NFMA) requires the USFS to develop, maintain, and regularly revise Land Management Plans (Forest Plans) that guide actions on these lands. Currently, the development and revision of USFS Land Management Plans are guided by the 2012 Planning Rule (36 CFR Part 219), which outlines procedures and identifies required components for new or updated plans [1]. The forest planning process follows a cyclical, adaptive management approach that includes three phases: assessment, plan development, and monitoring [1]. During the assessment phase, managers evaluate socio-economic and ecological conditions or trends present on the National Forest or Grassland and identify potential needs for change [1]. The next step is to develop or revise the Forest Plan [1]. Finally, managers use monitoring to track plan implementation and measure indicators of desired conditions, the results of which can inform the next assessment of conditions and trends [1].

The Planning Rule outlines a number of requirements resource managers must follow throughout the plan revision [1]. One requirement is the use of the best available scientific information. This means managers must seek existing high-quality data developed through

appropriate methods, with cited references and peer-review. A second requirement is that the assessment phase is rapid and evaluates existing conditions including the quality of air, soil, and water resources, the presence and abundance of fish, wildlife, and native plants, and the integrity of terrestrial and aquatic ecosystems. To complete the assessment, the Planning Rule indicates that managers must select key ecosystem characteristics (KECs) that are indicative of the structure, function, composition, and connectivity of terrestrial and aquatic ecosystems. These KECs should then be used to evaluate ecological integrity, which is defined by the Planning Rule as "the quality or condition of an ecosystem when its dominant ecological characteristics occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence."

To aid in meeting 2012 Planning Rule requirements for ecosystem assessment, we established a partnership with the USFS Intermountain Region in 2015 to assess riparian and groundwater-dependent ecosystems (GDEs) on National Forests in Idaho, Wyoming, Utah, and Nevada. We initially considered established ecosystem assessment methods that are applied internationally [2–12]; however, we found many failed to meet the specific requirements of the Planning Rule. Many assessment methods focus on the evaluation of ecosystem services [2,4–7], but lack a focus on ecological integrity. Additionally, many approaches are designed to be implemented through field visits that create new data [3,8–12] and do not rely on existing information. We designed new methods to meet Planning Rule requirements for the rapid evaluation of ecological integrity using only existing data. Our assessments address drivers and stressors that influence the condition of riparian ecosystems and GDEs. We integrate widespread, well-documented national or international data with local field data that may have been collected irregularly through space or time but remain valuable as the only available existing information capturing on-the-ground conditions. We use this information to determine whether evidence exists that ecological integrity has been compromised and have published a series of general technical reports summarizing our findings for each National Forest [13–17]. National Forest staff have identified these reports as effective and have used them to directly inform forest planning and management actions on several National Forests.

