Floodplain management for all: Addressing inequities and meeting needs of Indigenous communities

Olivia Zimmerman, Tanya Eison, Phil Levin

Abstract

Anthropogenic impacts have altered and degraded global ecosystems. Integrated resource management offers an important solution to enhance collaboration, holistic thinking, and equity by considering diverse perspectives in decision making. In Washington State, Floodplains by Design (FbD) is an integrated floodplain management and habitat restoration program. FbD emphasizes bringing together diverse stakeholders and supporting conversations between local, state, and Tribal governments while enhancing environmental justice in the region. Historically ignored communities continue to be disproportionately impacted by environmental disturbances. Our project interviewed Tribal natural resource managers to assess the degree to which they felt FbD was supporting their community's needs. Our research asked three questions: 1) What Tribal needs and inequities associated with floodplains are identified by Tribal natural resource managers? 2) Are these needs and inequities being addressed by FbD? and 3) How can FbD better address these needs and inequities moving forward? We found that while the integrated approach of FbD was driving solutions in some realms, there are ways in which the program could better support needs and address inequities in Tribal communities. Specifically, we found that conventional responses to environmental challenges are rooted in modernist paradigms that have created persistent dualities, including that of human-nature and human-nonhuman. Such a paradigm is in conflict with wellbeing and self-determination of Tribal cultures that are deeply connected to Pacific salmon. In closing, we provide insights on these mechanisms and offer solutions moving forward.

Keywords: Floodplain management, environmental justice, Indigenous self-determination, integrated management, Tribal natural resource managers, ecosystem restoration

1. Introduction

Humans and their use of terrestrial, aquatic and marine biomes have transformed the structure and function of global ecosystems resulting in major alteration to climate, biodiversity, biogeochemical cycling and geomorphic processes (Ellis et al. 2013; Halpern et al. 2008). Responding to such dire, complex anthropogenic impacts requires integrated, collaborative and holistic efforts (Beier et al, 2017; Levin et al, 2009; Levin et al; 2016; Pinkerton et al, 2000; Thomas et al, 2006). Despite acknowledgement that integrated management is critical, in practice, management of landscapes is often narrowly constrained (Foley et al. 2013), characterizes humans as independent of and external to ecosystems (Caillon et al., 2017; Poe and Levin 2017), and manages each use sector independently of other relevant sectors (Crowder et al. 2006; Ballanger et al, 2021; Pigford et al, 2018).

While sectoral management is still dominant, a number of examples are emerging that highlight the practical value of integrated management. In Belize for example, Arkema and colleagues (2014) demonstrated that an iterative, collaborative, and community-based approach to coastal zone management resulted in increased program capacity, enhanced support from stakeholders, and an effective solution that was "developed by and for Belizeans" (7). Similarly,

in a U.S. desert ecosystem, Arizona's Sonoran Desert Conservation Plan revealed that a balance between biological conservation goals and thoughtful economic development can support successful protection of both cultural and natural resources (Huckelberry, 2002). Likewise, in the Beaufort Sea, the Integrated Oceans Management Plan prioritized collaborative efforts between Indigenous, local, and federal governments and other non-regulatory parties to minimize resource conflicts and prioritize multi-benefit ecosystem-based management (Ayles et al, 2016). These cases, among many others, reveal that solving complex environmental problems requires integrated, cross-sectoral approaches to achieve equitable management that balances the needs of diverse parties.

A clear candidate for integrated management is riverine floodplains. Globally, riverine floodplains are among the most biodiverse and ecologically important ecosystems on earth (Opperman et al, 2010). Floodplains compose the low-lying ground that surrounds rivers, and are flooded during periods of high river flow (Meitzen, 2018). Fluvial dynamics associated with flooding generates a diversity of habitat types and contributes to a high level of spatial and temporal habitat heterogeneity that supports high species richness (Tockner and Stanford, 2002). Ecotones across a range of spatial scales and the connectivity among ecotones further contribute to the maintenance of their biodiversity (Ward et al, 1999). Floodplains also provide critical ecosystem services to human populations (Constanza et al, 1997). Intact floodplains create intricate landscapes which absorb excess waters during periods of high discharge, providing nature-based solutions to flooding (Turkelbloom et al, 2021). Additionally, they act as natural filters by removing excess sediments and nutrients, improving water quality thereby decreasing treatment needs. Floodplain forests sequester carbon and create stability in the soil, reducing erosion (Perosa et al, 2021). Intact floodplains create important habitat for economically and culturally valuable species (Ward et al, 1999). For example in the U.S. Pacific Northwest floodplains are crucial habitat for ESA-listed salmonids (Bellmore et al, 2013). With growing impacts from climate change, healthy and intact floodplains are increasingly important for climate mitigation and adaptation (Colloff et al, 2015).

Despite their value, floodplains have been heavily degraded. Habitat alteration, flow and flood control, species invasion and pollution have dramatically affected floodplain ecosystems, and in North America and Europe, 90% of floodplains are functionally extinct (Tockner and Stanford, 2002). In the last several centuries, the land surrounding rivers in the United States has been developed resulting in rivers being straightened, deepened, and channelized, and riverbanks becoming armored to protect human structures from floods (Christin and Kline, 2017). These alterations have made human communities more vulnerable to flood impacts, and this impact is increasing as climate changes (Arnell and Gosling, 2016; Ferdous et al, 2020). Inland flooding disproportionately impacts those without the resources necessary to mitigate, adapt, or rebuild from floods (Messager et al, 2021).

The ecological, social and economic importance of floodplains in concert with the complexity of the threats they face requires an integrated approach to their management. Floodplains by Design (FbD) was created in 2013 in Washington State, USA as a response to the lack of integrated floodplain management efforts in the region (Floodplains by Design, 2019). The program is a public-private partnership between The Nature Conservancy, Puget Sound Partnership, Department of Ecology, and the Bonneville Environmental Foundation. The goals of FbD are to utilize integrated floodplain management to 1) accelerate floodplain restoration and

2) reduce flood risk (Floodplains by Design, 2019). Since its founding, FbD has received $165 million in funding from Washington State Legislature for its grant program, designating it an important flood management resource in the state.

Threats from flooding are growing globally as climate change impacts intersect with increased habitat fragmentation and development (Löschner, 2017). However, flooding disproportionately impacts historically ignored communities, and in particular, communities of color. While socioeconomic factors have long been thought to play a key role in pollution and natural disaster vulnerability (Hallegatte et al, 2020), research has indicated that race can be the strongest predictor for environmental hazard exposure when controlling for income (Gilio-Whitaker, 2019; Tessum et al, 2021). Further, white communities have been found to gain wealth following impacts from natural disasters via aid services, while non-white communities lost significant wealth, enhancing wealth disparities (Howell and Elliott, 2019). As myriad climate change impacts shift water cycles, many populations will experience increased vulnerability to flooding but communities of color are expected to be disproportionately impacted (Gourevitch et al, 2022; Handwerger et al, 2021). Handwerger and colleagues (2021) found that Black communities in the Carolinas were seven times more likely to experience inland flooding than white communities. Likewise, Latinx communities in Washington State are twice as likely to live in a flood-prone zone than their white counterparts (Messager et al, 2021). Research has also documented that Indigenous communities in North America experience disproportionate exposure to anticipated flood sites (Chakraborty et al, 2021), and are less likely to receive federal aid to recover from extreme weather events (Messager et al, 2021). Further, due to the entangled (Sakakibara, 2020) and reciprocal (Coté, 2022) relations many Indigenous communities have with the nonhuman world, impacts from climate change are situated to further disrupt Indigenous food sovereignty and self-determination (Keleman Saxena et al, 2016; Settee, 2020; Whyte, 2017).

In this paper, we explore the degree to which Floodplains by Design and associated floodplain management supports Tribal needs and addresses inequities to Tribal communities. To this end, we asked the following three questions: 1) What Tribal needs and inequities associated with floodplains are identified by Tribal natural resource managers? 2) Are these needs and inequities being addressed by FbD? and 3) How can FbD better address these needs and inequities moving forward? In addition to these questions, we also assessed how our participants thought about climate change resiliency in relation to the community they worked for.

2. Methods

To investigate the degree to which the Floodplains by Design program is meeting the needs of Tribes in Washington State, we conducted semi-structured interviews (Smith, 1995) with natural resource managers from signatory Tribes that entered into treaty agreements with the U.S. government. In 1854-1855, Tribes throughout Washington signed these treaties, commonly known as the Stevens' treaties, which ceded millions of acres of land to the United States while simultaneously reserving the rights of the Tribes to continue fishing, hunting, and gathering in their usual and accustomed places (*United States v. Washington*, 1974). §53 of United States v. State of Wash., 384 F.Supp. 312 (1974) commonly referred to as the Boldt Decision, affirmed the right for treaty Tribes to take fish, established treaty Tribes as co-managers, and set conservation standards that restricted the ability of the state to regulate treaty

fishing practices.

