Management Implications from Pacific Northwest Intensively Monitored Watersheds

Robert Bilby[a], Amelia Johnson[b], John R. Foltz[c], and Amy L. Puls[d]

a – Washington Governor's Salmon Recovery Office (contractor), Olympia, WA 98504

b – Lower Columbia Fish Recovery Board, Vancouver, WA 98682

c – Snake River Salmon Recovery Board, Dayton, WA 99328

d - U.S. Geological Survey, Cook, WA, 98605

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Disclaimer

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Name	Affiliation	Name	Affiliation
Joseph Anderson	Washington Department of Fish & Wildlife	John Foltz	Snake River Salmon Recovery Board
Eli Asher	Cowlitz Indian Tribe	Sarah Gallagher	California Department of Fish and Wildlife
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Bob Bilby	Washington Salmon Recovery Funding Board Monitoring Panel	Mark Henderson	US Geological Survey
Pete Bisson	Washington Salmon Recovery Funding Board Monitoring Panel	Ian Jezorek	US Geological Survey
Kasey Bliesner	Oregon Department of Fish and Wildlife	Amelia Johnson	Lower Columbia Fish Recovery Board
Nick Bouwes	Eco Logical Research	Clayton Kinsel	Washington Department of Fish & Wildlife
Jeff Breckel	Washington Salmon Recovery Funding Board	Brian Knoth	Idaho Department of Fish and Game
Samuel Cimino	US Geological Survey/PNAMP	Kirk Krueger	Washington Department of Fish & Wildlife
Tim Copeland	Idaho Department of Fish and Game	James Lamperth	Washington Department of Fish & Wildlife
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Executive Summary

Many salmon and steelhead populations in the Pacific Northwest have been assigned protection under the U.S. Endangered Species Act over the last 30 years. A considerable investment in the restoration of freshwater and estuarine habitat has been made to address this problem. However, there is a desire to provide better quantification and evidence that these restoration efforts lead to improvements in watershed processes, habitat conditions, and therefore salmon and steelhead viability. This information gap led to the establishment of Intensively Monitored Watersheds (IMWs) in the early 2000s. An IMW is an experiment in one or more catchments with a well-developed, long-term monitoring program to determine watershed-scale fish and habitat responses to restoration actions. The IMW approach is considered an effective experimental design for evaluating watershed-scale salmon and steelhead responses to habitat restoration.

This report compiles general results to date from 13 IMWs across the Pacific Northwest and provides an initial indication of the management implications of these studies. The IMWs included in this report are evaluating a wide range of restoration actions; all but one IMW has implemented two or more different treatment types. The most common treatment types evaluated by the IMWs are large wood addition, riparian restoration, and barrier removal. Fish species included in the IMW evaluations include steelhead, Chinook and Coho salmon, Bull Trout, and Pacific Lamprey. Eleven of the IMWs indicated they are targeting more than one anadromous species.

This synthesis of IMW results is in no way intended to imply that these studies have completed data collection and analysis. All IMWs have applied treatment types and are engaged in post-treatment monitoring; however, only two IMWs have completed their assessment of habitat and fish response to restoration.

Core Messages

This synthesis project identified a set of 26 core messages that reflect collective findings across the IMWs. The core messages are grouped into three categories: Habitat and Fish Responses, Management and Coordination of Restoration Implementation, and Current Research Priorities and Future Opportunities. These messages can be used to help identify future research opportunities and be used to improve the effectiveness of habitat restoration and salmon recovery programs.

The 12 core messages for the Habitat and Fish Responses category indicate that many of the implemented restoration methods improve aquatic habitat and elicit a positive fish response. Habitat responses to treatments reported by the IMWs indicate that 75% showed a positive response, 2% a negative response, and 23% no change (ES Table 1). Fish responses reported by the IMWs included 53% identifying a positive response, 3% a negative response, and 44% no change (ES Table 1). Several treatment types such as removal of fish passage impediments like dams and culverts, were consistently associated with increased access to habitat and a positive fish response across IMWs. This result is consistent with previous studies done at reach or project scales. Similarly, enhancing fish access to floodplain or tidal delta habitat by removing barriers or encouraging beaver colonization increased abundance and growth of salmon and steelhead at most IMWs where this treatment type was evaluated. Preliminary results are less clear though for habitat and fish responses to large wood placement: some IMWs noted positive responses while others have yet to observe a response. The need to better understand how large wood restoration may support achieving watershed and population-scale goals is recommended given how common this treatment type is in restoration programs.

Positive fish responses were most commonly observed for smolt and juvenile life stages along with changes in distribution and life history diversity (ES Table 1). There were few IMWs that reported an increase in abundance of returning adult fish. Many IMWs noted that poor marine survival and factors impacting fish outside the area where habitat treatments were applied, such as harvest, hydropower, and hatchery programs, all could limit the capacity of adult fish to respond to improvements in freshwater and estuarine habitat conditions. One or more of these external factors affected fish at every IMW. The fact that some salmon populations are impacted by factors other than habitat conditions does not imply that habitat restoration is not beneficial; high-quality freshwater and estuarine habitat can support population resiliency by enhancing fish capacity to persist in the face of climate change or severe disturbance events (e.g., major floods, wildfire). Identifying the full suite of factors affecting salmon and steelhead should occur at project establishment and specific intervals following implementation. This process is essential for restoration and recovery programs to establish realistic expectations of fish response to habitat improvements.

Seven core messages related to management and coordination of restoration implementation are identified in this synthesis. These are based on collective challenges related to developing, implementing, and monitoring treatment types in the IMWs. These core messages highlight the importance of adaptive management processes with clear and measurable progress indicators, coordination across stakeholders, and information sharing to support application of IMW results. Adaptive management processes are lacking in some IMWs but are an essential tool for translating findings into management actions that can be incorporated into restoration strategies and projects. The importance of building and maintaining community support was also highlighted as essential to implementing restoration strategies that have the greatest opportunity to benefit fish. Coordination beyond the local community is also key in many cases, as broader stakeholder groups may be able to influence factors other than habitat that also limit salmon and steelhead.

This synthesis of IMW results is intended to provide a preliminary indication of the management-relevant information generated by the IMWs. It became clear during this synthesis process that further monitoring is necessary to fully evaluate habitat and fish response to treatment types. To address this knowledge gap, seven Current Research Priorities and Future Opportunities core messages are identified in this report. These core messages build on preliminary results and the wealth of data and information from the IMWs and may help habitat restoration and salmon recovery programs better adapt over time to changing conditions and threats, as well as better understand expectations of habitat and fish response. For instance, there is still uncertainty in how habitat restoration may influence marine survival or provide a resiliency buffer to climate change or out-of-basin impacts from harvest, hydropower facilities, and other management programs. IMWs are well situated to help answer these types of questions because of their long-term datasets, wide range of targeted species, spatially diverse locations, and existing monitoring community and infrastructure support.

Recommended Actions

To facilitate the incorporation of IMW findings into restoration program planning and implementation, the core messages were used to identify management and policy recommendations. Ten actions are identified in the Recommended Management and Policy Actions section of this report:

1. Build restoration plans and strategies at watershed scales and within a context of all potential impacts to salmon and steelhead viability.
2. Prioritize restoration methods based on aspects of restoration technique effectiveness like cost and certainty of success.
3. Implement restoration actions at continuous, landscape scales.
4. Prioritize and support the development of formal adaptive management processes across recovery and restoration programs.
5. Regularly communicate among IMW monitoring and restoration leads and local stakeholders to refine habitat restoration programs based on study results and facilitate adaptive management.
6. Support and implement natural resource programs at watershed and salmon- and steelhead-species scales.
7. Provide stable, long-term support for fish and habitat monitoring.
8. Consider converting some of the IMWs to long-term research sites.
9. Provide support for restoration planning and permitting to accelerate implementation timeframes.
10. Communicate with stakeholders about their expectations of habitat restoration.

These recommended actions are intended to support decisions concerning salmon conservation by recovery program managers, watershed restoration program managers, and habitat project practitioners to provide guidance and support program effectiveness. **These recommendations reflect the importance of upfront and broad coordination to build, maintain, and adaptively manage watershed and population-scale restoration and monitoring programs.**

IMWs remain one of the most promising tools to improve understanding of watershed-scale fish and habitat responses to habitat restoration actions. IMWs also provide opportunities to better understand other aspects of salmon ecology and watershed processes: multiple studies identified a diversity of life history strategies through the intensive, life-cycle monitoring that IMWs rely on, and monitoring activities have also captured climate change events, like drought and fires, that restoration programs must account for moving forward. This report illustrates the value of the information being produced by IMWs and highlights the need for improved methods for incorporating future IMW findings into the processes for selecting restoration projects.

How to Read This Report

There are 26 core messages in the report. Each core message includes supporting IMW examples and were discussed and reviewed with IMW monitoring program leads. The core messages inform the 10 recommended actions in the Recommended Management and Policy Actions section; this section can also be reviewed independently and most directly benefits the policy and management communities by providing specific suggestions on implementation considerations. The References and Other Literature section includes relevant literature to provide additional context and information for IMW roles in salmon recovery. To better understand how each individual IMW fits into the collective report messages, Appendix 1 contains summary tables with study design, results, and additional resources details and links for each IMW. Appendix 2 includes supporting information that informed the workshops and core message development with the participating IMW representatives.

ES Table 1: Summary of habitat and fish responses to restoration at the 13 IMWs included in this report. Percentages (in parentheses) reflect the proportion of IMWs in which a response was measured. Not all IMWs measured all habitat and fish responses. The composite response metric is the average of the response measures that showed positive response, negative response, or no change after restoration. Positive and negative changes do not necessarily represent statistically significant changes. In many cases this summary table is based upon incomplete data and data collection and analysis are still ongoing.

Habitat Response	**Positive**	**Negative**	**No Change**
Riparian quality or quantity	7 (88%)	0 (0%)	1 (13%)
Channel or channel units quality or quantity	11 (92%)	0 (0%)	1 (8%)
Floodplain or estuarine lateral connectivity	10 (100%)	0 (0%)	0 (0%)
Longitudinal connectivity	10 (91%)	0 (0%)	1 (9%)
Habitat complexity	9 (75%)	0 (0%)	3 (25%)
Sediment quality	7 (70%)	2 (20%)	1 (10%)
Sinuosity	5 (83%)	0 (0%)	1 (17%)
Stream width:depth	6 (100%)	0 (0%)	0 (0%)
Temperature improvements	4 (33%)	0 (0%)	8 (66%)
Flow improvements	4 (44%)	0 (0%)	5 (55%)
Water quality improvements	2 (40%)	0 (0%)	3 (60%)
Primary and/or secondary production improvements	3 (100%)	0 (0%)	0 (0%)
Composite Habitat Response Metric	**75%**	**2%**	**23%**
Fish Response			
Marine survival	0 (0%)	0 (0%)	4 (100%)
Adult abundance	2 (22%)	1 (11%)	6 (67%)
Redd numbers	2 (25%)	0 (0%)	6 (75%)
Smolt production	8 (67%)	0 (0%)	4 (33%)
Juvenile abundance	7 (70%)	0 (0%)	3 (30%)
Juvenile density	5 (56%)	0 (0%)	4 (44%)
Juvenile survival	7 (64%)	0 (0%)	4 (36%)
Juvenile growth or size	3 (27%)	1 (9%)	7 (64%)
Juvenile residence time	4 (67%)	1 (17%)	1 (17%)
Life history diversity	5 (83%)	0 (0%)	1 (17%)
Fish distribution	7 (88%)	0 (0%)	1 (13%)
Composite Fish Response Metric	**53%**	**3%**	**44%**

Introduction

Many salmon populations in the Pacific Northwest have been assigned protection under the U.S. Endangered Species Act over the last 30 years (NWFSC 2015). In response, many efforts have been initiated across the region to recover these populations. Various factors contributed to the decline in naturally spawning salmon. Impacts associated with fish harvest, hatcheries, hydropower, and freshwater habitat have received the greatest degree of attention (NRC 1996, NWFSC 2015). In some cases, these impacts have occurred for more than 150 years, leading to significant changes in watershed functions and the location, timing, and opportunity for salmon to spawn, rear, and migrate (Stouder et al. 1997). Salmon and steelhead are also impacted by temporal shifts in ocean productivity (Welch et al. 2020), and climate change is affecting both freshwater and marine habitat conditions (Mantua et al. 2009). Improved understanding of the impact of each of these factors on salmon and steelhead at different life stages is required to successfully address the full set of factors constraining salmon and steelhead productivity. Achieving this level of understanding requires monitoring and adaptive management programs that are integrated across all the factors impacting the fish.

A significant proportion of the resources spent on salmon and steelhead recovery have focused on restoration of freshwater and estuarine habitat (Katz et al. 2007). Hundreds of millions of dollars have been dedicated to habitat restoration over the last three decades (NMFS 2014), but there is limited evidence of the contribution these efforts have made toward salmon recovery (Cram et al. 2018, GSRO 2020). This information gap led to the establishment of Intensively Monitored Watersheds (IMWs) in the early 2000s (Bilby et al. 2005). An intensively monitored watershed is an experiment in one or more catchments with a well-developed, long-term monitoring program to determine watershed-scale fish and habitat responses to restoration actions. The basic premise of the IMW study design is to concentrate restoration treatments and monitoring resources at a watershed scale to maximize the ability to detect fish and habitat responses, if they occur. The IMW approach is still considered an effective experimental design for evaluating watershed-scale salmon and steelhead responses to habitat restoration (Bennett et al. 2016).

The intent of this project is to provide to the broader salmon recovery and habitat restoration community an initial indication of the management implications of the IMW results to date and to suggest how this information might be applied in their own programs. This project is not a technical evaluation of IMW monitoring programs nor an assessment of the effectiveness of IMW study designs. The target audience for this report includes salmon conservation and recovery managers, policy specialists, habitat restoration practitioners, and monitoring specialists (Table 1). IMW research teams regularly report results from their studies (e.g., Anderson et al. 2019), and there have been several reviews of IMW results (Roni et al. 2015; Bennett et al. 2016; Roni et al. 2018). However, there have been few attempts to synthesize results across IMW studies in the region for the purpose of identifying opportunities to improve the effectiveness of restoration programs.

Thirteen IMWs participated in the development of this report (Figure 1). The participating IMWs extend across much of the United States Pacific Northwest from northern California to the Canadian border and from the Pacific Coast inland to Idaho. The IMWs evaluate a wide range of restoration treatments but the most common treatments include wood addition, riparian restoration, and barrier removal (Table 2). Most IMWs evaluated multiple treatment types, averaging five different types across the participating studies. Anadromous species being monitored include steelhead, Chinook Salmon, Coho Salmon, and Pacific Lamprey. Several of the IMWs are also evaluating the response of resident trout to restoration treatments. A wide range of fish population metrics are measured and responses to treatments vary among IMWs (Table 2).

Table 1. The six different types of stakeholders that could incorporate management outcomes from the IMW studies into their own programs and projects.

Stakeholder	Role
Salmon Recovery Program Managers	Develop and implement strategies to support recovery and conservation of salmon and steelhead. Program success is based on achieving viability goals and, in some cases, reducing and managing impacts to salmon and steelhead across their life cycles: habitat, harvest, hatcheries, ocean and climate conditions, and hydropower systems.
Habitat Restoration Program Managers	Develop and implement habitat restoration and conservation plans and strategies to improve and protect watershed conditions. Programs support achieving salmon recovery and conservation goals.
Monitoring Specialists	Lead habitat and fish data collection, analysis, and assessment efforts. In the case of Intensively Monitored Watershed programs, implement long-term fish and habitat monitoring at watershed and population-scales.
Habitat Designers and Sponsors	Implement habitat restoration and conservation strategies by working with landowners, community members, and salmon recovery program managers to identify, design, and construct restoration and conservation projects.
Landowners and Land Managers	Local stakeholders that monitoring, habitat and salmon program managers collaborate with to implement recovery and restoration actions. Restoration projects cannot be implemented without landowner support and approval.
Program Funders, Policy Makers, and Elected Officials	Support the programs that fund and regulate salmon recovery and habitat restoration work. Essential partners to communicate priorities and results for long-term program implementation.

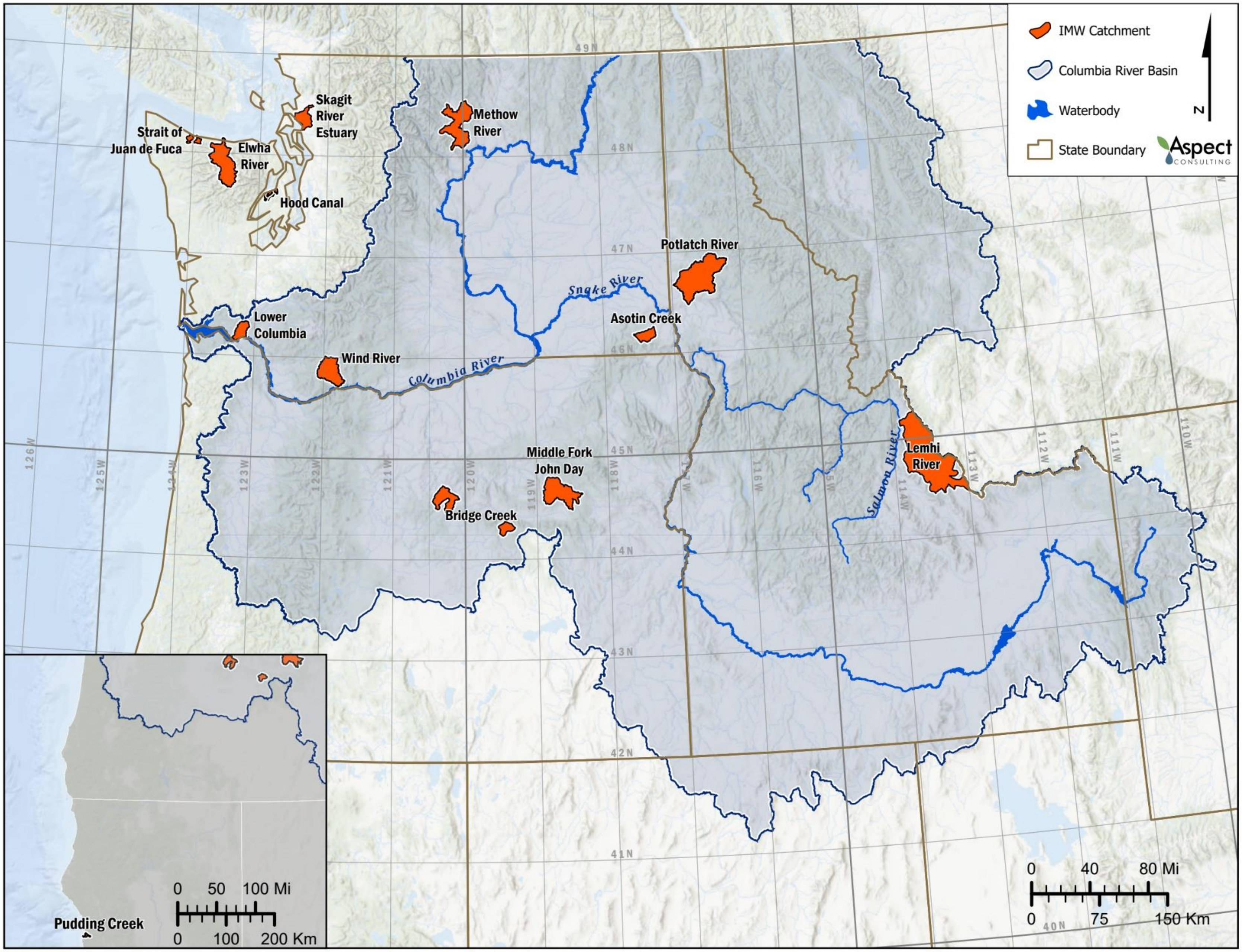

Figure 1. Location of the 13 IMWs that participated in the development of this report.

Table 2. Target species and life stages, treatment types assessed, and habitat and fish responses to date for individual IMWs. For species life stages, J=juvenile, A=adult. Habitat and fish responses represent a simplification of results intended to convey generalities. Individual IMWs have their own study designs and data collection and analyses methods that inform the results included in this table; more details on scope, assessment methodologies, and results can be found in Appendix 1 snapshots and in individual IMW report documents. In the table, green ↑ indicates increases to date, red ↓ indicates decreases to date, blue ↔ indicates no change to date, NEY indicates not evaluated yet, and blank cells indicates not reported. For metrics marked NEY, the results are in some cases forthcoming but in others are contingent on additional funding. Increases and decreases do not necessarily represent statistically significant changes. In many cases this summary table is based upon incomplete data and data collection and analysis is still ongoing.

	# of IMWs assessing	Asotin Creek	Bridge Creek	Elwha River	Hood Canal	Lemhi River	Lower Columbia	Methow River	Middle Fork John Day	Potlatch River	Pudding Creek	Skagit River Estuary	Strait of Juan de Fuca	Wind River
Targeted Species														
Steelhead	12	J, A	J, A	J, A	J, A	J, A	J, A	J, A	J, A	J, A	J, A		J, A	J, A
Chinook Salmon	8	J, A		J, A		J, A	J, A	J, A	J, A			J, A		J, A
Coho Salmon	7			J, A	J, A		J, A	J, A			J, A		J, A	J, A
Cutthroat Trout	4			J, A	J	J, A							J	
Bull Trout	3	J, A		J, A		J, A								
Pacific Lamprey	2	J, A		J, A										
Treatment Types														
Large wood or engineered log jam for instream complexity	11	X		X	X	X	X	X	X	X	X		X	X
Large wood or engineered log jam for lateral connectivity	11	X		X	X	X	X	X	X	X	X		X	X
Riparian restoration or protection	11	X		X	X	X	X	X	X	X		X	X	X
Longitudinal reconnection (e.g., dam removal, culvert replacement)	10			X	X	X	X	X	X	X		X	X	X
Beaver dam analogs	7	X	X		X	X		X	X	X				
Lateral reconnection (e.g., removal of dikes, levees)	7			X	X	X		X	X	X		X		
Road abandonment	6				X		X		X	X			X	X
Boulders	4					X		X	X				X	
Flow augmentation	3					X			X	X				
Hatchery augmentation	2			X				X						
Nutrient addition	2						X							X
Fish protection screens	2			X					X					

	# of IMWs with positive responses	Asotin Creek	Bridge Creek	Elwha River	Hood Canal[c]	Lemhi River	Lower Columbia[c]	Methow River	Middle Fork John Day	Potlatch River	Pudding Creek	Skagit River Estuary	Strait of Juan de Fuca[c]	Wind River
Habitat Response [a]														
Riparian quality or quantity	7	NEY	↑	↑	NEY	↑	NEY	↑	↑	↔		↑	NEY	↑
Channel or channel units quality or quantity	11	↑	↑	NEY	↑	↑	↑	↑	↑	↔	↑	↑	↑	↑
Floodplain or estuarine lateral connectivity	10	↑	↑	↑	↑	↑	↑	↑				↑	↑	↑
Longitudinal connectivity	10		↑	↑	↑	↑	↑	↑	↑	↑		↑	↔	↑
Habitat complexity	9	↑	↑	NEY	↔	↑	↔	↑	↑	↔	↑	↑	↑	↑
Sediment quality	7	↑	↑	↑	↔	↑	↓	NEY	↓			↑	↑	↑
Sinuosity	5	↑	↑	↑	NEY	↑	NEY	NEY	↔				NEY	↑
Stream width:depth	6			NEY	↑	↑	↑	NEY	↑				↑	↑
Temperature improvements	4	↔	↑	↑	↔	↔	↔	↔	NEY	↔	↔	↑	↔	↑
Flow improvements	4	↑	↑	↔	↔	↑	↔	↑	NEY	↔			↔	
Water quality improvements	2	↔		↑	NEY	↔	NEY	NEY		↔		↑	NEY	
Primary and/or secondary production improvements	3			↑	NEY	NEY	NEY	NEY	↑				NEY	↑
Fish Response [b]														
Marine survival	0	NEY		NEY	↔		NEY				NEY	↔	↔	↔
Adult abundance	2	NEY		↑	↔	↔	↔	↔	↔	↓	NEY	NEY	↔	↑
Redd numbers	2			↑	↔	↔	↔	↔	↔		NEY	NEY	↔	↑
Smolt production	8	↑	↑	↑	↑	↑	↑	NEY	↔	↔	↔	↑	↔	↑
Juvenile abundance	7	↑	↑	↑	↔	↑	↑	↑	↔		↔	↑		NEY
Juvenile density	5	↑	↑	NEY	↔	↔	↓[d]		↔	↔		↓[d]	↑	
Juvenile survival	7	↔	↑	↑	↔	↑	↑	↑	↔	↑	↔	NEY	↑	NEY
Juvenile growth or size	3	↔	↓	NEY	↔	NEY	↑	↑	↔	↑	↔	↔	↔	↔
Juvenile residence time	4	↑↓		NEY	↔	↑	NEY	NEY	NEY	↑		↑	NEY	
Life history diversity	5	NEY		↑	↔	↑	NEY	NEY	NEY	↑	NEY	↑	↑	NEY
Fish distribution	7	NEY		↑	↑	↔	↑	↑	↑	↑			↑	

Table 2 Footnotes

[a] Examples for Habitat Response categories:

Riparian quality or quantity: improvement in riparian, floodplain, or estuarine wetland condition, buffer width, riparian composition, non-native plant reduction, increase in large wood inputs, etc.
Channel or channel units quality or quantity: improvement in channels or channel unit types (e.g., pools, blind channels), increase in length, area, depth, number, areal extent, wetted extent, etc.
Floodplain or estuarine lateral connectivity: increase in the duration of floodplain or side channel inundation or reconnection, reducing stream power and redd scour, decreasing incision, etc.
Longitudinal connectivity: addressing upstream or downstream fish passage in some form, increasing longitudinal access in channel network
Habitat complexity: increasing the heterogeneity of habitat types in freshwater and/or tidal systems, increasing river complexity index value, increased marsh area per channel length, etc.
Sediment quality: restoration of sedimentation processes, improved sediment sorting, improving spawning substrate, reducing fine sediment, etc.
Sinuosity: linear length to stream length ratio, reducing stream power, etc.
Stream width:depth: improvements toward site specific objectives of width to depth ratio
Temperature improvements: improved temporal or spatial thermal heterogeneity, decrease in maximum summer temperatures, etc.
Flow improvements: increased low flow, decreased peak flow, decreased stream flashiness, etc.
Water quality improvements: an improvement in any water quality parameter, outside of temperature, identified as a site-specific objective
Primary and/or secondary production improvements: various measurements of biomass, macroinvertebrate or plankton biomass or composition

[b] Examples for Fish Response categories:

Marine survival: measure of out-of-basin survival, typically smolt to adult return ratio
Adult abundance: adult return estimates or escapement values
Redd numbers: count or estimate of redds
Smolt production: the number of smolts produced in the study area or per unit area
Juvenile abundance: total number of juveniles in the study area or for a defined area
Juvenile density: the number of juveniles per unit area
Juvenile survival: measure of freshwater production (e.g., egg to smolt) or seasonal survival (% survival from summer to fall)
Juvenile growth or size: growth rates by age class and season, size at out-migration
Juvenile residence time: date of out-migration, age at out-migration
Life history diversity: an increase or change in life history that could benefit the population
Fish distribution: percent of available habitat occupied, changes in relative density by location within distribution (for either juveniles or adults)

[c] The three western Washington IMW complexes comprise a cooperative study with a shared design and staff and some analyses that incorporate data from all 10 watersheds. See snapshots in Appendix 1 for individual IMW details.

[d] In these cases, decreased density or crowding of juvenile fish was the desired response and is considered a positive fish response.

Our synthesis effort included four primary steps:

1. A questionnaire was sent to the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) IMW Working Group, consisting of volunteer representatives from Pacific Northwest IMWs, asking for treatment types, habitat and fish population responses, and management and policy learnings. Thirteen of the 16 IMWs that received the questionnaire were able to provide responses.
2. A series of three workshops were held in November and December 2021 to discuss collective results from the questionnaire and to develop collective "core messages."
3. Some additional information was obtained from annual reports produced and shared after the final workshop and incorporated into the report.
4. Publication of this report detailing the collective core messages and recommending management and policy actions for applying IMW results.

The core messages identify findings common among IMWs and indicate possible alterations in restoration strategy that could improve program effectiveness and efficiency. This synthesis reflects commonalities in the group experience to date and is subject to change as we learn more. The core messages are presented in three categories: Habitat and Fish Responses, Management and Coordination, and Current Research Priorities and Future Opportunities. Within each of the categories, the core messages are organized to first present items related to establishing restoration program priorities, then progress to items more specific to individual project selection, siting, and design. The final section of the report provides a list of recommended management and policy actions that would facilitate the application of the IMW results.

The core messages are intended to provide preliminary management recommendations and are in no way intended to imply that the IMWs have completed data collection and analysis. Only two of the 13 participating IMWs indicated they have completed data collection efforts. In fact, it is abundantly clear from the information collected through this process that further evaluation of system response to the application of restoration treatments can improve our understanding of how to effectively develop and implement restoration strategies.

IMW Core Messages

Habitat and Fish Response

IMW findings to date indicate that many of the implemented restoration methods can improve aquatic habitat and elicit a positive fish response. However, the degree and type of habitat and fish response to restoration treatments varied among IMWs, as detailed below. Several factors are likely responsible for the diversity in system responses. IMWs vary in attributes like land use, vegetation, topography, and other factors that can influence habitat and fish response to restoration treatment. IMWs also evaluated different combinations of treatment types. An additional complicating factor is that fish responses to habitat restoration in many IMWs are impacted by out-of-basin factors, including ocean productivity effects on marine survival, fishing, and mortality associated with dams. Nonetheless, IMWs do provide evidence that some of the actions being implemented to improve freshwater and estuarine habitat conditions can result in positive fish and habitat responses. The IMW results also identify some areas where our understanding of the linkages between restoration action, habitat modification, and fish response is incomplete.

All IMWs measured habitat and fish responses to the application of restoration treatments. However, the habitat features and the fish population metrics that were measured varied among IMWs (Table 2). Fish metrics tracked by the IMWs were especially diverse. Most IMWs measured one or more indicators of fish abundance, such as spawner abundance, parr density, or smolt production. Some IMWs also measured more detailed demographic elements including life-stage-specific survival and production (i.e., the rate of change in total population biomass). Some IMWs also tracked changes in life history diversity, such as migration timing. All of these elements are important components of fish response to the application of treatments and are directly relevant to the four Viable Salmonid Population (VSP) parameters (abundance, productivity, spatial structure, diversity) that are used by the National Oceanic and Atmospheric Administration to track progress toward species recovery. For simplicity in the core messages, a desired fish response to habitat treatment is generically referred to as a “positive fish response.” For details about specific fish responses please refer to Table 2.

The core messages in this section are presented starting with items related to restoration program design and then providing more specific messages focused on fish and habitat responses to types of restoration projects. The order of the core messages does not reflect their degree of relevance to the development of restoration strategies.

1. **Identifying primary factors limiting fish production and survival is critical to the design of an effective restoration program. If restoration does not address the factors constraining fish production, a biological response is unlikely to occur.** IMWs have demonstrated that accurate identification of limiting factors can be difficult. Limiting factors are not static, and their relative impacts vary over space and time. A comprehensive assessment of factors limiting fish production can greatly improve the effectiveness of restoration programs. Reassessing these factors periodically, through a monitoring program, can help ensure restoration actions are focused on the factors constraining fish production and improve the likelihood of achieving desired fish responses. Some IMWs have altered their restoration design based on a more thorough evaluation of limiting factors. Examples of IMWs where additional factors controlling fish production were identified during the study include:
    a. Warm water temperature apparently limited steelhead and spring Chinook Salmon in the Middle Fork John Day IMW, preventing a population level fish response to restoration actions.
    b. Lack of a significant response in Coho Salmon smolt production at the Hood Canal IMW after wood treatments may be related low numbers of spawning fish in the watershed.

2. **Accounting for factors that may influence population responses outside of the target watershed is critically important for setting realistic expectations for a biological response.** Several IMW studies noted external factors that are likely limiting fish responses to restoration, including:
    a. Relatively poor habitat conditions in the mainstem Columbia River, notably mortality associated with the hydropower system, and variable ocean conditions likely reduced fish responses to restoration in all IMWs above the Columbia and Snake River dams.
    b. Variable ocean conditions and high harvest levels may limit the number of spawning fish, as noted in the Hood Canal and Lower Columbia IMWs.
    c. A combination of harvest restrictions and hatchery fish supplementation, in addition to dam removal, likely supported strong Chinook Salmon, Coho Salmon, and steelhead responses to dam removal in the Elwha River IMW.

3. **The time required for a monitoring program to evaluate effectiveness of restoration treatments is influenced by the pace of restoration project implementation and the extended period required for full expression of habitat and fish responses.** Habitat changes expected from restoration actions have different response times, ranging from less than a year to decades. Fish population responses can require even longer timeframes because full biological responses cannot occur until habitat changes are fully expressed and fish complete several generations. In cases where extreme disturbance events affect restoration progress (e.g., extreme flood event at the Strait of Juan de Fuca IMW), fish responses can take even longer to detect. Expected response time for restoration actions should be considered when developing monitoring plans to ensure that resources are available to fully evaluate restoration treatment effects.

