Improving Accessibility and Understanding: Studying the Impact of Human Activities and Dam Removals on Anadromous Fish Species in the Pacific Northwest

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Improving Accessibility and Understanding: Studying the Impact of Human Activities and Dam Removals on Anadromous Fish Species in the Pacific Northwest

A Thesis Presented

by

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To the Keck Science Department

of

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I. Abstract

Human activities in North American watersheds have significantly impacted anadromous fish, causing some species of salmon and steelhead to become threatened and endangered. These fish hold ecological, cultural, and economic importance, yet factors such as habitat destruction, overfishing, pollution, climate change, and hydroelectric dams continue to degrade populations. Dams are particularly harmful to anadromous fish, sparking a recent movement advocating for dam removals. This study uses NOAA’s 2022 *Biological Viability Assessment* to examine the response of anadromous fish to recent dam removals in the Pacific Northwest. Four populations were selected to analyze due to their interaction with sites that had major dams up until the past 15-20 years. Natural origin spawner estimates were modeled and visually analyzed to study the trends of these populations since the year of dam removal. Two t-tests were conducted to quantitatively assess the consistency in recovery trends. Despite observing similar trajectories in some populations, the quantitative analysis found there was no significant correlation between responses at this time. Several factors may contribute to this inconsistency between datasets and variability in population numbers, such as habitat recovery, dam conditions, geography, ocean conditions, climate change, or natural fluctuations. In conclusion, further time and monitoring are needed to fully understand how anadromous fish populations respond to dam removals and the reasons for these responses. A map was created in conjunction with this paper to visually present the data from the *Biological Viability Assessment*, which aims to create a more accessible medium to read and analyze the data.
II. Acknowledgements

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III. Introduction

A. Pacific Anadromous Fish and Ecological Challenges

Human activity in North American watersheds has a detrimental impact on anadromous fish species. “Anadromous” describes species that hatch in rivers and streams, travel to the sea where they spend most of their lives, and return to freshwater to spawn. The fish create nests in the freshwater habitats out of alluvial stream gravels known as reds, which can be used as proxies to measure population trends (Sellheim et al., 2022). The fry, or juvenile fish, emerge from the gravel and spend one to two years in the river ecosystem, feeding on insects and zooplankton. The fish then undergo smoltification, a physiological process that prepares them for the transition to saltwater environments. They may spend this adjustment period in estuaries, where they can acclimate to saltwater. Most growth and maturation occurs in the ocean, where food and nutrients are abundant. After spending one to several years at sea, anadromous fish return to their natal rivers to spawn (Seyler et al.). Pacific salmon are semelparous, meaning they will die after spawning. Steelheads may make this journey several times in a lifetime (NPAFC, 2023).

Figure 1: This image shows coho salmon, chinook salmon, and steelhead from top to bottom. These are the species examined in this paper, seeing as they are all anadromous and affected similarly by river blockages, although they vary greatly in length and weight (NOAA, 2022).
These remarkable fish species have persisted for approximately 300 million years, the earliest documented species being the jawless sea lamprey, which lives on in rivers across North America (Bardack et al., 1968). Most are considered keystone species because they occupy integral roles within their respective ecosystems, bridging the divide between terrestrial and aquatic ecosystems (Willson, 1995). If these species were to go extinct, the surrounding ecosystems may not adapt. The migratory journey between freshwater and saltwater habitats facilitates nutrient cycling from the marine environment into streams and rivers, as the decomposition of their bodies releases important elements into the ecosystem (MacAvoy et al., 2009). Moreover, anadromous fish serve as an important food source for apex predators, as well as humans. The salmon industry in the west coast alone provides substantial economic benefits, generating tens of thousands of jobs (ESC, 2020). In 2010, the Business Forecasting Center at the Eberhardt School of Business estimated that California’s salmon industry was worth $344 million, which has likely only increased over the past fourteen years (Michael et al., 2010). In addition to the economic importance of anadromous species, indigenous communities had, and continue to have, deeply important cultural and practical uses for these fish. According to the Columbia River Inter-Tribal Fish Commission, salmon have greatly influenced tribal cultures, diets, and even religions (CRITFC, 2021). Pacific salmon’s “keystone” title extends beyond ecological roles; they are integral to every aspect of human life in the area, from the economy, to culture, to the health of their surrounding ecosystem.