As co-managers, treaty Tribes are jointly responsible for fisheries management in the state. Any management decision that may affect the habitat of treaty reserved fisheries, reduce their populations, or limit the harvest for a treaty Tribe in Washington infringes on these reserved rights (Treaty Rights at Risk, 2011). Washington floodplains are habitat that can affect the reserved rights of treaty Tribes if not managed properly. For this reason, we focused on interviewing treaty Tribes that have received FbD funding for a project in the floodplains of their Usual & Accustomed places as described in the Boldt Decision. Importantly, Usual & Accustomed places do not coincide solely within reservation boundaries, but are defined by the current Hydrological Unit boundary classification system in Washington (State Wide WRAI Finder, 2022). Thus, we focused on tribes where an FbD project occurred within the watershed of a Tribe's Usual & Accustomed place because of the reserved right of taking fish.

This project included fourteen Tribes, and because of the breadth of geographies and cultures of focal Tribes, we opted to aim our interviews on Tribal natural resources managers (Castleden et al, 2012). To ensure that interview participants had a well established relationship with a tribe, we limited participation to individuals that had been employed or contracted by the Tribe for a minimum of two years. We identified 109 participants that met our eligibility requirements, and we recruited participants via employee directories listed on Tribal government websites. We then employed snowball sampling (Naderifar et al, 2017) to identify additional participants.

Twenty-one interviews were conducted between May and September 2021. Interviews were conducted via the Zoom video conferencing program, were recorded with consent, and subsequently transcribed. Interview duration ranged from 24 to 77 minutes with an average of 49 minutes.

We coded interviews using Dedoose software (Salmona et al, 2019). Our first-pass coding used grounded theory (Bernard et al, 2016) to identify Tribal concerns, inequities, and values. This round of coding resulted in hundreds of codes, with second and third passes being used to inductively aggregate codes of similar meaning into themed larger codes (Saldaña, 2021). Utilizing open-coding, we identified 26 codes. Authors (OZ and TE) coded interviews independently, and compared codes to ensure intercoder reliability (Cheung and Tai, 2021).

With coding complete, we focused analysis on identifying the needs and inequities experienced by Tribes, the degree to which FbD is addressing these needs and inequities, and how FbD could better address needs and inequities in the future. We divided each reported need into one of three categories: 'institutional,' 'social,' and 'biological' (cf. McInnis and Ostrom 2014). This distinguished among needs that were based upon policy/legislative action, human wellbeing and cultural concerns, and biophysical mechanisms.

We used regression analyses to explore relationships between demographic attributes of our interview subjects and number of needs and inequities they reported. We also conducted a co-occurrence analysis to assess the frequency that our codes were mentioned simultaneously.

This analysis identifies associations between concepts by looking at the prevalence of concepts that occur in the same statement or overlap in two consecutive statements.

3. Results

3.1 Participants

Participants ranged from 32 to 75 years of age ($\underline{X}$ =51, *SE*=2.8), and were 75% male (*N*=15), 25% female (*N*=5). On average, participants worked for their Tribal government for 17.5 years ($\underline{X}$ =18, *SE*=2.7, range 2.5 - 40 years). Seventy-five percent of our respondents worked for Tribal governments on the West-side of the Cascade mountain range (i.e., Western Washington)(*n*=14), and twenty-five percent of respondents worked for Tribes on the East-side of the mountains (*n*=6). About 43% (n=6) of participants from Western Washington lived on the coast) and 57% (n=8) resided by the Salish Sea, including the urban and periurban Puget Sound corridor.

Participants held a range of positions in Tribal governments: Director of Natural Resources (20%), Fisheries Biologist (15%), Environmental/Wildlife Program Manager (15%), Consultant (10%), Environmental/Restoration Planner (10%), Technical Services/Watershed Coordinator (10%), and Other (15%; comprised of an Ecologist, Hydrologist, and Tributary Projects Lead). For confidentiality purposes, the names of the Tribal governments involved in this research are anonymous.

3.2 Tribal Needs

Our interviewees identified 46 Tribal needs relating to floodplain management (Figure 1). On average, respondents reported 18.4 needs (*SE*=0.9). The number of Tribal needs reported by interviewees did not vary with age ($r^2 = 0.04$, P = 0.41), gender ($r^2 = 0.08$, P = 0.24) , or years in their position ($r^2 = 0.02$, P = 0.56).

Every Tribal resource manager we interviewed identified restoration of salmon habitat as a need (Figure 1). Additionally, a number of other needs that are directly related to salmon or access to salmon were mentioned by more than half of interviewees (e.g., access to resources, right to harvest, food sovereignty, water temperature, fish barrier removal, water quality, increased aquatic habitat; Figure 1). In general, the importance of salmon habitat was linked to the cultural importance of salmon. For instance, one Tribal resource manager highlighted the connection of their Tribe to salmon: "We've lost 90% of the [salmon] run, or 95%, that our people used to depend on…who we are as a people is connected to what the land and the fish do and say." Other respondents emphasized that the fate of tribes is deeply connected to salmon: "If we lose salmon, that's like cutting off our legs for Tribes," and "…the loss of fish is significant and it is deadly."

The majority of Tribal needs identified by interviewees (54%) were related to institutional issues. Biological issues constituted 25% of the needs mentioned, and cultural needs composed 21% (Figure 1). However, in general, biological and cultural needs were more consistently mentioned by respondents than institutional issues (Figure 1).

3.3 Regional Variation in Reported Needs

We found that 100% of respondents from east of the Cascades and from the Olympic Peninsula mentioned the need for fish barrier removal while only 38% of those in the Salish Sea region did (Figure 2a). Similarly, increased water in systems, such as the need for reservoirs or keeping water in rivers, was mentioned by ca. 2.6 times more managers east of the Cascades and from in the Olympic Peninsula than from those from the Salish Sea area (Figure 2b). In contrast, we found that respondents from the Olympic Peninsula and the Salish Sea spoke to the need to alleviate damage to shellfish beds caused by flooding and ocean acidification (Figure 2c) as well as removal of shoreline armoring (Figure 2d), while no managers from the east side mentioned these needs.

3.4 Inequities

Our analysis of interviews revealed 41 Tribal inequities relating to floodplain management. On average, respondents reported 13.6 inequities (*SE*=0.6*).* The number of Tribal inequities reported by interviewees did not vary with age ($r^2 = 0.04$, $P = 0.41$), gender ($r^2 = 0.03$, $P = 0.46$), or years in position ($r^2 = 0.03$, $P = 0.49$).

Every Tribal resource manager we interviewed identified loss of salmon as an inequity, and 95% of respondents stated that Tribal communities were disproportionately affected by climate change. (Figure 3). As we saw with needs, many other inequities that are directly related to salmon or access to salmon were mentioned by more than half of interviewees (e.g., loss of culturally significant species; decreased opportunities to harvest; loss of fishing income; ceremonial and cultural impact from salmon loss; Figure 3). Eighty-five percent of respondents stated that correcting past and ongoing management failures fell upon the Tribal community they worked for. As one respondent stated: “When we talk about equity and justice, [many] city and county jurisdictions do not have the staff that Tribe’s hire. They don’t have your biologists that are on the ground looking for restoration projects, or your funding specialist going after and managing the grants. It seems like the state, the counties and the cities, have been dependent on Tribes to provide those restoration activities…Tribes [conduct restoration projects] because it’s the only way to protect their treaty rights, and there’s an obligation by the federal government to protect those treaty rights”

Again we saw that many inequities were linked to the loss of salmon habitat, and particularly how current resource management drives the ongoing suppression of salmon populations through habitat degradation and climate change impacts. One respondent stated: “On our side of the mountains, the watersheds are dependent on snowpack and the disappearance of snowpack can have detrimental impacts on the salmon that we depend on as part of our culture. Then you start adding in the constant development. This land is changing from how we historically used it. As a Tribal member, we can’t take our treaty rights and change from salmon to bass because that’s not our way of life. We’re a salmon people.”

Another respondent emphasized how negative impacts to floodplains are perpetuated through Western value systems: "[I want] to highlight the fact that people look at the impacts on who is in the floodplain and who uses the floodplain. They don't think about how [infrastructure is] destroying aquatic species by degrading the floodplains. [This relates to] environmental justice for Indigenous people who rely on that resource. People who aren't walking in those shoes don't see what I call the ‘collateral damage.’"

The majority of Tribal inequities identified by interviewees (39%) were related to institutional issues. Cultural issues constituted 36% of the inequities mentioned, and biological inequities composed 25% (Figure 3). However, in general, biological and cultural needs were more consistently mentioned by respondents than institutional issues (Figure 3).

3.5 Co-Occurrence

Our examination of the co-occurence of codes revealed important connections (Figure 4). The quality of aquatic habitat frequently co-occurred with such diverse topics as colonial land management, ecosystem impacts from climate, flood infrastructure, hydrological shifts and salmon abundance. We found that enhanced resilience to climate change co-occurred frequently with salmon abundance, Tribal values and ways of being, human health and wellbeing, and aquatic habitat quality (Figure 4). Diminished resilience to climate change often co-occurred with colonial land management and policy, ecosystem impacts due to climate change, human challenges and needs for adaptation, hydrological shifts impacting habitat, and structural financial limitations.

