The 2021 Puget Sound Nearshore Restoration Summit Proceedings

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We acknowledge that the land upon which we live and work is part of the traditional homelands of the Indigenous peoples of the Salish Sea, who have resided on and stewarded this land from time immemorial and still thrive today. We respect and uphold the Indigenous communities and sovereign tribal nations as knowing bodies and defining partners in our effort to improve the integrity and resilience of ecosystem processes that support environmental and human health and wellbeing.

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Executive Summary

Led by the Washington Department of Fish and Wildlife's (WDFW) Estuary and Salmon and Restoration Program (ESRP) and the Puget Sound Ecosystem Monitoring Program (PSEMP) Nearshore Work Group, the goal of the Nearshore Summit was to connect natural scientists, social scientists, and restoration practitioners to synthesize Puget Sound nearshore restoration actions and science. Specific objectives were to:

1. Synthesize biophysical and social science research informing nearshore restoration in Puget Sound.
2. Synthesize nearshore restoration practice in Puget Sound.
3. Identify the most important science and restoration management questions that will guide actions that improve nearshore ecosystem conditions.
4. Update Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) conceptual models for the ecosystem responses of specific restoration actions and best practices to incorporate new research.
5. Develop and/or incorporate social science principles including diversity, equity, and inclusion (DEI) into conceptual models for nearshore restoration.

During the virtual Summit from March 10-25, 2021, 78 invited speakers representing over 50 institutions gave oral presentations to more than 500 registrants. Participation focused on engaging with presenters and taking part in discussions on *beach*, *delta*, and *embayment* shoreforms. In generating the Proceedings, we sought to not only represent the presentations by speakers, but to synthesize participation throughout the Summit in generating new and updated key messages, conceptual models, and syntheses on the three shoreforms, including the incorporation of social sciences. The Proceedings are organized into main sections of:

1. *Introduction to the Puget Sound nearshore ecosystem*: A brief overview of the social, physical, and cultural landscape.
2. *Summit goals and objectives*: The interdisciplinary vision for bringing together natural scientists, social scientists, and restoration practitioners to synthesize the restoration and research work in Puget Sound.
3. *Summit process*: A description of the timeline and content of Summit and Proceedings development, including the participation of the planning team, steering committee, speakers, and attendees.
4. *Key message synthesis*: A summary of key messages derived from presentations and discussions that we organized into themes associated with (1) implications from research and practice, and (2) uncertainties and future research needs.
5. *Speaker contributions*: The background and context, findings, key messages, and references for each presentation.
6. *Conceptual model synthesis*: Updates to Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) models for each shoreform, as well as the development of a broader conceptual model for social-ecological systems, informed by discussion sessions for each shoreform.
7. *Learning and knowledge cycle synopsis (Ecocycle)*: A summary of the Ecocycle discussions for each shoreform which allowed for a collaborative group approach to map the strategies,

culture, and ideas of nearshore restoration and analyze the natural evolution of its ideas and components.

8. *Pre and post-Summit surveys*: The results of surveys we conducted to gauge expectations and learn more about attendees before the Summit, and reflections following the Summit.
9. *Resources and citations*: References that provide context for the Summit and Proceedings content.

Detailed in the Proceedings is the development of several new conceptual model visuals to aid our understanding of the Puget Sound nearshore and a successful path for restoration into the future. Apart from model updates for each shoreform, we developed a new General Social-Ecological model for nearshore restoration which incorporated both the human and biophysical context for restoration, including DEI. A main theme that emerged throughout the Summit was the intention to deliberately create an interdisciplinary space to consider restoration work from the perspectives of natural science, social science, and practice.

Broad Implications

1. Creating interdisciplinary spaces that include social science, natural science, and insights from restoration practice can facilitate planning for resilient and inclusive restoration outcomes.
2. Ecosystem recovery and the development of landscape structure and function following restoration actions take time.
    - Monitoring this development over time is a key way to understand the effects of restoration actions to guide future restoration work.
    - Communication of this process is an important way to build trust and collaborations for future restoration.
3. The effects of climate change are already influencing nearshore ecosystems and restoration actions can help to address some of these effects.
4. Integration of social sciences and human dimensions into restoration work will allow us to plan for improved outcomes for ecosystems and people.
5. Coupled social-ecological models for restoration help to illustrate the connection between the human context and the biophysical components of ecological restoration.
6. As we enter the United Nations "Decade of Restoration[1]" working across disciplines will remain a key way to facilitate reversing the degradation of ecosystems and promoting wholistic restoration.
7. We recommend re-visiting the topics herein every 5-10 years to address emerging topics and to assess how social-ecological models have been incorporated into restoration science and practice.

Conceptual models

As part of the Summit process, we generated a new, social-ecological model for nearshore restoration in Puget Sound (Fig 6-3), as well as models specific to each of three geomorphic landforms considered by the Summit, beaches (Fig. 6-4), river deltas (Fig. 6-5), and barrier embayments (Fig. 6-6).

[1]https://www.decadeonrestoration.org

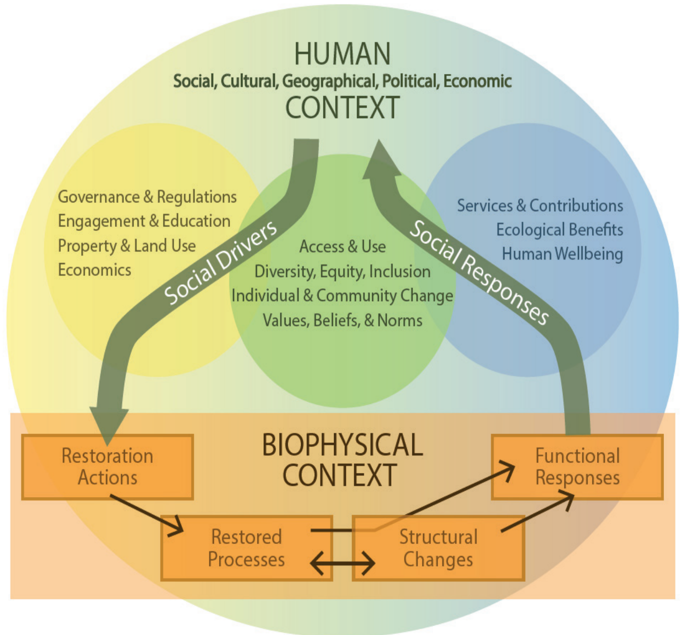


Figure 6-3. General Social-Ecological model depicting the human and biophysical context for nearshore restoration.

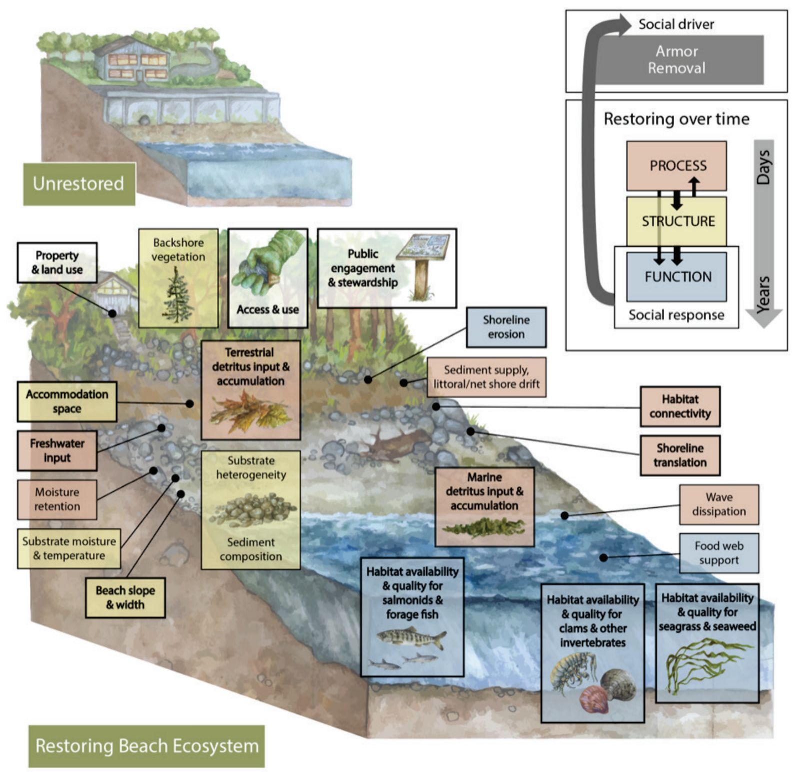
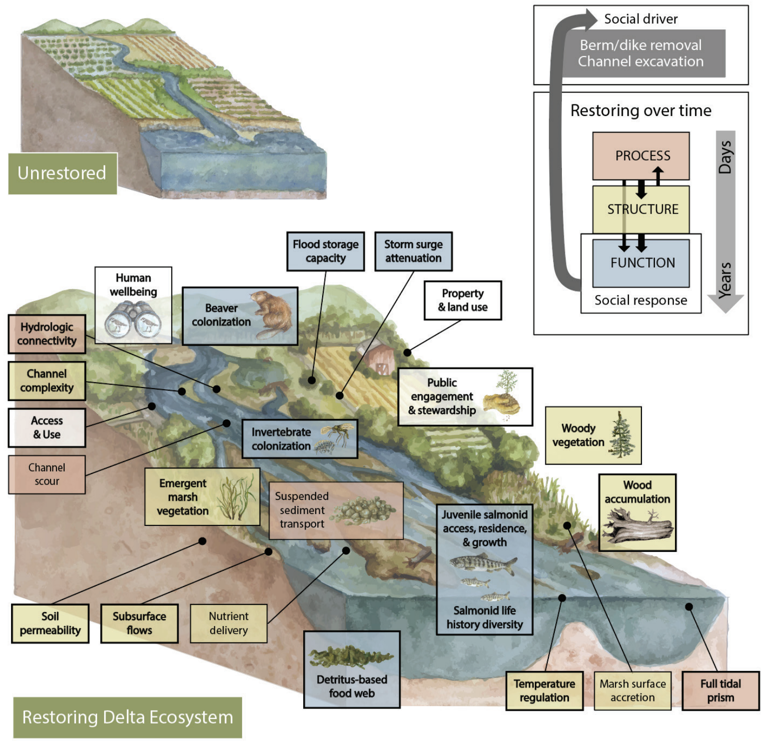


Figure 6-4. Updated beach shoreform conceptual model following restoration.



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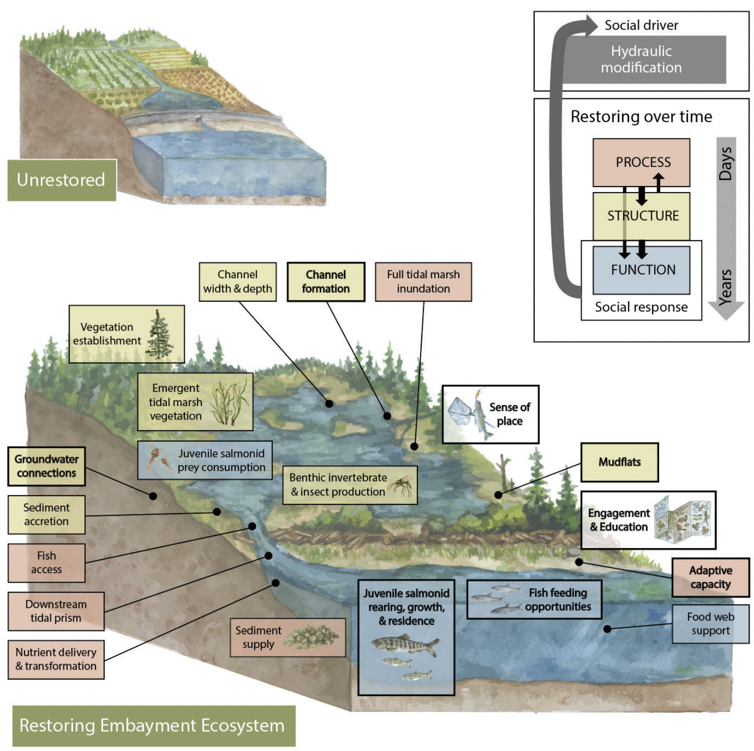

Figure 6-6. Updated embayment shoreform conceptual model following restoration

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1. Introduction to the Puget Sound nearshore ecosystem

Washington's Puget Sound is a fjordal estuary that is part of the broader Salish Sea within Canada and the United States supporting a rich ecosystem that includes diverse estuarine and marine habitats (Sobocinski 2021). This social, physical, and cultural landscape is the ancestral home of the Coast Salish and Indigenous peoples who have stewarded the land and water since time immemorial. Since the introduction of settlers and the advancement of industrialization, the Puget Sound region has experienced substantial population growth and urbanization (Puget Sound Regional Council 2022). The extent of human impacts on the Puget Sound ecosystem has been well described, including the physical changes to shoreline landscapes and effects on nearshore ecosystem function (Fresh et al. 2011, Simenstad et al. 2011, Sobocinski 2021, Trimbach 2021). The Puget Sound nearshore extends upland beyond tidal influence and waterward to the extent of light penetration that sustains photosynthesis. (Figure 1-1). This rich transition zone, spanning multiple landscapes and biological communities, is a key aspect of a functioning Puget Sound ecosystem. The nearshore ecosystem also contributes greatly to the region's human communities who rely on and benefit from these nearshore areas for cultural, social, spiritual, health, and economic purposes, like recreation, tourism, food, connection, relaxation, and overall wellbeing. It is comprised of a suite of habitats, ranging from intertidal habitats such as tidal swamps, salt marshes, and beaches (Johannessen and MacLennan 2007) to subtidal habitats such as eelgrass, kelp (Mumford 2007, Calloway et al. 2020), and shellfish beds (Dethier et al. 2006). Key species types that inhabit and rely on these habitats are native salmon (Fresh 2006, Munsch et al. 2016, Pearsall et al. 2021), forage fish (Rice 2006, Penttila 2007, Quinn et al. 2012), and birds (Buchanan 2006). Nearshore habitats are connected and maintained by ecological processes such as freshwater flow, sediment input, and exchange of detritus (Schlenger et al. 2011). The fundamental relationships between the ecological processes that create and maintain these habitats, structure on the landscape, and ecological function were articulated for this region by the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP), (e.g., Clancy et al. 2009, Fresh et al. 2011, Schlenger et al. 2011,

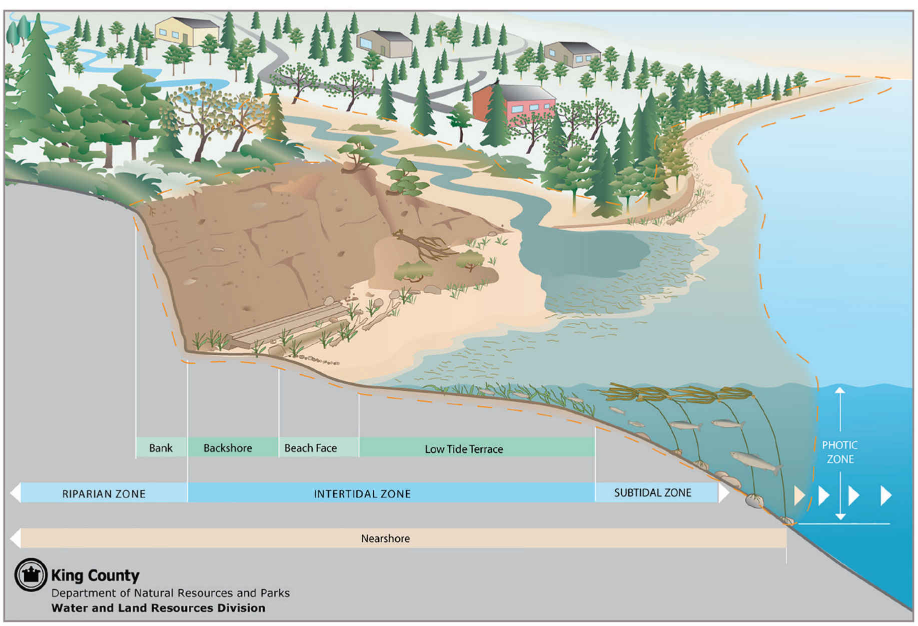

Figure 1-1. Depiction of the nearshore ecosystem, including riparian vegetation, tidal wetlands, beaches and bluffs, eelgrass, oysters, and kelp (reprinted from Schlenger et al. (2011) and Simenstad et al. (2011), image courtesy of King County Natural Resources).

Simenstad et al. 2011). This 20-year scientific investigation described the geomorphic nearshore landforms (hereafter, shoreforms) that comprise the Puget Sound shoreline (Johannessen and MacLennan 2007, Shipman 2008), identifying the 16 large river deltas, coastal inlets, barrier embayments, and beaches as unique environments that are shaped by distinct suites of ecological processes (Clancy et al. 2009, Schlenger et al. 2011, Cereghino et al. 2012). This investigation also developed a suite of conceptual models describing the relationships between restoration actions (management measures) and landscape-forming processes, structure, and function (Clancy et al. 2009), and articulating strategies for restoration and protection in Puget Sound that target these foundational processes (Cereghino et al. 2012). Understanding where and how to recover and maintain ecological processes is at the core of nearshore recovery strategy and principles.

2. Summit goals and objectives

2.1 Synthesizing nearshore restoration and practice

In the last few decades and since the PSNERP general investigation was completed in 2012, there have been a multitude of nearshore restoration projects to restore and protect ecosystem processes in the Puget Sound nearshore. There has also been a suite of research projects that have advanced our understanding of the relationships between restoration actions and nearshore ecosystems, and generated data and analyses to better plan, prioritize, and design restoration projects. This growing body of research and practical knowledge has been shared in a variety of ways, including regional conferences, local seminars, peer-reviewed journals, and the Salish Sea Wiki, yet it has not been synthesized to best inform the next generation of restoration and research projects. To advance this objective, an interdisciplinary team envisioned bringing together restoration practitioners and scientists to synthesize the restoration and research work in Puget Sound. The 2021 Nearshore Restoration Summit focused on PSNERP geomorphic shoreforms (beaches, deltas, and embayments) and restoration actions that target the processes that form and maintain them (Schlenger et al. 2011, Cereghino et al. 2012). We acknowledge the other nearshore habitats within Puget Sound that are vitally important to the ecosystem such as kelp forests, oyster beds, and eelgrass, and while restoration and protection of these habitats were not the primary focus of the Summit, we emphasize the interconnected nature of a functioning nearshore ecosystem such that the benefits of maintaining and protecting intact habitats likely transcend the physical boundaries of the habitats themselves. We also emphasize the importance of landscape connectivity across ecosystem components through the exchange of sediment, water, organisms, and detritus (Polis et al. 1997, Howe and Simenstad 2015, Olson et al. 2019). Maintaining and restoring this connectivity is frequently an explicit objective of restoration and protection actions, regardless of the landscape.

In addition to synthesizing the nearshore natural science and restoration work since PSNERP in Puget Sound, the Summit team sought to explicitly facilitate the integration of the social sciences into nearshore restoration science and practice. While PSNERP acknowledged the role of humans in the nearshore ecosystem (Leschine and Petersen 2007, Clancy et al. 2009, Fresh et al. 2011) the social sciences were not as developed in their body of work or the conceptual models generated therein. The PSNERP conceptual models in Clancy et al. (2009) focused on depicting restored processes, structural changes, and functional response for each restoration action, with some mention of social benefits such as public education and access at restored sites. We identified the integration of the social sciences as a key gap and opportunity for growth.

Box 2-1. Summit objectives (developed with guidance from the steering committee)

Summit objectives

1. Synthesize biophysical and social science research informing nearshore restoration in Puget Sound
2. Synthesize nearshore restoration work in Puget Sound
3. Identify the most important science and restoration management questions that will guide actions that improve nearshore ecosystem condition
4. Update Puget Sound Nearshore Ecosystem Restoration Project conceptual models for the ecosystem responses of specific restoration actions and best practices to incorporate new research (Clancy et al. 2009).
5. Develop and/or incorporate social science principles including Diversity, Equity and Inclusion into conceptual models for nearshore restoration

We convened the 2021 Nearshore Restoration Summit to bring together natural scientists, social scientists, and restoration practitioners and planners to synthesize Puget Sound nearshore restoration actions and science since PSNERP, with an important goal to explicitly integrate social science principles including diversity, equity, and inclusion (DEI). Box 2-1 describes key objectives of the Nearshore Summit including synthesis of existing knowledge and work, identification of key questions to guide future actions, updates to PSNERP conceptual models, and social science integration.

2.2 Social science integration

The social sciences offer much to nearshore restoration, management, planning, and natural science. The social sciences broadly refer to the academic body of theory, knowledge, and research methods aimed at understanding social systems, and consists of a range of disciplines, including anthropology, economics, geography, political science, psychology, and sociology, among others (Bennett et al. 2017, Trimbach et al. 2020). As observed within broader conservation, natural resource management, and environmental sciences, the social sciences can help justify and prioritize recovery actions, enhance governance processes and management practices, understand environmental inequities and injustices, and question biases, assumptions, and even models of recovery (Bennett et al. 2017, Stern 2018). Previous work in Puget Sound connecting social scientists with the natural environment has emphasized the role of the social sciences in explaining peoples' motivations for how they affect the environment as well as drawing connections between the environment and human wellbeing (Wellman et al. 2014). This work has also shed light on the kinds of policies that are more effective at eliciting human behavior change and articulating the kinds of social systems that best sustain natural resources (Wellman et al. 2014).

Often framed around human dimensions or human wellbeing (Bennett et al. 2017, Biedenweg and Trimbach 2021), the social sciences contribute a wealth of data, concepts, theories, methods, and approaches to nearshore and broader ecosystem recovery. For example, Poe et al. (2016) highlighted how shellfish harvesting, a nearshore cultural, recreational, and subsistence practice, fosters a sense of place among indigenous and non-indigenous Puget Sound residents. Furthermore, Puget Sound decision-makers, social scientists, and resident partners can collaborate to identify, modify, and prioritize human wellbeing indicators for recovery purposes (Biedenweg et al. 2017). Such indicators offer much to recovery, including demonstrating the human linkages to ecosystem health and illustrating the reciprocal relationships between communities and the natural environment. For example, Trimbach et al. (2021) illustrated Salish Sea residents' geographic literacy, including knowledge of place names, and what that means for transboundary (United States and Canada) recovery efforts, while Burdsey (2016) highlighted how British coastal communities have shifted over time with regards to demographics and cultures. Social science topics (e.g., social patterns and processes) can also be integrated into social-ecological conceptual models, including content associated with demographics, economics, political or economic institutions, and even culture (Redman et al. 2004). By integrating the social sciences into conceptual models, they can better reflect the complex social systems, contexts, processes, and agents (individuals or communities) that are intrinsically entwined with living in and managing ecological systems.

The integration of the social sciences alongside natural sciences into recovery and conservation efforts comes in many shapes and sizes (Robinson et al. 2012, Guerrero et al. 2018, Koontz and Thomas 2018, Robinson et al. 2019, Biedenweg et al. 2021). For example, Guerrero et al. (2018) examination of social-ecological research integration demonstrated that there are multiple dimensions of integration, including conceptual (general consideration), methodological (reflected in methods, frameworks, or tools), disciplinary (inclusion of content or frameworks from multiple fields), and functional (researchers and practitioners included, merging concepts, frameworks, and tools leading to solutions or recommendations). Similarly, Koontz and Thomas (2018) in their analysis of the use of science among Local Integrating Organizations (LIOs - local watershed groups based in Puget Sound), found that use of science ranged from instrumental (direct integration into plan text), conceptual (indirect integration through plan thoughts and discussions), and symbolic (integration after the fact to justify specific plan choices). While integration is taking place, including in the Puget Sound region (Wellman et al. 2014, Biedenweg and Trimbach 2021), considerable barriers remain. For example, time constraints and project timing, lack of knowledge and expertise of the social sciences, limited financial resources for social scientists, and bias against or rejection of social science research, are well-recognized barriers to the integration of the social sciences within recovery and environmental planning or management (Robinson et al. 2012, Kline et al. 2017, Marshall et al. 2017, Persson et al. 2018). Understanding social interrelationships with natural systems academically is one thing, managing and influencing social behaviors to further environmental stewardship is quite another.

2.3 Diversity, equity, and inclusion

Diversity, equity, and inclusion (DEI) are considered integral to addressing long-standing environmental injustices, including within environmental governance, ecosystem recovery, and conservation (Tienda 2013, Environmental Protection Agency 2016, Sarkki et al. 2017, Batavia et al. 2020, Bennett et al. 2021). While DEI and DEI's linked concepts such as environmental justice (EJ), are not new (Gleeson and Low 2008, Sultana 2015), their expansion within environmental fields, including ecosystem recovery and natural sciences, has only begun to gain considerable attention and traction (Schell et al. 2020, Bennett et al. 2021). This is demonstrated by Washington's Environmental Justice Task Force recommendations (Environmental Justice Task Force 2020) and the passing of the Healthy Environmental for All (HEAL) Act (Front and Centered 2021), both of which prioritize DEI within environmental management, planning, and policy. By intentionally including and addressing DEI-related concepts, tools, specialists, frameworks, and research within nearshore recovery, scientists and practitioners alike can better identify, prioritize, and alleviate major environmental and health inequities often experienced by overburdened communities (Environmental Justice Task Force 2020).

While DEI is often understood and examined as a singular monolithic concept or idea, diversity, equity, and inclusion are different concepts with their own backgrounds, definitions, approaches, and even literature (Box 2-2) (Tienda 2013, Sarkki et al. 2017, Batavia et al. 2020, Environmental Justice Task Force 2020).

Box 2-2. Diversity, equity, and inclusion (DEI) definitions.

DEI is not a singular concept or idea. DEI consists of three interwoven concepts with their own competing definitions, literatures, research, and frameworks. Below, are three definitions that can be applied while integrating or applying DEI within nearshore restoration.

Diversity: Illustrates the differences present within a particular collective, group, setting, or place. An individual is not diverse. Differences are often associated with social identities, including able-bodiedness, age, class, ethnicity, gender, race, religion, or sexual orientation.

Equity: The ability to develop, enhance, and support procedural, distributional, contextual, and recognitional fairness in systems, resource management or distribution mechanisms, governance, and procedures to foster more equitable opportunities for all people.

Inclusion: Practices and strategies aimed at promoting meaningful interactions among individuals or groups with differing backgrounds, experiences, worldviews, and traits.

(Tienda 2013, Sarkki et al. 2017, Batavia et al. 2020, Environmental Justice Task Force 2020)

For example, environmental equity can be defined as "the act of developing, strengthening, and supporting procedural and outcome fairness in systems, procedures, and resource distribution mechanisms to create equitable (not equal) opportunity for all people," (Environmental Justice Task Force 2020, p. 78). Equity is one of the most well-researched DEI concepts within the environmental or conservation social sciences (Sarkki et al. 2017, Batavia et al. 2020, Bennett et al. 2021). Equity is often broken down into four dimensions, that include:

1. Procedural equity (governance, processes, involvement, and decision-making fairness within ecosystem recovery)
2. Distributional equity (distribution or allocation of costs, benefits, rights, and burdens of ecosystem restoration outcomes, policies, programs, or actions)

3. Recognitional equity (recognition and respect for the rights, values, cultures, social norms, and knowledge systems of all partners involved in or impacted by ecosystem recovery efforts), and
4. Contextual equity (social and geographic conditions that inform an individual's or group's ability to obtain recognition, participate, and gain fairness in ecosystem restoration) (Sarkki et al. 2017, Law et al. 2018, Bennett et al. 2021).

Diversity, equity, and inclusion, along with environmental justice and other complementary concepts, are often more complex and nuanced than initially presented. Such complexity and nuance necessitate deeper interrogation and intentional integration of DEI within nearshore restoration, as shallow exploration, neglect, or conflation may lead to inadequacies, problems, or further inequities and injustices.

Similar to DEI as a whole, DEI and the social sciences are not the same. Not all social scientists are experts or have training in DEI, nor do DEI practitioners necessarily come from backgrounds within the social sciences. Importantly, work to bridge ecological and social-cultural world views extends beyond traditional sciences (both natural and social) and includes incorporation of different ways of knowing. While distinct, the social sciences have examined DEI and environmental justice for decades (Gleeson and Low 2008, Sultana 2015) and are deeply linked. Thus, while different, the social sciences are well-equipped to help better understand, assess, analyze, and integrate DEI within nearshore recovery efforts. According to the Environmental Protection Agency (2016), DEI-focused research necessitates a combination of diverse scientific approaches, including those stemming from the social sciences. The social sciences are recognized as key tools to better understand and integrate DEI and EJ into restoration efforts (Environmental Protection Agency 2016, Bennett et al. 2017, Law et al. 2018, Bennett et al. 2021). For example, Bennett et al. (2017) suggests that the social sciences can help with DEI-related recovery and conservation efforts by enhancing management and governance by better engaging partners and communities, assisting planners with goals or initiatives that better align with differing cultural, social, economic, and political contexts, and helping facilitate more equitable restoration processes and outcomes.

3. Summit process

3.1 Summit content

The idea for the Nearshore Restoration Summit emerged through conversations over multiple years and funding between the Puget Sound Partnership (PSP)'s Puget Sound Ecosystem Monitoring Program (PSEMP) Nearshore Work Group and the Washington Department of Fish and Wildlife's (WDFW) Estuary and Salmon Restoration Program (ESRP), who worked collectively to develop a vision of bringing together and integrating perspectives from natural science researchers, social science researchers, and restoration practitioners around a common goal of nearshore restoration in Puget Sound (Figure 3-1). With the Summit, we deliberately set out to create an interdisciplinary space that encouraged consideration of restoration work from the perspectives of natural science, social sciences, and practice.

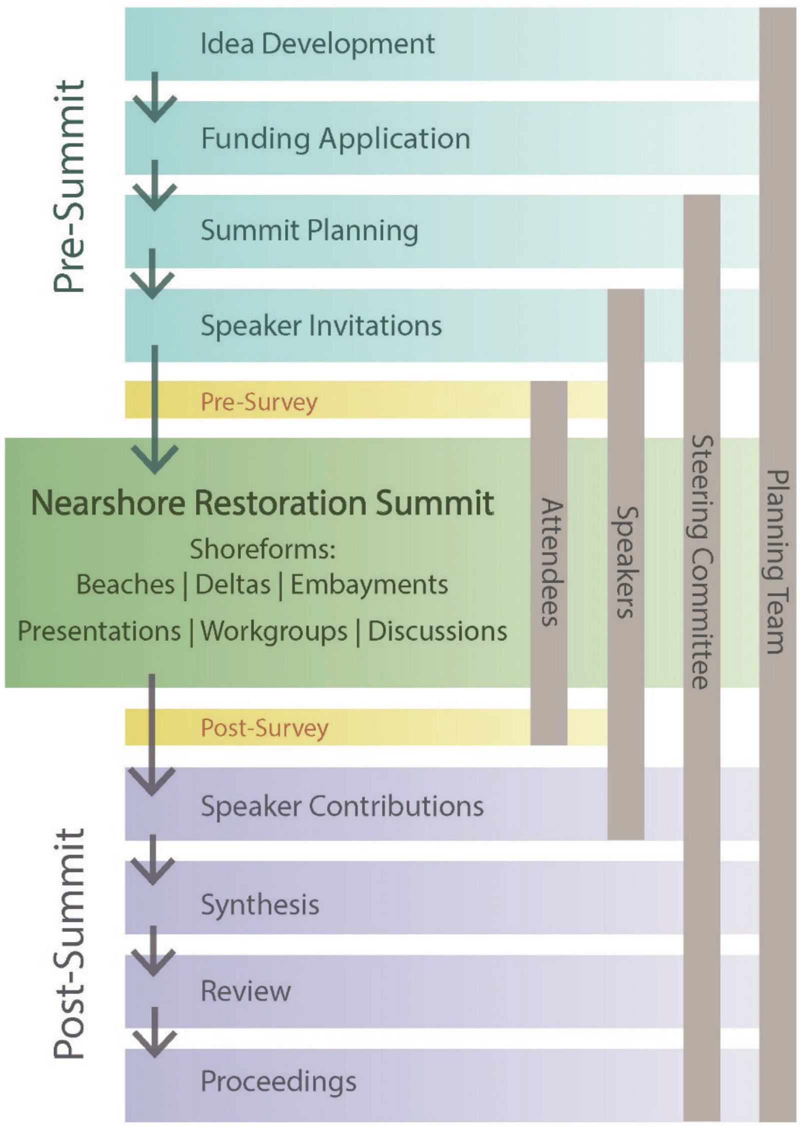

Figure 3-1. Diagram depicting the process of holding the Summit, participation of the Summit committees, speakers and attendees, and developing the Summit proceedings.

Building upon the growing knowledge of social science integration and social-ecological research in ecosystem recovery (Robinson et al. 2012, Guerrero et al. 2018, Robinson et al. 2019, Biedenweg and Trimbach 2021), the Summit Planning Team included key social science research within the Summit's various components. Using Guerrero et al. (2018) approach to social-ecological integration, the Team sought multiple types of integration, notably functional integration, in that the Team intentionally included cross-disciplinary social scientists to contribute to the Summit through presentations, discussions, conceptual model adaptive management, and the proceedings. The Team also included a social scientist (David J. Trimbach[2], Oregon State University) to help guide and ensure the integration of the social sciences was not purely symbolic (Koontz and Thomas 2018).

A steering committee was formed and met several times throughout the planning process to provide input on the objectives and format of the Summit and Proceedings, including speaker selection, presentation structure, and discussion format (facilitated and unfacilitated). The steering committee consisted of regional scientists and experts in restoration (Table 3-1) and helped to shape and articulate both the major Summit objectives and the organizing questions posed to the invited speakers that would help achieve Summit objectives.

Table 3-1. Summit steering committee members and affiliations.

Summit Steering Committee Members	Affiliation
Ron Thom	Pacific Northwest National Laboratory Emeritus and Puget Sound Partnership
Chris Ellings	Nisqually Indian Tribe
Megan Dethier	University of Washington
Paul Cereghino	National Oceanic and Atmospheric Administration
Dawn Spilsbury	The Watershed Company
Sydney Fishman	Washington Department of Ecology
Doris Small	Washington Department of Fish and Wildlife
Jennifer Griffiths	Washington Department of Fish and Wildlife
Devin Smith	Skagit River System Cooperative

The objectives were focused on synthesizing nearshore research and practice in Puget Sound, identifying key areas of future research to inform restoration, updating the PSNERP conceptual models to include findings from recent research and practice, and working to incorporate social science and principles of diversity, equity, and inclusion into restoration practice in Puget Sound (Box 1-1). To achieve these goals, natural and social sciences and restoration practitioners were integrated within the Summit's various components (Figure 3-2). Multiple mechanisms were used for integration and knowledge co-production, in which people with different knowledge sources and capacities spanning the science-policy-society interface came together to inform restoration science and practice throughout the Summit and proceedings development, similar to the process identified in Djenontin and Meadow (2018).

Integration of social sciences, natural sciences, and restoration practice was considered a primary goal and purpose of the Summit and was represented in the presentations, activities, and resulting contents. This integration is intentionally highlighted throughout this proceedings document (e.g., key message

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and theme synthesis, conceptual model updates, and post-Summit assessment survey results (Figure 3-2)). The Summit Team endeavored to offer restoration practitioners, natural scientists, and social scientists, a resource to recognize, imagine, and integrate the diversity of the social sciences within their own nearshore recovery decision-making, planning, and broader restoration efforts, including those that necessitate engagement or acknowledgment of humans and human-environment interactions or impacts within their efforts. While by no means exhaustive, the Summit and its contributors hoped to provide a range of content, information, and research to aid the restoration community in all facets of restoration planning, implementation, and research while encouraging an approach that considers the perspectives of the natural sciences, the social sciences, and practitioner insights.

To address the broad goals of the Summit (Box 2-1), speakers were identified and asked a set of discipline-specific questions that would help articulate both implications and uncertainties for restoration (Table 3-2). The questions were focused on understanding, from the perspective of each group, implications of their work for restoration (NS1, SS1, and P1) (Table 3-2) and identifying uncertainties to guide future research (NS2, SS2, and P2) (Table 3-2). Speakers that fit into multiple disciplines were asked to answer from the perspective of the group that best aligned with their expertise. To facilitate building on the Clancy et al. (2009) conceptual models for restoration, an additional question related to this was posed to the natural scientist group (NS3) (Table 3-2), while an additional question related to better integrating restoration science and practice with social science was posted to the social scientist group (SS3) (Table 3-2).

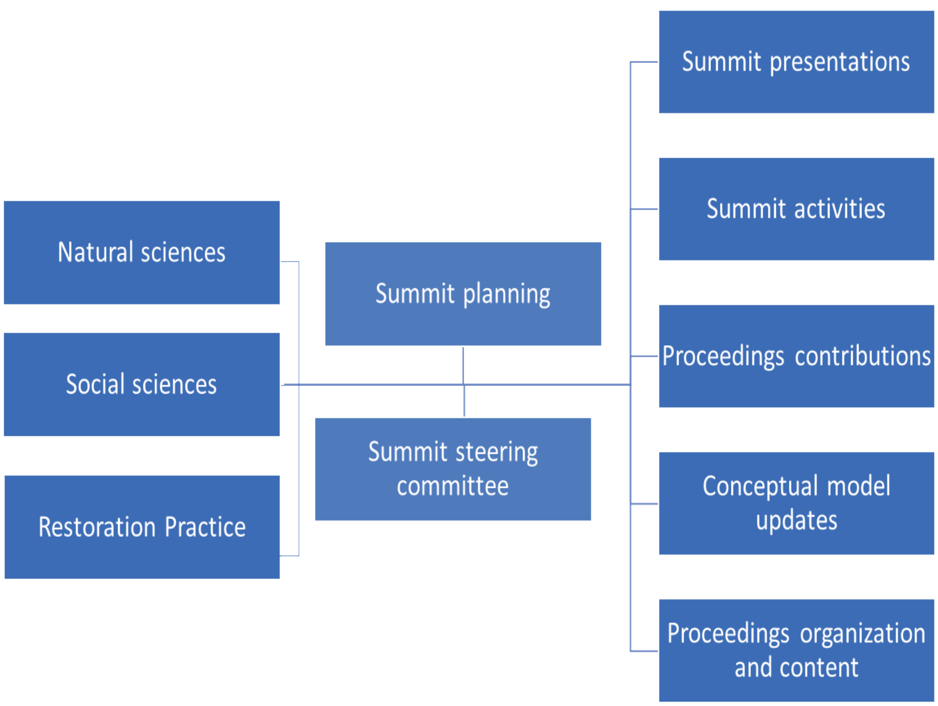

Figure 3-2. Integration of natural science, social science, and restoration practice in Summit planning, execution, and proceedings development.

The speakers invited represented a breadth of research, practice, and DEI expertise across Puget Sound, with several additional speakers from the Columbia River Estuary, Oregon coast, neighboring British Columbia, as well as the east coast. Seventy-eight speakers presented (including introductory remarks from retired coastal geologist Hugh Shipman), representing over 50 organizations including academic, tribal, non-profit, and local, state, and federal entities. (Table 3-3, Appendix B).

Table 3-2. Summit organizing questions posted to each speaker group to address in their presentation and written contribution.

Speaker Group		Questions posed to each group
Natural Scientists	NS1	What are the key implications of your research for planning or implementing process-based restoration?
	NS2	For you, what are the most important uncertainties to address with future research that will result in more effective restoration?
	NS3	How does your work build on PSNERP conceptual models for restoration from Clancy et al. 2009?
Social Scientist	SS1	What does (your) social science (field/area/expertise/etc.) contribute (value-add) to planning or restoration?
	SS2	What are major social science gaps and needs that you observe or experience within your field or area?
	SS3	What needs to be done in order for (you and your) research to be better integrated into practitioners' or natural science researchers' work?
Practitioners and Planners	P1	What have you learned through your experience with project development, design, and implementation that informs the future needs of restoration?
	P2	For you, what are the most important scientific uncertainties that limit planning, designing, implementing, or evaluation nearshore restoration?

Table 3-3. Number of natural scientist, social scientist, and practitioner/planner speakers within each shoreform session. Some presentations had >1 speaker.

Geomorphic Shoreform	Speaker Role	Number of Speakers
Beach	Natural Scientist	10
	Social Scientist	6
	Practitioner/Planner	9
	Beach Total	**25**
Delta	Natural Scientist	20
	Social Scientist	3
	Practitioner/Planner	12
	Delta Total	**35**
Embayment	Natural Scientist	8
	Social Scientist	4
	Practitioner/Planner	6
	Embayment Total	**18**
Total Speakers		**78**

Natural scientists invited were generally local or regional researchers whose work informs the planning, design, implementation and evaluation of nearshore restoration. These researchers included ecologists focused on the development of ecological function following restoration actions in beach, delta, or embayment shoreforms, geologists focused on sediment transport and processes, and GIS specialists focused on developing spatial tools to inform restoration planning. The natural scientists represented a broad array of institutions, including academic, federal, tribal, state, county, Non-Governmental Organizations (NGOs), and private companies. The practitioner and planner group consisted of individuals whose work consists of planning, leading, implementing or managing nearshore restoration projects in Puget Sound. They included representatives from lead entities, tribes, counties, state agencies, conservation districts, NGOs, private companies, and salmon enhancement groups. The social scientist group included social scientists or professionals with social science backgrounds from a diverse range of disciplines, including anthropology, economics, geography, and psychology. Social science research topics included content and knowledge ranging from in/equity within the context of nearshore recovery project site selection to sense of place of shorelines among Puget Sound residents. Several additional Summit participants presented, discussed, and provided proceedings contributions focused on DEI, from broader topics such as integration of DEI best practices and lessons learned to more focused research on inequities associated with Puget Sound shellfish harvesting.

The Summit was organized such that each week focused on a different geomorphic shoreform (beaches, deltas, embayments) consisting of a day of virtual presentations followed by a day of both presentations and small group discussions and facilitated workgroups. While the integration of our three primary disciplines was implemented throughout the Summit development process, the Team also intentionally created a schedule that would incorporate and balance these disciplines and topics for each shoreform; recognizing that communicating across such a diverse group of scientists, policy makers, practitioners, and lay-persons was important to do intentionally. Furthermore, because the Summit was to take place in a wholly virtual environment, we were sensitive to the challenges of knowledge transfer, social interaction, and listener attention. To address these challenges, the Summit team enlisted the assistance of Cathy Angell Communications. Cathy has decades of experience teaching people how to communicate science to non-scientists and has recently developed training for how to communicate more effectively in a virtual environment, emphasizing the importance of creating presentations that are engaging, interesting, and clear. All Summit speakers were provided an opportunity for a live virtual group training session and 30 or 60-minute personal coaching sessions with Cathy. We intended this to facilitate a higher quality of messaging, content delivery, and Summit speaker experience overall and we believe the Summit participant experience was better because of this resource.

3.2 Summit discussions

For each shoreform, we held three different types of breakout discussions in which all speakers were invited, as well as key additional participants identified by the planning and steering committees (see Appendix C).

1. **Virtual "Dinner parties":** These small group discussions were intended to spark conversation and dialogue among participants across disciplines that would help the Planning Team to articulate answers to the Summit's organizing questions related to implications for restoration and future research. We named these "Dinner Parties," each with 5 – 10 invited participants, designated host, and note-taker. Key messages from these discussions were then folded into the Summit synthesis of key messages along with speaker submissions. See Appendix C for the list of attendees for each shoreform.
2. **Learning and knowledge cycle** (hereafter referred to as "Ecocycle")**:** This discussion tool is a method of planning and prioritizing that builds on a concept taken from natural ecological systems. This method allows for a collaborative approach to planning that enables a group of people to map the strategies, culture, or ideas of an organization or program and analyze the natural evolution of its ideas and components. During these facilitated planning sessions,

participants used this tool to assess the current state of restoration, science, and human dimensions for Puget Sound nearshore recovery. See Appendix C for the Ecocycle participants.

3. **Conceptual models:** We convened a group of Summit speakers and attendees to integrate recent insights from research, practice, social science concepts, and DEI into conceptual models for restoration. This effort was built on the Clancy et al. (2009) conceptual models as well as models for social-ecological systems developed by Harguth et al. (2015), Redman et al. (2004) and Kline et al. (2017). We used google slides to share and iterate upon the Clancy et al. (2009) models for dike/berm removal for deltas, armor removal for beaches, and hydraulic modification for embayments, and the social-ecological models for all three shoreforms. See Appendix C for conceptual model exercise participants and Appendix D for the existing models that were modified through our facilitated exercise.

4. Key message synthesis

The foundational questions guiding the Summit were, broadly, “What have we learned that has informed restoration” and “What do we still need to know” (Box 3-2). Within each of these questions, we organized the Summit contributors’ and discussion participants’ answers and perspectives into several overarching themes including restoration planning and design, restoration monitoring, social sciences, and needed analyses to support restoration planning (Table 4-1). Below we discuss the themes and subthemes we identified from speaker contributions as well as insights generated from the facilitated “dinner party” discussions for each shoreform, reflecting both implications from research and practice and uncertainties and future research needs (Table 4-1). This synthesis draws primarily on the written contributions (Section 5) and insight from discussions (Appendices C and D), however content from presentations is also occasionally referenced. While not exhaustive, speaker names and discussion sections are referenced parenthetically when appropriate.

Table 4-1. Themes from key messages of Summit speaker contributions and discussion sessions.

	Theme	Subthemes
Implications from research and practice	Restoration planning and design	*Data, tools, and analyses* *Prioritizing new restoration* *Habitat connectivity*
	Restoration coordination	*Stakeholder engagement* *Communication* *Project team expertise and implementation* *Funding*
	Restoration monitoring	*Ecological and physical response to restoration* *Community science*
	Social sciences	*Diversity, equity, and inclusion (DEI)* *Multiple forms of knowledge (esp. indigenous knowledge)* *Integration with restoration planning*
	Climate change	*Sea level rise* *Increasing temperatures* *Carbon sequestration and mitigation*
Uncertainties and future research needs	Needed analyses to support restoration planning	*Embayment strategy for guiding restoration actions* *Predictive models of habitat-forming processes* *Fish use of nearshore habitats and potential benefits of restoration*
	Restoration monitoring and data	*Standardization of methods* *Funding challenges*
	Climate change and predictive analyses	*Sea level rise* *Rising temperatures*
	Social sciences	*Diversity, equity, and inclusion (DEI)* *Multiple forms of knowledge (esp. indigenous knowledge)* *Integration with restoration planning*

4.1 Implications from nearshore restoration research and practice

Natural scientist and practitioner speakers identified the key datasets, tools, and analyses for the success of existing and future restoration projects for all three shoreforms (beaches, deltas, and embayments) based on their research or practical experience. Their contributions included monitoring, evaluating, and adaptively managing existing restoration projects as well as prioritizing, planning, and designing new restoration projects. Many speakers emphasized the importance of engagement, relationship building, and trust among stakeholders, tribes, and landowners, and the utility of and need for prioritization that reflects values across different interests. The integration of the social sciences and multiple forms of knowledge was identified as an essential ingredient in promoting diversity, equity, and inclusion in the practice of restoration.

4.1.1 Restoration planning and design

a. Data, tools, and analyses

Restoration success at the scale needed for Puget Sound ecosystem recovery depends on collaborative data collection, new tool development, and diverse data analyses. Spatial and temporal data collection efforts in both “reference” (unimpaired) and restoring habitats for all three geomorphic shoreforms are essential for gauging the effects of restoration and thus informing strategies for future restoration efforts (Borde, Cote, Smith and Small, Chamberlin, Davis and Ellings, Greene, Faulkner, Toft, Dethier, MacLennan, Burgess). Natural scientists and practitioners are responsible for a variety of tools and analyses to help plan and understand the potential benefits and effects of restoration in nearshore habitats in Puget Sound and how these interact with ongoing impacts such as climate change.