At the request of our partners at the Intermountain Region, our assessments address riparian ecosystems and GDEs. Riparian areas are unique landscape features that exist at the interface of terrestrial and aquatic environments (Figure 1) [18]. They are influenced by the presence of surface water and groundwater and consist of plant communities that are distinct from adjacent uplands [18]. GDEs are "communities of plants, animals, and other organisms whose extent and life processes are dependent on access to or discharge of groundwater" [19,20]. For the purposes of forest planning, GDEs include fens and other wetlands fed by groundwater, terrestrial vegetation and fauna sustained by shallow groundwater, ecosystems in streams, lakes fed by groundwater, caves, karst aquifers, aquifer systems, hyporheic and hypolentic zones, and springs [21]. Although these ecosystems occupy a small percentage of landscapes in the western U.S., riparian areas and GDEs provide disproportionately large ecosystem services such as water filtration, essential wildlife habitat, recreational opportunities, and flood control [22–24]. Recognizing these valuable functions, National Forests have recently focused on the classification, inventory, and assessment of riparian ecosystems and GDEs, with monitoring effects of forest management activities and preserving high-quality habitat for threatened and endangered species often identified as management priorities. Although our assessments focus on specific ecosystems, the approach outlined here is an effective method for landscape analysis of many ecosystem types. Additionally, we provide lessons learned from participating in the Forest Plan Revision process and suggestions for how to adopt our framework for other applications.
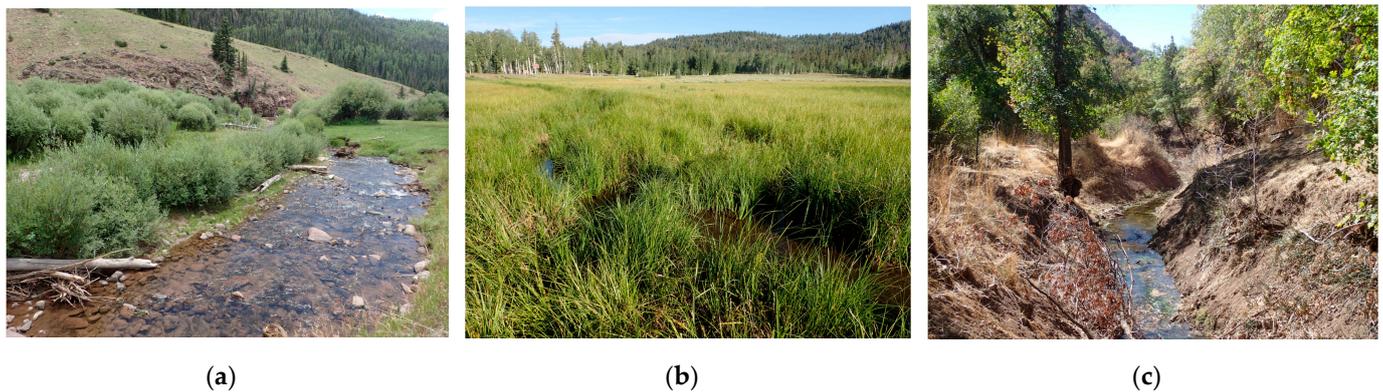
Figure 1. Examples of assessed ecosystems: (**a**) willow-dominated riparian vegetation along Merchant Creek on the Fishlake National Forest, Utah. (**b**) a groundwater-dependent wetland in the Dixie National Forest, Utah, and (**c**) a spring runout channel on the Fishlake National Forest, Utah.

2. Materials and Methods

We developed a new approach for assessing the current condition of riparian ecosystems and GDEs that exist after approximately 30 years of management actions guided by the past Forest Plan. Our methods have evolved through collaboration with the Intermountain Region. The approach is flexible, allowing us to incorporate datasets that differ across National Forests and to address unique landscape features or concerns that are present in localized areas. To ensure we are aware of these unique management concerns, we begin each assessment with at least one in-person meeting with staff from the focal National Forest. Because riparian areas are complex ecosystems that connect to many disciplines and are impacted by multiple interacting stressors, we aim for these meetings to be multidisciplinary. We often involve managers from different resource areas including hydrology, fish biology, wildlife biology, aquatic ecology, forest planning, and range conservation. During these meetings we discuss available datasets, goals for the updated plan, and topics of interest on the Forest. We also work with National Forest staff to establish geographic units within the Forest by which to complete our assessment. These units typically align with forest planning efforts and are often categorized by mountain ranges. Finally, we plan for a few days in the field to tour the Forest, visit unique sites, and get a general idea of potential drivers and stressors of riparian and GDE condition. These field visits are often more productive when accompanied by National Forest staff, who have in-depth local expertise related to ecosystems present on the National Forest.

We begin our analysis by inventorying, mapping, and calculating percent cover or density of riparian and GDE features in defined geographic units of each Forest (Figure 2). To describe the distribution of areas that can be considered riparian, we use existing spatial data representing geomorphology, surface flows, groundwater, and vegetation. These datasets have been used to map riparian ecosystems, but each has limitations [25,26]. Mapping geomorphic features associated with riparian ecosystems can demonstrate their potential extent, but changes in hydrology, natural or anthropogenic, may limit the development or persistence of riparian ecosystems, thereby resulting in an overestimation of riparian extent. Conversely, vegetation-based mapping may underestimate riparian extent because riparian understory species may be obscured by overstory vegetation and facultative riparian species may be incorrectly classified as upland [26]. To fully display the potential range of riparian extent, we incorporate both the existing vegetation and geomorphology data. These datasets include a GIS layer of riparian ecosystem extent developed by Abood et al. [27] that incorporate 50-year flood heights from stream gage data, a 10-m digital elevation model, soil units (hydric, drainage class, flood frequency, and hydrological soil group), and National Wetland Inventory (NWI) data. We also map the current distribution of riparian vegetation using data generated by the Vegetation Classification, Mapping, and Quantitative Inventory (VCMQ) program [28]. VCMQ products are