3.6 Are needs and inequities being addressed by Floodplains by Design?

Our interviews revealed that FbD was meeting the needs of 30% of our subjects. However, 15% said FbD was not meeting their needs, and 30% of tribal managers indicated that FbD supported Tribal needs in some ways and fell short in others. Twenty-five percent of respondents indicated that they didn't feel qualified to answer the question, 5% of which were unfamiliar with the program.

Twenty percent of our respondents had an FbD grant at the time of interview, and 70% worked for Tribal communities which have received an FbD grant previously. Sixty-seven percent of those reporting that FbD was not supporting their needs or addressing inequities had never received an FbD grant, but 15% had a grant at the time of interview. Of the 30% of respondents who stated FbD was meeting community needs and addressing inequities, 5% had a grant at the time of interview and 100% had received a grant from the program at some point.

Tribal managers that felt that FbD was meeting their needs often reported support in institutional domains such as providing funding for levee setbacks or to move infrastructure out of the floodplain. Importantly, funding that supports land acquisition was prominently discussed in our interviews; many respondents stated that this was the only way to ensure permanent protection of floodplains while zoning regulations continue to allow for development in floodplains. The program also received high praise in pursuing an integrated, holistic approach. Many interviewees stated that FbD's multi-benefit thinking at the ecosystem level is unique in floodplain management programs, and that this is where all natural resource management efforts should be heading.

We heard a diversity of responses from those who did not feel that FbD was addressing their needs. Many felt that efforts were falling short despite the program's intention to prioritize integrated floodplain management and support salmon habitat restoration while also moving people and property out of floodplains. This sentiment was evident in applications that developed

collaborative, multi-benefit projects and community relationships (as stated in the funding guidelines manual) but still did not receive grants. Respondents interpreted this to mean that the program is more focused on urban and high-income areas and less interested in rural locations.

Additionally, these tribal managers felt grant rejections were evidence that reviewers do not prioritize multi-benefit projects the way the program claims. These interviewees felt that this lack of support conflicts with the legal mandate for governments to support treaty rights. As one respondent stated: "Tribes [invest in habitat restoration efforts] because it's the only way to protect their treaty rights and there's an obligation by the federal government to protect those treaty rights. Yet Tribes are still asked to provide a match on something that the federal government should be carrying out. Tribe's aren't complaining about having to carry it out, but I think this is an equity issue when it comes to finances."

Other Tribal managers we interviewed felt FbD needed a better strategy to ensure that funds were not primarily allocated to areas with more "political funding or human base," such as the Puget Sound corridor. Though FbD aspires for a proactive rather than reactive approach, these respondents didn't feel this value was illustrated by the way they allocated funds since, as one respondent stated, "it is cheaper, easier, and better for the environment to protect something before it becomes destroyed instead of after the fact."

3.7 How can Floodplains by Design better address these needs and inequities moving forward?

Overall, respondents felt that FbD is doing well in some areas, but can improve in others. All respondents who felt that the program was not adequately supporting Tribal community needs or alleviating historical and ongoing inequities expressed that the benefits and burdens of local floodplain management should be more equally distributed amongst communities. These respondents suggested that FbD and other floodplain management programs could support this goal by adjusting their evaluation metrics to ensure Tribal wellbeing and needs are valued using non-colonial measures of wellbeing. In particular, those who felt that FbD was not meeting their needs perceived the program as continually prioritizing moving humans and property out of floodplains over salmon habitat restoration means that not all human dimensions are being considered. As one respondent stated: "The Tribal communities are compassionate and they understand the importance of taking care of Mother Nature around us. To Tribal communities, Mother Nature is a living, breathing being. She's a person, and they refer to salmon as people. The salmon people."

Funding that supports land acquisition of Tribal governments should be prioritized to optimally ensure Tribal needs are being met in floodplain management. Additionally, government funded aquatic restoration programs like FbD can reconsider match requirements in Washington State since these efforts are mandatory to successfully uphold Tribal treaty rights. A renewed focus on FbD's intention to have a proactive rather than reactive approach to environmental restoration by shifting funding to non-urban and less wealthy areas is also important since, as we heard from a participant, "it is cheaper, easier, and better for the environment to protect something before it becomes destroyed instead of after the fact." Additionally, community-based, co-produced, and collaborative efforts must continue to be invested in in Tribal communities to ensure FbD efforts center community needs.

4. Discussion

Floodplains and the people who inhabit them face a daunting array of challenges, and the plight of climate change may amplify issues such as flood risk, racial and ethnic inequities, and the loss of ecologically and culturally important species (Collins et al, 2018, Weiskopf et al, 2020). Conventional responses to these challenges are rooted in modernist paradigms that deconstruct complexity into more manageable components resulting in persistent dualities, including that of human-nature and human-nonhuman (West et al, 2020). While management action based on reductionist epistemologies has achieved some success, it is susceptible to missing critical elements underpinning management efficacy (West et al, 2020). Here, we assessed the degree to which a floodplain management program has supported Tribal needs and addressed inequities. Our interviews highlighted that floodplain management reflects institutional barriers to considering human-nature interconnectedness. For Tribal cultures that are deeply connected to Pacific salmon, the legacy of modernist paradigms may be manifested in challenges to wellbeing in these historically marginalized communities.

Tribal natural resource managers identified diverse needs that highlighted the importance of holistic approaches to floodplain management. For instance, our analyses of co-occurrence revealed a high degree of overlap in human dimensions (e.g., Tribal values) with biophysical themes (e.g., changes in hydrology, salmon abundance) and institutional concerns (e.g. colonial land management, harvest management). Tribal managers also highlighted critical needs that crossed conventional management sectors. For example, managers often discussed reducing flood risk to communities concurrently with salmon restoration and improvement of infrastructure. Thus, while interviewees intermingled these needs in single statements, they would require agencies such as FEMA and Department of Ecology to address flood risk, Tribal, State and Federal fisheries agencies to address salmon, and Department of Transportation, US Army Corps of Engineers, and other entities to address infrastructure needs.

The needs reported by floodplain managers often reflected Tribal inequities they observed. In most cases, Tribal needs and inequities were linked directly or indirectly to salmon. Importantly, our results demonstrate that the impacts of reduced access to salmon are significant and broadly diminish Indigenous health and wellbeing. When access to traditional foods such as salmon are disrupted by management regimes rooted in colonialism, it perpetuates food injustice as the needs of the dominant culture are prioritized over those of Indigenous peoples (Whyte 2017). While such prioritization may not be intentional in programs such as FbD, the Tribal resource managers we interviewed indicated that it does occur and negatively impacts community resilience.

The importance of salmon has been codified by federal, state and local governments (State of Salmon, 2020), and is a critical driver of floodplain policy (Goodsell, 2021). Indeed, all actors involved in floodplain management in the Pacific Northwest are concerned with salmon in some capacity, whether the existence of salmon creates an obstacle in their development aspirations and management plans (Barbarossa et al, 2020) or their restoration and conservation is the goal (Schindler et al, 2016). Thus, salmon connect varied knowledge systems to facilitate interplay between social groups, stakeholders, and agencies engaged with floodplains. Salmon provide an "object" (cf. Nel et al, 2015; Parker and Crona, 2012) for floodplain managers and Tribes to center mutual interests and values without diffusing them. This fostering of shared

knowledge can help move beyond established cultural or institutional norms, and can play a key role in enhancing equity within environmental management (Morgan, 2020). While modernist Western governance often deemphasizes human-nature interconnectedness, the conceptualization of salmon as a boundary object can help support less reductionist approaches to floodplain management.

Management which is rooted in modernist and colonial epistemologies and deconstructs social-ecological systems can privilege settler values over the cultural needs of Indigenous peoples. Such settler values include ownership (Moreton-Robinson, 2015), financial prosperity (Harfoot et al, 2018), and dominative land relations (Liboiron, 2021). While Indigenous communities regard both their biologically living and nonliving surrounding environment as relations (Coté, 2022), Western cultures have considered humans and nature separate and as a result, have constructed a society largely detached from the natural world (Cronon, 1996). A society established on separation of humans and nature faces inherent obstacles in shifting from a utilitarian (Manfredo et al, 2020) to reciprocal (Kimmerer, 2015) orientation in environmental management. A shift in the epistemology underpinning programs like FbD such that it more fully engages human-nature interconnectedness is key to improving management so that it better meets Tribal needs and enhances equity.

Management efforts that emphasize human-nature interconnectedness in integrated management programs should be driven by communities. Donatuto and colleagues (2016) provide a helpful model for centering Tribal needs and integrating seemingly diverse domains in environmental management. In collaboration with the Swinomish Indian Tribal Community, Donatuto and team developed non-colonial indicators of health. The development of these indicators was grounded in Indigenous knowledge, and placed Indigenous experiences at the center of health assessments. The six non-physiological heath markers developed by Donatuto et al. (2016) enhance self-determination while emphasizing the proper scale and focus of needs. Such a framework may enhance equity in programs like FbD, particularly when knowledge is co-produced and based on a foundation of intentional relationship building that centers community priorities. Braiding Indigenous and Western knowledge systems (cf. (Hopkins et al. 2019) provides a promising avenue for equitably operationalizing integrated management for the benefit of people and nature.