Data, tools, and analyses to predict and understand the effects of restoration have been developed for each shoreform. In embayment systems, for example, work is underway to collect and analyze geomorphological data that will help to inform guidelines for barrier embayment tidal outlet morphology (Cote). In beach systems, management recommendations are being informed by new spatial data to help understand how and where the greatest ecological benefits will be realized from restoration actions across the ~2,500 linear miles of Puget Sound beaches. These data provide context for strategic planning of shoreline armor removal and enhancement projects based on drift cell sediment dynamics, armor location and extent, and forage fish spawning locations (MacLennan). The Beach Strategies project and bluff recession data can further be integrated with other local data to highlight areas with greater resilience to sea level rise and identify opportunities for managed retreat (MacLennan, Kaufman). In major delta systems, natural scientists have developed predictive models for hydrology, channel allometry, and configuration (Hood), vegetation development (Borde, Hood, Davis, and Ellings), and sediment transport (Grossman), all of which are vital aspects of post-restoration habitat development (i.e. process, structure, and function) and thus informing the planning and design of future large scale estuary restoration projects. Scientists are collecting additional spatial data that depict restrictions of tidal connectivity and will help focus restoration actions based on the level of impairment (Burgess). Recent research in deltas shows that understanding the relationships between Chinook smolt outmigrant abundance and estuary habitat characteristics can help guide restoration actions in the context of other watershed goals (Greene). Furthermore, habitat-association models developed for tidal wetlands indicate that estuary restoration also has the potential to benefit a variety of bird species (Bayard). Because of the unique combinations of ecosystem processes that form each of the geomorphic shoreforms (e.g., large rivers vs. small streams) restoration planning tools for one shoreform may not translate to the others (e.g., beach strategies are beach-specific and tidal channel development models are delta-specific); however, because embayments have features of both beaches (e.g., drift cell sediment dynamics) and deltas (e.g., tidal wetlands) embayment restoration planning analyses may have elements in common with those developed for beaches or deltas.

b. Prioritizing new restoration

Restoration opportunities are best pursued holistically by connecting smaller localized efforts (e.g., focused on one parcel, inlet, or embayment) within the context of the larger-scale ecosystem (e.g., focused on drift cell, delta, or sub-basin) as well as considering degree and type of habitat loss and adaptation potential to climate change impacts such as sea level rise (Heerhartz, Bahls, Higgins, LeMoine, MacLennan, Kaufman, Davis and Ellings). For example, in Hood Canal, when practitioners identified the relevant landscape spatial scales necessary for embayment restoration, it included much of the shoreline adjacent to Hwy 101, as well as the Hood Canal bridge (Daubenberger, Embayment discussions). Distance from natal rivers and size of outmigrating population were identified as important considerations for prioritizing embayment restoration for Chinook salmon in northern Puget Sound (Beamer), while other factors such as nearshore habitat condition are also emerging as important factors for restoration of rearing habitat for Chinook and other salmonid species, including Hood Canal chum salmon (Beamer, Wait, Bahls, Daubenberger). Sufficient space for restoration actions, along with intact coastal processes and a historical shoreline context (e.g., referencing historical photos, and tribal cultural resources) were also noted as important ingredients in successful embayment restoration (Heerhartz, Cote). Within beach environments, there is value in exercising opportunities for lower priority or partial restoration projects via small, cumulative gains and influential shifts in landowner behavior and public perception (Higgins, Kereki), and these opportunities warrant further investigation and recognition. Whereas some prioritization frameworks target a specific habitat function, such as Chinook rearing (Beamer, Greene, Chamberlin, Davis and Ellings), or a particular impairment, such as a railroad (Schlenger), others can have multifaceted objectives that include habitat function as well as flood protection, farming viability or recreational access (LaFond, Baker). For all shoreforms, the presence of toxic contaminants may undermine restoration goals and was identified as a factor that should be taken into consideration when prioritizing different locations for restoration (O'Neill).

c. Habitat connectivity

Habitat connectivity is fundamental to nearshore ecosystem restoration. It is a central indicator of ecosystem function and restoration effectiveness and an important consideration for future planning, siting, and designing new restoration projects. Habitat connectivity plays an integral role in facilitating the exchange of fresh and saline water and nutrients, detritus, and organisms, both within estuarine habitats and as a conduit to the broader nearshore ecosystem (Borde, Howe). In river deltas, habitat connectivity is an important driver of juvenile Chinook abundance and restoring this connectivity as well as targeting parts of deltas with higher existing habitat connectivity for restoration can provide more opportunities for Chinook use of estuarine habitats (Chamberlin, LeMoine, Greene). Self-regulating tide gates can improve habitat connectivity hindered by flap gates or dikes but do not provide full connectivity which affects distribution and abundance of estuarine-dependent fish species, including juvenile Chinook salmon (Hall). Researchers are currently studying how the interactions among the degree of connectivity, water velocities, and fish use of tidal habitats affect fish rearing in restored estuarine habitats (Zackey, Smith and Small).

4.1.2 Restoration coordination

a. Stakeholder engagement and relationship building

Local and regional prioritization of restoration and protection projects among the many competing land uses and infrastructure needs is an important factor in successfully funding and building partner support and engagement, and navigating administrative jurisdictions and boundaries (Water Resource Inventory Area (WRIA), county lines, property lines) necessary for planning and implementing restoration. Devoting time and resources to engage with private landowners and to consult with multiple partners and technical advisors are a key part of the restoration process (Heerhartz, Marti, LaFond). For example, in agricultural deltas, engaging with and building trust with farmers and considering their interests is particularly important (Marti, Friebel, LaFond). The documentation of drainage and flood infrastructure and function before and following restoration, for example, can support conversations about restoration project performance and the concerns of local stakeholders (Griffith). Such engagement and relationship building can be strengthened by social science research, including research that identifies and supports DEI within recovery (Arnold and Wilson, Katz, King).

b. Communication

One key challenge for restoration practitioners and scientists is fostering communication without making unattainable promises to the broader public, landowners, partners, or stakeholders (Diefenderfer, Baker, Brokaw, Slater, Olivas). One strategy is translating restoration science into both what we know and what we don't know and past and potential 'successes' and 'failures'. This process takes practice and patience. Interactions with landowners, particularly on-site and via directed outreach and education encourage a greater understanding of different, and at times differing, perspectives and facilitate better communication of science, particularly coastal processes, ecological needs, and restoration opportunities and advantages (Strelioff, Kaufman). One concept that emerged in several speakers' contributions (Dethier, Nelson, Zackey, Rustay, LeMoine, Leonetti, Brokaw) was the challenges of communicating that once restoration actions are complete, habitat structure and function develop over varying timescales, ranging from days to decades. Because of this, we use the term "*restoring* habitat" rather than "*restored*" to signify habitat that is on a restoration trajectory. Visual aids (e.g., photographs), especially of restoring habitats, are particularly engaging and can help encourage and motivate collaborative action (Brokaw). Such communications can be enhanced by the social sciences research, including research that emphasizes why place matters to residents (Breslow, Trimbach).

c. Project team expertise and implementation

Successful restoration teams involve cooperation among people with different experiences, diverse skillsets, and varied institutional knowledge. This can include restoration professionals, and experts in land acquisitions (Griffith, Nelson). The structure for successful restoration teams varies among local project sponsors, from organizations that have most of the needed skills in-house to organizations that can lead project management and local coordination but need technical contracts for design and implementation (Johannessen, Griffith, Nelson). However, large-scale restoration projects frequently require more expertise than any one organization can bring to the table (Delta discussions). Most often, successful restoration includes some combination of project sponsor, partner coordination, and contracting and consultant support. Understanding all the required components of managing restoration projects and how to stage and coordinate among them is a relatively new skill set as large-scale restoration is a relatively new field of work (Delta discussions).

d. Funding

Complex restoration designs and coordination of strategic partnerships mean the timelines of restoration projects often extend beyond typical funding cycles. Funding is instrumental at every stage of the restoration project life cycle and is necessary even after the restoration implementation itself is technically complete (Ecocycle discussions). Funding at the early and late stages of restoration projects is particularly challenging (Toft, Harlow). Restoration projects are most typically funded through a combination of state capital dollars and federal funding for habitat and species recovery. Understanding where and how to restore ecosystems and recover species is complex and has very few funding sources. Early project funding can be funded through pre-design activities but those are limited (Embayment discussions). State and federal funding are more robust when projects are in the design and construction phases, but once construction is complete, governmental funding regulatory bodies restrict capital-funded post-construction activities (State of Washington Office of Fiscal Management). Because of this, monitoring the effectiveness of restoration and supporting integrated opportunities for adaptive management and maintenance are necessary components of the restoration process (Toft).

Unfortunately, monitoring efforts are difficult to fund after the implementation phase. Additionally, social science research is increasingly recognized both as integral to recovery but also a challenge to fund (Breslow). Partnerships with colleges, universities, and local communities are important for the implementation of effective pre- and post-project monitoring at a lower cost (Harlow). Lastly, while design and implementation funding are relatively robust, it is only a fraction of what is needed for Puget Sound ecosystem and salmon recovery and may be insufficient to overcome ongoing and legacy habitat loss (Delta Discussions).

4.1.3 Restoration monitoring

a. Ecological and physical response

Understanding and demonstrating the broader impacts of both small and large restoration projects on ecosystems is only possible with pre- and post-project monitoring (Harlow). Natural, unmodified reference sites with similar geomorphology in the same sub-basin enable comparative analysis and thus future restoration design (Borde, Hood, Cote). By monitoring restoration actions and measuring effectiveness, ideally at multiple spatial and temporal scales, we can provide data that advances our understanding of factors affecting ecosystem structure and function, including cumulative effects of restoration (Diefenderfer, LeMoine). Results from monitoring can inform adaptive management tools to gauge project ‘success’, corrective and maintenance needs, and future restoration efforts for beach (Toft, Dethier, Faulkner, Michel), delta (Zackey, Leonetti, Slater, LeMoine, Davis and Ellings, Nelson, Pavel, Belleveau), and embayment systems (Bahls, Beamer).

Monitoring has also shown that restoration actions can initiate ecosystem function and recovery trajectories that may take years in beach (Toft, Dethier, Faulkner, Michel), delta (Zackey, Leonetti, Slater, LeMoine, Davis and Ellings, Nelson, Pavel, Belleveau, Rustay) and embayment systems (Bahls, Beamer). Thus, while there are often some immediate responses to restoration, the complex interactions among habitat-forming processes, structure, and function take time. It is important to convey the extended ecosystem recovery time to restoration stakeholders, partners, and landowners to inform their expectations (Brokaw, Nelson, Zackey, LeMoine, Toft, Dethier, Faulkner, Davis and Ellings, Leonetti, Rustay).

b. Community science

Community science is a powerful outreach, research, and monitoring tool, and when integrated with standardized methods (e.g., shoreline monitoring toolbox, forage fish beach surveys) can contribute to region-wide datasets and analyses (Perla, Toft, Harlow, Bayard). We use the term “community science” rather than “citizen science” to reflect a more inclusive approach to this work (Charles et al. 2020). Community science can help foster an individual and shared understanding of and investment in a healthy and sustainable nearshore ecosystem (Perla, Harlow).

4.1.4 Social sciences and diversity, equity, and inclusion

The social sciences are integral to the success of nearshore restoration and contribute a diverse range of benefits to the recovery process, regardless of shoreform (Kinney) or restoration phase (Biedenweg). Social scientists involved in the Nearshore Summit demonstrated a unique ability to identify, prioritize, examine, analyze, and better understand the complex human dimensions of nearshore areas and communities. Eleven social scientists, some with diversity, equity, and inclusion (DEI) research and/or practitioner expertise, illustrated how the social sciences can and do contribute to nearshore restoration, particularly in the Puget Sound region. For example, DEI are major areas of interest and need within ecosystem recovery. This is exemplified by the recent efforts of the Washington Environmental Justice Task Force and the passing of the WA HEAL Act. Both efforts are considered stand-alone areas of work that can be integrated via practitioners (e.g., DEI manager, professional, or consultant) (Schutten) and scientifically examined as an area of social science inquiry (Katz, King), or both (Arnold and Wilson). World views and perspectives among restoration practitioners, scientists, and stakeholders undoubtedly influence and bias existing restoration conversations and approaches. As a result, there is an increasing need to self-reflect, acknowledge, identify, and incorporate more diverse ways of knowing, including those from Indigenous and local communities (Arnold and Wilson). This form of inclusion is reinforced by the potential contributions of Indigenous shoreline management practices to current management efforts (Grier).

Restoration can benefit from diverse, novel, and alternative approaches, understandings, data, content, ideas, and information by integrating the social sciences (Biedenweg) and other forms of knowledge and ways of knowing (Arnold and Wilson, Grier). The social sciences are a diverse field, consisting of a wide range of disciplines, subfields, methods, concepts, theories, and approaches. For example, social scientists use geovisualization tools (Katz) to reflect social or social-ecological patterns and examine major restoration topics, like human behaviors (Dundas), ecosystem services (Dundas), local governments (Fishman), and sense of place (Trimbach). Additionally, the social sciences often align with or are linked to the humanities or humanistic sciences (Breslow), which can offer innovative and creative ways of exploring, analyzing, or visualizing a particular topic or issue. While the social sciences are increasingly recognized as integral to nearshore recovery, barriers remain, including a lack of funding and opportunities to better engage in recovery efforts or their examination (Breslow). To enhance the functional integration of social sciences into restoration and recovery, restoration systems, like governance and management, need to prioritize the social sciences (Biedenweg). Further, expanded funding or other engagement opportunities will increase opportunities to link the social and ecological sciences within nearshore recovery.

4.1.5 Climate change

a. Sea level rise and increasing temperatures

The effects of global climate change, including sea level rise, and increasing temperatures are already being observed in tidal wetlands (LaFond, Davis and Ellings, Zackey, Poppe, Howe, Kaufman, MacLennan, Grossman, Corbett) and beach habitats (Kinney, Johannessen, MacLennan, Kaufman, Miller). In beach systems, rising sea levels are both exacerbating challenges faced by shoreline landowners and diminishing existing intertidal beach habitat. Planning future restoration and structure setback distances needs to incorporate rising sea levels (Kinney, Kaufman, MacLennan, Johannessen, Miller). In river deltas, lower elevation and subsided habitats are particularly vulnerable to SLR and habitats at the landward edge of estuarine influence (e.g., freshwater tidal swamps and further upland) may be particularly important to consider for incorporating resilience to rising sea levels in order to accommodate habitat migration (Davis and Ellings, Borde, Fuller, Grossman). While riverine sediment accretion appears to be keeping pace with SLR in some locations (Poppe), in other locations, SLR may outpace sediment accretion. Combined with increasing temperatures, this can further reduce the diversity and quality of tidal wetland habitat (Zackey, Davis and Ellings, Chamberlin). In the Snohomish and Stillaguamish agricultural deltas, SLR is also already increasing salt intrusion into soils and is projected to continue to affect the viability of farmland (LaFond). The use of predictive sediment dynamics models to inform the siting and design of restoration projects are an important way that practitioners and scientists are incorporating climate resilience into restoration projects (Grossman, Davis and Ellings). The impacts of climate change are also most likely inequitably experienced by frontline communities, demonstrating a further link and need for social science research, including DEI research (Katz, King).

b. Carbon sequestration and mitigation

Restoring tidal wetlands can help to mitigate the effects of climate change in a global sense through carbon sequestration (Poppe, Corbett) (this is referred to as “blue carbon”) and in a local sense by increasing habitat diversity (Chamberlin, Greene) and cold water refugia (Corbett). Restoration practitioners can also consider the carbon impact of restoration construction activities and explicitly mitigate for these impacts through actions such as additional tree planting (Corbett).

4.2 Uncertainties and future research needs

While there have been many important insights from past restoration and research, natural scientists, social scientists, and restoration practitioners all highlighted that there is still much we need to learn to advance future nearshore restoration work in Puget Sound. Efforts such as the development of an embayment-specific strategy for guiding management and restoration monitoring across all shoreforms, additional work to inform climate change resilience, and further work to integrate social sciences and DEI into all aspects of the restoration life cycle, were all identified as future research directions to improve and support resilient, sustainable, and inclusive restoration outcomes (Table 4-1).

4.2.1 Needed analyses to support restoration planning

a. Embayment strategy for guiding restoration actions

While recent work has updated regional strategic management recommendations for beaches (MacLennan), the Summit’s embayment discussions identified the need to expand this work to include barrier embayments. Ideally, a future embayment strategy includes consideration of project scale, adjacent and landscape-scale landforms and processes, and expansion of landowner engagement when prioritizing individual contributions to overall recovery. Monitoring data of embayments should inform the analyses used to generate the strategic recommendations as well as future adaptive management. Restoration of embayments and beaches alike will benefit from an expanded definition of ‘priority’ habitats and adapt strategies that define broader temporally and spatially integrated frameworks for recovery, including those that encompass opportunistic restoration (Higgins, Kereki).

b. Predictive models of habitat-forming processes

For beach systems, restoration project selection would benefit from more nuanced information about the behavior of ecosystem processes that includes local data on SLR, as well as bluff recession rates and the way these processes interact with shoreline features such as presence, extent, and condition of hard armoring (MacLennan, Miller). Further, the quality of conceptual and predictive models would be improved by increased measurement of ecosystem structure at a higher frequency, with greater accuracy, and at more locations (Miller). In river deltas, existing predictive models for habitat development following restoration would be enhanced by more explicitly incorporating the effects of tide range, fetch, sediment supply and grain size, vegetation type, and marsh elevation (Hood).

c. Fish use of nearshore habitats and potential benefits of restoration

Owing to the high mobility of fish species, assessing the benefit from nearshore restoration and communicating this benefit to a broad range of audiences is not easy. This is partly because the evidence is often nuanced and understanding is rarely unequivocal, particularly when translating from project scale data to landscape and population scales (LeMoine, Williamson). As a result, it is important to exercise caution when attributing broader population benefits of restoration beyond the more directly measured effects on habitats and habitat use. While recent research has contributed greatly to our understanding of the connection between Chinook smolt outmigration abundances and natal estuary habitat, additional research is needed to more fully describe the relative importance of density-dependent and density-independent mechanisms driving juvenile Chinook productivity and the interactions between hatchery and natural origin outmigrants in estuarine rearing habitats (Greene, Davis and Ellings). While researchers are documenting the effectiveness of shoreline armor removal and other shoreline modifications on higher elevation intertidal habitats, the ecological responses in lower tidal elevation habitats such as eelgrass and kelp may be more diffuse and thus warrant additional inquiry (Francis, Christiaen) including understanding in the context of other stressors such as water quality and hydrologic impairment (Christaen, Gaeckle). Furthermore, understanding broader landscape patterns of fish use of nearshore waters will demonstrate the potential benefits of shoreline restoration (Francis). Continuing to address research uncertainties will inform the practical application of restoration actions and adaptive management strategies and help justify project costs.

4.2.2 Restoration monitoring and data

For beach systems, the Shoreline Monitoring Toolbox (shoremonitoring.org) and associated database have been a powerful way to connect and compare data collection efforts across Puget Sound. An analogous standardized set of monitoring protocols for delta and embayment systems would help leverage existing work and foster additional analyses and insights for restoration (Bayard, Embayment and Delta discussions). Restoration planning and evaluation will also benefit from increased dissemination and publication of data and insights, including academic, peer-reviewed, and grey literature (Miller). Similarly, analysis and tools should be publicly available and accessible to a general audience, to elicit more local interest and landowner support (Kaufman, McTeague).

4.2.3 Climate change and predictive analyses

The site-specific effects of climate change are a key uncertainty facing restoration practitioners and scientists. Key parameters include sediment budgets and accretion, saltwater intrusion, drinking wells, septics, agriculture, and water temperatures. Despite the challenges of understanding the separate and combined effects of these factors, predicting how given sites will respond to the combination of rising sea levels and changes to freshwater quantity, timing, duration, and distribution across the landscape is an important component of successful restoration and planning (Hood, Grossman, Chamberlin, Howe). More discussion and integration are needed across agencies, governments, partners, disciplines, and landscapes.

4.2.4 Social sciences and diversity, equity, and inclusion

There is still a great need to better integrate the social sciences into nearshore restoration. This includes addressing DEI throughout all aspects of restoration planning and implementation, explicitly examining the inequitable effects of climate change on different communities and incorporating economics and Nature's Contributions to People (formerly ecosystem services) into restoration planning and actions. There is also a gap within the environmental social sciences themselves to better identify and prioritize key nearshore restoration needs, including through close collaboration among social scientists, natural scientists, and practitioners. For example, the social sciences can help inform climate change solutions in the context of DEI. Within the field of economics, more can be done to estimate non-market values for ecosystem services related to coastal retreat and natural infrastructure investments and to identify homeowner incentives in different future scenarios.

5. Speaker contributions

There were 73 presentations representing a breadth of nearshore restoration natural scientists, social scientists and practitioner/planners (see Summit program) some of which had multiple speakers within a presentation. Of these, we received 59 written contributions, each of which consisted of the following subsections:

Background/Context

Findings (if applicable)

Key Messages

Literature

Online resources

Link to video recording of presentation

Speaker bio

To facilitate navigation among the contributions, we have placed them into broad topical categories and organized them by geomorphic shoreforms, if applicable (Table 5-1). Many contributions were relevant to multiple topics.

Table 5-1. Topics and relevant Summit contributions related to each topic with hyperlinks to the contribution page of the Proceedings for each speaker.

Topic		Beaches	Deltas	Embayments
Climate change		Johannessen MacLennan Miller Dundas Kaufman Kinney	Corbett Chamberlin Davis and Ellings Fuller Grossman Howe LaFond LeMoine Poppe Slater Zackey	Grier Katz Scyphers
Community science		Perla, Toft	Bayard	Harlow
Diversity, equity and inclusion		Arnold and Wilson Katz King Schutten		
Monitoring Parameters	Birds		Bayard Slater	
	Channels		Hood Leonetti Zackey	Beamer
	Fish	Bahls Daubenberger Faulkner Francis Michel Perla Toft Williamson	Chamberlin Daubenberger Diefenderfer Belleveau Davis and Ellings Greene LeMoine Leonetti Smith and Small Wait Williamson	Bahls Beamer Daubenberger Williamson Wait Bahls Smith and Small
	Invertebrates	Daubenberger Dethier Toft	Borde Daubenberger Davis and Ellings Howe	Daubenberger
	Sediment	Dethier Faulkner Grossman Kaminsky Johannessen MacLennan Michel Miller	Brokaw Davis and Ellings Fuller Grossman Leonetti Poppe Rustay Zackey	
	Vegetation	Christiaen Dethier Perla	Belleveau Borde Davis and Ellings Hood	Beamer Gaeckle

		Howe Fuller	
Stakeholder engagement	Blair Dundas Kaufman Kinney Higgins Scyphers Strelioff Olivas	Baker Breslow Brokaw Friebel Griffith LaFond Marti Nelson Rustay Olivas	Scyphers Schlenger Olivas
Human well being and sense of place	Biedenweg King Trimbach Arnold and Wilson		
Economic incentives	Dundas Kinney MacLennan		
Restoration planning and prioritization	Fishman Higgins Kereki McTeague Whitman	Burgess Corbett Diefenderfer Greene Olivas	Daubenberger Heerhartz Schlenger Olivas
Restoration project design	Dethier Johannessen Strelioff MacLennan	Borde Corbett Diefenderfer Hall Howe Hood Grier Griffith Pavel Rustay	Bahls Cote Ketteridge
Restoration project management	Kaufman Kereki Johannessen Whitman	Baker Corbett Griffith Pavel Nelson Harlow Olivas	Bahls Harlow Heerhartz Olivas
Traditional knowledge	Arnold and Wilson Grier Breslow		
Toxic contaminants	O'Neill		

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5.1 Beaches

Restoring beaches on Puget Sound: How we got here.

Hugh Shipman[1]

[1]Washington Department of Ecology, *Retired*

Link to presentation recording https://youtu.be/jntLdMHl61I?t=1004

Hugh Shipman retired from the Washington Department of Ecology in 2019, after thirty years as a coastal geologist. His interests include the geomorphology of Puget Sound beaches, the impacts of shoreline modifications, and the geologic aspects of coastal restoration. He was a member of the PSNERP Nearshore Science Team and contributed to several reports on nearshore processes and restoration. He has helped ESRP on both program strategy and the review of individual restoration projects. For years, Hugh posted photos of beaches on his Gravel Beach blog. Hugh received his BA from Dartmouth in 1981 and his MS from the University of Washington in 1986. He's been spending his retirement on his bike and in his wood shop.

Green Shores ® – a tool in the coastal resilience toolbox

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Link to presentation recording https://youtu.be/9hxmTOEzeos?t=9252

DG Blair, B.Sc. M.Sc. As the Executive Director of the Stewardship Centre for BC, DG Blair provides leadership and project management for delivery of stewardship projects and resources to audiences throughout BC and across Canada. With deep experience in science-based best management practices for land and water, DG has been instrumental in the development, application, and proliferation of the Green Shores program, an incentive-based credit and rating system for minimizing the impact of new shoreline developments as well as restoring the shoreline ecosystem function of previously developed sites. She has coauthored numerous publications on Green Shores; is a member of Natural Resources Canada's national Coastal Management Working Group; manages the Green Shores Local Government Working Group; and provides overall project management for Green Shores in Canada: coast to coast to coast.

Potential impacts of shoreline armoring on intertidal eelgrass populations in Central Puget Sound

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Background and context

Most studies on how shoreline armoring affects submerged aquatic vegetation are from areas with vastly different geomorphology than Puget Sound (Gabriel and Bodensteiner 2012, Patrick et al. 2014, Patrick et al. 2016). As a consequence, the potential impacts of shoreline armoring on eelgrass populations in Puget Sound are not well understood. Shoreline armor is associated with changes in substrate composition, steepening of shorelines, and reductions in beach width. However, these effects are more pronounced close to the armor and are hard to detect at lower tidal elevations (Dethier et al. 2016). The majority of eelgrass in Puget Sound occurs between 0 and -4m relative to mean lower low water (MLLW), but at some locations, it has been observed as shallow as +1.4m (MLLW) (Christiaen et al. 2019). These habitats are generally too distant from shore to be directly impacted by wave refraction on shoreline armor, but they could be impacted by long-term changes in substrate composition. In Puget Sound, bluff erosion is an important source of sediments for beaches (Johannessen and MacLennan, 2007). If a large fraction of the shoreline is armored, reduced input of sediments could eventually impact eelgrass in the lower intertidal. Here, we relate data from DNR's Submerged Vegetation Monitoring Program (SVMP) to a series of covariates to assess potential impacts of shoreline armoring on intertidal eelgrass populations in the central basin of Puget Sound.

Findings

Between 2014 and 2020, DNR surveyed most of the Central Puget Sound shoreline through a series of collaborations with local governments and Tribes. We collected towed underwater videography along 3800 transects spread over 378 sites (Christiaen et al. 2018, Christiaen et al. 2020). We estimate that there is approximately 1,315 ha of eelgrass in the study area, 37% of which was found in the intertidal (defined as shallower than the extreme low tide line).

We calculated the fraction of transects with intertidal eelgrass per drift cell, as well as the mean depth of the shallow edge, and related these data to the total fraction of shoreline armored (MacLennan et al. 2017), the mean slope of the intertidal, the mean exposure, and the mean tidal range per drift cell (Hess and White 2004). Data were analyzed using principal component analysis. Results suggest that intertidal eelgrass was more frequently found in drift cells with long fetch, gentle intertidal slope, and lower tidal range. One possible explanation is that in Central Puget Sound, the upper edge of eelgrass beds is in part limited by desiccation at low tides. At sites with gentle slopes and more exposure, there can be more pooling of water at low tides, which can protect the plants from desiccation and allow them to grow higher up the intertidal. We did not see a strong effect of shoreline armor in this analysis. This may be due to the high variability in environmental data on regional scales.

We also compared our dataset with 65 pairs of beaches from research by Dethier and others (2016). Out of these, there were 23 pairs of beaches with SVMP transects within a distance of 50 meters, where both transects had intertidal eelgrass. At these locations we compared the shallow edge of eelgrass beds between armored and unarmored sites, using a paired t-test. On average, eelgrass grew 0.25 m higher at sites without shoreline armor ($p = 0.025$). The effect was most pronounced in the central basin. This suggests that shoreline armoring can affect the shallow edge of eelgrass beds. However, the effect is subtle and only detected by a paired analysis that removed some of the natural variability in other parameters. Other stressors, such as accumulations of green algae, may be more damaging for eelgrass beds in Central Puget Sound.

Key messages

- Shoreline armoring can impact intertidal eelgrass populations.
- The effect is subtle and difficult to detect due to high variability in environmental data.
- Other stressors than shoreline armoring may be more detrimental to eelgrass in Puget Sound.

Literature

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Online resources

Submerged Vegetation Monitoring Program website, WA State Department of Natural Resources. https://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science/nearshore-habitat-eelgrass-monitoring

WA State Department of Natural Resources eelgrass data viewer. https://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science/puget-sound-eelgrass-monitoring-data-viewer

Link to presentation recording https://youtu.be/9hxmTOEzeos?t=2608

Bart Christiaen is the current lead of DNR's eelgrass monitoring program (SVMP). He has been in this position since November 2014. Bart has a PhD in Marine Science from the University of South Alabama, and a Masters in Oceanography from the University of Liege, Belgium.

Learning what is ‘broken’ on armored shorelines, and how to fix them

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Background and context

Work by our UW research group and others has shown that shoreline armoring can alter a variety of parameters on beaches in the Salish Sea. While we have quantified some of these impacts, it is harder to characterize what processes are actually “broken” at these sites, since armoring can impact diverse processes such as sediment supply, sediment transport, hydrodynamics, and terrestrial-marine connectivity. This difficulty in defining which key processes are leading to changes in beach parameters (such as beach slope and width, sediment grain sizes, log and wrack accumulation) makes it harder to predict how well (and how quickly) particular restoration actions will restore beach functions. In short, it has been difficult to effectively draw arrows in conceptual models connecting management measures to restored processes to beach structure to beach function. To help address this limitation, we compared changes through time at two restoration sites that involved different management measures: a beach nourishment project in Snohomish County (with a small armor-removal component) and a substantive armor-removal project at a historic feeder bluff in South Sound. For each, we measured multiple beach parameters for several years before and after restoration.

Findings

Our prior work at 65 pairs of sites (armored and unarmored beaches) throughout the Washington state portion of the Salish Sea documented broad armoring impacts on beach parameters. These include narrowed beach width, decreased riparian vegetation and shade, a tendency towards coarser sediments and increased beach slope, reduced accumulations of logs and beach wrack, and reduced abundances of wrackline invertebrates. Few changes were found in conditions lower on the shore, such as sediments or communities at mean low water. Armoring impacts become increasingly evident the lower the armoring is on the shore; in particular, the retention of drift logs clearly declines when armoring is lower than a threshold value. However, with our static (one-time) sampling, we were unable to define what processes were being most impacted by armoring and thus what types of restoration might be most effective.

At the Snohomish County site, dredged sediment (mostly fine sand) was added to several sites on the shoreline south of Everett; we monitored those sites as well as a series of beaches in southern Snohomish County that were not manipulated in any way. The added sediment tended to move downdrift over subsequent months except in areas where some wave protection was provided by the shape of the shoreline. Thus changes in beach texture and slope were mostly short-term. Wrackline conditions showed few biological changes, or in some cases experienced a decline in infaunal invertebrates probably due to burial by sediment. Use of coarser added sediments likewise would have allowed longer local retention. At the South Sound Edgewater Beach site, removal of a seawall from a historic feeder bluff allowed rapid slumping of sediment and trees onto the beach face, broadening the beach and increasing the fine sediments locally. The shape of the beach and its biotic communities were still changing 3 years post-restoration, and some sediment was carried downdrift (as seen in Lidar images by Dept. of Ecology). Detailed figures and tables, including the time course of change, can be found in online reports accessible from the Salish Sea Wiki cited below.

Key messages

Under certain conditions, nourishing beaches with sediment is only a short-term solution, as shown at some Snohomish beaches; this is especially true when fine sediments are used, when there is low-shore armoring, and where there is substantial wave action.

- Small streams may be important in central Puget Sound for helping with lost sediment supply as they build out small deltas from which sediment can be winnowed downdrift.
- The absence of logs and wrack on a beach may be a useful indicator that armoring is so low on the shore that it likely is having a negative impact on multiple beach processes.
- Removing armoring from a feeder bluff restores many processes all at once, which should lead to a broad and persistent return to natural beach conditions. Our data suggest that some parameters will take >3 years to return to conditions found on reference beaches.

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Online resources

Salish Sea Wiki detailing the Edgewater Beach bulkhead removal and link to the full report, including data. https://salishsearestoration.org/wiki/Edgewater_Beach_Bulkhead_Removal

Salish Sea Wiki detailing the Snohomish Beach Nourishment project and link to full report, including data. https://salishsearestoration.org/wiki/Snohomish_Railroad_Grade_Beach_Nourishment

Link to presentation recording https://youtu.be/jntLdMHl61I?t=10844

Dr. Megan N. Dethier is Director of the Friday Harbor Laboratories, University of Washington, and is also a Research Professor in the Biology Department. She did her undergraduate work at Carleton College in Minnesota, then PhD work at the University of Washington. Since ~1978 she has been in working on the shoreline ecology of the Pacific Northwest.

Economic and policy implications for coastal housing markets facing sea level rise and erosion

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Background and context

Economic analysis is a crucial component in the management of shorelines where natural systems and human interests intersect. People respond to policy, information, and risks so understanding incentives created by those factors is necessary to recognize the effects of behavioral feedbacks on expected outcomes. The focus here is exploring the economic implications of shoreline armoring policy in Oregon, where a state land-use planning rule (i.e. Goal 18) differentiates oceanfront parcels that can armor and those that cannot based on development date. In the first study, we assess how a parcel's eligibility for armoring capitalizes into housing prices both for the parcel and neighboring land. The goal is to demonstrate how housing markets respond to options for protective investments in traditional (grey) infrastructure based on risk exposure and how estimates of the nonmarket value for protection services can form the basis for management strategies to adapt our coastlines to sea level rise. The second study builds a landowner decision model to estimate the influential determinants of the decision to install armoring. We test the idea that coastal homeowners respond to spillover effects from the actions of direct neighbors and learn from the actions of other nearby neighbors. Lastly, outcomes from studies on landowner responses to expected land-use restrictions due to sea level rise in North Carolina and a managed retreat policy in New Jersey are discussed due to potential implications for future management of shorelines in the Pacific Northwest.

Findings

In our study of the housing market impacts of armoring eligibility in Oregon (Dundas and Lewis 2020), we find evidence that the value of having an option for protection ranges between zero and 22 percent of land value. For an average parcel in our sample (30 feet above sea-level with an accreting shoreline), the effect was zero. This is an intuitive result as the need for protection from armoring is likely to decrease as risk factors decrease. For parcels on eroding shorelines, the effect was 13 percent and for those parcels at low elevation and on eroding beaches, the effect was 22 percent. These impacts imply a premium for armoring eligibility for homes vulnerable to coastal hazards between $79,000 and $135,000 per home. We also find that parcels that are ineligible for armoring but have an eligible neighbor could see property value declines up to 8 percent due to the potential spillover effects from deflected wave action. These values are currently being integrated into a scenario-based coastal futures model to understand the impact of climate change and policy options on Oregon's shoreline. The second study in Oregon (Beasley and Dundas 2021) estimates a model of landowner armoring choices over 25 years to assess the decision-making process. Results suggest that spatial spillovers are highly influential determinants in these private adaptation decisions by oceanfront landowners. We simulate future landscapes calibrated with our model results to show that scenarios that ignore spatial spillovers may under-predict future armoring by up 97 percent. We also show the critical importance of policy, as the removal of Goal 18 land-use restrictions could increase armoring by 69 percent over the next 40 years. Key implications for the management of shorelines in the Pacific Northwest can also be found from studies in other locations. Expectations of future land-use restrictions due to sea level rise may accelerate housing starts in risky coastal areas. Parton and Dundas (2020) show that a North Carolina state report on sea level rise was responsible for a 27 percent increase in housing starts due to the new incentives faced by landowners. In an analysis of a managed retreat voluntary buyout program, Hashida and Dundas (2021) find that participation is reduced in municipalities with higher property tax assessments, federal hazard programs have the potential to crowd out participation, and municipalities are not accounting for sea level rise in their participation decisions.

Key messages

- Applied economics contributes to the study of shoreline management by helping to understand behavioral responses to hazard risk and adaptation policies and by revealing misaligned incentives between individual behavior and what is best for society.
- Two major gaps are the lack of studies that 1) estimate nonmarket values for ecosystem services related to coastal retreat and natural infrastructure investments and 2) identify homeowner incentives in coastal retreat scenarios.
- Insights from economic analyses can be better integrated into practice through creating opportunities for stakeholder engagement, helping fill capacity deficits in local government adaptation planning and continuing collaboration efforts with natural science colleagues on policy solutions to complex problems.

Literature

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Hashida, Y. and S. J. Dundas. 2021. Managed Retreat and Local Government. Working Paper.

Parton, L. C. and S. J. Dundas. 2020. Fall in the Sea, Eventually? A Green Paradox in Climate Adaptation for Coastal Housing Markets. *Journal of Environmental Economics and Management* 104: 102381. doi: 10.1016/j.jeem.2020.102381

Online resources

Coastal Natural Infrastructure. Site summarizes current work on using natural infrastructure investments in the Pacific Northwest for the provision of coastal protection and other ecosystem services. https://appliedecon.oregonstate.edu/applied-economics/coastal-natural-infrastructure

Link to presentation recording https://youtu.be/jntLdMHl61I?t=6296

Steven J. Dundas is an environmental economist with a research focus on non-market valuation, coastal ecosystem services, adaptation to climate change, and environmental policy evaluation. He is an Associate Professor at Oregon State University in the Department of Applied Economics and the Coastal Oregon Marine Experiment Station.

It's Complicated: interpreting restoration effectiveness at two Puget Sound beach projects

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Background and context

Restoration aims to return degraded ecosystems to a more natural state, when possible, using management measures that produce durable and sustainable benefits over the long term. Monitoring and evaluation capture the effect and effectiveness of restoration actions on nearshore processes, beach structure, and functional responses, and are integral components to the project life cycle. The highly variable marine shorelines of Puget Sound, in Washington state, necessitate a diverse suite of restoration measures, and planners, practitioners, and scientists must consider numerous spatial and temporal factors. In this study, we explored and compared monitoring results from two restoration projects in Puget Sound:

(1) Snohomish Beach Nourishment Project (Everett), where sediments were distributed along a length of railroad-impounded shoreline to augment degraded sediment processes. Surveys included sampling at 4 pairs of armored and natural beaches throughout the nourishment area, involving additional armor removal at the updrift-most Howarth Park.

(2) Edgewater Armor Removal Project (Olympia), where a length of shoreline armor was removed along a historic feeder bluff to reinstate degraded sediment processes. Surveys included sampling within the restoration footprint and bracketed by an armored and natural reference site outside the restoration footprint.

Surveys were conducted before and after restoration for both projects. We hypothesized that restoration actions would increase the elevation of bluff toe, expand beach width, decrease beach slope and renew finer beach sediments. We anticipated that results would vary between armored and natural beaches and over time.

Findings

Snohomish. Our data showed substantial differences overall between armored and natural beaches, regardless of nourishment effect. As predicted, we found that the upper limits of armored beaches were located lower in the intertidal, and these beaches were narrower in width and steeper in slope. Contrary to predictions, percent sand was not necessarily less at armored sites, and instead varied spatially and temporally.

For changes associated with restoration, it was difficult to broadly attribute nourishment effects due to high site-specific and annual variability, as exemplified by measured changes in percent sand across sites. Before restoration, sites were dominated by pebbles, characteristic of sediment-starved beaches. Initially following restoration, we saw an increase in percent sand at all measured sites, but in the years following, we observed varying levels of decline back to pre-nourishment conditions at most sampled sites. We suspect that sediment retention was influenced by localized site features, including armor encroachment, shoreline shape, and proximity to subtle embayments and small stream deltas.

Edgewater. Without considering restoration effect, we observed some site-specific differences in beach structure, such that the natural site was greatest in beach width and percent sand, followed by the restoration and lastly the armored site. We presume this a factor of local wave dynamics, drift cell position, or feeder bluff sediment structure. Regardless, we quantified positive changes in most parameters following armor removal, including an increase in bluff toe elevation, beach width, and percent sand. However, we observed beach slope to steepen slightly following restoration. The effect of armor (presence or removal) on beach slope may be more difficult to isolate. Removal of armor at Edgewater exposed new upper beach areas and allowed the vegetated bank and fill held behind the structure to slump waterward, bringing with it an abundance of trees and sediments. We believe this contributed to the observed gradual but sustained rate of the change. At Edgewater only, we collected additional forage fish samples monthly, before and after armor removal. Surf smelt eggs were detected throughout our survey sites and study timeframe. Variability was high, but we distilled several key patterns: (1) eggs were found in greater numbers at our natural reference site; (2) the highest count of eggs occurred in winter months, as expected in South Sound, but we also detected eggs in summer months, and; (3) variability was multi-scaled and extreme at times, and differed by month, season, and year.

Key messages

- Armored and natural shorelines exhibited the greatest differences in physical beach structure and restored shorelines varied in measure between the two depending on restoration action, local site conditions, and restoration timeframe.
- Beach nourishment at Snohomish improved some key structural aspects of the shoreline, such as beach width and sediment composition, but these effects varied by site depending on local site conditions, and initial improvement may be unlikely to persist without the continued intervention of additional sediment supply.
- Armor removal at Edgewater exhibited a less pronounced initial change in beach structure compared to nourishment at Snohomish, but the gradual change toward more natural beach conditions was sustained over time. We anticipate this to continue as a result of restored sediment supply from the newly exposed feeder bluff.
- Nearshore ecosystem processes, whether natural, degraded, or recovering, operate at and are influenced by various spatial and temporal scales, of which our understanding continues to develop. Monitoring and evaluation are valuable tools in the interpretation and understanding of these processes and their multi-scale considerations, and the effectiveness of different management actions to restore nearshore ecosystem processes, structure, and function.

Literature

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Quinn, T., K. Krueger, K. Pierce, D. Penttila, K. Perry, T. Hicks and D. Lawry. 2012. Patterns of surf smelt, *Hypomesus pretiosus*, intertidal spawning habitat use in Puget Sound, Washington State. Estuaries and Coasts 35: 1214-1228.

Online resources

Salish Sea Wiki detailing the Edgewater Beach bulkhead removal and link to the full report, including data. https://salishsearestoration.org/wiki/Edgewater_Beach_Bulkhead_Removal

Salish Sea Wiki detailing the Snohomish Beach Nourishment project and link to full report, including data. https://salishsearestoration.org/wiki/Snohomish_Railroad_Grade_Beach_Nourishment

Link to presentation recording https://youtu.be/jntLdMHl61I?t=11685

Hannah Faulkner is a lead nearshore ecologist with Habitat Science Division at the Washington Department of Fish and Wildlife (WDFW). She contributes to the scientific foundation for WDFW's management decisions and technical assistance, including development of knowledge to inform land-use and monitoring of Puget Sound nearshore ecosystems and beach habitats.

Advancing the implementation of local shoreline armoring regulations

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Background and context

Nearly all Puget Sound jurisdictions have completed the comprehensive update of their Shoreline Master Program (SMP), and focus is turning to the implementation of the newly updated regulations. The issue of shoreline stabilization is a key focus area for evaluating and improving the implementation of SMPs throughout the region. Hard shoreline armoring is increasingly recognized as detrimental to nearshore functions, and there is greater awareness of and desire for alternatives to traditional armoring techniques. Furthermore, new SMP regulations ensure stricter scrutiny of bulkhead proposals and require alternatives to new hard armor where feasible. To better understand local governments' perspectives, challenges, and needs around the implementation of shoreline stabilization regulations, the WA Department of Ecology (Ecology) conducted interviews with 12 Puget Sound jurisdictions in 2019. The interviews were designed to characterize local processes for reviewing and approving shoreline stabilization, document the types of projects occurring in the region, capture implementation challenges and needs for different project types, and identify ways that Ecology could help address those needs. This research supports the Regulatory and Planning strategies of the Shoreline Armoring Implementation Strategy by improving the implementation of shoreline regulations and advancing regional strategic planning on the issue of shoreline stabilization and nearshore recovery.

Findings

Challenges and needs identified: Jurisdictions highlighted that shoreline project design is highly site-specific, and many sites face constraints that limit the ability to avoid or reduce hard armor. Some jurisdictions pointed to challenges with implementing code language. For example, unclear language may lead to inconsistent code interpretations between staff. Other internal barriers that staff face include insufficient capacity, funding, and training. Jurisdictions also noted that applicants and technical professionals have varying levels of awareness about alternatives to hard armor, leading to less usage of alternative techniques in projects.

Areas for improvement: Jurisdictions emphasized the need for improved education and training for all audiences who interact with the shoreline. This includes local government staff, homeowners, geotechnical consultants, and broader audiences such as real estate agents. Jurisdictions also noted that geotechnical reports are a key tool for understanding and properly managing shoreline sites, but must be prepared with the appropriate analysis to satisfy SMP requirements. Additionally, staff reviewing these reports must have a sufficient understanding of shoreline processes and stabilization techniques to understand the findings of reports and recognize when reports may be insufficient.

Positive takeaways: Jurisdictions reported low numbers of authorizations for new shoreline stabilization. The most common project types are repairs and replacements of existing armoring, and these projects are opportunities to lessen the impacts of armoring. Furthermore, there is a strong and growing body of knowledge and practitioners who can support local governments and property owners in improving shoreline management.

Opportunities for Ecology: Jurisdictions expressed a continued desire for technical assistance from Ecology. Jurisdictions also sought guidance from Ecology on improving local code language and review processes to make shoreline stabilization regulations more effective. Ecology can continue to promote existing resources and knowledge-sharing between jurisdictions and can foster partnerships between jurisdictions and other bodies such as state agencies, tribal governments, academic institutions, non-profits, and conservation districts.

Following the interviews, Ecology developed a web application to build knowledge of alternatives to hard shoreline armoring. The Examples of Puget Sound Soft Shore and Armor Alternatives website provides photos and project details to help property owners, local government staff, and others broaden their awareness of these shoreline management techniques. Ecology also collaborated with Washington Sea Grant and the Washington Department of Fish and Wildlife to produce a four-part webinar series targeted at local planners to improve their review of armor proposals.

Key messages

- Shoreline management in Washington is a partnership between local governments and the state Department of Ecology. Ecology supports local governments, who are primarily responsible for SMP implementation, through guidance and technical assistance, and by fostering knowledge sharing between jurisdictions.
- Nearly all Puget Sound jurisdictions have completed comprehensive updates of their Shoreline Master Programs. With new regulations (including those on shoreline stabilization) in local codes, Ecology is focusing more attention and resources on the implementation of SMP regulations.
- In interviews, local government staff identified two key areas that will support local implementation of shoreline stabilization regulations: improved education/training for a wide range of audiences, and improved site-specific analysis prepared in support of shoreline projects. Local government staff believe these steps will ultimately lead to better projects and better environmental outcomes on shorelines.
- There are opportunities around all areas of Puget Sound to lessen the impacts of hard armor. This was shared by local staff and was clearly demonstrated by the wide range of shoreline restoration and protection projects being conducted by Summit attendees.
- The body of knowledge around Puget Sound nearshore protection and restoration, as well as the network of contributing partners, are important assets to local governments. For example, local governments and their applicants benefit from strong connections to the local Shore Friendly program in the area. Ecology plays an important role in supporting local governments by fostering connections to partner organizations and making jurisdictions aware of new resources.
- The work being done to improve local implementation of shoreline stabilization regulations supports broader regional efforts to advance Puget Sound recovery, as outlined in the Shoreline Armoring Implementation Strategy.