customed to each National Forest and use different combinations of satellite imagery (e.g., MODIS, MISR, AATSR, ATSR), aerial photography (e.g., Forest Service digital orthorectified imagery, Forest Service resource photography), and field-sampled data to produce maps of existing vegetation types for each National Forest [28].
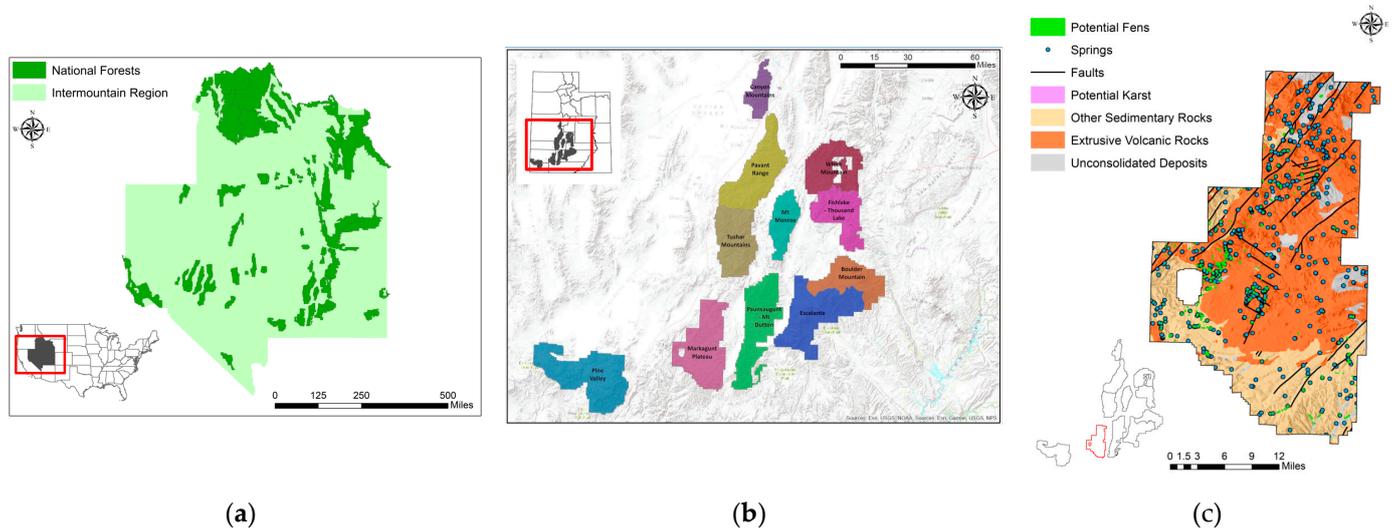

(**a**)

(**b**)

(**c**)

Figure 2. Geographic scales of riparian and groundwater-dependent ecosystems (GDE) assessments: (**a**) location of the Intermountain Region and its National Forests, (**b**) geographic units within the Dixie and Fishlake National Forests, and (**c**) GDEs mapped within the Markagunt Plateau geographic unit of the Dixie National Forest.

Most National Forests have limited knowledge of the landscape-scale distribution of GDEs. Because high quality existing data related to the location of GDEs is relatively rare compared to riparian ecosystems, we search for information from multiple sources including the U.S. Geological Survey (USGS), the Spring Stewardship Institute (SSI), the National Hydrography Dataset (NHD), and local shapefiles maintained by each National Forest. We compile relevant datasets and use this information to describe the known distribution of GDEs so these ecosystems can be more readily acknowledged in forest planning activities. The datasets we use for each assessment vary, depending on what is available for each Forest. We have used shapefiles representing potential karst, major aquifers, faults, and bedrock geology from the USGS [29–31]. We map the location of springs using shapefiles generated by the SSI, the NHD, and those provided by the Forests. We have also received shapefiles of potential fens in each Forest from the Colorado Natural Heritage Program (CNHP). Using NWI data and aerial imagery from multiple sources (e.g., National Agricultural Imagery Program, high resolution World Imagery from Environmental systems Research Institute, etc.), CNHP staff locate wetlands that are potential fens, hand-draw the best estimate of fen boundary, and rank them as likely fens, possible fens, and low confidence fens based on the number of fen-like characteristics they observe [32–37].