Our research focused on the perspectives and perceptions of Tribal natural resource managers. Importantly, Tribal natural resource managers do not speak on behalf of the Tribes they work for, and their perspectives are strictly provided as Tribal employees. While the average tenure of Tribal managers we interviewed exceeded 17 years, future work directly with Tribal community members that is built on genuine and ongoing relationships (Castledon et al. 2012; Hoover 2017), is likely to reveal additional and perhaps different insights.

The wellbeing of humans and nature are inseparable in many Indigenous cultures (Barker, 2019; Coté, 2022; Kimmerer, 2015; Liboiron, 2021; Whyte, 2017), and our research indicates that this reality has not been fully incorporated into regional floodplain management. Integrated management efforts are vital for addressing the complex problems of the Anthropocene. However, to enhance both the efficacy and equity of integrated management efforts, holistic frameworks that prioritize human-nature interconnectedness and the needs of historically ignored communities are needed. This will require carefully co-created solutions

which do not assimilate Indigenous knowledge into Western frameworks but create space for different knowledge systems to equitably and respectfully inform one another (Tuck, 2009; Reid et al, 2020). For programs like FbD, this may require attention to how well program management and evaluation matches the intention of a program. Our work highlights that iterative pluralistic, collaborative, and adaptive management conducted with Tribes will support just environmental governance that is rooted in community needs (Alonso-Yanez et al, 2019; Kimmerer, 2002; Turnout et al, 2020). With this shift, we have the best chance of confronting the challenges faced by floodplain (and other) ecosystems and meeting the needs of all communities connected to them.

References

Alonso-Yanez, G., House-Peters, L., Garcia-Cartagena, M., Bonelli, S., Lorenzo-Arana, I., Ohira, M., 2019. Mobilizing transdisciplinary collaborations: collective reflections on *de*centering academia in knowledge production. Glob. Sustain. 2, e5. https://doi.org/10.1017/sus.2019.2

Atleo, C., Boron, J., 2022. Land Is Life: Indigenous Relationships to Territory and Navigating Settler Colonial Property Regimes in Canada. Land 11, 609. https://doi.org/10.3390/land11050609

Arkema, K.K., Verutes, G., Bernhardt, J.R., Clarke, C., Rosado, S., Canto, M., Wood, S.A., Ruckelshaus, M., Rosenthal, A., McField, M., de Zegher, J., 2014. Assessing habitat risk from human activities to inform coastal and marine spatial planning: a demonstration in Belize. Environ. Res. Lett. 9, 114016. https://doi.org/10.1088/1748-9326/9/11/114016

Arnell, N.W., Gosling, S.N., 2016. The impacts of climate change on river flood risk at the global scale. Climatic Change 134, 387–401. ttps://doi.org/10.1007/s10584-014-1084-5

Ayles, B., Porta, L., Clarke, R.M., 2016. Development of an integrated fisheries co-management framework for new and emerging commercial fisheries in the Canadian Beaufort Sea. Marine Policy 72, 246–254. https://doi.org/10.1016/j.marpol.2016.04.032

Barker, J., 2019. Confluence: Water as an Analytic of Indigenous Feminisms. American Indian Culture and Research Journal 43, 1–40. ttps://doi.org/10.17953/aicrj.43.3.barker

Barbarossa, V., Schmitt, R.J.P., Huijbregts, M.A.J., Zarfl, C., King, H., Schipper, A.M., 2020. Impacts of current and future large dams on the geographic range connectivity of freshwater fish worldwide. Proceedings of the National Academy of Sciences 117, 3648–3655. https://doi.org/10.1073/pnas.1912776117

Beier, P., Hansen, L.J., Helbrecht, L., Behar, D., 2017. A How-to Guide for Coproduction of Actionable Science: Coproducing actionable science. Conservation Letters 10, 288–296. https://doi.org/10.1111/conl.12300

Bellanger, M., Fonner, R., Holland, D.S., Libecap, G.D., Lipton, D.W., Scemama, P., Speir, C. and Thébaud, O., 2021. Cross-sectoral externalities related to natural resources and ecosystem services. Ecological Economics, 184, p.106990.

Bellmore, J.R., Baxter, C.V., Martens, K., Connolly, P.J., 2013. The floodplain food web mosaic: a study of its importance to salmon and steelhead with implications for their recovery. Ecological Applications 23, 189–207. https://doi.org/10.1890/12-0806.

Bernard, H.R., Wutich, A., Ryan, G.W., 2016. Analyzing Qualitative Data: Systematic Approaches. SAGE Publications.

Caillon, S., Cullman, G., Verschuuren, B. and Sterling, E.J., 2017. Moving beyond the human–nature dichotomy through biocultural approaches. Ecology and Society, 22(4).

Castleden, H., Sloan Morgan, V., Lamb, C., 2012. 'I Spent The First Year Drinking Tea': exploring Canadian University Researchers perspectives on community-based participatory research involving indigenous peoples. The Canadian Geographer / Le Géographe canadien 56. https://doi.org/10.1111/j.1541-0064.2012.00432.x

Chakraborty, L., Thistlethwaite, J., Minano, A., Henstra, D., Scott, D., 2021. Leveraging Hazard, Exposure, and Social Vulnerability Data to Assess Flood Risk to Indigenous Communities in Canada. Int J Disaster Risk Sci 12, 821–838. https://doi.org/10.1007/s13753-021-00383-1

Cheung, K.K.C., Tai, K.W.H., 2021. The use of intercoder reliability in qualitative interview data analysis in science education. Research in Science & Technological Education 0, 1–21. https://doi.org/10.1080/02635143.2021.1993179

Christin, Z., Kline, M., 2017. Why we continue to develop floodplains: Examining the disincentives for conservation in federal policy. White paper. Earth Economics, Tacoma, WA.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253–260. https://doi.org/10.1038/387253a0

Collins, T.W., Grineski, S.E., Chakraborty, J., 2018. Environmental injustice and flood risk: A conceptual model and case comparison of metropolitan Miami and Houston, USA. Reg Environ Change 18, 311–323. https://doi.org/10.1007/s10113-017-1121-9

Colloff, M.J., Lavorel, S., Wise, R.M., Dunlop, M., Overton, I.C., Williams, K.J., 2016. Adaptation services of floodplains and wetlands under transformational climate change. Ecological Applications 26, 1003–1017. https://doi.org/10.1890/15-0848

Coté, C., 2022. A Drum in One Hand, a Sockeye in the Other: Stories of Indigenous Food Sovereignty from the Northwest Coast. University of Washington Press.

Cronon, W., 1996. The Trouble with Wilderness: Or, Getting Back to the Wrong Nature. Environmental History 1, 7–28. https://doi.org/10.2307/3985059

Donatuto, J., Campbell, L., Gregory, R., 2016. Developing Responsive Indicators of Indigenous Community Health. International Journal of Environmental Research and Public Health 13, E899. https://doi.org/10.3390/ijerph13090899

Ellis, E.C., Kaplan, J.O., Fuller, D.Q., Vavrus, S., Goldewijk, K.K. and Verburg, P.H., 2013. Used Planet: A Global History. Proceedings of the National Academy of Sciences, 110(20), pp.7978-7985.

Ferdous, M.R., Di Baldassarre, G., Brandimarte, L., Wesselink, A., 2020. The interplay between structural flood protection, population density, and flood mortality along the Jamuna River, Bangladesh. Reg Environ Change 20, 5. https://doi.org/10.1007/s10113-020-01600-1

Floodplains by Design: Report to the Legislature, 2019. URL https://apps.ecology.wa.gov/publications/summarypages/1906004.html

Foley, M.M., Armsby, M.H., Prahler, E.E., Caldwell, M.R., Erickson, A.L., Kittinger, J.N., Crowder, L.B. and Levin, P.S., 2013. Improving ocean management through the use of ecological principles and integrated ecosystem assessments. BioScience, 63(8), pp.619-631.

Goodsell, B. (OFM), 2021. 2021 Governor's Salmon Strategy Update 25.

Gilio-Whitaker, D., 2019. As Long As Grass Grows: The Indigenous Fight for Environmental Justice, from Colonization to Standing Rock. Boston, Massachusetts: Beacon Press.

Gourevitch, J.D., Diehl, R.M., Wemple, B.C., Ricketts, T.H., 2022. Inequities in the distribution of flood risk under floodplain restoration and climate change scenarios. People and Nature 4, 415–427. https://doi.org/10.1002/pan3.10290

Guernsey, P.J., 2021. The infrastructures of White settler perception: A political phenomenology of colonialism, genocide, ecocide, and emergency. Environment and Planning E: Nature and Space 2514848621996577. https://doi.org/10.1177/2514848621996577

Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Bangalore, M., Beaudet, C., 2020. From Poverty to Disaster and Back: a Review of the Literature. EconDisCliCha 4, 223–247. https://doi.org/10.1007/s41885-020-00060-5

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E. and Fujita, R., 2008. A global map of human impact on marine ecosystems. science, 319(5865), pp.948-952.