Literature

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Johannessen, J., A. MacLennan, A. Blue, J. Waggoner, S. Williams, W. Gerstel, R. Barnard, R. Carman, and H. Shipman, 2014. Marine Shoreline Design Guidelines. Washington Department of Fish and Wildlife, Olympia, Washington. https://wdfw.wa.gov/sites/default/files/publications/01583/wdfw01583.pdf

Online resources

Examples of Puget Sound Soft Shore and Armor Alternative Projects. This web application provides examples of projects on Puget Sound where alternatives to hard shoreline armoring were used. Projects avoided, reduced, or removed hard armor. www.ecology.wa.gov/softshoreprojects

Using Marine Shoreline Design Guidelines to improve shoreline stabilization permitting. This website provides the recordings and resources from a four-part webinar series on the Marine Shoreline Design Guidelines conducted in 2020. This series provides actionable information and helpful materials to shoreline planners and project reviewers as they review shoreline stabilization proposals for consistency with local Shoreline Master Programs (SMPs). https://www.coastalplanners.org/four-part-webinar-series

Link to presentation recording https://youtu.be/9hxmTOEzeos?t=10048

Sydney Fishman is the Shoreline Armoring Planning Associate at the Washington Department of Ecology. She assists local governments and Department of Ecology staff with review of shoreline stabilization projects under local Shoreline Master Programs and supports regional efforts to address shoreline armoring and improve the health of Puget Sound shorelines.

Effectiveness of shoreline restoration for nearshore fishes

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Background and context

Coastal and estuarine habitats have been degraded by shoreline development activities globally, and major efforts are underway to restore shoreline processes, structure and function. In Puget Sound, the removal of hard armor from beaches and intertidal zones has become a priority activity for state and local agencies. However, the effectiveness of these restoration programs for subtidal habitats and the fishes that use them are unknown. We surveyed six restoration sites in Puget Sound over two years to evaluate associations between shoreline structure and subtidal fish distribution. We measured the abundance of two salmonids, Chinook and chum, and two forage fishes, Pacific herring and surf smelt, all juveniles, at restoration sites as compared to adjacent natural and still-armored shorelines.

Findings

Bayesian generalized linear models showed limited support for associations between shoreline restoration and these fishes in the 3-7 years since armor removal. Herring and smelt were more abundant overall at natural or armored shorelines, as compared to restoration sites; for smelt, this effect varied by survey site. Shoreline structure was not an important predictor of salmonid abundance in nearshore habitats; the best models for Chinook and chum salmon included single predictors for survey site and eelgrass, respectively. Chum salmon and surf smelt showed seasonal patterns of abundance, and survey site was also retained in the top models for both forage fish, revealing the influence of underlying regional patterns, such as spawning locations, on abundance of all four species of fishes.

Key messages

- Our results suggest that juvenile forage fish and juvenile salmonids in estuaries are likely responding differently to shoreline features.
- Either the positive effects of armor removal reported for these species in beach and intertidal habitats may not extend into subtidal areas, or the benefits of armor removal for these nearshore fishes are not detectable at local scales.
- Coastal restoration programs aimed at improving habitat to support fishes using shallow nearshore waters may need to consider broader landscape patterns as well as species-specific habitat needs when prioritizing investments.

Online resources

A fact sheet summarizing the project and primary results can be found on the Habitat Strategic Initiative website. *https://pugetsoundestuary.wa.gov/wp-content/uploads/2019/12/SOS-HabitatSI_NEP_Factsheet_v2-002-2.pdf*

Link to presentation recording https://youtu.be/jntLdMHl61I?t=7167

Dr. Tessa Francis is the Lead Ecosystem Ecologist at the University of Washington Tacoma's Puget Sound Institute, and the Managing Director of the Ocean Modeling Forum. She is an aquatic ecologist, working to connect science to decision making in a variety of settings. Tessa currently leads several research projects related to conservation of forage fish, salmonids, and nearshore habitats in the Puget Sound and on the West coast of North America with agency, tribal and First Nations, industry, NGO and academic partners. Tessa holds a BA in Political Science from UC Berkeley, a BS in Wildlife Science from the University of Washington, and a PhD in Zoology and Urban Ecology from the University of Washington.

The Vashon Maury experience: To implement or prioritize

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Background and context

King County has several long-standing open space protection programs that have been used to protect shoreline habitats along Vashon and Maury Islands. With the listing of Chinook 20 years ago, King County shifted its approach by combining its acquisition strategy with a restoration strategy to focus on a physical processes approach at the drift cell scale. The focus areas were created based on analyses that evaluated and combined information on the community's open space vision, areas of high ecological value that are self-sustaining (including large areas of contiguous mature forests, drift cells or reaches within cells with a high percentage of intact sediment), and habitat rarity (e.g., salt marshes, exceptional feeder bluffs). The risk of residential development and consistency with other regional planning efforts was evaluated after the initial focus areas were created as a means of helping to decide which areas to prioritize in the near term. This approach led King County to lay out a vision of near-term (~10 years) and long-term (~30 years) priority areas. As a result, for the past 10 years, the County has focused most of its nearshore salmon recovery efforts on approximately four of the dozens of drift cells along the island, which has facilitated the removal of clusters of shoreline armoring.

Key messages

- The WRIA 9 shoreline has been prioritized for restoration and protection over ten times in the last 20 years. Stop analyzing and prioritizing and focus on restoring.
- Restoring the Puget Sound shoreline requires a *long*-term view with a *broad* set of priorities.
- Grant agencies generally treat project 'opportunities' as somehow bad or inappropriate to fund. We need to shift that paradigm and create a large enough strategy that defines 10 to 20 years of effort, and then work within that geography to be 'strategically opportunistic' when properties become available.
- Having a point person that is the entities' eyes and ears on the ground and is responsible for implementing the restoration plan(s) is a key to King County's success.
- While we do need to change how private landowners interact with the shoreline, acquisition of property for restoration and protection is a proven strategy that works, especially if you have a long-term vision.
- State and federal grant sources are great, but they have not been allocating enough money to do the level of restoration and protection necessary. Developing multiple local funding sources that can leverage state and federal programs is necessary to succeed at restoring Puget Sound.

Literature

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2004 Coastal Geologic Services prioritization of WRIA 9 marine shoreline https://your.kingcounty.gov/dnrp/library/2005/kcr1927.pdf

2005 WRIA 9 Salmon Habitat Plan: https://www.govlink.org/watersheds/9/plan-implementation/HabitatPlan.aspx

2005 Greenprint for King County: https://your.kingcounty.gov/dnrp/library/2005/KCR1856/0505_Greenprint.pdf

2006 Prioritization of WRIA 9 Marine Shorelines: https://www.govlink.org/watersheds/9/reports/NearshoreHabitatPrioritization.aspx

2008 King County. Greenprint for Ecological Focus Areas on Vashon-Maury Island. Prepared by Katheryn Gellenbeck, B. Fuerstenberg, and L. Larkin. 46 pages (*not online*)

2011 Shorefriendly Social Marketing Approach: https://salishsearestoration.org/images/8/8e/Social_marketing_approach_and_campaign_implementation_tools.pdf

2012 PSNERP Strategies for Nearshore Protection and Restoration: https://wdfw.wa.gov/sites/default/files/publications/02182/wdfw02182_0.pdf

2020 Beach Strategies https://salishsearestoration.org/images/7/71/CGS_ESRP_BeachStrategies_Phase2Report_Sept2020_revised.pdf

2021 WRIA 9 Salmon Habitat Plan https://www.govlink.org/watersheds/9/pdf/W9_SHP_2021.pdf

King County, 2019. WRIA 9 Marine Shoreline Monitoring and Compliance Project Phase 2 https://your.kingcounty.gov/dnrp/library/2019/kcr3021/kcr3021.pdf

Online resources

Maury Island Aquatic Reserve. WA State Department of Fish and Wildlife. https://www.dnr.wa.gov/managed-lands/aquatic-reserves/maury-island-aquatic-reserve

Link to presentation recording https://youtu.be/jntLdMHl61I?t=8194

Kollin Higgins is a Senior Ecologist with King County where he has worked for the last 20 years on salmon recovery efforts throughout the County, with an emphasis in the Green-Duwamish watershed and its marine shoreline. He has also worked on regulatory issues like the Shoreline Master Plan and Comprehensive Plan as well as evaluating the effectiveness of regulations to protect marine shorelines.

What I learned on the way home from school – Puget Sound coastal restoration design considerations for the rest of the 21st century

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Link to presentation https://youtu.be/9hxmTOEzeos?t=625

Jim Johannessen specializes in beach and estuarine processes, coastal erosion mitigation, coastal restoration, and applied coastal management. He has designed hundreds of beach nourishment and estuary restoration/enhancement projects, including over 40 armor removal projects, throughout Puget Sound and the Salish Sea.

Mapping the physical indicators of beach processes, structure, and function

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Background and context

Adjacent natural and armored shorelines throughout Puget Sound typically contrast in appearance. Natural beaches often appear more complex with more vegetation and large woody debris (LWD) in the backshore zone, whereas armored beaches often lack a backshore zone and are more homogeneous and barren in appearance, void of driftwood and wrack. But the location, character, and impact of shoreline armor vary greatly.

Some shoreline armor is more of a form of landscaping rather than erosion control. The armor may be positioned well above and landward of the mean higher high water (MHHW) line with a significant accumulation of drift logs and backshore vegetation fronting the armor. This type of armor could be viewed as a good candidate for removal, having low risk to the upland property. However, the armor removal would result in minimal restoration of processes, structure, and function.

More commonly, shoreline armor encroaches onto the beachface with the armor toe positioned below MHHW, eliminating the backshore zone. The armor typically reflects wave energy and results in a depressed beach profile composed of coarser sediment than the natural state. Unfortunately, this condition may be perceived as an erosion problem rather than an armor encroachment problem. The armor may be therefore considered essential to protecting upland property and maintained through repairs and replacement as needed. Moreover, restoration actions or viable soft solutions may not be even considered due to perceived risk.

We need to measure and monitor natural shorelines to have a reference for restoring shorelines.

Findings

In order to restore shorelines, and evaluate the effectiveness of restoration actions, we need to measure and monitor natural shorelines to have a reference to compare restored shorelines to natural intact conditions.

We can improve restoration when we measure *key shoreline features*, such as the MHHW line, bluff toe, backshore width, overhanging marine riparian vegetation, and LWD. We can then compare these beaches to armored shorelines and determine the relative encroachment based on the position of the armor toe relative to MHHW as well as the natural bluff toe elevation.

We are measuring these shoreline features by mapping with boat-based lidar technology (Weiner et al. 2018), which captures a 3D georeferenced point cloud of the shoreline landscape. We classify the point cloud, separating beach and bluff topography and shoreline armor from other physical features like riparian vegetation and LWD. By measuring key shoreline features at sites with adjacent natural and armored shorelines, we can quantify their differences (Drummond 2020).

Comparison of sites mapped with boat-based lidar reveals natural shorelines have significantly more backshore width, LWD, and vegetation overhang relative to armored shorelines.

Conducting successive lidar surveys enables the measurement of change over time. At Edgewater Beach, we measured changes associated with a bulkhead removal project and found the bluff supplied sediment to the beach, while LWD increased and enhanced sediment deposition (Weiner and Kaminsky 2018).

Progress on improving shoreline restoration and protection will be made through these steps:

1. Inventory and quantify *physical features* to provide a reference for restoration; measure the difference between modified and natural shorelines.
2. Develop *metrics* for assessment of condition and restoration potential.
3. Document the *linkages* between physical features and biological functions.
4. Map changes over time to understand and restore *processes and functions* – determine time and space scales of processes and responses to structural changes.
5. Mimic natural structure and integrate *natural dynamics* with restoration actions – focus on constructive processes such as beach sediment accretion.
6. Monitor restoration actions for *effectiveness*; compare to natural reference conditions, and with respect to dynamics and time scales.
7. Test and engineer nature-based designs for effectiveness along *eroding or high-energy shorelines* (e.g., Weiner et al., 2019; Kaminsky et al., 2020; Bayle et al., 2021) where hard armor can be justified based on the Marine Shoreline Design Guidelines decision tree (Johannessen et al. 2014).
8. *Integrate monitoring and learning with iterative construction and adaptive management* of shoreline restoration projects and nature-based solutions.

Key messages

- Prioritize armor removal projects based on relative encroachment (Dethier et al., 2016), impact, and restoration potential.
- Establish restoration reference criteria based on measurements of key shoreline features and monitoring the dynamics of natural beaches.
- Monitor restoration actions and nature-based designs (e.g., Weiner and Kaminsky 2018; Weiner et al. 2019; Kaminsky et al. 2020; Bayle et al. 2021; Toft et al. 2021), and adaptively manage these interventions based on observed processes and responses to structural changes.
- Learn from indigenous coastal engineering practices that illustrate effective approaches for working with natural processes to manage and mitigate erosion and sea level rise (Grier 2014; Grier et al. 2017).

Literature

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Link to presentation recording https://youtu.be/jntLdMHl61I?t=2022

Dr. George Kaminsky is a senior coastal engineer with 30 years of applied research experience in coastal engineering and geomorphology with expertise in coastal processes, morphology change, sediment budgets, and nature-based engineering design.

Using existing barriers to identify future opportunities and needs

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Background and context

The Northwest Straits Foundation (NWSF) is a partner in the regional *Shore Friendly* program sponsored by Washington Department of Fish and Wildlife Estuary Salmon Restoration Program. NWSF has been engaging shoreline property owners for over a decade to reduce impacts of shoreline armor through the removal of unnecessary structures and the prevention of new installations. However, it has only been a couple of years since it was deemed okay to address considerations for managed retreat (i.e. elevating or moving houses out of high-risk areas). Sea level rise (SLR) has not been addressed enough, and we didn't do enough to remind people that bulkheads don't stop water.

Many of the low-hanging fruit with the necessary intersection of feasible armor removal opportunities with willing landowners and fundable projects have been completed, but we are still far from achieving armor removal levels that will be necessary to ensure habitat protection in the face of climate change and projected SLR. We need to continue to address the remaining barriers to restoration and the prevention of new armor installation.

Shore Friendly site assessments have shown that structure setback distance is the most frequent constraint to removing armor from shoreline parcels in the region. Structure relocation is not viewed by many shoreline property owners as an alternative to armor, despite it being a more cost-effective long-term solution to erosion threats, particularly in the context of sea level rise. We need to incentivize moving homes, septics, and other infrastructure away from the shoreline. This then opens up the possibility of removing armor and avoiding installation in the first place.

Key messages

- The combined effects of sea level rise, coastal erosion, and insufficient shoreline regulations have resulted in many homes being located too close to bluff crests and high-water marks; resulting in risks to homes and lives, upper intertidal habitat loss, and constraints to sediment supply restoration and conservation.
- Inadequate setbacks are a barrier to armor removal and delaying discussions about managed retreat will lead to increased armor installation when other solutions are no longer feasible.
- Structure relocation (managed retreat) is not often considered by waterfront property owners as an option for managing shoreline erosion, yet it provides the most cost-effective long-term solution in most cases.
- Education and outreach to homeowners should include the long-term security that can be provided by opting for solutions of retreat (increased setbacks or elevating the home out of the flood zone) and potential pathways to restoration and protection.
- Tideland ownership in Washington state is unlike any other coastal states. The messaging has to be different to change behaviors. We need a toolkit specific to our issues and populations.

Literature

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Northwest Straits Foundation Shore Friendly Living Video Series, Coastal Beaches and Bluffs. https://www.youtube.com/watch?v=CB4AkTZhJnU&t=2s

Northwest Straits Foundation Shore Friendly Living Video Series, Managing Shoreline Erosion: Bulkheads or Natural Solutions. https://www.youtube.com/watch?v=wZAmPBAd_KI&t=24s

Northwest Straits Foundation Shore Friendly Living Video Series, Restoring the Connection Between Land and Water. https://www.youtube.com/watch?v=D9eWqIRpJLk

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Link to presentation recording https://youtu.be/jntLdMHl61I?t=5552

Lisa Kaufman has been managing nearshore restoration projects and shoreline landowner outreach at the Northwest Straits Foundation since 2013. Before joining the Foundation, Lisa spent over nine years as the Restoration Program Manager at the Washington Department of Natural Resources where she led shoreline restoration projects and the regional creosote removal program.

Intersection of science and opportunity: How Shore Friendly Kitsap projects rank on a local nearshore prioritization tool

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Background and context

Shore Friendly Kitsap (SFK) has been actively working towards motivating marine waterfront landowners to remove bulkheads or replace them with soft-shore protection for the last six years. SFK is voluntary and selects projects according to landowner interest and feasibility. I compare SFK projects completed through the program to prioritized (potential) restoration opportunities identified by our local nearshore prioritization tool (Confluence et al. 2017) to determine if we are completing priority projects.

The nearshore prioritization tool is salmon-centric and evaluates projects with respect to habitat benefits for juvenile Chinook salmon. It is also process-based, evaluating the affected ecosystem functions and processes of a project such as sediment transport, sediment source, cross-shore connectivity, tidal flow, and fish passage processes. When the tool was operationalized in 2017, SFK envisioned using it to screen projects to maximize restoration dollars. However, the voluntary nature of the program and lower than anticipated demand led to a project selection strategy that is opportunistic.

In six years, 11 SFK projects were completed. Five were originally identified and ranked by the nearshore tool as potential opportunities. When I applied the tool to all 11 projects, 10 projects ranked as Tier 4, and one project ranked as Tier 3. This result was somewhat expected since most armor removal projects score into lower tiers given the processes they address (i.e., cross-shore connectivity) and the tool's scoring formula. Of the five projects originally identified by the tool, all could have been larger projects with multiple parcels if landowner willingness was not a barrier.

Key message

- Cumulatively, Shore Friendly Kitsap projects are contributing to nearshore recovery. Even though they have not been projects of Tiers 1 and 2 as evaluated by our local nearshore prioritization tool (Confluence et al. 2017), they have been beneficial Tier 3 and 4 projects. These projects contribute to ecological gains and help shift landowners' behavior and the public's attitudes towards softer stabilization techniques and natural shorelines.
- A diversified approach to project selection for Shore Friendly Kitsap restoration projects will help identify and encourage higher priority projects (as ranked by the local nearshore prioritization tool (i.e., Tiers 1 and 2)), in addition to lower priority projects.
- A diversified approach consists of using opportunistic methods (which are already used) and targeted strategies (not yet employed) that focus on higher priority projects within specific reaches and neighborhoods. This means actively using and implementing local science available, like the West Sound nearshore framework and prioritization tool.
- A diversified approach recognizes the value of each project, from lower to higher ranking projects. Typically, lower scoring bulkhead removal projects are typed as cross-shore connectivity projects

by the nearshore framework and prioritization tool. These projects are in lower energy reaches with lower associated risks to infrastructure. These projects add to the Shore Friendly portfolio increasing public exposure and enhance the social marketing campaign. A wide array of Shore Friendly projects cumulatively affect and benefit Puget Sound shoreline health.

- To employ targeted strategies, we must start to answer the questions: How do we build a bridge between the science and a voluntary program? How do we creatively target higher priority projects and reaches? What role does social marketing play? What techniques and strategies do social marketing offer?

Literature

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Online resources

West Sound Nearshore Framework and Prioritization Tool (in Kitsap County Online GIS Resources). This webpage provides the interactive map that shows identified nearshore project opportunities and ranking, the report and user guide.
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Christina Kereki is a project planner with Kitsap County coordinating the Shore Friendly Kitsap program and other County nearshore projects. Her interest in restoration and applied ecology began with a fervor for field biology (favorite projects: marbled murrelets, Vancouver Island water shrews). Christina has a Bachelor's of Science in Biology from the University of Victoria and a Master's of Resource and Environmental Management from Simon Fraser University.

Ecological and social influences on salmon habitat restoration effort in the Puget Sound

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Background and context

In the past 20 years, thousands of salmon habitat restoration projects have occurred in the Pacific Northwest, focusing on the ecological goals of protecting and recovering threatened and endangered salmon species. However, in addition to ecological drivers, there are also social factors that potentially influence restoration. To better understand these dynamics, our project investigated the ecological and social influences on the distribution of salmon habitat restoration efforts in the Puget Sound region of Washington. We aimed to answer the following research question: How does the regional distribution of completed salmon restoration projects correlate with biological, physical, and human community characteristics? Understanding whether salmon restoration efforts tend to flow towards certain types of communities, could inform future effort allocations in the Pacific Northwest and raise awareness about potential equity and environmental justice issues. Previous literature on environmental justice highlights that environmental hazards may disproportionately affect certain social communities; however social and environmental impact assessments are commonly conducted separately (Sanchez et al 2013). Using salmon habitat restoration projects data obtained from the NOAA managed Pacific Northwest Salmon Habitat Project Database as dependent variables, this project explored whether salmon habitat restoration efforts in the Puget Sound tend to flow towards certain types of ecological and social communities, and the potential equity and environmental justice implications. Our project uses methods similar to those used in previous research that explored correlations between ecological and social variables and restoration sites along the California Coast (Stanford et al. 2018).

Findings

To complete our research, we utilized NOAA NWFSC's managed Pacific Northwest Salmon Habitat Project (PNSHP) database which contains data on over 26,000 restoration actions undertaken at over 42,000 locations. At the Puget Sound level, PNSHP contains data on over 1,500 restoration actions undertaken at over 2,100 locations from 2000- 2015. The number of restoration project sites in each catchment unit (12-digit Hydrological Unit Code) within the Puget Sound region were used as dependent variables. Ecological and social variables were collected for each catchment unit and as independent variables. We the fit statistical count models to assess correlations between dependent and independent variables. Based on preliminary statistical count model results, our findings identified correlations between the number of salmon habitat restoration sites in the Puget Sound and many of the social and ecological variables in our models across multiple project sites and project types. Preliminary results suggest that similar trends exist in the Puget Sound to those found by Stanford et al. 2018. However, we still are finalizing our models and results. After finalizing our models, we hope to expand our study area to Oregon and other parts of Washington.

Key messages

- This research project, as well as other social sciences and environmental justice-centered research, has the potential to raise awareness about social equity and justice issues associated with restoration actions in the Puget Sound. It also has the potential to inform future effort allocations and raise awareness about equity and environmental justice issues.

- In addition to researching ecological drivers of restoration projects, it is also important to consider social inequities and the roles they play, unintentionally and intentionally, in planning and management efforts.
- To better integrate environmental justice work into restoration science and practice, emphasis should be placed on the value of diverse perspectives and collaboration amongst researchers from different disciplines.

Literature

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Link to presentation recording https://youtu.be/9hxmTOEzeos?t=1555

Brittany King is an interdisciplinary social scientist whose research interests lie in the human dimensions of fisheries science, and diversity and inclusion. She is currently a Ph.D. candidate in the department of Fisheries and Wildlife at Oregon State University, where her research examines underrepresented racial and ethnic groups in marine and fisheries science professions.

Expanding the market for residential sea level rise adaptation with new Shore Friendly incentives

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Background and context

Since 2014, local Shore Friendly programs have provided free property assessments and management recommendations to hundreds of waterfront homeowners (Kinney and Francis 2019). These face-to-face interactions have prevented installation of new shoreline armor and facilitated restoration of critical beach habitat through the removal of shoreline armor. As risks associated with climate change become more apparent, these successful programs need additional incentive tools. When Shore Friendly was being developed almost a decade ago, homeowners were not ready to discuss sea level rise. Since then, there have been some extreme high-water level events and notable landslides. Program staff report that residents are increasingly concerned about coastal flooding and bluff instability hazards. It is time to expand the Shore Friendly toolbox to address climate change adaptation. Kinney et al. (2021) assessed the feasibility of one such tool: a new loan program to help homeowners finance armor removal as well as raising homes to reduce flooding risk and moving homes away from retreating bluffs. This effort aims to link implementation of climate adaptation measures and beach restoration via armor removal because the adverse impacts of conventional shore stabilization structures are expected to grow as sea level rises. Since single-family residential parcels occupy 57% of Puget Sound's marine shoreline, private voluntary decisions about shoreline management will have a major influence on the future of the region's beaches (Coastal Geologic Services 2020, Javeline and Kijewski-Correa 2019). Connecting projects to remove armor with modifications to reduce risk to homes will increase the resiliency of nearshore habitats and coastal communities.

Findings

This presentation summarized results of the market analysis conducted as part of the shoreline residential loan program feasibility study (Kinney et al. 2021). For the first element of the market analysis, study partner Coastal Geologic Services (CGS) estimated the number of residential parcels that may be vulnerable to coastal flooding and bluff retreat in the future. Existing data (CGS 2017, CGS 2020) was used to assign all 45,000+ Puget Sound residential parcels into groups based on combinations of four physical characteristics: the presence of a home, armor status, erosion potential, and shoretype (used as a proxy for potential hazard exposure). About 11,000 parcels had a home located on a low elevation shoretype (potentially vulnerable to flooding) and about 12,000 parcels had a home located on a bluff shoretype (potentially vulnerable to landslide). These estimates likely overstate hazards because no regional data on home elevation and location relative to buff crest was available. The second part of the market analysis assessed demand for home elevation and relocation projects. Existing homeowner survey and focus group data (Colehour + Cohen et al. 2014) was used to adjust the market size estimates. 3% of participants were interested in elevating their homes and 1% were interesting in relocation. Results indicated that, as of 2014, there was demand for more than 400 elevation or relocation projects. It is expected that this number will continue to grow into the future.

Social marketing techniques can be used to increase interest in and demand for Shore Friendly adaptation actions. A near-term priority is to conduct a new homeowner survey and focus groups to identify barriers and motivators for adaptation behaviors. Knowledge about coastal flooding/landslide hazards and factors likely to affect decisions to invest in hazard mitigation measures should be assessed. Widespread misperceptions about bulkheads protecting against flooding should be a focus of future communications materials. Many of the challenges ahead are social in nature, so other social science research can and should support the development and refinement of climate solutions. For example, economic evaluations that monetize the benefits of armor removal and hazard mitigation can support public investment in programs like Shore Friendly. Emergency management research may be useful in understanding risk perception and drivers for taking protective actions. Regulations will also play an important role in driving adaptation actions. Incentives are a complementary approach that can be used to further multiple policy objectives related to nearshore habitat and coastal communities.

Key Messages

- Sea level rise will exacerbate the degradation of Puget Sound beaches caused by shoreline armoring.
- Since single-family residential parcels occupy 57% of Puget Sound's shoreline length, voluntary decisions about shoreline management on private property will have a major influence on future condition of the region's beaches.
- If we want homeowners to choose and implement beach-friendly options to adapt to sea level rise, we need to expand technical assistance and financial incentives provided by local Shore Friendly programs.
- Social science tools and research can help us understand homeowner priorities, develop effective communication approaches, identify incentive tools most likely to result in preferred behaviors, and build support for public investments to increase resiliency.

Literature

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Online resources

Shore Friendly Program. Information and resources for waterfront homeowners. http://www.shorefriendly.org/

Link to presentation recording https://youtu.be/9hxmTOEzeos?t=4408

Aimee Kinney is a researcher for Puget Sound Institute at UW Tacoma. She provides analysis of existing programs and policies to support implementation of National Estuary Program recovery plans.

Restoration and protection in Puget Sound beach systems: Where do we go from here?

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Background and context

Puget Sound beaches are incredibly diverse – exhibiting huge changes across relatively short distances. We are still in the process of documenting this variability, as we work to restore and protect habitats for salmon and orcas, among others. Some sources of variability include fetch, which drives the rates of change we see on a given beach; and geomorphic shoretype, which determines the nature of the change that is occurring (e.g., erosion, accretion). A broad range of anthropogenic alternations has transformed the Puget Sound beaches - from residential shoreline armor and nearshore fill to regional deforestation, all of which contributes to current nearshore conditions and diminished resilience of these systems to further changing conditions resulting from climate change. So how can we avoid double-dipping in uncertainty, as we work to restore and protect systems that we are still working to understand, in the context of changing fundamental environmental conditions?

This presentation outlines new data developed as part of two ESRP learning projects that can be used to better inform restoration and protection of beach (and bluff systems) in the Puget Sound in the context of climate change. Using this data, we can better understand current conditions, which can enable more effective management, reduce risk to shoreline communities and potential economic loss, and be used to develop restoration and protection strategies and actions that will increase ecosystem resilience where it is needed most.

Findings

Data developed in two ESRP learning projects: Long-term Bluff Recession Rates in the Puget Sound (CGS 2018) and Beach Strategies Nearshore Restoration and Protection in Puget Sound (CGS 2017, 2020) enhance our understanding of Puget Sound marine shorelines.

Coastal bluffs are the most prevalent coastal landform in Puget Sound, accounting for over 1,000 miles of the region’s shoreline. Coastal bluff recession supplies the majority of sediment to Puget Sound beaches, which provide and maintain essential nearshore habitats for salmon, shellfish, and other fish and wildlife (Finlayson 2006, Johannessen and MacLennan 2007, Keuler 1988). Prior to this effort, there was little documentation of the range of bluff recession rates in the Puget Sound region (approximately 20-30 rates) or any exploration of how those rates reflect changes in bluff morphology, geology, stratigraphy, tidal range, and wave exposure.

The objective of this project was to increase understanding of the range and dominant drivers of long-term coastal bluff recession in Puget Sound. The data set includes 185 long-term bluff recession rates, measured from 23 to 101 years. A range of variables was analyzed in association with recession rates to develop a predictive model for bluff recession. The average long-term erosion rate was 0.29 FT/YR, which varied on average by 0.21 FT/YR across the bluffs sampled. Fetch and tidal range had the most influence on bluff recession rates.

The objective of the Beach Strategies project was to develop science-based strategies to guide future protection and restoration of Puget Sound Beaches. Prior to the initiation of the Beach Strategies project existing strategies were insufficient due to data gaps, errors, and insufficient spatial resolution. Phase 1 outputs included a geodatabase of best available science consisting of updated measures of maximum fetch, geomorphic shoretype, shoreline armor, shoreline parcels, and littoral drift cells (with linear referencing routes). In Phase 2, data developed in Phase 1 were organized and analyzed to provide nearshore recovery practitioners with a suite of tools to guide their decision making. An evaluation framework consisting of four different priorities (referred to as modules) was developed with input from end-users and the project steering committee. Each module includes query outputs and supporting data at multiple scales: from drift cells to shoretypes and reaches of armored and unarmored bluff. Queries were rooted in landscape-scale ecology and conservation biology principles – that provide insight into how broken nearshore processes are at various scales across the landscape.

Key messages

- Bluff recession rate data provides a robust foundation for documenting future changes in bluff recession associated with climate change and sea level rise.
- Bluff recession rates can be used to inform better management, particularly safe structure setback distances and evaluate areas where managed retreat may be an appropriate management response.
- Beach Strategies data can be paired with other local data to highlight high-benefit restoration and protection targets as well as identify areas with more or less resilience to sea level rise due to sediment supply and shoreline armor conditions.
- Beach Strategies data can be used to identify shores with armor at lower elevations where forage fish spawning habitats are endangered in the coming decades due to sea level rise.

Literature

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Online resources

https://salishsearestoration.org/wiki/Beach_Strategies_for_Nearshore_Restoration_and_Protection_in_Puget_Sound

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Link to presentation recording https://youtu.be/jntLdMHl61I?t=4577

Andrea MacLennan is a coastal geomorphologist that has been working to better understand nearshore ecosystem processes in Puget Sound for over 20 years. She has developed several nearshore geospatial data sets that can be used in Puget Sound recovery, shoreline management, and sea level rise planning.

Nearshore management prioritization in the south Salish Sea: coastal catchment analysis project

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Background and context

Strategies for effective protection/restoration have been previously outlined and developed by many authors (e.g., Johnson et al. 2003, National Resource Council 1992 and Shreffler, Simenstad, and Thom 1992). In general, they invoke concepts of the degree of ecosystem impairment versus ecosystem dynamics and therein ecosystem resilience, self-maintenance, and recovery. As cited in Johnson et al. (2003) "Shreffler, Simenstad, and Thom (1993) concluded that the strategies of restoration, enhancement, and creation should be applied depending on the degree of disturbance of the site and the landscape." For example, regarding the effect of restoration (protection or enhancement) in areas of lower or higher landscape disturbance (Johnson et al. 2003). This concept has a direct translation to the probability of projects being successful over time and is an important consideration for managers to implement best-suited management strategies depending upon ecosystem conditions and desired outcomes.

The Action Strategies defined for Nearshore Zones and Catchments are focused on the Conservation/Preservation of those areas (from the Zone to Catchment to 'Neighborhood' scale) that remain relatively intact in terms of their level of disturbance/development and retain many of the ecological and biological forms and features that are agreed to be indicative of healthy ecosystem function(s) and supportive of the salmonid lifecycle. Within that Conservation/Preservation context, Nearshore Zones and Catchments were selected based on the presence of beneficial and limiting attributes in addition to the level of disturbance and deemed to be candidates for either straight Preservation/Conservation or conservation with Restoration/Enhancement opportunities. The Coastal Catchments Analysis Project intends to provide a tool to assist Land Trusts, Enhancement Groups, and other groups in their selection of discrete sites for the placement of relatively small projects upon the landscape. Zones and Catchments with high levels of disturbance at the Site and/or Landscape scales which would require the re-creation of ecological forms and features and their related processes at a relatively grand scale are beyond the intent of the Coastal Catchments Analysis Project.

Findings

Assessing the current ecological functions/services (i.e., "health") of potential natural resource project locations is a critical step to planning, funding, and implementing those projects in such a manner as to achieve their intended effects and desired benefits that natural resources managers strive to achieve.

Many natural resource management agencies and groups have published data and analyses that provide information on the distribution of habitats and species and their status regarding their ecological health and function. The intent of the Coastal Catchment Analysis Project was to assemble these many data sources into one analysis and associated online map application that focused on the South Salish Sea. See citations/links below for those sources. The online map application makes the analysis and data layers available to the Squaxin Island Tribe's multiple partners with whom they collaborate on many projects throughout the Tribe's ancestral lands. These projects protect and enhance the many natural and cultural resources that the Tribe, its tribal members, and we all, rely on.

Significantly, the project used a relatively small analysis unit as compared to other previously completed projects and a series of spatial overlay operations to attribute each analysis unit for the assemblage of *beneficial* and *limiting* ecological functions. Analysis Units were then ranked relative to other units within their respective Analysis Areas (9 areas within the South Salish Sea – all nearshore watersheds south of the Tacoma Narrows).

Additionally, the project included a *neighborhood* component which scored and ranked each analysis unit's relative difference in its land use/land cover from the average of each/all of its immediate neighboring units. A project has a higher likelihood of success in a *neighborhood* that is in relatively good ecological condition.

The original analysis was completed in 2016. The 2020 update reran the spatial overlays using updated data where available. Additional enhancements to the online map application are planned for 2021 and will include the ability for users to import their data (e.g., properties, potential project locations.) and allow for the selection and querying of analysis datasets.

Key messages

The scale of geospatial analyses should be relative to the scale of typical projects. This is improving over time. Increased resolution (finer detail/location accuracy) greatly improves the value of the data and analysis's usefulness. Especially when attempting to evaluate broad areas for the placement of small projects.

- Analyses need to be re-run/updated as new/improved/additional data becomes available.
- Natural Resource Projects and their placement/location are often *opportunity based* either as landowners approach governments or NGOs or after an event that requires a response. As such, analyses and tools need to be dynamic and user friendly, and publicly available (web).

Literature

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Online resources

Coastal Catchment Analysis Project Nearshore Prioritization web map application. https://maps.squaxin.us/portal/apps/webappviewer/index.html?id=14a95765cd1b4777a78f4e207d03e558

Conceptual Approach to Prioritization for Restoration and Conservation of The South Salish Sea, WA Squaxin Island Tribe Natural Resources and Kyle Brakensiek Report Version 1, September 22, 2016. http://maps.squaxin.us/portal/sharing/rest/content/items/e8a28b2078564f1292e6be975b2c3d6f/data

Link to presentation recording https://youtu.be/9hxmTOEzeos?t=3545

Brian McTeague provides spatial database management, field data collection activity deployment, spatial analysis, mapping, application development, and generalized GIS support to all Natural Resources Department programs. Brian is also a certified drone pilot and recently passed his GIS Professional.

Shoreline armor removal fulfills nearshore ecosystem restoration following large-scale dam removal: Elwha nearshore

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Background and context

Sediment starvation due to large in-river dams adversely impacts coastal hydrodynamic and ecosystem processes. Removal of large-scale dams is assumed to restore these ecosystem processes but the nearshore response is poorly understood. In 2014, two century-old, large-scale dams in the Elwha River watershed were removed. In this presentation, we summarize the ecosystem effects of 100 years of shoreline sediment starvation due to large-scale, in-river dams, and the response of armored and unarmored shorelines when upwards of 10 million cubic meters of sediment was released to the coast as a result of dam removal. In 2016, we removed 1,000 linear meters of armor found to severely disrupt beach formation processes. We used physical metrics of beach topography, grain size, and ecological metrics of large woody debris (LWD), beach wrack, and forage fish egg abundance as indicators of shoreline response to both dam removal and armor removal. Within one year of the initiation of dam removal, unarmored reaches of shoreline in the drift cell broadened, flattened, and fined, and LWD volumes increased, while the armored reach continued to be steep and coarse. Almost immediately after the removal of over 1,000 linear meters of riprap, the previously armored beach broadened, fined, and LWD volumes increased significantly. Forage fish eggs were detected along the restored shoreline within the first year of armor removal. Restoration benefits were observed to extend several miles downdrift of the immediate project footprint. We conclude that only partial nearshore ecosystem restoration occurs from large-scale dam removal when nearshore impediments remain.

Key Messages

- As a result of prior chronic armoring of the project site, repeated restoration mobilizations were necessary to remove all impediments as they emerged as a result of natural beach adjustment to accomplish full process-based restoration.
- Nearshore ecosystem restoration associated with large-scale dam removals is incomplete until hydrodynamic disrupting features along the shoreline are fully resolved at the process scale.
- Once impediments are removed, restoration of physical processes is rapid, but ecosystem-scale life history restoration of fish, plants, and invertebrates takes time-possibly decades. However, we are already observing positive responses for LWD, benthos, and forage fish.
- Restoration benefits extended several miles downdrift of the immediate project footprint.
- To maximize nearshore ecosystem restoration, it is important to consider drift cell-scale sediment processes and coordinate implementation of related process restoration actions to gain complimentary benefits (Dam and Shoreline Armor Removal)

Online resources

Coastal Watershed Institute Project Blog. https://coastalwatershedinstitute.org/elwha-nearshore-rising-beach-lake-shoreline-restoration/

Link to presentation recording https://youtu.be/9hxmTOEzeos?t=8301

Jamie Michel is a Conservation and Restoration Biologist, currently working to understand, protect and restore marine shorelines on the Strait of Juan de Fuca. Jamie's work with the Coastal Watershed Institute includes researching the response of biological communities and physical processes to shoreline restoration. Jamie earned a M.S. in Environmental Science from Huxley College at Western Washington University and lives and works in Port Angeles.

Towards an improved understanding of Salish Sea shoreline processes

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Background and context

My shoreline processes research is intended to test the very simplistic conceptual models that we have for assessing when, how, and how much sediment moves along the shoreline. I'm interested in whether those models are adequate for managing the shoreline, and specifically the siting, design, and assessment of nearshore restoration projects. The fundamental thesis underpinning this presentation is that the only easily accessible insight about coastal processes relevant to the Salish Sea, that is delivered in a way (i.e. online, publicly accessible) to easily inform specific management or restoration decisions, comes from the drift cell mapping "arrows" available on the Washington State Coastal Atlas (https://apps.ecology.wa.gov/coastalatlas/tools/Map.aspx). I demonstrate that drift cell mapping arrows do provide useful insight about coastal processes in the Salish Sea, but also show, using a variety of examples, that the drift cell mapping is inadequate to address many questions that are asked in association with the design, implementation, and consequences of nearshore restoration projects or other shoreline perturbations. I end by outlining a proposed approach for developing improved conceptual models that describe the source, fate, and transport of coastal sediments in the Salish Sea and their potential implications for the design and implementation of restoration projects, and making those conceptual models available for practitioners.

Findings

To support my thesis, I summarize six different instances in which the drift cell mapping available in the Washington state coastal atlas does not provide adequate insight about expected coastal changes. All the examples are drawn from either restoration projects or instances in which management decisions about the uses of shorelines are being considered. The examples summarized include:

- A proposed estuary restoration project at Morse Creek on the Strait of Juan de Fuca. In this case, project reviewers cited a lack of an alongshore sediment source as an impediment for the project, whereas a more complete sediment budget suggested that sediment supply from Morse Creek itself (a source of sediment not represented in drift cell mapping in the Washington state coastal atlas) was almost surely the dominant source of sediment to the estuary.
- A summary of the sediment budget from the Elwha drift cell, where topography and bathymetry data showed that a very small fraction (~4%) of sediment delivered by the river to the coast was entrained into the littoral transport system and that most was pushed into deeper water (and presumably out of the littoral system).
- Analysis of shoreline changes after a large landslide on Whidbey Island suggested that the spatial extent of measurable beach change after a very large source of new sediment was added to the beach was relatively small (i.e. ~150 meters alongshore). Drift cell mapping provides no insight into the expected spatial extent of change on the shoreline for a given perturbation.

- Analysis of shoreline change after small-scale sediment nourishment on Ediz Hook was used to demonstrate the lack of insight provided by drift cell mapping in the Washington state coastal atlas about the temporal scale of change on the shoreline after a nourishment project.
- Analysis of shoreline change after small-scale sediment nourishment on Ediz Hook was also used to show that cross-shore sediment transport processes that are not represented in drift cell mapping in the Washington Coastal Atlas led to positive restoration outcomes, in that they likely supplied sediment to support eelgrass restoration.
- Finally, an example from a historic shoreline change analysis conducted for the Port Gamble S'Klallam Tribe was used to show that drift cell mapping in the Washington Coastal Atlas is likely inadequate for predicting shoreline response to sea level rise.

Key messages

I conclude by outlining an approach for improving the rigor and accessibility of conceptual and/or predictive quantitative coastal processes models for the Salish Sea that rely on:

1) Supporting more measurements of shoreline morphology (i.e. grain size, topography/bathymetry), at a higher frequency, with more accuracy, and in more places.
2) Facilitating rapid data publication, such that the data and observations made in #1 above are not "trapped" in hard drives or brains.
3) Coupling those data and observations with an expert elicitation process to derive shared insights from the available data.

Overall, I would like to see more nuanced information about the behavior of shorelines in response to waves, sea level, and sediment supply available for integration into restoration project selection and design. We work with poor conceptual models regarding when, how, and how much shorelines are modified by sediment transport processes, that are poorly informed by data-driven observations. I would like to see that change.

Literature

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Online resources

Department of Ecology Coastal Atlas. https://apps.ecology.wa.gov/coastalatlas/tools/Map.aspx

Link to presentation recording https://youtu.be/9hxmTOEzeos?t=7304

Dr. Ian Miller is Washington Sea Grant's coastal hazards specialist, working out of Peninsula College in Port Angeles. Ian works with coastal communities and public agencies on the Olympic Peninsula to strengthen their ability to plan for and manage coastal hazards, including tsunamis, chronic erosion, coastal flooding, and other hazards associated with climate change.

Eroding cliffs, building community

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Background and context

Vashon-Maury Island shorelines are regionally important habitat for salmon (Brennan et al. 2004). Due to the significance of island shorelines, King County began purchasing shoreline properties from willing landowners for protection and restoration. In 2016, Vashon Nature Center was engaged to create a community science monitoring effort with the double goal of quantifying changes on restored shorelines and raising public awareness about shoreline ecology and the impacts of shoreline armoring. This long-term community science monitoring effort involved both local community volunteers and school students in collecting data, alongside Vashon Nature Center scientists, on the impacts of shoreline armoring removal. Studies were conducted at 3 sites located in Maury Island State Aquatic Reserve. All three sites are in highly active landslide areas with steep beach bluffs. We present 5 years of data—2016, 2017, and 2018 pre-restoration and 2019 and 2020 post-restoration. We focus on two main questions: 1) how does armor removal impact these highly active sites? and 2) how can community science benefit shoreline restoration efforts?

Findings

Ecological: Before shoreline restoration took place there were statistically significant differences between armored and natural sites in number of logs, total beach wrack cover, vegetation cover, and fish use with all being highest on natural sites compared to armored sites (Perla and Metler 2018).

Within two years after restoration, we saw an increase in logs and some aspects of beach wrack on restored sites compared to armored sites (Grant 2021). However, other variables tested varied more by site than by pre-and post-restoration times. This indicates more time is needed for some aspects of natural shorelines to recover post-restoration. It also highlights that, in some ways, shorelines respond uniquely to restoration. High variability across space and time means that an immense and long-term data collection effort is needed to track changes due to shoreline restoration.

Social: Over 150 people contributed 655 hours of volunteer time per year to these surveys on Vashon-Maury Islands. Cooperation between different groups (from local NGOs to large universities) is needed for running a successful local community science program that can gather quality information for regionwide efforts. In particular, networking tools like the Shoreline monitoring toolbox and database help by providing standardized protocols, data management, data storage, and quality assurance controls.

Community science participation can change minds about shoreline restoration. Volunteers report increased awareness of the impacts of shoreline armoring and some went on to act as ambassadors for shoreline restoration in their communities (Emmer 2019). While this trend is encouraging it is also anecdotal. Social science research that better quantifies the community science experience is desperately needed. We would love to see research that helps answer questions like: does participation in community science change volunteers' understanding of shoreline ecology and the impacts of armoring; does this learning translate into changed habits or actions?

Community science is a bridge tool between scientists, policymakers, and the public and therefore can be an important component of the adaptive management cycle (Perla 2018). More social science research will help us improve the community science experience to make it as effective and beneficial as it can be to shoreline restoration efforts.

Key messages

- Multiple and site-specific responses to shoreline armoring removal and the long-time frame over which these changes occur underscore the need for large data sets covering long time periods.
- Community science is an effective way to lend people power to this immense research effort. Standardized protocols such as those from the Shoreline monitoring toolbox allow multiple local efforts to contribute to a robust regionwide study.
- Hands-on experience through community science creates a deeper understanding of shoreline processes in volunteers and creates local ambassadors for shoreline health.
- Social science documentation of the impacts of community science experiences on volunteers and how that may translate to changed habits or priorities is needed to go beyond anecdotes to quantify social implications.
- Instead of thinking of public education as a product that is given to the public after the information is created by experts, we need to start thinking of public education as a process of learning together authentically--an integral part of the adaptive management cycle. Community science is a bridge tool for doing this.

Literature

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Perla, BS. 2018. The citizen scientific method: tapping a human resource in natural resource management. Salish Sea Ecosystem Conference, Seattle WA. May 4, 2018. Available on-line: https://cedar.wwu.edu/ssec/2018ssec/allsessions/387/

Online resources

Shoreline monitoring toolbox. A collection of protocols for conducting shoreline armoring removal monitoring studies with community scientists. http://wsg.washington.edu/toolbox

Shoreline monitoring database. A depository of data collected by many different groups that conduct shoreline armoring removal monitoring across the Puget Sound region. http://shoremonitoring.org/

Vashon Nature Center project pages describing our volunteer programs where community scientists join us in the field for shoreline armoring removal surveys.
https://vashonnaturecenter.org/project/shorelines/

Link to presentation recording https://youtu.be/jntLdMHl61I?t=9063

Bianca Perla is the founder and director of Vashon Nature Center—a nonprofit organization conducting research, education, and community science on Vashon-Maury Island.

Beyond broader participation and impacts

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Background and context

Through engagement, research, education, and communications programs, Washington Sea Grant (WSG) works to ensure that coastal communities and ecosystems thrive by applying the principles of cultivating partnerships and welcoming diverse perspectives to enhance our understanding and effectiveness in marine conservation. This presentation aims to share how prioritizing diversity, equity, and inclusion (DEI) can lead to more innovative restoration solutions that benefit all communities.

One way to think about diversity is the effort to increase the diversity of the workforce. Diversity can be defined as the demographic representation and appreciation of individual, social, economic, and cultural differences. Diversity in the workforce can apply to an individual organization or institution, and it could apply to a broader industry or scientific study. For example, WSG is working to diversify its organizational staff and leadership, as well as the marine science and policy workforce overall.