Nevertheless, Pacific salmon and other anadromous species have been endangered for decades due to human activity. This includes habitat destruction, overfishing, dams and other river blockages, pollution, and climate change (WWF, 2024). Most salmon and steelhead species in the Pacific Northwest were added to the list of Threatened and Endangered Species in the
1990s, although extreme habitat destruction and overfishing began long before (NOAA, 2022). Since their decline, nutrient cycling has demonstrated a significant decline, which has detrimental effects for pre-established food chains, water quality in freshwater systems, and surrounding agricultural land. A 2017 study found that “current freshwater systems operate at approximately 6.7% of historical capacity of anadromous alewife biomass and abundance” (Mattocks et al., 2017). This statistic likely extends beyond alewife populations, and may act as a proxy for other anadromous fish populations in the United States. There are also economic and cultural implications due to the societal importance of these species. This issue is widely recognized within the scientific community, and catalyzed individuals and organizations from a variety of fields to take conservational initiatives to improve salmon numbers and overall ecosystem health.

B. Dams

Dams are a leading cause of the degradation of fish populations in Pacific Northwest rivers. Although they provide various resources to surrounding communities, such as hydroelectric power, flood protection, and regulated water availability, they pose a grave threat to local ecosystems. For anadromous fish especially, dams block the natural passageway for upstream and downstream migration (CDWR, 2024). This prevents fish species from returning to their natural habitats to spawn, severely affecting population health. The spinning turbines and intense water pressure through concrete structures can also cause fish to die upon impact. An estimated 10 to 15 percent of fish that pass through the main channel of the dam alone will die (NW Council, 2024). Dams form reservoirs, which create stagnant pools that can heat to temperatures that are lethal to salmon and steelhead (Keefer et al., 2015). These structures alter
sediment flow, changing the food web from the bottom up. They block nutrients trapped in sediments from reaching downstream communities, depriving species of the resources they have depended upon for thousands of years (Palinkas et al., 2019).

Dams without fish passages block migration entirely. Due to government mandates and regulations, most dams in the United States now have some system in place to ensure fish may pass (Smith, 2014). This may be in the form of fish ladders, fish elevators, or other transport systems. The effectiveness of fish passages is widely debated. NOAA and the U.S. Fish and Wildlife Service both attest that these structures are functional, but the data says otherwise (NOAA, 2022 and USFWS, 2024). One study conducted in New England watersheds found that a mean of 3% of American shad, an anadromous species of fish, made it from the first dam on a river all the way to spawning grounds (Brown et al.). Most dams in the Pacific Northwest have had fish passage systems in place for decades, although none of the anadromous fish species in their watersheds have been removed from the Threatened and Endangered Species list since their addition in the 1990s (NOAA, 2022).

Figure 2:
- Condit Dam (top left), photo by Thomas O'Keefe (American Rivers, 2011);
- Marmot Dam (top right), photo by unknown (Western Rivers Conservancy, 2007);
- Powerdale Dam (bottom left), photo by Phil Tennis of PacifiCorp and Joe May of Farmers Irrigation District (Hood River Watershed Group, 2010);
- Glines Canyon Dam on Elwha River (bottom right), photo by unknown (National Park Service, 2012).
There are currently over 500,000 dams in the United States, less than 3% of which are producing hydroelectric power, and less than 17% are providing effective flood protection. A large reason for these concerning numbers is that the average design life for a dam is only 50 years. 85% of our nation’s dams exceed this age limit (American Rivers, 2023). Although dams can have important functions, many are entirely obsolete. Unfortunately, dam removals are costly, which deters state governments from prioritizing these projects. Various groups estimate that dam removals can cost anywhere from a few hundreds of millions of dollars to over a billion dollars (Whitelaw, 2002).

A recent push for dam removals in the Pacific Northwest has ensued following decades of declining fish populations, despite restoration and mitigation efforts to work around the dams. One of the most notable of these projects took place in November 2020, when an agreement was reached between local tribes and the states of California and Oregon to move forward with the removal of four dams in the Klamath Basin (KRRC, 2020). The dams were finally removed in spring 2023. This was a groundbreaking achievement for Pacific Northwest river ecosystems and the people advocating for them.