Harfoot, M.B.J., Tittensor, D.P., Knight, S., Arnell, A.P., Blyth, S., Brooks, S., Butchart, S.H.M., Hutton, J., Jones, M.I., Kapos, V., Scharlemann, J.P.W., Burgess, N.D., 2018. Present and future biodiversity risks from fossil fuel exploitation. Conservation Letters 11, e12448. https://doi.org/10.1111/conl.12448

Handwerger, L.R., Sugg, M.M., Runkle, J.D., 2021. Present and future sea level rise at the intersection of race and poverty in the Carolinas: A geospatial analysis. The Journal of Climate Change and Health 3, 100028. https://doi.org/10.1016/j.joclim.2021.100028

Hoover, E., 2017. The River Is in Us: Fighting Toxics in a Mohawk Community. University of Minnesota Press. https://doi.org/10.5749/j.ctt1pwt6mk

Hopkins, D., Joly, T.L., Sykes, H., Waniandy, A., Grant, J., Gallagher, L., Hansen, L., Wall, K., Fortna, P., Bailey, M., 2019. "Learning Together": Braiding Indigenous and Western Knowledge Systems to Understand Freshwater Mussel Health in the Lower Athabasca Region of Alberta, Canada. Journal of Ethnobiology 39, 315. https://doi.org/10.2993/0278-0771-39.2.315

Howell, J., Elliott, J.R., 2019. Damages Done: The Longitudinal Impacts of Natural Hazards on Wealth Inequality in the United States. Social Problems 66, 448–467. https://doi.org/10.1093/socpro/spy016

Huckelberry, C., 2002. The Sonoran Desert Conservation Plan. Endangered Species Update 19, S12–S12.

Keleman Saxena, A., Cadima Fuentes, X., Gonzales Herbas, R., Humphries, D.L., 2016. Indigenous Food Systems and Climate Change: Impacts of Climatic Shifts on the Production and Processing of Native and Traditional Crops in the Bolivian Andes. Frontiers in Public Health 4.

Kimmerer, R.W., 2002. Weaving Traditional Ecological Knowledge into Biological Education: A Call to Action. BioScience 52, 432–438. https://doi.org/10.1641/0006-3568(2002)052[0432:WTEKIB]2.0.CO;2

Kimmerer, R. W., 2015. *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants*. Milkweed Editions.

Kovach, M., 2009. University of Toronto Press - Indigenous Methodologies. University of Toronto Press.

Levin, P.S., Fogarty, M.J., Murawski, S.A. and Fluharty, D., 2009. Integrated ecosystem assessments: developing the scientific basis for ecosystem-based management of the ocean. PLoS biology, 7(1), p.e1000014.

Levin, P.S., Breslow, S.J., Harvey, C.J., Norman, K.C., Poe, M.R., Williams, G.D. and Plummer, M.L., 2016. Conceptualization of social-ecological systems of the California

current: an examination of interdisciplinary science supporting ecosystem-based management. Coastal Management, 44(5), pp.397-408.

Liboiron, M., 2021. Pollution Is Colonialism. Duke University Press. https://doi.org/10.2307/j.ctv1jhvnk1

Löschner, L., Herrnegger, M., Apperl, B., Senoner, T., Seher, W., Nachtnebel, H.P., 2017. Flood risk, climate change and settlement development: a micro-scale assessment of Austrian municipalities. Reg Environ Change 17, 311–322. https://doi.org/10.1007/s10113-016-1009-0

Manfredo, M.J., Teel, T.L., Don Carlos, A.W., Sullivan, L., Bright, A.D., Dietsch, A.M., Bruskotter, J., Fulton, D., 2020. The changing sociocultural context of wildlife conservation. Conservation Biology 34, 1549–1559. https://doi.org/10.1111/cobi.13493

Mazzocchi, F., 2006. Western science and traditional knowledge: Despite their variations, different forms of knowledge can learn from each other. EMBO Rep 7, 463–466. https://doi.org/10.1038/sj.embor.7400693

McGinnis, M., Ostrom, E., 2014. Social-ecological system framework: initial changes and continuing challenges. Ecology and Society 19. https://doi.org/10.5751/ES-06387-190230

Meitzen, K.M., 2018. Floodplains, in: Reference Module in Earth Systems and Environmental Sciences. Elsevier. ttps://doi.org/10.1016/B978-0-12-409548-9.11027-9

Messager, M. L., Ettinger, A. K., Murphy-Williams, M., & Levin, P. S. (2021). Fine-scale assessment of inequities in inland flood vulnerability. Applied Geography, 133. https://doi.org/10.1016/J.APGEOG.2021.102492

Moreton-Robinson, A., 2015. The White Possessive. University of Minnesota Press.

Morgan, M., 2020. Conservation-Reliant Species as a Boundary Object for Interdisciplinary Engagements. Idaho L. Rev., 56, p.83.

Million, D., 2018. We are the Land, and the Land is Us: Indigenous Land, Lives, and Embodied Ecologies in the Twenty-First Century. University of Washington Press.

Naderifar, M., Goli, H., Ghaljaei, F., 2017. Snowball Sampling: A Purposeful Method of Sampling in Qualitative Research. Strides in Development of Medical Education In Press. https://doi.org/10.5812/sdme.67670

Nel, J.L., Roux, D.J., Driver, A., Hill, L., Maherry, A.C., Snaddon, K., Petersen, C.R., Smith-Adao, L.B., Van Deventer, H., Reyers, B., 2016. Knowledge co-production and boundary work to promote implementation of conservation plans. Conservation Biology 30, 176–188. https://doi.org/10.1111/cobi.12560

Opperman, J.J., Luster, R., McKenney, B.A., Roberts, M., Meadows, A.W., 2010. Ecologically Functional Floodplains: Connectivity, Flow Regime, and Scale1. JAWRA Journal of the American Water Resources Association 46, 211–226. https://doi.org/10.1111/j.1752-1688.2010.00426.x

Parker, J., Crona, B., 2012. On being all things to all people: Boundary organizations and the contemporary research university. Soc Stud Sci 42, 262–289. https://doi.org/10.1177/0306312711435833

Perosa, F., Fanger, S., Zingraff-Hamed, A., Disse, M., 2021. A meta-analysis of the value of ecosystem services of floodplains for the Danube River Basin. Science of The Total Environment 777, 146062. https://doi.org/10.1016/j.scitotenv.2021.146062

Pinkerton, E., 2000. Integrated management of a temperate montane forest ecosystem through wholistic. Linking social and ecological systems: Management practices and social mechanisms for building resilience, p.363.

Pigford, A.A.E., Hickey, G.M. and Klerkx, L., 2018. Beyond agricultural innovation systems? Exploring an agricultural innovation ecosystems approach for niche design and development in sustainability transitions. Agricultural systems, 164, pp.116-121.

Poe, M.R. and Levin, P., 2017. Looking forward: interconnectedness in the Anthropocene Ocean. In Conservation for the Anthropocene Ocean (pp. 481-490). Academic Press.

Reid, A., Eckert, L., Lane, J.-F., Young, N., Hinch, S., Cooke, S., Ban, N., Darimont, C., Marshall, A., 2020. “Two-Eyed Seeing”: An Indigenous framework to transform fisheries research and management. Fish and Fisheries 21, 1–19. https://doi.org/10.1111/faf.12516

Sakakibara, C., 2020. Whale Snow: Iñupiat, Climate Change, and Multispecies Resilience in Arctic Alaska. University of Arizona Press, Tucson.

Saldaña, J., 2021. The coding manual for qualitative researchers. Sage Publications.

Salmona, M., Lieber, E., Kaczynski, D., 2019. Qualitative and Mixed Methods Data Analysis Using Dedoose: A Practical Approach for Research Across the Social Sciences. Sage Publications.

Schindler, S., O’Neill, F.H., Biró, M., Damm, C., Gasso, V., Kanka, R., van der Sluis, T., Krug, A., Lauwaars, S.G., Sebesvari, Z., Pusch, M., Baranovsky, B., Ehlert, T., Neukirchen, B., Martin, J.R., Euller, K., Mauerhofer, V., Wrbka, T., 2016. Multifunctional floodplain management and biodiversity effects: a knowledge synthesis for six European countries. Biodivers Conserv 25, 1349–1382. https://doi.org/10.1007/s10531-016-1129-3

Settee, P., 2020. The Impact of Climate Change on Indigenous Food Sovereignty. Canadian Scholars. pp. 212-228.

Simpson, L.B., 2015. The Place Where We All Live and Work Together: A Gendered Analysis of "Sovereignty," in: Native Studies Keywords. University of Arizona Press, pp. 18–24.

Smith, J.A., 1995. Semi structured interviewing and qualitative analysis, in: Smith, J.A., Harre, R., Van Langenhove, L. (Eds.), . Sage Publications, pp. 9–26.