The environmental field overall is a predominantly white institution, though people other than those who are white care and access the environment. Dr. Dorceta Taylor led a study in 2014 that found that the green ceiling, or the cap of people of color that are employed by environmental organizations, was at 16%. This meant that people of color, on average, made up less than 16% of the staff of environmental organizations. This representation was disproportionate to the US that has more than 40% people of color, and Washington has more than 30% people of color. The gap between who is employed by environmental organizations is even greater when looking at those who have leadership positions within environmental organizations.

Prioritizing DEI

In conservation, equity can mean that individuals and communities most impacted by the needs for doing restoration and conservation are at the table and part of the decision-making of where and how restoration is implemented. WSG has made DEI a primary value of the organization and acknowledges that DEI is a core function of achieving institutional mission and vision. In part, WSG's DEI values state that "WSG works to create equitable access to resources and opportunities for Washington's diverse communities and seeks to reflect their voices and priorities." Addressing equitable conservation requires a shift in the priority of time and resources. It is critical to ask questions such as: Who is sitting at the table? Who has access to restoration opportunities? How can restoration initiatives be improved by making the table bigger, giving adequate space for others to voice their concerns and interests?

Inclusive leadership is a practice that may lead to more successful restoration efforts and can be defined as a state, quality, or ideal of being a part of a group or structure where the inherent worth and dignity of all people are recognized and respected. An example of inclusive leadership is through the work of the City of Seattle's Environmental Justice Committee, a group of leaders from communities of color who are focused on implementing the City's Equity and Environment Initiative. In its first year, the Committee created the Principles of Public Space for Communities of Color which states that "as urban areas continue to experience rapid growth, it is important for park planners, city officials, and residents to be creative about public space and for communities of color to reclaim these spaces in their communities." Among the seven principles, *Nature* emphasized that restoration and cleanup of waterways can provide "opportunities to reconnect communities to nature and increase their access to waterways while supporting the region's wildlife, native plants, salmon and other sea life." The report calls for public spaces that include "cultural traditions of fishing and foraging [that] support our urban ecosystem and the wellbeing of all our residents, including urban wildlife." Questions to consider in inclusive leadership may include: Who has access to lead in these spaces? What science and knowledge are respected? Is traditional and local knowledge adequately represented in this work?

Key messages

- Ideas to get you started:
    - Build a supportive network/community
    - Share knowledge and resources
    - Ask questions…respectfully
    - Get leadership on board
    - (re)Distribute capacity and resources
- Ask the important questions:
    - Whose knowledge/science?
    - How is success being measured?
    - Are resources being distributed equitably?

Prioritizing diversity, equity, and inclusion can lead to more innovative restoration solutions that benefit all communities.

Literature

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Equity and Environment Initiative. (2017). (rep.). *Principles of Public Space for Communities of Color*. Seattle, WA. Retrieved from https://www.seattle.gov/Documents/Departments/OSE/Equity/EEI-PublicSpace.pdf

Taylor, D.E. (2014). (rep.) *The state of diversity in environmental organizations: mainstream NGOs, foundations, and government agencies.* Ann Arbor, University of Michigan. Retrieved from https://www.diversegreen.org/the-challenge/

Online resources

https://wsg.washington.edu/developing-a-dei-committee-and-action-plan-resources/

Link to presentation recording https://youtu.be/jntLdMHl61I?t=9985

Melissa (Watkinson) Schutten (she/her) is a citizen of the Chickasaw Nation and also descends from the Choctaw Nation of Oklahoma. Melissa considers the Salish Sea her home, where she works as the Equity and Environmental Justice Manager at the Puget Sound Partnership. At the time of this presentation, Melissa was the equity, access, and community engagement lead with Washington Sea Grant. Melissa endeavors to ensure equitable and inclusive access to the marine environment and workforce. She has a master's degree in policy studies from the University of Washington Bothell.

Messy is beautiful – isn't it? Understanding homeowner responses to restoration and stewardship goals

Karin Strelioff[1], MLA

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Background and context

In my work as Conservation Program Manager for Thurston Conservation District, I provide direct technical assistance to private landowners and I focus on restoration project development, design, and implementation. My goal in the Shore Friendly program is to cultivate behavior change around marine shoreline stewardship within the private waterfront homeowner community. I established Shore Friendly technical assistance programs with partners at South Sound Conservation Districts to support this growing need for better shoreline stewardship. We also work to identify and develop hard armor removal projects. As part of our Shore Friendly South Sound effort, we have visited with over 250 residential marine waterfront homeowners. During my site visits, I have come to observe many of the motivating factors and barriers that influence stewardship decisions made by those homeowners living along Puget Sound. This presentation addresses their perspective with a compassionate eye to remind us that our restoration landscape is indeed complex. The complexity exists at the human scale as much as it exists at the coastal process scale and the ecological scale.

Key messages

- To be successful with stewardship and restoration at the residential waterfront scale, we need to factor in human considerations as much as coastal processes and nearshore ecology.
- We have to bridge the divide between restoration actions that support coastal processes and ecology, and homeowner needs to feel security, stability, a tangible connection to the water, and some sense of control within an inherently dynamic environment.
- We need to expand our definitions of what successful restoration means in the context of residential waterfront landscapes. In short, we need to help waterfront homeowners become more comfortable with "messy landscapes," and conversely, we may need to make some of our restoration projects "neater" to gain wider homeowner acceptance.

Literature

Joan Iverson Nassauer, Messy Ecosystems, Orderly Frames. Landscape Jrnl. September 21, 1995 14:161-170

Online resources

Shore Friendly Program. Information and resources for waterfront homeowners. www.shorefriendly.org

Shore Friendly Thurston. Thurston Conservation District Shore Friendly Program Webpages. https://www.thurstoncd.com/stewardship/shore-friendly/

Link to presentation recording https://youtu.be/jntLdMHl61I?t=2879

Karin Strelioff is the Conservation Program Manager at Thurston Conservation District and she coordinates the South Sound Shore Friendly partners (Thurston, Pierce, and Mason Conservation Districts), who work collaboratively to support nearshore stewardship by waterfront homeowners. Karin has worked in South Puget Sound for over 16 years, designing and implementing voluntary restoration projects with private landowners.

Restoring "living" to our armored shorelines

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Background and context

Nearly one-third of Puget Sound's shorelines are armored (e.g., seawall, bulkhead, riprap). Armoring has documented negative impacts on the flora and fauna that otherwise benefit from healthy intertidal beaches. Although shoreline armor may be necessary in some cases to protect people and property, there are often promising "living shoreline" alternatives that can restore the natural features of beach slope and stability. These options can be applied to situations where complete restoration is either impractical or not feasible given human constraints. Living shoreline techniques often include a mix of design options, including armor removal, sediment nourishment of beaches, log placement, planting vegetation, and moving seawalls further inland. Depending on site characteristics and demands, some engineering may be required for stability. Through regular monitoring, we can determine the effectiveness of these restoration efforts to rebuild a more natural living shoreline, applying what we learn to future management and alternatives scenarios.

Findings

Our group of collaborators has been studying the effectiveness of living shorelines for a number of years, at a broad spatial scale within the Washington state boundaries of the Salish Sea. We recently surveyed 30 beaches at ten locations, each with three strata of: (1) living shoreline beaches with armor removed (1-11 years post-restoration), (2) armored control beaches altered by seawalls or riprap, and (3) un-armored reference beaches with natural conditions. We sampled eight physical and biological attributes: beach wrack, wrack invertebrates, sediments, terrestrial insects, riparian vegetation, logs, beach profiles, and stable isotope signatures of beach-hopper amphipods – generating 27 metrics focusing on upper intertidal and supratidal elevations affected by armoring and targeted by living shoreline actions. These metrics spanned the functions of beach stability, ecological diversity, and food web support for juvenile salmon. Statistical tests showed that 19 of the 27 metrics had significant strata differences, indicating that some beach metrics restore quickly (e.g., wrack accumulation), while others take longer (e.g., log accumulation). Terrestrial-associated metrics were higher at reference beaches, but insect taxa richness and logs with plant growth increased at beaches restored for four or more years (the average age of the living shoreline sites). This implies that certain living shoreline functions increase through time, providing continued improvement of food web support.

Development of standardized monitoring protocols and a centralized Shoreline Monitoring Database (http://shoremonitoring.org) has helped enable our collaborators across multiple groups to collect and upload data (e.g., community science groups, agencies, and academics), combining datasets and ensuring data longevity and compatibility across groups. Ongoing efforts support the addition of more protocols to the database, incorporation of historical data, improvement to database features, the addition of data visualizations, and analysis of data to evaluate restoration effectiveness.

Key messages

- By monitoring restoration actions and measuring effectiveness, we can provide data that informs adaptive management tools to gauge the success of completed restoration, to inform future efforts.
- Armor-removal restoration projects are effective at initially improving upon armored shorelines, and with time may reach natural conditions.
- We are still learning the types and timing of responses to specific living shoreline features (e.g., vegetation, logs, sediments, amount of intertidal space), and the long-term effectiveness and resilience of restoration actions.
- Funding is instrumental not only for living shoreline design and implementation, but for monitoring to measure effectiveness, as successful collaborations with community scientists and student involvement require ongoing training, staff time for organizational support, and stewardship and analysis of the data.

Literature

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Online resources

The Shoreline Monitoring Database. A resource to upload data from standardized protocols for monitoring shorelines in Puget Sound, including data visualizations and a map of locations: http://shoremonitoring.org

The PSEMP Nearshore work group. A collaboration of monitoring practitioners, researchers, and data users: https://www.psp.wa.gov/PSEMP-overview.php

Link to presentation recording https://youtu.be/jntLdMHl61I?t=12627

Jason Toft is a principal research scientist at the University of Washington School of Aquatic and Fishery Sciences, focusing on nearshore restoration and effects of shoreline armoring in Puget Sound.

Exploring sense of place and shorelines in Puget Sound

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Background and context

The 12-county Puget Sound region is experiencing population and economic growth (Puget Sound Institute 2015; OFM 2017). While growth is often considered a positive (Trimbach et al. 2020), such processes are inequitable, with specific communities, ecological systems, and even landscapes being more negatively impacted than others. Such impacts, like landscape change, also impact residents' connections to and interactions with landscapes and the environment (Shuhei 2016; Marshall et al. 2019; Quinn et al. 2019; Reilly et al. 2019). For example, social scientists are recognizing the role of sense of place, people's connections and meanings associated with place, to gauge and predict people's responses to place change, including landscape change and infrastructure installation or removal (Quinn et al. 2019; Reilly et al. 2019). Social scientists are also increasingly approaching shorelines, among other landscapes, as distinct places referred to as liminal landscapes, or places that are at the fringes, limits, thresholds, and entail a sense of in-betweenness, escape, and freedom. Building upon this research and shoreline armor monitoring work in the Puget Sound region, this study examines residents' senses of place of the region's marine shoreline. This study examines residents' place attachments, dependencies, identities, and meanings associated with marine shorelines, a landscape that is experiencing pressures from development and shoreline armor installation (Habitat Strategic Initiative 2017). Through the implementation of a 12-county web-based survey (n=413), this study aims to demonstrate residents' senses of place associated with the region's shoreline and offer insights into how such information could contribute to shoreline management, planning, and policy in the region.

Findings

Survey respondents (n=413) were highly representative of the region's population, notably by age, sex, and county of residence. Overall, project findings demonstrated that Puget Sound residents do have a sense of place of the region's marine shoreline with variations amongst sense of place's multiple dimensions. For example, survey findings illustrated that residents hold or embody a strong place attachment (62% attachment, 54% belonging) to the region's shoreline, compared to weaker dependence (41.9%) (combined completely agree and agree). Additionally, place attachment responses were stronger than respondents' need to see (37.8%) or interact (36.3%) with the shoreline on a weekly basis. These findings are supported by other sense of place work in the region, which have illustrated that residents have a sense of place of Puget Sound's natural environment (Trimbach et al. 2020). Additional analyses demonstrated that length of residence, place of residence (county), and shoreline property ownership were strongly associated with sense of place responses. For example, length of residence was associated with place attachment, identity, and belonging responses. Respondents' place meanings varied encompassing 12, often linked, meanings. Building upon Williams (2014) place meaning layers (identity-expressive, inherent, instrumental, and sociocultural) and a grounded approach, responses reflected the following meanings: feeling (e.g., "calm"), identity (e.g., "cultural identity"), general positive (e.g., "great"), inherent (e.g., "nature"), aesthetics (e.g., "beauty"), instrumental (e.g., "fishing"), protection (e.g., "protect"), connection (e.g., "home"), uniqueness (e.g., "unique), other (e.g., "mix"), nothing (e.g., "nothing"), and liminal (e.g., "freedom"). The most frequently used meanings were feeling (49%), inherent (36%), and connection (36%). Additionally, many of these meanings were linked, for example, many respondents simultaneously used tangible and intangible meanings in their responses. This finding supports that of others (Poe et al. 2016), who have shown that sense of place is often associated with specific cultural practices or human-environment interactions (tangible and intangible aspects). Although liminal was not a common place meaning (12%), respondents did seem to partly grasp the liminality of shorelines, illustrating that some residents recognize shorelines as liminal landscapes. This project and its findings have much to offer nearshore restoration and shoreline management in the region. By gauging and including residents' senses of place, practitioners can harness or build on those connections or meanings for project or program design, or even conduct community outreach, education, or planning. Knowing residents' senses of place, can also help gauge, predict, or even address place-based conflicts.

Key messages

- Puget Sound residents have a sense of place of the region's marine shorelines, notably a strong place attachment.
- Puget Sound residents hold a diverse range of place meanings associated with the region's marine shorelines.
- Some Puget Sound residents understand the region's marine shorelines as distinct liminal landscapes.
- Sense of place helps tell a story of how and/or why residents feel and think about place.
- By gauging residents' sense of place of shorelines or nearshore habitats, managers or practitioners can better understand, identify, and even prioritize residents' connections, meanings, and interactions with landscapes and places at multiple spatial scales.
- Human geography and interdisciplinary social sciences that examine sense of place have much to contribute to nearshore restoration, including gauging, if not predicting, residents' connections to landscapes and potential landscape changes.

Literature

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https://link.springer.com/article/10.1007/s10708-020-10350-w

Online resources

Extended abstract published by the Puget Sound Institute, University of Washington Tacoma. https://www.eopugetsound.org/articles/sensing-liminal-landscapes-puget-sound

Office of Financial Management (OFM). 2017. County and City Data. Olympia, Washington: State of Washington. https://www.ofm.wa.gov/washington-data-research/county-and-city-data.

Link to presentation recording https://youtu.be/jntLdMHl61I?t=3760

Dr. David J. Trimbach is an interdisciplinary social scientist with a background in human geography. He completed his postdoctoral work in the Department of Fisheries and Wildlife at Oregon State University, housed at the Puget Sound Partnership, and is now a conservation social scientist with the Washington Department of Fish and Wildlife.

Greater than the sum of its parts: integrating nearshore restoration

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Link to presentation recording https://youtu.be/9hxmTOEzeos?t=6397

Tina Whitman is staff scientist for Friends of the San Juans where she has managed shoreline habitat research, restoration, and protection programs since 2002. Tina received an MS from the University of Oregon and has worked in coastal habitat conservation in New England and the Pacific Northwest. Tina lives on Orcas Island with her family and is happiest on a beach, for work or play.

5.2 Deltas

Estuary restoration strategic assessment (AKA Skagit hydrodynamic model project)

Jenny Baker[1]

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Background and context

Rich Skagit delta soils and a temperate climate support a vibrant agricultural economy and culture. Agriculture requires drainage and flood protection infrastructure that is aging and at risk of failure. The Skagit is also a stronghold for Chinook salmon, which are economically and culturally important to tribes. However, significant estuary losses have contributed to Chinook declines, and hundreds of acres of estuary restoration are needed. With a limited land base, multiple needs, and competing interests, how do we decide which estuary restoration project is next?

The Skagit Estuary Restoration Strategic Assessment is a project that prioritized restoration actions by integrating best available science with multiple community interests and local knowledge. The goal of the project was to develop a suite of projects that provide Chinook salmon estuary habitat and flood risk reduction in a way that protects and enhances farming and drainage.

We assessed 23 project concepts of all sizes and types. Projects were compared using objectives and corresponding indicators. Each interest developed their own objectives and indicators to ensure the results were meaningful. Some indicators were benefits and some were negative impacts.

The work group that guided the project was made up of a broad array of organizations representing farm, fish, and flood interests. We did outreach to the larger community to share our results and get feedback, and technical work by scientists incorporated best available science. The result is a tool that prioritizes projects and provides transparency about both the benefits and impacts of potential restoration projects to farm, fish, and flood interests.

Key messages

- Incorporating multiple community interests in habitat restoration planning helped build broad support for projects that benefit salmon and restore ecosystem processes.
- An inclusive and transparent process was key to understanding across interests and building trust in the results.
- Equal weighting of the objectives and indicators demonstrated that no single interest was more important.
- We were not able to include some issues of concern because we couldn’t find a way to quantitatively assess them relative to implementation of the restoration projects. For instance, how groundwater might be impacted by restoration projects was not something we could assess.
- We adjusted in response to how the conversations evolved. For instance, some objectives and indicators were abandoned when results didn’t differentiate between projects and new ones were added. Also, we shifted away from the original assessment framework, which was to provide a list of ranked projects based on their benefits to fish, farm, and flood interests, when

it became clear that we needed to account for negative impacts. Lastly, the timeline was extended to accommodate these changes and adjustments.

- Monitoring projects once projects are completed was included in our process for moving forward. Monitoring was considered critical to understanding outcomes and adapting future assessments and projects based on those outcomes.

Literature

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Online resources

Summary report of the Skagit Hydrodynamic Modeling Project. https://wdfw.wa.gov/sites/default/files/2020-02/hdm-ersa_summary_report_web_version.pdf

Link to presentation recording https://youtu.be/xPSLqFGhqpw?t=4253

Jenny Baker works for Washington Department of Fish and Wildlife planning and implementing estuary restoration projects. She has been involved in all phases of floodplain and estuary restoration since 1998. She earned a B.S. in natural science from University of Puget Sound and M.S. in environmental science from Western Washington University.

Studies on the impacts of sea level rise on agricultural viability inform future estuary planning

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Background and context

To understand the impacts of climate change on agricultural land viability and inform multiple benefit estuary planning in Snohomish County, the Conservation District initiated technical studies on flooding, groundwater levels, saltwater intrusion, land subsidence and aggradation, and crop impacts as part of an Agriculture Resilience Plan (SCD 2019). Cardno (2019) completed studies on the projected impact of sea level rise on estuary farmland by examining both current and future spring groundwater levels and conductivity in soils. Examination of existing groundwater conditions showed that groundwater in both watersheds declines at approximately one foot per month in the spring. Using this information, projected delays in spring cultivation dates were calculated using estimates of sea level rise into the future (Cardno 2019). On estuary farmland, where groundwater levels dictate the start of the growing season, our results indicate that rising seas will delay the time farmers can begin cultivation by up to four weeks by the 2050s and five weeks by the 2080s. Using conductivity values from groundwater wells and applying studied relationships between proximity to saltwater and salinity values in groundwater, it was further concluded that existing salinity impacts to agricultural soil health are expected to increase in the Lower Stillaguamish River estuary. These studies, along with newly modeled flooding projections (Mauger et al. 2018), provide valuable insights into the viability of estuarine agricultural land and informs multiple benefit discussions on how to best manage floodplains for both fish habitat and agricultural resilience.

Key messages

- Rising sea levels are projected to impact the viability of estuary farmland in the Stillaguamish and Snohomish River watersheds by delaying the start of the growing season or requiring additional pumping and drainage infrastructure.
- Estuary farmland in the Lower Stillaguamish River watershed is already experiencing impacts of saltwater intrusion in soils due to sea level rise and this is projected to increase over the next 50 years, making some areas unfarmable.
- Engaging the farming community as leaders for this impacts assessment and planning process was key to both gaining their trust and developing a scientifically-based plan outlining agricultural priorities.
- The completion of the Agriculture Resilience Plan for Snohomish County has resulted in growing trust and collaboration between multiple floodplain management interests and can serve as a model for other floodplains in the Puget Sound.

Literature

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Snohomish Conservation District (SCD), 2019. Agriculture Resilience Plan for Snohomish County. Lake Stevens, Washington.

Online resources

Agriculture Resilience Plan on Snohomish Conservation District website, including access the full document detailing the assessments completed to inform estuary planning. https://snohomishcd.org/ag-resilience.

The Nature Conservancy Coastal Resilience Tool. This online mapping tool provides results of flood and groundwater modeling work along with links to technical studies. https://maps.coastalresilience.org/washington/#.

Link to presentation recording https://youtu.be/xPSLqFGhqpw?t=8625

Bennet LaFond recently joined Snohomish Conservation District as the Agriculture and Floodplains Resilience Project Manager. Along with a background working on farms and vineyards, Bennett brings over seven years managing agricultural resilience and economic growth projects in the US and abroad. He has an MS in Plant and Soil Science from the University of Vermont with a focus in Agroecology and the intersection of agricultural, ecological, and social systems.

Dan Elefant is a senior restoration engineer with Environmental Science Associates (ESA). For this work, he completed technical analysis for sea level rise impacts to groundwater ponding and salinity intrusion. He is interested in constructing river and estuary projects that provide great salmon habitat while planning for future agricultural production resiliency.

Cynthia Dittbrenner served as the lead for development of the Agriculture Resilience Plan in her past role as Restoration and Floodplains Director for the Snohomish Conservation District. She has a masters in Ecology and Soils from UW and 20+ years of experience in restoration, agricultural resilience, and climate change adaptation.

Avian habitat suitability models for Puget Sound estuary birds

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Background and context

Extensive habitat loss and ecosystem degradation associated with human settlement in Puget Sound estuaries have resulted in an untold decrease in bird abundance and distribution. Protection and restoration actions associated with the Puget Sound Action Agenda, the state plan that charts the course for recovery in Puget Sound, have the potential to benefit birds. However, meaningful recovery of estuary bird communities in Puget Sound requires that we have a clear understanding of species status and trends, where and when they occur, and the environmental conditions and human pressures that influence their occurrence.

In this study, we present bird-habitat suitability models for five "narrative" species that represent unique niches associated with Puget Sound estuaries: Brant, Dunlin, Greater Yellowlegs, Marsh Wren, and Northern Pintail. These species were selected to help inform and tell the story of the complexity of avian habitat use across tidal gradients and seasons in Puget Sound estuaries. Our study used avian monitoring data from tribal, state, federal, and NGO partners, as well as community science data, to build separate habitat suitability models of occurrence and abundance by season for the five narrative species.

Findings

Of the 21 environmental variables included in the models, the three that most strongly influenced the probability of occurrence included proportions of estuarine emergent wetland, mudflat, and palustrine wetland cover. Where study species occurred, relative abundance was most strongly influenced by survey effort (survey distance and duration), followed by proportions of agriculture, estuarine emergent wetland, and mudflat cover.

This study provides valuable information about the environmental drivers of spatial patterns of bird distribution and abundance and identifies important areas for birds around Puget Sound. It also points to specific actions that land managers can take to ensure Puget Sound continues to serve as a vital link for Pacific Flyway birds. Our analytical approach can be replicated for other species, and the information can be used at a regional scale to identify priority areas for conservation. Similarly, the model outputs can be used to identify areas where birds are currently less abundant, but that are proximate to suitable habitat or marsh migration opportunities, suggesting that restoration may be beneficial. For example, we used our models to evaluate the potential benefit of estuarine wetland restoration for Northern Pintail and Greater Yellowlegs across the entire Puget Sound as well as a case study area in Port Susan Bay. Our identification of the environmental conditions that are most important to narrative species as well as the form of the relationship can also inform smaller-scale habitat management.

An important theme that emerged from this exercise is that data quantity and quality are essential for a robust understanding of bird-habitat relationships and distributions in Puget Sound, which in turn informs habitat management and restoration actions (Koberstein et al. 2017). Model performance may be constrained for some species by insufficient monitoring data across relevant seasons, the concentration of monitoring data in certain well-studied estuaries, and differences in species detectability across habitat types (Michel et al. 2021). The development of a regional monitoring framework for estuarine birds that aligns bird survey and sampling methods is an ambitious but critical step that will dramatically improve our ability to develop predictive tools and generate adaptive feedback for natural resource managers in a time of rapid environmental change (Bayard et al. 2019).

Key messages

- Estuarine emergent wetlands, mudflats, and freshwater emergent wetlands are important explanatory variables for modeling the occurrence and abundance of our five study species. Puget Sound estuary restoration and management projects that restore or protect these features can benefit a variety of estuary birds, including waterfowl, shorebirds, and landbirds.
- Prospective restoration sites that lie within historical wetlands, have currently low avian abundance, and have space for marsh migration, have a high potential to benefit estuary birds.
- Standardizing monitoring efforts across seasons and basins in Puget Sound estuaries will improve our understanding of avian-habitat relationships and increase the effectiveness of habitat management interventions.

Literature

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Michel, N., T. Bayard, A. Summers, G. Slater, and K. Spragens. 2021. Avian Habitat Suitability Models for Puget Sound Estuary Birds. Prepared for the Puget Sound Ecosystem Monitoring Program, Puget Sound Partnership. Tacoma, WA. https://pspwa.box.com/v/AvianHabModel

Online resources

2021 Avian Habitat Suitability Models Story Map w/interactive viewer. https://arcg.is/1Ke4iD0

Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=16121

Trina Bayard is Director of Bird Conservation at Audubon Washington and Coordinator for the PSEMP Marine Birds Work Group.

Integrating social science in Puget Sound restoration

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Background and context

Social science is central to effective ecosystem restoration. It can enhance stakeholder-driven management practices; excavate assumptions about management strategies; and improve understanding of failures and successes from restoration efforts. In this presentation, derived from a forthcoming peer-reviewed publication, we use a governance-oriented science-policy framework to assess the ways in which social science has gained structural support in the Puget Sound. We then compare this analysis to responses from Local Integrating Organizations (LIOs), local watershed groups, and Strategic Initiative Leads (SILs), and state-led regional recovery groups, in Puget Sound restoration to identify the extent to which they perceive governance support for social science integration.

Findings

We found that the Puget Sound region has substantively enhanced the governance structure for integrating social science in restoration and partner agencies have improved their ability to engage in meaningful dialogue around social science needs. Nevertheless, existing top-down planning processes dominated by natural science perspectives often hinder its application.

Key messages

- The Puget Sound region of Washington has conceptually and symbolically integrated social science in ecosystem recovery planning.
- Integration occurred at various points in the restoration governance system, including government mandates, internal and external funding and social scientific support, integrated planning frameworks, and interested clientele.
- Clients from different scales of implementation, however, noted there are still several barriers to actually using social science in planning and restoration activities.
- Functional (or instrumental) social science integration may rely on a science-policy interface that uses knowledge co-production with social scientists, natural scientists, and lay experts.

Literature

Biedenweg, K., D. Trimbach and W. Fleming. *In final revision*. Integrating Social Science in Puget Sound Restoration. Ecological Restoration.

Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=5099

Kelly Biedenweg in an Assistant Professor of Human Dimensions at Oregon State University and a member of the Puget Sound Partnership Science Panel.

Complex tools for a complex problem: Anthropology and political ecology in the service of salmon recovery

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Background and context

Disputes over habitat restoration have earned the Skagit Valley in northwest Washington State a reputation for being "mired" in intractable conflict. Goals of recovering salmon and protecting farmland are seemingly pitted against each other in competition for the same land. At stake are salmon runs essential to the Puget Sound, farmland that produces a large portion of the world's spinach, cabbage, and beet seed, and the future of local farming and tribal communities.

In this talk, I aimed to show how the fields of anthropology and political ecology can provide insight into the *humanistic* factors contributing to environmental problems. In the early 2000's I studied three central stakeholder groups—tribal, agricultural, and environmental, and asked: why is there a seemingly intractable conflict over salmon habitat restoration in the Skagit Valley? During two years of ethnographic fieldwork, I interviewed more than 150 people, attended more than 50 meetings and events, and went fishing, rode a tractor, attended a tribal ceremony, and helped collect biological data. Through analyzing my notes and documentary research, I identified multiple historical, legal, and cultural explanations of the Skagit conflict. Here I focus on my qualitative, cultural results.

Findings

Disputing the central problem: First, I found that my research participants disagreed on the causes of salmon decline. They did not agree on who was to blame for destroying the fish, and therefore they did not agree on who was responsible for recovering them.

Distinct realms of knowledge: These disparate perceptions of the central problem arose from distinct realms of experience and knowledge, such as what it takes to run a successful agricultural business, versus what it takes to restore a river, versus what it takes to manage a sovereign tribal nation. Furthermore, interviewees differed in what they accepted as legitimate forms of knowledge. Both farmers and restorationists learned from science and place-based experience but differed in the weight they assigned to each.

Tangled axes of mistrust: Even more complicated was that axes of mistrust, disagreement, and perceptions of unfairness, were not aligned. While farmers blamed fishing for salmon decline, their distrust was directed primarily at restorationists, who they perceived as urban outsiders. Meanwhile, although the tribes' proximate contenders were farmers, tribal members expressed distrust of white people in general, incurred through historical and ongoing persecution. Finally, restoration advocates did not demarcate another social group as "other;" rather, they expressed mistrust of people in general.

Incompatible senses of place: At stake in this disagreement and mistrust was much more than natural resources: rather, it was the identities, communities, and moral commitments of the people who created and depended on the landscape and its resources. Both the farming and tribal communities had been co-constructed with the natural resources on which they depend such that they are place-based communities. And, while not dependent on harvests, restorationists are also becoming a community that is co-constructed with the landscape it is attempting to re-create.

Divergent land management philosophies: With such deep-seated senses of place and uncompromisable stakes, interviewees expressed predictably different philosophies toward the landscape and its human inhabitants. Ultimately, they disagreed on who should take care of the land; who should be responsible for creating and maintaining its productivity. For farmers, it was farmers; for Native Americans it was tribal land managers; and for restorationists, it was nature herself, in the form of the river.

The broader context: These tangled social relationships and divergent philosophies are not new or unique to the Skagit Valley. They have identifiable historical roots, they resonate with broader cultural narratives, and some have been institutionalized in governmental policies.

Key messages

- *Social hierarchies, stereotypes, prejudices, power imbalances, marginalizations, injustices and perceptions of injustice divide local communities*—such as Native and non-Native people, urban and rural people, and scientists and nonscientists. These are social divisions that can both complicate conservation and that conservation can exacerbate. Especially important is grasping the profound sensitivities caused by colonial injustice, historical trauma, and cultural loss. Managers can learn about and navigate local histories and hierarchies by reading historical and ethnographic books, talking to local people, and tracking media sources accessed by different communities.
- *Scientists and managers are also local actors with actual or perceived positions in the local social order.* Despite standards for objectivity, environmental professionals are also cultural beings with our own perceptions of injustice, mistrusts, senses of place, landscape philosophies, and cultural histories. Literature in the environmental humanities and science and technology studies fully explores these human dimensions of environmental science, including restoration ecology. These studies can help managers recognize implicit values in environmental professions, and the degree to which they may support, or possibly hinder, intended conservation goals.
- *Disagreement over how the central problem is framed, different sources of legitimacy for knowledge, and lack of trust between place-based communities and environmental professionals are interrelated and limit cooperation and support for conservation.* As environmental sociologists Carolan and Bell observe (2003), we are unlikely to trust a community that claims things we believe to be untrue, and vice versa: we are unlikely to believe things claimed by a community we do not trust. This insight suggests the value of building rapport with local communities through genuine relationships, and learning what kinds of knowledge and framings are most effective in communicating with them.
- *Senses of place are real and can have powerful effects on how people respond to conservation measures*. Gaining an understanding and respect for local senses of place entails learning about how local people ascribe meaning to specific places through family and personal experiences, livelihoods and identities, perceptions of their history, and spiritual and philosophical understanding. Such insights may suggest strategies for restoration that can honor ecological as well as cultural values. For example, while Skagit restorationists strove to recreate a sense of wildness, Skagit farmers expressed an ethic to work the land. Restoration projects that proposed to take land and labor out of farmers' hands may have added unnecessary insult to injury, offending the people needed to implement them.
- *Environmental disputes may be the artifact of complex, unclear, changing, and/or conflicting governmental land-use policies, institutional approaches, and legal standards.* Awareness of the

broader institutional context can check assumptions that resource users are simply uncooperative or un-educated about science and conservation; certain land management practices may have been shaped by previous or ongoing governmental policies, explained in histories of environmental science and policy. This suggests the value of coordinating across agencies and institutions to address collective land management goals and to ensure that institutional structures support, rather than hinder, local stakeholder cooperation.

- *Language and discourse matter in shaping public opinion, professional approaches to conservation, and the landscape itself.* In particular, the dominance of technical and scientific discourse in conservation masks underlying social factors complicating ecosystem recovery, especially those perceived as "intangible." Managers are in a position to shift the terms of ecosystem recovery by choosing to expand their language and framings to include humanistic dimensions and start talking, with as much rigor as we discuss the science, about the role and importance of values, identities, cultural narratives, senses of place, philosophies, and histories--including one's own.

The fields of environmental anthropology, political ecology, environmental history, and science and technology studies can provide rich insight into these social and humanistic dimensions of restoration thought and practice. Briefly: anthropology is the study of human and cultural diversity, past and present; political ecology joins anthropology with the field of geography to explain environmental problems as the interaction of local social-ecological dynamics with broader political and economic forces; environmental history produces narrative explanations of how people, ideas and places are co-created over time; and science and technology studies (abbreviated STS) is the sociological study of science and its effects as social processes. Emerging literatures within these fields focus on restoration as a subject of study; I cannot speak to current gaps.

To better integrate my work into restoration science and practice I would need funded opportunities to produce and translate my research for the ecosystem recovery world, ideally in conversation with a growing community of interdisciplinary social science peers who are co-located with natural scientists in restoration-implementing institutions; and in conversation with new departments and programs focused on environmental social science and humanities in our regional universities. In short, to address the increasingly complex human dimensions of environmental challenges in a rigorous way, I believe we need to campaign for a significantly expanded applied environmental social science professional sector.

Literature

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Link to presentation recording https://youtu.be/xPSLqFGhqpw?t=3362

Sara Breslow is an environmental anthropologist and transdisciplinarian interested in collaborating across disciplines and partnering with local communities to address complex challenges in the human-nature relationship. In her empirical research, Sara uses ethnographic and mixed methods to study senses of place, environmental conflict, and human well-being with a focus on the Salish Sea region. She has worked to develop foundational concepts, build institutional capacity, and promote policies that advance sustainability and social justice in a variety of positions locally and abroad, including at UW EarthLab, NOAA, IPBES, the Western Governors' Association, The Puget Sound Partnership, and The Nature Conservancy.

Lost in translation: Closing the gap between stakeholders and scientists

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Background and context

Washington Department of Fish and Wildlife (WDFW) and partners have implemented several large estuary restoration projects on public lands in the last 20+ years. In most cases, these public properties supported a variety of uses prior to project implementation such as outdoor recreation, agriculture, and more. Often these uses change as a result of the project. Stakeholders experience a sense of loss when their activities are not compatible or less well-suited with newly restored estuary habitat. This sense of loss has caused some stakeholders to oppose estuary projects on public lands. Projects that are well supported are more likely to advance to construction because the opposition can cause project delays such as permit appeals. Additionally, part of WDFW's (and many other public landowners) mission includes supporting public use on properties so stakeholder attitudes towards projects are an important consideration when deciding to move forward with a project. This presentation is meant to share lessons learned and tips for increasing the odds that projects will be supported and move forward.

Key messages

- All stakeholders and members of the community in which your project is proposed fall somewhere on a conceptual "support meter" that ranges from "red" for opposers to "green" for supporters to "yellow" for people who are undecided. Red and green categories are usually entrenched in their positions and it isn't likely that they will change their views because we engaged with them. The yellow category, however, is often willing to shift their positions depending on our effectiveness at conveying messages. The yellow category often has limited or no information about a project and why they should support or oppose it. The yellow category is also the largest in the community.
- Our communication and outreach are key to understand where people fall on this scale and if we do a good job, people will shift more towards green and less towards red. This matters because well-supported projects can be implemented more quickly and with less expense than projects that are opposed and appealed. It also matters on a larger scale because no individual project will achieve Puget Sound recovery alone and the success or failure of past projects in a community impacts the likelihood of success of future projects.
- During outreach in initial project planning, most people are trying to figure out how a project intersects with their values and how it may impact them. Lessons learned during this phase include meeting people where they are, not over promising things you can't deliver, and doing your best to translate information from predictive models in terms people can understand.
- Outreach is also very important and often overlooked after a project is implemented because it's always tempting to move on to the next project. However, demonstrating results is critically important for the next generation of projects within that community. Success metrics are different for different people and it is important we address as many of them as we can, including ecological, recreation access, and flood resilience metrics.

- Nearshore science is the foundation of communications between restoration practitioners and stakeholders. Translating science to stakeholders takes practice and trial/error. Effective messages must to framed to stakeholder values and can sometimes be as simple as photo evidence of fish and wildlife using a new restoration site.

Online resources

Leque Island Restoration Project. Washington Department of Fish and Wildlife. https://wdfw.wa.gov/species-habitats/habitat-recovery/nearshore/conservation/projects/leque-restoration

Link to presentation recording https://youtu.be/xPSLqFGhqpw?t=7827

Loren Brokaw is a Restoration Project Coordinator for WDFW in the North Puget Sound region, working on projects on WDFW-owned lands. He has worked in the position for almost ten years.

Skokomish estuary restoration

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Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=4202

Lisa Belleveau is the habitat biologist for the Skokomish Tribe. She has a Bachelor of Science and a Master of Environmental Studies degree from The Evergreen State College. Previous to working for the Skokomish Tribe, she worked with the Nisqually Delta Restoration monitoring team. She has over 10 years of monitoring experience focused on documenting changes associated with estuary restoration.

Improving restoration success and resilience through reference-site research and experimentation: lessons from the Columbia River estuary

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Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=18857

Mapping tidal connectivity barriers to support identification and evaluation of restoration opportunities

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Background and context

Restoration of estuarine habitats has been identified as a top priority for recovery of declining Salish Sea salmon populations with estuarine-dependent life histories (Beechie et al. 2017), and barriers to tidal connectivity represent the greatest potential for restoration of functional tidal wetland habitat. Numerous regional datasets exist that map tidal connectivity barriers (i.e., levees, roads, tide gates, culverts), and current and potential tidal wetland habitat extents in Puget Sound. However, datasets differ greatly in their structure, extent, and resolution, and this represents a significant data gap and obstacle to regional salmon recovery planning. To address these issues, we created a standardized regional database of tidal barrier features using a combination of existing datasets, remote sensing (aerial imagery, oblique shoreline imagery, and digital elevation models), and regional expert review to correct misalignments, digitize missing features, and attribute status and connectivity information. The synthesized and updated tidal barrier data were also used to inform the mapping and classification of tidal wetland habitats. The updated regional tidal barrier and wetland database created by this project will support regional salmon recovery by providing readily accessible and regionally consistent information to identify restoration opportunities; develop recovery goals and targets, and; evaluate progress towards recovery. This presentation summarizes the methods used to develop this database, and the results of data compilation, regional and field review, and our mapping efforts.

Findings

We collected over 43 datasets containing 243 data layers mapping tidal barriers or tidal habitat from federal, state, county, tribal, and NGO sources, which had varying coverage from individual deltas to West Coast-wide. We found these layers to have significant variation in attribution, temporal and spatial resolution, alignment, and geometry. In our dataset, we developed a polyline dataset for all tidal barriers for 16 Puget Sound large river deltas, including segmentation of water crossing features (e.g., bridges, culverts, tide gates). All features were assigned connectivity impact ratings using a rule-based system based on feature types and status.

In total, we mapped approximately 1,200 miles of potential barrier features, of which 736 miles were classified as complete tidal barriers. Over 3,015 water crossing features (bridges, culverts, flap gates, self-regulating tide gates) were identified, of which 49% were mapped using aerial imagery and not present in any regional datasets and this represents a substantial improvement in the regional inventory. We used the mapped tidal barrier network to attribute the connectivity of tidal wetland features. Approximately 18,500 ha of tidal wetland habitat was classified as completely restricted, but within an elevation that would be tidally flooded if connectivity were present (PMEP 2018). There were 3,300 ha of tidal wetland habitat classified as currently accessible to tidal connectivity but restricted by culverts, bridges, levees, and roads. Lastly, 8,500 ha of tidal wetlands and distributaries were classified as having unrestricted tidal connectivity.

Ensuring regional buy-in is critical to the development of this database to ensure its usefulness as a tool for restoration planning and tracking. We contacted 81 potential reviewers and received review from 43 different regional experts, that provided feedback on feature classifications and connectivity, as well as for the structure of our database and rules for attribution.

Key messages

- The products developed in this effort represent an important tool for regional salmon recovery planning in Puget Sound by providing consistent, up-to-date, and accessible spatial information to support the identification, evaluation, and prioritization of tidal barrier removal and tidal wetland restoration opportunities for the region.
- This effort substantially improved the regional inventory of tidal barrier features in the Puget Sound large river deltas, however, the use of aerial imagery to identify features is limited by visibility and field verification efforts are currently underway to identify unknowns. Future updates of this database should target surveying unknown features to identify types and connectivity impacts.
- Efforts are underway to determine how this data will be shared and updated to reflect the current status of tidal barriers and wetlands in Puget Sound. We intend to make these data available with an interactive map to allow continued input from regional experts on restoration work and to identify unknown features.
- We have received additional funding from the Estuary and Salmon Restoration Program to continue mapping efforts to the rest of the Puget Sound Nearshore (PRISM Project #20-1941). These efforts will begin in 2022.

Literature

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Pacific Marine and Estuarine Fish Habitat Partnership (PMEP). 2018. West coast USA current and historical estuary extent. Available at: http://www.pacificfishhabitat.org/data/estuary-extents

Online resources

Puget Sound Tidal Wetland Barrier Removal Planning Wiki. This page provides an overview and description of the Tidal Barrier Removal project.
https://salishsearestoration.org/wiki/Puget_Sound_Tidal_Wetland_Barrier_Removal_Planning

Puget Sound Tidal Wetland Barrier Removal Planning PRISM Project. This PRISM page provides a project description, contacts, worksites, metrics, milestones, and attachments.
https://secure.rco.wa.gov/prism/search/projectsnapshot.aspx?ProjectNumber=18-2250

Nearshore tidal barrier and riparian mapping PRISM Project. This PRISM page provides a description of the next step of the tidal barrier mapping project, which will extend mapping to the rest of the Puget Sound nearshore. https://secure.rco.wa.gov/prism/search/projectsnapshot.aspx?ProjectNumber=20-1941

Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=7753

Shelby Burgess is a fisheries biologist at Cramer Fish Sciences where she helps to lead and execute large-scale habitat assessments and restoration monitoring projects across the Puget Sound and Columbia River Basin. Her work focuses on utilizing field and GIS techniques for riverine and nearshore ecological assessments and habitat mapping and restoration planning.

System-wide patterns of Chinook salmon distribution: Supporting habitat restoration in the Snohomish Delta

Joshua Chamberlin[1], Todd Zackey[2], Jason Hall[3], Frank Leonetti[4], Mike Rustay[4], Matt Pouley[2], Michael Abrahamse[2], Michelle Tottman[2]

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Background and context

Given the considerable difference between current and historical delta habitat availability, estuary restoration has become a primary component for salmon recovery plans throughout the region. Understanding fish-habitat associations is important for making informed management decisions relevant to habitat restoration and species recovery. Landscape attributes can have considerable influence over fish distributions in delta habitats (Bottom et al. 2005, Greene et al. 2021). Documenting variability in Chinook salmon distributions/ densities and relating them to landscape attributes and habitat distribution could be useful for restoration evaluation and planning. We leveraged observations from 6 years of intensive monitoring of juvenile Chinook salmon in the Snohomish delta to describe patterns in density with respect to landscape connectivity and seasonal variability. The goal of our work was to inform restoration project evaluation and aid future restoration and recovery planning in the Snohomish basin.

Findings

Our work highlighted three primary pieces of information relevant to Chinook salmon and restoration planning/evaluation in the Snohomish delta: 1) landscape connectivity is positively correlated with Chinook salmon density across the delta, 2) seasonal patterns of Chinook density are associated with habitat availability/distribution and may reflect an opportunity to support life history diversity, and 3) water temperature is negatively associated with both peak density and seasonal residence in the Snohomish delta. We found Chinook salmon were not uniformly distributed throughout the Snohomish delta and densities were positively correlated to landscape connectivity (higher densities at sites closer to freshwater outmigration). Similar patterns between Chinook salmon density and landscape connectivity have been identified within several large river deltas throughout Puget Sound (Beamer et al. 2005, Greene et al. 2021). Across four years, seasonal patterns of Chinook salmon density varied spatially and were likely related to habitat distribution and availability (Chamberlin et al. in review). Where the majority of off-channel habitat is available in the Snohomish delta, we found seasonal densities were more protracted and reached peak density earlier in the season. Such patterns were indicative of extended rearing in these locations and may disproportionately support life history diversity for local Chinook populations. Documenting these patterns can aid project evaluation (Are fish rearing in restored sites? Are patterns different than before restoration?) and inform project planning by identifying areas where habitat is currently unavailable though Chinook salmon are present (i.e. restoration opportunity/potential). Lastly, we found that water temperature can influence seasonal densities of Chinook salmon in delta habitats by contracting the period of rearing and/or shifting the timing of peak density earlier in warmer than average years. Similar patterns have been found in estuaries along the west coast that suggest increased temperatures can negatively impact timing/use of delta habitats for juvenile Chinook salmon (Crozier et al. 2019, Munsch et al. 2019). Our results build toward understanding important fish-habitat relationships to better inform estuary habitat restoration evaluation, prioritization, and recovery planning.

Key messages

- Landscape connectivity is a strong driver of Chinook salmon density in delta habitats and should be considered when planning and prioritizing restoration actions as well as evaluating/updating recovery targets for habitat capacity.
- Seasonal patterns of Chinook salmon density vary spatially across the delta, are likely related to habitat availability/opportunity, and may reflect an opportunity to support life history diversity for Chinook salmon. Documenting seasonal patterns can thus help with restoration project evaluation and aid planning efforts by identifying where high juvenile Chinook salmon densities overlap with areas that lack available habitat.
- Given predicted increases in temperature due to climate change and the negative association between elevated temperatures and delta rearing, further research is warranted to determine potential ecological consequences for local Chinook populations (e.g., reduced growth, reduced residence time, increased densities).
- Long-term monitoring programs are critical for evaluating important ecological interactions for Chinook salmon in delta habitats and aid regional syntheses that provide context for restoration actions and population recovery.

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Online resources

Snohomish delta monitoring webpage. https://salishsearestoration.org/wiki/Snohomish_Delta_Ecosystem_Monitoring_and_Evaluation;

Evaluating density dependence in large river deltas throughout Puget Sound including the Snohomish delta (related work). https://salishsearestoration.org/wiki/Evaluating_Salmon_Rearing_Limitations_in_River_Deltas:

Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=10544

Josh Chamberlin has worked for the Northwest Fisheries Science Center since 2005. His research focuses on juvenile salmon ecology in estuarine and nearshore marine habitats in the Snohomish estuary and greater Puget Sound. Josh is primarily interested in how habitat and species interactions influence behavior, growth, and survival of Chinook salmon and how restoration enhances these traits during early life history.