4. **Habitat restoration can enhance life history diversity of targeted salmon and steelhead populations.** Increased life history diversity of salmon and steelhead populations enhances population resilience and can contribute to overall productivity.

a. Steelhead life history diversity expanded in the Elwha River IMW because of barrier removal. Notably, summer steelhead reappeared in the system.
b. The Potlatch River IMW documented a shift in steelhead emigrant life history in one of the study watersheds toward older, larger emigrants with an associated positive shift in survival to Lower Granite Dam. The extent to which this change is associated with habitat restoration is being evaluated.
c. Expanding delta habitat for migrating Chinook Salmon fry at the Skagit River Estuary IMW increased growth rates, residence time in the delta, and, apparently, smolt-to-adult survival rates.

5. **The IMWs provided a more complete understanding of migratory behavior of juvenile salmon. This information can be valuable in the development of restoration strategies that directly address survival bottlenecks**. A variety of juvenile salmon and steelhead migration behaviors were observed in the IMWs. The high degree of movement exhibited by these fish emphasizes the need for restoration programs with a watershed-scale perspective. IMW examples of juvenile migratory patterns, and the habitat actions these behaviors might suggest, include:
    a. Chinook Salmon fry emigration to the Skagit River delta indicated that increasing estuarine habitat could generate a positive fish response.
    b. Fall Coho Salmon parr emigration at the Strait of Juan de Fuca and Lower Columbia IMWs suggests that increasing availability of winter habitat could be an effective restoration strategy.
    c. Large numbers of Coho Salmon fry emigrants seen at several of the IMWs suggests that expanding habitat suitable for fry could be an effective restoration technique.
    d. Juvenile steelhead migration from tributaries to mainstem river habitat (and continued rearing before smolting) has been documented in the Asotin Creek, Potlatch River, and Wind River IMWs, suggesting that restoration plans need to incorporate elements to enhance both tributary and mainstem habitat.
    e. In the Asotin Creek IMW, scale analysis and PIT tag monitoring identified as many as 25 steelhead life history strategies, differing in timing of movements and duration of residency in various freshwater, estuary, and ocean habitats. Resident steelhead that produce anadromous offspring have been found to be an important mechanism for maintaining population levels, especially when adult escapement of steelhead is low.
    f. Migration of juvenile Chinook Salmon from warmer mainstem habitat into cooler tributaries during summer periods was documented in the Middle Fork John Day IMW, suggesting restoration actions targeting connectivity at tributary confluences could be beneficial.

6. **IMW results support previous work that suggest that restoration efforts should be prioritized following the general strategy of “protect, reconnect, and then restore.”** The strength of the habitat and fish responses to treatments may be, partially, a product of initial watershed condition. Locations where watershed processes are relatively intact appear to have a higher probability of generating a more rapid fish response to habitat treatments (e.g., Asotin Creek, Elwha River). Watershed scale habitat restoration requires a suite of complementary, stepwise actions to address limiting factors. Multiple treatments that enhance and build on each other are likely necessary, along with time and patience.
    a. Focusing initial restoration actions on locations close to relatively intact habitat and gradually working into more degraded reaches is an effective strategy. If connectivity in downstream reaches limits access to areas of higher quality habitat, restoring connectivity should be a priority. The Asotin Creek, Elwha River, Lemhi River, and Hood Canal IMWs are examples of this approach and all generated positive fish responses.
    b. Reconnection of isolated habitat, which is in relatively good condition, consistently generates a rapid, positive fish response.

7. **Removing longitudinal barriers resulted in dramatic and immediate fish and habitat responses across multiple IMWs.** The removal of fish passage impediments, such as dams and culverts, improved habitat conditions and resulted in positive changes in fish response at all IMWs where this treatment type was evaluated. Fish responses observed included increased juvenile and adult abundance, expanded distribution of juvenile and adult fish, and increased life history diversity. These responses indicate longitudinal barrier removal can both increase salmon abundance and enhance population resilience. Examples of this include:
    a. Dam removal in the Elwha River IMW resulted in increased distribution and adult abundance of steelhead, juvenile abundance of Chinook Salmon, as well as the reappearance of a summer-run steelhead life history.
    b. Reconnecting tributaries in the Lemhi River watershed increased distribution of Chinook Salmon, steelhead, and Bull Trout, and improved juvenile salmon survival.
    c. Improving passage through the lower Potlatch River watershed by modification of existing structures resulted in increased steelhead spawning distribution.
    d. Coho Salmon spawning distribution increased one year after a bedrock stream channel limiting fish passage was addressed at the Lower Columbia IMW.
    e. Removal of a culvert at the Hood Canal IMW led to an increase in Coho Salmon smolt production.
    f. Aquatic organism passage projects and the removal of the single log weirs in tributaries of the Middle Fork John Day IMW expanded Chinook Salmon parr distribution.

8. **Removing lateral barriers also resulted in positive fish and habitat responses at several IMWs.** Fish have consistently demonstrated that they will colonize new habitat as soon as it is available. The removal of levees and other floodplain and tidal habitat barriers was found to result in greater abundance and diversity of salmon and steelhead. Examples of this include:
    a. Removal of levees that were restricting access to tidal channels reduced competition, increased residence time, and increased growth of emigrating Chinook Salmon fry in the Skagit River Estuary IMW.
    b. Floodplain reconnection promoted through the use of Beaver Dam Analogs, and subsequent increase in beaver activity, was associated with a strong, positive response by juvenile steelhead (see following core message).
    c. One exception to positive fish response to floodplain reconnection was reported at the Hood Canal IMW. Initial results indicate that floodplain reconnection through levee removal and increased beaver activity has not led to an immediate increase in Coho Salmon smolt production, but these results are preliminary (only three years after restoration).

9. **A strong, positive response from juvenile steelhead to floodplain reconnection caused by increased beaver activity and encouraged by the use of Beaver Dam Analogs (BDAs), was observed at Bridge Creek IMW.** BDAs are effective at increasing pool habitat and reconnecting floodplains. Although the impact of beaver activity on habitat and fish was monitored primarily at the Bridge Creek IMW, evaluation of recent treatments at the Asotin Creek, Lemhi River, and Hood Canal IMWs are ongoing and may provide additional information on the efficacy of this restoration approach. Some key considerations regarding the use of BDAs include:
    a. BDAs can mimic beaver dams and promote benefits of beaver, such as providing deep water and side-channel habitat as well as support greater floodplain inundation, habitat complexity, water storage, flood attenuation, increases in riparian extent and health, temperature refugia via groundwater pathways and summer and winter temperature heterogeneity.
    b. Habitat changes initiated by BDAs can be sustained in the long term by beavers, and BDAs should be considered part of beaver reintroduction programs.
    c. Stream size, gradient, and sediment movement should be considered when siting BDA projects. Modeling of beaver dam capacity, and including beavers as part of stream restoration, indicate

that beavers and dam building appear to take place across a wide range of stream types, gradients, and elevations.

10. **Estuary habitat reconnection at the Skagit River Estuary IMW generated some of the strongest biological responses across the IMW studies.** Results from this study include:
    a. Levee removal increased availability of delta habitat for juvenile Chinook Salmon fry, leading to reduced competition, increased residence time, and increased growth.
    b. There is some evidence that improved estuarine rearing conditions are causing a positive trend in smolt-to-adult survival rates, which could ultimately translate into increased adult abundance.
    c. Benefits observed from the reconnection of tidal habitat also may be achieved by reconnecting floodplain habitats in freshwater systems with limited floodplain access (Bridge Creek IMW).

11. **Wood placement can have beneficial effects on habitat and fish, but some IMWs have not yet observed a response to wood treatments**. Wood is typically added to streams to enhance aquatic habitat by providing cover and influencing hydraulics and sediment dynamics. Wood additions can result in changes to stream channel morphology and habitat features like increased quantity and depth of pools and reduced width-to-depth ratios. Evaluating habitat and fish responses to this treatment type was complicated by the fact that wood addition was often only one of several restoration actions implemented in IMWs (Table 1) and sometimes was only one of several actions taken within a single stream reach. As a result, fish and habitat responses at the watershed scale are a product of a suite of restoration actions, making it difficult to isolate responses to the wood treatments. However, wood placement is the most common treatment applied at the IMWs and is a very common restoration action across the Pacific Northwest. Therefore, the variable habitat and fish responses to large wood treatments among the IMWs indicates a need to better understand how to best utilize this restoration technique.
    a. Some IMWs reported positive habitat changes in response to wood addition (e.g., Asotin Creek IMW), but not all. A detailed analysis of habitat response to treatments across three western Washington IMWs (Lower Columbia, Hood Canal, and Strait of Juan de Fuca IMWs) concluded that trends in large wood and other habitat metrics ranged from positive to none to negative, even in stream reaches with substantial restoration. Several possible explanations for the unexpected results are:
        i. Habitat quality continues to decline, possibly a legacy of past land use actions. For example, numerous projections of wood input suggest that the buffers on streams, required since the 1980s, will not begin to make significant contributions of wood for several more decades. Therefore, channel complexity continues to decline in most systems. This decline in habitat quality is occurring more rapidly than habitat improvement from restoration, making it difficult to detect a habitat response to the treatments.
        ii. There is a high degree of natural, temporal variability in habitat condition. Ranges of habitat metric values among years often exceeded estimated effects attributable to restoration, making detection of a habitat response difficult. This dynamic nature of regional watersheds necessitates long periods of monitoring to detect impacts from restoration efforts.
        iii. Wood added was undersized for the stream power and sometimes placed in transport reaches. As a result, much of the added large wood moved in high flow events and failed to have the anticipated effect on habitat condition. This result emphasizes the importance of proper siting and design of wood structures to maximize the likelihood of having the desired habitat effect.
    b. Fish response to treatments also varied among IMWs.
        i. IMWs with modest, positive improvements in fish response after wood placement included the Asotin Creek, Strait of Juan de Fuca, and Lower Columbia IMWs.

ii. Little or no fish response was observed following wood additions at Pudding Creek, Hood Canal, Methow River, and Middle Fork John Day IMWs. A life-cycle model for steelhead in the Middle Fork John Day IMW demonstrated that wood additions would be unlikely to elicit a fish response unless paired with reductions in summer water temperatures.

12. **Many restoration treatments seek to restore natural river processes. However, some level of ongoing maintenance, adjustment, and enhancement are likely required before conditions are suitable for natural processes to maintain high-quality habitat.** Support for project maintenance should be considered when a restoration project is initially implemented, as should the likelihood of maintenance needs, given the project location and site conditions. Climate change may affect the ability to achieve process-based habitat goals, and this possibility should be acknowledged in project design and maintenance expectations.
    a. Project performance needs to be assessed periodically; aquatic ecosystems are dynamic and restoration treatments may need to be modified to adapt to changing conditions.
    b. Large wood and riparian restoration efforts often require maintenance or enhancement to ensure the desired habitat response is achieved (e.g., addition of more wood, enhancement of existing structures, or construction of new structures to promote more positive habitat changes). Upkeep of projects may be required for a period to help re-establish self-sustaining processes, (i.e., mimic, promote, and sustain wood accumulation and habitat complexity benefits). Maintenance of both wood added to the channel and riparian treatments may be needed to achieve project objectives.

Management and Coordination of Restoration Implementation

IMWs identified a variety of challenges related to project management, public and private landowner relationships, agency permitting, and other issues that complicated study implementation. The IMW scientists consistently identified several issues that should be considered in the design of future monitoring programs. Some of these core messages are also directly applicable to the design and execution of habitat restoration programs. Note that literature identified in the References and Other Literature section expands and provides detail on several of the core messages identified below.

Many IMWs reported consistent issues with treatment application and the translation of project results into management recommendations. Assumptions made in initial project design about the feasibility of applying restoration treatments within a narrow time window often proved to be overly optimistic. Applying treatments over an extended time period was often inconsistent with the original experimental design and complicated evaluation of treatment effects. Translation of study results into concrete management recommendations was hindered by the lack of a formalized adaptive management process at most IMWs. Development of a clearly defined process for the application of IMW results to restoration program strategies and habitat project design will greatly enhance the value of the IMW studies to managers.

Evaluation of fish response to habitat treatments was compromised at nearly all the IMWs by out-of-watershed and non-habitat influences on fish populations. These factors, which were beyond the control of the project scientists, may have limited the capacity for fish populations to respond to habitat restoration treatments. Ocean conditions, fish harvest, hatchery, and hydropower impacts on migrating fish were identified as being factors that could limit the response of the fish to modifications of freshwater and estuarine habitat conditions. Climate change is likely masking the benefits of habitat treatments to targeted fish. Considering these factors in setting reasonable expectations for fish responses to restoration would improve scientific understanding because most of these factors are not under the control of habitat restoration programs. The fact that some salmon populations are impacted by factors other than habitat conditions does not imply that habitat restoration is not beneficial; high-quality freshwater and estuarine habitat can support population resiliency by enhancing fish capacity to persist in the face of climate change or severe disturbance events (e.g., major floods, wildfire).

1. **Adaptive management requires a defined process for extracting management-relevant principles emerging from IMWs or other monitoring programs, translating those findings into management actions, and communicating this information to restoration practitioners in a timely manner.** Some, but not all, IMWs have formal adaptive management plans. Restoration strategies are most effective when adaptive management frameworks are developed with clear and measurable progress indicators and resources are sufficient to support regular monitoring and assessment. Multiple IMWs indicated that the lack of an explicit adaptive management process was at least partly due to funding limitations. Resources earmarked for developing and maintaining adaptive management processes and community outreach activities are necessary to convey IMW results and build and maintain stakeholder support.
    a. Developing and implementing adaptive management plans for each IMW would expedite the translation of IMW results into on-the-ground management decisions and actions. Adaptive management plans require the clear articulation of specific target metrics in restoration and monitoring plans, and defined actions when target metrics are achieved.
    b. A greater emphasis on developing and communicating the management-relevant information being generated by IMWs would greatly enhance their value. This type of outreach has occurred to some extent through IMW presentations, handouts, previous synthesis efforts, and presented in symposia and workshops. However, a more consistent and aggressive communications effort, and more robust data exchange among IMWs, would improve future synthesis and application efforts.

2. **Establishing a program to centralize storage of monitoring data and results should enhance the effectiveness of adaptive management programs.** Data management is an ongoing challenge identified by multiple IMWs. Dedicated data storage and analysis could help address this issue and accelerate the communication of IMW results. A centralized system would provide the technical foundation for a region-wide adaptive management program that generates periodic updates of monitoring results and recommended management actions based on the findings.

3. **Coordination with entities beyond local landowners and habitat restoration community is necessary to achieve desired population responses to habitat restoration.** Multiple IMWs noted that out-of-basin threats and impacts of climate change and other factors likely limited positive fish responses to habitat improvements. Better communication and coordination would be useful in understanding the role of habitat improvements relative to other factors (e.g., hydropower, fisheries, hatcheries, predation) in determining fish population responses.
    a. Collaboration with tribes, agencies, and other stakeholders that influence factors other than habitat is a key step in salmon and steelhead recovery and conservation: freshwater habitat conditions are unlikely to be the only limiting factor to salmon and steelhead. Understanding all life cycle impacts is key to evaluating drivers of fish population status and trends.
    b. Freshwater habitat restoration can lead to increases in juvenile productivity, but adult returns may not increase until other factors are addressed.
    c. Positive fish responses in the Elwha River IMW may be, in part, due to the multi-pronged approach of restoration. Harvest limitations, natural fish recolonization, and hatchery fish supplementation were combined with the expanded availability of freshwater habitat to accelerate fish response. This approach illustrates the benefit of addressing multiple limiting factors in a coordinated manner. Genetic analysis showed that the return of the summer steelhead run was independent of the hatchery fish supplementation program, but the abundance of other populations in the watershed were influenced by supplementation.

4. **Restoration program implementation and monitoring would be more efficient and effective if consistent, stable funding sources were available to support long-term and large-scale restoration strategies.** Current funding is often highly competitive and limited, leading to inconsistent and piecemeal implementation of restoration. Communicating with program funders on the need for more planning support to work with landowners and permitting agencies on restoration strategies would help enable the development of more effective, long-term restoration and monitoring programs. Support for planning and project coordination would be especially helpful in watersheds with multiple landowners and multiple restoration organizations where project support can come from a variety of sources.

5. **IMWs have developed the monitoring infrastructure, scientific partnerships, and landowner relationships that enable the intensive monitoring required to evaluate fish response to restoration treatments.** The IMW concept remains one of the only experimental designs available to evaluate watershed-scale fish response to habitat restoration. As a comprehensive understanding of fish response to various types of restoration actions is key for adaptively improving the effectiveness of restoration programs, continuation of data collection at IMW sites will be valuable. These studies are key for assessing new restoration methods, or how past restoration projects function under new conditions.
    a. Quantifying the cumulative benefits of multiple restoration actions can only be captured by long-term, comprehensive monitoring efforts. IMWs provide the data required to conduct this type of analysis.
    b. IMWs are an important component of adaptive management processes because their time series data are critical for refining restoration and management strategies.

6. **Supportive landowners, land managers, funding partners, and local community members are critical to ensuring that restoration actions can be implemented at locations most likely to benefit fish.** Salmon recovery and habitat restoration programs rely on diverse stakeholder groups and funding resources to accomplish their goals. Building community support has been shown to be an important part of restoration planning, and when adequately supported can improve outcomes. It takes a great deal of effort to build the relationships required to accomplish restoration program goals. One important and recurring message from the IMW synthesis effort was the importance of collaboration among program funders, monitoring specialists, designers, landowners, and managers. IMW studies illustrate the complexity of working in these highly collaborative environments when conducting long-term monitoring, designing, and constructing restoration projects, and adaptively managing programs. Experiences from IMWs provide some insights on effective landowner interactions.
    a. Successful project development and implementation are highly dependent upon strong, long-term, working relationships with landowners and land managers. Time, effort, and thoughtful care given to developing relationships can improve project success. Community and town-hall meetings were a critical part of the strategy to increase beaver activity in the Bridge Creek IMW, where community members were not initially in support of this effort. Another good example of effective community engagement is provided by the Skagit River Estuary IMW. The Skagit Watershed Council, the primary organization leading restoration efforts in the IMW, has developed strong working relationships with landowners and local governments.
    b. Communicate consistently and ensure messaging is tailored to the audience and presented in an appealing format. Demonstration projects can be a valuable communications tool. Coordination of communication efforts with other entities doing restoration or monitoring is necessary to ensure messages to the public are consistent.
    c. Helping landowners and stakeholders understand restoration principles and project objectives has been shown to generate support. A current watershed assessment and illustrations of the potential benefits of habitat restoration are effective communication tools.

d. Working on public lands or acquiring private property where local support exists may enable the application of large-scale restoration strategies and streamline restoration and monitoring efforts. Elements of this approach were utilized at the Middle Fork John Day and Methow River IMWs.
e. Once landowners and community members are engaged in a restoration program, they may become restoration advocates and encourage additional landowner participation in the restoration effort.
f. It is important that landowners and the local community understand the long-term commitment that restoration design, implementation, monitoring, and adaptive management require. Outreach to landowners and funders during restoration program development can help ensure timelines are understood. Coordinated engagement among restoration practitioners may help prevent landowner fatigue from constant and varied restoration contacts.

7. **Although IMWs are widely distributed across the Pacific Northwest, careful consideration of the specific conditions at the study sites will be required to reliably extend results to other watersheds.**
   a. By understanding the mechanisms of habitat and fish responses in IMWs, we should be able to apply these results to other watersheds; however, there isn't a good framework for extrapolation.
   b. The IMWs have relatively good regional representation, including numerous sites in both coastal areas and east of the Cascade Range.
   c. None of the freshwater IMWs included in this compilation of results were in the western Cascade Range. There would be increased certainty in applying IMW results to watersheds in this region if an IMW watershed had been located there.
   d. Land use activities in the IMW watersheds were primarily forestry, agriculture, and low-density residential development. The results obtained from the IMWs will likely require careful review and adaptation before they can be applied to watersheds where urban land use predominates.
   e. Extension of results of other geographies could be facilitated by classification of hydrogeomorphology.

Current Research Priorities and Future Opportunities

Through the conversations and discussion of this project and the development of this report, several newer questions and opportunities were identified. The following are current research priorities and future opportunities, and in some situations, IMWs are uniquely positioned to help answer.

Monitoring at 11 of the 13 IMWs is incomplete and meaningful additional information can be generated by completing planned evaluation efforts. Some consideration should be given to providing long-term support for some of the current IMWs for evaluation of new restoration strategies and protocols. Having these sites available will greatly reduce the time and expense required to answer these questions. The IMWs also provide a mechanism for tracking the impacts of a changing climate on aquatic habitat and fish populations. And the IMWs can help provide a realistic perspective on the time required for ecosystem processes supporting fish populations to be restored. Land use impacts on watersheds and estuaries have been ongoing for over 150 years, and re-establishment of fully functioning systems may require considerably more time than was envisioned when restoration programs were established several decades ago. One possibility is to convert some of the existing IMWs into long-term research sites, like those managed by the Long-Term Ecological Research Network.

1. **Continued monitoring of system responses to treatments are required to fully characterize fish and habitat responses at most of the IMWs.** At many IMWs, habitat and fish population responses may not yet be fully expressed. Lack of responses is due in some cases to extended restoration treatment timelines and the complexity of detecting a fish response, especially considering out-of-watershed

effects on populations. Power analyses were conducted by several of the IMWs to estimate length of time required to determine if a fish response occurred. This type of analysis can help identify monitoring timeframes for individual IMWs, although implementation schedules, environmental conditions, or new study questions may require expanding the monitoring timeline.

2. **Develop a better understanding of the degree to which improved spawning and rearing habitat influence marine survival and adult returns.** Evaluation of the extent to which improved habitat conditions contribute to achieving recovery goals remains a key question for restoration programs. The Skagit River Estuary IMW has found some indication that estuary restoration appears to enhance smolt-to-adult survival of Chinook Salmon, and there are early indications of increased adult abundance. This observation suggests habitat restoration can positively affect adult abundance. However, many questions about the extent to which habitat restoration can contribute to increases in adult salmon and steelhead abundance remain.
    a. Can improvements in freshwater habitat and productivity provide survival benefits in downstream habitats, including the ocean?
    b. To what extent can improved freshwater and estuarine habitat conditions help offset negative effects from out-of-basin factors, such as fish harvest, dam mortality, and poor ocean conditions?

3. **Further assess if habitat restoration increases resiliency of salmon and steelhead to climate change impacts.** IMW provide an opportunity to assess the extent to which different restoration strategies contribute to resilience of freshwater and estuarine ecosystems when impacted by extreme high and low flow conditions, fires, or other disturbances. This understanding could aid in the development of restoration strategies and designs to address climate change impacts.
    a. An improved understanding of the effect of habitat condition on life history diversity and survival rates could help identify limiting factors likely to be worsened by climate change and aid in the development of more effective restoration approaches.

4. **Identify the factors responsible for the variable fish response to wood addition treatments.** There was variation in both habitat response and fish response to large wood treatments among IMWs. Additional monitoring at the IMWs evaluating response to wood addition should help identify some of the factors responsible for the variation in response. Some hypotheses about the variation in response were raised during the workshops and merit additional attention. These hypotheses included:
    a. Not enough wood was added or not enough of the watershed was treated. Therefore, the added wood did not have a sufficient effect on habitat condition during the study period to cause a fish response (e.g., Pudding Creek).
    b. The added wood was transported out of the treatment or monitoring site(s) so it could not be assessed.
    c. A longer evaluation period is required to detect fish response. Large wood changes habitat conditions following channel-forming flow events. This is especially true with large wood treatments designed to interact with and reconnect floodplain habitats. Lack of fish responses to wood placement at some IMWs may be due, in part, to the lack of a channel-forming flow after treatment.
    d. Wood loading was not a primary factor limiting fish production.

5. **Assess how restoration techniques could provide benefits for native salmon and steelhead to reduce impacts of predation and competition.** Native salmon and steelhead are impacted by native and non-native species through competition for resources and by predation. The severity of these impacts is an area of increased interest. Can impacts of predation and competition be reduced by habitat restoration? None of the existing IMWs are examining this question but there may be an opportunity to collect information at some IMWs to enhance our understanding of this issue.

6. **Determine the relative value of floodplain connectivity in supporting freshwater rearing of salmon and steelhead.** More research on how restoration actions may reconnect floodplain habitat and support positive fish responses would improve understanding of the benefits of this restoration strategy.
   a. Reconnection of floodplain habitat at Bridge Creek IMW generated a very positive fish response. However, preliminary results of a large floodplain reconnection project at the Hood Canal IMW indicate no fish response. What are the characteristics of floodplain reconnection projects that yield positive fish responses?

7. **Quantify the ecosystem benefits of freshwater and tidal habitat restoration.** Some IMW results indicate that habitat restoration provides ecosystem benefits, including buffering against climate change impacts, thermal regulation, improved riparian habitat and increased wildlife habitat capacity. Habitat restoration also supports ecosystem resiliency to fire and other disturbance events. Only a few of the IMWs are monitoring system responses beyond aquatic habitat and fish, but inclusion of a few additional parameters at some of the IMWs may help better characterize the full range of ecological benefits associated with habitat restoration.
   a. Habitat changes include climate change amelioration for low flow and water temperature, floodplain water storage and groundwater recharge, flood attenuation, and sediment dynamics (Pudding Creek, Lemhi River, and Bridge Creek IMWs).
   b. These habitat changes are associated with biological changes including increased number of clutches per year for American Dipper in the Elwha River watershed following the increase in marine derived nutrients from salmon runs, and the potential increase in spawning success of reintroduced Pacific Lamprey in the Asotin Creek IMW.

Recommended Management and Policy Actions

In this section, the core messages are used to identify a set of management and policy recommendations to facilitate the incorporation of IMW findings into restoration program planning and implementation. The recommendations are intended to support decisions by salmon conservation and recovery program managers, watershed restoration program managers, and habitat project practitioners and are intended to provide guidance on improving the effectiveness of their respective programs. These actions build on existing work and published literature in many cases and emphasize the need for continued investments and coordination at watershed and species scales.

1. **Build restoration plans and strategies at watershed scales and within a context of all potential impacts to salmon and steelhead viability.** Identifying the role of habitat improvements relative to other factors is critical in understanding fish population responses to management changes. Although freshwater and tidal habitat degradation are key impacts to salmon and steelhead, multiple factors may limit or prevent viability of improvements even when habitat restoration occurs. Effective restoration strategies would fully consider how these in- and out-of-basin impacts, like hatchery production, harvest programs, hydropower systems, ocean conditions, and climate change, may all reduce survival, distribution, productivity, and life history diversity of salmon and steelhead. Effective habitat restoration programs would clearly identify the full suite of habitat factors limiting fish production and understand their role relative of other impacts to establish realistic expectation for benefits from habitat restoration. Gains in fish survival, productivity, distribution, and diversity could be realized through improved habitat; however, fish response to improved habitat can also be muted or masked by other impacts. IMWs demonstrate that salmon and steelhead utilize multiple habitats across watersheds for rearing and spawning. Therefore, progress toward recovery goals for salmon and steelhead will often require developing strategies that encompass the full range of habitat being used by the fish. The following questions help focus resources when developing a restoration program:

   a. Can in and out-of-basin impacts be coordinated to maximize, and not undermine, restoration benefits?
   b. Can habitat be restored and protected at watershed scales?
   c. Can restoration support from riverbank and floodplain landowners and the adjacent community be achieved?
   d. Is there a process to collect data and information necessary to support adaptive management of restoration strategies?

2. **Prioritize restoration methods based on aspects of restoration technique effectiveness like cost and certainty of success.** When selecting restoration approaches, carefully consider cost and certainty of success in light of desired fish and habitat outcomes and climate change. The established general strategy of protect, reconnect, and restore continues to hold true. Habitat reconnection actions like removing longitudinal (e.g., stream corridors upstream of undersized culverts) and latitudinal (e.g., disconnected floodplain and wetland habitats behind levees) fish passage barriers consistently lead to positive fish and habitat gains even though there may be considerable planning and coordination effort required. Consider prioritizing low cost, effective restoration approaches like hand placed post assisted log structures, beaver reintroduction, and beaver dam analog construction where watershed conditions support these types of actions. Large wood continues to be an integral part of restoration, but the habitat factors limiting fish production must be understood and large wood treatments must be deployed in a manner that addresses fish survival constraints. Maintenance needs should be accounted for in budgets and project timelines, as treatments often shift and degrade in shorter time periods than watershed process improvements occur. Periodic reassessment of limiting factors and revisiting restoration priorities throughout strategy implementation can aid in ensuring the most effective habitat restoration actions are being implemented.

3. **Implement restoration actions at continuous, landscape scales.** Watershed scale habitat restoration likely includes a suite of complementary and stepwise actions to address limiting factors. Multiple treatments that enhance and build on each other are usually necessary, along with time and patience, to restore natural riverine and habitat forming processes. Actions should be scaled to river processes and consider aspects like stream size and geomorphology.

4. **Prioritize and support the development of formal adaptive management processes across recovery and restoration programs.** Adaptive management is often poorly supported despite being essential for translating monitoring results to management and policy actions. Restoration strategies are most effective when adaptive management frameworks are developed with clear and measurable progress indicators, and resources are sufficient to support regular monitoring and assessment. However, progress indicators are often poorly defined and actions to be taken if benchmarks are not achieved are rarely specified.

5. **Regularly communicate among IMW monitoring and restoration leads and local stakeholders to refine habitat restoration programs based on study results and facilitate adaptive management.** Strong coordination between monitoring and restoration efforts is essential for a successful IMW study. IMWs are led by ecological monitoring and analysis experts, who are great resources for discussing how their latest findings may be applied to restoration programs. While many IMW monitoring leads regularly present at conferences and meetings, more discussion-oriented forums are needed to improve the exchange of information between restoration and monitoring practitioners. This goal could be accomplished by establishing regularly scheduled, science-to-policy forums to ensure efficient incorporation of new science findings and general “lessons learned” into policy and planning efforts. These forums could help build connections between monitoring results and management actions and identify new questions and opportunities.

6. **Support and implement natural resource programs at watershed and salmon and steelhead species scales.** IMW studies have clearly identified that salmon and steelhead rely on multiple life history approaches, and that changes in habitat quality and quantity in certain parts of a watershed may target specific life histories, like fry and parr migrants to lower mainstem and tidal areas. If habitat availability is not considered at all life history scales, opportunities to improve salmon and steelhead viability are limited.

7. **Provide stable, long-term support for fish and habitat monitoring**. Monitoring is the foundation of any adaptive management program. Regular assessment of factors limiting fish production and modification of restoration priorities accordingly is necessary to support more effective restoration programs and improve the likelihood of achieving desired fish outcomes. Ensuring that the information required to adaptively improve restoration program effectiveness is available will require an ongoing investment in monitoring. Monitoring support must be sufficient to quantify fish and ecosystem response and is most effective when conducted in coordination with salmon and watershed managers to identify recommended actions from monitoring results. Monitoring of all impacts (e.g., hatcheries, harvest, hydropower, habitat) to the best of our abilities will ensure an optimal scientific understanding of life cycle bottlenecks and the role of habitat relative to other impact types.

8. **Consider converting some of the IMWs to long-term research sites.** IMWs remain a useful tool for evaluating watershed-scale fish response to habitat restoration. IMWs have evaluated some of the restoration approaches in the region, but not all. Restoration approaches, along with scope and scale, are likely to evolve over time, and new approaches may be developed. There may be considerable value providing long-term support to retaining at least some IMWs or IMW components to assess emerging restoration options and to develop a long-term habitat and fish database that can help quantify the effects of climate change and other evolving impacts.

9. **Provide support for restoration planning and permitting to accelerate implementation timeframes.** Restoration actions are often delayed due to limited capacity for upfront landowner and community engagement coordination, permitting and consultation processes, and the need to continually apply for small-scale grants to complete large-scale projects. Reducing and removing some of these common delays will support more effective restoration and monitoring programs.

10. **Communicate with stakeholders about their expectations of habitat restoration.** Regularly discuss long-term program expectations with monitoring and management stakeholders. Identifying indicators of success, what factors may impact achieving these, and timeframes for achieving success should be clearly articulated to all stakeholders and updated as necessary. Time and patience are necessary when implementing habitat restoration at watershed scales, which is likely what is necessary in many areas given the legacy of historical habitat loss. Fish responses are measured across multiple cohorts and cannot be expected until habitat changes have occurred and non-habitat survival bottlenecks are addressed. If non-habitat bottlenecks are understood but cannot be fully addressed, fish response to habitat actions will be limited. Habitat restoration programs also have the potential to support ecosystem goals other than fish production, such as water quality, stream flow, wildlife, and green space needs. These broad benefits are important components when communicating program benefits to stakeholders.

Advancing This Effort and Parting Thoughts

There is a great deal to be learned from the IMWs now and in the future. The state of science for habitat restoration has evolved from relatively small site scale efforts with limited or no monitoring to larger scale process-based efforts that work to address identified limiting factors (Beechie et al. 2010, Booth et al. 2016).