Once riparian ecosystems and GDEs are inventoried and mapped across the Forest, we evaluate the ecological integrity of several KECs, including surface water and groundwater fluctuations, water quality, channel and floodplain dynamics, and the composition and structure of riparian ecosystems and GDEs. To determine whether KECs are functioning in a way that contributes to long-term ecological integrity, we review scientific literature, published reports, and available datasets to identify drivers and stressors specific to each KEC in the Forest. For riparian ecosystems and GDEs of the Intermountain West, drivers tend to include climate, geology, topography, and beaver (*Castor canadensis*) activity. We have found that level IV ecoregions [38] and reports completed by USGS tend to be excellent sources of information to summarize local climate, geology, and topography, but data related to beaver activity are often difficult to acquire. Common stressors considered in our assessments include roads [39,40], grazing [40–45], water diversions [40,45], dams and large

reservoirs [40,46–48], mining [40,45], invasive species [40,45], recreation [40,45,49], vegetation mortality, high severity wildfire [40,50], timber harvest [40,45], and drought [40,45]. Many public datasets provide excellent spatial data on stressors (Supplementary Table S1). For stressor data, we frequently rely on the USFS National Dataset, state points of diversion GIS layers, and national monitoring efforts related to drought or burn severity.

For each potential stressor, we compile datasets to quantify the level of stress (e.g., diversion density) within geographic units and 12-digit HUC subwatersheds. We then evaluate whether the stressor has had a likely impact using datasets such as the USFS Watershed Condition Classification (WCC) [51] or the USFS Terrestrial Condition Assessment (TCA) [52]. The WCC is an evaluation of watershed condition using multiple indicators that is completed by National Forest staff and can be aggregated for assessment [51]. Similarly, the TCA calculates several indicators to evaluate the effects of uncharacteristic stressors and disturbance agents on National Forests [52]. We may calculate road density as road miles per acre within a watershed and then consult the WCC and TCA datasets that provide information on the proximity of roads to streams and waterbodies, whether road infrastructure has been maintained, and whether road density is sufficiently high to impact hydrologic function or wildlife. Finally, using HUC12 subwatersheds as sampling units, we test for associations between different stressors using the non-parametric Spearman's rank order correlation. For example, on some Forests it may be true that high grazing pressure is correlated with stress imposed by water diversions or roads. In this case, watersheds with a large percentage of land within a grazing allotment would also tend to have high diversion density and high road density. We use this information to categorize stressors that generally occur together and determine whether a watershed with one stressor present is likely to have multiple stressors impacting riparian ecosystems and GDEs.

Once we have identified relevant drivers and stressors for each KEC, we estimate ecological integrity using indicators of KEC function that can be measured with available datasets (Supplementary Table S1). We tend to rely on multiple data sources that range from plot level to national scale. Like stressor data, we quantify indicators for each unit and subwatershed. We then test for associations between indicators (e.g., conversion of riparian area to upland vegetation) and stressors (e.g., diversion density) using Spearman's rank order correlation. For geographies and KECs for which there is sufficient data, we integrate several existing indicator datasets to determine the natural range of variation (NRV) status in each geographic unit. In some cases, we use an index calculated from the quantitative assessment of stressor and indicator variables. For example, in the case of surface water and groundwater fluctuations, we typically consider stressor variables such as deviations in winter precipitation and temperature and indicator variables like the WCC Flow Characteristics attribute that describes whether natural flow regimes are properly functioning [51]. For some KECs, such as the composition and structure of GDEs, applicable data come from various sources and were not collected in a standardized manner. In these situations, qualitative scoring is more appropriate.

Based on an index that integrates multiple existing datasets, we describe KEC status as functioning within NRV, moderately altered from NRV, or functioning outside NRV. For the purposes of our assessment, KECs that are moderately altered from NRV are not fully contributing to ecological integrity, but with changes in management or plan direction, could do so in the future. KECs that are functioning outside NRV are not expected to contribute to ecological integrity because changes to address stressors are likely outside the Forest's management abilities. If we cannot locate multiple datasets that describe the condition of a KEC, we state that there is insufficient information and do not determine NRV status. This outcome of "insufficient information" remains valuable for National Forests that must determine monitoring needs during plan revision.