Integrating climate adaptation and mitigation measures into the ecosystem restoration program for the lower Columbia River

Catherine Corbett[1]

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Background and context

Between the 1880s and 2009, anthropogenic changes have reduced the coverage of native habitat in the lower Columbia River by 50% (up to 70% for some habitats), mostly through the diking and conversion of habitat for agriculture, industry, and urban development. To stop the trajectory of degradation, the Lower Columbia Estuary Partnership with its partners developed an ecosystem restoration program that has accomplished over 246 projects representing 29,099 acres restored or protected. Additionally, we developed ecologically-based habitat coverage targets using conservation biology approaches that focus on the recovery of the historic habitat coverage template. However, the shifting climate is altering ecological conditions and creating additional stressors and threats to native lower Columbia River species. Presently, we are focusing on integrating shifting climate conditions into our restoration program as well as individual project designs. On a programmatic scale, we are identifying, protecting, and enhancing cold water refuges to fill landscape-scale gaps in thermal refugia that cold water species such as salmon and steelhead rely on to complete their migration during summer months. We also are assessing the threats to our floodplain habitats and coastal communities posed by increased flooding from sea level rise and fluvial flooding with more intense storm events using nature-based solutions (e.g., living shorelines, setback levees). On the individual restoration project design level, we are integrating living shorelines, hyporheic exchange for thermal cooling, and drought-tolerant plants as climate adaptation measures. We also are changing our engineering design standards to accommodate increased frequency and more intense storms.

Key messages

- Not only is integrating climate adaptation measures into our restoration program critical to the long-term success of projects, but climate mitigation will be needed. To limit global warming to less than 1.5°C above pre-industrial levels, the Intergovernmental Panel on Climate Change has repeatedly recommended rapid and far-reaching reductions in greenhouse gas emissions by including globalizing a carbon market amongst other methods (e.g., IPCC 2014, 2018, 2019). Intact forests have been shown to remove about a quarter of global carbon emissions annually, while tidal wetland habitats may sequester as much if not more carbon (Ripple et al. 2019). Up to a third of emission reductions needed to meet the Paris agreement by 2030 could be obtained by protecting intact forests, tidal wetlands, grasslands, and savannahs, and recovering and reforesting those that have been lost/degraded (Ripple et al. 2019).
- A key major next step for our restoration program is to assess the potential role of various floodplain wetlands in carbon sequestration by inventorying carbon stores and methane emissions at the site scale (within an individual site from emergent marsh, shrub scrub, forested) and across the estuarine-tidal freshwater longitudinal gradient. After creating the inventory habitats and their sequestration potential, we hope to then track conversions of

habitats, including new losses and recovery of native habitats. This information will be critical for a carbon market and in compensatory mitigation (e.g., tracking GHG emissions from conversions of native habitats to development, agriculture, logging, and grazing).

- We are working on making our restoration projects "carbon neutral," starting with our Steigerwald Floodplain Reconnection Project, where we will offset any carbon emissions during the construction process (e.g., the burning of diesel fuel by construction equipment) by planting additional trees.
- Another critical aspect of integrating climate adaptation and mitigation into our overall program includes our definition of "restoration." Our current focus of recovery of native habitats to support the persistence of native flora and fauna needs to expand to also include enhancing working lands and other "less-than-optimal" habitats for increased permeability and carbon sequestration. Native flora and fauna are expanding their ranges, often northward and to higher altitudes (cited in Chen et al. 2011), and will need to do so in order to maintain their climate niche. This raises a question of whether we are managing these lands for these "novel" species assemblages or are we continuing traditional management practices? How do we better manage for change and novel ecosystem conditions and species assemblages that are evolving with shifts in climate? Workings lands can play a critical role in this, as can areas that are not "pristine" native habitats. Working lands and other areas can be enhanced to improve how they sequester carbon, retain soil, and cycle nutrients, all components of limiting global warming to 1.5°C above pre-industrial levels.

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Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=17902

Catherine Corbett joined the Estuary Partnership in 2008 and led the development of habitat coverage targets and shift towards climate-smart conservation programming. Before that she served as the Senior Scientist for the Charlotte Harbor NEP, worked for International Union for the Conservation of Nature in Washington DC, and as a wildlife biologist in the Middle Atlas Mountains of Morocco.

Nisqually delta restoration research and Chinook salmon recovery planning: State of the science and management implications

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Background and context

The Nisqually River flows from glaciers at the base of Mount Rainier into southern Puget Sound, forming a large delta that is comprised of a mosaic of estuarine habitat types. Numerous fish and wildlife species forage and rear in the Nisqually River Delta, including natural and hatchery-produced juvenile Chinook salmon, which are an important cultural, economic, and ecological resource in the Pacific Northwest. The Nisqually Indian Tribe has treaty reserved fishing rights on the Nisqually River and depends on hatchery-derived Nisqually Chinook salmon for the bulk of their fishery, but conservation concerns around naturally produced Chinook limit the Tribe's opportunity to take advantage of hatchery fish. In order to boost the recovery of naturally produced Nisqually Chinook salmon, the Nisqually Indian Tribe and Billy Frank Jr. Nisqually National Wildlife Refuge began a collaborative effort to remove several of the century-old dikes and levees acting as barriers to tidal influence. This culminated with the 2009 removal of the "Brown Farm Dike" on the western side of the River. This large-scale restoration project served as a major disturbance event, converting large swaths of subsided and degraded marsh into unvegetated mudflats. Through time, some of these areas have started to revegetate and gain elevation. Detailed, long-term monitoring efforts examining factors such as geomorphology, vegetation, salmon diets, and habitat use have allowed us to assess how the structure, function, and ecological processes of the Delta have changed after restoration, but there is still uncertainty surrounding future habitat conditions. More information is needed to determine how climate change, sediment and water management decisions, and shifts in habitat accessibility through time will affect habitat quality for juvenile salmon, and what management actions we can take to offset potential negative effects.

Findings

The story of the Nisqually River Delta restoration and its benefits for out-migrating juvenile salmon has been revealed through time as multiple, collaborating agencies work their way through almost a decade of monitoring data. A comprehensive, initial monitoring effort (2009-2012) followed the "*opportunity, capacity, realized function*" framework of Simenstad and Cordell (2000). We used a control-impact study design to compare metrics between restoring habitats of different ages and reference marshes. An assessment of Delta opportunity using monitoring data and remote sensing imagery showed that accessibility (particularly the number, length, and complexity of available pathways for salmon to traverse the Delta) increased after the restoration during mid-to-high tides (Ellings et al. 2016). The Delta's functional capacity (in terms of prey abundance, biomass, and energy) also increased after the restoring marsh became accessible to salmon, with the early-stage (2009) restoration site harboring high densities of aquatic insects, especially dipteran larvae and adults (Woo et al. 2018). Newly restored habitat was estimated to contribute an additional 1,000,000 kJ (or ~600 hamburgers) of prey energy at any given time — enough to support 500,000 to 1,000,000 additional juvenile salmon depending on size and thermal conditions (Davis et al. 2018). Indeed, bioenergetics modeling output and otolith analyses have shown that higher prey biomass and energy density (as observed in the 2009 restoration area) may offset potential negative effects from competition and sub-optimal water temperatures (David et al. 2014, Davis et al. 2018).

More recent analyses have worked to contextualize the Nisqually River Delta restoration as a part of the broader habitat mosaic (Woo et al. 2019) *and* to evaluate the habitat mosaic's resilience in the face of large-scale disturbance (Davis et al. 2019). We developed MOSAICS — a marsh accretion model and decision support tool — to evaluate how the habitat mosaic might shift under varying sea level rise and sediment management scenarios. The model indicated that under high sea level rise, much of the Delta's emergent marshes would be converted to mudflat unless more sediment was added to the system. A spatially explicit bioenergetics model that was linked to the MOSAICS model output showed that this marsh habitat loss, in tandem with rising ocean temperatures, could reduce the ability of juvenile salmon to benefit from delta habitat. Predicted weights by the end of July, which are correlated with survival to adulthood (Duffy and Beauchamp 2011), declined from 15g to 9g in worst-case scenarios. Together, these findings indicate that while restoration actions have generally improved the opportunity, capacity, and realized function of the Nisqually River Delta, decreases in habitat diversity and complexity, increased water temperature, and increased prey demands to offset thermal stress could reduce the Delta's nursery habitat quality in the future as climate change takes hold. Management strategies integrating harvest, hatcheries, habitat, and dam management (hydropower) are necessary to ensure the persistence of healthy wild Chinook salmon populations into the future.

As habitat restoration in the Nisqually Delta increases the amount of prey available and the number of fish that can be supported, it is important that these improvements support natural Chinook recovery and future harvest opportunities. Fish monitoring shows that natural Chinook are present in the delta over a prolonged period. In contrast, hatchery Chinook are released in the Nisqually as a pulse of 4,000,000 parr-sized Chinook over a roughly one-month period each year, resulting in a narrower but high-density timing of presence in the delta primarily in May and early June. While current natural Chinook salmon abundances are low, plans for a recovered population predict a ten-fold increase in their abundance. The current hatchery management strategy, with its high-density pulse of fish that end up residing in the delta at a time of declining delta capacity, represents a likely constraint on carrying capacity and could limit the potential for natural Chinook recovery. Using delta bioenergetics research as a guide, an alternative management scenario being considered is to stage the hatchery releases to better match prey availability and the timing of the natural Chinook salmon. Commencing hatchery releases earlier in the year and spreading them over a broader period of time, with a range of fish sizes released, could better match the modeled energetic availability. This could then reduce the constraint on carrying capacity, improve the success of natural Chinook residing in the delta, and promote better harvest opportunity on hatchery Chinook through released pressure on the natural stock.

Key messages

- The Nisqually River Delta restoration added almost one-million kJ (~600 hamburgers-worth) of high-quality prey to the system — enough to feed hundreds of thousands of out-migrating juvenile salmon.
- Sea level rise is expected to reduce the habitat quality and habitat diversity of the Delta, and the restoration area is at high risk due to its low initial elevation and sparse vegetation.

- Increased sea-levels, rising temperatures, and loss of salt marsh habitat will reduce salmon growth rate potential, but slowing the rate of habitat loss by adding suspended sediment to the system could mitigate some of the negative impacts.
- Delta research can be used to identify hatchery management actions to support salmon recovery, in concert with habitat and harvest actions.

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Online resources

Nisqually Delta Restoration, Nisqually River Foundation provides photos and information related to the Nisqually River Delta restoration monitoring project. http://deltarestoration.nisquallyriver.org/

Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=1391 and https://youtu.be/jP5S3ZNxJas?t=2313

Melanie Davis is currently Assistant Unit Leader for the Oregon Cooperative Fish and Wildlife Research Unit in Corvallis, Oregon. Prior to that, she was project coordinator for the USGS Western Ecological Research Center's Olympia Substation for about seven years. Her most recent work has examined the role of estuarine habitat diversity in supporting juvenile salmon during their out-migration. Her broader research interests include aquatic food webs, disturbance ecology, and ecosystem resilience to climate change.

Christopher Ellings manages the Nisqually Indian Tribe Salmon Recovery Program which is dedicated to recovering all species of Nisqually salmon and the habitat that they depend on.

Potential of cumulative-effects research to aid restoration of salmon-habitat functions of the nearshore Salish Sea

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Background and context

When restoring coastal ecosystems of the Puget Sound nearshore and elsewhere, in essence, we are working to reverse the cumulative impacts of land uses, toxics, and other stressors. Achieving net ecosystem improvement for Puget Sound despite human population increases and development is a great challenge, and the ability to make strategic use of systems ecology to increase the effectiveness of restoration will likely be necessary for achieving results at the desired scale. This research treats the newly recognized role of beneficial cumulative effects in restoration and how the concept and associated methods support the management of large-scale, long-term programs. The particular focus of this case study is on juvenile salmon use of estuarine habitat in the Pacific Northwest, with lessons from the Columbia Estuary Ecosystem Restoration Program (CEERP).

The CEERP programmatic area comprises the floodplain of the 87-km Columbia River estuary and the 147-km tidal river, which like Puget Sound are terrestrial-aquatic ecosystems set within the Northeast Pacific Coastal Temperate Rainforest (NPTCR; Bidlack et al., 2021). The hydrologic complexity of the reaches of the Columbia River is analogous to Puget Sound watersheds in that some are primarily affected by snowmelt from the Cascades and eastward (like Puget Sound's Skagit River delta) while others, in the Coast Range, have predominantly rain-driven hydrographs. The Columbia and Puget Sound, like the entire NPCTR, are linked by salmon migrations encompassing habitats in the watersheds, estuaries, and Pacific Ocean.

Findings

Our research was motivated by the question: *Given the diverse and wide-ranging salmon life histories across different stocks and environmental conditions, how is it possible to link monitoring data from a tidal wetland habitat restoration project to the larger question of salmon recovery with its complex of drivers?* Ultimately, the managers of large-scale restoration programs need to know whether the program is making a difference. Our research found that after dike breaching to reconnect floodplain areas to the mainstem river, particulate organic matter from tidal marshes important to the food web (Meier and Simenstad 2009) is hydrologically exchanged among restoration projects through river flow and tides and exported at least 7-km down tributary rivers to the mainstem Columbia River (Thom et al., 2018). This may help to re-establish prey subsidies for threatened and endangered juvenile salmonids from east of the Cascades migrating to the Pacific (Diefenderfer et al. 2016). From a beneficial cumulative-effects perspective, this encompasses both indirect and cross-boundary effects working together (Diefenderfer et al. 2021). This is an example of thinking at a program versus a project scale. At the program scale, there are opportunities to consider the cumulative effects of reducing overall diked area and improving wetland habitat quality through multiple restoration projects, which are funded and managed discretely yet hydrologically connected (Littles et al. 2022). An interim synthesis and evaluation of the cumulative effects of restoration in CEERP considered seven lines of evidence for large-scale aquatic-ecosystem restoration, which may be applicable to Puget Sound, and concluded that there was “a cumulative beneficial effect on juvenile salmon” (Diefenderfer et al., 2016).

It is expected that another type of beneficial cumulative effect of restoration may occur on Puget Sound: *space crowding*, or the effects of the density of restoration projects. In this case, stormwater green infrastructure projects include rain gardens, bioretention, and green roofs. On the mid-Atlantic coast, higher densities of green infrastructure have been shown to reduce peak runoff, the frequency of high peaks, and loads, due to hydrogeomorphic processes through compounding effects (Pennino et al., 2016). Similarly, in Tampa Bay, watershed-scale wastewater and stormwater management combined with habitat protection and enhancement produced systemwide improvements in water quality (Greening et al., 2016). However, to put the Puget Sound effort into spatiotemporal context, it should be cautioned that Tampa Bay required 887 restoration projects beginning in 1971; this cumulative effect of restoration is termed time lags (Beck et al. 2019). As noted in the 2018-2022 Action Agenda for Puget Sound (p.44), “...quantifying the cumulative effect of individual local projects remains difficult and will require new analysis methods.”

Key messages

- At least eight categories of cumulative effects may occur in large-scale ecosystem restoration programs, the Puget Sound included, such as compounding effects, indirect effects, cross-boundary effects, and space crowding.
- These categories provide a basis for using empirical, hydrodynamic, and ecological models to project the cumulative effects of a suite of projects across the landscape, and advance synthesis and evaluation of monitoring data from restoration and reference sites.
- In restoration program planning, a cumulative-effects perspective is useful for leveraging system thresholds and positive feedback, and for avoiding unintended consequences by forecasting project interactions.
- Understanding the collective, cumulative effects across individual projects and watersheds will aid in the communication of recovery progress, provide evidence for ecosystem benefits, and contribute essential information needed for planning and adaptive management processes.
- Interim tracking and reporting of outcomes for ecosystems and target species at the *program* scale, as happens in a cumulative effects evaluation, are essential synthesis activities linking wetland restoration *project outcomes* with important long-term targets like salmon recovery.

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Online resources

The Columbia Basin Fish & Wildlife Program, Estuary Program, Documents: https://www.cbfish.org/EstuaryAction.mvc/Documents

Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=19815

Dr. Heida L. Diefenderfer, Restoration Ecologist, is affiliated with Pacific Northwest National Laboratory's Marine and Coastal Research Lab, Sequim, WA, and the University of Washington College of the Environment, School of Environmental and Forest Sciences, Seattle, WA.

Partnerships Matter – Lessons learned from the Skagit Hydrodynamic Model (HDM) and Fir Island Farm Restoration Project

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Link to presentation recording https://youtu.be/xPSLqFGhqpw?t=5142

Jenna Friebel has over 20 years of experience working as a hydrologist and project manager. Her work has focused on hydrologic analysis, restoration planning, design, and construction.

Restoration surprises: The roles of history, climate change, and killer moths

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Link to presentation https://youtu.be/xPSLqFGhqpw?t=10398

Roger Fuller coordinates habitat restoration, stewardship, and related research at the Padilla Bay National Estuarine Research Reserve.

Density-dependent habitat limitations for juvenile Chinook salmon in large river deltas of Puget Sound

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Background and context

Efforts by people to restrain tidal inundation to promote agriculture and development have led to high tidal wetland habitat loss in estuaries across the Pacific coast (Brophy et al. 2019). These losses are one of the multiple threats facing estuary-dependent species such as Chinook salmon, yet concomitant declines in these populations have raised questions about the extent to which juvenile Chinook salmon compete for limited estuary habitat and how estuary restoration will help recover populations.

The idea that competition among individuals limits populations has a long history in fish ecology (e.g., Ricker 1954). Competition can result in reduced growth (Chapman 1966), early migration at high densities (Greene and Beechie 2004), and higher mortality (Ricker 1954). Analyses examining density dependence in specific life stages are useful for linking field biology to management actions like habitat restoration because the analysis can isolate whether populations are limited by habitat conditions occurring within that life stage.

Density dependence can be measured for a population by examining life-stage specific transitions using multiple measures of abundance and other population traits. In the typical stock-recruit context for evaluating density dependence (e.g., Barrowman et al. 2003, Zimmerman et al. 2015), evidence for competition is a saturating relationship between the population at a given time (stock) and the population at a future time (recruits). We used a stock-recruit approach to examine the potential for density dependence in tidal delta habitats by taking advantage of thousands of observations in four large river tidal deltas in Puget Sound (Nooksack, Skagit, Snohomish, and Nisqually River systems).

Findings

We have found several lines of evidence for negative density dependence in large river deltas. These findings have long been known for the Skagit delta (Beamer et al. 2005, Greene et al. 2016), and extended to four tidal deltas in Greene et al. (2020).

- Across four tidal deltas with monitoring of outmigrants and delta rearing, we detected strong evidence for density-dependent rearing habitat limitations.
- We were able to estimate a density at which capacity was likely exceeded at an instantaneous (daily) time scale, and this estimate is within the range of other independently observed density-dependent processes like diet selectivity and reduced growth.
- While density dependence was observed within most years in all deltas, certain systems were much more likely to exceed capacity than others.

- We also observed both total lack of use of some locations even when capacity had been exceeded elsewhere, as well as local densities at over 10 times estimated capacity. Both results are likely the consequence of thousands of outmigrants with incomplete information striving to grow in a disconnected, dangerous environment.

Key messages

Key implications for restoration include:

- Our findings call into question simple conceptualizations that 1) deltas gradually fill as they near capacity and 2) fish immediately "spill over" into other habitats upon reaching capacity. Metaphors of capacity as an overflowing cup or a hotel with no vacancies may be misleading. An alternative metaphor of a road network at rush hour with gridlock on the main corridors but open side streets may be closer to our research findings.
- Based on the tools we developed in Greene et al. (2020), we can estimate the likelihood for systems to exceed capacity if they have outmigrant or delta fish monitoring data.
- For those systems that surpass these levels, estuary restoration is likely to have immediate, consistent, and widespread benefits.
- For systems that do not regularly surpass capacity, careful consideration of the desired future population state (i.e., meeting recovery plans) in the context of other possible recovery strategies will help practitioners determine the long-term efficacy of estuary restoration.

Key uncertainties include:

- What mechanisms promote higher juvenile productivity in restored tidal deltas? Possible sources of density dependence include aggressive or exploitative competition for prey or space, increased risk of disease, and predator attraction at high densities. Possible density-independent processes include temperature variation and predation refuge afforded by wetland habitat. A better understanding of these processes will help determine the degree to which restoration ameliorates density dependence or improves conditions in a density-independent manner.
- How do hatchery-origin juveniles interact with natural-origin migrants? Many systems in Puget Sound and elsewhere have large hatchery programs, and research indicates that juveniles may rear for 1-4 weeks in tidal deltas (Lind-Null and Larsen 2009). During this time, they may contribute to density dependence depending on habitat availability and number and timing of natural-origin juveniles, but little is known how fish interact during hatchery releases. Some research suggests that delta restoration may benefit hatchery-origin juveniles as well as natural-origin fish (Magnuson and Hilborn 2003), but this issue also deserves more direct study.

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Online resources

Salish Sea Wiki. https://salishsearestoration.org/wiki/Evaluating_Salmon_Rearing_Limitations_in_River_Deltas

As part of ESRP contract study results were subject to extensive technical review. This report documents that review and the authors response to comments on Chinook estuary use. https://salishsearestoration.org/wiki/File:Greene_et_al_2021_chinook_estuary_use_technical_review_and_response.pdf

Link to the ESRP webinar on Chinook estuary use on March 4th, 2021. https://geodataservices.wdfw.wa.gov/hp/esrp/DensityDependenceWebimar.mp4

Link to presentation recording https://youtu.be/xPSLqFGhqpw?t=2393

Correigh M. Greene has been studying salmon and associated species in the estuary and nearshore since starting work at the Science Center as a biologist in 2001. While working at the Science Center, Correigh has co-led the Skagit Intensively Monitored Watershed Project examining how estuary restoration is benefiting juvenile Chinook salmon, and has been part of the Salish Sea Marine Survival Project examining multiple causes of declines in marine survival of Coho and Chinook salmon since the 1980s.

The benefits of being the dumbest in the room

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Background and context

My presentation was a simple look back at our experiences implementing the zis a ba tidal wetland restoration project at the mouth of the Old Stillaguamish Mainstem, between 2012 and 2017. Some of the project details: 88-acre footprint; site diked for 100+ years; 7000 feet of levee removed; 800 feet of levee built; 3.1 miles of tidal channels excavated; 43,000+ yards of material moved; $2.3 million spent between acquisition, feasibility and design, construction; significant infrastructure that had to be worked around. These are lessons and observations gleaned from managing the project, since I oversaw it from purchase, through feasibility and design, to construction and post-project monitoring. I am happy to discuss any of the bullets below in more detail if someone would like to. Feel free to email me and we can set up a time to talk!

Key messages

If you implement your project so that you are the dumbest (least experienced is more of an accurate description, but not as catchy) then you are likely to find that:

1. The pressure is off.
   a. Stakeholder concerns addressed by those more credible.
   b. Potential legal challenges are planned for.
   c. You aren't looked to for solutions.
2. You learn from history (not your own mistakes).
   a. Document existing drainage/flood infrastructure performance. Don't argue about how things worked later.
   b. Design for the neighborhood, not a perfect world. Your project doesn't need to be perfect, just better than what is around it.
   c. Use tracked equipment whenever possible. This will prevent problems with site evolution later.
   d. Dig as many channels and outlets as appropriate/feasible. This will reduce energy and lead to quicker vegetation colonization.
   e. The cheapest option isn't always, in the long run. What do you need to do in design to limit legal or permit challenges?
3. Things will probably turn out OK! For example, pretty good chance that it will be/have:
   a. On time
   b. On budget
   c. No change orders
   d. No lawsuits

e. Built per plan

f. Loved by fish and birds

Online resources

https://www.stillaguamishwatershed.org/subpages/Documents.html

Link to presentation recording https://youtu.be/xPSLqFGhqpw?t=9589

Jason Griffith has worked for the Stillaguamish Tribe for the past 20 years on a wide variety of Chinook related projects. Over the past decade he has focused on protecting and restoring land from the estuary to the spawning grounds.

Process-based models and studies of coastal change to inform habitat restoration and climate change adaptation

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Background and context

Puget Sound salmon and estuary recovery strategies identify tens of thousands of acres of floodplain and estuary habitat restoration needed to re-establish ecosystem functions lost or degraded from western land use (Simenstad et al. 2011); the extent for nearshore habitat remains uncertain. Sediment is critical for shaping the structure and functions of these ecosystems and the success of many habitat recovery strategies. This is particularly important in the Pacific Northwest, where high sediment flux through the coastal zone makes it a more dynamic ecosystem driver than other regions where estuary restoration guidance has been developed and especially for extensive marshes and floodplains that have subsided due to lost sediment delivery from placement of flow control (flood protection) structures (Grossman et al. 2020). Fluvial sediment delivery to Puget Sound is expected to greatly increase in many systems under projected climate change (Lee et al. 2016), requiring better models and tools to evaluate complex ecosystem responses.

Guidance for estuary habitat recovery (e.g., Clancy et al. 2009) rests on a paradigm of restoring historic habitats and connectivity by simply removing or lowering levees assuming sediment delivery and accumulation will occur. Outcomes of several restoration projects and studies show that restoring "opportunity" for sediment delivery may not be enough. Improved knowledge and predictive models of land-use and climate change effects on sediment budgets, sediment properties, and coastal change can refine restoration guidance to evaluate quantitative expectations for sediment flux, composition, accumulation, and timing critical to achieving more effective recovery, resilience, and community support.

Findings

Integrated sediment transport and coastal habitat change research in the Nooksack, Skagit, Stillaguamish, and Nisqually River deltas indicates that predictive sediment transport models help evaluate the interaction of geomorphic processes and ecologic responses that affect restoration outcomes. Models and data are needed to assess the increasingly complex tradeoffs between restoration alternatives, potential undesired, downstream effects of restoration, and non-linear changes expected with sea level rise, climate, and land-use change. Improved understanding of land-use effects, hydrodynamics including coastal processes, and sediment budgets and transport properties will help refine estuary restoration guidance with direction for siting, phasing, and design strategies within a more informed geomorphic context. The information will also help define more measurable expectations for sediment flux, composition, accumulation, and timing critical to evaluating alternatives and achieving recovery and resilience.

For example, recent studies show that a 2-5 times increase of the Skagit River sediment load and its focusing offshore by river channelization continues to disrupt eelgrass and marsh habitats (targets for recovery), drive channel instability and flood risk, and impair Skagit lowland resilience to sea level rise

(Grossman et al. 2020). The refined model of sediment routing effects also informs trade-off decisions, including the potential undesired outcomes of a proposed Fir Island Cross-Island (distributary) Connector that would ostensibly lead to widespread loss of eelgrass as demonstrated by a recent avulsion and sediment burial, unless excess sediment in the system was addressed and phased strategically (Grossman et al. In prep). In contrast, and despite trapping over 80% of the Nisqually River sediment load in Alder Lake, sufficient sediment delivered to the coast could rebuild and maintain subsided marshes in the 762-acre 2009 Brown's Farm restoration project in the Nisqually Delta. However, only 14–20% of the river sediment load accumulates in the marshes as restoration efforts, restricted to the lower river, have limited capacity to route sufficient supply leaving full marsh recovery to likely take 80-200+ years (Grossman et al. In review). Estimated sediment flux to the 2012 Port Susan Estuary Restoration may maintain marsh accretion at current rates of sea level rise but not projected future rates (Nowacki and Grossman 2020). Restoration guidance will benefit from improved models and knowledge of sediment routing to help identify alternatives that minimize impacts to valued eelgrass and kelp habitat suitability related to turbidity (Stevens et al. 2018), which is projected to increase with higher sediment runoff in the future (Lee et al. 2016).

Key Messages

- Recent studies of sediment budgets, sediment routing dynamics, and land-use effects indicate that inclusion of geomorphic context and metrics (like watershed sediment load, delta sediment retention, potential wetland sediment accumulation, project position, and area in tidal prism) in restoration guidance (e.g., Clancy et al. 2009) will more effectively achieve recovery goals.
- Estuary, beach, and embayment restoration will benefit from predictive models that can evaluate diverse outcomes sensitive to complex sediment dynamics.
- Quantitative data for sediment budgets and properties, hydrodynamics, and land-use effects are needed to better characterize geomorphic processes in the Pacific Northwest, where high sediment flux to the coast is a principal ecological driver.
- Improved understanding and integration of geomorphic context will refine estuary restoration guidance with direction for siting, phasing, and design strategies to achieve goals more effectively.
- Integrated models that evaluate potential benefits (e.g., flood protection) and effects (e.g., downstream impacts) of restoration alternatives will help identify opportunities to achieve success, resiliency, and garner societal support.

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Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=9579

Eric Grossman is a Research Geologist who leads the USGS Coastal Habitats in Puget Sound (CHIPS) Project and development of the Puget Sound Coastal Storm Modeling System (PS-CoSMoS). His research focuses on sediment transport and coastal change to inform how coastal habitats are influenced by hydrodynamics and sediment and how their structure and function along with restoration outcomes will respond to changes in sea level, climate, and land use.

Biological and physical effects of self-regulating tide gates and implications for restoration planning

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Background and context

A number of restoration techniques exist to counter widespread estuary habitat and connectivity loss across the Pacific Northwest, ranging from dike breaching and removal to installation of "fish-friendly" or self-regulating tide gates (SRTs). However, the physical and biological effects of these techniques have not been rigorously examined. In this presentation, we focus on the effects of SRTs, and examine their effectiveness in two different ways. First, we used a spatially extensive design to compare three site types: SRTs, flap gates, and unimpeded reference sites. The study compared ten SRT sites located from the Columbia River estuary north to Samish Bay in northern Puget Sound, five traditional flap gate sites (designed to drain freshwater but prevent tidal inundation and saltwater intrusion), and five unimpeded tidal channel reference sites. Second, we used a temporally extensive design at three SRT sites to determine changes in upstream cumulative densities of Chinook salmon across the rearing season, relative to downstream values, before and after SRTs were installed. Our objectives were to develop a better understanding of the biological and physical effects of SRTs to inform restoration planning.

Findings

The results of this research provide information on the effects of "fish-friendly" or self-regulating tide gates (SRTs) on fish assemblages and abiotic conditions (e.g., water salinity, temperature, elevation). The results can be used to help evaluate the use of SRTs to address salmon recovery goals and provide data that can be used to support the evaluation and prioritization of tidal barriers based on water crossing feature types. We found that SRTs provide approximately 5 times higher connectivity (with respect to juvenile salmon access based on water depth/perch, gate position, and velocities) compared to flap gates, but SRTs provide only 50% of the connectivity observed at reference channel sites. In addition, we observed statistically similar reductions in densities of estuarine-dependent species, and Chinook salmon in particular, upstream of flap gate and SRT sites compared to reference sites. Juvenile salmon assemblages were more similar upstream of flap gates and SRT sites and statistically dissimilar from downstream and reference sites. However, with respect to physical conditions (temperature, salinity, water depth, and connectivity), conditions upstream of SRT sites were more similar to downstream and reference sites. These results are summarized in a project report (Greene et al. 2012) and will be published in more detail in a manuscript that is currently in preparation.

Key messages

- Our results suggest physical habitat conditions upstream of SRTs (variation in salinity, temperature, and depth) are more similar to downstream and reference conditions, which provides some evidence for restoration benefits of SRTs for estuary habitat.

- However, our study also found that SRTs significantly impact habitat use and access among estuarine-dependent fish species, with SRTs significantly reducing both connectivity to upstream habitats and the observed density and assemblages estuarine-dependent fish species.
- SRTs and flap gates vary widely in their design, function, and landscape setting, which can significantly impact fish habitat and use, and seasonal variations (e.g., river flow) can also significantly impact fish habitat and use associated with tide gates. Our study was limited in spatial and temporal extent, and monitoring data from additional sites and designs, as well as longer temporal periods, would provide useful information on how these factors affect fish habitat and use.
- More studies aimed at evaluating fish use and assemblages and abiotic conditions in altered estuarine environments are needed to improve our understanding of how physical factors influence connectivity for juvenile salmonids and estuarine-dependent fish species. This information can then be used to improve fish barrier assessment and evaluation protocols in tidally influenced habitats to support estuary habitat restoration planning in Puget Sound.

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Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=6857

Jason Hall is a Senior Scientist with Cramer Fish Sciences and has over 18 years of experience in fisheries research and restoration effectiveness and status and trends monitoring. Jason's research has focused on developing and implementing regional scale status and trends monitoring data to support salmon recovery planning and evaluation.

Using tidal landform scaling for habitat restoration planning, design, and monitoring

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Background and context

Tidal channels are structurally and functionally prominent features in tidal marshes, so their restoration is central to tidal marsh restoration. Critical design questions in tidal marsh restoration include: How many tidal channels can a restoration site support, and thus, how many dike breaches should be made to restore tidal inundation and tidal channels? How much total channel surface area will be supported by a restored marsh, and thus, how many fish or other animals can be supported by restored channel habitat?

These basic design questions can be addressed by landscape allometry, which describes the proportional relative rates of change in a system between two entities of particular interest—in the case of marsh restoration, between the amount of marsh area to be restored and a wide variety of measures of tidal channel network geometry, such as tidal channel network surface area, length, and outlet count (Hood 2007a, b). I review the development of landscape allometry, the insights it provides into landforms and related ecological patterns, and its utility and application to marsh restoration planning, design, and monitoring.

Findings

The number of tidal channels draining a marsh island and the total surface area and length of the tidal channels scale increase non-linearly with island area. The latter two parameters increase faster than does island area, so that larger marsh islands have disproportionately larger total channel surface area and length. Additionally, the size of the largest, 2nd-largest, 3rd-largest, etc., channels also scale with marsh island area. These scaling patterns (allometry) can be used to predict how many dike breaches should be made for a restoration site and how much total channel surface area and length can be expected. From the surface area or length predictions, one can then generate the predicted number of juvenile Chinook salmon that might use the restoration site. These types of predictions can be used for recovery planning and to set expectations for monitoring. For example, a survey of tidal marsh restoration projects in Puget Sound over the last several decades shows that restoration sites have, on average, 1/5 the number of tidal channel outlets (dike breaches) as do reference marshes. As a community, we have been underestimating the number of dike breaches that our restoration sites need because we have not had a predictive model to guide our restoration design. This has likely impacts on site accessibility by juvenile salmon; we are building restoration sites, that are not necessarily fully accessible and thus not fully utilized by juvenile salmon.

Recent vegetation monitoring that compared a site (zis a ba) where tidal channels were excavated to match allometric predictions with a size (Fir Island Farm) where tidal channels were severely under-excavated relative to allometric predictions, showed that the under-excavated site had poor establishment of vegetation compared to expectations generated by a predictive vegetation model (PVM), while the well-excavated site had unusually rapid vegetation establishment that was in accord with the PVM. It seems likely that the under-excavated site has a relatively small amount of its tidal prism diverted to channelized flow, leaving high amounts as sheet flow, resulting in high shear stress on the marsh surface that prevents seed germination. The well-excavated site in contrast has low sheet flow shear stress, so vegetation is easily established. Comparison of model expectations to observations was key in interpreting monitoring results and learning. This example shows how important it is to develop and use predictive models in habitat restoration for project design, monitoring, and learning.

Key messages

1. Prediction is essential to restoration ecology: for planning and design; to evaluate outcomes by providing expectations or standards against which to evaluate monitoring results; and to better learn from experience.
2. Landscape allometry provides useful design guidance, but not absolute prescriptions, because of unexplained variation. It is good for pushing design to meet at least the lower 80% confidence limit of a prediction.
3. Further model improvement by accounting for effects of tide range, fetch, sediment supply, sediment grain size, vegetation type, marsh surface elevation could reduce the amount of unexplained variation.
4. Even with only 70%-90% of variation explained (depending on channel parameter), landscape allometry is still useful for the development of design, monitoring, and evaluation standards (e.g., channel outlet count).
5. Landscape allometry provides unexpected insights (e.g., non-additive cumulative effects, scaling of channelized tidal prism and revelation of otherwise cryptic anthropogenic landscape impacts).
6. Tidal channel allometry may have implications for more than fish; hydrodynamic consequences of channel geometry may also affect vegetation colonization of new restoration sites if too much sheet flow prevents seed germination and seedling establishment.

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Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=5985

Greg Hood focuses his work on the interaction between geomorphology and ecology in tidal wetlands with application to habitat restoration and recovery of threatened Chinook salmon. Greg has been working for 30 years in Pacific Northwest wetlands, with experience ranging from the Columbia River Estuary to the Yukon-Kuskokwim Delta. Greg received a PhD from the UW School of Fisheries and MS from FSU where he studied myrmecology.

Zeroing in on food web function; a landscape connectivity viewpoint

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Background and context

Estuarine deltas are transitional ecotones between terrestrial, freshwater, and marine ecosystems. Estuaries have long been recognized for their high level of primary productivity, which fuels both nearshore and offshore marine food webs alike (Conway-Cranos et al. 2015). In the Pacific Northwest, estuarine deltas have been identified as critical habitat for endangered Chinook salmon, which rely on abundant food resources produced within estuarine marsh ecosystems before ocean entry. However, estuarine-dependent species exist worldwide and are under threat by the loss of estuarine delta habitats to human development and the encroaching effects of climate change.

Estuaries are pulse-dominated ecosystems, reliant on the daily pulse of tides to exchange materials, nutrients, and organisms, as well as the seasonal pulse of snowmelt freshets and winter rains which bring new subsidies from terrestrial systems (Polis 1997). Historically, the boundaries between land and sea were fluid. Thus, it follows that a key driver of estuarine productivity is related to the level of landscape connectivity affiliated with the estuary - including the longitudinal, lateral, and vertical connectivity of the river system to the surrounding landscape and floodplains, as well as the connectivity of the estuarine delta's channels and marshlands to the sea.

While we understand that there are linkages between ecosystem form, process, and function, these relationships are not necessarily folded into estuarine restoration planning and design, nor in our accounting of what has been lost. By studying the nexus of landscape form, process, and function in estuarine deltas from Puget Sound to San Francisco Bay, our work elucidates the mechanisms that link ecosystem form to food web functions and allows us to design our way forward.

Findings

In northern Puget Sound, we compared food web connectivity across five estuaries representing a gradient of fluvial inputs. We used stable isotopes to link detritus-feeding organisms to vegetation communities and were then able to examine drivers of food web connectivity (Howe et al. 2017). Food web connectivity varied according to freshwater input, area of habitat types, and feeder type. In general, we showed that tidal pulsing in combination with river pulsing acts to distribute detritus and integrate food webs across space, with bigger river systems resulting in greater food web connectivity. However, we observed that consumer feeding mode and anthropogenic landscape alteration can disrupt this pattern. Specifically, when coupled with large flow volumes, constrained rivers discharge in high-velocity jet-like plumes rather than low-velocity diffuse plumes. As a result, organic matter (OM) fails to settle in delta sediments, consequently disrupting food web connectivity for benthic-deposit feeders. Constraining rivers can be just as disruptive to food web functions as habitat loss itself.

In the Skokomish estuary, we examined the effect of restoration design on food web connectivity (Howe and Simenstad 2015). We observed that mussel diets in restoring marsh sites with greater hydrologic connectivity (i.e., more channel outlets and a full levee removal) were more similar to reference conditions than restoring marsh sites with very little hydrologic connectivity. We also observed that mussels depend on a variety of OM sources for growth and that connectivity affects the availability of different OM types. As such, we showed that recovery of food web functions in estuarine restoration sites is dependent on recovering a diversity of habitats, as well as connectivity among those habitats.

Finally, in the Sacramento-San Joaquin Delta, we observed that loss of marsh area does not scale 1:1 with respect to loss of marsh functions. Building off a mapping effort to reconstruct the historical delta's plant communities, we calculated net primary productivity (NPP) for the modern and historic delta in both dry and wet conditions. We observed that a 77% loss in total wetland habitat area translated to a 94% loss in ecosystem NPP, an 89% loss in NPP flow to herbivores, and a 94% loss of detrital production. We also observed a qualitative shift in the type, timing, and accessibility of primary producer types within the delta, and showed that the current restoration plans for the delta will recover 12% of total NPP and rebalance the food web portfolio of primary producer types. This is important, because although phytoplankton is the dominant source of OM within the modern delta, it is ephemeral in availability, less productive than marsh vegetation, and the delta's native consumers continue to rely on marsh-derived detritus for food web support (Young et al. 2020).

Key messages

- Food web connectivity is related to river size, habitat area and type, organism feeding mode, and levee constraints, as well as the fluidity of landscape boundaries.
- Estuarine produced detritus is a key source of food web support in nearshore ecosystems
- Habitat area does not scale 1:1 with habitat function; some habitats have higher levels of net primary production and higher food web value than others.
- Estuarine restoration projects must consider both landscape configuration and climate change (sea level rise and freshwater inputs), as both influence hydrologic connectivity and therefore vegetation communities, material flux, and food web function.
- Climate change modeling at the site scale, as influenced by the watershed scale and local relative sea level rise, is a key uncertainty for working in estuarine landscapes. Understanding how climate change will influence connectivity and habitats in specific estuarine deltas is critical to designing high-functioning restoration sites. A question that is asked repeatedly by restoration practitioners is how restoration designs can approach both sea level rise and changes to fluvial discharge in terms of freshwater quantity, timing, duration, and distribution.

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Link to presentation recording https://youtu.be/xPSLqFGhqpw?t=6950

Emily Howe, PhD, is an aquatic and estuarine ecologist at The Nature Conservancy. Emily's work focuses on estuarine restoration, food web connectivity, and climate adaptation pathways for freshwater and estuarine systems.

Multi-scale evaluation of Chinook salmon responses to estuary restoration in the Skagit tidal delta.

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Background and context

Salmon recovery goals are often established from population-specific productivity and capacity estimates derived from stage-specific counts. Estimates of productivity and capacity are then used to inform specific habitat protection and restoration actions, for example in the Skagit River, productivity from egg to fry is associated with peak river discharge (Zimmerman et al. 2015) and the capacity of fry rearing in the estuary is limited by lack of available habitat (Beamer et al. 2005). Salmon recovery plans acknowledge the link between the number of Chinook salmon at a local, site-specific, scale and a larger population scale, and recovery actions to be implemented at a site and across the landscape. Understanding of ecological processes supporting these populations is incomplete across both local and population scales. Assumptions are often required to plan and implement restoration actions that may or may not achieve the desired salmon recovery goals.

In the Skagit River estuary, we have studied juvenile Chinook salmon recovery at two scales within the Skagit delta that includes individual projects (i.e., project-scale) and the full tidal delta (i.e., population-scale). Our work encompasses both local and broader Before-After-Control-Impact (BACI), (Underwood 1994) designs. This approach relies on focused evaluation of restoration actions at the site before and after restoration while maintaining a broad reference network across the Skagit estuary that is linked to long term habitat and Chinook salmon population monitoring. We apply this approach to evaluate if recovery actions are increasing rearing capacity within the Skagit River estuary.

Findings

Skagit River estuary restoration is increasing the available habitat for juvenile Chinook salmon, yet natural losses from erosion are slowing the progress of habitat gains (Beamer and Wolf 2017). The current pace of restoration will achieve the Skagit Chinook Recovery Plan’s desired future condition for estuary habitat extent in 80-90 years, however, climate-induced sea level rise, wind-driven wave intensity, and human-caused changes in sediment routing may slow the pace further (Hood et. al. 2016).

Nevertheless, we have observed benefits to juvenile Chinook salmon at local scales (individual sites), where restoring tidal inundation to estuarine marshes results in juvenile Chinook salmon rearing (e.g., Greene et al. 2016, Beamer et al. 2015, Beamer et al. 2017, Beamer et al. 2018). The utilization of these newly inundated sites is attributable to the millions of Chinook salmon fry out-migrating from the Skagit River annually that often exceeds estuary habitat capacity. We have also learned that some restoration designs work better than others. Generally, restoration projects that continue to have muted tidal exchange (e.g., self-regulating tide gates) or limited connectivity (e.g., dike breaches) to adjacent distributaries have fewer juvenile Chinook salmon compared to matched reference areas (Greene et al. 2012).

Location of restoration projects within a delta distributary network is important. We find more rearing potential by out-migrating juvenile Chinook salmon at locations that are more connected to the riverine distributaries (Beamer et al. 2005, Beamer and Wolf 2016). Two conclusions follow from this result, 1) restoration projects in the upper portions of the delta will be used by more out-migrating Chinook salmon, and 2) restoration of connectivity across the delta network will improve rearing across many habitats. We are currently working to validate these two conclusions.

If recovery goals are to be met, site-specific restoration benefits must scale up to population response. Greene et al. (2016) confirms that juvenile Chinook salmon is capacity-limited in the Skagit River estuary, where increased densities result in decreased residence time and smaller juvenile Chinook. At high estuarine densities, smolt to adult survival tends to decrease. Restoration appears to be increasing the capacity of juvenile Chinook salmon by decreasing mean densities and increasing estuary residence and growth. More restoration is needed to counter losses in estuarine habitat and safeguard against new pressures on Skagit River Chinook salmon (e.g., climate change), and as land available for restoration and conservation becomes more limited, improving the effectiveness of restoration becomes more important.

Key messages

We have found that at the project (site) scale:

- If you build it, they will come! Juvenile Chinook salmon were observed using the restored habitats that were monitored. This is because the Skagit River produces ample numbers of out-migrating Chinook salmon fry and has limited estuarine habitat to support them, so all habitats become seasonally occupied.
- Some restoration designs work better than others. Restoration projects that enable full hydrologic and geomorphic processes work better for Chinook salmon response than projects that mute these natural processes.
- Location, location, location. Restoration projects have more juvenile Chinook salmon seeding potential, and thus more recovery potential, in more connected landscapes than more disconnected landscapes.

Our "population" results suggest:

- Juvenile Chinook salmon in the estuary are capacity-limited. Under high densities juvenile Chinook salmon have reduced residence in important delta nursery habitats and attain smaller sizes, indicating growth limitation. Skagit River Chinook salmon could benefit from more restoration actions increasing estuarine habitat.
- Restoration actions seem to be increasing capacity. Juvenile Chinook salmon become less crowded in the estuary as the overall habitat increases. Length of fish residence in the estuary increased with cumulative estuary restoration. Improved estuary capacity may be leading to higher smolt to adult return rate, but more time and more restoration are needed to confirm this trend.

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Online resources

http://skagitcoop.org/documents/

Link to presentation recording https://youtu.be/xPSLqFGhqpw?t=1530

Michael LeMoine is a community and population ecologist interested in life history tradeoffs as they promote population resilience.

Snohomish Estuary – Smith Island and Mid-Spencer Project Monitoring

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Background and context

The Smith Island tidal estuary restoration project was breached in 2018 after years of planning, review, and design supported by numerous stakeholders and funding partners. This presentation describes the post-construction baseline and monitoring efforts to assess site “Opportunity” and “Capacity” for juvenile salmon, characterized by fish access, channel form, and marsh development. The restored tidal area at Smith Island covers 382 acres and fully exchanges tides across 4,270 lineal feet of removed dike (44% of perimeter). One restored and 16 new blind tidal channels/connections were created (+16 at Mid-Spencer Island) and are compared to regional marsh area/channel relationships. Low-tide LIDAR was collected in 2019 and 80+ cross-sections or long profile surveys were established. Juvenile salmon and other fish species were sampled in 2019 across all parts of Smith Island including a re-connected natural channel, designed channels, tidal flats and the face of the setback dike indicating accessibility to the subsided site. Results are compared to off-site locations (Union/Mid-Spencer). The die-off of upland vegetation continues, including large trees recruiting to tidal flats or channels. Large wood from off-site is being entrained as well. Emergent marsh species colonization is being documented among vegetation macroplots/transects. Sediment monitoring (pins and rSET tables) has only just begun at Smith Island, but ongoing monitoring at Mid-Spencer Island highlights recent sediment accretion. This effort is coordinated with Tulalip Tribes and NOAA across the Snohomish estuary to contribute to system-wide monitoring and frame Smith Island benefits and change relative of other restored or breached locations in the Snohomish estuary.