Modern restoration actions are attempting to restore the full riverscape, channel, floodplain, and estuary, where possible. IMWs still remain one of the most promising tools to provide an understanding of population and watershed-scale fish and habitat responses to habitat restoration actions (Bennett et al. 2016). However, there are still significant data gaps that exist both in and outside of the IMWs (Roni et al. 2018). The workshops and report effort show the need for continued and ongoing information sharing and dialogue as IMWs continue with their studies.

This synthesis effort highlighted the value in discussing IMW data and results with principal investigators, restoration practitioners, and policy and management staff and how results might be applied. It is important to recognize that this effort compiled core messages at a summary level rather than an individual IMW level – a similar effort should be considered that is focused on individual IMWs to develop IMW-specific, detailed core messages and management applications. Additionally, this effort was limited to IMW informed core messages: workshop discussions identified additional sources of information that collectively could be used to improve restoration program effectiveness. It may be useful to support a broader synthesis effort that includes IMW results as well as results from other monitoring programs and information from the scientific literature to identify additional opportunities to enhance restoration program effectiveness and efficiency.

In general, IMWs have shown the value of, and the need for, close coordination of habitat restoration planning, outreach, funding, project implementation, and monitoring. They have also highlighted the importance of understanding site specific conditions and correctly identifying habitat limiting factors and ecological concerns and applying this understanding to address survival bottlenecks. IMWs have also indicated the need for patience in evaluating restoration programs. System response to restoration treatments is not fully expressed until habitat has responded to the treatment, often a function of the hydrograph, and the fish have responded to the altered habitat, which may require multiple generations.

The IMWs have demonstrated that many of the restoration treatment types being applied in the region have a positive effect on habitat and fish. However, the IMW results also identify some areas where the understanding of the linkages between restoration action, habitat modification, and fish response is incomplete. The lack of fish and habitat responses to some IMW treatments appears to be due to inaccurate identification of factors controlling fish production or an inability to address those factors because they were out of basin. In some cases, restoration scope and scale may have been too limited to elicit a response. In some cases, monitoring protocols or challenges in implementing the monitoring could also be a factor. Coordination of management programs and establishment of formal adaptive management processes across the various impacts to fish and habitat would help make recovery efforts more effective. Improving the technical rigor of processes used to identify limiting factors will not only support more effective salmon and steelhead recovery programs, but also enable the establishment of realistic expectations about the contribution freshwater and estuarine habitat restoration can make to salmon recovery.

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List of Acronyms and Abbreviations for Appendices

BA	Before-After study design
BACI	Before-After Control-Impact study design
BDA	Beaver dam analog
CHaMP	Columbia Habitat Monitoring Program
CI	Control-Impact study design
CRITFC	Columbia River Inter-Tribal Fish Commission
CTWS	Confederated Tribes of the Warm Springs Reservation of Oregon
ELJ	Engineered log jam
ESA	Endangered Species Act
GRTS	Generalized random tessellation stratified sample
IMW	Intensively monitored watershed
km	Kilometer
LC IMW	Lower Columbia Intensively Monitored Watershed
LW or LWD	Large wood or large woody debris
MFIMW	Middle Fork John Day Intensively Monitored Watershed
NFJDWC	North Fork John Day Watershed Council
NOAA	National Oceanic and Atmospheric Administration
ODFW	Oregon Department of Fish and Wildlife
OWEB	Oregon Watershed Enhancement Board
PALS	Post-assisted log structures
PIT	Passive integrated transponder
PNAMP	Pacific Northwest Aquatic Monitoring Partnership
SRFB	Salmon Recovery Funding Board

Appendix 1 - IMW Snapshots

Information in the following snapshots came directly from the IMWs and may contain varying levels of details. In many cases the snapshots contain preliminary results as data collection and analysis are still ongoing.

Asotin Creek IMW

Location	Washington
Study Tributaries	Charley, North Fork Asotin and South Fork Asotin creeks
Monitoring and Treatment Years	Pre-treatment monitoring: 2008-2012 Treatment: 2012-2014, 2016 Post-treatment monitoring: 2012-2025
Status	Treatments complete in 2016. Monitoring ongoing through 2025.
Focal Species	Snake River summer steelhead (note this is functionally a wild population; hatchery fish are removed at mouth and no supplementation); also designated as a wild steelhead refuge by WDFW
Limiting factors	Lack of pool habitat and cover for fish, lack of spawning habitat, lack of floodplain connectivity with limited refugia during high flows, and reduced large woody debris (LWD).
Restoration Plan	Staircase design with LWD treatments in 2012 (South Fork), 2013 (Charley Creek), 2014 (North Fork), and 2016 (South Fork).
Monitoring Experimental Design	Each creek has one treatment and two control reaches each of which is 4 km long.
Restoration Treatment	High density LWD placement (majority of the wood is placed by hand to minimize the disturbance to recovering riparian; cost of implementation order of magnitude lower than heavy machinery)
Magnitude of Treatment	39% of study area, 654 structures (4.7 structures/100 m stream length)
Pre-treatment Data	Stream temperature, discharge, geomorphic diversity, erosion rate, deposition rate, substrate composition, percent pool habitat, and net rate of energy intake
Physical Results to Date	Significant increases in frequency of LWD (150-1,000%), log jams (100-800%), pools (20-60%), bars (50-250%), overall geomorphic complexity
Biological Results to Date	Significant increases in juvenile steelhead density (15- 450%), no change in growth or survival, significant increases in production (40-50%), and significant increases in smolt productivity (25-75%).
Top 3 Management Implications	1. Developed and implemented a cost effective, low impact approach to adding large woody debris to streams to improve riverscape health 2. Demonstrated that high densities of large wood are effective at retaining wood in the system, promoting natural log jams, increasing geomorphic complexity, and improving fish habitat 3. Changes in habitat occurred mainly within the channel and led to modest increases in fish abundance, production, and productivity; however, ongoing maintenance and enhancement of restoration treatments, and use of beaver dam analogs to force greater floodplain connection could lead to increases in fish responses due to creation of more habitat area / mile of valley bottom
Additional Resources	Low-tech Process-Based Manual and Workshop Materials Asotin Creek IMW Story Map Low-Tech Process-Based Restoration Video, in Southeast Washington Asotin Creek IMW 2021 Annual Progress Report Asotin Creek IMW Experimental Design Manuscript Asotin Creek IMW Restoration Plan Asotin Creek IMW Adaptive Management Plan Manuscript

Bridge Creek IMW

Location	Oregon
Study Tributaries	Bridge Creek, tributary of the lower John Day River Bear and Gable creeks, tributaries of Bridge Creek Murderers Creek, tributary of the South Fork John Day River
Monitoring and Treatment Years	Pre-treatment monitoring: 2007-2009 Treatment: 2010, 2016 Post-treatment monitoring: 2010-ongoing
Status	Phase I treatment and monitoring completed in 2014, Phase II restoration in 2016 with post-treatment monitoring ongoing.
Focal Species	Middle Columbia steelhead
Limiting factors	Highly incised channel form, low habitat complexity, high stream power, floodplain and groundwater disconnection, high water temperatures
Restoration Plan	Construct beaver dam analogs and then measure response at 4 treatments and 7 control reaches in Bridge Creek, 2 tributary references in Bear and Gable Creeks, and 3 watershed reference reaches in Murder's Creek
Monitoring Experimental Design	Spatially Hierarchical Staircase BACI. Intervention analysis. Treatment and reference reaches were randomly selected. Selection of streams and watersheds was based on existing infrastructure.
Restoration Treatment	121 beaver dams constructed on the mainstem of Bridge Creek. Additionally, beaver constructed almost 150 more dams in treatment and control sections.
Magnitude of Treatment	4 km - about 30 % of degraded habitat
Pre-treatment Data	Approximately 3 years of juvenile survival, juvenile growth, juvenile density. Adult returns, water temperature, groundwater elevation, channel aggradation rate, and riparian vegetation extent.
Physical Results to Date	Increases in beaver dams and pools, almost 200% increase in inundation area (i.e., floodplain connection), 1,200% increase in side-channel length, 2-3 increase in groundwater height, trap 1-3 feet of sediment behind dams, moderation of high-water temperature, increase in cold water refugia
Biological Results to Date	Increases in juvenile steelhead density (168%), survival (52%), and production (175%)
Top 3 Management Implications	1) A massive loss of structure in streams occurred by the near extirpation of beaver. 2) Mimicking beaver dams with BDAs can provide many of the same hydraulic, hydrological, geomorphic and ecological benefits of natural beaver dams. They can also provide stable structures and refugia to promote natural beaver activity. 3) Because beaver tirelessly work to maintain dams, they can greatly accelerate sustainable processes that lead to floodplain reconnection and greater quantity and quality fish and wildlife habitat.
Additional Resources	Bridge Creek IMW Science Reports Habitat & Fish Results Manuscript Bridge Creek IMW PLOS ONE Temperature Manuscript Utah State University Beaver Restoration Assessment Tool Manuscript Using Beaver Dams to Restore Incised Streams Manuscript Modeling of beaver dam capacity (i.e., BRAT https://tools.riverscapes.xyz/brat/),

Elwha River IMW

Location	Washington
Study Tributaries	The Elwha and Quinault rivers
Monitoring and Treatment Years	Pre-treatment monitoring: 2000-2010 Treatment: 2011-2015 Post-treatment monitoring: 2014-present
Status	Post-treatment monitoring underway
Focal Species	Chinook, Coho, Pink, Chum, and Sockeye salmon, steelhead, Bull Trout, Cutthroat Trout, and Pacific Lamprey
Limiting factors	Lack of habitat connectivity (two dams over 30 m and 61 m in height that previously blocked about 90% of the anadromous salmonid habitat in the Elwha River Watershed and prohibited significant sediment accretion in the delta)
Restoration Plan	Complete removal of two dams, natural colonization of fish along with limited hatchery planting
Monitoring Experimental Design	BA or BACI depending on metric
Restoration Treatment	Complete removal of two dams, LWD placement
Magnitude of Treatment	About 128 km of salmon habitat opened
Pre-treatment Data	Multiple metrics of fish, habitat, food web, and water quality
Physical Results to Date	Sediment accretion created new habitat and altered the lower river from pool-riffle to a more braided morphology. 300% increase in available habitat length.
Biological Results to Date	Recolonization of many habitats by all anadromous life stages, resumption of anadromous life history (Bull Trout). Changes to the food web for juvenile salmonids
Top 3 Management Implications	1. Cumulative restoration actions are critical to the recovery of salmon and steelhead populations. 2. Recovery time takes longer than funding occurs because our populations are so much lower than historical levels and habitat degradation has been the norm over a large expanse for decades. 3. Without multiple forms of monitoring, quantifying ecosystem response is not possible.
Additional Resources	Rising from the Ashes - a short video from Trout Unlimited https://data.usgs.gov/drip-dashboard/ https://pubs.er.usgs.gov/publication/70099125

Hood Canal IMW

Location	Washington
Study Tributaries	Little Anderson, Seabeck, Big Beef and Stavis Creeks
Monitoring and Treatment Years	Pre-treatment monitoring: 1992-2007 Treatment: 2007- ongoing Post-treatment monitoring: 2003 – present
Status	Post-treatment monitoring ongoing; additional restoration projects proposed but currently unfunded.
Focal Species	Coho Salmon are the focus, as their abundance is estimated at three distinct life stages. Cutthroat Trout, Chum Salmon, and steelhead are also present in some watershed and/or at some life stages.
Limiting factors	Road crossings (culverts) reduce connectivity, reduced number and complexity of river channels, sediment imbalance: increased stream power/erosion in some reaches, severe deposition in other reaches
Restoration Plan	Remove barriers and constraints to flows of water, sediment, and fish, and restore stream roughness elements (LWD) and processes that will lead to future wood recruitment (riparian restoration and protection). Reconnect floodplain and wetland habitats though road removal.
Monitoring Experimental Design	Multiple BACI. Spatially balanced design. Approximately 20 habitat sites per watershed. Fish data from 10 parr monitoring sites plus spawner surveys throughout known spawning distribution plus smolt traps in each of four watersheds
Restoration Treatment	LWD placement, floodplain reconnection, and barrier removal
Magnitude of Treatment	In Little Anderson Creek, 3.7 km were treated with 495 pieces of LWD in three phases, and a barrier culvert was removed. In Big Beef Creek, 7.5 km were treated with 213 pieces of LWD in three phases, and a dike was removed, reconnecting 4.5 hectares of floodplain wetland habitat. In Seabeck Creek, three culverts were replaced, though two of these were primarily road infrastructure projects.
Pre-treatment Data	Comprehensive fish and habitat data collection began in 2003, though some fish data available back to early 1990s.
Physical Results to Date	Significant interannual variation in several metrics but generally not attributable to LWD placement
Biological Results to Date	In Little Anderson, a significant increase in Coho Salmon smolt abundance after 2002 culvert replacement and non-significant increase in Coho Salmon smolt abundance after LWD placement
Top 3 Management Implications	1. Prioritize connectivity in stream restoration – clear cut, large magnitude response in smolt abundance to culvert replacement. Stream connectivity not just about fish passage, it's also critical for transporting sediment and woody debris. 2. Think big! Large magnitude actions are needed to detect restoration effects. 3. Factors external to freshwater habitat (marine survival, harvest) may constrain efforts to improve abundance through stream restoration. Fish response to restoration is most pronounced when treatment alleviates density dependent limits on productivity.
Additional Resources	Coho Salmon and Habitat Response to Restoration in a Small Stream Hood Canal Intensively Monitored Watershed Annual Report 2021 Hood Canal Intensively Monitored Watershed Annual Report 2020 Hood Canal Intensively Monitored Watershed Annual Report 2019 Hood Canal Intensively Monitored Watershed Study Plan

Lemhi River IMW

Location	Idaho
Study Tributaries	The Lemhi River Watershed - Big Timber, Bohannon, Canyon, Hawley, Kenney, and Little Springs Creeks. Hayden Creek is a reference.
Monitoring and Treatment Years	Pre-treatment monitoring: 2007-2008 Treatment: 2009 - present Post-treatment monitoring: 2011-present
Status	Treatment and monitoring ongoing
Focal Species	Snake River steelhead, Chinook Salmon, and Bull Trout
Limiting factors	Lack of connectivity between the Lemhi River and tributaries, reduction of spawning and rearing habitat, reduced flow in the mainstem
Restoration Plan	Tributaries: Prioritize 6 candidate Lemhi River tributaries for reconnection based on productivity, historical fish distribution and feasibility. Mainstem: Increase flow, re-establish floodplain connection, restore riparian function, and improve habitat complexity.
Monitoring Experimental Design	BA and BACI designs. Juvenile density estimates at the sub-basin, tributary, and reach scales. Juvenile distribution and survival.
Restoration Treatment	Barrier removal, flow augmentation, LWD, floodplain reconnection
Magnitude of Treatment	Five of six priority tributaries reconnected, allowing migrations without delay, one partially connected tributary that is not fully connected year-round due to a seasonal barrier at low summer flows. Lower Lemhi River minimum flow agreement: 25-35 cfs through June 30 and minimum of 25 cfs beginning July 1. Large scale restoration projects on mainstem Lemhi River including channel re-meandering, floodplain reconnection, side channel construction, braided channels, and LWD.
Pre-treatment Data	Productivity comparison: 5 years pre-treatment, tributary standing stock: up to 8 years depending on tributary
Physical Results to Date	Tributaries Barrier removals expanded accessible spawning and rearing habitat in Lemhi tributaries. Minimum flow agreement in lower Lemhi River, water conservation measures in select reaches and tributaries, including source switches to redirect water withdrawals from mainstem Lemhi River verses tributary. 10+ mainstem river projects containing LWD for improved habitat complexity. Two projects in the upper Lemhi River and 3 in lower Lemhi River 8 containing expanded floodplain with lateral river channels and LWD.
Biological Results to Date	Juveniles: increase in abundance and upstream expansion of Chinook Salmon, steelhead, fluvial Bull Trout, providing survival advantages of fish using reconnected tributaries. Adults: Steelhead spawning activity in 3 fully reconnected tributaries, Chinook Salmon entry into 2 fully reconnected tributaries, and steelhead entry into 1 partially reconnected tributary, but no observed spawning activity.
Top 3 Management Implications	1. Tributary reconnections in the Lemhi River basin provided additional habitat for spawning adult steelhead and for rearing juvenile Chinook Salmon and steelhead. 2. Newly created braided channels and floodplain reconnections in the Lemhi River were used immediately after implementation by adult and juvenile Chinook Salmon and steelhead. 3. Overwintering habitat for juvenile anadromous fish is limited in the Lemhi River. Increased habitat diversity will result in increased overwinter survival and productivity.
Additional Resources	Intensively Monitored Watersheds and Restoration of Salmon Habitat In Idaho: Ten-Year Summary Report

Lower Columbia IMW

Location	Washington
Study Tributaries	Abernathy, Germany, and Mill Creeks, direct tributaries of the Lower Columbia River
Monitoring and Treatment Years	Pre- treatment monitoring: 2001-2012 Nutrient enhancements: 2010-2015 Habitat treatments: 2012-present Post-treatment monitoring: 2013-2032
Status	Post-treatment monitoring ongoing
Focal Species	Coho Salmon, Chinook Salmon, and steelhead
Limiting factors	Channel complexity, habitat diversity, off-channel/side channel connectivity, floodplain connectivity, habitat accessibility
Restoration Plan	1. Nutrient enhancement in the form of salmon carcass analogs 2. Increase connectivity of off-channel and instream habitats 3. Increase complexity of the instream habitat 4. Improve fish passage in select tributaries 5. Riparian enhancement
Monitoring Experimental Design	BACI. Juvenile production, size/growth, adult returns, Coho Salmon parr apparent overwinter survival, and multiple habitat metrics
Restoration Treatment	Nutrient enhancement (addition of salmon carcass analogs), LWD placement, floodplain reconnection, barrier removal, riparian planting
Magnitude of Treatment	Approximately 30% of habitat accessible to salmonids has been treated in Abernathy and 28% in Germany
Pre-treatment Data	Juvenile production, size/growth, overall productivity (recruits per spawner), and apparent overwinter Coho Salmon parr survival for brood years 2004-2011.
Physical Results to Date	Treatments have resulted in 17.7 km of instream habitat, 1.8 km of off-channel and side-channel habitat, 0.39 km^2 of riparian area, and 2.7 km of improved fish passage
Biological Results to Date	Nutrient enhancement resulted in short-term growth increases in juvenile Coho Salmon following spring treatments but did not translate to increased survival. However, Abernathy has taken over as the highest producer of Coho Salmon in the last 4 years, following intensive LWD placement that began in 2015.
Top 3 Management Implications	1. Juvenile production and life history expression appears to be limited by the quantity and quality of rearing habitat, demonstrated by measured relationships between juvenile abundance and apparent overwinter survival for Coho Salmon and life history diversity for Chinook Salmon. 2. Large-scale wood additions to improve spawning and rearing habitat appear to be having a positive impact on juvenile Coho Salmon apparent overwinter survival (up 68%) and smolt production (up 59%) since implementation in 2015, but further monitoring is needed to detect a response. 3. Nutrient enhancement treatments (e.g., Salmon Carcass Analogs) should be implemented in watersheds with nutrient retention features or coupled with other restoration treatments (e.g., beaver dam analogs) to help retain nutrients within the food web.
Additional Resources	https://www.lcfrb.gen.wa.us/monitoring-habitat-restoration

Methow River IMW

Location	Washington
Study Tributaries	Methow River and Beaver Creek (a tributary of the Methow River)
Monitoring and Treatment Years	Pre-treatment monitoring: 2009-2012 Treatment: 2012-2014 Post-treatment monitoring: 2015-2018
Status	Three years of post-treatment monitoring completed. USBR Completion report in Spring 2019
Focal Species	Upper Columbia River spring Chinook Salmon and upper Columbia River steelhead.
Limiting factors	Habitat fragmentation, reduced flows, reduced habitat complexity, and riparian condition
Restoration Plan	Protect and restore access, flow, and habitat complexity for upper Columbia River spring Chinook Salmon and steelhead
Monitoring Experimental Design	BACI
Restoration Treatment	Methow River: 1 instream flow project, 3 fish screens, 4 fish passage structures, 19 stream and floodplain enhancements, 4 riparian rehabilitation projects, and 50 land acquisitions and easements Beaver Creek: 4 instream flow projects, 1 fish screen, 8 fish passage projects, 4 stream and floodplain enhancements, 2 riparian rehabilitation projects, and 2 land acquisitions
Magnitude of Treatment	Treatment occurred in approximately 8% of the Methow River and 22% of Beaver Creek
Pre-treatment Data	Five years of habitat, fish, and prey data
Physical Results to Date	Yet to be determined
Biological Results to Date	Increase in juvenile growth rate and density
Top 3 Management Implications	Not provided
Additional Resources	Link to USBR Summary Report: https://www.usbr.gov/pn/fcrps/rme/methowimw/metmonitoring2019.pdf

Middle Fork John Day IMW

Location	Oregon
Study Tributaries	Middle Fork John Day and South Fork John Day rivers and tributaries
Monitoring and Treatment Years	Pre- treatment monitoring: 2004- ongoing at the project scale Treatment: 2008-ongoing Post-treatment monitoring: ongoing
Status	Treatments and post-treatment monitoring ongoing
Focal Species	Spring Chinook Salmon, summer steelhead
Limiting factors	Water temperature, degraded floodplain habitat and channel structure, altered hydrology and sediment routing
Restoration Plan	Implemented over 125 restoration projects since 2008
Monitoring Experimental Design	BA, BACI, GRTS
Restoration Treatment	Channel restoration, floodplain reconnection, riparian fencing, LWD placement, log weir removal, fish barrier removal, flow restoration
Magnitude of Treatment	From 2017-2020 partners completed or implemented over 25 major restoration projects including treatment of 29 miles of instream habitat; improving or protecting 14 miles of riparian habitat and removing 58 fish passage barriers.
Pre-treatment Data	Four years of salmonid population abundance and productivity
Physical Results to Date	from 2009-2019 trends in cumulative physical habitat index scores were not statistically significant, but trends indicate that for most metrics stream habitat is improving. However, analyses showed an increase in pool tail fines, across all sites, trending in the opposite direction than desired. This finding is likely a response to sediment sorting and an increase in fines due to the increased hydrologic complexity from large woody debris inputs during restoration. Sites encompassing both passive and active restoration exhibited deeper residual pool depths, narrower greenline-to-greenline channel widths, more habitat units per kilometer (i.e., increased complexity), and higher large wood densities than passive or active restoration actions implemented alone.
Biological Results to Date	Monitoring efforts have not yet detected a change in steelhead or Chinook Salmon productivity at the population scale compared to reference watersheds (Figure 3), and it will likely take several salmonid life-cycles (20-30 years) before improvements in productivity can be detected. While average redd count and spawner abundance has remained static, redd distribution has shifted downstream to restored reaches (– indicating a preferential selection of restored habitat for spawning activity.
Top 3 Management Implications	1. Identify the limiting factor of most concern and implement the restoration actions at a sufficient scale to address that limiting factor. Restoration actions need to occur at a large scale to address the limiting factor and have a detectable fish population response. 2. Removing barriers to improve tributary connection is very important for juvenile rearing. In hot years the fish leave the mainstem and rear in the tributaries to access cold water refugia. In addition, the tributaries provide a cooling effect to the mainstem. 3. Reducing warm water temperatures by improving riparian shading is key. It is crucial to protect riparian plantings from wild and domestic ungulate grazing for many years to allow these plantings to become established and are free to grow.
Additional Resources	Website: http://www.middleforkimw.org/ 2017-2021 Accomplishments Report: https://www.pnamp.org/document/15125 Link to Publications and Reports

Potlatch River IMW

Location	Idaho
Study Tributaries	Potlatch River Basin; Big Bear Creek (BBC) and East Fork Potlatch River (EFPR) watersheds.
Monitoring and Treatment Years	Pre-treatment monitoring: BBC 2005 and EFPR 2008; Treatment: BBC 2013-present and EFPR 2009-present; Post-treatment monitoring: ongoing for both watersheds
Status	Treatments and monitoring ongoing
Focal Species	Snake River steelhead
Limiting factors	Tributary blockages and dewatered reaches in BBC subwatershed, simplified habitat in EFPR subwatershed
Restoration Plan	Barrier removal and flow supplementation in BBC, in-stream LWD and riparian restoration in EFPR.
Monitoring Experimental Design	Hierarchical scaled design (BA, BACI) at the watershed, tributary, and reach scale; adaptive management.
Restoration Treatment	BBC: Barrier removals and flow supplementation. EFPR: LWD placement and riparian restoration.
Magnitude of Treatment	Removed or modified 10 barriers, opened > 18 km. Installed >190 LWD structures, 8.4 km treated. Flow supplementation, >16 km treated (temporary project). Development of projects on private lands still in progress.
Pre-treatment Data	Production and productivity at watershed scale and juvenile density, growth, and survival and habitat conditions at the tributary and reach levels.
Physical Results to Date	Barrier removals or modifications expanded accessible habitat. Water releases <1.0 cfs resulted in restored connectivity, reduced water temperatures, and increased dissolved oxygen (temporary benefits). LWD structures increased aquatic habitat complexity and stream hydrologic function
Biological Results to Date	Spawning by adults in a blocked reach after barrier removal. Use of in-stream structures by juvenile steelhead. Increased proportion of older and larger steelhead emigrants leaving the EFPR and improved survival to Lower Granite Dam. Flow supplementation benefitted growth, survival, and density of juvenile steelhead (temporary benefits).
Top 3 Management Implications	1. Improvements to fish passage barriers resulted in rapid re-colonization of steelhead into blocked spawning and rearing areas in the Potlatch River basin. 2. Extensive large wood additions and floodplain restoration/protection can lead to positive shifts in emigrant life history. Analysis is ongoing to determine primary factors influencing the documented shift in the East Fork Potlatch River. 3. Flow supplementation resulted in more wetted channel habitat and improved water quality during the summer, benefitting growth, survival, and density of juvenile steelhead. Permanently implementing flow supplementation projects has been delayed due to permitting and funding challenges.
Additional Resources	Intensively Monitored Watersheds and Restoration of Salmon Habitat In Idaho: Ten-Year Summary Report Potlatch River Steelhead Monitoring and Evaluation Project- 2019 and 2020 Biennial Report

Pudding Creek IMW

Location	California
Study Tributaries	Pudding Creek and Caspar Creek. Both watersheds drain directly into the Pacific Ocean near Fort Bragg in Northern California.
Monitoring and Treatment Years	Pre-treatment monitoring: 2011 - 2015 Treatment: June - August 2015 Post-treatment monitoring: 2016 - 2020
Status	Completed spring 2020
Focal Species	Central California Coast Coho Salmon and North-Central Coast steelhead
Limiting factors	Overwinter survival due to insufficient habitat complexity and lack of slow water refugia.
Restoration Plan	Additional of large wood at the watershed scale using the accelerated recruitment method (Carah et al. 2014)
Monitoring Experimental Design	Paired watershed BACI with Caspar Creek as the reference watershed. Generalized Linear Modeling, CJS models.
Restoration Treatment	Installation of LWD (n=438)
Magnitude of Treatment	Treated 12.1 km, eighty percent of Pudding Creek, with large wood
Pre-treatment Data	Juvenile abundance, growth, survival, and habitat conditions at the watershed scale.
Physical Results to Date	Increased LWD density, increased summer slow water volume. No change in residual pool depth, pool frequency, winter slow to fast water ratios.
Biological Results to Date	For Coho Salmon, increased growth relative to LWD density in summer and winter. However, growth did not increase more in the experimental watershed compared to the control watershed. No change in survival in winter.
Top 3 Management Implications	1. The accelerated recruitment method of large wood treatment may require more high flow events, time, and natural recruitment to result in increased wood loading that creates habitat and fish response. Extend post-treatment monitoring to better evaluate population level effects response. 2. Wood loading levels were below recommended targets post treatment. Increase initial wood loading to achieve desired effects. 3. Re-evaluate limiting factors and restoration strategies with respect to changing climate.
Additional Resources	Effects of Large Wood Restoration on Coho Salmon in a Northern California Watershed: A Before-After-Control-Impact Experiment: https://digitalcommons.humboldt.edu/cgi/viewcontent.cgi?article=1583&context=etd
References	Carah, J. K., Blencowe, C. C., Wright, D. W., & Bolton, L. A. (2014). Low-cost restoration techniques for rapidly increasing wood cover in coastal Coho Salmon streams. North American Journal of Fisheries Management, 34(5), 1003-1013.

Skagit River Estuary IMW

Location	Washington
Study Tributaries	North and South Forks of the Skagit River.
Monitoring and Treatment Years	Pre-treatment monitoring: 1992-present Treatment: 2001-present Post-treatment monitoring: ongoing in many sites
Status	Treatments and post-treatment monitoring ongoing
Focal Species	Skagit River Chinook Salmon - six wild stocks
Limiting factors	lack of habitat connectivity, reduced rearing habitat
Restoration Plan	Ongoing restoration of tidal habitat in the South Fork of the Skagit River with the North Fork being an unrestored control.
Monitoring Experimental Design	BACI to test for estuary restoration on population effects with North Fork used as a reference. BA with covariates used to test for the effects of estuary restoration upon post-estuarine life stages.
Restoration Treatment	Dike removals, setbacks, and breaches; tidal muting devices, fill removal
Magnitude of Treatment	Skagit River Estuary
Pre-treatment Data	Average juvenile Chinook Salmon size, change in size during rearing, rearing density over the season, timing of residence, changes in timing, marine survival, and frequencies of life history types
Physical Results to Date	Over 600 acres restored, gaining habitat despite erosion losses.
Biological Results to Date	Juvenile residence time increased and estuary-wide densities decreased. Size and densities increased locally at restoration sites.
Top 3 Management Implications	1. Limited availability of estuary habitat causes competition among juvenile Chinook Salmon that constrains abundance, residence period, fish size, and life history types. Limited estuary habitat is likely reducing smolt to adult return rates, yet important uncertainties exist. 2. Restoration in the Skagit estuary has reduced crowding of juvenile Chinook Salmon, leading to larger body size and residence period. Although heading in the right direction, changes in adult returns are not strong enough to attribute to estuary restoration activities in the Skagit. 3. Three factors affecting uncertainty in adult returns are: 1) not enough estuary restoration, which has been offset by natural habitat loss, and 2) large environmental variation in adult returns, and 3) few large outmigrations that could reveal reduced density dependence.
Additional Resources	Skagit River Estuary Intensively Monitored Watershed Annual Report for 2021

Strait of Juan de Fuca IMW

Location	Washington
Study Tributaries	Deep Creek, East Twin River, and West Twin River
Monitoring and Treatment Years	Deep Creek Treatments: 1996-2018 Deep Creek Monitoring: 1992-present East Twin River Treatment: 2000-2011 East Twin River Monitoring: 2002-present West Twin River Monitoring: 2004-present
Status	Treatments complete and posttreatment monitoring ongoing
Focal Species	Coho Salmon, steelhead, and Cutthroat Trout
Limiting factors	Simplified channels with high stream power
Restoration Plan	The goals of restoration were to: 1) increase the amount of in-stream wood, 2) increase overwintering habitat, 3), reduce the frequency of anthropogenic influenced landslides, and 4), restore riparian forest. The IMW treated one third of the anadromous habitat in Deep Creek and the East Twin River. The West Twin River was used as a control watershed because it was similar in size, hydrology, and geomorphology to the East Twin River and Deep Creek
Monitoring Experimental Design	Varies with scale and metric. Could view watershed scale as CI while some habitat measures are BACI
Restoration Treatment	Addition of LWD, fish passage, off-channel development, riparian tree planting, culvert replacement, and road abandonment
Magnitude of Treatment	Treated approximately 1/3 of the anadromous habitat in Deep Creek and East Twin rivers. No treatments were conducted in West Twin River
Pre-treatment Data	Varied by metric and watershed
Physical Results to Date	In the ~6 kilometers of wood placement we saw an increase in wood loading and channel spanning logjams, which contributed to deeper and more frequent pools, a reduction in particle size distribution, increases in sediment storage, reduced stream width, vegetation re-establishment in the riparian zone, and increased development of floodplain channels. The largest geomorphic changes occurred due to restoration wood effectively trapping wood being recruited, mobilized, and routed downstream.
Biological Results to Date	Juvenile Coho Salmon expressed multiple life histories and emigration timing but could not directly link to restoration. Small increases in Coho Salmon and steelhead adults in Deep Creek and East Twin River relative to West Twin River.
Top 3 Management Implications	1. Life history diversity contributes to the abundance of salmon populations. 2. Long-term restoration of habitat, coupled with long-term monitoring can show positive changes to streams and watersheds. 3. Fish response to habitat restoration actions occur, but multiple fish demographics need to be monitored because it is not obvious all the time which will result in a positive response.
Additional Resources	Nomads no more: early juvenile Coho Salmon migrants contribute to the adult return - https://doi.org/10.1111/eff.12144 Life History Diversity of Steelhead in Two Coastal Washington Watersheds - https://doi.org/10.1080/00028487.2016.1194893

Wind River IMW

Location	Washington
Study Tributaries	The Wind River Watershed, Trout Creek, Panther Creek, Upper Wind Subbasin
Monitoring and Treatment Years	Baseline studies/reach-scale work: 1995-2001 Pre-dam removal treatment monitoring: 2000-2009 Dam Removal & Trout Creek Subbasin Restoration: 2009 with some lateral reconnection continuing through present Post-dam-removal monitoring: 2010-present
Status	Post dam-removal monitoring through present; increasing future habitat work focus shifting to other subbasins
Focal Species	Steelhead (primary), Coho and fall Chinook Salmon (secondary; limited to Little Wind River)
Limiting factors	Historical dam construction; Lack of habitat connectivity, low habitat complexity
Restoration Plan	Examine the effects of 1) dam removal (partial passage barrier), and 2) improved channel and floodplain habitat complexity on steelhead abundance and production in the Wind River
Monitoring Experimental Design	The monitoring design was developed around the sub-basin and basin-scales for smolt and adult abundance, with intensive reach-level evaluation of parr abundance and growth. These enable basin-and sub-basin BACI analysis for abundance and a BA for productivity, and capacity, and growth.
Restoration Treatment	Barrier removal (Hemlock Dam) primarily, but also culvert removal, Engineered Log Jams (ELJ) and LWD placement, road decommissioning, and side channel reconnection
Magnitude of Treatment	Treatment primarily in Trout Creek which improved access to 22 km of fish habitat and improved habitat quality in the former reservoir and nearby road-affected floodplain
Pre-treatment Data	Some data from 1992-2000 but primarily 10 years (2000-2009) leading up to Hemlock dam removal
Physical Results to Date	Changes in long profiles, substrate composition and water temperature were quantified and reported in a publication following dam removal
Biological Results to Date	Large increases in steelhead adult returns and smaller increases in smolt abundance in Trout Creek (treatment) vs. Wind River (control)
Top 3 Management Implications	1. Removal of Hemlock Dam (a partial barrier to adult steelhead) appears to be having a very positive response to both juvenile and adult populations in the Trout Creek watershed compared to the rest of the Wind River Subbasin. 2. Full effects (channel aggradation, improvement in riparian health) of LWD treatments in larger floodplain reaches may take many years to be fully realized and thus fish response may also lag. Long-term monitoring is crucial. 3. We need to know more about the diversity of life histories and habitat usage by life stage. There appears to be much movement of juvenile pre-smolt fish that is not well understood.
Additional Resources	Website: https://www.ucdwa.org/wind-river-watershed-project Reports: https://www.cbfish.org/Project.mvc/ProjectDocuments/1998-019-00

Appendix 2 – Questionnaire and Responses

This report is based on information collected in a questionnaire distributed to the PNAMP IMW Working Group in July 2021 and a series of three workshops held in November and December 2021 to discuss results from the questionnaire and develop collective “core messages.” Below you will find the questionnaire that was distributed and a compilation of responses from the 13 participating IMWs. The responses are reported here nearly verbatim with minor editing for clarity.