As a final step, we examine spatial patterns in the condition of KECs by mapping NRV status across the Forest. We incorporate any additional information about the condition of these ecosystems from a literature review, meetings with Forest staff, and visits to field sites. We conclude our assessments by describing the overall levels of ecological

integrity, issues and locations where changes in management could be considered, and remaining information gaps. When the draft assessment is completed, we submit it to the Intermountain Region and the focal National Forest for review. We solicit both oral and written feedback to improve the assessment and ensure we have included all relevant datasets. Recognizing Forest-level managers are often busy, we have found breaking the full assessment into shorter chapters tends to increase the amount of high-quality feedback and reviews we receive. This step is critical for producing an accurate end product that will be useful for forest planning and decision making.

3. Results

The results of our assessment include a summary of the presence and impact of stressors across each National Forest. Our assessment work in the USFS Intermountain Region is incomplete and ongoing; however, for the six National Forests for which we have produced a report, we have found livestock grazing, water diversions, and roads to be the most extensive, wide-spread stressors to riparian ecosystems in Idaho, Utah, and Wyoming. These three stressors also tend to occur together within HUC12 watersheds, with high diversion density often correlated with high road density and a large percent of the landscape within a grazing allotment. Several other common stressors include mining, dams and large reservoirs, invasive species, recreation, vegetation mortality, high severity wildfire, timber harvest, and drought. These stressors and their effects tend to be more localized and impact specific watersheds within the National Forests we have assessed.

Due to the use of different indicator datasets, estimations of current conditions are not comparable across National Forests; however, our results suggest there is wide variation in the condition of riparian areas and their KECs in the Intermountain West. For example, an evaluation of KECs on the Bridger-Teton National Forest in Wyoming indicated generally high ecological integrity of riparian areas and GDEs, with all units classifies as within NRV for groundwater and surface water fluctuations, water quality, riparian composition, and channel and floodplain dynamics. In contrast, only 10, 41, 33, and 35 percent of the Salmon-Challis National Forest was considered within the NRV for groundwater and surface water fluctuations, water quality, and channel and floodplain dynamics, and riparian composition, respectively. Our assessment work is ongoing, but based on completed analysis for six National Forests, groundwater and surface water fluctuations are generally altered from the NRV with likely consequences to riparian ecological integrity. Similarly, channel and floodplain dynamics tend to be at least moderately altered from NRV in many areas, with intact channels present in Utah, Idaho, and Wyoming. The composition and structure of riparian areas appears somewhat resilient to multiple interacting stressors, with many units classified as within NRV on the Ashley, Manti-La Sal, Salmon-Challis, and Bridger-Teton National Forests. Finally, water quality is often within NRV and contributing to ecological integrity throughout many of the National Forests we have assessed.

For most areas within the National Forests we evaluated, data were inadequate to evaluate current conditions at GDEs. Where data were available, we determined that composition and structure were either moderately altered or outside the NRV. Additionally, in the few places with sufficient data for assessment, spring runout channels appear strongly impacted by multiple interacting stressors and are often altered from NRV. With limited data we found localized impacts to water fluctuations at GDEs and generally high water quality. We made these determinations based on reports detailing impacts of livestock grazing, diversion of water from springs, and the presence of nonnative plant species.

4. Lessons Learned
4.1. Less Information Is Available on GDEs Than Riparian Ecosystems

In conducting our assessments, several issues have emerged that are common among the Forests. Most notably, there is limited information and data on GDEs in comparison with riparian ecosystems. Whereas numerous riparian sites have been measured in most geographic areas of each Forest, GDE measurements are often limited in number and are

more unevenly distributed. At each Forest, most GDE surveys have been conducted at springs. Surveys at fens are fewer or nonexistent and are usually conducted by external groups such as university researchers. As a result, fen survey methods are inconsistent within and among Forests. Future application of the USFS GDE Level I and II survey protocols [19,20], in coordination with the SSI's Springs Online database, will improve the consistency of GDE surveys and availability of their results.