Key messages

- Salmonid fishes and a complement of other estuary fish species made extensive use of habitat types in 2019 (the first full year of connectivity) across the expanse of Smith Island presumably due to large tidal exchange with source distributary sloughs.
- At Mid-spencer Island, average sediment accretion rate over 4 years averaged 1.3 cm/yr (range, 0-4.1 cm/yr, n=26 sediment pins).
- Vegetation colonization is visually occurring on higher elevation surfaces and surfaces nearest undisturbed slough sedge benches.
- Key uncertainties include the productivity of subsided tidal flats without vegetated marsh growth in expanded estuarine emergent marsh (EEM) zone relative to the more productive historical estuarine forest transition (EFT)/forested riverine tidal (FRT) zones. Additionally, the non-conformance (to regional models) of the designed tidal channel geometry may remain fixed or changed as dependent upon actual capture of tidal prism by individual channels. This is not known. The uncertainty of project interaction (Mid-Spencer and Smith island) affected by volume exchange, new flow pathways, and sediment delivery or export will be evaluated.

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Online resources

Smith Island website – Smith Island Restoration Project | Snohomish County, WA – Official Website (snohomishcountywa.gov)

WA DNR LiDAR Portal – Washington Lidar Portal

Tidal Marsh Monitoring (USGS, USFWS, Nisqually Tribe) – Home | Tidal Marsh Monitoring

USGS Surface Elevation table (SET); Overview - https://www.usgs.gov/science/regions/northeast/maryland/science/surface-elevation-table

Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=14184

Frank Leonetti works with the Resource Monitoring team to assess and interpret the status of and changes in stream, river, estuary, and nearshore habitat conditions. This work informs environmental planning and prioritization, conservation project development, and post-project evaluation at Snohomish County.

Are you serious about salmon recovery in Puget Sound?

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Background and context

Salmon are impacted by the actions or lack of actions by every human that engages with the natural environment of the Puget Sound. Salmon recovery will require that we all do our part to support these goals while maintaining a healthy economy that can financially support the required actions. Public engagement and support are critical. Without an actively engaged public, funding will not be available at the level required and subsequent actions/projects will not be implemented. As a result, as we have seen, the road to recovery will be long and potentially "too little too late."

We must work together to:

- Engage private landowners, and encourage them to take actions that benefit salmon recovery and shared public goals.

  We must go beyond just engaging private landowners as "advisors" to help guide our planning processes. We must realize that success will require a sustained initiative built upon mutual respect and trust. We must listen and understand the needs of others, as well as share/express our needs. This type of work is not easy but can lead to successful outcomes, for the private landowners and salmon recovery.

- Identify the desired actions on private land and secure the funding necessary to implement.

  By listening and working with private landowners, we can collectively identify the suite of actions that can work for private landowners and help advance recovery. This collaborative effort will broaden the base of support for future funding requests.

- Broaden the array of projects and look beyond our individual projects.

  A lot of great work is being done and the list of great projects is impressive. However, recovery hinges on diversity within the environment and the suite of projects (especially on land in private ownership).

Given that we are all serious about salmon recovery, I encourage us all to take this bold and challenging step forward. Salmon recovery hinges on how well we engage and work with private landowners, and our ability to work together to secure the funding. To broaden the base of support for salmon recovery we need private landowners.

Key messages

- If we are serious about salmon recovery, we must engage private landowners at the community level.
- We must pursue new funding to engage private landowners.
- We must look beyond our individual projects.
- We must implement a wider array of projects.
- We must secure the support of private landowners and the public.

- We must be sincere and honest in our engagement and must be willing to invest to time (years), effort, and energy to sustain this engagement into the future.
- We must build trust by working together, by listening well and helping others become successful.
- Our main limitation is our willingness to take on the challenge of working with the public and private landowners. It is difficult to work at such a large scale (landscape) and small scale (individual landowners). However, salmon recovery will pivot on whether we can (or cannot) collectively tackle this challenge.

Link to presentation recording https://youtu.be/xPSLqFGhqpw?t=6008

Monte Marti has spent over 35 years working with tribes, agencies, NGO, and private landowners on solutions to tough natural resource issues. Monte was on the Executive Committee for the Snohomish Sustainable Lands Strategy effort, and was also highly active in implementation of and advocacy for the salmon recovery plans, Floodplains by Design, and other initiatives that intersect with private landowners and community engagement.

20:21 Perspective on the Qwuloolt Estuary Restoration Project

Kurt Nelson[1] and Todd Zackey[1]

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Background and context

The purpose of the project was to restore essential habitat for salmon and improve fish passage to 16 miles of stream habitat. Since 2005, Chinook escapement in the Snohomish River has been well below recovery targets, emphasizing the need for restoration of essential habitat. The 2005 Snohomish River Basin Salmon Recovery and Conservation Plan hypothesizes that the quality and quantity of rearing habitat in the estuary is one of the primary factors limiting Chinook and bull trout char. The Snohomish River estuary provides essential habitat for salmon, including threatened Chinook and bull trout. Salmon use the estuary for rearing as juveniles and as an important transition zone as they migrate from freshwater to saltwater as juveniles and return as adults.

The Qwuloolt Estuary Restoration Project is located in Marysville, in western Snohomish County, Washington, at the mouth of the Snohomish River. The project intended to restore tidal processes to historically what was a scrub-shrub and forested wetland. The actions taken to restore these processes included the construction of a setback levee, lowering of the existing levee, the construction of a new outlet channel and an interior channel network, ditch filling, building of wave attenuation berms, riparian planting, and new stormwater and sewer facilities.

Findings

Restoration lessons

- Large complex projects, especially in an urban or urban fringe take much longer to complete.
- Where projects include property acquisition, project managers should consider engaging real estate experts to assist in land acquisition.
- Permitting and planning can be challenging and managers should expect the unexpected, other parties may have an entirely different set of issues associated with the project. Public outreach was important pre and post-project to address public concerns.
- The project's interagency advisory committee was instrumental in helping surmount hurdles.
- The largest costs associated with the restoration project were built measures designed to protect offsite properties. These measures accounted for over half the project cost.
- Understanding site conditions (e.g., hydrologic conditions) is critical to managing construction. We found proper hydrologic modeling was useful in evaluating/anticipating future conditions.
- Consider engaging a construction manager who has experience with construction management procedures.

Restoration uncertainties

- Future restoration projects in delta locations need to consider the implications of sea level rise and what it means to how and where a project is constructed, and how the site may evolve over time so that the desired results are achieved.
- There is generally too little post-project monitoring performed. We need more information to determine whether projects that are constructed are performing as planned.
- Offsite benefits or impacts of delta projects need to be more closely monitored, including water quality, detrital dynamics, and erosional effects.
- We all would benefit from additional studies on prey dynamics associated with these projects. The growth of juvenile salmon is critical to their survival, increasing space without appropriate levels of prey may not have the benefits that were originally anticipated.

Key messages

- Habitat restoration is costly and challenging, but the costs to resources that rely on those habitats are even greater.
- Restoration starts a healing process that takes time – so it's a beginning point, not the end point.

Literature

Snohomish Basin Salmon Recovery Forum. June 2005. Snohomish River Basin Salmon Conservation Plan. Snohomish County Department of Public Works, Surface Water Management Division, Everett WA

Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=11523

Kurt Nelson has been employed by the Tulalip Tribes as a fisheries biologist and an environmental manager for 34 years and has technical expertise in aquatic ecology, habitat restoration, water quality, fisheries, fluvial geomorphology, and hydrology. Kurt has a Bachelor of Science degree in Fisheries Biology from the University of Minnesota, and a Master of Science in Wildland Hydrology, from the University of Washington.

Toxic contaminants: An under-appreciated barrier to "process based restoration"

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Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=15107

Sandie O'Neill is a senior Research Scientist with the Washington Department of Fish and Wildlife. She investigates the health of the Puget Sound ecosystem, with a primary focus on the role of contaminants on marine biota, including the influence of fish life history on contaminant accumulation, the flow of contaminants through the aquatic food web, and the effects of toxic substances on ecological and human health. She received her B.Sc. in Zoology from Memorial University of Newfoundland in 1981 and her M.Sc. in Zoology from the University of British Columbia in 1986.

Skokomish estuary restoration design and implementation adaptive and functional considerations

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Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=3315

Sediment accretion in the Stillaguamish River estuary

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Background and context

Sediment accretion can be considered foundational to marsh maintenance and recovery. Marshes need to accrete sediment to maintain their elevation relative to sea level rise. They may need even more sediment accretion to recover after restoration, because marshes can experience substantial subsidence while diked and drained, without regular flooding. Unfortunately, many of the world's major deltas lack the sediment needed merely to keep pace with sea level rise (Giosan et al. 2014), let alone build up extra sediment for restoration, which means that restoration may not be successful in these systems.

We used our years of sediment accretion monitoring to understand how Puget Sound marshes fare in terms of resilience to sea level rise and recovery after restoration. We focused on the Stillaguamish River estuary since we have the most comprehensive dataset there in both restored and reference marshes. The Stillaguamish estuary contains a 150-acre marsh restored to tidal and riverine flooding via dike lowering and two dike breaches by The Nature Conservancy in 2012. The Estuarine Ecology Lab at WWU has been monitoring surface elevation change since 2011, now with 20 active surface elevation tables (SETs) throughout the estuary. We also have Pb-210 dated sediment cores at the same 20 locations to provide long-term (100-year) accretion rates, as part of a blue carbon study.

Findings

After nine years of monitoring elevation change in the Stillaguamish natural (reference) marshes, we see an average elevation gain of 1.0 cm/yr, which is much higher than the current rate of sea level rise of 0.181 cm/yr (NOAA Tides and Currents Station 9444900). Dated sediment cores from the same natural marsh sites resulted in an average accretion rate of 0.6 cm/yr, lower than the elevation change rates but still higher than the rate of sea level rise.

The restored marsh had subsided by up to 1 meter before restoration, so it will need to accrete more than the natural marshes just to regain its original elevation. Our SETs in the restored marsh have measured an average elevation gain of 2.5 cm/yr since restoration, which is more than twice the rate of natural marshes, indicating that this area is indeed making up for its previous subsidence.

Others have been monitoring SETs in recently restored marshes in other Puget Sound deltas, and have allowed us to mention their results to date for comparison to the Stillaguamish rates. The WDFW has measured an average elevation gain of 1.7 cm/yr in the Fir Island Farm restoration site in the nearby Skagit River delta (L. Brokaw, personal communication, March 2, 2021). That rate is on a similar scale though slightly lower than the Stillaguamish restored marsh rates. In the Nisqually River delta, USGS has measured elevation gain of approximately 0.5 to 1.0 cm/yr since 2015 (I. Woo, personal communication, March 10, 2021), lower still than the Stillaguamish and Skagit rates but still higher than the rate of sea level rise. All sites so far are demonstrating that marsh restoration in Puget Sound is allowing these marshes to both recover from subsidence and keep pace with sea level rise.

One additional implication of high sediment accretion rates is that high accretion rates allow for high carbon sequestration rates. Our Stillaguamish blue carbon study combined sediment carbon density with sediment accretion rates to estimate a respectable average carbon sequestration rate of 123 g carbon/m^2/yr in the Stillaguamish natural marshes (Poppe & Rybczyk, 2019). Sequestration rates were nearly twice as high in the restored marsh, averaging 230 g carbon/m^2/yr. These high rates were mainly driven by high accretion rates, indicating that restoring the ecosystem process of carbon burial goes hand in hand with restoring resilience to sea level rise, and can be yet another motivation for marsh restoration.

Key messages

- Active deltaic marshes in Puget Sound appear to be accreting enough sediment for maintenance and recovery.
- High rates of accretion also allow for high rates of carbon sequestration.

Literature

Giosan, L., J. Syvitski, S. Constantinescu, and J. Day. 2014. Climate change: Protect the world's deltas. Nature 516:31-33.

NOAA Tides and Currents: Sea Level Trends. National Oceanic and Atmospheric Administration. Available from: https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=9444900

Poppe, K.L., and J.M. Rybczyk. 2019. A blue carbon assessment for the Stillaguamish River estuary: Quantifying the climate benefits of tidal marsh restoration. Summary report prepared by Western Washington University for Washington Sea Grant and The Nature Conservancy. January 2019. (Peer-reviewed article currently in revision).

Online resources

Salish Sea Wiki page on Port Susan. Provides notes, plans, and monitoring reports on the marsh restoration in the Stillaguamish estuary. https://salishsearestoration.org/wiki/Port_Susan_Restoration.

Link to presentation recording https://youtu.be/xPSLqFGhqpw?t=691

Katrina Poppe is an estuarine ecologist with a focus on sediment dynamics and carbon sequestration, often in relation to restoration. She works as a Research Associate with the Wetlands Ecology Lab at Western Washington University in Bellingham, Washington.

Smith Island and Mid-Spencer: Restoration and enhancement in the Snohomish River delta

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Background and context

The 2005 Snohomish River Basin Salmonid Conservation Plan identifies the Snohomish Estuary as an important bottleneck to Chinook recovery. To push the Snohomish Basin nearer to estuary restoration goals, Snohomish County implemented the Smith Island and Mid-spencer estuary restoration projects in 2018 and 2019, respectively. While these projects were related in time and space, they had very different scopes, restoration approaches, and constraints. The Smith Island project was large (greater than 370 acres), expensive (in total nearly $30 million) and complicated (many different funding sources, critical infrastructure built and protected, and intense stakeholder opposition.) Mid-spencer was smaller (74 acres with construction costs around $1.3 million) and because it was publicly owned, un-developed, and tidally connected since the 1960s, met little opposition from stakeholders. The fact that the entire site was tidally influenced did lend itself to construction challenges.

This presentation described these projects as part of the larger Snohomish Estuary restoration effort and provides details about the challenges, solutions, outcomes, and lessons learned for each. It also provided background for a subsequent presentation by Frank Leonetti (Snohomish County) which describes Snohomish County's project monitoring questions, methods, and preliminary monitoring results.

Key messages

- Big projects like Smith Island are hard and expensive but removing constraints to delta processes should be well worth these hardships in the long run.
- For Smith Island, there was no crystal ball to identify all the pitfalls but project partners should have been more prepared to handle controversy and balance stakeholders' demands with restoration commitments.
- On future big projects, we now know we need to:
    - Ensure strong support exists at the highest levels of our organization and is sustained over a very long project implementation timeframe.
    - Identify and address opposition early and throughout the process.
    - Make sure to keep project partners and proponents in the loop and at the ready to step in with broad support at critical decision points.
- The Mid-Spencer project is a great example of an enhancement action that can be implemented with relative ease for a comparatively smaller cost in time and capital.
- For enhancement of already connected estuary, consider methods that provide a light touch. On Mid-Spencer, aquatic excavators provided maximum access with a minimal footprint.

- For projects big and small, restoration is just the beginning. Project monitoring and adaptive management are key to ensuring projects provide the maximum benefit into the future and contribute to the knowledgebase for the next projects in the pipeline.

Online resources

Smith Island Restoration Project Page. Snohomish County WA. https://snohomishcountywa.gov/1150/Smith-Island-Restoration-Project

Mid-Spencer Project Page. Snohomish County, WA. https://www.snohomishcountywa.gov/5417/Mid-Spencer-Island-Restoration-Project

Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=13268

Mike Rustay is a Senior Habitat Specialist with Snohomish County Department of Conservation and Natural Resources (DCNR), Surface Water Management Division. Mike has been involved in Salmon Recovery planning and science in the Snohomish Basin since 2000.

Understanding Shoreline Management Decisions and Incentivizing Living Shorelines Among Private Landowners in the Southeast U.S

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Link to presentation https://youtu.be/jP5S3ZNxJas?t=8656

Steven Scyphers is an Assistant Professor in the Department of Marine and Environmental Sciences and Affiliated Faculty in the Department of Sociology and Anthropology at Northeastern University. Steven's research integrates ecology and sociology and focuses on sustainable shorelines, fisheries, ecosystem restoration, and climate adaptation.

Assessing effects of estuarine restoration on bird populations in North Puget Sound

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Background and context

Puget Sound estuaries support 92 species of birds across multiple taxa, including waterfowl, shorebirds, landbirds, and marshbirds. These species rely on estuarine habitats across their annual life cycle, although the highest diversity and concentrations occur during wintering and migrating periods.

Estuaries have been heavily impacted by development and face new threats such as climate change. Estuarine restoration has been an important conservation strategy to address these impacts for the last decade. Most of the justification and monitoring have been centered on restoring commercially and culturally important salmon populations. We are still learning about the full spectrum of benefits and costs of restoration on other ecosystem components. The lack of information about the consequence of estuary restoration on birds has several implications: 1) increased stakeholder conflict, and ultimately delays, in implementing restoration projects; 2) limited ability to link restoration benefits to national and regional bird conservation objectives; and 3) the absence of information on how the practice of estuary restoration influences bird populations, such as the creation of starter channels, which limits our ability to provide recommendations to achieve shared conservation objectives.

The goal of this project is to quantify the response of bird populations to restoration actions, specifically dike setback. We are conducting the work in North Puget Sound because estuary habitats have been heavily impacted, numerous restoration projects are ongoing or planned, and the region supports significant populations of estuarine birds.

Findings

The project is in the early stages and data analyses have not been conducted yet. We are sampling three types of habitats: pre-restoration sites, restoration sites of various ages, and reference sites. Currently, sampling is being conducted at two pre-restoration, four restoration, and four reference sites. We decided to use a cell-based sampling approach that will allow us to evaluate a number of quantitative methods for analyzing data, including occupancy modeling. We have established 47 sampling cells across our study site. In addition to bird data, we are collecting other habitat predictor variables, such as channel length, and vegetation cover.

We are collecting bird data across four seasonal periods that coincide with their annual cycles: winter, breeding, and spring and fall migration. We use line transects across the cell during winter and migration to survey for waterfowl and shorebirds, conducting three surveys in both low and high tide periods. We use point counts, incorporating a call-broadcast component, from the center of the cell during the winter and breeding seasons for landbirds and marshbirds. Three surveys are conducted for this group during low tide. These methods will allow us to estimate detectability, which is a critical issue as we expect bird detectability to change substantially as habitat changes over time.

For data analysis, our response variables will include individual species, guilds, taxa, and community composition measures. Several predictor variables will be included in our models (e.g., time since restoration, percent water cover, channel length, and vegetation). We expect to conduct two types of analysis. We will conduct a time series analysis, looking at how bird abundance changes over time since restoration. We will also conduct a comparative analysis to evaluate differences between restoration sites and reference marshes.

Although data have not yet been analyzed, we have several hypotheses about bird abundance in relation to time since restoration. We hypothesize that not all avian taxa will respond to restoration actions in a similar manner. For shorebirds, we expect abundance will increase after restoration as agricultural fields turn into nutrient-rich mudflats; but abundance will decrease as estuary vegetation becomes established. Passerine species using the shrubby hedgerows are likely to be the biggest losers when it comes to estuary restoration, although some wetland-associated species like marsh wrens will increase. Finally, we expect secretive marshbirds to begin using restoration sites as the vegetation becomes established.

Key messages

- This study will improve our understanding of the effects of estuary restoration on birds. Specifically, results will:
  - Help reduce conflict by informing estuary stakeholders about the consequences of restoration on birds. These groups have an interest in what is happening to birds and keeping them informed will ensure they are connected to long-term recovery objectives.
  - Quantify and link the contribution of estuary restoration to large-scale bird conservation objectives.
  - Inform estuary practitioners on the best techniques to monitor birds at restoration sites.
  - Provide recommendations that contribute to the science and practice of estuarine restoration.

Literature

Bayard, T., G. Slater, K. Spragens, and A. Summers. 2019. Recommendations for a Puget Sound estuary monitoring strategy. A synthesis report to the Puget Sound Ecosystem Monitoring Program and Puget Sound Partnership. Tacoma, WA. https://pspwa.box.com/v/Bayard-avian-strategy.

Koberstein, M., G.L. Slater, T. Bayard, and T. Hass. 2017. Avian monitoring in support of the estuaries vital sign in Puget Sound: inventory and assessment. Report to the Puget Sound Partnership, Tacoma, WA. https://pspwa.box.com/v/Koberstein2017.

Michel, N., T. Bayard, A. Summers, G. Slater, and K. Spragens. 2020. Avian habitat suitability models for Puget Sound estuary birds. Prepared for the Puget Sound Ecosystem Monitoring Program, Puget Sound Partnership. Tacoma, WA. https://pspwa.app.box.com/v/AvianHabModel

Online resources

2021 Avian Habitat Suitability Models Story Map with interactive viewer.
https://storymaps.arcgis.com/stories/3ceca87f5e544265aee6d516ee95aec9

Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=17010

Gary Slater's passion for birds began as a child watching chickadees at the family bird feeder. Gary received a B.S. in Wildlife Science from Purdue University and a M.S. in Wildlife Ecology from the University of Florida.

Qwuloolt restoration project: Monitoring the response to restoration

Todd Zackey[1], Josh Chamberlin[2], Casey Rice[3], Michelle Totman[1], Holly Zox [4], Jason Hall [5], David Bailey[1], Molly Alves[1], Eric Grossman[6]

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Background

The Qwuloolt Restoration project is an estuary restoration project in the Snohomish River Estuary completed on August 28th, 2015 with the reintroduction of tidal waters to approximately 340 acres of former farmland. Pre-restoration monitoring of the site and surrounding reference sites began in 2009 with post-restoration monitoring beginning in September 2015. The monitoring framework for the Qwuloolt Estuary restoration project was developed through consultation of several sources and with relevant project partners (e.g., Simenstad et al. 1991; Thom and Wellman 1996; Elzinga et al. 2001; Neckles et al. 2002; Thayer et al. 2003; Rice et al. 2005; Roni et al. 2005; Diefenderfer et al. 2011; Thom et al. 2007; Hood 2009; Roegner et al. 2009). The vision for this monitoring program was to develop an intensive project-scale monitoring framework focused on key monitoring elements that were nested within a landscape-scale framework with shared core monitoring elements. This approach was designed to allow project-scale responses to be evaluated within the context of larger landscape-scale patterns and trends, and to establish a monitoring framework applicable and adaptable to other projects as they are implemented throughout the delta. In this way, the monitoring framework would provide a consistent long-term project- and system-scale framework from which responses at an individual project level and a cumulative ecosystem level to multiple projects across the landscape could be evaluated using a core suite of monitoring elements and standardized protocols.

Findings

The monitoring effort at the Qwuloolt site includes monitoring of abiotic (sedimentation/subsidence, elevation/bathymetry, hydrology, water chemistry, and groundwater) and biotic (fish with a focus on juvenile salmon, Chinook in particular, vegetation, birds, and invertebrates). Monitoring methods can be found in Rice et al. 2005, Hall et al 2019, and the 2013 Quality Assurance Project Plan: Monitoring ecosystem response to restoration and climate change in the Snohomish River estuary.

Fish

- Fish assemblages post-restoration are more similar to the adjacent slough channel than pre-restoration.
- Chinook densities in the Qwuloolt site were more similar to adjacent slough channels than other off-channel (blind tidal channels) sites.
- Chinook fry densities were lower in the Qwuloolt site than at reference sites and it appears that high-velocity waters ebbing and flooding out of the Qwuloolt site are acting as a barrier/deterrent for Chinook fry to enter the site.
- Chinook parr densities were similar to the adjacent slough channel but did not match reference blind tidal channel reference sites.

Bathymetry

- Significant erosion at the mouth of the restoration site due to large water volumes and high water velocities flowing in and out of the site causing scouring and redistribution of eroded material around the site and in adjacent blind tidal channels.

Elevation

- From the elevation data (RTK GPS profiles, LiDAR data, and orthophoto derived elevations) there has been some elevation loss in some areas near the breach site otherwise the site's elevation has not changed significantly since the dike was breached.

Sediment Accretion

- Most reference rod sediment elevation table and marker horizon (rSET/MH) data shows on average a modest amount of accretion but not sufficient to keep up with SLR this data set may take a couple of decades to provide clear accretion rates and trajectories for the Qwuloolt and reference sites.

Vegetation

- Pre-restoration the site was dominated by invasive vegetation, reed canary grass and Himalayan blackberry.
- Post restoration within 2-3 years most of the invasive species died off and Qwuloolt was primarily mud flat.
- 2-3 years post-restoration we saw the expansion of marsh vegetation in the higher elevations areas.
- 4-5 years post-restoration we have seen the colonization of the lower-lying mud flat areas by brass buttons and native small spike rush.

Birds

- One year after restoration there was up to a 25-fold increase in the average observed number of birds per survey, with the largest increases seen in granivores, then carnivores, then omnivores then insectivores, and then herbivores.

Groundwater

- The presence of tile drains delays the die-off of pre-restoration invasive species and the establishment of native marsh vegetation.

Key messages

Lesson Learned

- Fish assemblages inside Qwuloolt are following the expected recovery trajectory.
- Water velocities seem to be limiting fry Chinook use of Qwuloolt.
- Surface elevations inside Qwuloolt are static or slightly increasing.
- Current observed sedimentation rates will not keep pace with SLR.

Data Gaps

- System-wide and project level sediment budget for the Snohomish River Estuary.

- Post-restoration hydrodynamic analysis to determine if predictive models match post-restoration observations.
- Modeling of future climate scenarios to help guide restoration design and strategies.

Literature

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Thom, R. M., and K. F. Wellman. 1996. Planning aquatic ecosystem restoration monitoring programs. IWR Report 96-R-23, Institute of Water Resources, and Waterways Experimental Station, U.S. Army Corps of Engineers, Alexandria, Virginia, and Vicksburg, Mississippi.

Online resources

USGS website about rSET/MH https://www.usgs.gov/centers/eesc/science/surface-elevation-table?qt-science_center_objects=3#qt-science_center_objects

Qwuloolt Restoration Project Website. https://www.qwuloolt.org/

Link to presentation recording https://youtu.be/jP5S3ZNxJas?t=12364

Todd Zackey has been working at Tulalip for 18 years and is the program manager for the Tulalip Tribes Natural Resources Marine and Nearshore Program. His work has been focused on restoration monitoring of the Qwuloolt Restoration Project and use of the Snohomish estuary by juvenile salmon.

5.3 Embayments

Bridging worldviews in the Salish Sea

Jennifer S. Arnold, Ph.D.[1], Althea Wilson, B.S.N.E.S.[2]

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Background and context

Our work guides researchers and restoration practitioners toward deeper self-reflection to understand the personal work needed to authentically engage people and communities most impacted by environmental degradation, who have the most at stake for restoration. Specifically, we speak to bridging western science and indigenous knowledge to better understand and restore the Salish Sea recognizing the critical role of tribal co-managers.

As a first step, we acknowledge that each person's work is shaped by their worldview. We must each reflect on this and talk about it. Yet this can run counter to dominant scientific traditions whose concept of valid knowledge is anchored in the objectivity of researchers. According to this worldview, objective scientists simplify complex systems into attributes and processes for hypothesis testing to arrive at optimal solutions and a blueprint for action. Who you are is not considered relevant. Applying this positivist theoretical perspective to social science is especially problematic. Seeking to describe "human systems" and behaviors in order to change them is laden with assumptions about who knows what's best for others.

Indigenous knowledge and other ways of knowing emphasize that who you are and your connection to place and community fundamentally matter. It influences how questions are asked, information is gathered and findings are applied to decision-making. To be more inclusive, scientists and practitioners need to create time and space to develop relationships, be more aware of their own worldview, assumptions and identity in relation to others and be open to changing core assumptions embedded in their work.

Findings

We start by briefly introducing our own worldviews.

My name is Tli'nuk'dzwidzi. It means "she who hosts." My name originates from the KwaKwaKawak people of Northern Vancouver Island British Columbia. I received this name as part of a Dowry at the ceremonial wedding. My father is the late Cluxten, James Wilson a Hereditary Chief from the L'amalche First Nations Band in British Columbia. My father's mother was Margaret Solomon Casimere of the Lummi Nation.

My mother is the late Roberta Hunt Wilson she is the direct descendant of Anislaga, Mary Ebbetts who was Tlingit from the Double Headed Raven Clan originally from Wrangell Alaska, and the daughter of Chief Shakes. I call myself a native woman born of matriarchs. With my natural traits, I was born with a certain amount of responsibility. My work has everything to do with integrating science, sense of place and cultural ways of being (Wilson 2020).

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I am Jennifer Arnold. My ancestors include English colonial settlers and German and Polish immigrants with generations of strong female leaders. I moved a lot growing up and enjoyed connecting to people. I was exposed to social justice from a young age and noticed how racial segregation and injustices took different forms in different places. As I developed my career as a natural resource scientist and planner, I *focused on critical, participatory research methods as a framework to work in solidarity with others to ask questions and build understanding to create the inclusive, equitable world that I want to be a part of (Arnold and Fernandez-Gimenez 2008; Arnold and Fernandez-Gimenez 2007).*

Before the invasion of the Europeans, the original people of an inhabited place had a way of educating their own people, not by indoctrination but through experience in the natural world and a sense of responsibility to the community and families (Deloria 2001). With these invasions came many different views. From the stand point of the invaders, these discovered people were not civilized and they needed to be educated in western worldviews.

Western science does not give equal credit to indigenous knowledge or traditional native technology, often claiming it as a historical remnant or extracting what is of use to western science (Tuhiwai Smith 1999). When a scientist interviews people to fill in the boxes of a conceptual framework, they are asking people to fit within or measure up to their framework. For people who have felt the oppression of colonization, whose way of knowing is holistic and relational, these interview questions are not worth answering (Tuck and Wayne Yang 2014).

We offer examples of alternative approaches that give us hope (e.g., Wilson 2020; Fernandez-Gimenez et al. 2006; Frank 2016; Arnold and Fernandez-Gimenez 2007).

Key messages

- Hope – We believe it is possible for scientists and restoration practitioners to build trust and open dialogue by being transparent about one's own worldviews, openly questioning one's assumptions and inviting others to co-create foundational concepts and visions that are resourced and implemented. It takes a great deal of patience, commitment and intentionality. It is a journey at all levels. It is inter-generational work.
- Internal reflection – Continually reflect on core aspects of your identity in relation to others, your worldview and assumptions about objectivity and the "right" way to frame problems and solutions. Prepare yourself to be uncomfortable and recognize that it may be hard to hear and understand other people's truths, especially if you are coming from a relative position of privilege.
- Relationship building – Dedicate substantial time to relationship building, including reflection and intentionality around who to engage and why and what kind of relationship is desired. Stay open to making changes to core assumptions and framing as a result of listening and learning, including power-sharing and changing roles.
- Cultural ways of being – Dedicate time to learning about cultural ways of being in the Salish Sea by doing one's own research and attending public events hosted by tribal communities or volunteering as an ally if invited. Stay open to invitations to share in cultural events and offer invitations for cultural exchange and reciprocity, as appropriate. If relationship building leads to a co-created research or restoration projects, dedicate resources and attention to honor cultural ways of being and practice reciprocity with the natural world and community, for example investing in gifting, sharing food or witnessing.

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Jennifer Arnold, Ph.D. leads applied research, facilitation and training to help groups learn together and make decisions together in the context of complex social-ecological challenges. Her work embraces diverse ways of knowing and the power of engaging people most impacted by policies and decisions.

Althea Wilson is a Native American environmental scientist, basket weaver and filmmaker from the Lummi Nation. Her work focuses on indigenous knowledge in the Salish Sea, social justice and wellness.

Three crazy concepts for nearshore restoration in the 21st century

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Key messages

In this presentation, I introduce three ideas that run counter to broadly accepted beliefs and practices that underlie nearshore restoration and funding.

- Only since the late 1980s has the value of large wood to stream habitat been broadly recognized. In a similar fashion, large wood deposited on beaches of Hood Canal and elsewhere may form critical habitat for salmon and other nearshore species. Yet, much of the wood has been removed. In a 2018 study, Gordon and Bahls documented the close relationships between plainfin midshipman, suitable spawning areas such as occur under large oyster clumps and logs, and spring convocations of eagles that gather to feed at specific beaches with suitable spawning habitat for the fish. Adding large wood to nearshore habitat may be an important restoration action, similar to "artificial reefs" and more research and pilot studies are needed.
- For decades, the Salmon Recovery Funding Board (SRFB) funding for nearshore restoration in Hood Canal has been guided by the Hood Canal Coordinating Council's strategy that the most important nearshore habitat for juvenile summer chum and Chinook is close to the mouths of the natal rivers where they emerge. Yet, field research and survey studies starting in 2004 (see Literature), demonstrate that this is not the case for summer chum salmon, which can migrate miles along the shore within hours of emergence and were widely distributed in Hood Canal. The studies indicate that non-natal embayments such as Tarboo-Dabob Bay are quite important to summer chum rearing. Policy and funding need to be guided by the weight of the evidence and best available information, even when they overturn long-established paradigms.
- In Tarboo-Dabob Bay, Northwest Watershed Institute and over 40 partnering organizations have been working for nearly 20 years on a landscape-scale strategy to protect and restore nearshore habitat by protecting the larger estuarine ecosystem. Over 4,000 acres, including over 40 individual parcels, have been protected as part of the state's expanded Dabob Bay Natural Area. Many of the most impacted shoreline parcels have been restored with ESRP and other funding. Yet, grant programs tend to continue to focus on the relative importance of specific parcels, with too little weight given to the larger conservation context. This can make it difficult to fund the low priority parcels that are essential in the long run to the integrity of the larger conservation effort. While a funding strategy of prioritizing low-hanging fruit makes sense in many respects, there is also a need to recognize the value of a proposed funding site as part of the larger ecological and conservation context.

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Peter Bahls is the Director of Northwest Watershed Institute. He earned an M.S. in Fisheries Science and Aquatic Ecology from Oregon State University and has been focused on researching, protecting, and restoring Tarboo Creek and Dabob Bay for nearly 20 years.

Non-natal estuary and small stream rearing of juvenile Chinook salmon associated with inland marine waters of northern Puget Sound

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Link to presentation recording https://youtu.be/85a0tr7qbDk?t=2100

Eric Beamer is the Research Director for Skagit River System Cooperative, where he has worked examining salmon freshwater, estuarine, and nearshore ecology since 1984. Eric is the principal investigator in the following fields of research: landscape processes influencing habitat conditions; identification of juvenile Chinook salmon life history patterns; identification of factors influencing wild Chinook salmon production; use of natal estuaries, non-natal estuaries, and small streams by juvenile Chinook salmon; and monitoring effectiveness of estuary restoration projects for Chinook salmon recovery.

Criteria for restoring the primary tidal channel in barrier embayment systems

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Background and context

Many barrier embayments in Puget Sound have been impacted by development and restorations are performed because these systems can provide important habitat for juvenile fish, birds, wildlife, and can improve water quality.

Currently, there are no accepted guidelines for the restoration design of tidal estuaries in Puget Sound. Early Puget Sound-wide restoration planning work conducted in the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) scaled hydraulic geometry relationships developed for San Francisco Bay to tide range in Puget Sound (PSNERP 2011). However, the differences between San Francisco Bay and Puget Sound are substantial and limit the utility of the PSNERP scaled hydraulic geometry relationships for restoration design. Puget Sound and San Francisco Bay differ in terms of sediment composition, tide range, rainfall, and differing salinity distribution and plants.

This research project addresses the lack of tidal channel reference data needed to efficiently design restoration of barrier embayments in Puget Sound. The project used detailed field data collection methods and geospatial desktop analysis to inventory parameters and tidal channel geometry of 18 intact barrier embayments. The data were used in a multivariate regression analysis to identify the best predictors of tidal channel geometry and build models to apply to restoration design. Parameters evaluated include outlet cross-sectional area, depth, and width, marsh area, and tidal prism. The project also identified and evaluated geomorphic factors such as wind-wave energy, sediment composition, shoreline orientation, and average elevation to understand the drivers for the formation of dominant habitat types within the estuaries.

Findings

Several evaluations of tidal channel hydraulic geometry have shown that outlet cross-sectional area, depth, and width are correlated with marsh area and tidal prism (Williams et al. 2002; Hughes 2002; Hood 2015). Tidal prism is often defined as the volume of water entering an estuary on a flooding tide (Williams et al. 2002; Hood 2007). Tidal prism can also be defined as approximately the area of the embayment multiplied by the mean tidal range of the embayment (NOAA 1999; Hughes 2002).

Through an Estuary and Salmon Restoration Program (ESRP) Pre-planning project, definitions, and methods for calculating marsh area and tidal prism for Puget Sound barrier embayments have been developed and vetted through technical review (Côté et al. in preparation). The evaluation of barrier embayment tidal channels for Puget Sound has shown that tidal prism is a better predictor than embayment marsh area of the primary tidal channel hydraulic geometry (cross-sectional area, width, and depth). It is important to note that these parameters were evaluated at mean higher high water (MHHW) local to the site to scale appropriately. In the absence of tidal prism information, marsh area defined as the area submerged up to the mean higher high water (MHHW) elevation can be used as a proxy but will underpredict the optimal geomorphic tidal channel dimensions.

Additional variants (factors) were considered in the regression analysis to determine factors that are significant to the model predictions such as sediment supply, freshwater input, wind-wave energy, and freshwater input. The analysis identified sediment supply and shoreline orientation as key factors to predicting the geomorphology of the barrier spits fronting the barrier embayment and the sustainability of the tidal channel dimensions. The regression analysis found fetch distance (wave power) was not an important parameter in determining the potential for tidal channels to remain open for Puget Sound although it has been used in other regions (Williams et al. 2002).

Freshwater input and the average elevation within the marsh area were not significant factors in the regression analysis, but the data suggest these factors might be important in predicting the dominant ecology of the embayment. Beamer (in preparation) has identified three dominant habitat types within barrier embayments which include marsh, mud flat (or tide flat), and impoundment. These habitat types have been used to classify the embayments inventoried for this project, and field observations suggest freshwater input and higher elevations are correlated with marsh systems. Lower elevations are correlated with impoundments and lack of freshwater input is correlated with tide flats. However, there is an insufficient sampling of each of the three types to confirm these hypotheses at present.

This research is being applied to barrier embayment restoration design in Puget Sound by the research team.

Key messages

- Tidal prism and marsh area at MHHW are the key physical parameters required to determine the appropriate tidal channel dimensions for barrier embayment restoration design.
- Shoreline orientation and available sediment supply are important to determine the geomorphology of the barrier spits (overlapping, single alongshore, or parallel).
- Freshwater input is not a key factor in determining primary tidal channel dimensions but is hypothesized to be a key factor in determining dominant habitat type.
- Primary control over interior habitat types of embayment systems as marsh dominated, mud flat dominated, or impoundments are hypothesized to be average site elevation and thalweg elevation but require additional data to confirm.
- Reference sites with similar geomorphology in the same sub-basin combined with regression models are the preferred method for designing the restoration of barrier embayment tidal channel.

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Jessica Côté is a Coastal Engineer and Geomorphologist who has been conducting research on the dynamics of Puget Sound beaches for 15 years. She has been applying her expertise in sediment transport to determine the key design considerations for reopening and restoring tidal channels in barrier embayment systems over the last four years.

Mapping nearshore nodal habitats

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Link to presentation recording https://youtu.be/ESf48q7v6Rs?t=2458

Hans Daubenberger has been a research scientist with the Port Gamble S'Klallam Tribe since 2006. His work has focused on projects intended to provide information, opportunity, and direction to the restoration community, fisheries management, and the fishers of the Port Gamble S'Klallam Tribe.

Seagrass restoration: some success with challenges ahead

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Background and context

Seagrass transplants can complement process-based restoration by reintroducing these essential marine plants into recruitment limited areas. Seagrasses are considered ecosystem engineers and will perpetuate conditions towards increased system productivity and resilience (Carr et al. 2012). Successful transplants will eventually restore ecosystem processes commonly found in natural seagrass systems (see Conceptual Model for Revegetation, Clancy et al. 2009).

A number of embayments throughout greater Puget Sound previously supported eelgrass, which provided critical ecosystem functions for a variety of organisms. These include Quartermaster Harbor, Westcott Bay, Blind Bay, and Port Gamble Bay to name a few. There is a long record of seagrass presence documented in Westcott Bay, Port Gamble Bay, and Quartermaster Harbor from Washington Department of Fish and Wildlife's (WDFW) herring spawn surveys and other research and monitoring efforts (Dethier and Ferguson 1998, NewFields 2007). The WDFW surveys extend back as early as the 1970s with evidence of seagrass presence throughout these embayments (Shelton et al. 2017), along with abundant herring spawn biomass (Sandell et al. 2019).

The ShoreZone Inventory (2000) also identified the presence of eelgrass in these embayments in the late 1990s. Shortly thereafter, significant declines in eelgrass area were documented throughout Westcott Bay and Quartermaster Harbor (Gaeckle et al. 2008, Gaeckle 2009) and in Port Gamble Bay (Vavrinec and Borde 2015).

The observed eelgrass loss has generated an interest to restore this critical habitat as one step to recover embayments and ecosystem health throughout greater Puget Sound. However, eelgrass restoration efforts in these areas have not been successful.

Findings

Seagrass restoration has made many advancements with the development of site selection models (Hotaling-Hagan et al. 2017, Lanura et al. 2018, Short et al. 2002, Thom et al. 2018) and effective transplant methods (Fonseca et al. 1998, Fonseca et al. 2011, Paling et al. 2009, Tan et al. 2020). However, seagrass restoration is not always successful due to a range of confounding factors (Fonseca 2011, Moksnes et al. 2018, Paulo et al. 2019).

Over the last two decades, eelgrass has been transplanted with different methods and donor sources in Westcott Bay, Port Gamble Bay, and Quartermaster Harbor with limited to no success. In Westcott Bay, eelgrass was transplanted in 2007 (Schanz et al. 2010), 2013 (Vavrinec et al. 2014), 2017 (Gaeckle 2021), and again in 2020 (unpublished data). Test plots closer to the mouth of Westcott Bay and greater water circulation survived while all other transplants failed within 6-12 months after transplanting. At three years post transplanting, the shoot survival rate was less than 25%. In Port Gamble Bay, eelgrass was transplanted in 2014 and 2015 with some initial success (Vavrinec and Borde 2015) but eventually complete failure. In Quartermaster Harbor, eelgrass was transplanted along a spatial gradient from the mouth towards the head of the embayment in 2018. The site closest to the mouth of the embayment with the greatest water exchange performed the best (Gaeckle 2021). Additional sites were test transplanted in 2021 with complete failure two weeks post transplanting (unpublished data).

There is some commonality in all three of these embayments. Westcott Bay, Port Gamble Bay, and Quartermaster Harbor have experienced many different human uses, yet eelgrass has declined and restoration has not been successful at the heads of each embayment, in areas of low flushing rates and longer residences times. Whether it was a single disturbance or the combination of multiple drivers, recovery from the new stable state to previous conditions did not occur. These changes are likely from a combination of factors that have caused a shift from stable seagrass systems to a different community with poor ecosystem functions and lower biodiversity (Moksnes et al. 2018, Montefalcone et al. 2015).

Future research should focus on factors within these embayments that limit seagrass recovery, such as human modifications of sediment, water circulation, water quality, and water clarity.

Key messages

Although there have been great advancements in seagrass restoration techniques, there are areas that continue to fail even when taking into account different methods, donor sources and time of planting.

- In the recent past, many shallow embayments in Puget Sound supported eelgrass and diverse fauna that used this critical nearshore habitat. However, efforts to restore eelgrass and natural system processes in three embayments (e.g., Westcott Bay, Port Gamble Bay and Quartermaster Harbor) have failed.
- Each of these embayments has experienced a shift to an un-vegetated stable state. The effect was most pronounced in areas with low circulation. At these locations, we need to restore sediment and water quality to promote eelgrass recovery.

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Submerged Vegetation Monitoring Program website, WA State Department of Natural Resources. https://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science/nearshore-habitat-eelgrass-monitoring

Eelgrass Stressor-Response Program website, WA State Department of Natural Resources. https://www.dnr.wa.gov/programs-and-services/aquatics/aquatic-science/nearshore-habitat-eelgrass-stressor-response-project

Link to presentation recording https://youtu.be/85a0tr7qbDk?t=7462

Jeff Gaeckle completed his dissertation at the University of New Hampshire, while he worked on eelgrass restoration and monitoring projects throughout the northeastern US and traveled the world monitoring seagrass distribution and status for SeagrassNet, a global seagrass monitoring project. Jeff joined the Washington State Department of Natural Resources in 2006 as a seagrass ecologist and leads DNR's Eelgrass Stressor-Response Program and the Seagrass Restoration Program with a focus on eelgrass restoration among other seagrass research throughout Puget Sound.

Indigenous shoreline management in the Salish Sea: The view from archaeology

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Background and context

Archaeological research in the Southern Gulf Islands (Strait of Georgia, British Columbia) of the Salish Sea over the past decade has revealed that shorelines were constructed by Indigenous peoples over the last five millennia (Grier et al 2009; Grier 2014). Investigation of archaeological sites on these shorelines shows that shell-bearing matrix was added and manipulated to produce a variety of resource production features, water control systems, and terraced habitation areas at cultural keystone places (Grier et al. 2017; Lepofsky et al. 2017). These construction investments were primarily small-scale and iterative but also involved larger-scale investments that dramatically reshaped and transformed coastlines. These practices created a diversity of microenvironments that promoted sustainability, resilience, and productivity in coastal ecosystems, and fostered long-standing connections to place.

Many of these constructed places are now eroding due to anthropogenic sea level rise, intensified storms due to climate change, and increased marine and terrestrial traffic. These environmental factors are coupled with the alienation of Indigenous peoples from their traditional managerial role in maintaining these places. Cumulatively, these factors are having a significant impact on the coastal archaeological record. Attempts to protect cultural keystone places are being made that are bottom-up in approach, in that they involve local and Indigenous-driven actions and solutions that mirror past strategies and practices (Angelbeck and Grier 2014).

Can we utilize this record of past Indigenous practices and current efforts at shoreline protection, restoration and management to retool our own conceptual approach to shoreline management across the Salish Sea?

Findings

To answer this question, it is useful to recognize that the goals embedded in past Indigenous management practices are the same that we all share now — fostering resilient, sustainable, productive shorelines. Indigenous practices clearly were successful in achieving these ends over the Holocene. They were resilient to sea level and ecosystem change, and the approach accommodated resource intensification required to meet the demands of high-density human populations.

Accordingly, it is important to draw distinctions between two idealized and opposing strategies (and related practices) for shoreline management. The first can be referred to as “interventionist” and can be described by several key attributes: singular, transformative, outcome-driven, restorative, and transactional. A second can be thought of as “managerial” and can be characterized by several quite different attributes: iterative, adaptive, additive, managerial, and relational.

Given what we know from archaeology and traditional knowledge, Indigenous practices lean heavily towards the managerial strategy, involving long-term, observation-driven engagements with shorelines to generate a set of recursive practices that promote healthy and sustainable shorelines. Conversely, the seawall and bulkhead-focused “hold the line” strategy represents the “interventionist” strategy, relying on singular interventions designed to solve a narrow problem (usually shoreline stabilization). We now recognize this approaches produces significant impacts to the health of shorelines.

Our current practices are a complex mix of many of these elements. How do we shift our approach more towards a managerial strategy based in practices that have worked for millennia, both in what we do and how we communicate about what we are trying to accomplish? The message is not “go back to the past.” Rather, we must press forward to better manage a developed shoreline that needs significant reconfiguration.

A key first step is to meaningfully partner with Indigenous communities in thinking about ways to approach shoreline restoration and management efforts, to draw on multiple ways of knowing that honor rather than appropriate deep-time vetted knowledge and practices. Adopting a more relational perspective is central here; we must foster long-term, committed engagements with shorelines that seek to identify and amplify what works and move away from what does not.

An equally critical second step is to revise funding priorities to support projects that explicitly adopt a managerial approach to shoreline management, and to discourage singular “quick fix” solutions. Shoreline restoration and management is a process rather than an event.

Key messages

- The archaeological record of the Salish Sea shows indigenous peoples have been constructing and managing shorelines for thousands of years.
- Shorelines were built in an iterative, additive, and adaptive way, incorporating a long-term engagement with places.
- These time-vetted, successful management practices had similar objectives to those today — to create sustainable, resilient and productive shorelines.
- We can retool our approaches to shoreline restoration and management to reflect more of a managerial strategy involving persistent engagements with shorelines that honor time-vetted and successful Indigenous strategies.