State of Salmon in Watersheds Executive Summary, 2020. 28.

State Wide WRIA Finder, 2022. Watershed look-up - Washington State Department of Ecology.

Tessum, C.W., Paolella, D.A., Chambliss, S.E., Apte, J.S., Hill, J.D., Marshall, J.D., 2021. PM2.5 polluters disproportionately and systemically affect people of color in the United States. Science Advances 7, eabf4491. https://doi.org/10.1126/sciadv.abf4491

Tockner, K. and Stanford, J.A., 2002. Riverine flood plains: present state and future trends. Environmental conservation, 29(3), pp.308-330.

Thomas, J.W., Franklin, J.F., Gordon, J. and Johnson, K.N., 2006. The Northwest Forest Plan: origins, components, implementation experience, and suggestions for change. Conservation Biology, 20(2), pp.277-287.

Treaty Rights At Risk., 2011. Northwest Indian Fisheries Commission 35.

Tuck, E., 2009. Suspending Damage: A Letter to Communities. Harvard Educational Review 79, 409–428. https://doi.org/10.17763/haer.79.3.n0016675661t3n15

Tuck, E., Yang, K.W., 2012. Decolonization is not a metaphor. Decolonization: Indigeneity, Education & Society 1.

Turkelboom, F., Demeyer, R., Vranken, L., De Becker, P., Raymaekers, F., De Smet, L., 2021. How does a nature-based solution for flood control compare to a technical solution? Case study evidence from Belgium. Ambio 50, 1431–1445. https://doi.org/10.1007/s13280-021-01548-4

Turnhout, E., Metze, T., Wyborn, C., Klenk, N., Louder, E., 2020. The politics of co-production: participation, power, and transformation. Current Opinion in Environmental Sustainability 42, 15–21. https://doi.org/10.1016/j.cosust.2019.11.009

United States V. State of Washington, 384 F. Supp. 312 (W.D. Wash. 1974), 1974. https://law.justia.com/cases/federal/district-courts/FSupp/384/312/1370661/

Ward, J. V., Tockner, K., Schiemer, F., 1999. Biodiversity of floodplain river ecosystems: ecotones and connectivity1. Regulated Rivers: Research & Management 15, 125–139.

https://doi.org/10.1002/(SICI)1099-1646(199901/06)15:1/3<125::AID-RRR523>3.0.CO;2-E

Weiskopf, S.R., Rubenstein, M.A., Crozier, L.G., Gaichas, S., Griffis, R., Halofsky, J.E., Hyde, K.J.W., Morelli, T.L., Morisette, J.T., Muñoz, R.C., Pershing, A.J., Peterson, D.L., Poudel, R., Staudinger, M.D., Sutton-Grier, A.E., Thompson, L., Vose, J., Weltzin, J.F., Whyte, K.P., 2020. Climate change effects on biodiversity, ecosystems, ecosystem services, and natural resource management in the United States. Science of The Total Environment 733, 137782. https://doi.org/10.1016/j.scitotenv.2020.137782

West, S., Haider, L.J., Stålhammar, S., Woroniecki, S., 2020. A relational turn for sustainability science? Relational thinking, leverage points and transformations. Ecosystems and People 16, 304–325. https://doi.org/10.1080/26395916.2020.1814417

Whyte, K., 2017. Food Sovereignty, Justice and Indigenous Peoples: An Essay on Settler Colonialism and Collective Continuance. Oxford Handbook on Food Ethics.

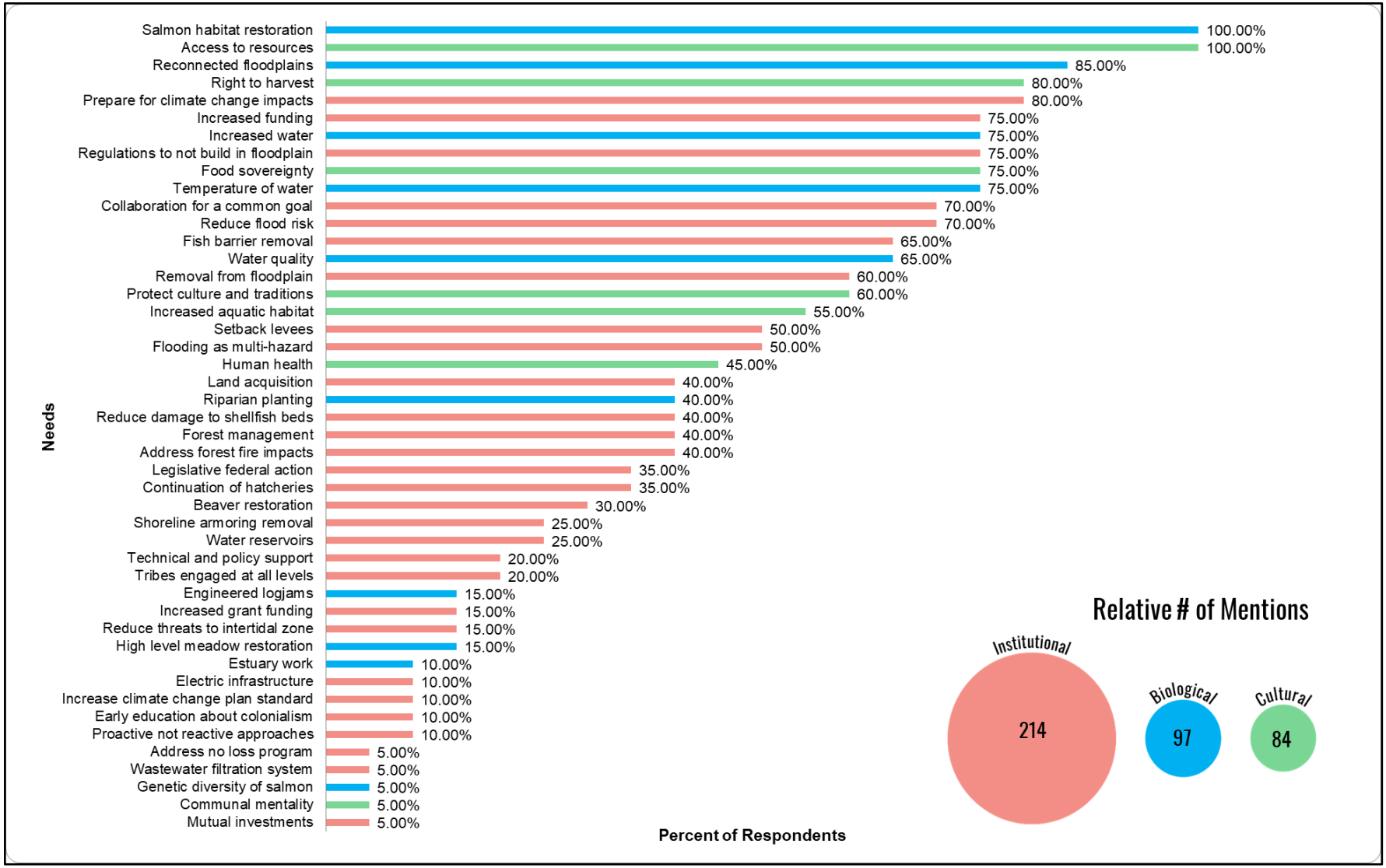

Figure 1: Self-reported needs in floodplain management by interview respondents. Pink bars represent institutional needs, blue bars represent biological needs, and green bars represent cultural needs. These items indicate the ways in which current floodplain management falls short in supporting Tribal needs.

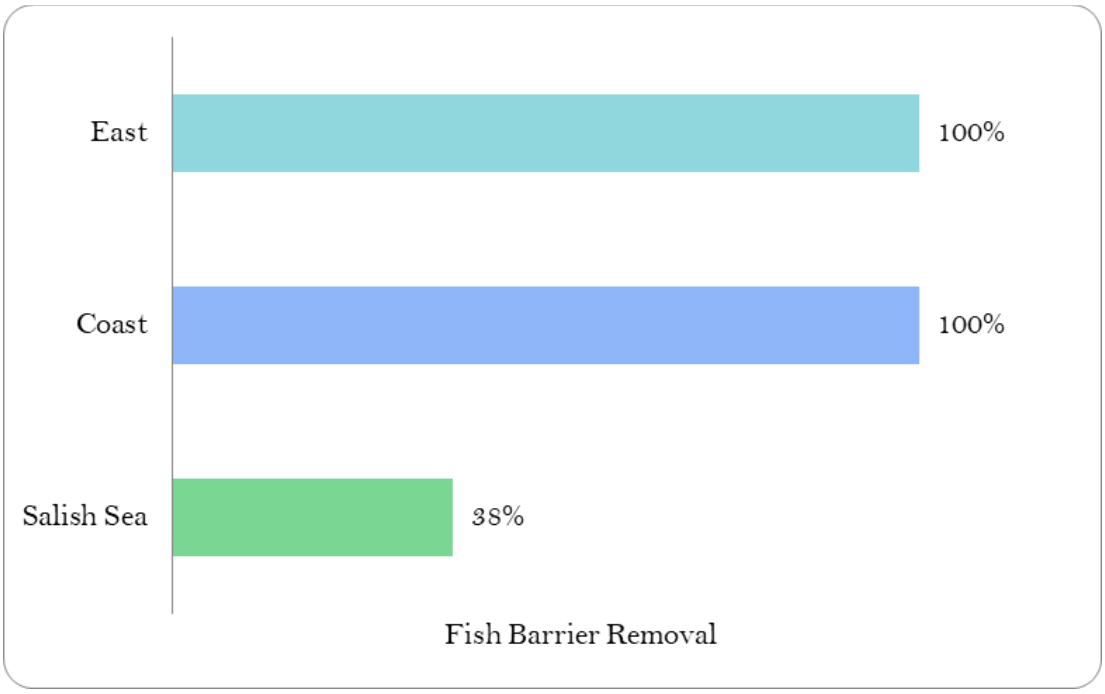

Figure 2a: Minimal variances in required needs were detected by demographics, but we did find some variances by region. Here, 100% of respondents from the Coast and the East-side of the Cascades mentioned the need for fish barrier removal while only 38% from the Salish Sea did.