Despite this success, many dams in the Pacific Northwest remain in place with no plans for decommissioning in the near future. Even with the removal of these facilities, immediate recovery is not guaranteed nor anticipated. According to a 2017 study, physical responses to dam removal, such as sediment discharge, occur much faster than previously anticipated. Ecological responses, however, are more complex and take longer due to various factors such as geography, dam size, dam removal strategy, and environmental conditions (Foley et al., 2017). Because the recovery of fauna is less predictable and occurs over extended periods, our understanding of the
process is limited. Significant discourse around dam removal only began 30 years ago, thus this subject is understudied and not well-understood.

C. The Biological Viability Assessment Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act

Following the designation of Pacific salmon and steelhead as endangered and threatened species, depending upon the evolutionarily significant units (ESUs) or distinct population segments (DPSes) under the ESA, a regulatory mandate was instituted. This mandate required periodic assessments by the National Marine Fisheries Service (NMFS). The NMFS must conduct quinquennial assessments to determine whether any changes should be made to their statuses, for better or for worse (Barnas et al., 2022). This information may also be used to understand which factors are most greatly affecting fluctuations in population so that changes can be made to improve Pacific salmon numbers and the overall health of the ecosystem. The most recent Biological Viability Assessment Update for Pacific Salmon and Steelhead Listed Under the Endangered Species Act was conducted in 2022. This assessment is composed of the research of many surveys, compiled to create a comprehensive review of the health of eighteen different ESUs or DPSes (Barnas et al., 2022). They each belong to one of five different anadromous fish species: chinook salmon, chum salmon, coho salmon, sockeye salmon, or steelhead, all of which belong to the same genus, *Oncorhynchus* spp. (NPAFC, 2023). For each ESU or DPS, the authors provide summaries of viability conclusions from previous years, newly available data, return and spawner rates, ocean condition indices, abundance and productivity, spatial structure and diversity, non-treaty harvest, recovery goals, and a summary (Barnas et al., 2022).
This assessment is exhaustive, encompassing hundreds of detailed pages describing the population information. Additionally, the authors offer an examination of environmental conditions observed in both marine and terrestrial environments, and their influence on Pacific salmon within the Pacific Northwest region. This document, composed of 312 pages and its associated spreadsheet containing upwards of 7700 data points, presents a vast amount of valuable information. However, the high volume of information, the numerous variables considered, and the abundance of methodologies employed for each ESU or DPS pose challenges in deriving broader conclusions solely from the text. Without clear direction, interpretation of the data and assessment of the effectiveness of this quinquennial assessment becomes difficult. Technical language, complex figures, and limited outreach efforts are all factors that limit accessibility of academic texts to the general public. The length of many scientific documents alone can be enough to deter people from gaining interest in academia. The primary challenge is not a lack of information or analysis, but rather a need for synthesis, simplification, and improved accessibility.

The democratization of knowledge is important, both as an equity issue and as a catalyst for advancement within scientific disciplines. Greater accessibility to knowledge expands the pool of scientists and innovators, accelerating progress in the field. Widespread dissemination of knowledge also generates greater understanding among diverse communities, which translates to increased support, funding, and participation within the scientific field. In light of pressing science-related equity issues such as climate change and misuse of resources on colonized land, inclusive involvement of marginalized communities in scientific discussion is not only important in an ethical sense, but is also beneficial to the overarching cause. Restricting access to
information to a niche group of academics and researchers is not only a disservice to the world, it undermines the progress of science itself.

D. The Objective

The objective of this project is to explore findings in the data provided by NOAA’s *Biological Viability Assessment Update* in a novel way. While the assessment offered very specific, exhaustive information about individual populations and environmental conditions at the time, there was little synthesis that demonstrated, on a broad scale, the overarching success or failure of the quinquennial assessments. This project provides a more accessible medium to read and analyze the data in question through ArcGIS data visualization, in response to the rapidly evolving ways society absorbs media.