Questionnaire

Intensively Monitored Watershed (IMW) programs have been active across the Pacific Northwest for over twenty years. These study systems represent one of the few opportunities to understand fish-habitat relationships at watershed scales and across multiple life cycles. This information is essential to salmon and steelhead conservation and recovery programs, which annually invest millions of dollars in habitat projects and population and habitat monitoring. As IMW studies move into post-treatment monitoring phases, preliminary take home messages can help natural resource managers, policy makers, and practitioners more effectively implement recovery and habitat programs, as well as convey the benefits of long-term monitoring at a time when investments in salmon recovery are being reassessed at local, state and federal levels.

Please answer the following questions to the best of your ability or share with IMW partners that are best suited to answer the questions, using plain language that can be adapted for public outreach materials. Major take-home messages across survey responses will be used for communicating IMW study results and benefits from our collective efforts to restoration practitioners, natural resource managers, property owners, tribal, local, state, and federal decision-makers and funders.

We strongly encourage you to respond to these questions in the shared google spreadsheet. In the spreadsheet, questions are on the left and IMWs are listed alphabetically along the top. Questions 2, 3, and 10 have separate tabs in the spreadsheet and are answered using drop-down lists in each cell.

If you have concerns or issues accessing the shared Google spreadsheet, please email Amy Puls (apuls@usgs.gov) and we will arrange an alternate way to submit your responses.

Some of the questions in this questionnaire have been asked in past synthesis efforts (i.e., the WA GSRO survey distributed in February of 2021 to SRFB funded IMWs in Washington, and the PNAMP IMW questionnaire distributed in November of 2017 to all PNW IMWs). For these questions, the spreadsheet has been prepopulated with your previous survey responses. Please review this information and edit if necessary.

Responses are due by August 15th, 2021.

1. Briefly explain the original goal/intent of your IMW and the parameters being monitored.
2. What types of restoration are being assessed in your IMW in relationship to the targeted species and life stages? Are the restoration methods and approaches being implemented in your IMW designed to address watershed processes and/or site-scale needs? Using the drop-down menus in the spreadsheet, identify the scale for each combination of restoration type, targeted species, and life stage that is applicable.

    Treatments: barrier removal, beaver dams, boulders, ELJ, floodplain reconnection, flow augmentation, hatchery augmentation, LWD, nutrient addition, reconnection of tidal channels, tidal wetland inundation, riparian improvement, road abandonment, screens

    Species: Steelhead, Coho Salmon, Chinook Salmon, Cutthroat Trout, Bull Trout, Pacific Lamprey

    Life stages: juvenile, adult

    Scales: WS=watershed scale, SS=site scale, Both=watershed and site scale, blank=not applicable

3. How long do you anticipate the treatments and their benefits in your IMW to last? Using the drop-down menus in the spreadsheet, identify the length of time each applicable treatment type is anticipated to be functional.

Treatments: barrier removal, beaver dams, boulders, ELJ, floodplain reconnection, flow augmentation, hatchery augmentation, LWD, nutrient addition, reconnection of tidal channels, tidal wetland inundation, riparian improvement, road abandonment, screens

Time periods: 0-5 years, 5-10 years, 10-20 years, 20-30 years, 30+ years, self-sustaining, blank=not applicable

4. Questions 4a-h ask about insights the IMWs are revealing. Note in your responses if you can draw any preliminary conclusions, trends, or patterns, and if these are statistically significant results or there is instead simply a weight of evidence you can document to support these statements.
    a. Have fish populations responded to habitat improvements to date? Describe responses and why, or why not, you think you are observing these.
    b. What were some key assumptions and were they validated during the course of the study?
    c. What are the IMW's strengths (best/most valuable/strongest elements) that should be shared with funders (e.g., ability to shed light on restoration efficacy, understanding outcomes of specific restoration types, etc.)?
    d. What are you learning about the spatial scale of restoration needed to achieve population scale responses?
    e. Share any insights regarding the importance of restoration sequencing and watershed location to effective restoration strategies.
    f. Are there factors not being addressed by restoration treatments that are limiting fish response? Predation, competition, climate change, ocean conditions, land use, harvest, hatchery, etc.
    g. What are you learning about salmon life history (e.g., run timing, abundance, juvenile emigration/outmigration timing, etc.)? What are you learning about the relationship between salmon life history and in-stream restoration and overall habitat diversity?
    h. What are you learning about the role of floodplain and upland land use in shaping habitat conditions and achieving restoration outcomes?
5. What types of watersheds do you think IMW results are applicable to in terms of legacy and current land uses, watershed size, stream order, flow regimes, and other watershed characteristics? And, what watershed characteristics or treatment types are not applicable for restoration activities being evaluated by the IMW?
6. To what degree can preliminary results be extrapolated to other salmon and steelhead populations in terms of limiting life stages, life histories, and geographic location?
7. How is what you are learning being translated into information that can be used to inform policy, funding, and salmon recovery and watershed restoration decisions? Give examples. Do you have suggestions on how these types of outreach efforts could be improved?
8. Do you have recommendations on how to work with landowners on successful project development and implementation?
9. What haven't you learned from your IMW that you expected to learn? Is it attainable with more time? If yes, estimate how long it would take to get the thing you expected to learn?
10. What issues have arisen during the study that have compromised your ability to address the primary study objectives? Using the drop downdrop-down menus in the spreadsheet, please respond to the following categories with yes or no; we will discuss the details at the workshop.

    Categories: unanticipated difficulties with study design, insufficient number and size of restoration actions in the treatment watersheds, the treatment phase being so long the ability to measure response was impacted, unanticipated environmental variability obscuring treatment effects, other.
11. What are the key items that would be lost or that we would miss out on if IMW funding decreases or disappears?

12. What do you see as your minimum and desired funding levels over the next 5 years? Please specify if there are specific, one-time, funding needs outside of the regular monitoring activities, such as data analysis, synthesis, and/or outreach and communication.

Compiled Questionnaire Responses

Question 1

Briefly explain the original goal/intent of your IMW and the parameters being monitored.

IMW responses

Asotin Creek: The goals of the IMW are to test the effectiveness of LWD additions at 1) increasing channel complexity, promoting and sustaining overbank flow, floodplain connection, riparian extent and function, and riverscape physical and biological processes (e.g., erosion, deposition, and sustained wood accumulation) and 2) increasing freshwater productivity and production of juvenile steelhead. We are also attempting to fully develop and test an alternative restoration strategy for dealing with structural starvation (i.e., loss of LWD and beaver dams from stream) using post-assisted log structures (PALS) and beaver dam analogues (BDAs). We call the restoration approach low-tech process-based restoration of riverscapes and the goal is to cost-effectively add wood, protect recovering riparian habitat, and expand the scale of restoration (i.e., miles treated) to address the large scope of riverscape degradation (i.e., 10,000’s of km of degraded streams). To assess fish populations, we partner with WDFW that operate an adult weir and smolt trap near the mouth of Asotin Creek. The fish-in fish-out operation provides a wealth of life-history data as well as estimates of adult escapement and juvenile emigrants. The IMW is implemented in three tributaries of Asotin Creek (Charley, North Fork and South Fork Asotin creeks), we conduct two-day mark-recapture in the summer and fall and tag all unmarked juvenile steelhead > 70 mm with 12 mm passive integrated transponder (PIT) tags. From the summer and fall PIT tagging data, we estimate site abundance (fish/km) and biomass (g/km). We then estimate annual growth, survival, and production rates across two periods: summer to fall and fall to summer. We also estimate juvenile emigration and productivity (smolts/year and smolts/female by brood year) by estimating the age of PIT tagged juvenile steelhead from 10%~ subsample of scales, tag detections at PIT tag interrogation sites (of juveniles and adults), and the ratio of tagged/untagged juveniles in the study creeks to estimate total juvenile emigrants. There are four PIT tag interrogation sites, two located at the mouth of each IMW study stream, and two located near the mouth of Asotin Creek. We also monitor stream temperature and discharge throughout Asotin Creek and the study creeks. We also monitor a wide range of stream habitat attributes using the Columbia Habitat Monitoring Protocol as well as collect detailed topographic data of habitat sites which allows the creation of digital elevation models which can be used to derive rates of erosion and deposition and support various modeling tools for assessing restoration effectiveness (e.g., Net Rate of Energy Intact, Geomorphic Unit Delineation).

Bridge Creek: To test the effectiveness of installing beaver dam analogs (BDAs) at 1) promoting the establishment of persistent beaver complexes leading to channel aggradation and increased floodplain and groundwater connectivity and 2) increasing freshwater productivity and production of juvenile steelhead. We are also attempting to fully develop and test an alternative restoration strategy for dealing with structural starvation (i.e., loss of LWD and beaver dams from stream) using BDAs. We call the restoration approach low-tech process-based restoration of riverscapes and the goal is to cost-effectively to mimic, promote, and sustain beaver activity to reconnect floodplains and expand the scale of restoration (i.e., miles treated) to address the large scope of riverscape degradation (i.e., 10,000’s of km of degraded streams).

Elwha: The intent of removing the Elwha River dams was to restore connectivity to the entire watershed and allow for natural watershed processes related to the movement of water, sediment, nutrients, and energy longitudinally and laterally.

Hood Canal: The goal of the Hood Canal IMW is to evaluate restoration effectiveness by determining if, when and how restoration measurably improves fish population status. We focus primarily (but not exclusively) on Coho Salmon because the species inhabits fresh water for a full year prior to seaward migration, and therefore is exposed to the full seasonal range of stream conditions. The habitat monitoring was intended to address the "how" question by helping describe the mechanism by which restoration might benefit salmon populations. In essence, the Hood Canal is a watershed-scale restoration effectiveness experiment.

Lemhi: The Lemhi River IMW study is designed to evaluate fish and habitat responses to restoration actions in the Lemhi River basin and use the information learned to help guide and prioritize future habitat project implementation. Results from this study provide a better understanding of the relationship between habitat and fish at specific life stages and are used in fisheries conservation and management. The main objectives of the Lemhi River IMW study are:

- Monitor changes in distribution, abundance, and survival of Chinook Salmon, steelhead, and resident/fluvial salmonids of all life stages (fry, parr, presmolt, smolt, and adult) in the Lemhi River, Hayden Creek, and candidate tributaries for reconnection.
- Measure changes in productivity (number of juveniles per adult) of Chinook Salmon and steelhead
- Monitor fish population and habitat responses to individual restoration projects and specific habitat treatment types.

Lower Columbia: The original goal of the Lower Columbia (LC) IMW project was to evaluate the effects of freshwater habitat actions on production of juvenile Coho Salmon (ESA threatened), but focal species have expanded to include Chinook Salmon (ESA threatened) and steelhead (no listing status). Historically, watersheds in the LC IMW complex were impacted by land use that disrupted sediment transport processes and disconnected riparian and instream ecosystems. Habitat improvement actions were planned for Abernathy and Germany creeks, while Mill Creek provided a reference watershed with no improvement actions. Subsequently, restoration has been implemented to increase the carrying capacity and productivity of salmon and steelhead, and to increase adult spawning spatial distribution. These habitat treatment actions target limiting factors such as habitat complexity, connectivity, passage barriers, and nutrient enhancement. Parameters being monitored annually include: (1) fish life cycle metrics (population productivity, spawner abundance and distribution, smolt abundance in spring, Coho Salmon parr abundance and distribution in summer, Coho Salmon overwinter survival, and juvenile growth); (2) habitat metrics (large woody debris density, percent pools, percent gravel, thalweg depth, and percent side channels); and (3) water quality and quantity (stream flow and stream temperature).

Methow: Protect and restore access, instream flow, habitat complexity for juvenile upper Columbia River spring Chinook Salmon and upper Columbia River steelhead. The Methow does not, and never had, a formal IMW structure. We had specific studies related to restoration effectiveness as well as a host of status and trends monitoring, but this was not coordinated or designed under an IMW. Bull Trout are an ESA species of interest in the Methow. Increasing floodplain connectivity and improving riparian condition and water quality are also goals of our work.

Middle Fork John Day:

a. Compare changes in watershed-scale productivity as a result of restoration actions in MFIMW for summer steelhead and spring Chinook Salmon relative to the South Fork John Day and upper mainstem John Day rivers.

b. Learn how specific restoration actions influence salmonid abundance, survival, and growth at the reach and project-scale.

c. Understand how specific restoration actions impact instream habitat, riparian condition, and water temperature at the reach, project, and watershed scales.

Potlatch: The goal of the Potlatch River IMW study is to evaluate fish and habitat responses to habitat restoration projects in the Potlatch River basin. The study is designed to assess responses in steelhead production and productivity at multiple scales: 1) a broad-scale monitoring effort to document steelhead response within two index watersheds, Big Bear Creek (BBC) and the East Fork Potlatch River (EFPR); 2) a finer-scale effort to assess habitat and fish response to restoration projects at the tributary level; and 3) reach-scale monitoring to assess whether individual projects produced the intended outcome. The study design allows managers to better understand the relationship between a habitat action and fish response and how localized responses to restoration propagate up to a higher, management-scale level.

The main parameters we are monitoring:

- Watershed scale: juvenile steelhead emigrant abundance, adult steelhead escapement, freshwater productivity (juvenile recruits per spawner), and emigrant & adult steelhead life history metrics.
- Tributary scale: juvenile steelhead density, growth (summer to fall), and survival. Habitat conditions including the amount of wetted habitat, LWD density, pool density, canopy cover, water temperature and flow conditions.

<u>Pudding</u>: The goal of this study was to evaluate salmonid and habitat response to a large wood restoration treatment in a coastal California stream. We initiated a Before-After Control-Impact paired watershed experiment in Pudding Creek and Caspar Creek, Mendocino County, Calif. By strategically adding large wood to 80% of Pudding Creek, we aimed to increase channel complexity and restore processes that lead to future wood recruitment and floodplain connectivity, improving the habitat thought to limit Coho Salmon and steelhead production. We hypothesized that adding large wood would increase habitat heterogeneity of winter and summer habitat, and thereby improve growth, survival, and abundance of juvenile Coho Salmon and steelhead.

<u>Skagit</u>: The original goals of the Skagit IMW were:
1) to determine the cumulative effects of estuary restoration (i.e., improvements to both connectivity and capacity in the delta) upon the following characteristics at the population scale: juvenile density, size, timing, residence, recruitment to nearshore, and marine survival of natural-origin Chinook Salmon; and
2) to estimate how these factors influence demographic trajectories of Skagit River Chinook Salmon populations.
3) provide long-term sampling of the juvenile Chinook Salmon populations in the estuary and Skagit Bay nearshore as restoration projects were completed. Effectiveness of individual restoration projects were not to be covered by the IMW, but were monitored by SRSC as part of the restoration efforts. The IMW also depended on outmigrant trapping performed by WDFW, funded separately through status and trends dollars.

<u>Strait of Juan de Fuca</u>: Goals are to 1) increase in channel wood, 2) increase over-winter habitat, 3) reduce rate of anthropogenic landsliding, 4) restore functional riparian forests.

<u>Wind River</u>: The goal of the Wind River project is to restore wild steelhead populations through active and passive restoration actions and maintain a research and monitoring program to assess wild steelhead Viable Salmonid Population (VSP) metrics, response to habitat actions, and populate a life cycle model. The Wind River project has monitored adult and smolt wild steelhead abundance for over 20 years. Additional work on parr life-history strategies, growth, and survival is ongoing. A network of screw traps and instream PIT tag detection systems allow for resolution at watershed scales (Trout Creek, Upper Wind, and Panther Creek) and the subbasin scale. Although not funded specifically under an IMW Program, we have some commonalities. Restoration has included removal of Hemlock Dam on Trout Creek, reach scale LWD and ELJ placement to restore floodplain processes in alluvial reaches, ELJ placement to reconnect side channels, and a Carcass Analog Study in two small tributaries. In the Little Wind River, a tributary in the lower watershed accessible to Coho and Chinook Salmon, LWD has been extensively added to increase channel complexity.

Question 2

What types of restoration are being assessed in your IMW in relationship to the targeted species and life stages?

Treatments: LW or ELJ for instream complexity, LW or ELJ for lateral connectivity, riparian restoration or protection, longitudinal reconnection (e.g., dam removal, culvert replacement), beaver dam analogs, lateral reconnection (e.g., removal of dikes, levees), road abandonment, flow augmentation, boulders, nutrient addition, fish protection screens, hatchery augmentation

Species: Steelhead (STT), Coho Salmon (COS), Chinook Salmon (CHS), Cutthroat Trout (CUT), Bull Trout (BUT), Pacific Lamprey (LAY)

Life stages: juvenile (J), adult (A)

Table of IMW responses*

	# of IMWs assessing	Asotin	Bridge	Elwha	Hood Canal	Lemhi	Lower Columbia	Methow	Middle Fork John Day	Potlatch	Pudding	Skagit	Strait of Juan de Fuca	Wind
Treatments														
LW or ELJ for instream complexity	11	X		X	X	X	X	X	X	X	X		X	X
LW or ELJ for lateral connectivity	11	X		X	X	X	X	X	X	X	X		X	X
Riparian restoration or protection	9	X			X	X	X	X	X	X		X		X
Longitudinal reconnection (e.g., dam removal, culvert replacement)	8			X	X	X	X	X	X	X				X
Beaver dam analogs	7	X	X		X	X		X	X	X				
Lateral reconnection (e.g., removal of dikes, levees)	6				X	X		X	X	X		X		
Road abandonment	6				X		X		X	X			X	X
Flow augmentation	3					X			X	X				
Boulders	3					X		X	X					
Nutrient addition	2						X							X
Fish protection screens	1								X					
Hatchery augmentation	1							X						
Targeted Species														
Steelhead	12	J, A	J, A	J, A	J, A	J, A	J, A	J, A	J, A	J, A	J, A		J, A	J, A
Chinook Salmon	8	J, A		J, A		J, A	J, A	J, A	J, A			J		J, A
Coho Salmon	7			J, A	J, A		J, A	J, A			J, A		J, A	J, A
Cutthroat Trout	4			J, A	J	J, A							J, A	
Bull Trout	3	J, A		J, A		J, A								
Pacific Lamprey	2	J, A		J, A										

* Please note that responses to Question 2 may differ from results presented in report Table 2; several rounds of feedback and revisions took place to agree on terminology and how to best represent complex information in simplified ways.

Question 3

How long do you anticipate the treatments and their benefits in your IMW to last? Using the drop-down menus in the spreadsheet, identify the length of time each applicable treatment type is anticipated to be functional.

Treatments: LW or ELJ for instream complexity, LW or ELJ for lateral connectivity, riparian restoration or protection, longitudinal reconnection (e.g., dam removal, culvert replacement), beaver dam analogs, lateral reconnection (e.g., removal of dikes, levees), road abandonment, flow augmentation, boulders, nutrient addition, fish protection screens, hatchery augmentation

Time periods: 0-5 years, 5-10 years, 10-20 years, 20-30 years, 30+ years, SS (self-sustaining), blank=not applicable

Table of IMW responses

	# of IMWs assessing	Asotin	Bridge	Elwha	Hood Canal	Lemhi	Lower Columbia	Methow	Middle Fork John Day	Potlatch	Pudding	Skagit	Strait of Juan de Fuca	Wind
Treatments														
LW or ELJ for instream complexity	11	10-20		20-30	20-30	20-30	10-20	10-20	10-20	20-30	10-20		20-30	20-30
LW or ELJ for lateral connectivity	11	10-20		20-30	20-30	SS	SS	10-20	10-20	20-30	10-20		20-30	20-30
Riparian restoration or protection	9	SS			SS	SS	SS	30+	SS	SS		30+		SS
Longitudinal reconnection (e.g., dam removal, culvert replacement)	8			SS	30+	SS	SS	SS	30+	SS				SS
Beaver dam analogs	8	5-10	SS		0-5	10-20		5-10	SS	0-5				
Lateral reconnection (e.g., removal of dikes, levees)	6				SS	SS		SS	SS	SS		30+		
Road abandonment	6				SS		SS		SS	SS			SS	SS
Flow augmentation	3					20-30			SS	SS				
Boulders	3					SS		10-20	SS					
Nutrient addition	2						0-5							0-5
Fish protection screens	1								10-20					
Hatchery augmentation	1							30+						

Questions 4a-h ask about insights the IMWs are revealing. Note in your responses if you can draw any preliminary conclusions, trends, or patterns, and if these are statistically significant results or there is instead simply a weight of evidence you can document to support these statements.

Question 4a

Have fish populations responded to habitat improvements to date? Describe responses and why, or why not, you think you are observing these.

IMW responses

Asotin Creek: Yes. We have seen modest increases in juvenile steelhead abundance (fish/km) ranging from 15-40%. This equates to between ~140-600 juveniles/km. We have also seen increases in Biomass (g/km), Production (g/km/period), and an increase in smolts produced in treatment areas compared to control areas.

These fish responses are still being evaluated. All three IMW streams are showing the same trend with the larger streams showing the greatest increases. We have seen large increases in habitat diversity due to the restoration structures and we believe the structures are responsible for the positive fish responses . It is less clear what life stage is benefitting the most from restoration, but it appears to be the fry stage. The mechanism for this response could be that LWD is providing more cover and refuge from high flows for fry compared to age $\geq$ 1 fish. Growth and survival of PIT tagged steelhead appear to not have changed in restoration areas compared to control areas suggesting that increased growth and/or survival of younger ages classes may be responsible for this increase.

Bridge Creek: Relative to our control watershed, 168%, 52%, 175% increase in juvenile steelhead abundance, survival, and production, respectively, post-treatment (2010-2013) than pre-treatment 2009. We collected information from 2014-2016 in which we continued to see about the same difference in abundance post-treatment, but survival, growth and production was not analyzed. Funding for the project was terminated in 2016. Recently a new source of funding was obtained and fish sampling resumed again this year 2021. This year was extremely warm and flows were very low, and steelhead abundance also appears low, relative to our control watershed. Our control watershed is farther up the John Day River drainage, where water temperatures are cooler. This might suggest that restoration can provide benefits unless temperature becomes limiting.

Elwha: Initial response to dam removal by Chinook Salmon and steelhead was an increase in the number of returning adults and their watershed distribution over the pre-removal run size and area. Hatchery production and harvest restrictions have helped to increase Elwha Chinook Salmon and winter steelhead abundance, particularly during dam removal. Naturally produced juvenile Chinook Salmon and steelhead outmigrant abundance increased three years after adult passage was restored, suggesting that short-term impacts due to downstream sedimentation during and immediately after dam removal were short-lived. We have also observed a natural "reawakening" of the summer steelhead, particularly above the former dams. Our results suggest an integrated set of habitat, hatchery, and harvest actions can result in positive responses to salmonid populations.

Hood Canal: Yes, the most dramatic response to restoration has been a large magnitude, immediate increase in Coho Salmon smolt abundance in Little Anderson Creek following replacement of a barrier culvert with a bridge near the creek mouth. We think this response was strong because restoration immediate restored access to existing habitat that was capable of supporting spawning and rearing. The response to LWD placement has been less pronounced, we have observed non-statistically significant increases in one but not all life stages.

Lemhi: In the Lemhi River watershed, both anadromous and resident fish have responded positively to habitat improvements. A prime example is recolonization of reconnected tributaries by juvenile Chinook Salmon and steelhead. We have documented that reconnected tributaries have provided important rearing and overwinter habitat for salmon and steelhead by increasing habitat quantity and quality. Juvenile abundance and survival has increased for fish that spend the winter in the upper Lemhi River tributaries rather than the mainstem river. Tributaries also provide thermal refugia during summer when main stream temperatures can approach lethal. For example:

- Juvenile salmon abundance in Big Timber Creek has increased. Adult salmon spawning has not been documented in Big Timber Creek in recent years, which could be attributed to low escapement into the Lemhi watershed. Nonetheless, tributaries are providing crucial rearing habitat to early life stages.
- There has been an increase in the number of smolts per redd emigrating from the upper reach of the Lemhi River relative to Hayden Creek (serves as a reference system for statistical comparisons of fish populations because it has maintained a perennial connection with the Lemhi River following agricultural development in the basin and provides insight into the historical importance of tributaries in the Lemhi River basin).
- Over the past several years, adult steelhead have been observed spawning in Little Springs Creek, which prior to restoration, was partially disconnected from the Lemhi River during critical migration periods.
- Adult fluvial Bull Trout have been observed in reconnected tributaries. Bull Trout that spawn in Bear Valley Creek (tributary of Hayden creek) have been observed migrating into two reconnected tributaries (Big Timber Creek and Little Springs Creek) in the upper Lemhi River.

Lower Columbia: Projects in the LC IMW watershed were only recently concluded in 2021. It is too soon after completing restoration projects to detect a fish population response to habitat improvements. In Abernathy Creek, the site of major ELJ, LWD, and floodplain reconnection projects, we may be seeing the beginning of a population response with juvenile abundances higher in this system in recent years compared with either the reference watershed or the other treatment watershed, where there has been relatively less restoration.

Methow: If we look at numbers of returning adults, as well as Bull Trout populations, fish are not responding well to the efforts to improve habitat conditions. Population numbers are currently approaching very low abundance. That said, numerous observations indicate that target species and life stages are using restored areas (i.e., floodplains, areas upstream of repaired barriers, large wood structures), but, I would argue, recent monitoring has not been robust enough to elucidate the fate of these fish. The work of USBR and researchers has shed some light on several projects, but these were fairly limited in scope and treatment type and there were some significant logistical issues with these studies. These studies do show some improvement in growth and survival, but more work is needed to fully address this situation. My sense is that out of basin conditions (ocean and mainstem Columbia River and reservoirs) are exerting significant negative pressures on Methow fish.

Middle Fork John Day:

1. Watershed scale fish population abundance and productivity values have not statistically improved from 2004-2021. This may be due to many factors including: limited statistical power of BACI design, influential conditions outside the MFIMW area, unexpected positive increases in reference populations, limited temporal scope (esp. response time for riparian growth to affect water temperature through shading), limited spatial scope of key restoration actions (e.g., limited riparian regeneration and resultant shading), limited access to key habitats for restoration actions, delays in restoration implementation, and drought conditions.
2. Work conducted by the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWS) showed a significant shift of Chinook Salmon spawning activity from upstream unrestored reaches to the downstream restored CTWS reach at Oxbow Conservation Area (Oxbow). The key word here is “shift,” we did not observe a change in overall spawning density across the MFIMW. We expect that in high Chinook Salmon escapement years the habitat improvement project at Oxbow will increase overall productivity due to an increase in spawning habitat capacity.
3. The observed shift in spawning distribution from long-term consistent data collection, has led to investigations of juvenile salmonid movement, use, distribution, growth and survival at the Forrest Conservation Area restoration project and reach scale. This work is currently in the pre-restoration phase, and we hope will help answer questions about restoration at a reach scale. Restoration project implementation will occur in 2022, so stay tuned for results that can describe what the juvenile response is to these restoration efforts.

Potlatch:

- We documented an expansion of adult steelhead spawning distribution following barrier removals/modifications in the lower Potlatch River watershed. The expansion of spawning distribution was documented via telemetry and genetic techniques and is statistically significant.
- We documented positive responses in juvenile steelhead growth, survival, and density in response to a flow augmentation study in the lower Potlatch River watershed. The positive responses were short term and did not persist because the flow study was a pilot project that only lasted 2 years.
- We documented improvements to juvenile steelhead rearing conditions in response to a flow augmentation study, including increased rearing habitat, improved pool density and connectivity, and moderated stream temperatures and dissolved oxygen levels. The positive responses were short term and did not persist because the flow study was a pilot project that only lasted 2 years.
- We have documented an initial watershed-scale response in juvenile steelhead in the upper Potlatch River watershed. We have observed positive shifts in juvenile steelhead age structure, growth, and survival during

recent treatment years. We hypothesize that as habitat conditions improve, juveniles will rear longer in the watershed instead of emigrating early and emigrant growth will increase as a result of improved energetic conditions in the drainage.

Pudding: We did not see obvious treatment-based juvenile salmonid response. Coho Salmon smolt abundances decreased in Pudding Creek in the post-treatment period, as juvenile growth, and survival rates as well as wood density increased. Both watersheds experienced a similar increase in growth rates between treatment periods. Decreased smolt abundance post-treatment was not due to fewer spawning adults. Analysis of habitat data from site specific CHaMP surveys and watershed level summer habitat surveys showed increases in large wood and slow water habitat post-treatment. Although large wood density increased in both watersheds from pre- to post-treatment, we found evidence that it increased more in Pudding Creek compared with Caspar Creek. Some geomorphic changes were observed at a more localized level due to wood treatment. We did not observe increases in other habitat metrics evaluated, which may be why we did not observe a fish response. In addition, drought conditions in the pretreatment period may have played a role in increased growth and survival detected in both watersheds post treatment. In addition to effects drought, we also believe that juvenile density affected differences in growth between the watersheds.

Skagit: Yes -- cohorts are rearing at lower densities, achieve larger average body size and have extended estuary timing. Marine survival has improved in the right direction.

Strait of Juan de Fuca: Results are mixed - please refer to the Strait of Juan de Fuca IMW Annual Reports, and the 2018 retrospective synthesis report for in-depth analyses of fish population responses.

Wind River: There have been several restoration actions in the Wind River that have provided opportunity to assess effects. Because the Wind River does not receive direct IMW Funding (we are primarily Bonneville Power Administration funded, though Forest Service and other funding entities provide money for actual restoration), much of the restoration is somewhat opportunistic within our restoration and monitoring group. Restoration actions to date have included the removal of Hemlock Dam (a partial upstream migration barrier to steelhead) on Trout Creek, a major floodplain restoration effort in a headwater reach of the mainstem Wind River (Mine Reach Project) involving LWD and ELJ placement to aggrade the channel, increase complexity, and reconnect side channels, and an effort in the Little Wind River involving ELJs to increase complexity and retain spawning gravels for anadromous spawning. Additionally, a carcass analog study was done in small tributaries to assess changes in primary production and fish growth.

Our most robust monitoring of steelhead response to a restoration action involves removal of Hemlock Dam on Trout Creek in 2009. Hemlock Dam did have an adult fish ladder however, we documented adult steelhead avoidance of the ladder and the trap that was operated there for adult census. Monitoring of the response to Hemlock Dam removal has been ongoing for both adult and juvenile steelhead using a BACI design with the rest of the Wind River watershed acting as control. Although it is preliminary in nature, data to date for both juvenile and adult steelhead in Trout Creek suggest an increase in abundance of both relative to the rest of the Wind River Subbasin. These apparent increases in abundance are important in that removal of even partial barrier may have population effects.