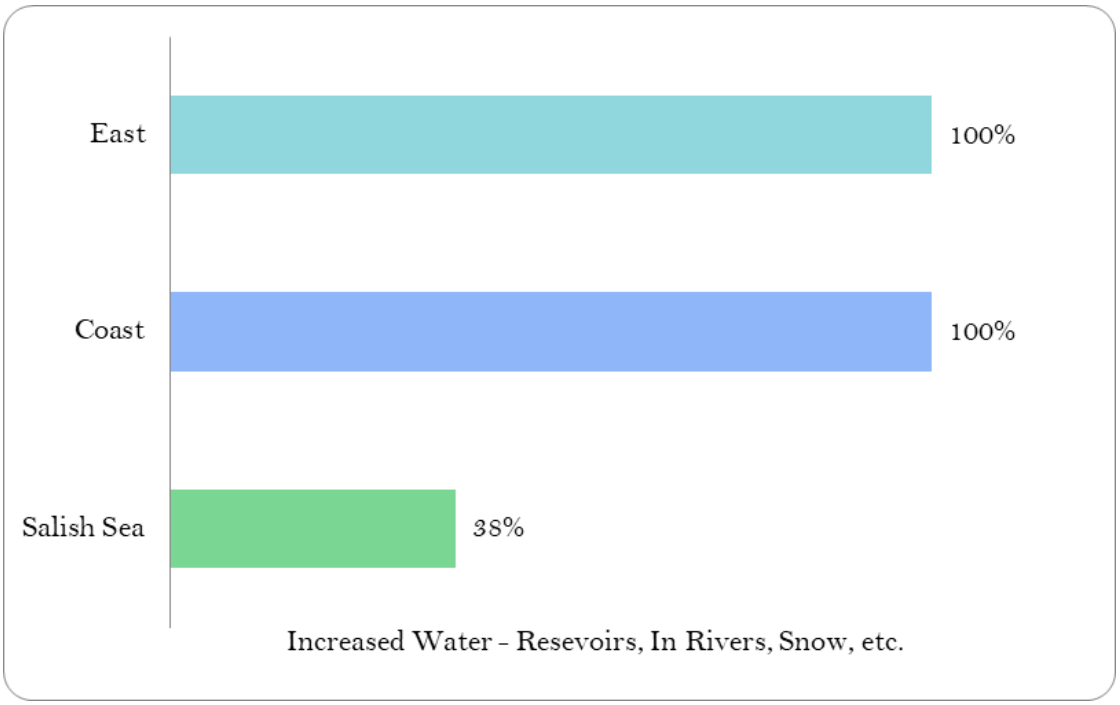

Figure 2b: In a similar pattern to figure 2, East-side and Coast respondents unanimously agreed that their river systems required increased reservoirs, water in rivers, etc., while only 38% from the Salish Sea echoed these needs.

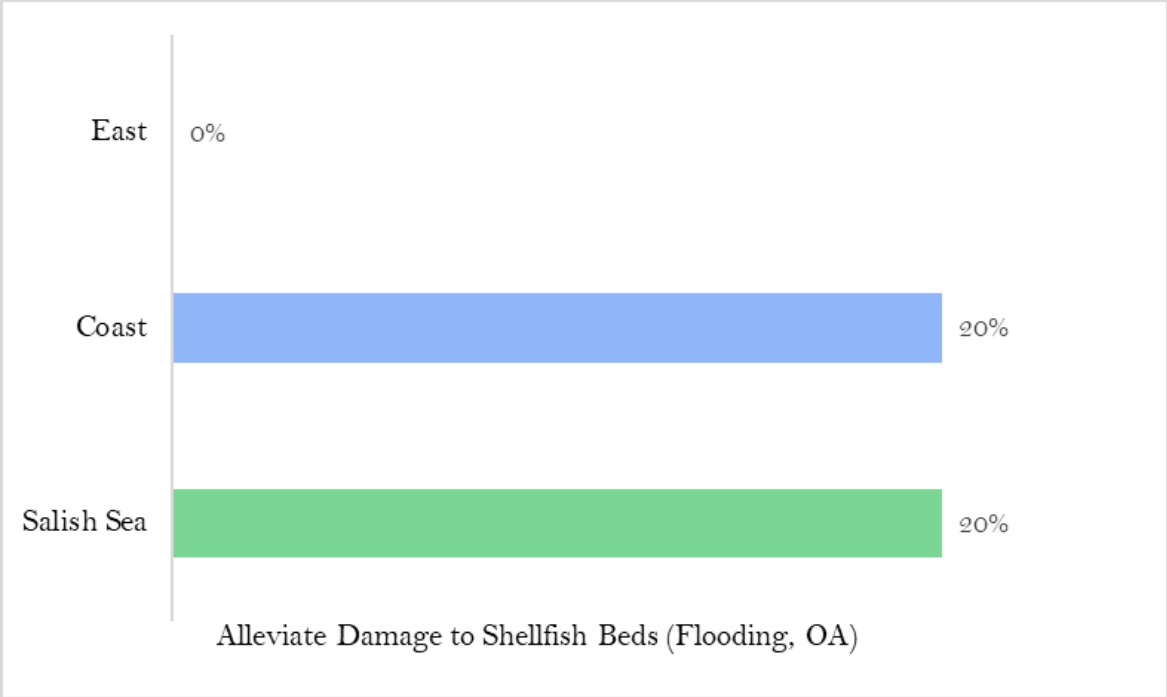

Figure 2c: As one may expect based on the geographic reality of Washington State, no respondents East of the Cascades (without a coastline) mentioned the need for shellfish bed protection.

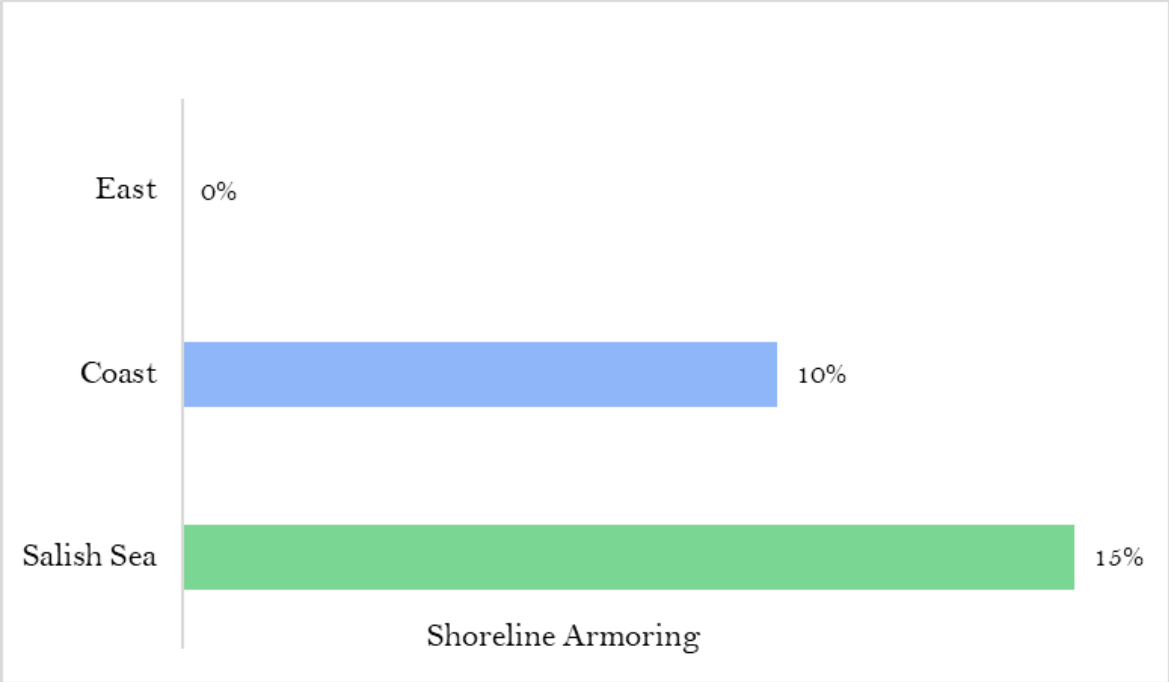

Figure 2d: Shoreline armoring is most prominent on the West-side of the Cascades in Washington State, as demonstrated here by our participant's responses.