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Link to presentation recording https://youtu.be/ESf48q7v6Rs?t=1551

Colin Grier is an archaeologist and an Associate Professor in the Department of Anthropology at Washington State University. His research focuses on Coast Salish resource management strategies, the construction of cultural keystone places, and how these practices relate to social change. His research takes a long-term perspective, drawing heavily on the archaeological record of the Salish Sea over the last 10,000 years.

How can we show we are making a difference?

Mendy Harlow[1]

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Background and context

The Hood Canal Salmon Enhancement Group (HCSEG) has been working to restore salmon habitat throughout Hood Canal since 1990. Our work varies from smaller projects such as culvert replacements to larger estuary restorations. As we have begun to take on larger, more expensive projects, we have begun to see the need to collect pre- and post-project monitoring in order to show whether or not our restoration work is having the desired restoration outcomes. Funding for such monitoring efforts is hard to come by and to resolve this problem, HCSEG utilizes volunteers and interns to collect our monitoring data.

Key messages

- Large estuary restoration projects need pre- and post-project monitoring to show impacts to ecosystem recovery.
- Monitoring efforts are difficult to fund after the implementation phase of habitat restoration projects.
- Partnerships with colleges, universities and local communities are important to implement effective pre- and post-project monitoring at a lower cost.

Online resources

Hood Canal Salmon Enhancement Group. www.pnwsalmoncenter.org

Link to presentation recording https://youtu.be/ESf48q7v6Rs?t=3340

Mendy Harlow has focused the majority of her time with the Hood Canal Salmon Enhancement Group on managing small- and large-scale habitat restoration projects throughout Hood Canal. Mendy became the executive director in 2013, but has not left her passion for managing meaningful restoration projects behind.

Barrier embayment restoration planning: two examples from the West Sound

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Background and context

Mid Sound Fisheries Enhancement Group is sponsoring two barrier embayment restoration projects located within the same drift cell on the northeastern shore of the Kitsap Peninsula. One project occurs on 32 acres in a Kitsap County Park, the other spans 3 acres across two private properties, and both are currently in the planning and design phase. The presentation explores common themes and differences between the two projects that have influenced project funding and design considerations.

Key messages

- Local and regional prioritization: Both the Rose Point and Point No Point estuary restoration projects are identified as regional priorities for the East Kitsap/West Sound watersheds, an important factor in successfully funding and building partner support and engagement. Both project sites are identified in the PSNERP Lost Embayments Strategy, and the West Sound Nearshore Integration and Synthesis of Chinook Salmon Recovery Priorities ranks Point No Point as the highest priority nearshore project and Rose Point as number 25, out of a total of 420 projects.
- Lead entity support: Lead entities are the local organizations that develop and coordinate the implementation of salmon recovery strategies. The West Sound Partners for Ecosystem Recovery (WSPER) Lead Entity has been critical in recognizing these two projects as highly beneficial both for local salmon recovery efforts and for restoring nearshore ecosystem functions and supporting Mid Sound in seeking funding to develop the projects.
- Time invested early is time well spent: While the Rose Point project is entirely on private property and the Point No Point project is within a Kitsap County park, both can proceed because of supportive landowners. Time was invested early on by Mid Sound and others, including WDFW and Kitsap Shore Friendly, to gain the support of landowners before any major steps toward design development were taken. In addition to landowner engagement, Mid Sound has consulted with multiple partners and technical advisors in project planning from the beginning, including local, state, and federal agencies, tribal natural resources and historic preservation staff, and local community groups. The willingness of so many partners to share their knowledge and provide input early in the process on both projects has enabled us to develop plans and conceptual designs for moving forward that are likely to be technically successful and broadly supported.
- Room to restore: While the sizes of the two projects are very different, both have enough space on the landscape available for barrier embayment restoration to be technically feasible. Point No Point has more infrastructure-related constraints compared to Rose Point, however, the unique coastal processes at this location will allow us to design a self-sustaining barrier embayment with a different configuration compared to its historical condition.
- Intact coastal processes: Both projects are located within a largely intact drift cell, with south-to-north sediment transport. We know that the sediment supply will support the formation of barrier

spits once an appropriately-sized tidal channel is restored. Our conceptual plan for Point No Point includes opening tidal connection to the eastern shore, rather than its historical opening to the north. The proposed altered configuration is only possible because of the intact coastal processes along the eastern shore and is critical to the success of the project because it avoids impacts to infrastructure (roads, homes, park access) and cultural resources known to be present along the north shore.

- Historical shoreline context: Analysis of t-sheets and historic photos of both project locations provided important context from which to begin our conceptual design efforts. The Rose Point project started as a Shore Friendly bulkhead removal on one property, however referencing the t-sheets revealed the historic barrier estuary shore form and footprint that spanned the neighboring property as well. The historical context allowed us to recognize the true potential of the site and coordinate with the neighboring property owner to be able to include the full embayment footprint in our planning and design. At Point No Point, we learned from early consultations with tribal archaeologists that the area around the historic tidal channel and the north shore should not be disturbed because of the presence of cultural resources, but that restoration to the east would be a good alternative. We also learned that Point No Point was historically an important area for foraging and gathering native plants, and restoring the opportunity for this to occur again is an element we plan to include in our future restoration designs at the site.

Online resources

Mid Sounds Fisheries Enhancement Group. https://www.midsoundfisheries.org/

Link to presentation recording https://youtu.be/85a0tr7qbDk?t=4771

Sara Heerhartz, as the executive director of the Mid Sound Fisheries Enhancement Group, leads a small (growing!) and dedicated staff in coordinating habitat restoration and conservation projects with local and tribal governments and agencies, other nonprofits, community groups, and landowners across marine, estuarine, and freshwater habitats of the central Puget Sound region. Sara's priority beyond the execution of these projects, is to build community around habitat restoration and salmon recovery for the benefit of the vibrant and diverse landscapes, wildlife, and people of the Puget Sound region.

Access to recreational shellfish and its implications for environmental justice in the Puget Sound

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Background and context

Shellfish and shellfish harvesting are extremely important to the cultural and economic vitality of the Puget Sound region of Washington State (State of Washington, 2011). Shellfish beds and recreational shellfish harvesting have been declared priority indicators for ecosystem health and recovery monitoring by the Puget Sound Partnership (Partnership), a government agency responsible for coordinating ecosystem recovery in the Puget Sound region. The Partnership set a goal to increase the harvestable acreage of tidelands that support safe, edible shellfish by 10,800 acres between 2007-2020, of which 7,000 acres were to be accounted from previously prohibited harvest areas, and they have dedicated between $27 to $41 million to their Shellfish Strategic Initiative (Puget Sound Partnership, 2018). These actions stem from the fact that Puget Sound is considered to have some of the most valuable shellfish habitat in the country, but harvesting areas are frequently closed due to health concerns (Anderson and Plummer 2016). As is becoming more common globally, the Pacific Northwest has seen increased harmful algal blooms (Moore et al. 2020) as well as pollution-based closure events (Anderson and Plummer 2016). Environmental leaders have also recognized the inequitable effects that environmental risks, including those which affect shellfish harvesting, will have on vulnerable groups such as Indigenous communities (Puget Sound Partnership, 2018). Limits to shellfish harvesting, legislative support for environmental justice actions (Washington State Environmental Justice Task Force 2020) and requests for mapping tools make Puget Sound an ideal study area to geovisualize and assess the relationships between shellfish harvest closures, harvest frequencies, and race using spatial techniques.

Findings

We found that the strongest relationship tested was a negative correlation between the duration of total recreational shellfish harvest closures and the reported frequency of individual shellfish harvests, and that this relationship was driven primarily by biotoxin closures. This finding, consistent with previous research (Anderson and Plummer 2016), suggests that people living in places affected by high-duration closures, especially biotoxin closures, were less likely to harvest shellfish for local food than people in places with low-duration closures. This relationship could indicate that public health advisories were effective in limiting local shellfish harvests during biotoxin closures, or that people living in places with low-duration closures were more likely to harvest shellfish as local foods. People living in the sub-basins most closed due to biotoxins reported harvesting shellfish the least. Those places were the Nooksack, Strait of Georgia, and Dungeness-Elwha sub-basins. In contrast, people living in the sub-basins least closed to biotoxins reported harvesting shellfish the most. Those places were the Hood Canal and Puget Sound sub-basins.

The next strongest relationship tested across watershed sub-basins was a positive correlation between the reported non-white population and the duration of recreational shellfish harvest closures due to pollution. This finding, though not significant, suggests that in 2020, non-white communities were more likely to be living in places affected by high-duration pollution closures affected by land-based processes. This finding is consistent with literature on non-white communities being disproportionately impacted by environmental hazards (Hicks 2020; Jorgenson et al. 2020), often through racist and discriminatory practices of exclusion (Méndez et al. 2020), gentrification, and redlining (Krieger et al. 2020) which may confine marginalized populations to relatively more hazardous locations that could reduce their overall life-chances (Israel and Frenkel 2020).

We found no relationship between the reported frequency of individual shellfish harvests and the reported non-white population. This finding suggests that white and non-white communities alike harvested shellfish as local foods with mostly similar harvest frequencies. We found that people in most sub-basins harvested infrequently in 2020, except for Hood Canal, where residents reported harvesting shellfish much more frequently than residents in other sub-basins. The high harvest frequencies reported in Hood Canal are consistent with previous research which has highlighted the importance of access to shellfish as local foods for Hood Canal residents who live closest to the Puget Sound's most abundant shellfish densities (Biedenweg et al. 2014).

Key messages

- This study highlighted where, when, and how shellfish harvest closures may limit access to shellfish as local food across diverse communities of Puget Sound.
- The duration of shellfish harvest closures, especially those due to biotoxins, may be inversely related to harvest frequencies, implying that biotoxin-affected areas may be prioritized for restoration actions aimed at sustaining access to shellfish as local food.
- Non-white populations may be disproportionately impacted by the types of shellfish harvest closures that arise from land-based run-off processes which close harvestable tidelands due to pollution, conditional, or emergency reasons, implying a need for targeted stormwater and water quality improvements that are informed by engagement with non-white communities.
- The geovisualization tool developed in this study contributes to planning and restoration by aiding site selection and identifying priority areas for follow-up action and engagement with local communities.
- To better understand the local contextual factors that help to explain the differential patterns of shellfish harvest closures, harvest frequencies, and harvester race identified in this study, restoration practitioners could integrate the geovisualization tool in community workshop settings to highlight trends at different scales, and to facilitate discussion on how the trends are explained, and what actions could be taken to reduce risk and equitably improve human wellbeing.

Literature:

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Online resources

"Shellfish Harvest Closure Risk Map: Puget Sound." This map was developed for this research project to visualize Puget Sound shellfish harvest closures and human wellbeing survey responses on shellfish harvest frequencies and harvester race in 2020. The purpose of this map is to identify locations and times that may have implications for environmental justice – through the intersection of frequent harvesters, non-white populations, and high-duration shellfish harvest closures. The map displays circles wherever a shellfish harvest closure occurred in the Puget Sound between 2017-2020. Circles are sized by the duration of each closure, represented as the percentage of days closed per month. Graphs shown in the side panel are synchronized with the map and will dynamically update by panning around or zooming in or out on the map. Graph metrics are recalculated based on the harvest closures that are visible in the current map filter. https://briangkatz.github.io/WA-shellfish-harvest-closures

Link to presentation recording https://youtu.be/ESf48q7v6Rs?t=5093

Brian Katz recently graduated with his M.S. in Geography from Oregon State University, where he now works as a research assistant to David Wrathall and Kelly Biedenweg. Brian creates geovisualization tools to advance research and action at the intersection of human well-being, climate change adaptation, and environmental justice.

Using hydrodynamic modeling to improve embayment restoration options without breaking the bank

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Link to presentation recording https://youtu.be/85a0tr7qbDk?t=3836

Dr. Kathy Ketteridge has more than 20 years of experience in hydrodynamic analysis/modeling and design of a wide variety of habitat restoration projects in coastal, estuarine, and riverine environments. She has spent the last 13 years of her career working on restoration projects in the Pacific Northwest region.

The duty and burdens of supporting impactful restoration

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Background and context

I work with multiple partners to move forward salmon habitat protection and restoration actions. This is done by consulting with watershed partners and working with technical and citizens groups on everything from planning design work and making sure the work is well thought out and feasible, piecing together funding opportunities, and ensuring work is both important for salmon recovery needs as well as important for our communities.

Key messages

- As salmon recovery habitat restoration has evolved, we have been able to take on projects that are much more encompassing of the natural processes we are trying to restore. Some of the most impactful projects are very complex, and they are becoming more and more feasible. We are aiming and taking on restoration actions that are more appropriate in scale to meet our goals. Sometimes this is done as a large project, many times it is in multiple phases and built over time. Both approaches take a lot of time. All these complexities have to be worked out at the project level and it takes a strong stance on the priorities to ensure the resulting project is impactful to recovery efforts.
- Our project proponents are often NGOs, fish enhancement groups, conservation districts, land trusts, and the like. We are asking a lot of these organizations to develop and move forward projects as they have evolved to a large scale and are increasingly complex. We rely on these groups to build stakeholder support, to work through thorny issues, and to keep these projects moving forward. How can we better support this effort? Once feasible, in the sense of being able to develop a design and having stakeholders on board, there is a need to continue the support of project through implementation.
- We need to address the appropriate timescale to utilize funding. These projects require longer timelines to address more complex designs as well as coordination of strategic partnerships and strategic funding sources. Then we need to continue to support all these aspects as they move through permitting processes. How do we keep all these balls in the air? At the very least, we need to be able to say “it is an important project.”
- We need to invest in the feasibility of larger picture priorities. Having the appropriate data and analysis is important for communication and education purposes to garner support for protection and restoration actions to happen.
- We need leaders to take a stance on priorities. That stance supports practitioners who implement restoration priorities. Encourage and support leadership in taking a stance on priorities. Regional Salmon Recovery Organizations need to have clear priorities to guide impactful recovery efforts, allowing support of large-scale (reach) actions at multiple stages (feasibility, planning, funding, implementation, permits, etc.). This can also happen at a smaller scale as watershed partners

work in a "bit by bit" approach to achieve a larger action. But they need the support and guidance to get those difficult pieces (holdouts) in place to make it all work in concert.

- Without the stance on priorities, the priorities become project-level actions that are limited to opportunistic circumstances and are limited in scope for the funding source. These projects are not necessarily the complete picture. Let people know what the priorities are beyond the project scale and how the various actions are working in concert with one another.

Link to presentation recording https://youtu.be/ESf48q7v6Rs?t=5954

Alicia Olivas works with community stakeholders, citizens, partner organizations, and member governments to assure sound science and community values guide the implementation of salmon recovery projects in the Hood Canal region.

Restoration planning at coastal streams and embayments along the railroad

Paul Schlenger[1], Phil Bloch[2], Todd Zackey[3]

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Background and context

The railroad right-of-way is a prominent modification along the eastern shore of the Washington portion of the Salish Sea. It runs along 52 miles of the shoreline, while another 73 miles of railroad is within 200 feet of the shoreline. In many places, the railroad bisects the mouths of coastal streams and embayments which impacts the quantity and quality of nearshore habitats and fish access to coastal streams. Because nearshore restoration along the railroad is expensive and requires extensive planning, restoration efforts should be focused on areas that would provide substantial benefits to fish habitat and nearshore processes. In order to identify these locations, this project inventoried and prioritized the nearly 200 stream mouth crossings and 13 embayments along the railroad between the Nisqually delta and Canadian border. At each site, field data were collected on downstream habitat, crossing characteristics, and upstream habitat. The prioritization focused on the potential benefits for juvenile Chinook salmon based on the likelihood of use and upstream habitat quality. To guide the development of the prioritization framework, an advisory team was formed which included representation by Burlington Northern Santa Fe (BNSF), WDFW, Ecology, and Snohomish County. Seventeen streams were identified as the highest priorities for restoration. In early 2021, a follow-up project focusing on implementation planning got underway. The work includes preliminary design evaluations for three of the highest priority sites, recommendations for conceptual restoration treatments among four coastal stream categories, and initiation of a regional dialogue with BNSF and regional leaders on restoration planning along the railroad.

Key messages

Habitat restoration along the railroad is important because of the extent of Puget Sound shoreline impacted (railroad on shoreline for 52 miles and within 200 feet of shoreline along additional 21 miles).

- Coastal streams and embayments impacted by the railroad were prioritized for potential benefits to juvenile Chinook salmon through restoration.
- Implementation planning work is underway to advance site-specific and regional restoration along the railroad.

Online resources

Search railroad. https://pugetsoundestuary.wa.gov/what-we-do/projects/habitat-projects/

Burlington Northern Santa Fe Railroad Grade. Salish Sea Wiki. https://salishsearestoration.org/wiki/Burlington_Northern_Santa_Fe_Railroad_Grade

Link to presentation recording https://youtu.be/ESf48q7v6Rs?t=586

Paul Schlenger is a principal fisheries biologist working at ESA. He has been working on nearshore assessment and restoration throughout his career.

Juvenile salmon movement related to the tide cycle: a study to inform tidal fish passage in Puget Sound

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Background and context

Our project does not neatly fit into beach, delta, or embayment so this was not discussed in the background.

Technical guidance for tidal fish passage barrier assessment and water crossing structure design is limited, with project sponsors struggling to determine "how much is enough" to provide fish access and habitat connectivity. Tidal water crossings are the lowest in the watershed and have the potential to impact more stream miles than crossings higher in the watershed. While the ideal approach to habitat restoration is the complete removal of stressors, project-specific constraints for restoration projects often lead to the need for replacement of undersized water crossing structures or construction of structures within setback dikes to ensure project support from stakeholders. Larger structures eliminate or significantly reduce ecological impacts, but they are often many times more expensive than removal. Evaluating alternatives is challenging without more information on the environmental consequences of the range of design options. There is a rate of diminishing returns where reducing a water crossing structure size to accommodate constraints (cost, land availability, access, etc.) no longer provides adequate ecological benefits to warrant the project cost.

We know that tidal events may naturally preclude migration during certain time periods, and that undersized culverts and water crossing structures increase water velocities that can further reduce migration periods, particularly for juvenile salmon. While fish behavior is notoriously difficult to quantify, an understanding of when they move within the tidal cycle is key to providing technical guidance for barrier assessment and design. In this study, we seek to understand fish movement related to the tide cycle in reference conditions.

Findings

Useful concepts to guide fish passage and restoration projects are available in Appendix D of the Water Crossing Design Guidelines (Barnard et al. 2013) in a "hierarchy of benefits" approach. However, project sponsors and permit applicants frequently request technical assistance to select design options, requesting more prescriptive information than is currently available in Appendix D. Engineers can derive velocities throughout the tidal cycle for structures of various sizes, but what is missing is a thorough understanding of what this means to fish access. Fish access in the tidal environment includes adult fish returning to spawning grounds and juvenile salmon accessing important tidal rearing habitats in the estuary. Our key questions included:

- When are fish moving during the tide cycle?
- Do fish move with or against the tide?
- Are fish moving volitionally at all tidal stages? Does it matter if they are not?
- Are fish behaviorally affected by physical changes in hydrology at crossing structures?

- What are the consequences of blockage or delay?

We used passive integrated transponder (PIT) tags and antennae to detect juvenile salmon movement in tidal channels at four sites in the Nisqually River Estuary and Skokomish River Estuary in 2018-20. We tagged and released 3,386 juvenile hatchery Chinook salmon collected in the field or from George Adams hatchery in the Skokomish watershed with approximately half subsequently detected at our antenna arrays. We were most interested in fish moving between antennae in the same channel and were able to detect individual fish movements throughout the tide cycle. Fish moved both with and against the tidal flow direction and throughout the day and night. Movement detections increased at a higher rate of change in the tidal stage, although more data analysis is needed. This pattern is similar to juvenile Chinook movement at Salmon River, Oregon (Hering et al. 2010), where fish movement detections peaked at 2 hours before and 2-4 hours after high slack tide.

We are currently completing our 2021 data collection and planning a 2022 sampling season. As such, our findings are preliminary and need additional analysis before we can make recommendations about restoration practices. Following additional data collection and analysis in 2021-22, we plan to:

- Evaluate current barrier criteria based on fish movement study results.
- Evaluate habitat impairment impacts from hydraulic structures.
- Model tidal hydraulics with structures.
- Engage practitioners and policy staff for the development of technical guidance.

Key Messages

This study is ongoing such that results to guide restoration practices are not yet available.

- This study is ongoing with future work planned to continue data collection in spring 2022 and to complete data analysis.
- Use of PIT tag antennae in the estuarine environment was successful in monitoring the movement of tagged fish through the tide cycle.
- Using multiple antennae, individual fish movement was detected both with and against tidal flow direction and during the day and night.
- Preliminary results suggest that much of the fish movement occurs during high tidal rate of exchange.
- Channel hydraulics lead to eddies and other features that complicate analysis of fish movement related to tidal flow.

Literature

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Online resources

WDFW Fish Passage information. Fish Passage barrier assessment and design guidance as well as barrier replacement funding opportunities https://wdfw.wa.gov/species-habitats/habitat-recovery/fish-passage

Barriers to Tidal Connectivity HUB. Information and presentations from the Oct 2020 symposium and data sources on tidal connectivity along the West Coast https://btc-psmfc.hub.arcgis.com/

Link to presentation recording https://youtu.be/85a0tr7qbDk?t=2994

Pad Smith has worked professionally in the water resources industry for nearly 25 years and is currently a fish passage and habitat restoration engineer with WDFW. Pad has a strong background in hydraulics and hydrology, geomorphology of riverine and marine systems, as well as many years' experience with fish passage.

Doris Small has worked as a fish habitat biologist with WDFW for over 30 years, focusing on nearshore and estuarine habitat protection and restoration projects.

Hood Canal summer chum use of nearshore embayment habitats

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Background and context

Over a three-year period, Wild Fish Conservancy assessed nearshore habitat usage by outmigrating juvenile summer and fall chum. Intertidal habitats were sampled using beach seines, with up to 50 sites sampled weekly. This work was done to guide policy makers and restoration planners that are making decisions regarding the prioritization of funding for nearshore habitat restoration projects that are intended to benefit Hood Canal summer chum.

Findings

Results of the study suggest that summer and fall chum salmon fry exhibit differential use of nearshore estuarine habitats within the Hood Canal that may be dependent on seasonal nearshore ecosystem conditions. Previous research has determined that cooler and less productive estuarine emergence conditions cause early emerging chum salmon juveniles—most of which are now known to be of summer run origin—to emigrate at a faster rate from Hood Canal than later emerging fall chum salmon. Differences in nearshore ecosystem conditions and subsequent impacts on emigration likely result in reduced summer chum residence time within seasonally unproductive delta habitats. This may be the cause of the relative increase in winter season use of barrier lagoon and estuary habitats observed within the Hood Canal outmigration corridor and the significantly lower probabilities of chum salmon occurrence in delta habitats in comparison to later spring months. These findings demonstrate the importance of embayment habitat features (such as barrier lagoons and estuaries) to the recovery of Endangered Species Act (ESA)-listed Hood Canal summer chum salmon. Protection and restoration of embayment features will help maintain or increase shelter and feeding opportunities for juvenile chum and Chinook salmon that may seek substitute rearing habitats to seasonally unproductive or anthropogenically diminished river deltas prior to entering the North Pacific Ocean.

Key messages

- Hood Canal summer and fall run chum salmon utilize nearshore habitats in different ways.
- Summer run chum salmon show a relative increase in the use of non-natal barrier lagoon and barrier estuary habitats (pocket estuaries), and a decrease in the use of delta habitats.
- Embayment habitat features such as barrier lagoons and barrier estuaries are seasonally important habitat for summer run chum salmon that may seek to substitute rearing habitats from seasonally unproductive or anthropogenically diminished river deltas prior to entering the North Pacific Ocean.
- Protection and restoration of embayment features will help maintain or increase shelter and feeding opportunities in the nearshore for juvenile Hood Canal summer run chum salmon.

Literature

https://salishsearestoration.org/wiki/File:Tuohy_et_al_2018_hood_canal_summer_chum_nearshore_use.pdf Link to our full paper.

Link to presentation recording https://youtu.be/ESf48q7v6Rs?t=6820

Micah Wait is an ecologist and Conservation Director for Wild Fish Conservancy. His work is focused on the science of habitat restoration for salmon recovery.

Where are the fish? Articulating natal and non-natal fish benefits to justify large capital investments in estuary restoration projects

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Background and context

The South Puget Sound Salmon Enhancement Group is assisting partners with technical planning and design efforts on three estuary restoration projects at Chambers Bay, Titlow Park, and in Clear Creek on the lower Puyallup River. Meaningful restoration at each of these sites requires large capital investment in major infrastructure projects including removal of a dam and replacement of 65-foot span County Bridge with a 350-foot span bridge, replacement of a three-foot culvert with a 96-foot span rail bridge under the BNSF mainline, and replacement of two six-foot wide gated culverts with a large span bridge under a four-lane State Highway. These large investments warrant a better understanding of how fish populations will benefit from these projects. However, our understanding of how fish behave when they leave their natal rivers and streams and how they use non-natal stream mouths and estuaries like the ones involved in these three projects is limited in South and Central Puget Sound.

We have been working to employ multiple methods, from low intensity to higher intensity efforts, to characterize how fish utilize delta and nearshore habitats in the WRIA 10 and 12 shorelines. Methods employed have ranged from a synthesis of available literature to draw on existing science, to simple snorkel surveys and underwater video to higher-cost fish mark-recapture and telemetry tracking studies. We have found these data to be extremely useful in communicating investment needs with broad stakeholder groups to leverage support and funding from entities operating outside of the Puget Sound restoration community.

Key messages

- Strong evidence from studies throughout Puget Sound point to the utilization of non-natal estuaries as critical habitat for rearing salmon and trout and early growth in fry and smolt life history stages as being a primary driver of survival for returning adults (Beamer et al. 2005; Beamer et al. 2013; Campbell et al. 2017). It is important to be able to articulate the benefits natal and non-natal fish populations can derive from estuary restoration to justify investments in large capital projects to leverage a more diverse funding portfolio and increase the rate of restoration in Puget Sound.
- Fish biologists understand that the degree of variability expressed by rearing life stages of salmon and trout implicates the importance of providing spatial diversity and temporal connectivity of habitats along salinity, dissolved oxygen, and temperature gradients in the nearshore to maximize foraging and growth opportunities and ensure the continued survival of a diverse range of life-history strategies. However, articulating where and what fish are doing in the nearshore to a broad range of audiences is not easy and restoration practitioners often lack concrete evidence to provide an unequivocal understanding of how fish will benefit from nearshore and estuary restoration projects.

- Albeit labor-intensive and challenging to fund, gaining a better understanding of fish behavior in the nearshore, including migration patterns, timing and duration of utilization in different habitat types, and growth and survival benefits derived from different habitat types, would inform the practical application of restoration actions and help justify project costs.
- We have found that relying on available literature to help build an understanding of fish behaviors in Puget Sound can be helpful. Much of the existing science is localized around large river deltas and we can construct probable migration pathways between those points. We have used published data from Coded Wire Tags extracted from North and Central Sound hatchery Chinook in the Nisqually estuary to infer restoration of estuaries in WRIAs 10 and 12 would provide important non-natal rearing habitat for multiple populations of fish (Hodsgon et al., 2017). We have also used published data from North Sound in the Skagit Delta and small streams on Whidbey Island to assume fish employ similar non-natal rearing strategies in South and Central Sound (Beamer et al, 2006; Beamer et al., 2013). However, inferences and assumptions make much fewer compelling arguments than site-specific stories of how fish are using locations for rearing and growth to justify support for multi-million dollar projects.
- Even small investments in site-specific investigations of fish use can be an incredibly powerful communication tool. We devoted time for three biologists to complete three snorkel surveys, each less than two hours, at the Titlow estuary Restoration project site. Snorkel surveys provide a snapshot of data to better understand fish utilization and behavior at any given location of interest. While it is difficult to make quantifiable conclusions regarding fish utilization and abundance with snorkel surveys alone, we were able to observe unmarked and marked Coho and Chinook juveniles at the site with 100 percent consistency on all three survey days spanning a period of 71 days. These data provide strong anecdotal evidence that fish use of this shoreline is high and the underwater video of the high velocities sucking fish into the culvert illustrate clearly to non-technical audiences' the problems caused by undersized culverts. This small amount of data and video footage proved to be an integral tool to help project partners secure one million dollars in State Transportation funds to match $150,000 in salmon recovery funds for final design and permits for the project.
- Where possible, larger investments in site-specific investigations can not only justify capital investments in Puget Sound recovery efforts, they can also further the state of fisheries science and ensure we are doing the right projects, in the right location, at the scale necessary to see change. Puyallup Watershed partners are undertaking a detailed study of non-natal fish utilization in the Clear Creek tributary system, in the freshwater tidal zone of the lower river. Using mark-recapture, telemetry tracking, and diet analysis methods to evaluate passage through 6-foot by 120-foot long gated culverts and utilization of the freshwater tidal wetlands, we can develop site-specific science to understand not only how important this specific location is for growth and survival for Puyallup River fish, but these data can also further the broader restoration community's understanding of how places like this all around our region are important for fish populations.

Literature

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Link to presentation recording https://youtu.be/85a0tr7qbDk?t=1168

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6. Conceptual model synopsis

6.1 Introduction

Conceptual models have been widely used in ecological restoration planning and evaluation worldwide (Gann et al. 2019) including throughout the United States (e.g., Ogden et al. 2005, DiGennaro et al. 2012, Krueger et al. 2017). A conceptual model can be defined as a non-quantitative representation of relationships within an ecosystem that synthesizes existing knowledge. When used in service of ecological restoration, they can communicate both how natural systems have been modified by human stressors as well as predicted responses to restoration or recovery action, and can facilitate communication between restoration scientists, policy-makers, and planners (Ogden et al. 2005, Gann et al. 2019). Because conceptual models are necessarily dependent on the body of research and knowledge that informs them, they can be thought of as works in progress to be updated and refined over time as restoration science progresses and knowledge is gained. Furthermore, there is an increasing awareness that the body of information to underpin successful restoration should draw upon multiple types of knowledge, including practitioner experience, Traditional Ecological Knowledge, Local Ecological Knowledge and scientific discovery (Gann et al. 2019). As such, one of the primary goals of the Nearshore Restoration Summit was to update existing biophysical conceptual models for restoration of the Puget Sound nearshore ecosystem (e.g., Clancy et al. 2009) and to integrate social factors and practitioner experience into the updated models.

The integration of social sciences and human dimensions into more ecologically aligned conceptual models is not new, yet such integration processes can be challenging due to the inherently interdisciplinary nature of the exercise and historic siloing between biophysical and social sciences (Redman et al. 2004, Kline et al. 2017). Existing integrated social-ecological conceptual models such as those developed by Harguth et al. (2015), Kline et al. (2017), and Redman et al. (2004) articulate broad interactions between humans and ecosystems while emphasizing the central role of human behavior and ecosystem recovery actions and their effects on human wellbeing and condition (e.g., Harguth et al. 2015), specific kinds of social and ecological patterns and processes (Redman et al. 2004) or different kinds of human management actions (Kline et al. 2017). These models were useful starting points to facilitate a more explicit inclusion of social factors into restoration models for Puget Sound. In Washington, the Department of Fish and Wildlife (WDFW) Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) developed a basic conceptual model for restoration in nearshore habitats of Puget Sound, describing the biophysical relationships among ecological processes, structure, and function (Simenstad et al. 2006a) and helped to inform a guiding philosophy for PSNERP that restoration actions will be most effective if they specifically target impairments to ecological processes by restoring resilient, functioning, and diverse ecosystems (Goetz et al. 2004, Simenstad et al. 2006b, Figure 6-1).

These relationships fit within a broader understanding of ecosystem-based management in Puget Sound as a social-ecological system (Ruckelshaus and McClure 2007, Sobocinski 2021) and are the basis for more detailed conceptual models describing the predicted effects of specific restoration actions on nearshore ecosystems (Clancy et al. 2009).

Clancy et al. (2009) described 21 management measures (restoration actions) aimed at recovering at-risk and degraded nearshore ecosystem processes with varying levels of applicability and utility across geomorphic landforms (i.e. shoreforms, including beaches, deltas, and embayments). These management measures may be implemented alone or in combination, depending on objectives and scale. For each management measure, Clancy et al. (2009) developed a conceptual model to articulate the relationships that originate from a restoration action (i.e., management measure), and ecosystem processes, structures, and functions. These models were derived from the ecosystem principles articulated by Simenstad et al. (2006a) (Figure 6-1), but emphasized a more linear relationship between actions, process, structure and functions (Figure 6-2).

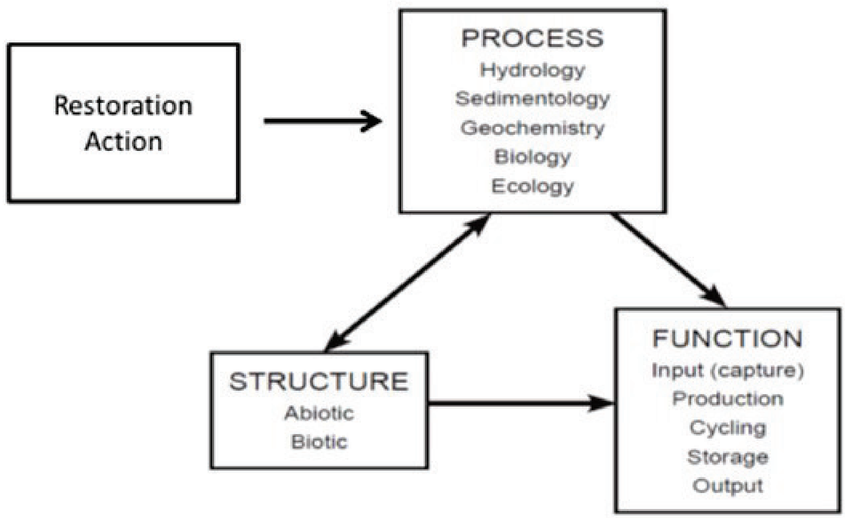

Figure 6-1. General conceptual model for the relationships between restoration actions, process, structure, and function (modified from Simenstad et al. (2006a).

For example, the **armor removal** management measure is expected to affect a suite of ecosystem processes, including sediment supply, littoral/net-shore drift, and accumulation of wood and detritus. These processes in turn are expected to affect structural changes to the beach including restored beach profile and substrate moisture and temperature. Finally, these structural changes promote functional responses such as increased salmon production and reduced shoreline erosion (Figure 6-2). Further, actions may be at a specific time and place (e.g., armor removal in beach systems) and thus have a more direct and measurable effect on processes, or they may be implemented broadly across landforms (e.g., protection policies) and thus have indirect effects that are more difficult to measure. To support the thoughtful integration of actions at varying levels of decision-making for a given site, and to achieve broader restoration goals, Clancy et al. (2009) categorized management measures as restorative, enhancing, prerequisite, and protective, based on their potential restorative effect on physical nearshore processes (Table 6-1).

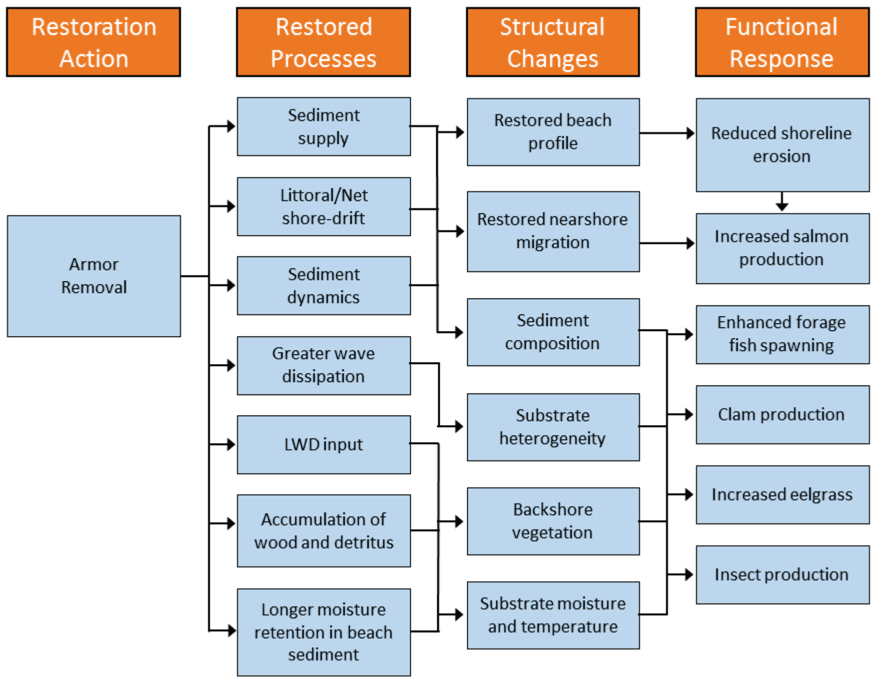

Figure 6-2. Conceptual model for shoreline armor removal that was the focal point of the Beach discussions. Reprinted from Clancy et al. (2009).

Table 6-1. Categories of management measures from Clancy et al. (2009)

Category	Restorative	Enhancement	Prerequisite	Protective
Role	**Exert long-lasting effects on ecosystem processes**	**Create/promote structural elements (habitats) and/or mimic natural processes**	**Remove or prevent physical and chemical disturbances**	**Protect existing resources, limit future impairment, influence human behaviors**
Management Measures	Armor Removal or Modification Berm or Dike Removal or Modification Groin Removal or Modification Hydraulic Modification Overwater Structure Removal or Modification Topography Restoration	Beach Nourishment Invasive Species Control Large Wood Placement Species Habitat Enhancement Reintroduction of Native Animals Substrate Modification	Contaminant Removal and Remediation Debris Removal Physical Exclusion Pollution Control	Habitat Protection Policy or Regulations Public Education and Involvement
	Revegetation (Restorative and Enhancement) Channel Rehabilitation or Creation (Restorative and Enhancement)		Property Acquisition and Conservation (Prerequisite and Protective)	

Understanding the relationships between action, process, structure, and function and the way these components interact with the broader nearshore social-ecological system are critical aspects of planning, implementing, evaluating, and communicating ecological restoration. Since Clancy et al. (2009), there have been many research efforts in Puget Sound that have shed new light on some of these relationships. Furthermore, there is a growing recognition of the importance of human dimensions in restoration science and practice, including human behaviors, climate change impacts, human wellbeing, governance, and justice (Biedenweg et al. 2017, Raymond et al. 2018, Wells et al. 2021). Clancy et al. (2009) acknowledged these human dimensions, both in the effects and benefits of certain management measures to social, political, and economic aspects of society, such as human well-being, public education, as well as how these connect with global anthropogenic stressors such as climate change and sea level rise. This body of work also highlighted existing gaps and uncertainties in the effects of social, cultural, and economic values on restoration (Clancy et al. 2009). Related material in the Leschine and Petersen (2007) PSNERP report on Valuing Puget Sound's Valued Ecosystem Components provides more focused information on the human dimensions of nearshore restoration.

One goal of the Nearshore Summit was to use the Clancy et al. (2009) conceptual models to re-evaluate our ideas, strategies, and constraints to nearshore restoration and protection in Puget Sound. Specifically, we sought to update the relationships among restoration actions, processes, structures and functions to reflect research that has taken place since the publication of Clancy et al. (2009), as well as to more fully incorporate the role of human dimensions in our understanding of nearshore restoration by explicitly including social factors and integrating principals of diversity, equity, and inclusion (DEI) into both the broader and shoreform-specific conceptual models for restoration (Summit Objectives 4 and 5, Box 1-1). To meet these objectives, we held three discussion sessions with Summit participants and invitees, each centered around refining a broader conceptual model for restoration as well as models developed for each shoreform (beaches, deltas, and embayments), while also explicitly emphasizing and considering the social components of nearshore restoration.

6.2 Conceptual model refinement methods

The virtual discussions to refine conceptual models took place following presentations for each shoreform (beach, delta, and embayments). Participants were a mixture of Summit presenters and invited participants who play key roles in regional nearshore restoration science or practice. The makeup of the participants varied each week, with 11-14 people engaging in the discussion. Participants were self-selected such that while many were invited, only those who wished to participate attended the sessions. No prior commitment was required or requested. Each discussion was led by a professional facilitator as well as Summit organizers who provided expertise on the model (s) in question and the role of social sciences.

As part of each discussion session, we focused on one Clancy et al. (2009) model for that shoreform, as well as examples of broader conceptual models for social-ecological systems that could be adapted to more intentionally reflect the human context of restoration (e.g., Redman et al. 2004, Harguth et al. 2015, Kline et al. 2017). Using google slides, in each shoreform-specific discussion session, we asked participants to manually add, modify, and highlight elements of the model(s) to reflect updated knowledge, information, and need. We encouraged individuals to both comment on the original biophysical-centric elements of the models and incorporate more of the social science aspects.

We selected three management measures (one per shoreform) to highlight during our Summit discussions from the Primary Restorative Measures category, described as measures that exert comprehensive and lasting restorative effects on ecosystem processes (Clancy et al. 2009). For each one, we also recognized that it may be paired with one or more complementary management measures. See Appendix A for the full list of management measures and descriptions, and Table 6-1 for the anticipated effect on nearshore processes from Clancy et al. (2009). For beaches, we focused on the primary management measure of *Armor Removal*, and the complementary management measures of *Beach Nourishment, Contaminant Removal/Remediation, Large Wood Placement,* and *Topography Restoration* (Appendices A, D). For deltas, we focused on the primary management measure of *Berm/Dike Removal and Modification* and the complementary management measures of *Hydraulic Modification, Topography Restoration* and *Channel Rehabilitation or Creation* (Appendices A, D). For embayments, we focused on the primary management measure of *Hydraulic Modification* (e.g., replacing a tide gate with an open breach) and complementary management measures of *Berm or Dike Removal or Modification, Topographic Restoration,* and *Channel Rehabilitation or Creation* (Appendices A, D).

During these facilitated discussions, social scientists participated in the integration process while non-social scientists were invited to think about the social or human elements of nearshore restoration, including DEI. Participants identified aspects of the existing models where a human dimension currently existed (whether overtly recognized or not) and ways to integrate or build additional social elements. Through this facilitated process, 23 participants identified and shared 193 social or human elements, some of which were shared and similar to others and across shoreforms, and some which were new and unique. For example, participants included new items like outreach, regulations, and public access. To analyze and integrate these items, the Summit team organized and categorized the items through a collaborative process.

6.2.1 Theme identification and discussion data distillation

For the model elements related to social sciences, we implemented a theory-based coding process to handle the qualitative nature of the data produced, coding for themes or patterns derived from the participant-provided content (e.g., new items or model elements) (Tie et al. 2019). Coding included identifying concepts, similarities, and conceptual reoccurrences among the written content provided by participants. We (testing the updates to the models) refined themes over time and expanded upon definitions (Tie et al. 2019, Vollstedt and Rezat 2019). We then further discussed themes so that they best communicated and aligned with nearshore recovery. While themes were identified and defined, their model linkages were also identified, including the modifying action (e.g., governance and regulations), their modifier type(s) (e.g., social response and social driver), relative priority (high vs. low) and application across shoreforms. Through this process, we created 18 linked social science themes, two broad (broad response or driver) and 16 narrow (Box 6-1).

For the biophysical components of the models, following the discussions for each shoreform, we categorized the added or modified model elements as “process,” “structure,” or “function,” and commonalities among the participants’ modifications were identified to facilitate consolidation of similar entries. We used this information to generate new and modified components of the models that captured the contents of the discussions and the modifications by participants.

6.3 Updated model results

Based on discussion content from all three sessions, we generated a single broad social-ecological conceptual model as well as three shoreform specific models. We identified 16 narrow social science model themes, which are listed in Box 6-1. The themes of time and context were particularly prominent such that contextual elements (social, economic, political, and cultural) emerged as key underlying new components of the model. Temporal elements such as timing affiliated with degradation, land use, development, population growth, economic development, restoration actions, funding, site selection, community engagement, regulations, among other key items, were also identified as important new facets of the model. Social science themes also varied by shoreform and in the way they were applied, with some unique to beaches, deltas or embayments and some more frequently and/or broadly represented than others. We selected several themes that were represented among all shoreforms to be included in the updated integrated conceptual model, including access and use, regulation and governance, and individual and community change (Figure 6-3).

Box 6-1. Social science themes identified by the conceptual model discussions.

- Access and use
- Climate change
- Diversity, equity, and inclusion (DEI)
- Ecological benefits, contributions, and services
- Economics
- Engagement and education
- Hazard reduction
- Human wellbeing (HWB)
- Individual and community change
- Knowledge
- Management
- Negative human impacts
- Property and land use
- Regulations and governance
- Time and context
- Values, beliefs, norms (VBN)

6.3.1 General social-ecological model results

The updated general model produced from the Summit discussions considers the human and biophysical context for restoration. It contains elements that are common to all three shoreforms (beaches, deltas, and embayments) and relates these human and biophysical contexts primarily through the social drivers of restoration actions, resulting changes to the ecosystem process, structure and function, and the social responses to these changes (Figure 6-3). Importantly, it acknowledges the human context that encompasses both the social and biophysical components of restoration.

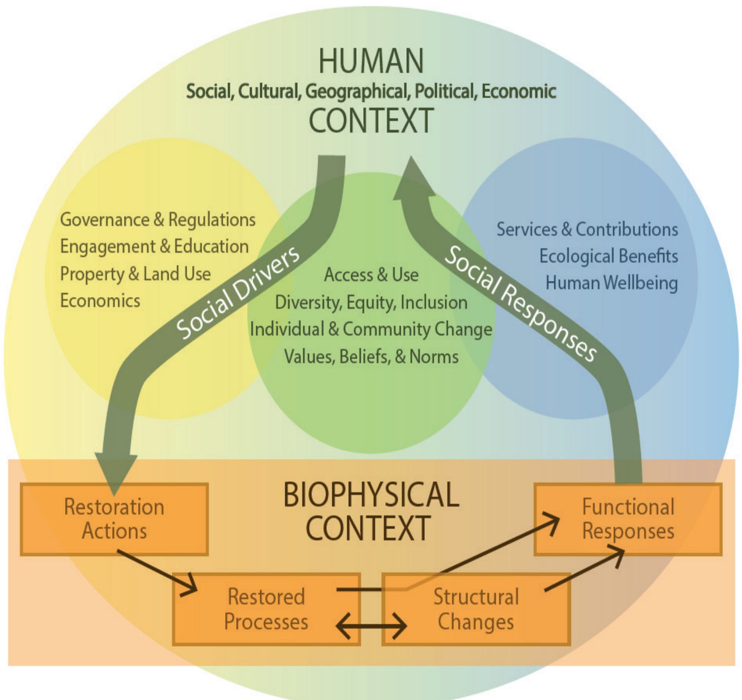

Figure 6-3. General Social-Ecological model for nearshore restoration incorporating both the human and biophysical context for restoration and the social drivers and responses that were common to all three geomorphic shoreforms (beaches, deltas, embayments). Social drivers are listed in yellow, social responses in blue, and factors common to both in the middle green.

Included within the human context are broad *Social, Cultural, Geographical, Political,* and *Economic* factors that influence the social drivers of and responses to restoration, as well as the biophysical context of restoration. This broad human context also includes anthropogenic climate change and the associated social and physical effects of it. The text in the middle of the figure in the green bubble (e.g., Access and Use) indicates social factors that were identified as both social drivers of restoration and social responses to restoration by the discussion participants, while the text in the yellow bubble represents social drivers, and the text in the blue bubble represents social responses to restoration. For example, access and use by people are likely determinants of both whether and how a restoration project may happen and are likely to be affected by restoration actions. Social drivers of restoration included Governance and regulations, Engagement and education, Property and land use, and Economics. Social responses included Ecological benefits, (Ecosystem) services and contributions, and

Human wellbeing, for example, Increased fish rearing, Flood protection, or Improved recreational access. This depiction emphasizes the interconnected nature of the human and biophysical contexts for restoration (Fig 6-3).