Rather than analyzing all relevant factors that affect Pacific salmon populations and river ecosystem health included in the assessment, this paper focuses on the effects of major dams blocking fish migration and how fish respond to dam removals. The populations in the study that are affected by recent dam removals from the past fifteen years include White Salmon River, Sandy River, Hood River, and Elwha River. The associated dams were named the Condit Dam, Marmot Dam, Powerdale Dam, and Elwha Dam, respectively. The response of these populations is analyzed based on the estimated number of returning natural-origin spawners, and interpreted to determine if they are showing signs of consistent and significant recovery.
IV. Methods

A. Mapping Procedure

This project used ArcGIS Pro version 3.0 to create a spatially organized visual for the population data used in the Biological Viability Assessment. Following the extraction and compilation of all populations throughout the eighteen ESUs and DPSes, the next step involved identifying the main testing sites associated with each population to establish precise points on the map. One shortcoming of the Biological Viability Assessment was the inconsistencies in information between populations. Some groups had precise testing locations listed, others did not. If locations were absent from the document, points on the map were marked at the tributary.
For example, for chinook salmon in the Lower Columbia basin, the point for the Sandy River population is marked at the tributary between Sandy River and the Columbia River. This was the case for most of the 200+ points.

![Map Image]

**Figure 4:** The images above provide a closer look at four of the eighteen ESUs in question. The data presented happens to come from surveys conducted in 2012. Locations include Puget Sound (top left), Lower Columbia (top right), Lower Snake River (bottom left), and Upper Snake River (bottom right). This magnified perspective aims to improve understanding of the data and of the interactive nature of the map.

Once the map was created, the Salmon Population Summary excel data, shared publicly by NOAA Fisheries, was integrated. This connection allows users to access the data by clicking on specific points, navigating spatially around the map. Each point is attached to relevant data, such as population information, natural origin spawner estimates, and age returns (up to age seven). Age return data is determined by tagging and is therefore not consistently available across populations, making it not the ideal measurement to determine progress across all populations. Natural origin spawner estimates are available for all populations, since it is the primary metric employed by those conducting the surveys. For this reason, this project uses the
“number of natural origin spawners” metric to measure improvement and degradation across populations.

Two layers, dams and former dams, were created and added to the Pacific salmon map. These two layers delineate major dams that are currently blocking rivers and streams in relevant watersheds, as well as major dams that have been decommissioned in the past two decades. For simplicity, only dams referenced in the Biological Viability Assessment Update are included, focusing on their impact on relevant ESUs and DPSes. Information such as establishment year, removal year (if applicable), type of fish passage, the impacted ESU/DPS, and the river it occupies are available on the interactive map.

B. Analytical Methods

For this study, the experimental hypothesis states that anadromous fish populations will respond positively to dam removals. A positive response is represented by a consistent and significant increase in the annual number of estimated natural origin spawners. The null hypothesis then states that there is no significant nor consistent increase in the number of natural origin spawners following dam removal. Natural origin spawners are employed here as the metric to track population numbers over time.

Figure 5: These images show the magnified perspective of the four decommissioned dam sites. The sites are dispersed between two locations: the Condit Dam, Marmot Dam, and Powerdale Dam resided in the Lower Columbia River, and the Elwha Dam in Puget Sound. The data visually represented above is from 2012, around the time that each of these dams were removed.
Using R-Studio, response trajectories were modeled and analyzed to measure the responses of four populations that were most profoundly affected by recent dam removals. Subsequently, two 4-sample t-tests were conducted utilizing ANOVA to quantitatively assess the consistency, or lack thereof, in recovery trends.
V. Results

![Graph showing trends of natural origin spawner estimates](image)

Figure 6: Trends of natural origin spawner estimates from the year preceding dam removal to most recent available data are charted above. The effects of each removal is represented by an ESU or DPS from the river or stream affected. The effects of the Condit and Marmot Dam removals are represented by the Lower Columbia River Chinook Salmon ESU, the Powerdale Dam by the Lower Columbia River Coho Salmon ESU, and the Elwha Dams by the Puget Sound Chinook Salmon ESU.

The estimated number of natural origin spawners from the four study sites are plotted in Figure 6. The populations affected by Condit Dam, Marmot Dam, and Powerdale Dam all had similar trajectories. Immediately following the dam removal, these three study sites exhibited a drop in population numbers, followed by a small spike before dropping again. Two of these sites, Marmot Dam and Powerdale Dam, have begun to demonstrate a rise in population numbers. Salmon passing through the former Condit Dam site were still declining in numbers as of 2018. The Elwha Dam site is the exception here, with continuingly increasing natural origin spawners since the dam removal in 2011, except for a small dip in 2014. Since then, these numbers have
been increasing by over 1000 individuals per year. All four dams exhibit an initial decrease in population numbers immediately following dam removals.