The Mine Reach restoration effort involved placement of LWD and ELJs in 4.8 kms of alluvial reach of the mainstem Wind River. Over 1,700 logs were placed. The Mine Reach restoration effort was completed in 2000. Physical habitat changes in the Mine Reach following the treatment included: LWD increased from 42 to 210 pieces per kilometer, pool volume increased, low flow width/depth ratios decreased 56%, and qualitative observation indicated that channel aggradation has begun and multiple side channels were reconnected. Juvenile steelhead abundance data in the Mine Reach (treatment) and both upstream and downstream untreated (control) reaches were collected as part of a concurrent study. During years following, abundance of age-1 steelhead in the Mine Reach increased markedly compared to an upstream control reach. During the years 2005 – 2007 age-1 steelhead abundance decreased in a downstream untreated reach, but increased in the Mine Reach. Age-0 abundance changes were mixed, with similar values to an upstream control reach, but increasing abundance relative to two downstream control reaches, where age-0 steelhead abundance decreased. These data suggest the increase in LWD and habitat complexity favored age-1 steelhead rearing.

The Little Wind River restoration effort involved ELJs to increase instream complexity and retain spawning gravels. About 2 km of stream was treated with about 100 logs, as well as boulders, and removal of streamside berms. Restoration actions began in 2014 and completed in 2019 Following treatment, redd counts for Coho Salmon have increased in the Little Wind River. Though we lack a control reach we believe that the restoration effects have benefitted anadromous spawning and rearing habitat.

The carcass analog study (2005 and 2006) was completed in two tributary streams with control and treatment reaches. The addition of carcass analogs in the summer and fall to two oligotrophic-mesotrophic streams in the Wind River watershed significantly increased the growth of steelhead, produced mild to moderate increases in periphyton and insect production, and, for the most part, did not negatively impact water quality. The growth rates of fish in stream sections that received analogs were 10 – 150 times higher than those of fish in untreated control sections. Results indicate that seasonal additions of analogs can provide a temporary boost in productivity to streams that may be nutrient deficient due to low runs of salmonids. However, any benefits of the nutrient subsidy we provided to these streams may be only short lived. Questions remain, for example, about whether short term increases in fish growth, such as those seen in our treatment fish, actually translate into increased overwinter survival, more productive smolt outmigrations and, ultimately, increased adult returns.

Difficulties have been in knowing what restoration actions are coming and having time to enact monitoring to include any site specific study. Funding limitations also constrain our ability to enact site specific monitoring or to increase our resolution on some questions and metrics. Additionally, control sites can be difficult to identify, and because conditions are not static, control areas can concurrently be changing through active or passive measures. This highlights the need for long-term studies with stable funding mechanisms to ensure consistency of data collected.

Our current monitoring network provides good resolution in multiple sub-watersheds and is a strong setup to evaluate watershed effects of large scale restoration. Monitoring of steelhead parr life-histories, growth and survival, coupled with Viable Salmonid Population (VSP) parameters and life-cycle monitoring provide numerous metrics with which to assess future large-scale restoration. US Forest Service is proposing large scale instream restoration in the upper Trout Creek watershed (some side channel reconnection work has been recently completed in lower Trout Creek and additional work there is planned). We hope to continue monitoring relative to other sub-watersheds to assess response of various metrics for adult and juvenile steelhead in the Wind Subbasin.

Question 4b

What were some key assumptions and were they validated during the course of the study?

IMW responses

Asotin Creek: Key assumptions were: 1) there was a lack of LWD, 2) that there was a lack of cover and flow refugia, 3) there was a lack of quality feeding areas, 4) there was a lack of pools, bars, and side-channels and 5) that these habitat limitations were limiting juvenile steelhead production. As we continue to collect and analyze pre and post-restoration data it appears that there is evidence for many of our initial assumptions. 1) We have increased the frequency of LWD by >100-800% and believe that the current frequency is still not as high as reference conditions (i.e., higher densities of LWD could lead to more improvements in habitat conditions). Also, the density of LWD jams has increased > 100-400% and we have noted that jams are often responsible for creating more complexity. 2) Our fish results suggest that fry may be benefiting more from the restoration as growth and survival has not changed in $\geq$ 1 age fish, suggesting that fry are benefiting from the cover and refugia provided by PALS. 3) We have not seen changes in growth in $\geq$1 ages but we have seen increases in abundance which suggests that there are either more feeding areas/km or higher quality feeding areas thereby allowing more fish/km with no decrease in growth. 4) We have seen increases in pools and bars and these were observed almost exclusively around LWD structures (PALS) suggesting that the lack of LWD had led to a loss of pools and bars. We have not seen a significant increase in side-channels but feel that with further maintenance and enhancement of LWD additions, along with strategic implementation of BDAs to maximize floodplain conntection, we could see a large increase in side-channels and overall floodplain connection. This is likely due to time it takes to aggrade the channel (i.e., capture sediment and build bars), the resistance of the banks and channelized nature of the streams, and because log jams do not generally force overbank flow at low flows (but BDAs can).

Bridge Creek: Key assumptions were that the lack of larger woody material prevented beaver from building longer lasting dams, slowing the rate at which they could help aggrade the incise channel, reconnect the floodplain and create more fish habitat. Once BDAs were added to the system we observed 6-fold increase in the number of natural beaver dams including those built on BDAs. Beaver dams built on BDAs last 8 fold lower failure rate than natural beaver dams.

Elwha: Probably the greatest assumption was that sedimentation impacts during dam removal would be so high as to cause widespread mortality of Elwha River salmon populations. Because of this, hatcheries were heavily utilized to conserve genetic integrity during dam removal. The effectiveness of this strategy is still being evaluated.

Hood Canal: A key assumption of the study was that the collaborative IMW team (monitoring scientists, SRFB, restoration practitioners) would have sufficient control over factors affecting salmon abundance that the study could be treated as a watershed-scale experiment. For example, a fundamental expectation of the study was that restoration would be of sufficient spatial extent and magnitude that it could measurably improve fish population status. However, restoration has generally not occurred at the rate or magnitude desired for a punctuated experiment. Additional factors outside the control of researchers likely also affect study outcomes. For example, marine survival and harvest play a role in adult abundance, which appears to be below habitat capacity in most years, possibly making it more difficult to detect a response to restoration. While these issues may not be ideal from a research perspective, we feel they are representative of the challenges facing salmon recovery. Therefore, IMW study results present important learning opportunities for salmon recovery, despite a lack of tight experimental control over all the factors affecting population status.

Lemhi:

- Tributary reconnections should increase the amount of spawning and rearing habitat accessible to migratory salmonids.
    - To date, we have observed multiple species of fish at various life stages using reconnected tributaries for summer rearing, overwintering, and adult spawning. While we have observed the majority of tributary use from juvenile fish, we would expect a similar response with anadromous adult fish. However, this is predicated on sufficient escapement numbers that are influenced by multiple out of basin factors that are not addressed under Lemhi habitat rehabilitation efforts. In recent years, adult salmon and steelhead escapement to the state of Idaho has been low and we hope to see an increase in adult returns in the future.
- Flow improvements in the mainstem river, as a result of tributary reconnections and mainstem water conservation projects, should provide sufficient fish passage conditions for all freshwater life stages.
    - As a result of these efforts, no passage barriers were present in the mainstem Lemhi River during their annual migration period. Moreover, tributary reconnects and water conservation projects that maintain a minimum stream flow have created sufficient passage conditions for adult salmon in the lower Lemhi River.
- The combination of tributary reconnections and mainstem upper Lemhi River habitat improvement projects should improve freshwater productivity for salmon and steelhead by improving habitat for life stage specific requirements.

- Improved rearing conditions in the mainstem river and tributaries were assessed via salmon productivity estimates, measured as the number of age-1 smolts per redd. Results suggested that productivity of age-1 smolts increased in the Lemhi River basin. Results also suggest that the increase in smolt productivity may be the result of more fish remaining in the mainstem river (upstream of Hayden Creek confluence) and tributaries through the winter and/or high winter survival of fish that stay in the Lemhi River watershed.

Lower Columbia:

A. There will be a measurable increase in juvenile fish production in response to restoration in treatment watersheds (Abernathy and Germany creeks) compared to the controlled watershed (Mill Creek) over time. This assumption appears to be partially supported in Abernathy Creek following six recent years (2015-2020) of intensive restoration designed to increase complexity, impacting 30% of habitat accessible to salmon. For the fourth year in a row, Abernathy Creek produced the most Coho Salmon smolts among the three basins. It is estimated that 10 years of monitoring are required post restoration, which is ongoing, to validate this assumption.

B. Monitoring of multiple fish life stages (parr, smolt, adult) will provide insight into which life history stages are most affected by restoration. This assumption also appears to be partially supported with evidence of increased apparent Coho Salmon parr overwinter survival in treatment watersheds during restoration (brood years 2012-2018) compared to the baseline period prior to restoration (brood years 2004-2011). By contrast, parr survival in the control watershed appears to have decreased over the entire time period. There is no evidence of increased adult production over time, and this may be due to factors occurring outside of the LC IMW complex (e.g., poor marine survival and increased harvest).

C. The survival of Juvenile salmon and steelhead is limited by freshwater habitat (i.e., juvenile survival is density dependent). This assumption appears to be supported across the LC IMW complex, suggesting that freshwater habitat is limiting productivity. For example, apparent overwinter survival of Coho Salmon parr across all watersheds (brood years 2004-2018) is a function of summer parr abundance (i.e., higher survival with fewer parr). In addition, tributary and headwater reaches are important habitats for producing large spring Coho Salmon smolts.

D. Juvenile Chinook Salmon life history diversity is a density dependent function of total juvenile abundance (i.e., life history diversity is density dependent). This assumption was supported in Germany Creek (2005-2018), where it was determined that the ratio of subyearling to all life history types is a function of the total number of juveniles that emerge from the gravel (i.e., fewer parr with increasing juvenile abundance). Coho Salmon fall outmigrants may also be affected by habitat conditions.

E. Habitat treatments targeting limiting factors such as channel complexity, connectivity between instream channels, off-channel/side channel areas, and floodplains, fish passage, and riparian habitat will increase capacity, productivity, survival, and growth of juvenile salmon and steelhead at the watershed scale. This assumption may be supported, although several more years of post-treatment monitoring are required to validate this assumption. For example, for the fourth consecutive year in 2020, Abernathy basin, where the majority of restoration treatments have taken place, produced the most Coho Salmon smolts among the three basins. Juvenile steelhead abundance is also trending upward in the Abernathy and Germany treatment watersheds.

F. Salmon Carcass Analogs (SCAs) can be used as a form of nutrient enhancement for juvenile Coho Salmon. This assumption was tested on Germany Creek in the fall (2010-2013) and Abernathy Creek in the spring (2013-2015) and was not supported; neither fall nor spring SCA treatments had a significant effect on Coho Salmon growth or survival. Monitoring of SCA treatments was finalized in 2017.

G. Barriers to fish passage limit spawning habitat. This assumption was supported in 2020 resulting from the passage barrier removal project on Sarah Creek, completed in 2019. In 2020, just one year after project completion, eleven Coho Salmon redds were observed in the newly accessible habitat, which was ten times more than ever observed across the time series.

H. Freshwater habitat conditions that affect juvenile salmon survival are dynamic and on similar or measurable trajectories in treatment and reference watersheds, but restoration activities in treatment watersheds will generate changes in stream habitat that should be detectable relative to the reference watershed. This assumption may be supported but disentangling stochastic (i.e., environmental) change from treatment effects through time has been a challenge across all IMW complexes. Work is ongoing to address this issue using a state space model framework.

I. Annual fish and habitat monitoring will be required post-treatment to reliably detect treatment effects. This assumption was supported by power analysis and a Monte Carlo simulation conducted in 2016 that determined 10 years of post-treatment fish monitoring were required to detect a measurable change in fish production given the proposed habitat actions. The analysis also found that proposed treatments in Germany Creek might be too small to detect any change in fish abundance.

<u>Methow</u>: It's challenging to summarize this as we do not have just one study that has been operating, many independent ones and no comprehensive IMW approach. The foundational/overarching assumption would be to determine the effectiveness of habitat restoration efforts on improving growth and survival of target species. The assumption that improved habitat quality - through addressing identified limiting factors at the reach scale - would increase growth and survival of target species and thus contribute to recovery. Not sure if this has been validated to the extent necessary. For example, floodplain reconnection has been a widespread treatment in the Methow, but we have scant data on its effectiveness. The hatchery program effectiveness monitoring provides the most long-term fish related data available but this program is not designed to assess the effectiveness of restoration actions.

<u>Middle Fork John Day</u>:

1. We assumed that we could detect population-scale, fish productivity responses using a BACI design. Limited power of our statistical test, due to limited precision and cumulative statistical error of sampling efforts required to estimate productivity, has limited our ability to detect change. This limitation has elevated the importance of our reach-scale monitoring.
2. Despite gains made in habitat quality, suitable stream temperatures and habitat quantity remained limited, suppressing significant increases in watershed-scale salmonid productivity.
3. Inconsistent temporal and spatial monitoring for some research studies (e.g., macroinvertebrates, water temperature, vegetation) has made detection of change difficult.
4. The monitoring plan designed at the beginning of the study was compromised by unanticipated restoration projects that were implemented during the course of monitoring. There were many organizations implementing restoration actions across the MFIMW study area, and a lack of initial coordination resulted in some restoration projects being implemented in designated control reaches.
5. Restoration actions aimed at improving watershed function may take decades to mature. Some processes and cycles that influence salmonid populations span much longer than 10 years and will not manifest a fish population response within a 10-year period.
6. It was assumed that if cattle grazing was restricted, riparian plantings would grow and recover. Studies conducted by MFIMW partners showed that high ungulate browsing was inhibiting riparian recovery and without fencing riparian plantings would not recover at the rate expected.
7. In addition, restoration practices evolved as restoration practitioners learn from initial actions and initial active restoration projects may not be as effective as later actions that were informed by initial shortcomings. These adaptations and iterations may reduce our ability to detect statistically significant responses over time or to management (McDowell et al. 2020).
8. One assumption currently under investigation is that increased fish productivity at the restoration level equals increased productivity at the population level. We are validating (or nullifying) this assumption through a paired study of fish abundance and movement. The second tier to this assumption is: at what

scale is this assumption validated (i.e., if you restore 5 km of stream and observed increased productivity is this productivity reflective of a true increase) – research is ongoing, and no results are available yet.

Potlatch:

Project specific assumptions from the Potlatch River IMW:

- Barrier removals are cost efficient treatments to increase the amount of available spawning and rearing habitat in high priority drainages . Improved passage will result in the expansion of adult spawning and juvenile rearing distribution and in the long-term, upstream distribution of steelhead spawners may increase the number of emigrants through an increase in rearing habitat available to juveniles and a reduction of density dependent effects.
    - This assumption was supported from 2 major barrier removal projects in the lower Potlatch River watershed. We documented successful upstream passage of adult steelhead and spawning for each project within 2 years of project completion. Our ability to assess potential increases in juvenile production has been confounded by low adult steelhead returns in recent years. From 2017-2020, adult steelhead returns to the Potlatch River basin and elsewhere in Idaho have been below average, likely as a result of out of basin factors. Continued monitoring is needed to assess changes in emigrant production resulting from these projects.
    - The location of barrier removal projects is important. Barrier removal/modification projects should be located within close proximity of the source population to have a positive impact on fish distribution/production. Projects located in low priority drainages and/or intermittent streams have little to no positive impact on fish distribution.
- Flow augmentation should increase the quantity of juvenile rearing habitat (increased available wetted habitat and pool abundance) and improve the quality of existing rearing habitat (improved temperature and dissolved oxygen) for juvenile steelhead. In the short-term, flow augmentation is expected to increase growth and condition of juvenile steelhead. In the long-term, parr-to-smolt survival is expected to change in response to flow augmentation, ultimately resulting in increased steelhead productivity within the drainage.
    - These assumptions were supported from an Idaho Department of Fish and Game flow augmentation pilot project on Spring Valley/Little Bear Creek. We observed a significant increases in the amount of juvenile rearing habitat, pool density and connectivity, as well as moderated stream temperatures and dissolved oxygen levels. We documented positive responses in juvenile steelhead growth, survival, and density in response to the augmentation efforts. We will be able to assess long-term responses in juvenile production/ productivity once the project is fully implemented.
- LWD treatments are intended to increase the quantity of instream rearing habitat (e.g., pool formation) and increase hyporheic exchange between the river and surrounding aquifer. Expected fish responses include increased parr abundance and parr-to-smolt survival in treatment tributaries compared to control tributaries. Other potential responses include changes in emigrant age structure and/or length-at-age.
    - Preliminary data support the assumption that changes in emigrant age structure and length-at-age may result from improved rearing conditions in the EFPR. During recent treatment years, we have observed positive shifts in emigrant age (i.e., more 2 yr. old smolts), growth, and survival.

Higher Level assumptions from the Potlatch River IMW:

- Restoration would occur at a pace and magnitude to elicit a sustained, watershed response in steelhead.
    - This assumption has not been supported, especially in the lower Potlatch River watershed. We have identified three high impact projects that our modeling suggested would significantly increase juvenile steelhead production. However, only 1 of the 3 projects has been implemented and the other two have been delayed or canceled by permitting and funding issues. Working with private landowners also limits the pace of project implementation. It takes a considerable amount of time and effort building relationships with private landowners.

- Restoration projects would be implemented in areas that would have the greatest impacts on juvenile fish production/productivity. Prioritizing where restoration occurs has been a challenging aspect of this work and too often projects are implemented in places where there are willing landowners as opposed to areas that would have the greatest impact.

Pudding:

1. Prior to the study, we determined that over-winter survival and low summer growth were major limiting factors for Coho Salmon, and that lack of winter slow-water rearing habitat was limiting Coho Salmon production.
2. Wood treatment would increase habitat for fish during periods that are limiting by increasing (1) habitat complexity, (2) slow water winter refugia, and (3) summer habitat. Treating 80% of the watershed would be enough to detect a change/response. Because we did not see much of a habitat response, this level of treatment may not have been enough.
3. The control (Caspar) was in similar in condition to Impact (Pudding) to detect changes caused by the restoration. Fish abundance, survival metrics trended similarly. Stream habitat characteristics were similar. instream large wood was found to be low in both streams. While we validated this in the pre-treatment, some of the differences between watersheds may have played role in the fish response.
4. That the rapid habitat census technique would be comparable to the site-specific Champ methods. Rapid habitat census technique matched well with ChaMP reaches- signaling repeatability and supporting limited habitat change.

Skagit: We predicted that estuary restoration would result in:

1) decreases in juvenile Chinook Salmon density for the estuary as a whole (for a given outmigration) as fish expand into restored habitat, and decreased incidence of fry migrating directly into nearshore environments where survival rates are much lower than the estuary;

2) increases in juvenile Chinook Salmon size and residence in the estuary; and

3) increased smolt-adult return rates based on run reconstruction, and increased estuary system carrying capacity based on life stage specific stock-recruit model predictions.

These predictions contrast to some degree with effects of individual restoration projects at the local level; for example, restoration should cause increases in density within restored wetlands. Likewise, improvements to connectivity would result in increases in density in areas with improved connectivity. However, for a given run size, the overall density in the delta will decrease as the new habitat is created and existing habitat becomes more accessible.

These predictions followed from conclusions in the Skagit recovery plan that 1) tidal wetland rearing habitat in the Skagit estuary represented a major limiting factor in the early life stages of juvenile Chinook Salmon fry, and 2) these fish would benefit from restoration because most Skagit River fish migrate as fry into the estuary. These assumptions have been validated as additional monitoring has been conducted.

Strait of Juan de Fuca: No response

Question 4c

What are the IMWs strengths (best/most valuable/strongest elements) that should be shared with funders (e.g., ability to shed light on restoration efficacy, understanding outcomes of specific restoration types, etc.)?

IMW responses

Asotin Creek: Strengths of our approach are to measure a large number of habitat/geomorphic and fish parameters (and processes like wood accumulation, wood recruitment, channel widening, etc.) cost efficiently which will allow us to understand in greater detail the causal mechanisms of habitat and fish responses. We also have three replicate experiments (three IMW streams) with different characteristics (gradient, substrate, stream power, etc.) which will allow us to inform management of a greater range of stream types. In addition, we are developing a process-based restoration approach (low-tech process-based restoration; Wheaton et al. 2019) which will have broad applicability to 10's or 100's of thousands of kms of low order, wadeable streams. The method we are developing can also be implemented by a broad range of restoration practitioners and is easy to teach people how to implement - making restoration accessible to a wide range of people.

Bridge Creek: This IMW developed beaver dam analogs as means to mimic beaver activity and give beaver a chance to build more stable complexes. Beavers once established are far more capable than humans at building and maintaining beaver dams that can lead to extraordinary geomorphic, hydrologic, and biological responses. Thus, beaver continued the trajectory of recovery to incision far beyond the initial investment in BDAs. Mimic, promote, and sustain beaver activity with BDAs. These structures can be built quickly, cheaply without the need of heavy machinery and by a much broader restoration community. Both BDAs and PALS (Asotin Creek) have now been adopted by restoration practitioners throughout the world as a means to treat structurally starved systems (a very common degraded state) and engage processes that can reconnect floodplains for a relatively low cost that might actually scalable to the scale of stream degradation.

Additionally, the mechanisms by which beavers and structure impact fish habitat includes geomorphic and hydrologic responses (e.g., connected floodplains multithreaded systems sometimes referred to as stage-0) that lead to a greater quantity of habitat rather than a focus on habitat quality of what is considered "ideal" salmonid habitat. The assumption by several fish biologists that habitat created by beaver is not conducive to salmonids was challenged in this IMW. The added complexity and quantity at the watershed scale created a large population level steelhead response.

Elwha: This IMWs greatest strength has been the partnerships developed between diverse agencies including the Lower Elwha Klallam Tribe, Washington Department of Fish and Wildlife, NOAA, US Fish and Wildlife Service, US Geological Service, US Bureau of Reclamation, and the National Parks Service. Monitoring has included a mix of physical and biological sciences.

Hood Canal: One of the primary strengths of the Hood Canal IMW is that the fish and habitat monitoring occurs at the watershed scale. Thus, we can determine if restoration improves the status (e.g., abundance) of the entire population, not just locally in the restoration project area. Another strength is that we obtain watershed-scale abundance estimates at three distinct life stages, allowing us to partition the life cycle in assessing factors affecting abundance. The study design includes a control watershed, aimed at reducing uncertainty due to natural environmental variation. Another strength is that the study streams are generally representative of lowland, rain- dominated small streams facing rural residential development, a broad landscape encompassing many salmon streams across western Washington and Oregon. Lastly, over the last 18 years, the consistency of monitoring, with few significant deviations from the study plan, is a strength of the study as it provides informational stability for detecting change.

Lemhi: The Lemhi River IMWs most valuable strength is relating fish abundance to key habitat metrics (e.g., large woody debris), and then developing habitat restoration actions that improve upon existing conditions for each of the freshwater life stages. Combining information on factors that limit life stages of salmon and steelhead, and relating this to ongoing habitat restoration actions has proved useful for managers as projects are developed under an adaptive management approach. In short, the Lemhi River IMW provides a good model for watershed rehabilitation, particularly with respect to addressing life stage specific needs to improve productivity while providing recommendations for other watersheds.

Lower Columbia:

A. The LC IMW program is comprised of a highly collaborative, well-qualified team consisting of many local, state, tribal, and federal agencies, and organizations, responsible for the scientifically based study design, implementation, and monitoring framework.

B. The LC IMW treatment (Abernathy, Germany) and reference (Mill) watersheds provide a natural experiment to test and validate salmon habitat improvement strategies by monitoring fish response (abundance, productivity [e.g., recruits-per-spawner], life history diversity, and distribution) to variable habitat through time.

C. At least one of the LC IMW treatment watersheds (Abernathy) is small enough to ensure that restoration actions have targeted a sufficient proportion of the habitat to elicit a measurable fish response within 5-10 years based on power analysis and a Monte Carlo simulation.

D. Monitoring of juvenile salmon smolt production, Coho Salmon parr abundance and overwinter survival, and adult spawning abundance within the LC IMW complex, allows researchers to measure and track population life history diversity and viability over time (i.e., before and after treatments).

E. Information on smolt abundance generated from the LC IMW is used to manage fish populations in the Lower Columbia River (forecast future abundance, evaluate escapement goals, set harvest exploitation rates, etc.) and to guide future restoration actions in the Lower Columbia region.

<u>Methow</u>: We don't have an IMW. I would say the Methow's strength would be our collective desire to work together across agencies and organizations. We share data, staff, and expertise. This has been of incredible value as we pursue the various goals of separate, but interrelated, projects.

<u>Middle Fork John Day</u>:

1. Restoration:
    a. The Heat Source model indicates that stream temperatures are far more sensitive to changes in shade than to changes in either air temperature or stream discharge (Crown 2010, Diabat 2014, Lawrence et al. 2014).
    b. Further monitoring and models have shown that for the MFIMW, water temperatures are limiting juvenile salmonid distribution. High density maximum riparian growth has the most potential to decrease water temperatures and positively affect fish populations.
    c. Tributary inputs of cold water to the mainstem channels, rather than groundwater inputs from the Middle Fork John Day River mainstem floodplain, play an important role in cooling the mainstem channels (O'Donnell 2012) and providing cold-water refugia for salmonids (Ebersole 2015).
    d. Solar radiation is the primary driver of temperature gain along the mainstem Middle Fork John Day River; therefore, channels with more surface area are more susceptible to temperature increases.
    e. Riparian plantings can reduce stream temperatures, but they require time and stewardship. Even when grazing livestock are absent, browsing pressure from deer and elk limited plant growth.
    f. River restoration is a long-term investment. Given the lag time for riparian plantings to mature (15-40 years) and the 5–10-year life cycle of focal fish species, the limited fish responses to restoration actions are reasonable.
    g. Re-meandering channels, without limitation of the wetted area during summer low-flow, may cause temperature increases in the absence of tall riparian vegetation. The results suggest all restoration efforts be assessed for their impact of low-flow stream surface area as a predictor of the expected impact on critical stream temperature.
    h. *Carex nudata* (Torrent sedge) was an unexpected and important ally in increasing functioning systems and increased habitat diversity. Complementary research by Goslin and McDowell in the Middle Fork John Day River has found that *C. nudata* is enhancing geomorphic complexity in the system. The most apparent *C. nudata* effect is the development of *C. nudata* islands which result in multi-threaded channel segments, a process that could lead to new habitat units *(McDowell et al. 2020).*
    i. Temperature modeling and information gathered during the IMW effort has changed some design strategies for restoration projects. For example, there is more emphasis on undersized and/or multiple braided channels that are more easily shaded by riparian hardwood species. While there is a recognition that riparian shade is key to reduce stream temperatures, methods to reduce low flow channel width/surface area of existing channels are also being used to reduce stream temperature.

2. Collaboration:
    a. The MFIMW is comprised of a large group of research, monitoring, restoration and funding agencies and groups established in 2008. When asked this question, across the board, every partner agency listed collaboration, the stable group structure, and shared science and resources as one of the most important successes to share with funders. The MFIMW framework has provided countless examples of how bringing together various agencies, stakeholders, interested parties focused on improving watershed health and function can create higher quality output by providing a forum for partners to interact and share what they are learning. Numerous research projects have been greatly improved by collaboration with partners outside the Middle Fork John Day River and would not have been as successful if implemented in isolation of other researchers/biologists/stakeholders. This shared science has allowed for real-time sharing with restoration practitioners and has reduced duplication of research and monitoring efforts. In addition, past funding, and current research relationships have allowed the MFIMW group to bring in academic institutions and researchers which has strengthened the scientific integrity of MFIMW research.
    b. Project-level assessments of restoration efficacy highlight the highly collaborative nature of the MFIMW working group, which brings together federal (Malheur National Forest, Bureau of Reclamation) state (Oregon Department of Fish and Wildlife (ODFW), University of Oregon, Oregon State University), tribal (Confederated Tribes of the Warm Springs Reservation of Oregon, Columbia River Inter-Tribal Fish Commission (CRITFC)), and non-governmental organizations (NGOs) (North Fork John Day River Watershed Council, The Freshwater Trust).The collaborative nature allows for more creative project planning and for input from people with diverse backgrounds and across agencies. For example, ODFW's work with juvenile movement data inspired conversations between ODFW, CTWS and CRITFC, which inspired a CRITFC/Oregon State University project utilizing innovative parentage genetics study that also utilized data and resources from an ongoing fry emergence study. Findings from assessments like this provide the basis for an adaptive management approach to assess ongoing / future restoration in the MFIMW.
    c. The IMW framework allows for continued development in our understanding of these topics. There isn't a one-size-fits-all approach to restoration and recovery, so context matters, and the MFIMW provides the flexibility to think outside the box, continue to investigate and develop better science, and speed up the process of turning sound science and research into sound management at a local scale.
3. Research:
    a. Sampling of juvenile Chinook Salmon and steelhead during summer demonstrated that Chinook Salmon and steelhead were not present at water temperatures exceeding 22° and 24° C, respectively. Forward-looking infrared (FLIR) and fish distribution surveys conducted during 2006 on the Middle Fork John Day River indicated a two-order magnitude difference in parr density between the warm mainstem (19.5°C) and cooler tributary (15°C) habitats, suggesting that parr were using cold tributaries as thermal refugia to escape stressful or lethal temperatures in the mainstem.
    b. At the foundation of the MFIMW is the collection of consistent long-term datasets characterizing key phases of the salmon / steelhead lifecycles (e.g., spawning ground surveys for adult estimates, rotary screw trap operations for juvenile migrants) across treatment (Middle Fork John Day River) and reference watersheds (mainstem John Day and South Fork John Day rivers). A strength of the monitoring approach in the MFIMW is that the long-term data collection designed for watershed scale monitoring can also be used for finer scale spatial and temporal analyses (e.g., reach/project scale), to assess questions of restoration efficacy.
    c. Ability to assess productivity response at a scale that matches project objectives (site, reach, watershed). Effectiveness monitoring takes time and often requires a collaborative effort because the monitoring is too involved for any one organization. The MFIMW approach is key is for keeping

this collaborative effort alive. Additionally, it is extremely important to have a partnership committed to long term monitoring with the capacity to support long term monitoring objectives.

Potlatch:

- The Potlatch River IMW study design is scientifically based and monitors the key parameters to document a watershed-scale response to restoration activities, including adult abundance, emigration abundance, and freshwater productivity.
- The monitoring framework is adaptable and allows us to respond to changing conditions in the basin as well as data needs of project implementers.
- Monitoring data are used to help direct and prioritize future restoration actions and provides a feedback loop to the restoration implementers.
- Products generated from the IMW are regularly distributed to the public and other stakeholders which generates interest and support for the project.
- The Potlatch River IMW targets wild steelhead habitat restoration and the recovery of Potlatch River steelhead is vital to recovery efforts of Clearwater River basin Major Population Group (MPG).

Pudding: IMWs provide a platform for experiments to evaluate restoration effectiveness and look at long term trends in fish production and freshwater and marine survival. These findings can then be applied in other watersheds and populations to guide restoration and understanding of populations trends and life history strategies. They are equally as important to determine when some restoration strategies do not work, or if there is new information about what may be driving populations, so we may shift efforts for recovery if needed.

Skagit: The strongest elements of the IMW are

1) This is the only IMW targeting habitat restoration for Chinook Salmon in Puget Sound and is located in a system dominated by natural-origin fish.

2) The two forks of the Skagit provided a straightforward way to test BACI (Before-after-control-impact) designs because initially all restoration was focused on the South Fork of the Skagit, leaving the North Fork as a control.

3) The Skagit has benefited from a six year (1994-2000) pre- restoration monitoring within the delta, matched in those same years by outmigrant monitoring.

4) The types of restoration examined by the IMW comprise high- priority projects by Skagit's lead entity. Hence, we are confident that projects are "in the pipeline" to produce a tidal wetland restoration effect.

5) SRFB IMW funds would more efficiently be used by leveraging them with existing funding commitment of the Skagit IMW PIs' own funding sources and additional funding through WDFW for monitoring outmigrants. SRFB IMW funds support approximately 30% of the funds necessary to execute annual data collection called for in the Skagit IMW study plan. The remaining 70% necessary for annual data collection is provided by IMW PIs through other tribal, federal, and state funding sources. No IMW funding is provided for analysis and reporting. The Skagit IMW PIs have sought funding for analyses envisioned for completion over the next few years.

Strait of Juan de Fuca: No response

Question 4d

What are you learning about the spatial scale of restoration needed to achieve population scale responses?

IMW responses

Asotin Creek: We treated a large portion of the study area (14/36 km or ~ 40%) and it appears that this was an adequate restoration scale to produce detectable results. However, the caveat here is that because we treated a large area, habitat changes are variable, some sections of the treatment have become very diverse … others not so much. This is why maintenance is so important – we keep adding wood where the responses are less until the whole treatment is complex.

We are learning that the three streams are responding differently to the treatments. Fish responses are NF>SF>CC generally but habitat responses are SF>CC>NF. We are still assessing the fish and habitat responses and have not used other parameters (temperature, discharge, adult escapement, etc.) to explain these results so far. We also need to complete a full round of maintenance on all three treatments to better compare the three streams responses.