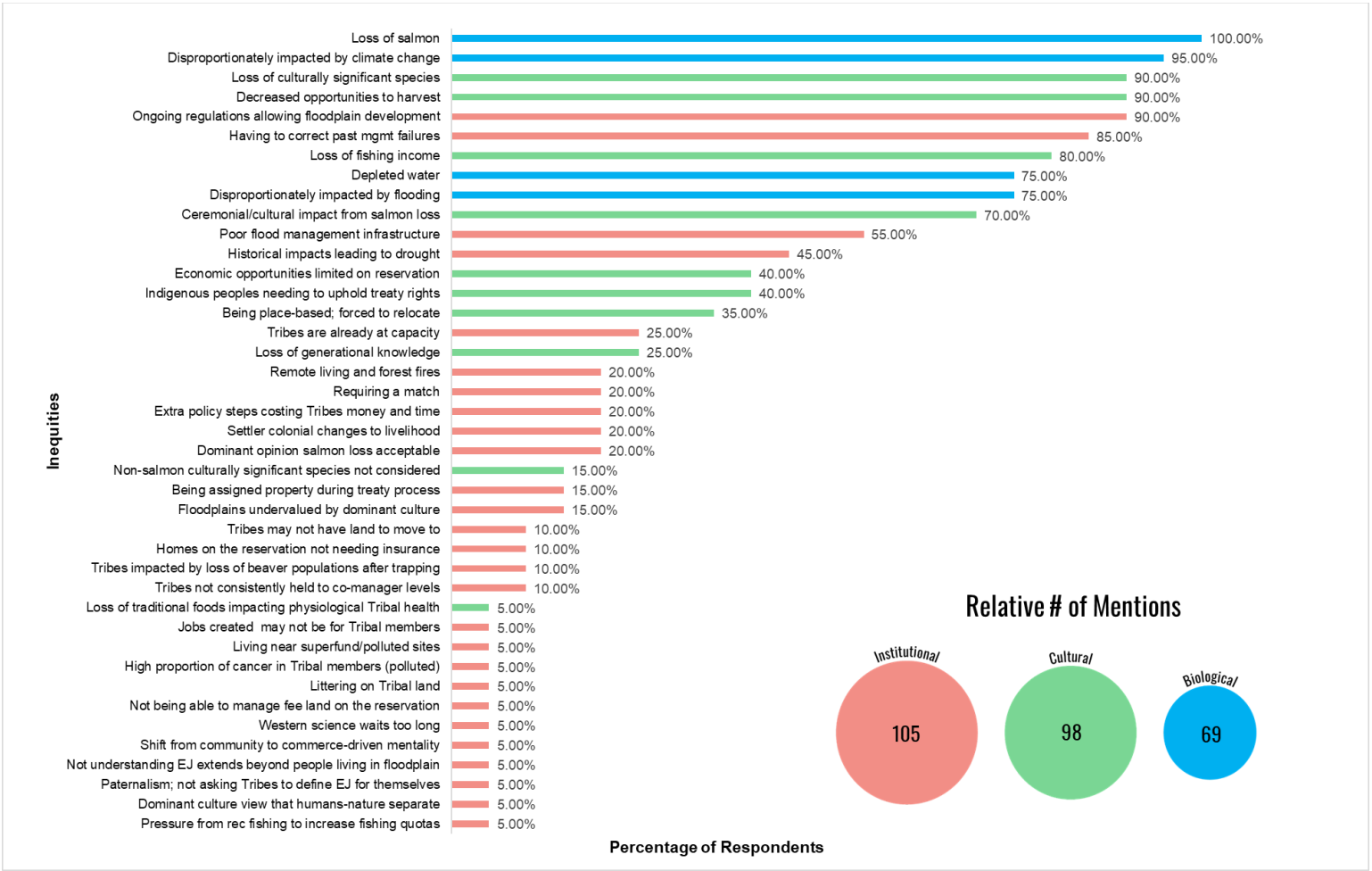

Figure 3: Self-reported inequities in current floodplain management by interview respondents. Pink bars represent institutional needs, blue bars represent biological needs, and green bars represent cultural needs. These items indicate the ways in which current floodplain management currently perpetuates, or fails to eradicate, inequities to Tribal communities.

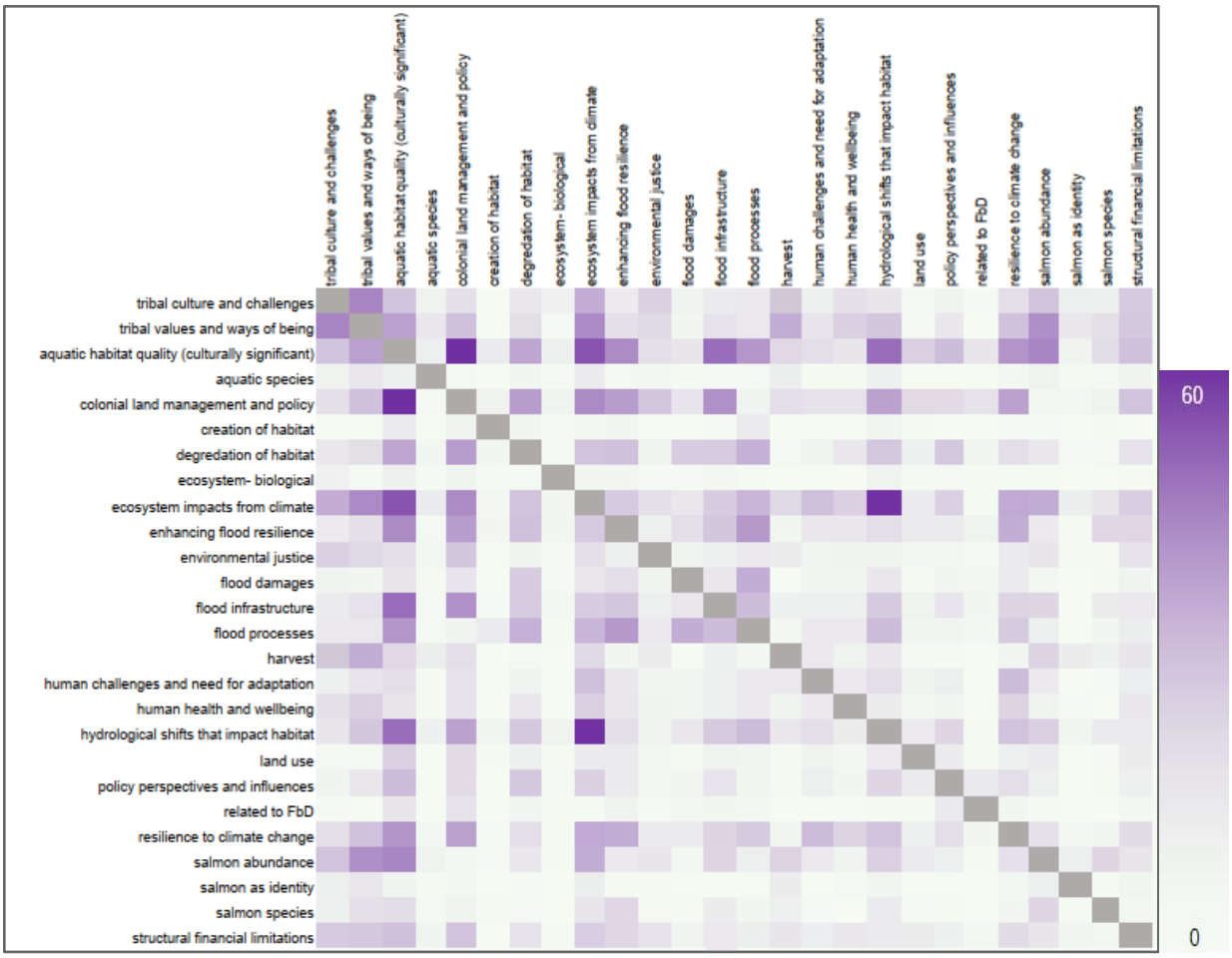

Figure 4: Co-occurrence chart for our 26 codes. This tool observes associations between concepts by looking at the frequency that two concepts either occur in the same statement or overlap in two consecutive statements. This is a useful mixed methods analysis that can identify important associations, but which requires observations of the quotations within which these codes are embedded to best understand the relationship between the codes. The gradient bar (right) indicates the spectrum of co-occurrence frequency, with white being zero and deep purple being 60. Of note, the same codes are on the x and y axis so there are replications across this figure.

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For publication: short biography of each author (~100 words);