4.2. High Resolution Spatial Data and Strategic on-the-Ground Monitoring Are Necessary

There are pros and cons to solely working with datasets of a certain scale. National data are widely available, have well documented methods, and provide consistent information that make it possible to compare results across geographies. Only considering national level data, however, results in a loss of local expertise. Large-scale datasets are generally too coarse for describing the conditions at a specific location within one of our study areas. For example, we often use the Riparian Condition Assessment Tool (RCAT) [53,54], which estimates changes in riparian ecosystems using 30 m LANDFIRE data [55,56]. In some cases, this 30 m resolution is too coarse to accurately capture changes in narrow riparian corridors that are common throughout the Intermountain West. In these situations, it may be possible to use higher resolution imagery; however, these datasets tend not to be available at large enough spatial scales to estimate departure across a full planning unit or entire National Forest. For these ecosystems, RCAT tends to overestimate the conversion of riparian cover to alternative cover types such as upland vegetation or invasive species. However, if we combine RCAT output with local riparian plot data, we may be able to confirm that conversion to other cover types has been observed.

Local data provides the benefit of incorporating local expertise. We have found many resource managers at the National Forest level are able to offer extensive information related to on-the-ground conditions. In addition to information that we receive from local managers through discussion during in-person meetings and through reviews of the draft assessment, many Forests have collected at least some local field data through monitoring efforts. These monitoring data, however, are typically tied to a specific project or management activity. As a result, local datasets generally lack random sampling or a robust experimental design. Additionally, riparian monitoring methods tend to vary across, or even within, Forests. Due to this inconsistency, we are frequently unable to compare local datasets across landscapes. A final downside of many local datasets is lack of repeated measures. We have found many local datasets were collected once several years in the past, which inhibits its use to understand trends or the current condition.

For these reasons, we find using a combination of local, regional, and national data allows us to evaluate ecological integrity and determine NRV status with greater confidence. For example, when determining whether surface water and groundwater fluctuations have been impacted by roads, we may consider the national-scale USFS TCA [52], the USFS WCC [51] that was completed by each Forest, and local riparian plots that describe disturbances present within a stream reach. If all three datasets provide evidence that roads have altered hydrologic regimes, we can be confident an actual impact exists.

Overall, landscape analysis for planning purposes would benefit from consistent higher resolution spatial data to better inventory ecosystems and capture condition, as well as regular strategic on-the-ground monitoring that occurs within a robust experimental design. As new methods and datasets become available, National Forests can build on our initial results to fully inventory the aquatic and riparian resources they manage.

4.3. Quantitative and Qualitative Data Are Valuable for Ecosystem Assessments

Though the types of available data vary among the Forests we have assessed, we have found value in both quantitative and qualitative datasets. We find the quantitative measurements of variables such as water quality, and vegetation cover are complimented by qualitative descriptions of community composition, streambank condition, and other features at stream reaches and GDE sites. Protocols yielding useful quantitative data include

Pacfish-Infish Biological Opinion Effectiveness Monitoring Program (PIBO) and Winward greenline measurements [11,12,57]. Level II riparian surveys and PFC assessments have provided us with useful qualitative descriptions of riparian areas and GDEs. Given the varied and dynamic settings of these ecosystems, no single protocol or category of data can provide the full picture of current conditions, making the availability of multiple datasets important to conducting our assessments.

4.4. Climate Change Should Be Considered in Multiple Ways

Climate change has obvious implications for assessments of ecological integrity that include the evaluation of NRV. We tend to incorporate climate into our assessments in two ways. First, we often consider climate change as a stressor to the current condition of KECs. For example, reduced snowpack, earlier snowmelt, increased drought, and altered precipitation regimes that include shifts from snowfall to rain impose stress on KECs such as surface water and groundwater fluctuations or water quality. In these situations, we use data from the USFS TCA [52] that capture deviation in seasonal temperature and precipitation or data from the U.S. Drought Monitor that describes the length and severity of drought within an area over time. Secondly, we recognize that climate change may contribute to substantial alterations from NRV that may not be addressed through management. To address this concern, we attempt to include information about potential future conditions. For example, we have included data from Western Flow Metrics [58] that report several hydrologic parameters for streams for the historical period of 1915–2006, and estimated parameters for the 2040s and 2080s under different climate projections. We also summarize the temperature and precipitation deviation information described above by subwatershed in the hopes of identifying watersheds with limited climatic changes.