Two F-tests were conducted in R-Studio to create a quantifiable metric to measure the significance of the data. The first test compared the mean values of each group to understand how different the four datasets are as a whole. The resulting p-value was 0.00171, which is less than 0.05, the common threshold to determine significance. From this statistic we infer that the mean natural origin spawner estimates between populations are significantly different, without consideration of trends over time. The second F-test compares regression coefficients between populations. Linear regressions were plotted on each chart and the respective equations were derived, which can be seen in Figure 7. The values of coefficients for each group were -52.4 (Condit), 88.4 (Marmot), -49.5 (Powerdale), and 331 (Elwha). It is important to note that although the trajectories appear similar in the Condit Dam, Marmot Dam, and Powerdale Dam, the regression values from the linear representation of each dataset tell us that these population
responses are quite varied. The p-value for this test was 2.2e-16, which is considered in R-Studio to be infinitely small. Contextually, this means that the overall trends over time are “infinitely” different, so to speak. Thus, the null hypothesis is rejected in both F-tests, meaning that there is no discernable significant nor consistent increase in the number of natural origin spawners following dam removal.
VI. Discussion

A. Analysis of Results

These results demonstrate great discrepancies in natural origin spawner estimates, both within and between datasets. Each standalone graph exhibits significant fluctuation with little proof of overall recovery. Populations interacting with the Condit Dam, Marmot Dam, and Powerdale Dam appear to show similar trends based on the shapes of the smoothed trend lines on the graphs in Figure 6. According to the F-test however, the average trends modeled by linear regressions indicate that the net recovery of these three populations is dissimilar. The Marmot and Powerdale Dams recently began demonstrating recovery, although the timeline is too short to know whether this trend is true recovery or simply a manifestation of natural fluctuation. The similar trajectories of these two populations is interesting, because they are the only two sites that had fish ladders in place prior to dam removal. Despite the similar response seen in Figure 6, the presence of fish ladders preceding decommission does not appear to have a significant impact upon recovery. In fact, the Condit Dam and Powerdale Dam appear to have the most similar average trends, according to their linear regression coefficients seen in Figure 7.

The Elwha Dam site stands out as an exception due to its sustained increase in natural origin spawners since dam removal, suggesting successful recovery efforts at this site. The reason for the difference in response at this site remains unknown. The outstanding nature of salmon recovery on the Elwha River is interesting to note, however, because the timeline and geography are so similar to the other three study sites. The Elwha and Condit Dam populations are the most comparable in terms of size, highlighting the surprise surrounding their notably different responses to dam removal. The F-tests were both highly significant, which respectively analyzed the variance in mean and in average trends between the four groups. In this case, these
results indicate that the anadromous fish response to dam removal in all four sites are vastly different.

The reason for the fluctuation within populations and variance between sites remains unclear. Natural variation can be considered normal within these populations due to external environmental factors, although this would not account for inconsistencies between sites. Potential causes for the insignificant results are discussed below.

B. Potential Explanations for Inconsistencies

(1) Dam removal methods

As discussed earlier, river blockages prevent the natural downstream flow of sediment. These sediments are trapped and built up behind the dam, storing valuable nutrients necessary for downstream ecosystems. The amount of sediment buildup and type of sediment both affect the rate of transport, and in turn, the rate of restoration. The method of dam removal and sediment management plans, which depend on the size and material of the dam, also have a major impact on habitat restoration. Dams may be removed all at once or in stages. The Elwha and Condit Dams were removed in stages due to their size. A recent synthesis on the geomorphic responses to dam removal found that sediment discharge occurs more efficiently in response to sudden removals, rather than in stages (Major et al., 2017). Removal can take place “in the dry,” which describes draining the reservoir behind the dam by pumping water around the structure. The dam itself may also be removed from top down, allowing water to flow over the structure. Explosives are also occasionally used (McClain, 2023). Each of these methods has different implications regarding rate of flow and sediment discharge, and is highly dependent on dam and river conditions. Thus, methods must be chosen on a case-by-case basis.
The habitats themselves recover far faster than macrofauna, which was observed and recorded in recent studies in Pacific Northwest watersheds (McClain, 2023). The Condit Dam is a useful example of this phenomenon. The structure held 1.8 million m³ of fine-grained sediment. Approximately 10% of the sediment bank eroded within the first 90 minutes, and over 60% of the trapped sediment eroded within the first fifteen weeks (Wilcox et al., 2014). Despite this rapid transformation, the graph in Figure 6 shows that chinook salmon populations associated with Condit Dam on the White Salmon River continued to decline seven years following the dam removal.