Bridge Creek: The experimental design for this IMW was hierarchical where treatment control pairs occurred within the watershed and between watersheds. Differences in fish responses between treatment and control pairs within the watershed were difficult to detect because 1) the treatment was not independent from the controls (i.e., beavers started building dams in both treatment and control reaches) and 2) the number of recaptured juvenile steelhead was not sufficient to obtain precise estimates in growth and survival at the reach level and thus had to be pooled across the watershed and 3) longitudinal differences throughout Bridge Creek in temperature can cross threshold levels that can limit fish production (in lower reaches), thus population responses can be highly influenced by amount and location of the watershed included in the IMW.

Elwha: For Elwha River the primary limiting factors were that dams were not only barriers to upstream life histories, but also barriers to the transport of alluvium and wood necessary to support habitat forming processes in downstream reaches. There have been complimentary restoration efforts to dam removal including tributary restoration, construction of engineered logjams, removal of floodplain dikes, floodplain revegetation and conservation of private lands. These represent a large spatial and temporal effort. There is more work to be done, but dam removal was certainly the largest event leading to measurable changes in populations at the watershed scale.

Hood Canal: The restoration action that has proven most successful impacted the entire watershed. In Little Anderson Creek, replacing a barrier culvert near the mouth provided consistent fish passage to the entire watershed. By contrast, the response to a reach-scale LWD placement farther upstream was more muted. Thus, the scope (number and size of logs, spatial extent) of the Little Anderson LWD placement was not large enough to elicit a pronounced response, though that conclusion may change as the channel continues to evolve following treatment. A further nuance is that the LWD placement occurred after the culvert replacement, and it appears that the culvert replacement released the population from habitat capacity constraints, which may have contributed to the more muted response to LWD placement (see response to question 4d).

The lesson for restoration is to think big and pursue projects that have potential to enhance habitat quality or access across a large geographic area.

Lemhi: Large scale habitat improvements are necessary to accrue significant changes in productivity that would support the recovery of ESA listed fish in the Lemhi River. However, a sufficient amount of time is necessary to develop large scale restoration actions. In some instances, landowner participation and acceptance, design development, and acquiring sufficient funding can take more than a decade to complete. Once a habitat project is completed, research, monitoring, and evaluating fish response to habitat actions can require a substantial amount of time and effort, especially when taking into consideration the anadromous life cycle. Thus, large spatial scale habitat restoration projects require a tremendous amount of time and energy to achieve a population scale response.

Lower Columbia: Restoration planning at the watershed scale appears to be more efficient and effective than piecemeal restoration. For example, it is estimated that instream habitat treatments in the Abernathy Creek basin have impacted approximately 30% of salmon habitat, including 11.8 km of instream habitat, 1.3 km of off-channel and side-channel habitat, 0.19 km2 of riparian area, and 2.7 km of improved fish passage. Restoration treatments should target specific problems and be sized to the stream reach in which they are placed. We are encouraged by recent increases in juvenile Coho Salmon and steelhead production in Abernathy and Germany creeks after just a few years of fish passage improvement and large-scale wood placement actions.

Methow: That perhaps restoration at the subbasin scale is too small to effect change at the population scale. So many outside influences. Bull Trout populations may provide a good opportunity to assess in-basin effects, as they do not migrate to the ocean, but this has been hampered by large-scale disturbance (mostly fire) across much of their spawning and rearing habitats which has strongly influenced their recent populations trends.

Middle Fork John Day:

1. Habitat restoration to reduce stream temperatures needs to be large in scale and targeted to reaches with the greatest potential for influencing change. This is particularly true in riparian planting locations where reaches do not need major restoration in the channel to restore floodplain and water table function to promote vegetation growth.
2. Riparian vegetation restoration, providing shade to the stream channel, has great potential to address stream temperature concerns, but riparian maturation takes significant time and careful stewardship to ensure success.
3. The role of NGO's has proved to be vitally important for the MFIMW, with the Nature Conservancy playing an important role in the acquisition of conservation properties within the MFIMW, which has recently been transferred to the CTWS to manage in perpetuity. A more recent example of this is the recent acquisition of an impaired section of the Middle Fork John Day River with high conservation value (Phipps Meadow) by the Blue Mountain Land Trust.
4. Vegetation species that are susceptible to grazing disturbance but are well-adapted to fluvial disturbance with stabilizing root systems can colonize gravel bars and bank bases, expand toward the water's edge, and stabilize these edges. Carex nudata, in particular, may accelerate this process. C. nudata establishes along the edge of the low-flow summer channel, stabilizing the leading edge of any open areas and facilitating further colonization and infilling of the channel.
5. In the context of passive restoration, in-stream geomorphological change may proceed at a slower rate and may follow behind, dependent upon these initial system-wide changes in greenline vegetation and narrowing of the channel.
6. Our findings imply that in future restoration projects, the role of passive restoration should be explicitly identified and monitored. Restoration strategies should consider which riparian vegetation species might respond, and which might not, as well as the implications of that response. The response of vegetation through passive restoration should be used as a restoration tool. Active restoration of riparian vegetation (planting) also can be important, but it should be planned in concert with response to passive restoration. In addition, our results showed that passive + active restoration (including instream habitat restoration) has positive effects, sometimes outperforming passive restoration alone.

Potlatch:

- Restoration treatments need to be concentrated in focused areas in order to treat enough habitat to generate a population-level response. This requires a great deal of coordination among restoration and funding partners.
- Modeling exercises and observations suggest the large-scale restoration projects (or accumulation of smaller-scale projects) are needed to achieve population scale response. For example:
    - Life cycle models suggested three passage barrier/ & flow augmentation projects could generate a significant improvement in smolt production. However, the scale of these projects is extensive and together they would effectively double the linear amount of rearing habitat currently available in the drainage.
    - Nearly 7 miles and 220 acres in the Corral Creek have been treated with meadow restoration projects to improve flow conditions in the drainage. However, we have not documented a positive increase in flow conditions (i.e., amount or duration of wetted habitat) as a result. Techniques such as meadow restoration or riparian plantings take a long time to mature and become fully functional and require a vast amount of area to be treated to generate watershed-scale responses.
    - In the East Fork Potlatch River nearly 14 km (approximately 20-25% of core juvenile steelhead distribution area) has been treated with LWD treatments to increase habitat complexity. We have

begun to observe positive improvements to emigrant age, growth, and survival during recent treatment years.

Pudding: The restoration design was to whole watershed approach to strategically place large wood throughout the 80% of watershed to increase habitat complexity and produce significant and measurable fish response. While this provided full watershed coverage and wood levels increased, they are still below target levels described in recovery plans for Coho Salmon. We did not see much change in the habitat metrics evaluated during the study. Because the accelerated recruitment method is intended is to initiate and restore natural wood recruitment processes, it may take more time and natural recruitment to meet target levels and begin to see more of a habitat and fish response.

Skagit: We have learned that within the course of the IMW, the pace of restoration is likely too slow to detect large changes in the adult populations. To date, 10% of the estuary restoration goals laid out in the recovery plan have been implemented. We have observed responses to restoration (changes in size, changes in residence) but not major changes in marine survival (although results provide some indication they are moving in the right direction). Additional funding through another project may allow us to examine marine survival responses in comparison to other populations with less restoration.

In addition, juvenile Chinook Salmon outmigration abundance has been skewed to the lower than average range in the recent decade when more restoration has been completed. This fact causes limitations in our ability to use a stock-recruit function as a main analytical tool. It would be statistically helpful to have some larger outmigrations in upcoming years.

Strait of Juan de Fuca: A full suite of restoration activities that saturate the watersheds is necessary to effect a noticeable result, especially in heavily-impacted areas. These activities include, but are not limited to, road decommissioning, riparian planting, bank stabilization, LWD placement, and barrier removal. Wood placement in particular takes time and effort to get right.

Question 4e

Share any insights regarding the importance of restoration sequencing and watershed location to effective restoration strategies.

IMW responses

Asotin Creek: We used a staircase restoration experiment where 2-4 km (1.25-2.5 miles) of stream was treated in different years (2012, 2013, 2014, 2016). The benefits of this approach is it is logistically and economically easier to implement the restoration and there is less chance that a "year effect" (e.g., drought or large flood) will bias the experiment results. The Asotin Creek IMW was implemented in the mid-upper portion of the watershed where habitat conditions were not severely degraded and there were decent numbers of fish already. This likely also helped us detect a change because the treatment created better habitat, but the basic processes (stream flow and temperature) and populations (juvenile steelhead) were healthy enough to respond to the treatment. This setting also had a low LWD frequency as a primary cause of low steelhead production. Locations in the watershed where high temperatures, low flow, and very low population levels exist may not have responded to LWD additions because there are more limiting factors in play. This suggests that a "top-down" restoration strategy where typically upper elevation "refugia" be expanded downstream rather than trying to restore highly degraded low elevation areas first.

Bridge Creek: The goal of projects employing BDAs should include how the system will be self-sustaining. This can occur either by having a goal of having beaver maintaining the system or applying treatments in phases with maintenance until stream incision has been reversed and floodplains are reconnected (i.e., pushing the system to stage-0). Thus, this restoration (and probably all restoration) is not a one-and-done practice as is commonly assumed.

Elwha: We think there is an argument to be made that efforts to restore the lower river prior to dam removal were complimentary to dam removal. In particular the removal of old push up dikes in combination with the installation of 60 ELJs between river mile 1.0-3.5. These increased connectivity to floodplain forests resulted in new side channels. The ELJ's also formed scour pools that maintained even through peak sediment yield.

Hood Canal: We feel our overall results support the approach of prioritizing connectivity projects (read crossings, floodplain reconnection) before improving channel structure (LWD placement).

Lemhi: Watershed location and scale as well as restoration sequencing is important when designing habitat restoration projects. Selecting the appropriate location of a habitat restoration site is based on species specific life history strategies, the habitat metrics required by individual life stages, and the limiting factors affecting their persistence. Data collected from the research, monitoring, and evaluation of fish populations enables project managers to target specific fish life stages, prioritize important tributary reaches, and develop appropriate restoration actions to achieve the best biological outcome. The watershed scale at which a restoration project is based on is dependent upon the effects to the watershed. In the Lemhi River basin, tributary reconnection efforts have been successful when specific projects have been sequenced to allow for the best outcome while reducing effects to the resource

Effective restoration strategies also require restoration sequencing at the project and reach scale. Habitat improvement projects should be implemented in a manner to efficiently address limiting factors while reducing direct effects to fish and their habitat from associated construction activities. For example, floodplain rehabilitation efforts (constructing channels, grading floodplain areas, installing LWD and other types of logjams) are typically constructed off channel, and then connected to the active river when in-water work windows allow for such activities.

Lower Columbia: Large wood additions and engineered log jams have been an important restoration treatment in the LC IMW complex, particularly in Abernathy Creek. Scale seems to be an important factor, with increases in Coho Salmon productivity in the last 4 years associated with treatments of 30% of salmon habitat. Wood additions are also designed to increase floodplain connectivity by raising the water table in highly incised channels. Landowner willingness is extremely important in restoration sequencing for these actions, as property may be directly impacted by the water level change.

Methow: We are working now with our Upper Columbia prioritization framework which will guide locations, less so for sequencing, moving forward. We have had very little coordinated sequencing in the Methow, it's not been in place. Mostly it was to address the 'low hanging fruit' first then move elsewhere. We have used the Upper Columbia Biological Strategy for years to guide what types of restoration and where and this has been a prioritized approach. I would say this has been very important and the Upper Columbia Regional Technical Team and Upper Columbia Salmon Recovery Board deserve great credit for their work on the Biological Strategy and Prioritization.

Middle Fork John Day:

- Successful actions identify and treat the primary factor limiting fish abundance, distribution, and productivity within watersheds (Hillman 2019). Early restoration in the MFIMW may not have focused on actions to adequately treat the primary limiting factor.
- In some locations, restoration practitioners took the approach to first restore stream process and function that would then allow riparian vegetation to recover over time. Efforts are now shifting to focus more on implementing riparian vegetation restoration across previous implemented projects and integrated into new restoration projects.
- To maximize benefits from restoration actions, restoration practitioners should identify and target cold-water input locations (including instream and tributary confluences) for more effective habitat improvements.

- Carefully consider the potential trade-offs between restoration actions during planning and design phases. Keep in mind the long-term benefits of increasing habitat quality/quantity and vegetation recovery with other factors, such as short-term elevated stream temperatures.
- Prior to implementation, determine whether restoration plans will increase stream surface area at low flow; models show that greater surface area could further elevate water temperatures. However, other long term ecological functions that should reduce stream temperatures over time generally outweigh short term temperature impacts. These long-term ecological functions include but are not limited to increased floodplain connection and increased water table to promote vegetation growth.
- Watershed location is likely an important determinant of the efficacy of restoration actions in the MFIMW. Impaired sections of the Middle Fork John Day River, including private land near Bates, OR and Bates Pond, occur upstream of ongoing and future large scale restoration projects on CTWS properties. The spatial patterning of ownership and land management practices creates persistent challenges for restoration practitioners in the MFIMW.

Potlatch:

- Watershed-level geomorphic assessments are one of the most effective ways to help identify and prioritize sequencing and strategies. However, funding for these assessments is difficult as funding is prioritized toward design/implementation.
- There is a definite need for restoration sequencing and location to maximize the benefits of habitat restoration. For example, it makes no sense to conduct instream habitat treatments in an area upstream of a passage barrier before the barrier issue is addressed. Likewise, it is ineffective to conduct instream habitat treatments in locations where the target species are not located.
- It is generally best to start lower in a drainage and work upstream; however, there are examples when it is better to work from "top down." For example, maintaining and securing stable base flow conditions through flow augmentation techniques should occur before any instream restoration projects are implemented.
- It is desirable to try to build off successful projects and link projects together to effectively treat a larger reach versus tackling individual projects piecemeal in a drainage.

Pudding: The accelerated recruitment was a cost-effective approach to treat a large portion of the watershed all at once. The method is intended to mimic the process of natural wood recruitment within the active channel. The Pudding Creek watershed is located almost entirely within privately owned timber, with good access to the stream to deploy this wood loading strategy. As far as sequencing, this treatment was done all at once. It will be important to reassess to determine the rates of natural recruitment, habitat change, and if there should be retreatment of wood.

Skagit: Analyses suggest that connectivity to the mainstem source of juvenile Chinook Salmon migrants strongly predicts use of estuarine wetlands. Hence, restoration projects closer to the initial forks would likely see higher effectiveness in terms of utilization by fish.

Strait of Juan de Fuca: Restoration actions have occurred over a two-decade period. Restoration has attempted to be holistic and watershed scale but in reality has focused mostly on the anadromous reaches. Study watersheds have been heavily impacted by historical land uses and the effort to reverse these impacts will take time, possibly well beyond our ability to sustain them. We have been iterative in our approaches to restoration, particularly large wood projects. We have found that our two-stage approach to wood restoration in proving to be effective. Stage one projects were older ground based using small aggregations of wood (primarily cut logs). These were effective at initiating channel recovery processes. Stage two projects are newer and helicopter based and used designs that included channel spanning logjams. In low gradient unconfined reaches, the combination has resulted in increased floodplain reconnection.

Question 4f

Are there factors not being addressed by restoration treatments that are limiting fish response? Predation, competition, climate change, ocean conditions, land use, harvest, hatchery, etc.

IMW responses

Asotin Creek: Yes - ocean conditions, eight mainstem dams (4 on Columbia RIver and 4 on Snake River), commercial and recreational harvest, historical channelization, and current infrastructure (houses, feedlots, and roads) within the floodplain. Beaver populations appear to be suppressed by predation from bears and cougars, limiting population growth. Riparian areas have been mostly protected and historical planting has helped recover young riparian forests. However, much of the floodplain on the mainstem Asotin Creek flows through private property where the river is confined by levees and rip rap - reducing the extent of active floodplain significantly. In the IMW area, there is less infrastructure in the floodplain but there are still areas where floodplains appear to be disconnected by historical channelization and rip rapping. We are focusing more on floodplain connection with our ongoing maintenance and adding BDAs, and will have better idea of the percent disconnected and the potential for reconnection after further analysis.

Bridge Creek: Much of the valley bottoms in Bridge Creek are still irrigated for planted crops thus water use and upland landuse is still having impacts to fish habitat. Bridge Creek has sections that can reach lethal temperatures during warmer summers. Climate change and water use can exasperate impacts of temperature. This IMW does not account for any out-of-watershed responses that are undoubtedly important (e.g., mainstem dams and reservoir operation, ocean conditions, harvest and predation.

Elwha: The Elwha River is fairly unique in that 83% of the watershed is protected within the boundaries of Olympic National Park. The river is also mostly undeveloped and has an intact floodplain. Complimentary restoration actions are also occurring in the lower river, tributaries and former reservoirs. Probably the biggest unknowns revolve around the impacts of marine fisheries and ocean conditions on Elwha River stocks.

Hood Canal: I think one relevant point of emphasis here is that restoration of freshwater habitat conditions can only get you so far for a species that inhabits the marine environment for half its life. Over the course of our 40-year time series at Big Beef Creek, we have observed a long-term decline in Coho Salmon marine survival, and during the IMW era, harvest rates have often exceeded 60%. We suspect that these two factors are part of the reason that Little Anderson Creek was consistently below habitat carrying capacity in the years surrounding the LWD addition, potentially leading to the muted response to LWD placement that we have observed so far.

Lemhi: Factors that make it challenging to address fish response to habitat actions include predation, competition, ocean conditions, land use, and harvest. Concern has been raised in regard to Bull Trout predation on juvenile Chinook Salmon. Competition between native and non-native species is assumed but can be challenging to address. Currently we are evaluating potential effects with the presence of non-native Brook Trout utilizing rearing habitat for juvenile steelhead at the treatment and reach scale. Additionally, other factors such as ocean conditions, Federal Columbia River Power System, and harvest (commercial and recreational) influence adult salmon and steelhead returns to the Salmon River basin. In recent years, adult returns to the Lemhi River have been low enough to limit our ability to assess fish responses to restoration treatments.

Lower Columbia: Habitat restoration in the LC IMW watersheds has largely focused on increasing quality habitat for overwinter rearing and survival. Evaluating density dependent relationships related to overwinter survival may be a more direct evaluation of population response to habitat actions in these stream networks. A comparison of Coho Salmon parr overwinter survival “before restoration” and “during restoration” shows an increase in overwinter survival in the treatment watersheds (Abernathy and Germany) and decrease in the control watershed (Mill) over the course of the study (brood years 2004-2018).

Methow: We are doing almost no work on predation, ocean conditions, land use and development, harvest, etc. So, I would say there are a host of LFs that are not being addressed. Mostly it's been the habitat related LFs that have been the subject of monitoring efforts. Exceptions include hatchery program monitoring and the development of aquatic productivity models.

Middle Fork John Day: Climate change (drought conditions, lower snowpack), Columbia River passage, ocean conditions, overshoot at Columbia River dams by adult steelhead, downstream passage and water conditions (e.g., low flows as a result of water diversions and climate conditions)

Potlatch: Factors not being addressed directly by restoration treatments include poor ocean conditions for marine survival, migration through the hydrosystem, climate change, and land use changes. Restoration treatments may indirectly address some of these issues by creating refugia during critical periods or by producing more “fit” fish (i.e., larger and older), but these issues can confound the final assessment.

Pudding: The addition of wood should work to increase habitat complexity and help build resilience to climate change impacts (ex. increased summer habitat in response to lower base flows in drought; flow refugia in winter in response to higher more extreme winter flows) However, extended drought, changing ocean conditions and flow timing will likely limit fish response. The truncated rain season (starting later and ending earlier) influences timing and magnitude of flows the opening and closing of bar-built estuaries, which can block or delay adult and juvenile migration.

Skagit: One likely challenge confounding our ability to detect effects of restoration on Chinook Salmon is that there have not been many bonanza years of Chinook Salmon abundance. Bonanza years are years of high productivity and abundance that go well beyond the system’s capacity; in our case is when we have extreme numbers of in-river outmigrants. Those years would produce the greatest effects of restoration-based changes because more fish would benefit from the restored wetlands.

We have 27 years of data. Since our more continuous restoration period starting in 2007, however, we have only observed river outmigration abundances exceed expected capacity once in 2013. We would benefit from more observations at these higher abundances. In this respect, low marine survival is likely having a strong effect on population response.

Strait of Juan de Fuca: Ongoing land use impacts including mass wasting from mid-slope roads has impacted watersheds in some years. However, the overall trend in the SJF has been a dramatic reduction in the rate of landslides as compared to the 1980's-1990's period. Road abandonment and Forest Plan restrictions on logging oversteepened lands has been effective. A huge factor that has not been addressed is the marine survival of Coho Salmon as affected by ocean conditions.

Question 4g

What are you learning about salmon life history (e.g., run timing, abundance, juvenile emigration/outmigration timing, etc.)? What are you learning about the relationship between salmon life history and in-stream restoration and overall habitat diversity?

IMW responses

Asotin Creek: We have an excellent resource in the Asotin with the fish in-fish out monitoring managed by the WDFW which has been running since 2004. WDFW has an efficient adult weir and smolt trap and provides good estimates of escapement, emigration, age, size, and sex structure, run timing, etc.- see Herr et al. 2020). WDFW have identified 25 different life-histories with the dominant being 2.1 and 2.2 adults (totaling 68% of all returning adults). We hope to add to the list of life history diversity detected with further analysis of IMW fish in the tributaries that appear to have a larger resident component and spend more time in fresh water.

Bridge Creek: No response

Elwha: Increased life history diversity was a predicted response to the removal of the Elwha River dams and adaptive management guidelines recognized the importance of life history diversification to the recovery of

Chinook Salmon and steelhead in the basin. Given the considerable longitudinal differences in habitat characteristics in short, coastal rivers such as the Elwha River (e.g., temperature, gradient, floodplain valley width), colonization of upstream habitats may present new environmental conditions. Diversification of habitat niche utilization during colonization can increase life history diversity, and in turn, benefit abundance and productivity. In Puget Sound, snowmelt river conditions favor early adult spawning and stream-type juvenile rearing strategies in Chinook Salmon, but occupancy of these headwater habitats is under-represented in the region due to dams, restricting life history diversity.

Specific life history types of Chinook Salmon and steelhead in the Elwha River where thought to be part of those populations historically, including spring Chinook Salmon and summer steelhead, due to the environmental conditions and geomorphic characteristics of the Elwha River basin. The cold-water stream temperature regime above the dams had been thought to be conducive to slower growth rate and overall size of juvenile Chinook Salmon, creating a growth trajectory favoring the stream-type life history characterized by one year of freshwater rearing prior to outmigration. Similarly, summer steelhead were hypothesized to predominate in the upper Elwha River basin due to its series of canyons interspersed between alluvial valleys, creating habitats conducive to that life history.

Summer steelhead have been documented over the last four years, increasing in numbers from 2015 to 2019. The “reawakening” of the summer steelhead life history strategy in the Elwha River, particularly since 2017, is a positive sign that the ability of fish from the basin to express this life history strategy is a response to dam removal and re-connectivity of the watershed. Configuration of the Elwha River watershed and potential genetic disposition of resident O. mykiss could both play a role in this life history re-expression since dam removal. As we have already stated, the Elwha River is a series of alternating alluvial and canyon reaches, and it has generally low stream temperatures for the majority of the basin across the year, both of which favor expression of the summer steelhead life history. Preliminary genetics work completed suggest that these fish are most likely originating from the resident population of O. mykiss above both dams, owing to the harboring of alleles for early run timing in the up-river population.

Hood Canal: We have been collaborating with scientists at Simon Fraser University to investigate changes in smolt migration timing over the course of our fish time series, which runs back to the early 1990s (Seabeck, Little Anderson, Stavis creeks) or late 1970s (Big Beef Creek). In our IMW study streams, Coho Salmon smolts are now migrating earlier in the season, with a rate of change of several days per decade. This is consistent with the hypothesis of more rapid species phenology in a warmer climate. At a broader scale, by examining data compiled from Alaska to California, our collaborators have found that rates of smolt timing change are hard to predict according to geography. Thus, a “predict-and-prescribe” approach to conserving salmon populations impacted by climate change is unlikely to be successful, arguing for protection of diverse habitats and diverse life histories.

Lemhi: The IMW has provided an opportunity to learn about the diverse life history strategies of salmon and steelhead and how specific life history strategies relate to in-stream habitat diversity. Over the years, we have monitored run timing, species abundance, juvenile outmigration, and adult escapement of salmon through a variety of sampling methods (i.e., rotary screw trapping, mark-recapture electrofishing, spawning ground surveys, radio telemetry, and PIT-tag arrays).

- Juvenile salmon will emigrate from the Lemhi River at various life stages. We have observed age-0 salmon migrating out of the Lemhi River, some of these fish are detected at Lower Granite Dam relatively soon after leaving the Lemhi River, while others are detected at the dam at a much later date (reared in the Salmon or Snake rivers), and a majority go undetected.
- Early migration behavior of age-0 fish may be in part a result of poor overwintering habitat in the Lemhi River. Juvenile salmon that choose to overwinter in the upper Lemhi River have a better survival rate than fish that move down river to overwinter. This is likely a result of poor habitat conditions in the lower Lemhi River.

- From the 2017 Upper Salmon Subbasin Integrated Rehabilitation Assessment (USSIRA), we have learned that the Lemhi River is limited in overwinter habitat capacity (the amount of specific habitat needed for juvenile salmon to survive through winter). There is a need for reduced velocity, deep pools, floodplains, and woody debris for juvenile fish in the lower Lemhi River. Creating habitat diversity is expected to result in more juvenile fish overwintering in the Lemhi River and emigrating as age-1 smolt (rather than age-0) where they are larger in size and have a better chance of survival to the ocean.

For a detailed explanation, please see the USSIRA 2017 report prepared by Quantitative Consultants, Inc., RIO Applied Science and Engineering, U.S. Bureau of Reclamation, Idaho Governor's Office of Species Conservation, Trout Unlimited, and the Nature Conservancy, Boise.

<u>Lower Columbia</u>: In the LC IMW complex, we are learning a lot about juvenile Chinook and Coho Salmon life history diversity. We have found that density affects the migratory life history expression of juvenile fall Chinook Salmon (i.e., fewer parr with increasing juvenile abundance). We have also found that tributary and headwater reaches are important habitats for producing spring Coho Salmon smolts. Analysis of Coho Salmon apparent overwinter survival data showed that upper reaches of the LC IMW basins are more likely to produce spring smolts, and Coho Salmon that are larger at the end of the summer are more likely to be detected as spring smolts. Data from our smolt trap in Abernathy Creek that operated through fall 2019 also indicated that a large proportion of Coho Salmon emigrate from their natal streams during the first year of residency beginning in mid-September. There is still a lot to learn about the contribution of the fall migrants to the overall adult return. Additional insight into apparent overwinter survival has come from observations of a fall migrant life history. The emigration of subyearling Coho Salmon from their natal streams in fall may partially explain the observed overwinter survival patterns, suggesting that the expression of this life history may be related to overall habitat conditions in the basin.

<u>Methow</u>: There is much diversity in life history and habitat use. We seem to learn something new all the time. I see the releases of hatchery fish make determining the effectiveness of restoration and habitat efforts more challenging. Couple that with recent and extensive fires (disturbance) also contributing to noise. We have very little project sequencing so effects can be masked by multiple projects occurring in the same reach. We do see lots if sue of wood structures and floodplains post-restoration, but the fate of the fish using these areas is largely unknown. It may come down to how much inference one is comfortable taking on.

<u>Middle Fork John Day</u>:

1. Average redd counts and spawner abundance remained static, Chinook Salmon redd density (redds/km) on the Confederated Tribes of Warm Springs' Oxbow Conservation Area more than doubled after restoration, as spawning shifted from upstream reaches to restored reaches where disturbance occurred.
2. We are evaluating differential survival and fish-habitat relationships at restored and unrestored sites where habitat was intensively measured at a reach scale. Recent juvenile movement tracking efforts suggest an over-summer survival bottleneck and tracking data will be used to identify survival patterns for restored and unrestored reaches.
3. The importance of tributaries for Chinook Salmon parr to access thermal refugia – building on work from other research to confirm this finding.
4. Exceptionally hot and dry conditions of summer 2021 drive home the importance of habitat diversity that in-stream restoration would ideally provide in the face of the current climate crisis.
5. Work by various partners relating fish distribution to summer stream temperature provided important empirical evidence that stream temperature is a key limiting factor for juvenile salmonids in the system. Recent publications using data collected in the MFIMW highlight the crucial role stream shading will play in efforts to combat increasing stream temperatures in the system (Hall et al., 2020; Wheaton et al., 2018).
6. Outmigration timing: Examining outmigration timing has informed population limiting factors. In the Middle Fork our tagging efforts and antenna network have allowed us to understand outmigration timing of fish in the upper Middle Fork, which indicates over-winter rearing habitat is limited.

7. Thermal refugia: From the ten-year summary report we know temperature is limiting in the mainstem Middle Fork John Day River and that reducing temperatures in the mainstem is crucial for rearing habitat. Identifying, protecting, and promoting thermal refugia, including tributaries, is going to be critical to the survival of salmonids during heat spikes. This year we have observed fewer than average fish in the mainstem, but high densities in the tributaries. These data are very applicable to other populations as our results indicate the way we view spawning and rearing habitat may look very different in a warming climate, and in some cases may not even be the same river (i.e., spawning in the Middle Fork and rearing in the tributaries).
8. We hope to learn from 2021 monitoring, how survival is influenced by habitat characteristics and rearing location. We will be looking at how rearing in a tributary vs. mainstem impacts survival as well as how rearing in the upper Middle Fork John Day River (unrestored, very simple), vs. the CTWS restored Oxbow Conservation Area (restored and diverse) habitat influences survival.
9. We are still learning about salmonid-habitat relationships, especially at the juvenile life stage. Data are especially limited for the <65mm (i.e., PIT-tag sized) juvenile salmonids, and the egg-parr life-stage.

Potlatch: We have documented a wide diversity of steelhead life histories in the Potlatch River with distinct differences between the index watersheds. Of note, we have observed differences in peak emigration and escapement timing between the watersheds. Also, we have documented differences in emigrant age structure and survival between the watersheds. We are learning that life history characteristics are not static and can be influenced by changing habitat conditions as documented by the recent shifts in the East Fork Potlatch River. We have also gathered knowledge about the prevalence and importance of resident O. mykiss and their relationship with anadromous steelhead in the Potlatch River basin.

Pudding: We have learned Coho Salmon juveniles that spend two summers in fresh water are present every year but go undetected because of overlap in size with one-year smolts. While growth rates and size also drive outmigration timing, the two- summer freshwater life history is likely more prevalent under drought conditions when low flows delay or block passage. We found that when Coho Salmon were blocked from returning to their natal watershed due to lack of rainfall and closed sandbars at the mouth in 2014-15, the cohort was rescued by previously unrecognized life history diversity in our watersheds; namely fish that were born in 2012-2013 that spent two winters in fresh water and two summers in the ocean. This life history emphasizes the importance of diverse habitat for different life history expression.

Skagit: We have learned a lot about density-dependent and -independent factors affecting Chinook Salmon fry in the estuary. In addition to strong density-dependent effects of outmigration numbers, body size is influenced by temperature, timing is influenced by temperature and peak flows, and abundance of pink-salmon like fry migrants in Skagit Bay is related to peak flows.

One of the most fascinating aspects of local project monitoring work (not IMW-funded) include findings of non-natal habitat use by juvenile Chinook Salmon that bypass the natal estuary. These include nearshore lagoons and bay shorelines, and even non-natal creeks that they swim into after moving through the marine nearshore. Based on timing, residence, and growth results, these non-natal habitats appear to perform the function of the natal estuary.

Strait of Juan de Fuca: Life history monitoring has yielded valuable information for Coho Salmon and steelhead. Results are summarized in: Bennett et al. 2014 Nomads no more: early juvenile Coho Salmon migrants contribute to the adult return. Ecology of Freshwater Fish doi:10.1111/eff.12144. Hall et al. 2016 Life history diversity of steelhead in two coastal Washington Watersheds. Transactions of the American Fisheries Society 145:990-1005.

Question 4h

What are you learning about the role of floodplain and upland land use in shaping habitat conditions and achieving restoration outcomes?

IMW responses

Asotin Creek: Asotin Creek was one of the first watersheds in Washington to have a Model Watershed planning process implemented and completed in 1995. The focus of restoration efforts as a result of the model watershed plan were to improve upland farming practices and fence off riparian areas in the Conservation Reserve Enhancement Program to let them recover. When the Asotin Creek IMW started in 2008 it was apparent that the earlier restoration actions had improved upland farming and thereby reduced erosion and excess sediment entering Asotin Creek, and much of the riparian areas were recovering providing shade and source or organic matter to the streams (leaves and small woody debris). These past actions allowed us to identify that the largest limiting factors left to address were lack of large woody debris, lack of overbank flow, and disconnection of floodplain pockets throughout the IMW study area. Our data to date suggests that the addition of wood has increased fish production, but further gains could be made if the remaining disconnected floodplain areas are re-engaged with more regular flows and potential active side-channels even during low flow periods (i.e., summer).