4.5. Tools Are Available to Aid in the Consideration of Beaver-Based Restoration during Planning Efforts

Historically, beaver activity throughout the western U.S. played a major role in the development and maintenance of functional riparian ecosystems. Resource managers are increasingly interested in beaver reintroduction or using structures like beaver dam analogs that mimic beaver activity to achieve desired conditions. These types of management actions are often considered during development and revision of Forest Plans; however, we have found accurate data related to beaver populations and activity is difficult to acquire. Two tools developed at Utah State University may aid in considering beavers during plan revision: The Beaver Restoration Assessment Tool [59] and the Beaver Monitoring App [60], with which users can report beaver activity. The Assessment Tool can provide information on potential to use beavers as a conservation or restoration tool at watershed or landscape scales.

4.6. Research Describing Natural Range of Variation Is Necessary

Consideration of NRV is only one component of evaluating ecological integrity; however, we have found that determining NRV can be one of the more difficult tasks to accomplish in our assessments. Additionally, defining NRV is one of the most common concerns expressed by National Forest staff and it is what we are most frequently asked about when presenting these assessments in professional meetings or workshops. While we have identified some data sources that effectively aid in estimating NRV, better descriptions of NRV are a topic ripe for research. We suggest research focused on NRV should consider both qualitative and quantitative data. Researchers interested in improving the understanding of NRV may consider landscape descriptions from historical publications, diaries, traditional knowledge, tree rings, packrat middens, soil or lake sediment cores, and specimen collections held by natural history museums, among other historical datasets.

5. Discussion

Assessments of ecological integrity are a critical step for informing land managers and decision-makers during planning efforts. Although ecosystem assessments are widely

used to inform land management worldwide [7,61–63], many evaluate ecosystem services rather than ecological integrity [7,64] (e.g., the European Union's mapping and assessment of ecosystems and their services (MAES) program [65], hydrological ecosystem services mapping in Australia [4], quantification of ecosystem services in Asia [6], and the United Nations Millennium Ecosystem Assessment [2,62]). These are large-scale examples, but the number of assessments and the body of literature related to assessing ecosystem services at variable spatial scales has grown substantially since the 1970s [7,66]. While the evaluation of ecosystem services are effective for some applications, resource managers have indicated they often do not find these types of assessments entirely relevant to planning efforts [7,64,67,68], and it is rare for studies to indicate how ecosystem service assessment was used in local decision making [64]. In contrast to the evaluation of ecosystem services, our approach focuses on ecological integrity, which has been identified by managers as more useful for decision-making [68]. The efficacy of our approach and the usefulness of our end-products are evident, as National Forest planners and resource managers have directly incorporated our results into revised Land Management Plans.

Like the evaluation of ecosystem services, protocols for assessing ecosystem condition, specifically for riparian areas, are widely available [8–12,19,20,69–71]. These protocols generate valuable data describing on-the-ground conditions; however, on their own, these approaches typically do not meet the needs for a rapid assessment to inform land managers. Many of these methods require substantial investment of time and resources, including field visits by professionals trained in the methodology. Because the Planning Rule requires use of existing data, we are not able to generate new data using these protocols to inform our assessments. Additionally, while many of these methods are "rapid" because they can be completed within a few hours, applying these protocols on spatial and temporal scales sufficient for identifying patterns and trends relevant to planning requires years of effort. For these reasons, we are unable to apply these approaches, but our assessments frequently rely on datasets that have been collected using these methods. Throughout our assessment work, we have found numerous datasets that have been collected through the application of field protocols. In many cases these datasets have not been compiled or analyzed in a way that supports resource management and our National Forest partners are especially pleased when we integrate these datasets and make them available to inform planning efforts.

Recognizing that although development of ecological integrity indices had advanced and were successful at small scales, Reza and Abdullah [72] suggested no index of ecological integrity exists at the regional scale for terrestrial and aquatic ecosystems. Additionally, their study outlined six characteristics that should be considered in the development of an effective regional-scale index: (1) multi-scaled, (2) grounded in history and succession, (3) relevant and helpful, (4) flexible, and (5) comprehensive [72]. Our assessments are multi-scaled, as we conduct analyses and summarize results at the HUC12 watershed, mountain range, and National Forest scale. We ground our assessments in history and succession through consideration of geologic and topographic setting, climate, natural range of variation, and anthropogenic history of the landscape. To ensure our work is relevant and helpful, we include multidisciplinary National Forest staff who are local experts. We meet with these managers as the first step in the assessment process and continue to involve them through reviews of our assessment reports. As outlined in this paper, our methods are intentionally flexible to accommodate unique features and datasets that differ across National Forests. Our evaluation of ecological integrity uniquely integrates largescale and local datasets in a measurable way that is interpretable by decision makers and could be applied repeatedly to determine trends. Finally, our assessments are comprehensive as they consider KECs that capture the composition, structure, function, and connectivity of riparian areas and GDEs. We developed the approach described in this paper to meet the requirements of the USDA's 2012 Planning Rule; however, the methods and lessons learned are relevant to resource managers or researchers interested in completing a rapid assessment of ecological integrity using only existing data.