It is important to acknowledge the initial decline in natural spawner estimates immediately after dam removal across all four populations (this decrease appears later in the Elwha Dam population data because there were two dams undergoing removal on the Elwha River: one in 2011 and one in 2014). Scientists hypothesize that dam removals negatively affect populations in the first generation post-dam destruction. This phenomenon is caused by high sediment loads discharging and burying downstream eggs and fry-stage fish (Pess et al., 2024). This side-effect would explain the initial decrease in natural origin spawner estimates across populations.

(2) Fish passages

Fish passages are implemented beside dams with the intention of restoring access to historical spawning grounds for migrating anadromous fish. Although the extent of the functionality of these structures is widely debated, their presence is preferable to the complete obstruction of the river. The Marmot and Powerdale Dams were the only sites equipped with fish passages prior to dam removal. The fact that fish were already passing the dam site in two out of the four study sites could introduce bias to the data. Sites with fish ladders prior to dam
decommissioning may demonstrate less dramatic recoveries, as their anadromous fish populations already had enhanced access to historical spawning grounds. Conversely, the sites with fish ladders might experience an accelerated recovery due to the established upstream spawning sites. Regardless of the effects of the bias, it is important to acknowledge that the presence of a fish passage prior to dam removal could be a variable affecting recovery rates.

(3) \textit{Geography & geomorphology}

Geography and geomorphology are key variables that inform the way in which macrofauna and their habitats recover following dam removals. Several factors require consideration, including the dam’s proximity to the ocean, the number of preceding dams, the width of the waterway, and the alterations in the river system’s geomorphology induced by the dam (Foley, 2017). The geography of the dam in relation to the ocean and other upstream blockages influences the extent of impact made by dam removal. Take for instance the removal of a dam closest to the ocean (such as the Elwha), which would typically be situated in the widest section of the river and preceding other dams. This dam would likely result in a dramatic increase in the number of naturally originating spawners, in contrast with the removal of a smaller dam located upstream in a narrow creek. These overlooked variables may, to some extent, explain the inconsistencies observed in the data.

(4) \textit{Climate change}

Anadromous fish depend on a number of environmental cues for navigation and migration timing. One significant environmental factor is the seasonal temperature changes. With climate change causing ocean temperatures to rise, the annual upstream migration of these fish is delayed. This delay not only negatively affects anadromous fish, but also has detrimental consequences for the entire surrounding ecosystem, given the role of these fish as keystone
species (Cobb, 2020). Climate change also causes extreme weather events, alongside long-term warming, potentially contributing to the year-to-year fluctuations observed in the data. We would expect these fluctuations to be similar across populations, however. These trends are depicted on one graph in Figure 8 for comparison.

![Graph showing comparative trends in natural origin spawner data between dams.](image)

**Figure 8**: This graph shows salmon natural origin spawner estimates from 2007 - 2018 at the four dam sites. These trends are placed on one graph so year-to-year trends may be observed and analyzed, to determine whether environmental factors are influencing fluctuation.

C. **Concluding Remarks**

Further research and monitoring are necessary to understand exactly how anadromous fish species respond to dam removals, and the numerous variables involved. More data points, studies of variables affecting the data, and an extended timeline are all crucial components needed to elucidate reasons for varying recovery rates. The inconsistencies observed in the data do not imply that dam removals lack a positive effect on anadromous fish populations; in fact, it’s quite the opposite. This lack of immediate response in the years following dam removals
underscores the urgency of addressing these dams sooner rather than later, before threatened and endangered anadromous fish species go extinct.

Despite the inconsistencies in the response trajectories, recent research showcasing rapid recovery in sediment discharge and river morphology provides hope for the future of macrofauna in these same river systems (Wilcox et al., 2014). Additionally, even if natural origin spawner estimates have not yet begun to rise, visual observations of salmon and steelhead occupying historical spawning areas upstream of former dam sites were recorded at most of the study sites (Duda et al., 2021). This observational evidence underscores the importance of the dam removal movement and offers reassurance that these conservation efforts are not in vain. With continued dedication and ever-improving management strategies, progress toward the restoration of our waterways and ecosystems improve, marking an important step toward the renewed preservation of the natural world.
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