Bridge Creek: Active floodplains are critical to a properly functioning riverscape. The increase in water storage and riparian vegetation was observed in this IMW as the floodplain was reconnected. Reconnected floodplains allowed for a 1200% increase in side channels. The increase in side channels and woody vegetation (mostly willow) likely provides critical fish habitat for both high flow (flow refugia) and low flow (increase of available habitat) conditions. Also, a decrease in temperature was observed with increase beaver dam activity likely though an increase in lateral and vertical hydrological connectivity.

Elwha: The connection between upland land use, or lack thereof in the case of the Elwha River, and adjacent and downstream floodplains has been critical to the success of the dam removal. The upstream area housed over 15million cubic meters of sediment that was routed downstream. The connected, forested floodplain became a great storage area for the upstream sediment. Approximately 50% of the upstream sediment that stayed in the river was in the floodplain and side channels. Having a relatively intact uplan area and a functioning floodplain helps to dampen impacts, whether they be from long term land use or short-term restoration impacts.

Hood Canal: A major floodplain reconnection project (4.5 hectares of wetland reconnected) was completed in Big Beef Creek 2016, and it appeared to substantially increase the availability of high-quality overwinter habitat for Coho Salmon. We plan to evaluate the fish response to increased access to wetland habitat in the coming years.

Lemhi: In the Lemhi River basin, floodplain and upland use has reduced or eliminated the natural processes that create healthy and diverse riverine habitats. In addition to loss of key habitat attributes, removing floodplains results in degraded water quality. Reduced water quality from upland use includes increased sedimentation, warmer water temperatures, and reduced biological productivity. As a mitigation measure, project managers are focused on enhancing historical floodplains to restore some of these natural processes while creating better quality habitat for fish. Floodplains store water and increase flow from groundwater sources (recharge of ground water), and assist in flood and erosion control which reduces sediment inputs into the river and can lower water temperatures. They also provide wetland vegetation which creates shelter (predation avoidance) and food for juvenile fish. Most importantly, floodplains increase biological productivity in riverine system. Thus, floodplain rehabilitation projects are a great mitigation tool that creates ideal habitat conditions for fish.

Lower Columbia: Upland land use (e.g., landowner property and agriculture) is a limiting factor when considering restoration activities that promote floodplain reconnectivity. Flooding is not the desired outcome of restoration in these areas.

Methow: No response

Middle Fork John Day:

1. Over the past two centuries, the Middle Fork John Day River incurred significant post-EuroAmerican settlement impact from beaver trapping, road building, clear-cut logging, fire suppression, channel re-routing, floodplain/wetland drainage, grazing, and mining. Fortunately, the most damaging of these practices have since been curtailed and the watershed has good recovery potential. One of the most dramatic changes was dredge mining of a large portion of the Middle Fork John Day River in the 1930s, near what was then referred to as the Oxbow Ranch, resulting in destruction of floodplain vegetation and soils and a straight, trench-like channel. This change has been largely remedied by building a new meandering channel in the Oxbow Phase 2, 3, 4, and 5 projects in 2012-16.
2. Implicit in stream restoration is the notion that there is a range of reference “pre-EuroAmerican settlement” ecosystem conditions, and that one can evaluate the degree of departure from this range in order to quantify ecosystem degradation or improvement. However, defining a specific, pristine “reference” condition for a watershed is untenable because natural disturbance processes have continually shaped river systems over time (Mann 2011). Metrics of restoration success should not be based on an imaginary static condition that once existed but focused on re-establishing dynamic natural ecosystem structure and function. These functions include riparian biodiversity and natural plant community regeneration, nutrient cycling between the floodplain and channel, maintenance of natural channel morphology through hydraulic processes, and resilience to natural disturbance processes such as floods and fires (Kauffman et al., 1997; Palmer et al., 2005; Williams and Reeves, 2006). Re-establishing and maintaining these natural processes is especially important to ecosystem resilience as the Pacific Northwest faces impacts from a changing climate.
3. Expectations for restoration outcomes need to be tempered with a realistic understanding of the rate at which natural systems can recover from almost two centuries of Euro-American settlement and land use. Slow restorative processes, such as vegetative change, and those that manifest over generations of the target species require planning and monitoring over decadal scales. However, responses to restoration actions such as fish passage, channel reconfiguration, and cover enhancements require less time to observe a fisheries response and can be targeted successfully for shorter term experiments.
4. Tributary inputs of cold water to the mainstem Middle Fork John Day River, rather than groundwater inputs from the mainstem floodplain, play the most important role in cooling the Middle Fork John Day River. Additional floodplain evaluation is currently underway for juvenile Chinook Salmon. We are currently investigating floodplain use by early emerging juveniles.
5. We used a numeric model to investigate whether a Middle Fork John Day River floodplain reconnection project could mitigate late-summer low flows and elevated stream temperatures through increased mainstem flow by delivery of water stored in the floodplain, from high winter flows, in the summer. This restoration action was shown to be ineffective in the mitigation of summer water temperatures. It should be emphasized, however, that the floodplain reconnection has benefits to salmonid communities during high flow periods. Consistent with summer flows being generated from stored groundwater, it was also found that groundwater did provide significant cooling to the MFJD tributaries, which deliver this cool water to the mainstem.

Potlatch:

- Floodplain and upland land use can dramatically influence habitat conditions and add complexity to achieving restoration outcomes. For example, the majority of the lower Potlatch River watershed has been converted to tiled agricultural fields which has greatly altered the hydrology of the system (more frequent high spring flow events and lower summer base flow conditions). Due to the vast scale of the impact, it is unfeasible to restore the hydrology of the system using strictly process based approaches and alternative methods need to be considered. For example, we have demonstrated that flow augmentation from headwater reservoirs is highly effective in improving flow conditions and is a cost-effective approach relative to the alternatives.
- Responses in habitat conditions to treat upland/floodplain habitat degradation will take time to fully develop. For example, plantings to improve riparian conditions and ultimately instream complexity, will take

decades to fully mature and actively recruit material to the stream. Meadow restoration techniques will also become more functional over time as native plant communities adjust to wetter conditions. These types of projects will likely require multiple treatments over time until the site becomes more self-sustaining.

- For the most part we cannot regulate changes in upland land use and it is hard to predict what impact they will have on the project. For example, there is an influx of people moving into the local communities around the Potlatch River basin and agricultural/timber land is being converted into homesteads. The impact this will have on already degraded flow conditions in the basin are unknown.

Pudding: Floodplain connection may require more natural recruitment of wood, retreatment of wood as and years with higher winter flows. Under drought conditions, it may take more time to achieve habitat change and floodplain connection by adding wood alone.

Skagit: This is not included in the Skagit IMW. However, independent research across Puget Sound rivers (Hall et al. 2018) that includes Skagit data illustrates that freshwater productivity is highly related to floodplain complexity, and the Skagit represents the most complex watershed in Puget Sound

Strait of Juan de Fuca: Historical and ongoing land-use practices (road construction, logging) continue to influence the effectiveness of the restoration activities. Mass-wasting events and avulsions can dramatically change or negate the effects of restoration. Equilibration of the systems will take decades or longer to occur. Riparian recovery in particular will take centuries.

Question 5

What types of watersheds do you think IMW results are applicable to in terms of legacy and current land uses, watershed size, stream order, flow regimes, and other watershed characteristics? And, what watershed characteristics or treatment types are not applicable for restoration activities being evaluated by the IMW?

IMW responses

Asotin Creek: This is one of the most important parts of the Asotin IMW. Because we have developed a technique that is specifically relevant to wadeable streams, the knowledge and outcomes from the Asotin Creek IMW could be applicable to 10,000s of miles of streams across the Pacific Northwest. Wadeable streams include order 1-5 streams and these typically make up over 90% of all perennial streams in a watershed. We are implementing low-tech process-based restoration in three streams in the Asotin (Charley, North Fork, and South Fork) and each has a different flow regime. So we can see how the structures work and how effective they are in large streams (> 1,000 cfs), flashy streams with low summer flows (2-600 cfs), and spring dominated streams with relatively consistent flows (5-50 cfs). Each one of these stream types is responding differently but all are showing positive responses in both habitat and fish. The streams also range in gradient from 1.25-almost 4% and have varying floodplain/valley settings from large alluvial valley bottoms to narrow confined valleys. Therefore, the Asotin Creek IMW can help export lessons learned to a wide variety of watershed types and could be highly applicable to headwater streams in a wide variety of ecoregions. The low-tech methods we have developed also are applicable to many intermittent streams which are often ignored by traditional restoration planning despite intermittent streams being particularly important parts of fish life history patterns especially on the east-side of the Cascade Range. The low risk and cost-effectiveness of low-tech also allows a greater level of "learning by doing." If practitioners are not sure if the method is appropriate, the cost and risk is low of implementing a pilot project to see if the approach is appropriate in their watershed.

Bridge Creek: Bridge Creek results are likely applicable to the majority of streams in watershed. Many streams are structurally starved, incised, or simplified. Most stream miles within a watershed are wadeable where this approach is most appropriate. Large streams with flashy flows will be difficult to build or maintain BDAs or beaver dams in. The Beaver Restoration Assessment Tool (BRAT) was inspired by the results of Bridge Creek. The model predicts the ability of beaver to build dams based on stream power at both low flows (when dams can be built) and high flows (what dams can withstand). This information can be used to guide the stream size and location where BDAs can be built.

Elwha: The Elwha River is a fairly unique watershed with an intact headwater area, functioning forest floodplains below, and a limited number of tributaries. It is also fairly unique in having both rain-on-snow and snow-dominated hydrology. That being said the treatment type of dam removal is generalizable. Salmon increase their distribution and extent immediately after barrier removal. In addition, resident life forms can contribute to life history types as well as overall abundance when connected. The rate and extent will vary with species and the given situation (i.e., initial population size, hatchery contribution, etc.).

Hood Canal: In general, we feel the Hood Canal IMW is representative of small, low elevation streams west of the Cascade Range characterized by rain-dominated hydrographs and mixed rural-residential land use. Such streams, commonly inhabited by Coho Salmon and steelhead, are found throughout western Washington and Oregon. Thus, although Coho Salmon are not listed in Hood Canal, we feel the results of our work are generally applicable to Evolutionary Significant Units where the species is listed (i.e., Lower Columbia and Oregon Coast).

Lemhi: From the physical habitat and biological perspective, IMW results are applicable to most of the tributaries in the upper Salmon River basin. Multiple limiting factors are consistent across tributaries, including, fine sediment, temperature, fish passage, channel form and function, riparian zone function, hydrology (stream size/order), and land use practices (e.g., irrigation). Improving upon these factors increases the quantity and quality of habitat condition that would be expected to increase freshwater productivity. Additionally, most of the biological factors among watersheds of interest, generally speaking, are comparable. These biological factors include species composition, life history strategies, and specific fish life stage requirements. Differences in physical factors (e.g., hydrology, geomorphology, land use practices) would have to be considered, and clearly, the more similar tributaries are, the more applicable IMW results and recommendations would be.

All restoration actions proposed or implemented in the Lemhi River watershed are developed to address factors that are currently limiting fish production and survival. Therefore, evaluating limiting physical and biological requirements that influence the distribution, abundance, and survival of fish at all life stages would provide useful information relative to their importance for conserving or restoring populations. Moreover, all treatment types in the Lemhi River basin would be applicable for restoration activities being evaluated by the IMW.

Lower Columbia: The LC IMW complex was selected because it was representative of small, low gradient coastal tributaries that had been impacted by land use (forestry, agriculture). Results from this system are applicable to other small coastal watersheds but likely not informative to high elevation, inland systems or strictly estuarine restoration treatments. Watershed treatment types that have not been evaluated by the LC IMW complex include beaver dam analogs, flow or hatchery augmentation, screens, or tidal wetland inundations and reconnection.

Methow: No response

Middle Fork John Day:

1. Results from the MFIMW are applicable to similar watersheds in the Mid- Columbia with historical mining and grazing practices, where the floodplain has been dredged and the channel altered and where there has been significant uplands harvested for timber and heavily roaded with culverted stream crossings. Lessons learned for the recovery of riparian conditions can be applied to watersheds where grazing by cattle and browsing by wild ungulates has impacted herbaceous and woody vegetation.
2. Results learned concerning temperature recovery are not applicable to coastal systems that have adequate temperatures but diminished complexity from large wood inputs.
3. *C. nudata* (Torrent sedge) has a limited distribution, but where it is available, it has great potential to enhance in-stream habitat diversity, increase important fish habitat and cover, and provide stability to banks.
4. Data from the MFIMW has been used to inform restoration in similar and nearby watersheds owned by the US Forest Service.

5. The structure and processes within the MFIMW group set the framework for monitoring and data infrastructure in the nearby Desolation Creek basin, which is operating like an IMW.
6. The temperature data that is collected and managed through MFIMW funding is widely shared both locally and regionally. Regionally, our temperature data has contributed to the NorWeST stream temperature database as well as Oregon's Department of Environmental Quality stream temperature database. On a more local level, restoration practitioners utilize our temperature data to inform prioritization of restoration actions.
7. Currently, our long-term temperature monitoring dataset is being used to develop a spatial stream network model to predict continuous thermal profiles throughout the MFIMW. Output from the spatial stream network model will be used to i) compare temperature trends in watersheds with ongoing restoration actions and those without, and ii) to prioritize watersheds for future restoration efforts. Prioritization will be given to watersheds that are classified as thermal buffers (i.e., resilient to warming air temperatures), as well as those that are on the cusp on becoming a thermal buffer.
8. Collectively, the Heat-Source model and the spatial stream network temperature model highlight the power and importance of long-term monitoring datasets. The Heat-Source model has been successfully used in other watersheds, and the use of this model developed for the MFIMW in conjunction with riparian and fish distribution models could be applied in other watersheds to understand the effects of shade, flow, and riparian growth on stream temperatures and effects on fish distribution.
9. Stream flow data are complementary to a variety of ongoing monitoring efforts. USBR and CTWS have used stream flow data in conjunction with drone imagery to determine what flows cause floodplain activation at particular reaches of the Middle Fork John Day River. CTWS is planning on using the NFJDWC stream flow data in their analysis of water table wells within the restored reaches of the floodplain. ODFW plans to use the stream flow monitoring as part of their life-cycle monitoring work, particularly in tributaries such as Camp Creek and in the upper sections of mainstem. In particular, flow monitoring efforts in the Camp Creek drainage complement on-going long-term monitoring (> 10 year) of juvenile summer steelhead abundance and survival by ODFW biologists.
10. Within the MFIMW we are seeking to monitor the effectiveness of habitat implementation actions to restore ecosystem structure and function. Ecosystem structure and function can be characterized by both abiotic and biotic indices. Thermal and hydrological regimes are fundamental abiotic indicators of ecosystem function, and the macroinvertebrate community is a key biotic indicator of ecosystem function. Because thermal and hydrological regimes, followed by macroinvertebrate communities are key indicators of ecosystem function and are quick to respond to landscape alterations, our monitoring program focuses on characterizing and tracking trends in the thermal and hydrological regimes as well as changes to macroinvertebrate communities, pre and post restoration actions. The MFIMW has allowed us to build upon a rich temperature dataset that is both spatially and temporally robust. We will continue to use this dataset into the future as more restoration projects are implemented within the MFIMW project area.

Potlatch:

- The Potlatch River is characteristic of the majority of tributaries in the lower Clearwater River basin, with similar land use practices, limiting factors, and focal species. It would be valid to apply some of the lessons learned and techniques used in the Potlatch to address limiting factors in these drainages that share similar characteristics.
- Certain techniques such as flow augmentation could be an effective technique to use in other systems that suffer from low summer base flow conditions.
- As stated previously, treatments to address upland land use practices such as tiled agricultural fields is one example where it would be challenging to address under the confines of the IMW. The sheer cost, size of the treatment, and timeframe needed to make a measurable impact are prohibitive.

Pudding: The Pudding Creek IMW applies to smaller coastal Coho Salmon watersheds with small lagoonal estuaries, with habitat impacts from legacy logging currently under timber harvest management. Our data may not translate well to larger, more inland watersheds.

Skagit: Skagit IMW most strongly applies to large rivers with Chinook Salmon and with large estuarine deltas and a legacy of wetland conversion to agriculture.

Strait of Juan de Fuca: The results are broadly applicable to other small, coastal streams impacted by logging/road building practices in the Pacific Northwest (SE AK, WA, OR, N. CA).

Question 6

To what degree can preliminary results be extrapolated to other salmon and steelhead populations in terms of limiting life stages, life histories, and geographic location?

IMW responses

Asotin Creek: The Asotin results will be broadly to a wide variety of species, life stages, life histories and geographic locations in forested environments where wood historically played an important role in shaping geomorphology of streams and their associated floodplains. All life stages of resident and anadromous life histories of various species (e.g., steelhead, Cutthroat Trout, Bull Trout, and Dolly Varden) for example would benefit equally from low-tech wood additions in streams that have lack of wood as a limiting factor. The most applicable settings would be wadeable streams (order 1-5) streams. However, the techniques could be adapted easily to off-channel and side-channel habitat of larger rivers (ie., > order 5). We are not directly monitoring adult steelhead responses to wood additions, but it is likely that wood additions are benefitting adults by providing more cover and refugia from flow during spawning migration as well as providing better spawning areas (i.e., newly deposited bars and riffles). We are also seeing lamprey begin to spawn in treated sections of Asotin Creek which is exciting since lamprey have been out-planted by the Nez Perce for several years. Backwater areas with deposits of fine sediment forced by the wood structures appear to be rearing sites for lamprey amocetes.

Bridge Creek: The responses from Bridge Creek are driven more by the geomorphic, hydrological, and biological changes caused by beavers building dams than by addition of BDAs. The results of this IMW suggests that beaver dams can improve habitat conditions that can increase egg to smolt production, which should not be surprising given the coexistence of beaver and salmon and steelhead for over a million years when the densities of both were far higher than they are today.

Elwha: Extrapolation to other river systems and populations is possible for some of the results. Change in salmon distribution due to barrier removal is a relatively common result. In addition, the concept of re-awakening of life history due to extended movement, in general, in something also that should occur in other systems. The concept of resident fish such as Rainbow Trout and Bull Trout, contributing or having an additional life history strategy should also be something that can be considered generalizable. The details of how these occur and the rates should not be considered generalizable. In terms of the watershed characteristics and condition, the Elwha River is fairly unique. Having an intact headwaters or 80% of the watershed does not occur in many locations. The low down barrier removal is fairly generalizable. The dual hydrologic regime (rain on snow and snow dominated) is fairly unique as well.

Hood Canal: We feel that we are learning general scientific principles regarding salmon ecology and interactions with habitat. Thus, although we might not be able to extrapolate results in a numerically predictive sense to different species or habitat conditions, our research on factors affecting salmon abundance, productivity, spatial structure and diversity is broadly relevant to salmon recovery efforts.

Lemhi: We have demonstrated that products developed for the Lemhi River basin have direct applicability to other tributaries in the Upper Salmon basin. For example, the North Fork Salmon River, Pahsimeroi River, and the upper Salmon River share similar limiting physical and biological features that hinder fish productivity. Managers have been addressing these concerns through a variety of mitigation actions that are similar to the habitat restoration techniques in the Lemhi River basin (Upper Salmon Subbasin Integrated Rehabilitation

Assessment (USSIRA) 2017 and Upper Lemhi Multiple Reach Assessment Report (ULMRA) 2020). Preliminary results of salmon and steelhead response to habitat restoration can be extrapolated to other salmon and steelhead populations within the Pacific Northwest but specific habitat features need to be taken into consideration when comparing watersheds. Information gathered on life stage specific survival within the Lemhi River has identified the limiting life stage to be overwinter survival of presmolts. Interestingly, life history strategies of salmon in the Lemhi River have shown that age-0 fish (fry, parr, and presmolts) have migrated out of the Lemhi before reaching the smolt life stage. This information suggests that overwintering habitat is in poor condition and/or limited in the Lemhi River. Lemhi monitoring results have been applied to other watersheds with respect to evaluating life stage specific limitations, and similar trends were observed (USSIRA 2017). As a result, geomorphic and biological goals and objectives have been established for these tributaries (ULMRA 2020), and this is a direct result of Lemhi monitoring efforts and the products that were developed.

For a detailed explanation, please see the ULMRA 2020 report prepared by Biomark and RIO Applied Science and Engineering.

Lower Columbia: Similar to other IMW complexes in western Washington (Hood Canal, Strait of Juan de Fuca), the limiting life stage in salmon and steelhead populations appears to be the juvenile rearing period, when productivity is density dependent. Apparent overwinter survival of Coho Salmon is a function of summer parr abundance and tributary and headwater reaches are important for producing large spring smolts.

Methow: No response

Middle Fork John Day:

1. Life-cycle model is likely applicable to other steelhead populations with some adjustment. Results can be applied to other Mid-Columbia and interior populations with similar restoration needs especially where elevated temperatures are considered limiting.
2. Results from the MFIMW are applicable to similar watersheds with historical mining and grazing practices, where the floodplain has been dredged and the channel altered. However, research is ongoing especially for juvenile life-stages and habitat use, and we are hopeful that in watersheds experiencing similar land-use issues that the results of these investigations will provide useful, management-oriented information.

Potlatch:

- At this point in the project, results from individual restoration projects are probably the most feasible to be extrapolated to other populations. For example:
    - Barrier removal projects to enhance fish passage are one of the most straightforward projects to implement and assess, and in most cases they are the first step in restoration sequencing. Results of these projects are easy to visualize and generate a lot of public interest and support for restoration.
    - Flow augmentation projects are cost-effective treatments to address low base flow conditions and can provide immediate benefits to juvenile rearing conditions over large spatial scales.
- It takes several years of instream habitat improvement to elicit small fish population and life history shifts. To maximize these responses, restoration should focus efforts on areas where successive projects can result in several miles of contiguous habitat.
- Prioritize work in geographic areas that are supported by current fish distribution rather than areas where numbers are extremely sparse to maximize benefits.

Pudding: Difficult to say because we did not see a response. But would be in the smaller watersheds with Coho Salmon and steelhead where the main habitat is formed by large wood.

Skagit: The Skagit River has a high proportion of migrating fry, but many other Puget Sound populations have higher proportions of migrating parr. Attempts to equate Skagit results with other systems should be mindful of the juvenile life history types dependent on estuaries.

Strait of Juan de Fuca: The results are broadly applicable to other small, coastal streams impacted by logging/road building practices in the Pacific Northwest (SE AK, WA, OR, N. CA).

Question 7

How is what you are learning being translated into information that can be used to inform policy, funding, and salmon recovery and watershed restoration decisions? Give examples. Do you have suggestions on how these types of outreach efforts could be improved?

IMW responses

Asotin Creek: We have presented widely at American fisheries symposium (multiple states, western and national level), Salmon Recovery Conferences, Salmon Recovery Funding Boards, Ecological and Restoration Symposiums, published numerous journal articles on the results, methods, and experimental designs of the IMWs we manage (Bridge and Asotin), supported MSc and PhD research and theses directed at specific IMW questions, published a manual on low-tech process-based restoration, trained over 3,000 land managers, NGOs, biologists, and private land owners about low-tech process-based restoration approaches, made publicly available online all our data and training resources, and participated in coordinating, synthesizing and making available IMW resources and summarizes online (e.g., Snake River Salmon Recovery Board, PNAMP, Columbia Basin PIT Tag Information System, website), helped to implement and support other groups (e.g., Conservation Districts, NGOs, state and federal agencies) to implement low-tech process-based restoration in a wide variety of other watersheds and ecoregions.

The Asotin Creek IMW results will help inform future management decisions to:

1) Determine the effectiveness of one of the most common restoration actions (addition of LWD) at increasing fish productivity and production

2) Our detailed survey methods (seasonal assessment of survival, modeling of net rare of energy intake, enumeration of smolts and adult abundance, etc.) should shed light on the casual mechanisms of any fish response we detect. Understanding why productivity changed should help us provide recommendations for improving LWD restorations actions.

3) Our detailed CHaMP surveys that provide topographic surveys of each habitat reach allow us to build models of stream character (delineate geomorphic units) and are used to populate net rate of energy models (NREI). NREI models integrate food, habitat and temperature and can be used to run restoration scenarios to better design restoration actions.

4)There are tens of thousands of stream miles in the PNW that are structurally starved (i.e., in a LWD deficit); the Asotin Creek IMW will provide valuable information on how to most cost effectively add LWD to streams and cause the largest positive changes to stream habitat and fish populations.

To date we have learned that:

1) Experimental Design – staircase designs are a powerful alternative to BACI designs and have several advantages including accounting for treatment x year interactions, being more logistically feasible to implement, and allowing for multiple streams to be treated (allowing results to be extrapolated to a greater number of stream types)

2) Monitoring Plan and Data Management – ChaMP habitat protocol provide data that other habitat programs do not and allowed development of NREI models, geomorphic delineation, multiple habitat metrics can be obtained from the digital elevation model created from topographic surveys, erosion and deposition rates can be quantified. Monitoring fish year-round provides ability to assess seasonal survival and fish movement. These data help confirm assumptions of the experimental design like independence. Data management for IMWs is a

major challenge and more resources need to be provided to IMW practitioners to assist with management of large volumes of data IMWs generate.

3) Restoration Implementation – staircase design makes implementation more logistically feasible because treatments are spread out over several years. The HDLWD can be a viable, cost-effective action that promotes immediate habitat change over large areas without damaging recovering riparian areas.

4) Restoration Effectiveness, Habitat change – large wood restoration actions need to stop focusing on single structures and instead build numerous structures in high density to promote greater habitat change and build resilience into the stream by buffering large flows.

5) Restoration Effectiveness, Fish response – rapid designs of structures should target sites to promote large changes in habitat using existing features where possible (activate old side-channels, create scour pools by constricting the stream using natural features (tree roots, boulders)

6) General Logistics/ Information Transfer – focus on treating large sections of stream, load wood as much as safe for the local conditions, do not over-design the structures unless there are infrastructure or safety concerns. Be patient with IMWs – the 100's of millions of $$ we spend on restoration can only be effective when we understand the fish and habitat responses – these include short-term (1-5 years) and long-term responses (5-10+ years). Streams were degraded over 200 years … it will take time to figure out the best way to restore them

7) Restoration maintenance should be a common practice and planned for - it is not practical to expect one restoration treatment can reverse all degraded habitat conditions - however the low-tech restoration method we have developed is so simple and cost effective that maintenance is not a burden, but instead an opportunity to review how the treatment is working and engage the local community to help sustain restoration benefits with simple maintenance efforts.

<u>Bridge Creek</u>: Bridge Creek IMW has demonstrated how low-cost process-based approaches, such as using beaver and BDAs, can be used to implement restoration of salmonid habitat over broad spatial extents. Project data has also demonstrated that the influence that beavers have on stream habitat positively affect salmonids at least in high gradient systems in the west. Based on this science from Bridge and Asotin Creek IMWs, many workshops have been given across the US on low-tech processed based restoration using BDAs and PALS to address structural starvation in watersheds. These workshops have included several thousand restoration practitioners who many of now use these techniques. A manual has also been created and shared on Research Gate that has been accessed 10's of thousands of times.

BDAs from Bridge work have been included in the following programmatic NOAA ESA consultations. This means that the potential impacts to ESA listed fish has been evaluated in advance, thereby facilitating permitting (ESA part only) if the relevant entity is involved in the action: HIP3 Biop (Bonneville Power Administration), Natural Resources Conservation Service conservation practices programmatic, ARBO (US Forest Service/ Bureau of Land Management), SLOPES (WA US Army Corps of Engineers), PROJECTS (US Fish and Wildlife Service). Proposed programmatic with Wheeler and Gilliam Oregon counties. ODFW has also provided guidance on BDA implementation to help streamline and avoid fish passage concerns.

Strong science basis for Low-Tech Process Based Restoration is resulting in shifts to permitting practices. Focus on process-based restoration versus not. Continue pressure on regulatory community to leverage science basis of Bridge Creek IMW work as source of risk mitigation around ESA and National Environmental Policy Act concerns at federal level.

<u>Elwha</u>: The Elwha River is definitely a posterchild for dam removal. The Elwha River can help be used to inform long-term monitoring of large-scale projects. Once the infrastructure for monitoring is in place (i.e., SONAR, smolt trap, etc), having value added projects really becomes a lot more cost effective, because the basics are covered. Setting up long-term IMW like monitoring (fish in/fish out, specific environmental parameters

monitored) can allow for less expensive research to take place. For example, genetics work is less costly because we have multiple life stages monitored already.

Hood Canal: We feel that all of our results are directly relevant to policy and funding decisions regarding habitat restoration. Our work is designed to measure restoration effectiveness and so it helps address prioritization and expectations for return on investment in restoration.

We have made every effort to communicate results from our study into lessons for restoration in a variety of formats and venues that are accessible to the restoration community. This includes presentations at conferences frequented by restoration practitioners (e.g., Salmon Recovery Conference), participation in IMW synthesis workshops organized by PNAMP, presentations to the SRFB and SRFB Monitoring Panel, presentations at local Hood Canal workshops/meetings, and publishing our findings in the peer reviewed literature. If there are barriers to the consumption of our information, we are certainly open to other methods of communication. Our team appreciates collective efforts to improve IMW outreach, such as the "lessons learned" workshops and synthesis report presented in this document.

Lemhi:

- Results from research, monitoring, and evaluations (RM&E) have helped guide future habitat restoration actions. For example, RM&E has identified that tributaries provide good summer and winter rearing habitat for juvenile fish. Therefore, the reconnection of tributaries to the mainstem Lemhi River has been a high priority.
- Information gathered from our IMW projects has been summarized and shared with our stakeholders (landowners, local government officials, students, anglers, etc.) through reports, presentations (professional conferences and regional meetings), blogs, site tours, and short videos.

Lower Columbia: Results from our fish monitoring program in the LC IMW complex have informed restoration treatments. For example, our observation that upper reaches of the LC IMW basins are more likely to produce large, spring Coho Salmon smolts, has been used to guide restoration efforts in Abernathy Creek, where the majority of projects have occurred in upper reaches of the basin. The information we produce also helps guide the Lower Columbia Fish Recovery Board as it works with its Technical Advisory Committee to fund habitat restoration projects. For example, the Lower Columbia Fish Recovery Board used habitat limitation information on Coho Salmon from the LC IMW to guide restoration funding decisions in similar watersheds in its Lead Entity area.

We have produced several reports using data from the LC IMW study, including a MSc graduate thesis, and were featured in the Pacific Coastal Salmon Recovery Fund's Report to Congress in 2016. Through outreach and communication, we strive to inform stakeholders on the effectiveness of our restoration activities in forums such as Recreation and Conservation Office Salmon Recovery Conferences, Pacific Northwest Aquatic Monitoring Partnership IMW Workshops, and River Restoration Northwest Symposia. The Abernathy projects led by the Cowlitz Indian Tribe have been featured in StoryMaps by the Recreation and Conservation Office and newspaper articles emphasizing how the landscape work is done more strategically and for lower overall cost. We have also led multiple site tours to interested parties. Below is a list of some of those efforts.

Pacific Coastal Salmon Recovery Fund FY 2016 Report to Congress:
https://archive.fisheries.noaa.gov/wcr/publications/recovery_planning/salmon_steelhead/pcsrf/pcs rf-rpt-2016.pdf

Nutrient Enhancement:

Sturza, M. T. 2017. Effectiveness of Salmon Carcass Analogs as a Form of Nutrient Enhancement for Juvenile Coho Salmon (Oncorhynchus kisutch) in Three Lower Columbia Watersheds. M. Sc. Thesis, Western Washington University, Bellingham, Washington http://cedar.wwu.edu/wwuet/597/.