In addition to differing from established methods that focus on ecosystem services, require generation of new data, or occur at scales other than the regional level, our assessments provide a meaningful product quickly. Like the time investment required to create a meaningful dataset from field-based protocols, many existing ecosystem assessment methods take years to complete. One of the goals of the Planning Rule is to reduce the amount of time it takes to revise a forest plan so that management plans can be updated more often. Because we rely only on existing data, we are typically able to acquire and integrate data from various spatial scales, analyze the data, summarize results, complete a literature review focused on drivers, stressors, NRV, and desired conditions, submit a draft to the focal National Forest for review, address feedback and begin the publication process for the report in less than a year. In general, we publish the assessment before the focal National Forest even begins the plan revision process.

In addition to providing an alternative to approaches that either assess ecosystem services or require field visits, our methods are useful for planning efforts that aim to identify locations for the maintenance or restoration of ecological integrity. Innis et al. [68] identified assessment of current ecological integrity as a key component of any management issue, specifically preservation and restoration. Consequently, state and federal land management agencies, countries, and international groups frequently engage in environmental analysis and planning to inform this type of decision-making [2,5,7,65,68]. For example, the Millennium Ecosystem Assessment aimed to provide science to support sustainable ecosystem management and enhanced conservation [2] and MAES provided an understanding of the location and status of threatened and degraded ecosystems to guide restoration efforts [65]. As these examples suggest, projects intending to maintain or enhance ecological integrity increasingly involve large landscape restoration projects that expand beyond single watersheds or administrative boundaries. The steps outlined in this paper for a rapid assessment of riparian and GDE condition can be used to prepare for projects related to these ecosystems, as well as other ecosystems, such as forests or grasslands, that managers focus on during planning efforts. For example, the methods outlined in this paper could be used to identify watersheds with limited stressors or minor alterations from NRV. This information can aid managers in selecting areas that are an appropriate fit for restoration or maintenance projects.

Completing an analysis such as ours across relatively large landscapes can also be used to highlight significant gaps in monitoring efforts. We have found it is common for geographic units within National Forests to lack local field data collection. Additionally, we find it is rare that monitoring plots are repeatedly measured over time. By conducting an assessment that incorporates these field datasets, we can identify geographies or ecosystems that require monitoring, locations where monitoring occurred in the past, but the information is out of date, or locations that could be revisited to establish trends in condition. It is for this reason that we specifically identify geographic units with insufficient information to evaluate a KEC. National Forest staff can then ensure these areas or ecosystems are targeted for sampling as they develop a monitoring program through Forest Plan Revision. This type of output is obviously not limited to National Forests but can be generated for any landscape that has been irregularly monitored across space or time.

Finally, our approach can also be used to specifically assess wildlife habitat and inform the creation of wildlife management strategies. When completing an assessment, researchers or managers may consider different, more wildlife-specific KECs, or assess the same KECs through a wildlife-focused lens. For example, the USFS Intermountain Region, recognizing this potential, has requested additional assessments for National Forests that have no plan revision scheduled but do require updates to wildlife management strategies. Furthermore, we are completing assessments for National Forests in Oregon and California that provide habitat to many threatened and endangered species. We are addressing these needs by adjusting our KECs to ensure they address the connectivity of riparian habitats within and across watersheds and specifically address salmonid habitat quality as a KEC. Additionally, for these assessments of Forests in the Pacific Northwest, we are increasing

the focus on fish and wildlife by further breaking ecosystems out from solely riparian and GDE to more specifically focused on habitats such as fish or non-fish bearing perennial and intermittent streams.

Overall, the above examples suggest assessments such as ours, and the methods we use provide a useful and flexible framework for general support of natural resource management decision making. These approaches can be expanded for use to other National Forests and other USFS Regions, as well as landscapes managed by other state, local, or federal agencies within the U.S or abroad.

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