Recreation and Conservation Office LC IMW StoryMap:

https://wa- rco.maps.arcgis.com/apps/Cascade/index.html?appid=d723d3fe4c6843d6a8fef1095ba38915

NOAA Fisheries Feature Story 2019:

https://www.fisheries.noaa.gov/feature-story/cowlitz-tribe-restores-lower-columbia-salmon- habitat-benefiting-juvenile-and-adult

<u>Methow</u>:

Fish Passage:

1) Recolonization following barrier removal may occur slowly and be strongly influenced by out-of-basin factors

2) The population uplift generated by barrier removal depends on factors limiting fish production before barrier removal, and how well improving passage to new habitat addresses those limiting factors. Limiting factors of the target population should be determined before performing barrier removal to scale expectations of recolonization rates, and to pair the barrier removal with habitat enhancement or other actions as appropriate

Floodplain and side channel habitat enhancement

1) Side channels contain higher densities of rearing steelhead and Chinook Salmon compared to mainstem habitat and provide refuge from larger piscivorous fish

2) Increasing hydrologic connectivity between off channel habitat and the mainstem has been shown to increase use by target species, particularly for seasonally disconnected side channels where fish previously had only a limited time to access the habitat

3) Strategies that provide high side channel habitat diversity, such as a combination of perennial flow through, alcove, seasonally connected, etc. are expected to be the most effective at increasing production of multiple target species and improving resilience over time. Diverse habitat patches within the floodplain landscape are valuable because they host very different local food webs that are used extensively by juvenile Chinook Salmon and steelhead

4) Side channel enhancement projects that have sufficiently deep pools with large wood have been shown to improve habitat suitability and carrying capacity of the habitat, especially for side channels that are seasonally disconnected

Channel complexity

1) Studies in the mainstem and side-channels of the Methow River showed that target species densities are positively associated with deep pools with large wood and overhead cover

2) Channel reconstruction and large wood enhancement in a small stream can increase spawning densities, total fish production, and the degree of consumption of invertebrate food resources. Enhancement may also decrease the relative consumption of food resources by non-target species such as Brook Trout

3) Large wood configured to promote local scour and bed movement has been shown to increase benthic invertebrate food available to drift-feeding ESA-listed juvenile salmonids

Food web

1) Food web analysis in the middle Methow showed that the structure of food webs, including species compositions and the types and strengths of predator-prey interactions, varied among habitat patches, presumably influenced by the type of habitat (e.g., mainstem versus side channel) and the degree of hydrologic connectivity. The analysis also showed that when you scale up to the larger channel/floodplain system, high spatial complexity produces weak trophic interactions, which promotes biodiversity and stability of food webs that are important for sustaining fish populations

2) In the middle Methow, for both mainstem and side-channel sample sites, the available prey base appeared to be able to support a greater density of rearing juvenile salmonids than was present at those sites, suggesting that the carrying capacity for juvenile rearing had not been reached

Middle Fork John Day:

1. MF IMW learnings are being shared to inform decisions related to salmon recovery and watershed restoration in a number of ways. First, Jim Ruzycki, ODFW, and John Selker, Oregon State University, presented to decision makers at the January 2018 OWEB Board meeting after the 10-year Summary Report was completed to share the value of long-term monitoring in understanding the outcomes of restoration actions in a relatively large watershed.
2. Secondly, MFIMW related staff has taken technical information from the MFIMW and translated it into two separate 4-page facts sheets to highlight key findings to help describe results and lessons learned. The majority of the information has been targeted at restoration practitioners to inform their future work. This information has been communicated at Oregon American Fisheries Society conferences, River Restoration Northwest (RRNW), and other technical conferences.
3. Also, the MFIMW maintains a public facing website, http://www.middleforkimw.org, to make available MFIMW documents and provide updates on current restoration and monitoring efforts. The website was developed to share MFIMW findings with both the local community and a broader audience beyond the Middle Fork John Day River watershed. Finally, the MFIMW Working Group has met annually with the John Day Basin Partnership since 2018 to facilitate two-way communication between the groups doing the long-term monitoring and those that are planning and implementing restoration actions in the MFIMW study area. This technical information exchange has directly informed watershed restoration planning with an intent of more effectively advancing salmon recovery.
4. MFIMW results are providing valuable information to OWEB about the need for grantees to prioritize the limiting factors to be addressed and where in the watershed they can affect the most change. OWEB has used the information from the MFIMW to generally inform expectations about how long restoration actions can take to show an improvement in salmon and steelhead populations. A variety of restoration actions are being implemented across the MFIMW study area by a diversity of organizations. The MFIMW has helped reinforce the reality that it will take more than 10 years to see an improvement in limiting factors and, thus, a measurable result in fish populations.
5. The modeling work from Drs. Mousa Diabat and Steve Wondzell shows that riparian revegetation efforts can mitigate warm water temperatures, but that it will take several decades for this to occur—especially in areas where significant negative impacts occurred over the preceding 100 years due to anthropogenic actions.
6. The steelhead life cycle modeling that was completed by Integrated Status and Effectiveness Monitoring Program to estimate juvenile fish responses to habitat improvement and/or water temperature reductions was very telling. This modeling effort contributed to greater recognition that water temperature is the primary limiting factor and that restoration designed to reduce temperature was more influential than those projects designed to increase habitat complexity alone. Understanding this information is important when evaluating restoration proposals, and steps being taken to address water temperature will be particularly helpful given the warming climate conditions that are occurring.
7. Collectively, this information helps OWEB board and staff set realistic expectations about how long it will take to see a measurable response from restoration actions, and awareness that drought conditions during a particular year can outweigh habitat improvements due to the fact that water temperatures simply may be too high.
8. Outreach efforts can be improved by working with a wide range of partners and funders to share the technical information in a distilled manner. Continuing to target key audiences and tailoring information to those audiences is key to long term success. Working with a variety of audiences to understand what information is needed to be clear how to present it is extremely helpful. Recent efforts by NOAA Pacific Coastal Salmon Recovery Fund to highlight MFIMW findings in their 2020 report to congress and the GIS Story Map that was developed is an example of successfully highlighting what has been learned to disseminate this information to policy makers. Working with funders such as NOAA and others to elevate

MFIMW findings to different audiences is needed to leverage public relations/communication specialist's resources to convey highly technical information and disseminate it broadly using existing websites and targeting relevant webinars, workshops, conferences, etc.

Potlatch:

- Fish monitoring results have helped inform future restoration treatments. For example, monitoring work has identified potential passage barriers to steelhead which were later addressed by restoration implementers.
- We have produced multiple reports to disseminate results of the project. We also work to inform stakeholders on restoration and monitoring activities by giving presentations in forums such as American Fisheries Society meetings (both national and Idaho chapter), PNAMP IMW workshops, Pacific Coast Steelhead Manager Meeting, and other conferences.
- We produce blogs, news releases, videos, and brochures highlighting restoration and monitoring activities for the public. We conduct site tours with various stakeholders, including local government officials, private landowners, school groups, etc. to discuss our project.
- One of the most effective means of outreach with policy makers and the public are quality short videos that highlight pieces of the program and can be distributed through many platforms. Collecting quality interviews and video production often require specific expertise. Developing a funding mechanism or competitive grants to produce these materials would vastly improve the ability to produce these materials.

Pudding: Overall, the Pudding Creek IMW life cycle monitoring data supports population status and trend evaluation for Coho Salmon and steelhead for the Mendocino coast region to help inform recovery. From this experiment, we have not quite begun to discuss how these results may inform new approaches in restoration strategies, but we will begin to outreach through our partners.

Skagit:

1) Through external funding from the Estuary and Salmon Restoration Program, we are putting the Skagit IMW in the context of other juvenile Chinook Salmon monitoring efforts in Puget Sound to determine the degree to which density dependence occurs in Puget Sound estuaries (Greene et al. 2021) and if the magnitude of restoration is producing benefits on adult returns (project ongoing).

2) Greene et al. 2021 also strongly points to the importance of connectivity – sites that are more connected to the head of tidal influence and source of juvenile outmigrants will likely support more fish than sites farther away.

3) Our effectiveness monitoring results should be helpful in providing the SRFB results to prioritize projects that are more likely to result in improvements to estuary wetland habitat use.

4) Due to the multiple methods for monitoring fish numbers in different stages of the Chinook Salmon outmigration, the IMW monitoring program will help determine the success of different hatchery release timing strategies initiated in October 2020.

Strait of Juan de Fuca: We work through the Monitoring Panel to inform the SRFB. SRFB can initiate changes to restoration guidance.

Monitoring Plan and Data Management

1) Managing large quantities of data can be difficult without proper support; building the PIT tag database was instrumental in making data entry and analysis much more efficient.

2) Habitat surveys conducted in within each system of an IMW on the same year may provide better trends detection as compared to staggered monitoring across years and systems given the potential influence of interannual variations in stream flow.

Restoration Effectiveness

1) habitat change: Wood jam volumes and/or piece counts should be collected in addition to counts of wood jams to monitor changes in woody debris within a system.

2) fish response: Monitoring fish migrations with PIT antennas can provide a more complete picture of life history diversity, migration timings, and outmigrant productivity as compared to traditional spring smolt trap monitoring. We have demonstrated that large numbers of fish move downstream during periods not typically covered by spring smolt traps.

General Logistics/ Information Transfer

1) It is important to keep up with PIT tag and communications technology: Recent advances represent a vast improvement over the original gear re PIT tag detection and antenna and infrastructure durability (increased ability to survive high-water events, less maintenance). Improved tag detection and reduced down time during fish migration windows are keys to the success of this project.

2) NOAA developed an Oracle Application Express (APEX) application for housing PIT tag and habitat data from IMW collaborators. The database provides an easy-to-use, web-based interface and allows for customized reports and data queries. Strait IMW collaborators have access to the entire database and the general public can access NOAA's IMW data. https://www.webapps.nwfsc.noaa.gov/apex/f?p=274:1:25521899047110

Question 8

Do you have recommendations on how to work with landowners on successful project development and implementation?

IMW responses

Asotin Creek: Yes - low-tech process-based restoration is intuitively appealing to landowners. It is simple to understand and implement and speaking openly about "letting the river do the work" makes sense to many landowners. In our experience landowners also understand that maintenance is a natural part of a restoration treatment and they appreciate that there is a long term plan - rather than a "one and done" approach. We have also found that having a demonstration project with a willing landowner is often the start of growing interest. Once one landowner implements low-tech - their neighbors get more interested and often want to try it.

Bridge Creek: Creating partnerships with private landowners is crucial in promoting similar restoration efforts on other landowner properties. There are several landowners that are interested in improving not only issues that directly effect their interest but also for the intrinsic value of the watershed they are part of. The development of a good working relationship with landowners and permittees goes beyond the immediate project you are collaborating on but they can also become ambassadors to other landowners to getting similar projects completed as they are quickly able to establish trust with their peers.

Elwha: Communicate till it hurts. It is better to over communicate than under communicate.

Hood Canal: No response

Lemhi: Successful project development and implementation is highly dependent upon a strong working-relationships with landowners. To build this trust, it is important to clearly discuss and disclose the rationale (goals and objectives) of restoration efforts. It is crucial that the landowners understands why the project is being proposed in the watershed and on their property. More importantly, the landowner needs to feel that they are being heard and their needs are met. It is through these negotiations that conceptual ideas are developed and restoration actions are designed. Budget constraints can influence these negotiations. For example, some landowner needs often cannot be met given the limitations in annual budgets. Therefore, it is critical to be flexible and willing to propose alternatives to find "common ground" that make landowners feel comfortable in the affects to their property while managers develop a beneficial habitat project. Most importantly, it is crucial to maintain this relationship and to stay in constant communication with the landowners throughout the project.

Lower Columbia: No response

Methow: Relationships are important so invest the time to nurture them for the long-term. Be able to admit when things do not go according to plan. Invest in adaptive management.

Middle Fork John Day:

1. Talk early and often and plan projects and communication as early as possible to address landowner concerns so there is time and resources to mitigate for these concerns. In some instances, landowner incentives have been successful in convincing reluctant landowners to participate in restoration or monitoring activities. The NFJDWC or Grant Soil and Water Conservation District can apply for these types of landowner incentives and have had success in writing letters to inform landowners of these projects.
2. Demonstrating upper-level commitment from agencies can help with landowner participation – i.e., Curt Melcher (ODFW Executive Director) has had phone contact with landowners in the John Day River basin.
3. A key initial step in the process of working with landowners is establishing working relationships with individual landowners. For ODFW staff this has meant reaching out and taking the time to discuss the purpose and importance of fish monitoring activities in the MFIMW. The practice of following up with results for individual landowners from specific monitoring actions (e.g., spawning ground surveys, juvenile fish movement / survival assessment) seems to have laid a good foundation for ODFW's relationship with private landowners in the MFJD. ODFW's success in maintaining access to sites on private land in the MFIMW study area is reflective of past actions and attitudes of staff involved in the MFIMW.
4. One goal of the NFJDWC is effective communication with landowners for the mutual benefit of the resource and those living on the land. The NFJDWC had had some success reaching out to landowners and explaining some of the restoration projects that were occurring in their area and letting them know they could reach out to the staff with any questions. These letters also served to inform landowners about opportunities to partner with us to do work on their private land.
5. Findings by outside MFIMW partners (McDowell et al. 2020) suggest that watershed wide restoration strategies should not discount the potential contributions private landowners can make and that it is critical to include them in the conversations around restoration. McDowell et al. suggests that this reflects "collaborative management" -- because restoration is visible at some sites, other land managers in the neighborhood incorporate best management practices, perhaps in subtle ways, that lead to ecological improvements over time on land without explicit restoration projects.

Potlatch: Effective communication is the key to successful project development and implementation with a landowner. Clearly laying out expectations and listening to the landowner's questions/concerns goes a long way to eliminating problems down the road. Not all landowners are the same, some want to be heavily involved while others are very hands off, be prepared to modify your style to the landowner's degree of involvement. For large land holdings with multiple family members/owners, establishing a primary contact early in the process will help facilitate communication and avoid misinterpretation.

Pudding: It takes a community of many different groups and trust. Finding common ground seems important as we may all have slightly different objectives. This experiment involved a single large timber company and a state-owned timber property, and both support salmon recovery. We partner with the timber company to do our monitoring and share costs.

Skagit: No response

Strait of Juan de Fuca: No response

Question 9

What haven't you learned from your IMW that you expected to learn? Is it attainable with more time? If yes, estimate how long it would take to get the thing you expected to learn?

IMW responses

Asotin Creek: - How long will the responses last? Can we increase the responses with increased maintenance/enhancement of the original treatment and the addition of BDAs to force greater floodplain connection? What are the most important factors linked to the responses we are seeing (e.g., how do adult abundance, temperature, discharge, and habitat conditions interact to influence abundance and production responses)? Can large wood treatments match the responses seen in systems where beaver recolonized and were linked to large fish responses?

We think we could get answers to these and other questions in the next 3-5 years.

Bridge Creek: Because of the dynamic nature of streams and their interaction with restoration actions, reliance on short term responses alone can potentially be misleading. The evolution of streams dominated by beaver have been proposed in low gradient systems in boreal forest but largely remain undocumented in the west. This would be attainable with more time including the impacts they have on salmon and steelhead. We believe that a minimum of 15 years is necessary, but this is dependent on the number of high water events that are experienced during the study.

Elwha: We expected that focusing in on changes to habitat type would give us insights into how habitats are created and maintained. Due to the variability in habitat type delineation due to observer error and process error that will not be the case. This is not attainable with more time.

Hood Canal: We still feel there is a lot to learn about how fish respond to restoration.

Perhaps most directly, this includes evaluating the fish response to recent restoration actions in Big Beef Creek and Seabeck Creek. We simply have not had enough time after restoration to pass judgment on whether there was any increase in abundance, survival or life history diversity following these projects. In Big Beef Creek, a three-phase restoration project that occurred in 2015 – 2017 installed LWD jams and reconnected approximately 11 acres of floodplain wetland habitat. In Seabeck Creek, an undersized culvert in the anadromous zone was replaced with a 60-foot bridge in fall 2020.

However, clear, obvious signs of impairment in the study streams, especially Seabeck Creek and Little Anderson Creek, present additional opportunities for learning how fish respond to restoration.

We have consistently targeted 10-12 years of monitoring after restoration. For projects completed to date, this would be 2027-2029 in Big Beef Creek and 2031-2033 for Seabeck Creek.

Lemhi: One of our goals for the Lemhi River IMW is to observe a population response (increase in the number of fish into and out of the basin) to habitat restoration actions. We have observed a response from at a finer scale (e.g., juvenile response to reconnected tributaries) and observed an increase in salmonid abundance in specific river reaches but have yet to determine how the population as a whole has been influenced. A population response to our habitat actions may be attainable, given sufficient funding resources and the necessary time to evaluate multiple generations. An aggressive habitat restoration program implemented by multiple collaborators is ongoing in the Lemhi River, and the focus has expanded to the reach scale to rehabilitate large floodplain and river segments. With all the new and upcoming habitat projects, we suspect that will take time to evaluate a population level response. The Lemhi River basin is also a very large watershed and we have observed salmon at various life stages using different portions of the mainstem Lemhi River and its tributaries. Therefore, it will take a lot of effort (time and number of people) to monitor fish response in the basin. We estimate a time frame of a minimum of 10-15 years to observe a population level response of salmonids to habitat restoration actions.

Lower Columbia: Overall, we are meeting our goals and don't think there are any data gaps. However, we have not been able to detect a habitat signal from any restoration activities to date. We are exploring new time series models to attempt to differentiate random variability from treatment effects in the habitat dataset. For fish, there are many compelling research questions that remain that were not identified at the onset of the study. For example, we have not learned about the carryover effects of increased spawning and rearing habitat on marine survival or about the relative importance of life history diversity on overall adult returns, particularly as this relates to climate variability and climate change.

Our analyses suggest we need at least 10 years of post-treatment monitoring to detect a change in fish productivity, meaning continued monitoring through 2032.

Methow: No response

Middle Fork John Day:

1. How restoration across the watershed influences overall population productivity. We were expecting to see a watershed level fish response – but not surprised that we haven't given the iterative restoration process in the MFIMW, and the generational timeframe for riparian growth to effect stream temperatures.
2. Restoration projects in the MFIMW are ongoing and adapting to current research and thus many research projects are currently in pre-restoration monitoring phases or have one or two years of data collection with preliminary results but are not currently complete. Examples listed below.
    a. Fish habitat preference: Last year we examined juvenile salmonid use across study sites using the mobile PIT antenna in an attempt to tease out habitat preferences, but results were inconclusive. Juvenile salmonids either don't display strong habitat preferences or are keying into something we did not measure.
    b. We conducted pre-restoration fish monitoring in Summit Creek to document use and dispersal from ephemeral and perennial reaches. Upcoming restoration projects in Summit Creek will help us understand the effects of watering ephemeral sections on fish use, movement, and dispersal.
    c. A key area of the MFIMW that was previously under private ownership was recently purchased by the Blue Mountain Landtrust and plans for restoration are underway.
3. Monitoring and research in the MFIMW has been collaborative and iterative, with research building on results from previous projects and from identifying knowledge gaps. Examples below:
    a. Adult habitat selection – we have evidence of shifting spawning distribution of Chinook Salmon, but are unclear of the why or how, e.g., is it spawner habitat or adult holding habitat that is driving the distribution shift?
    b. Building on distribution shifts of adult Chinook Salmon - we are currently evaluating differential juvenile salmonid survival and fish-habitat relationships at restored and unrestored sites where habitat was intensively measured at a reach scale.
    c. We have produced models showing that decreased temps will have positive effects on juvenile salmonid distribution and survival, but we haven't had enough time to validate the models.
    d. Tracking dispersal patterns from redds is yet another step in understanding how fish are utilizing available habitat and how restoration and changes in water temperature (due to restoration or climate change) influence movement and survival of juvenile salmonids.
    e. More information is needed to understand what happens with fish less than 65 mm. Most MFIMW work has been done on PIT-tag sized fish. We are currently monitoring Chinook Salmon fry dispersal and movement from redds using innovative genetic techniques. We have one year of monitoring completed and need more years to fully understand and document this understudied and important life-stage.
    f. Additional long-term monitoring of juvenile salmonids in Middle Fork John Day River tributaries like Camp Creek (2008 – 2021) will be used to assess the influence of environmental variability (e.g., stream temperature and hydrology) on population dynamics in freshwater rearing areas.
    g. We have identified a knowledge gap regarding Chinook Salmon parr moving out of upper reaches and their overwinter habitat use.

4. Research and models identified that water temperature is the limiting factor of greatest concern for salmonids in the MFIMW, and that riparian growth could lower stream temperatures. Documenting changes in water temperatures and effects on salmonids is a long process and results are incoming.
    a. Vegetation changes, riparian growth, and effects on stream temperature - just starting to see changes and need more time to analyze and create models to detect change over time.
    b. Water temperature products are under development including a spatial stream network model which will predict reach scale average summer stream temperatures across the MFIMW area, and a model that will forecast water temperature and utilizes flow data from the Middle Fork John Day River at Camp Creek gage. Stream temperature models tailored to produce biologically relevant variables at a reach- scale resolution will allow us to better track and evaluate changes in water temperature throughout the MFIMW area, allowing restoration practitioners to target projects in areas of highest impact.

<u>Potlatch</u>: There is still a lot to learn about how fish respond to restoration at the watershed scale. The pace of project implementation in the EFPR has increased in recent years and we are beginning to see positive improvements in emigrant life history and habitat conditions. However, the pace of implementation in the BBC watershed has stagnated, and the two highest priority project we have identified have not been implemented. Both of these projects fall outside the realm of traditional habitat restoration and present complexities in terms of funding and permitting. There needs to be more time to overcome these hurdles.

We anticipate achieving the bulk of restoration goals by 2028-29 and need a minimum of 7-10 years post-treatment monitoring to accurately assess the response of population productivity to restoration actions.

<u>Pudding</u>: Why the treatment did not cause habitat change. It could be attainable with more time. Not sure how long, at least 2-3 more generations of fish.

<u>Skagit</u>: The core IMW question is whether estuary restoration works to improve population abundance/productivity, and in that respect the IMW has achieved success. However, we also expected to see changes in the frequency of fry migrants entering the nearshore and improved smolt- adult return rates following restoration. Although these patterns are heading in the right direction, to date there has not been a large signal.

However, positive responses of adult returns are more sensitive to environmental variation than juvenile population responses. It is possible that estuary restoration may have a large positive population response at the juvenile stage, but that positive response is not carried through to the adult stage simply because other factors absorb or offset the earlier benefit. If this is the case, then it is untrue that estuary restoration did not work (indeed, population response may have been better than without the restoration). Communicating this life-cycle and cumulative-impacts perspective is difficult but necessary to maintain public support for restoration projects of this scale.

Measuring population response within a stock-recruit framework requires enough years of both spawners and subsequent recruits. It also requires sufficient treatment in habitat to induce a change in demographics that will shift stock-recruit relationships. We discuss the need for population bonanzas to test the stock-recruit relationships under current restoration. We have uncertainty when this will occur in the Skagit populations. For restoration, we do have a schedule for additional restoration actions that are intended on the landscape. We know that a number of restoration projects are planned within the next 5 years that would apply more treatment to assess population response. Several ongoing modeling efforts may allow us to project whether restoration planned within the time frame of the IMW will produce a response given larger outmigration sizes and the current range of variation in marine and early freshwater survival.

<u>Strait of Juan de Fuca</u>: No response

Question 10

What issues have arisen during the study that have compromised your ability to address the primary study objectives? Using the drop down menus in the spreadsheet, please respond to the following categories with yes or no; we will discuss the details at the workshop.

<u>Categories</u>: unanticipated difficulties with study design, insufficient number and size of restoration actions in the treatment watersheds, the treatment phase being so long the ability to measure response was impacted, unanticipated environmental variability obscuring treatment effects, other.

Table of IMW responses

	Asotin	Bridge Creek	Elwha	Hood Canal	Lemhi	Lower Columbia	Methow	Middle Fork John Day	Potlatch	Pudding	Skagit	Strait of Juan de Fuca
unanticipated difficulties with study design		Yes	Yes	No	Yes	No	Yes	Yes	Yes	No	No	Yes
insufficient number and size of restoration actions in the treatment watersheds		Yes	No	Yes	No	Yes	No	Yes	Yes	No	Yes	No
the treatment phase being so long the ability to measure response was impacted		No	No	No	No	Yes	Yes	Yes	Yes	No	Yes	Yes
unanticipated environmental variability obscuring treatment effects			Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
other*	Yes	Yes	Yes		Yes		Yes		Yes	No	Yes	

*Asotin IMW had difficulties with the ability to maintain large monitoring infrastructure and manage large amount of data. There was not enough funding to implement a large monitoring program and manage the data. We also lost some data due to a private land owner not allowing access to two monitoring sites for 1-2 years.

Question 11

What are the key items that would be lost or that we would miss out on if IMW funding decreases or disappears?

IMW responses

<u>Asotin Creek</u>: Fully developing the low-tech process-based restoration method - understanding how to implement, maintain, and what is possible (i.e., extent of floodplain connection, habitat improvements, etc.). Completing the experiment to - finishing the monitoring (3-5 years), understanding and quantifying the fish response, being able to explain how best to add LWD to improve habitat and fish abundance. And understanding what is possible - what are the costs of restoration, the extent that can be treated, the amount of maintenance

required, how different stream types respond, synthesis of results into coherent recommendations for future restoration.

Bridge Creek: The long-term impacts such as what happens when ponds fill will not be evaluated. The Bridge Creek IMW did decrease after 7 yrs and finished the following year. Recently funding was provided by OWEB to continue monitoring after a 4 yr hiatus. Monitoring was resumed during this hot drought year. The loss of cumulative tagging of the population, especially in low a population abundance year will result in a low sample size and the ability to estimate survival, growth, and production, will be greatly diminished as will the ability to track the trends during the warm low water past years has been lost.

Elwha: How long does it take to develop self-sustaining salmon populations after dam removal? How does it vary according to species and management strategy?

Hood Canal: Our expectation is that both the hydrologic processes we are attempting to restore and the fish population will take time to respond to restoration. In our project planning, we had always targeted 10-12 years (roughly 4 Coho Salmon generations) of post-project monitoring to evaluate the fish response. With restoration occurring as recently as fall 2020 (Seabeck culvert replacement), reducing or cutting funding now would undermine or eliminate our ability to evaluate a fish response.

Lemhi: Habitat restoration efforts in the Lemhi River, and arguably throughout the upper Salmon River basin, would suffer if IMW funding was reduced or lost. Significant Lemhi River restoration actions (tributary reconnections/large floodplain enhancement projects) are ongoing, thus, ample time is need to evaluate benefits. Furthermore, practitioners are depending on monitoring results to inform and shape future project development (adaptive management), which would not be possible without the Lemhi IMW.

Lower Columbia: Fish population monitoring in the LC IMW complex is not complete, despite a valuable time series of life cycle monitoring dating back to 2000. The workplan developed in 2015 identified a post-treatment monitoring period of 10 years to significantly detect a population response in salmon and steelhead. Restoration treatments are just wrapping up, meaning that an additional 10 years of monitoring through 2032 are required to assess the effects of restoration on salmon and steelhead populations in this complex.

Methow: Not applicable, no IMW funding in place.

Middle Fork John Day:

1. The iterative, evolving, adaptive framework of the MFIMW allows for the flexibility for new talent and ideas to flourish in an area, and afford people who have a fresh perspective the opportunity to approach a problem with a new way of thinking. Reduced or eliminated funding would significantly stall progress toward understanding watershed ecology and using that information to manage our watersheds more effectively.
2. Oregon Watershed Enhancement Board Focused Investment Partnership funding has provided focused restoration actions in the MFIMW area - if IMW funding decreases or is lost, we will lose the opportunity to measure response to these targeted restoration actions.
3. The MFIMW is in the second phase of adaptive monitoring following the initial 10 years of restoration and monitoring which resulted in a long list of lessons learned and recommendations - loss of funding would impact the ability of MFIMW partners to continue with adaptive research and focused restoration projects.
4. Challenges within the watershed are ongoing and unknown, i.e., climate change, extreme drought conditions, invasive species, predation, etc. As challenges and changes arise, the IMW platform and organization has allowed partners to leverage the long-term datasets and knowledge, and the flexibility to answer future questions.
5. Decreased or lost IMW funding would curtail our ability to carry out the essential watershed scale and project restoration monitoring actions and conduct the analyses required to assess the efficacy of the MFIMW and document changes to salmonid populations, distribution, and habitat use. If the MFIMW were to lose funding at this stage in the study, it would jeopardize our ability to assess changes in population productivity over an appropriate time scale (i.e., multiple generations of salmonids and a reasonable time

for riparian growth). In addition, we would lose the multi-agency collaboration and pooled funding for resources and staff dedicated to MFIMW work within partner agencies (ODFW, CTWS, NFJDWC).

6. We are currently in pre-restoration monitoring for several important restoration projects – decrease or loss of IMW funding would curtail our ability to document fish response to these restoration projects.
7. Response of riparian and aquatic systems to restoration takes time. While some parts of the system respond quickly, other parts respond slowly. For example, growing trees large enough to supply LWD to the stream may take decades. Therefore, our 23-year span of monitoring some sites is an important and valuable step, but monitoring should continue on the Middle Fork John Day River. In particular, the valuable systematic monitoring under the MFIMW program, which started in 2008, should be continued.

Potlatch: We utilize multiple funding sources to monitor and evaluate the steelhead response to restoration activities in the Potlatch River. IMW funds cover approximately 50% of the annual monitoring expenses. We would have to make drastic changes to our monitoring activities, either dropping an entire tier of monitoring (i.e., tributary monitoring activities) or reduce the spatial extent of our monitoring to a single index watershed. As a result, the IMW project could not be fully evaluated if funding decreases or disappears.

Pudding: No response

Skagit: Understanding how well one of the largest connectivity restoration projects planned in Puget Sound (McGlinn Island) benefits Chinook Salmon.

Strait of Juan de Fuca: The effects of restoration can take years to decades to manifest, and can be masked by the large variability in population dynamics due to outside factors (ocean conditions, harvest, etc.). Restoration actions can also take years to settle in and reach full effectiveness.

Question 12

What do you see as your minimum and desired funding levels over the next 5 years? Please specify if there are specific, one-time, funding needs outside of the regular monitoring activities, such as data analysis, synthesis, and/or outreach and communication.

IMW responses

Asotin Creek: Minimum is to continue current level of funding ~250-290,000 for 4 years (i.e., until 2025). It would be desirable to have an extra $15-25,000 to fly the IMW study area and collect Lidar (a repeat flight to allow comparison with pre-restoration lidar), 5$0-100,00k to continue maintenance enhancement, and installation of BDAs, and $100-150,000 for more analysis and reporting budget to finish analysis and write a comprehensive report and publish several journal articles.

Bridge Creek: No response

Elwha: The current monitoring program on the Elwha River costs ~300K/year and funds adult enumeration using SONAR, smolt outmigrations, spatial distribution monitoring, and proportion of natural origin (pNOS) and hatchery origin (pHOS) spawners on the natural spawning grounds. Maintaining that level of funding would be ideal for at least another 10 years

Hood Canal: We wish to maintain our fish and habitat monitoring field operations for the next five years (and beyond). I expect that we can conduct data analysis, paper writing and external communication activities as in-kind contributions of our project team's time even though these activities are under-funded.

Lemhi: At minimum, we would like to continue to see our current funding maintained over the next five years. Currently, we depend on three different sources (including IMW) to obtain sufficient funding to achieve our goals in the Lemhi River basin. Ideally, IMW budgets would include an annual 2-3% increase. It is also important to note that much of the monitoring infrastructure, such as PIT-tag arrays, backpack electrofishers, and nets (just to name a few) are nearing the end of their useful life. Replacing this equipment will be difficult under flat budget scenarios. Finally, once we have achieved the bulk of our restoration goals, we need a minimum of 7-10 years post-treatment monitoring to accurately assess the response of population productivity to restoration actions. This funding will be critical to effectively determining the outcomes and success of the IMW program. A request for additional funding would help to further evaluate and summarize (e.g., publish) our results.

Lower Columbia: Complete life cycle monitoring of fish populations in the LC IMW complex requires ~$450,000 per year. Currently, we receive ~$250,000 annually for all monitoring tasks. The discrepancy is supplemented by Pacific Coastal Salmon Recovery Fund Shortfall dollars, but this is not sustainable in the long term.

Methow: Not applicable, no IMW funding in place.

Middle Fork John Day:

1. Funding levels as they currently stand are functional, but we rely on partner collaboration (without IMW funding) within and outside our IMW to accomplish monitoring at the current levels. Our IMW would benefit from additional funding for a statistician to assist with large-scale analyses and to assess the statistical power of monitoring results. In addition, we do not have an individual in charge of or dedicated to outreach and communication, and our IMW, along with partners in the basin, would benefit from assistance with regular website updates, data sharing, communications, and graphical design.
2. We are currently at minimum direct funding level for maintaining monitoring efforts. We have benefited from continued funding from Bonneville Power Administration and OWEB supporting fish and habitat monitoring, respectively. However, funding for important collaborators has drastically declined limiting our ability to leverage the expertise of academic institutions and consultants with experience in regional restoration monitoring.

Potlatch: At a minimum, we need to stay at our current funding levels over the next 5 years. However, funding has been stagnant for the past decade although the cost of salaries, equipment, and supplies have increased considerably. Ideally, IMW budgets would include annual 2-3% increases. It is also important to note that much of the monitoring infrastructure in many IMWs, such as PIT tag arrays, backpack electrofishers, etc., are nearing the end of their useful life. Replacing this equipment will be difficult under flat budget scenarios. Finally, once we have achieved the bulk of our restoration goals, we need a minimum of 7-10 years post-treatment monitoring to accurately assess the response of population productivity to restoration actions. This funding will be critical to effectively determining the outcomes and successes of the IMW program.

Pudding: No response

Skagit: We would like to see at least the same amount of funding we have previously received maintained for at least the next 5 years. That said, our relatively fixed budgets, combined with higher costs over time, have resulted in a net erosion of funding for the basic work. A 10% increase in funding would help facilitate better monitoring, production of research papers on the project, and other outreach.

Strait of Juan de Fuca: Current funding is adequate to cover salary, travel, PIT tags, and some equipment maintenance. A one-time investment of ~$25,000 would allow us to upgrade the last of three PIT tag antenna sites (East Twin River). The gear is obsolete and failing and provides only 1/4 of the detection range of the new systems currently in Deep Creek and the West Twin River. In terms of funding to support restoration, this has always been a struggle. Additional restoration work has been identified but there is not money available to complete it.