6.3.2 Shoreform-specific model results

The Summit team used information from model updates and small group discussions to construct an updated model for each shoreform (Figures 6-4, 6-5, and 6-6). Although Summit discussions focused on primary restorative management measures, we also paid attention to complementary enhancement measures. The resulting updated conceptual models considered suites of restoration actions for each shoreform, thus more closely reflecting restoration in practice which often include multiple simultaneous measures (Cereghino et al. 2012). To better incorporate model updates, we shifted away from the unidirectional box and arrow diagrams featured in Clancy et al. (2009). Instead, we used simpler depictions of key ecosystem elements, (i.e., process, structure, function, and social drivers and responses), overlayed onto illustrations of restoring landscapes, inspired by the depictions of shoreforms and features of restoring landscapes from Brandon et al. (2013). This format de-emphasizes the relationships between specific model elements which were present in the original Clancy et al. (2009) models and instead takes a more objective approach that considers the broader relationships between processes, structures, and functions. While this broader approach enables the consideration of more context-dependence in the direction of specific relationships, it also doesn’t as readily depict certainty in the strength of relationships, as previous conceptual models have done by using either the shading or thickness of the lines connecting boxes. We identified ecosystem elements in a modified and expanded general diagram to establish an updated framework for our new models. In the original conceptual models from Clancy et al. (2009), the relationship from the process, to structure and function was depicted as a unidirectional sequence. We added an inset to each shoreform, showing a cartoon of the shoreform in a pre-restoration (impaired state), and to which we added arrows (after Simenstad et al. 2006a, Simenstad et al. 2006b) highlighting the influence of habitat structure on ecosystem processes, (e.g., the impact of marine riparian or riparian clearing on sediment supply processes), and the influence of ecosystem processes directly on function, (e.g., increased space for fish rearing following armor removal). We also added consideration of time to reflect variability in ecosystem response to restoration from days to years. Finally, we integrated the important role of social drivers and responses such that each updated shoreform graphic, (i.e., beaches, deltas, and embayments), depicts predicted ecosystem responses to restoration, as well as social drivers and responses to restoration that were identified for that shoreform.

Input from contributors included both explicit modification or addition of model elements, and broader appeals for updates to model structure and format. In general, there was a desire to clarify existing terms and standardize the levels of detail where possible to refine related ecosystem components and make clear what each element encompasses (e.g., beach sediment dynamics). For each shoreform, we retained much of the original Clancy et al. (2009) conceptual model content, adjusting some of the language for clarity and consistency, or to reflect the breadth of potential physical and biological responses following restoration. In many cases, we also modified language to be more neutral, to reflect context-dependence in the direction of responses and to shift away from qualifiers that denote value (e.g., positive, negative). Below we describe the modifications, additions, and updates to the models that resulted from the Summit discussions.

New social conceptual model content, as represented by coded themes, varied only slightly by shoreform, and most themes were frequently reflected among all shoreforms. For example, human well-being (HWB), (e.g., sense of place), was depicted as a common social driver in all three shoreforms and is thus highlighted in the broader social-ecological model (Fig. 6-3). Participants also identified some shoreform-distinct themes, demonstrating that some human dimensions' variation or uniqueness may be specific to shoreform. However, there were some social themes represented in some shoreforms, but not others such as values, beliefs and norms (VBN), which were represented in beaches and embayments, but not deltas. To facilitate the visual depiction of some of the human elements of the models, representatives for each kind of modification were added to the Figures (6-4, 6-5, 6-6), rather than depicting an exhaustive representation of all human elements or themes that are captured in the broad social-ecological model (Fig. 6-3). Social elements that were identified as unique or particularly relevant to each shoreform but not visually depicted are noted in the text below and in the figure legend. Furthermore, some articulations or terminology vary among the shore-form specific figures in order to demonstrate further specificity or specific distinctions presented during the discussions.

a. *Beaches*

The updated beach model (Figure 6-4) represents a compilation of additions and modifications primarily to the Clancy et al. (2009) model for shoreline armor removal and considering the influence of complementary management measures such as vegetation establishment (Appendix D, Fig. D-1). The resulting composite model reflects additional details describing the biophysical results of beach restoration, including highlighting the importance of habitat connectivity, its relationship to accommodation space and the resulting function of habitat availability and quality for a myriad of species. Many of the social or human elements represented in the updated beach model were consistent with the other shoreforms and are thus reflected in the broad social-ecological model (Fig. 6-3) (e.g., access and use). Though economics as a social driver was a key element of all shoreform discussions, it was solely considered as a social response in the beach model.

Added social drivers and responses

- **Property and land use** was added to reflect the importance of ownership and land uses in driving decisions related to restoration.
- **Access and use** was added to reflect the importance of human access and different human uses in driving restoration actions for a potential beach location and also the way that these may change as a result of restoration actions in beach systems.
- **Sense of place** was added to reflect the potential for sense of place to increase as a result of restoration actions in beach systems (not depicted visually in Fig. 6-4).
- **Public engagement and stewardship** was added to emphasize the importance of public engagement and stewardship in both driving decisions related to beach restoration and as having the potential to increase following restoration.
- **Economics** was added to denote the role of economic drivers in how and where restoration occurs as well as economic responses to restoration actions (not depicted visually in Fig. 6-4).

Added or modified ecological processes:

- **Terrestrial debris input and accumulation** replaced "Large Woody Debris (LWD) input" to first, clarify the source of large woody debris input (i.e., fallen from uplands); second, further encompass other terrestrial inputs such as leaf litter; and third, acknowledge retention and storage of debris.
- **Marine detritus input and accumulation** replaced "Accumulation of wood and detritus" to reflect marine wrack recruitment and storage, which includes large woody debris and other organic matter such as marine algae and eelgrass.

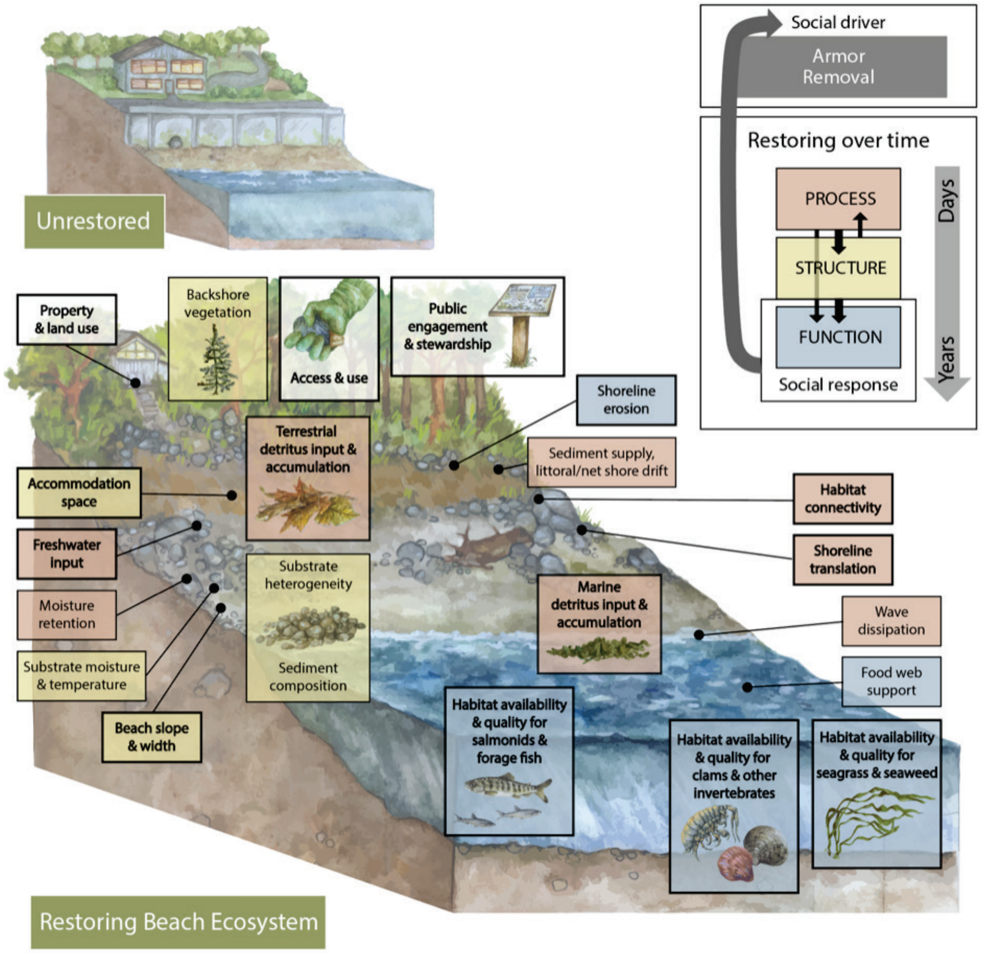

Figure 6-4. Updated beach shoreform conceptual model following restoration, depicting the suite of ecosystem processes (light brown), structural changes (tan), ecosystem functions (blue) as a result of restoration actions, and social drivers and responses (white). Model elements that were added or modified through the Summit discussion process are highlighted **in bold.** The upper inset depicts some of the features of an impaired (pre-restoration) landscape. The inset on the right shows the connections between social drivers, restoration actions, and ecological processes, structures and functions and various timeframes that these may occur within. Social elements not visually depicted were 1) Sense of place and 2) Economics.

- **Freshwater input** was added to represent the important role of freshwater sources, such as local streams and groundwater seepage, for beach sediment dynamics and substrate conditions.
- **Shoreline translation** replaced *"Nearshore migration"* to represent the important process by which a beach can adapt for shifting shorelines in response to large wave action, higher high tides, and sea level rise.
- **Habitat connectivity** was added to highlight the critical linkages between the upland and marine environments necessary to maintain and sustain sediment, debris, accommodation space, and habitat processes.

Added or modified structural responses:

- **Beach slope and width** replaced “Restored beach profile” to specify key elements of beach morphology.
- **Accommodation space** replaced “Nearshore migration” to better describe the increase in intertidal and backshore areas after armor (and fill) are removed, further supporting debris accumulation, shoreline translation, and habitat availability.

Added or modified functional responses:

- **Shoreline erosion** replaced “Reduced shoreline erosion” to account for both the potential for increased passive bluff erosion following armor removal and restoration that builds and maintains beaches, as well as the reduction of active beach-terrace erosion, which can occur as the result of shoreline armor.
- **Habitat availability and quality** replaced “increased production” and “enhanced spawning” for a select list of important nearshore species to better describe the increased opportunity for and quality of habitats and resources for species.
- **Food web support** was added to represent the important indirect effect on marine food webs via functions like habitat availability and quality.

b. Deltas

The delta updated model (Figure 6-5) represents a compilation of additions and modifications primarily to the Clancy et al. (2009) model for berm/dike removal and channel excavation (Appendix D, Fig. D-2). The resulting composite model reflects additional details describing the biophysical results of delta restoration, including highlighting the importance of hydrologic connectivity, its effects on subsurface flows and water temperatures, and resulting functions such as invertebrate and beaver colonization, flood storage capacity, and access by juvenile salmonids.

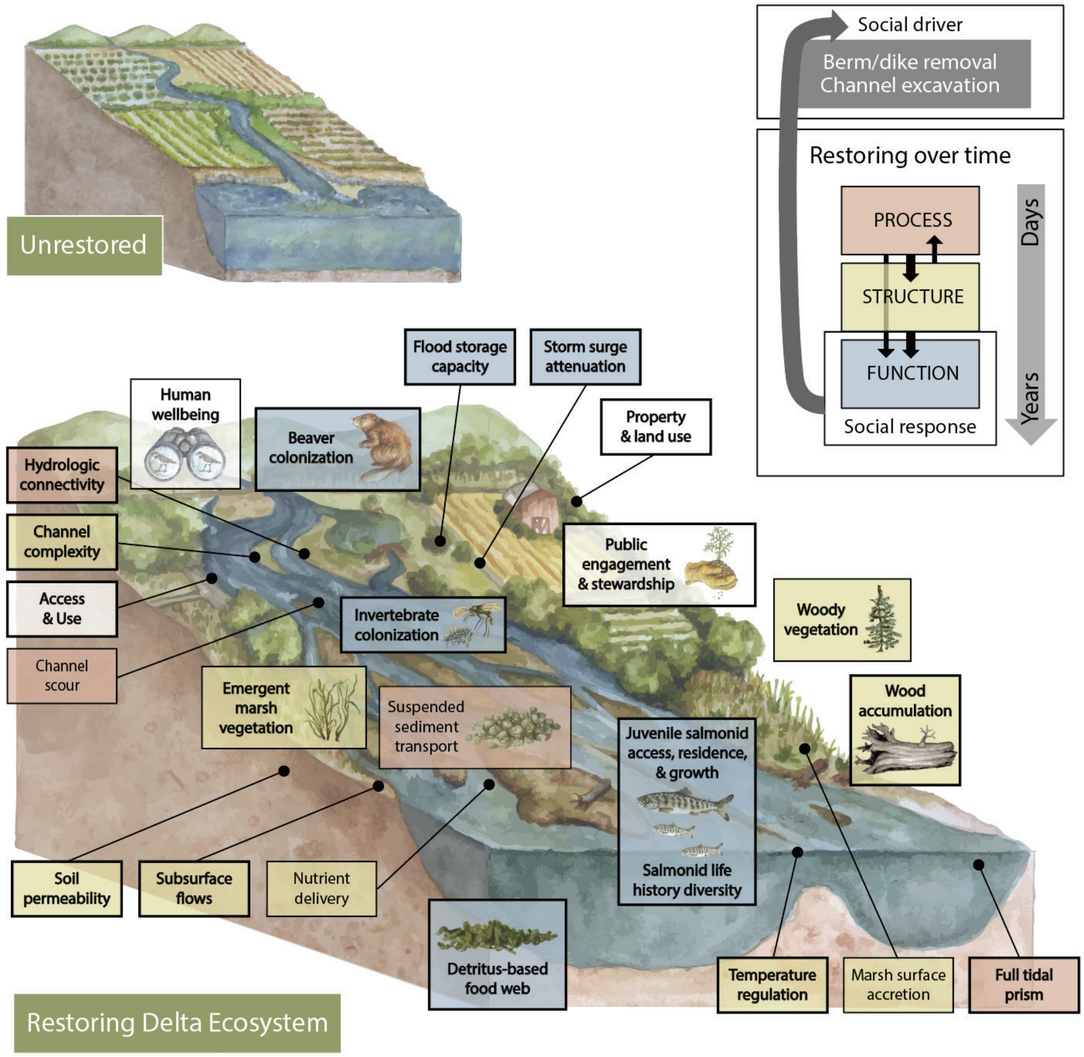

Figure 6-5. Updated delta shoreform conceptual model following restoration, depicting the suite of ecosystem processes (light brown), structural changes (tan), ecosystem functions (blue) as a result of restoration actions, social drivers and responses (white). Model elements that were added or modified through the Summit discussion process are highlighted **in bold.** The upper inset depicts some of the features of an impaired (pre-restoration) landscape. The inset on the right shows the connections between social drivers, restoration actions, and ecological processes, structures and functions and various timeframes that these may occur within. Social elements not visually depicted were 1) Negative human impacts and 2) Diversity, Equity, and Inclusion.

For social factors, some human elements represented in the updated delta model were consistent with the other shoreforms, such as benefits, contributions, and services (e.g., ecosystem services) as a social driver for restoration. While DEI was widely recognized during the conceptual model discussion process, it was uniquely included in the deltas responses as a social driver, reflecting the lack of consideration of issues of diversity, equity, and inclusion in delta restoration and management. Negative human impacts were also a unique social driver and response reflected only in the deltas model which were driven by human behaviors, including those linked to contaminants and sediment supply disruptions (e.g., dams).

Added social drivers and responses:

- **Property and land use** was added to reflect the importance of ownership and land uses in driving decisions related to restoration.
- **Access and use** was added to reflect the importance of access and use as both a driver and response of restoration actions in delta ecosystems.
- **Human Well Being** was added to reflect the potential for human well being to increase as a result of restoration actions in delta ecosystems such as through increasing recreational opportunities
- **Public engagement and stewardship** was added to emphasize the importance of public engagement and stewardship in both driving decisions related to delta restoration and as having the potential to increase following restoration.
- **Diversity, Equity, and Inclusion** was added as social driver for restoration delta ecosystems (not depicted visually in Fig. 6-5).
- **Negative human impacts** were added as both a social driver and response, reflecting the potential for human impacts to slow down or work counter to restoration actions (not depicted visually in Fig. 6-5).

Added or modified ecological processes:

- **Full tidal prism reintroduction** was moved from a restoration action to a restored process.
- **Hydrologic connectivity** was added to reflect the importance of hydrologic connectivity as a key restored process following delta restoration.

Added or modified structural changes:

- **Temperature regulation** was added to reflect the cooling effect that restoration can have on subsurface flows on surface water temperatures.
- **Soil permeability** was added to reflect the effect of vegetation colonization on soils and the potential for a feedback loop among vegetation, soil, and topography.
- **Emergent and woody marsh vegetation** replaced “Recolonization and growth of emergent tidal marsh vegetation” to capture the additional importance of woody shrubs and swamp vegetation as part of the restoration trajectory and a functioning estuarine habitat.
- **Subsurface flows** was added to capture the increase in subsurface flows as a result of increased hydrologic connectivity.
- **Wood accumulation** was added to reflect the important role of woody debris in estuarine habitats.
- **Channel complexity** replaced “High tidal channel network complexity.”

Added or modified functional responses:

- **Flood storage capacity** was added to reflect the potential increase in the storage of river deltas in the face of flooding events.
- **Beaver colonization** was added to reflect the role of beaver colonization in restoring deltaic habitats.
- **Salmonid life history diversity** was added to reflect the role of rearing habitat diversity in helping promote and maintain salmonid life history diversity.
- **Storm surge attenuation** was added to reflect the role of salt marshes in helping to decrease the impacts of storm surge on river deltas.
- **Juvenile salmon access and growth, and residence time** replaced "Juvenile salmon access to shallow water habitat" as a process, and "Increase juvenile salmon residence time" and "Higher growth and survival in the nearshore" as a function.
- **Detritus-based food web** was added as a function to reflect the importance of the role detritus generation of plant material.
- **Invertebrate colonization** replaced "Increase production of benthic invertebrates and insects" as a structural response.

c. Embayments

The embayment updated conceptual model (Figure 6-6) represents a compilation of additions and modifications primarily to the Clancy et al. (2009) model for *hydraulic modification* (e.g., replacing a tide gate with an open breach and associated complementary actions including berm/dike removal and channel rehabilitation) (Appendix D, Fig. D-3). One concept that emerged in the embayment conceptual model discussions was balancing species-specific habitat needs (e.g., finfish, shellfish, birds) prior to and following restoration and how this fits into restoring habitat-forming processes. The resulting composite model reflects additional details describing biophysical results of embayment restoration including adaptive capacity, channel formation and feeding opportunities for fish. Many of the social or human elements represented in the updated embayments model were consistent with the other shoreforms. In particular, education and engagement (e.g., community outreach) was a social driver across shoreforms.

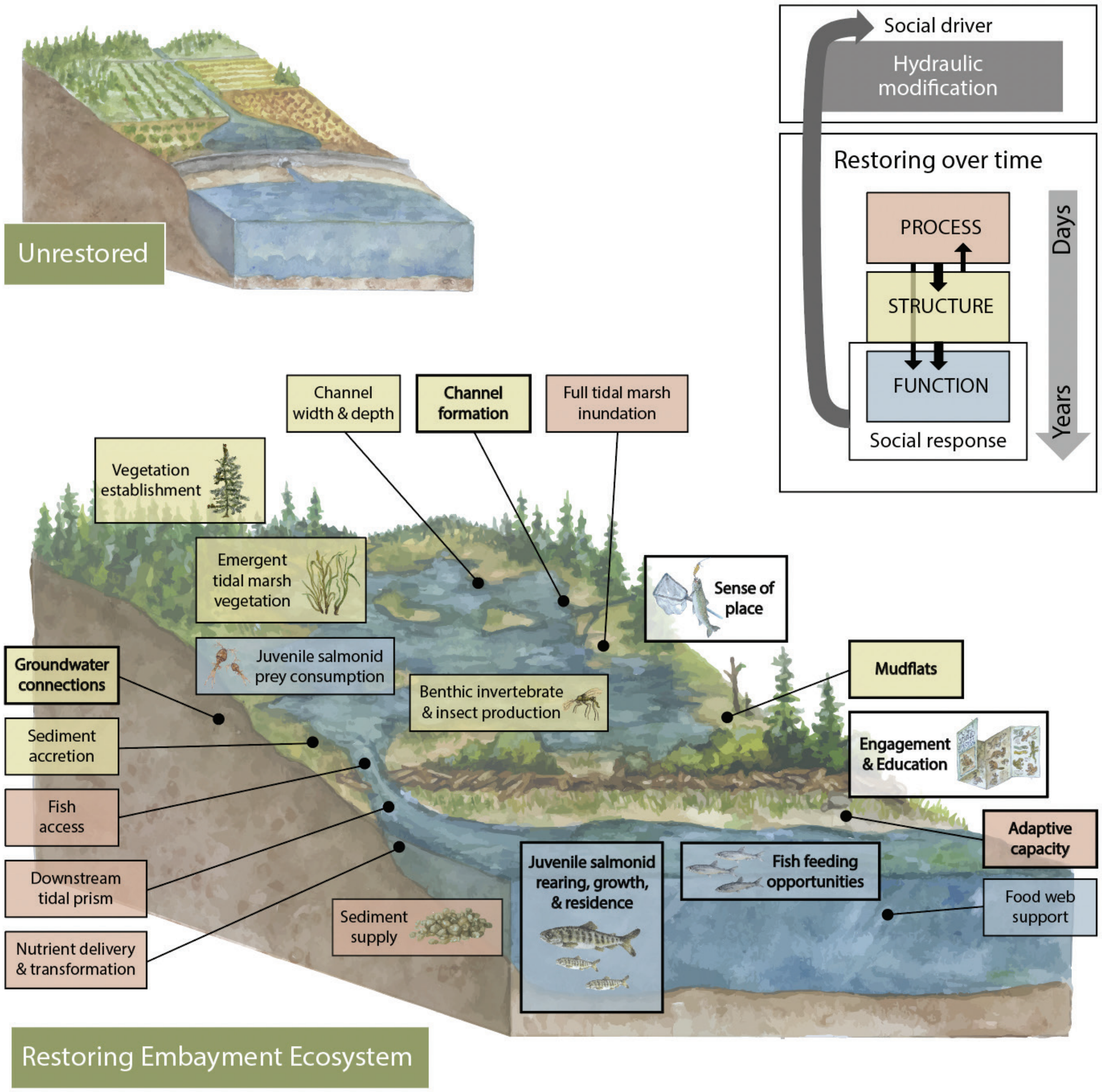

Figure 6-6. Updated embayment shoreform conceptual model following restoration, depicting the suite of ecosystem processes (light brown), structural changes (tan), ecosystem functions (blue) as a result of restoration actions, key social drivers and responses (white). Model elements were added or modified through the Summit discussion process are highlighted **in bold.** The upper inset depicts some of the features of an impaired (pre-restoration) landscape. The right inset shows the connections between social drivers, restoration actions, and ecological processes, structures and functions and various timeframes that these may occur within. Social elements not visually depicted were 1) Access and use and 2) Management.

While management (e.g., adaptive management) was a key element of discussion for all shoreforms, it was solely represented in the embayments model as a social driver and response.

Added social drivers and responses

- **Access and use** was added to reflect the importance of human access and different human uses in driving restoration actions for a potential embayment location (not depicted visually in Fig. 6-6).
- **Sense of place** was added to reflect the potential for sense of place to increase as a result of restoration actions in embayment systems.
- **Engagement and Education** was added to emphasize the importance of public engagement and stewardship in both driving decisions related to embayment restoration and as having the potential to increase following restoration.
- **Management** was added to reflect the role of management actions including adaptive management as both a potential driver and response of restoration actions (not depicted visually in Fig. 6-6).

Added or modified processes:

- **Adaptive capacity** was added to capture the increase in adaptive capacity to both rising sea levels and increased saltwater intrusion.

Added or modified structures:

- **Channel formation** was added to capture the importance of distributary and blind tidal channel development in restoring barrier embayments.
- **Early establishment of mudflats** was added to reflect the formation of mudflats immediately following restoration actions.
- **Emergent vegetation** was added to depict this phase of establishment and growth onto unvegetated mudflats.
- **Groundwater connections** was added to capture the potential for an increase in estuarine groundwater connectivity.

Added or modified functions:

- **Feeding opportunities for fish** was added to reflect the increase in opportunities for a variety of fishes within and offshore of embayments following restoration.
- **Natal and non-natal juvenile salmonid rearing and growth** was added to account for both natal and non-natal populations of salmon and replaced “Juvenile salmon residence time.”

6.4 Applications and conclusions

Conceptual models are useful tools to reflect an understanding of complex systems, and, in our application, can illuminate the predicted and realized effects of specific restoration actions on nearshore ecosystems, in addition to social-ecological elements. Conceptual models reflect the state of knowledge at the time they are created and thus warrant periodic updating and refining. We held a Summit whereby we invited natural scientists, practitioners and social scientists to share their knowledge on restoration of nearshore ecosystems and to inform the collective refinement of exiting conceptual models. The updated shoreform models for beaches, deltas and embayments based on Clancy et al. (2009) help visualize the relationships among processes, structures and functions, as well as incorporate social drivers, responses and consider the role of DEI. These refined models can serve as both hypotheses to predict future restoration outcomes as well as communication tools between restoration scientists, practitioners and stakeholders (Ogden et al. 2005, DiGennaro et al. 2012).

Continuing to revisit and adaptively manage conceptual models for restoration will be important to broaden our understanding of the Puget Sound nearshore social, physical and restoration landscape, as well as the broader Salish Sea. Since the original PSNERP models (Clancy et al. 2009) were developed, there has been over a decade of learning, and we produced this synthesis to help integrate existing and new information, as well as highlight what questions we still need to address or new questions that have arisen. While the updated models reflect and improve our collective understanding of restoration and its effects on nearshore ecosystems, we acknowledge that because the outcomes were generated by the Summit discussions which were attended by a subset of the Summit attendees and speakers, the suggested additions and modifications were necessarily dependent on the viewpoints of the participants and their field of specialty. Because of this, we see these updates as useful snapshots depicting insights from the Summit that will be further refined in the future, as research and understanding continue to progress. Furthermore, although we focused efforts on a select few of the total 21 models for management measures within Clancy et al. (2009), their updates via Summit participation could be applied to multiple measures as appropriate. For example, the updated embayment model represents a compilation of adaptations to the hydraulic modification restoration action, but similar updates could be applied to complementary management measures like berm or dike removal or modification, topographic restoration, and channel rehabilitation or creation.

One key outcome of our process was to generate a broad social-ecological model that emphasizes the interconnected nature of human and biophysical factors when considering restoration actions (Figure 6-3). While challenging, social sciences and/or human dimensions integration can produce fruitful outcomes, such as facilitating a more inclusive and collaborative restoration process, and restoration outcomes that serve a broader array of people through the development of more cohesive social-ecological systems' conceptual models. Building upon the works of others, (e.g., Redman et al. 2004, Harguth et al. 2015), the Summit's conceptual model adaptive management process illustrated that the intentional application of an integrated social-ecological systems perspective can produce a more comprehensive grasp of the complex relationships between humans and nearshore environments (Guerrero et al. 2018). Human dimensions and social sciences integration within recovery faces innumerable barriers, including lack of financial resources, knowledge and expertise, and understanding or acceptance of social sciences among some practitioners, natural scientists and restoration projects. As demonstrated by the Summit, even with these barriers, integration can still successfully occur. One potential reason for success is an intentional integration of diverse researchers and stakeholders (e.g., social scientists, natural scientists, practitioners, and planners), which takes place in the research or planning process, and leads to merged conceptual frameworks and problem-focused solutions to identify recommended actions or strategies (Guerrero et al. 2018).

Our collective work in Puget Sound can build upon and add to that of others, both in coastal systems and beyond. For example, Wells et al. (2021) showed that incorporating equity in project planning and implementation processes can improve restoration outcomes. We also hope to improve restoration outcomes by applying what we have learned and providing a framework for incorporating multiple social-ecological viewpoints of natural scientists, social scientists, and restoration practitioners to a common goal that is useful to others. Restoration goals of the Puget Sound landscape are complex and require an engaged community that can work together to build from individual project applications to a broader restoration target. Recognizing that large-scale solutions arise from small-scale successes, and the important role of these successes in helping to facilitate achieving larger ecosystem recovery goals through the injection of social values into recovery planning (McAfee et al. 2021), we hope that creating models that reflect updated restoration science and the role of human dimensions will be beneficial to future restoration through improved ecological and social outcomes.

7. Learning and Knowledge Cycle synopsis

7.1 Introduction

The Learning and Knowledge Cycle, hereafter also referred to as Ecocycle, is a method of planning and prioritizing that builds on a concept taken from natural ecological systems. This method allows for a collaborative approach to planning that enables a group of people to map the strategies, culture, or ideas of an organization or a program and analyze the natural evolution of its ideas and components. There are four interwoven categories of the Ecocycle:

1. **Old ways** *(creative destruction)* – Practices or approaches that have been moved away from, left behind, or let go dormant.
2. **Initiatives gaining momentum** *(development)* – Aspects of the work that are new, growing, or gaining momentum.
3. **Mature programs and practices** *(maturity)* – Parts of the work that are strong and working well.
4. **Sparks of inspiration** *(exploration)* – Approaches that need testing and new ideas that need work.

Each of these four categories connects to one another in a feedback loop. Lessons learned from elements in the old ways category can inform elements in the sparks of inspiration category. As those new elements grow they start to gain momentum and shift to the Initiatives gaining momentum category. Those elements will then eventually mature and shift to the mature programs and practices category. And finally, some of those mature elements will become less relevant or outdated and shift to the old ways category where the lessons learned from them can again inform new elements which starts the cycle over again.

This approach to mapping was inspired by natural ecological systems. When an old mature tree falls it eventually composts and feeds the next generation of trees and other plants. These plants start as seeds (sparks of inspiration), grow as saplings (initiatives gaining momentum), mature, and then eventually die and compost.

This natural cycle ensures that the overall system is dynamic and abundant. By creating a similar set of relationships, the Ecocycle planning method helps to ensure that projects, communities, organizations, and the like are kept abundant and dynamic.

The Ecocycle planning method creates an insightful snapshot of the state of the system being evaluated. For example, if the majority of the elements are in the mature or old ways then that would imply the system is fairly established but may need to make room for new sparks of inspiration and consider creative destruction. Other systems may have the reverse and show that more work needs to be done to help the system mature and develop. The ultimate goal is a mature system with a balance of young, up-and-coming elements – mature elements along with old elements being recycled and shifted out regularly. Going through the Ecocycle planning method can help an organization or program honestly assess its current state and consider how it can be balanced across these categories.

As part of the 2021 Nearshore Summit, a series of Ecocycle planning sessions were conducted to explore the current state of the restoration/conservation community for beaches, deltas, and embayments in Puget Sound. Restoration community members were invited to attend these virtual planning sessions focused on each shoreform (delta, beach, embayment) facilitated by the Washington Department of Fish and Wildlife staff through Zoom breakout rooms. During these facilitated planning sessions, 21 total participants contributed to the workshops (though there were many repeat participants among the three workshops) to assess the current state of restoration, science, and human dimensions for Puget Sound nearshore recovery and place them within the four categories. This was done anonymously. The result was a list of items broken up by Ecocycle category. After everyone had a chance to list their items, each session (beaches, deltas and embayments) shifted to a guided discussion about what was learned through the Ecocycle planning session regarding the current state of the restoration community.

Notes from these guided discussions and the results from the Ecocycle planning sessions were then collected, consolidated, and used to generate the key messages from the Ecocycle portion of the Summit. The following is a narrative summary and synthesis of information from these sessions.

7.2 Results from the Ecocycle planning sessions

7.2.1 Beaches

The results from the Ecocycle planning session for beaches showed that as a whole, the restoration techniques across Puget Sound are a relatively mature aspect of our work. There are 53 individual notes/ideas describing up-and-coming elements in the gaining momentum and sparks categories. This would tend to indicate a relatively healthy balance across the Ecocycle categories for beaches, though care needs to be taken to ensure that old elements are shifted out and replaced by new ones. Doing this will ensure that the work to restore and conserve beaches in Puget Sound remains effective and continues to grow and improve.

In general, the Ecocycle planning session for beaches identified that over time, the restoration community has come to increasingly appreciate the complexity of recovering beach ecosystems. Formerly, funding sources were relatively limited, permitting was very linear and did not fit restoration projects, and projects were limited in their scope by often focusing on a single purpose. However, the community has made progress in addressing these issues. Today, grant programs are mature and funding has been established that has helped improve the overall understanding of the complex processes associated with beach restoration work. This has greatly improved the overall effectiveness of the restoration of Puget Sound beaches.

a. Old ways

We have traditionally relied solely on public funding for beach restoration, for single purposes, and with limited resources. Public funding alone is inadequate to restore the beaches of Puget Sound. We need to transition away from competing for limited resources, support new efforts for restoration implementation, develop private-public funding partnerships and incentives programs, and scale up our efforts to accelerate beach restoration outcomes. This work requires continual adaptation as we integrate new and shifting science and knowledge, such as changing ocean conditions and the benefits and priorities of beach restoration.

b. Mature programs and practices

Restoration programs that are reaching maturity in Puget Sound are the Shore Friendly program (newly mature) and nearshore restoration funding programs like the Estuary and Salmon Restoration Program (ESRP), the Salmon Recovery Funding Board (SRFB), and the Puget Sound Acquisition and Restoration fund (PSAR). Additionally, shoreline data collection and mapping tools like the Shoreline Monitoring Toolbox (http://shoremonitoring.org) and ESRP Beach Strategies project provide valuable information to guide restoration in Puget Sound and need continued maintenance and refinement to adapt and target state capital investments. There has been a lot of work to coordinate among programs and make new strategic approaches to accelerate outcomes. These coordination efforts should continue and increase their collaboration with landowners and shoreline communities. Lastly, there are highly functioning established funding programs, but those funding sources need to be increased and supported to meet the needs of our future (e.g., harvestable diverse fish and wildlife species and resilient coastal human communities). There are effective protective policies led by public regulatory agencies, and those regulatory protection efforts should be implemented while increasing funding and incentives for restoration.

c. Initiatives gaining momentum

The approach of programs like Shore Friendly is to bring together new social science and human dimensions elements into restoration planning and implementation, which is important for success for ecosystem recovery in Puget Sound. This concept is growing in its impact and there is broad and strong support for its actions. The regional Shore Friendly program supports the engagement of landowners and communities through workshops and technical assistance, such as permitting, design, drainage management, and installation of habitat-friendly projects. This program functions by supporting local Shore Friendly organizations that are engaged in finding efficiencies and new techniques in all phases of the beach restoration project cycle. Local Shore Friendly organizations are helping to inform local contractors and consultants about new tools, so they can be stronger partners for healthy shorelines. Several needs were identified to further develop these types of programs:

- Reduce administrative barriers, by coordinating among different programs to bring in non-typical funding partners (e.g., from federal agencies like the Federal Emergency Management Agency (FEMA)).
- Increased inclusion of under-represented communities in local efforts.
- Bring together new interdisciplinary teams of social and natural scientists.
- Harness opportunities to rebuild or redesign shoreline infrastructure which supports sustainable and resilient shoreline process, structure, and function in the face of climate change and sea level rise.

d. Sparks of inspiration

Beach restoration is an innovative restoration industry with many sparks of inspiration. With strong regional learning networks and connections to local community leaders, new programs and ideas are emerging to address gaps in our goal to restore the beach ecosystem. Several new approaches or ideas were identified:

- Programs rooted in social science, to motivate private landowners to be shoreline stewards.
- Revolving loan program funding, to help landowners with their contributions to shoreline restoration incentives projects.
- Partnerships and funding sources that support climate change adaptation on shorelines, in particular through setting back infrastructure and purchasing lands where rising seas threaten marine waterfronts.
- A better understanding of the economics, ecological benefits and costs, and motivations and needs of waterfront homeowners. This requires additional social, economic, and ecological science, to continue innovation for private waterfront beach restoration and motivate landowners to be involved in this work.
- Develop positive strategic partnerships with key large organizations, such as the Department of Transportation, Burlington Northern Santa Fe Railway, Federal Emergency Management Agency,

and the network of agencies responsible for hazard planning, so that they can consider marine shoreline restoration as a viable initiative within their existing organizational priorities.

7.2.2 Deltas

The results from the Ecocycle planning session for deltas showed that while the work to restore and conserve Puget Sound deltas has been successful, there is still more room to grow and develop. As a whole, this Ecocycle planning session skewed towards the up-and-coming elements of the work compared to mature and established elements. This indicates that the restoration of Puget Sound deltas is in a younger state" of its ecocycle and is ripe for growth to reach its full potential. Projects that were limited in scope and focused on a single species and practitioners working in silos were identified as old ways no longer serving the ecosystem as a whole. Progress has been made to improve funding sources, collaborative approaches, and community engagement, which have resulted in a better overall understanding of what makes a Puget Sound delta restoration project successful. Moving Puget Sound delta restoration work forward needs to be done in a way that continues the growth that has been seen already.

a. Old ways

The restoration community is improving how local collaboration and community engagement are done. In years past, project ideas, funded work, and land use considerations have not brought together the level of diverse input needed to advance ecosystem recovery as fast as is needed. Today there is increasing attention to adaptive management, more sophisticated modeling, and better scientific certainty of anticipated outcomes for restoration projects, now considering the scale that is needed for expected results. For example, restoration techniques and priorities need to be adjusted to adapt to changing climatic conditions, and while the community has begun to do this in recent years, there are significant hurdles ahead. Additionally, incorporating single-species, or single-interest group perspectives may have been adequate in the past, but this is not sufficient anymore. The good news is that the old ways are being actively shed to make way for new sparks for inspiration, to maintain mature and functioning approaches, and to creatively build initiatives that have been underway for at least the past decade.

b. Mature programs and practices

There is a mature and strong community of recovery advocates, and strategically organizing this human capital has strong benefits. The standard of practice for engaging local communities around restoration and estuary land use management is newly mature and is having good results. Continuing to find new ways to bring more local partners, tribes, landowners, and organizations who often have divergent ideas will ensure long-term resiliency when actions are taken with the blessings of multiple partners.

Monitoring and science for river delta restoration are mature and growing, yet funding for this work continues to be a struggle. Increasing attention to funding monitoring and engaging scientists with local diverse communities is very important. In addition to developing diverse local and regional partners, those relationships need to be cultivated and supported for the long term. With multiple funding programs that are mature, new initiatives are needed to streamline and coordinate funding for the benefit of project efficiency. While there are a healthy number of active and effective restoration funding programs which comprise our “restoration funding system,” there are some new initiatives and sparks of inspiration gaining momentum. Several mature, yet innovative programs that could be increasingly utilized within the broader funding system include multi-benefit/multi-purpose funding, phased and streamlined “portfolio” funding, and ecosystem-based “pre-design” project funding.

c. Initiatives gaining momentum

Greater focus is being placed on the need for social and economic science regarding restoration planning across all systems including river deltas. For example, even if restoration actions have verifiable scientific evidence for positive ecosystem outcomes, we now know that more education about aspects in addition to science is what is needed to bring a broad distribution of interest groups to support recovery actions. Building trust and understanding and demonstrating concern for the interests and values of many people and cultures who rely on these delta landscapes is foundational to the success of river delta recovery planning and implementation. Increased capacity for local diverse teams is required to develop a suite of actions across many land use needs to garner buy-in and develop innovative solutions for restoration projects. Private land ownership and cultural histories are part of the fabric of how decisions are made and incorporating fairness and justice for people impacted by changing delta landscapes is part of restoration project planning. In river deltas with agriculture, incorporating cultural knowledge and historical understanding from tribal elders, generations of farmers, and other sources of local knowledge is critical to know what is possible.

While human dimension aspects of restoration planning are needed, this should occur alongside a strong foundation of understanding dynamic ecosystem processes, and there is a need for additional hypothesis-driven studies to inform and predict the ecosystem outcomes we desire. New funding sources are needed to address emerging issues like climate change, adaptive management, longer-term monitoring, and in-Lieu Fee systems to capture the incremental net loss of listed threatened and endangered species.

d. Sparks of inspiration

Many people and cultures rely on healthy river deltas, and as a result, there are dynamic ideas for how those landscapes should be used or transformed and how to achieve those outcomes. In the past few decades, our collective ability to manage large river delta restoration projects has matured and we have learned many lessons. Because of the diverse and rich landscape, serving so many needs and interests, much of the sparks of inspiration for river delta restoration include improving the funding system for this work so it is more integrated and coordinated across programs. This is needed to enable the many actions that are required to be implemented together with maintaining and transforming this landscape while sustaining and building resilience for the established cultures and groups who rely on river deltas. Developing and funding interdisciplinary teams that include both social and natural scientists would help move this forward. We believe that new funding sources are needed to help coordinate existing funding programs and enable expansion of current program capabilities (beyond just restoration capital) to tackle the substantial multiple needs within deltas. Transforming the funding system should reduce the burden for project sponsors, provide innovative infrastructure design in the face of climate change, maintain agricultural infrastructure, support advanced research and modeling, build the capacity for local multiple interest planning teams, and adaptively manage these landscapes over time. New tools and initiatives are being envisioned and developed to incorporate justice and diversity, accelerate integrated planning, and strengthen the transfer of information between the scientific community, land managers, and holders of traditional knowledge. Lastly, among the many lessons learned from past experiences, we need to increase our efforts for outreach and communication and incorporate social science to include all voices to make progress towards river delta restoration.

7.2.3 Embayments

Results from the Ecocycle planning session for embayments showed that while the work to restore and conserve Puget Sound embayments has been successful there is still more room to grow and develop. As a whole, this work is less mature than the restoration work associated with Puget Sound beaches. The Ecocycle planning session for embayments skewed towards the up-and-coming elements of the work compared to mature and established elements. This indicates that the restoration of Puget Sound embayments is at a younger overall stage and needs to grow and develop to reach its full potential. Many of the comments provided within the embayments workshop were repetitive of the Beaches and Deltas workshops, and there was less to convey in the synthesis below than the other discussions. Therefore we have woven the four categories into a single narrative for embayments.

Similar to delta restoration, although many ideas were identified as new and gaining momentum, several elements were also noted as no longer contributing to embayment restoration progress. Early restoration work in embayments often lacked collaboration between practitioners both due to and resulting in a limited overall understanding of what was needed to be successful. Approaches and methods were used that have now been shown to not be as effective as expected. This also resulted in the limited effectiveness of funding due to projects not being successful in sufficiently restoring embayment functions.

Over the past decades, the restoration community has begun to develop a more robust technical understanding of how to restore shoreline processes in embayments. Increasingly, project sponsors are incorporating restoration designs that consider more reference sites and process models, and today there is a better understanding of important design aspects including cost/benefits of tide gates, the number, size, and orientation of tidal channels, and fish passage dynamics in marine environments. This understanding is setting the stage for new practices, and the restoration community understands now that a process-based restoration approach provides increased benefits to our ecological systems. Thanks in part to improved funding for research, projects today are better at taking into account the need to restore complexity and connectivity over spatial and temporal scales to support multiple species and life stages of salmonids and other wildlife.

To further develop embayment restoration in Puget Sound, several main issues were identified which need attention:

- **Funding** – including addressing stakeholder resistance, data accessibility, sources of match, and availability for small localized projects.
- **Climate change and sea level rise** – including further research to better understand these impacts now and into the future.
- **Social science inclusion** – including interdisciplinary teams of both social and natural scientists and the recognition and incorporation of traditional ecological knowledge. This can help ensure that the human dimension of restoration projects is effectively integrated into project planning and development, which can help to improve local stakeholder engagement and project success.
- **Research** – to help projects succeed, including increased monitoring of past and current projects, will help determine how to improve the effectiveness of future embayment restoration projects.

7.3 Ecocycle conclusions

All sessions on beaches, deltas, and embayments came back with similar themes for future growth and development of these systems:

- Better understand the processes that drive the natural functions, including the current and future impacts of climate change and sea-level rise.
- Fund monitoring of restoration projects to advance our understanding of nearshore ecosystems and project effectiveness.
- Develop interdisciplinary teams that include both natural and social scientists across the stages of restoration work, including project development, implementation, research, and monitoring.
- Incorporate the human dimensions of restoration work to effectively engage with stakeholders and help ensure local buy-in for projects.
- Engage with local tribes to incorporate indigenous knowledge into restoration practice.
- Improve the permitting process for restoration projects.
- Improve the overall effectiveness of existing and future funding sources and grant programs, including changes to match requirements and increased collaboration between grant programs.

8. Pre and Post Summit surveys

To gauge expectations and to learn more about attendees prior to the Summit and to understand participants' reflections following the Summit, we conducted surveys before and after the Summit. The pre-Summit survey helped us to assess the breadth of organizations represented by the attendees as well as their fields of expertise and what they hoped to learn from the Summit. The post-Summit survey helped us to understand how satisfied with the Summit the attendees felt and how the Summit may contribute to their own restoration work.

8.1 Pre-Summit survey

There were 530 registrants to the Nearshore Restoration Summit. Upon registration, we asked people to complete a pre-registrant online survey to inform our planning and goals for the Summit. Results from the survey showed that registrants represented 109 cities, mostly from Washington, but also included registrants from Oregon, California, Hawaii, Florida, Massachusetts, Maryland, Texas, and British Columbia, Canada.

Summit registrants worked in a diverse array of work categories, with the highest percentage assigning themselves to state government (25%), and descending to local government (16%), nonprofit organization (14%), business such as environmental consulting (12%), federal government (12%), tribal government (9%), higher education (7%), and other (5%) (Figure 8-1).

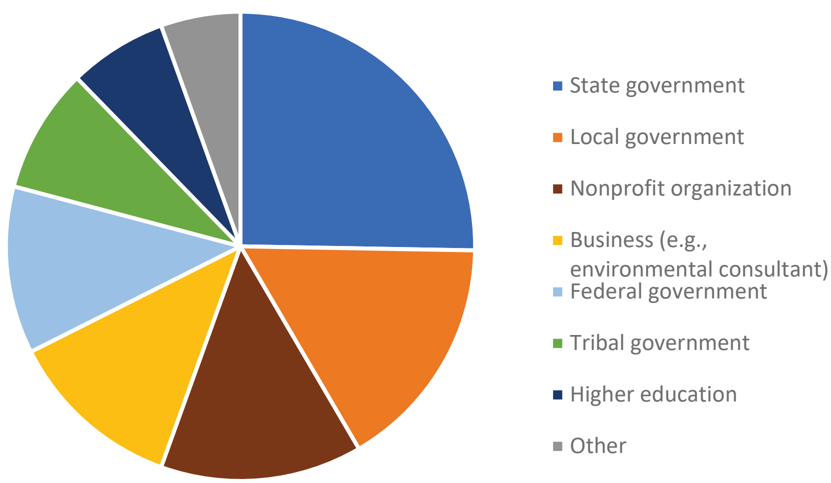

Figure 8-1. Affiliations of Summit registrations.

The primary field of expertise or training of registrants was mainly in 3 categories – natural science (32%), environmental management or planning (25%), ecosystem restoration (25%) – with less assigning themselves to categories of community outreach and education (9%), social sciences (4%), and other (5%) (Figure 8.2). When asked what registrants expected to get out of the Summit, the top two responses were to learn about nearshore natural science research (25%) and restoration projects (24%), followed by community outreach and engagement projects (15%), nearshore social science research (13%), network and make new partnerships (11%), participate in and contribute to discussions (9%), participate in and contribute to conceptual model building (4%), and other (1%) (Figure 8-3).

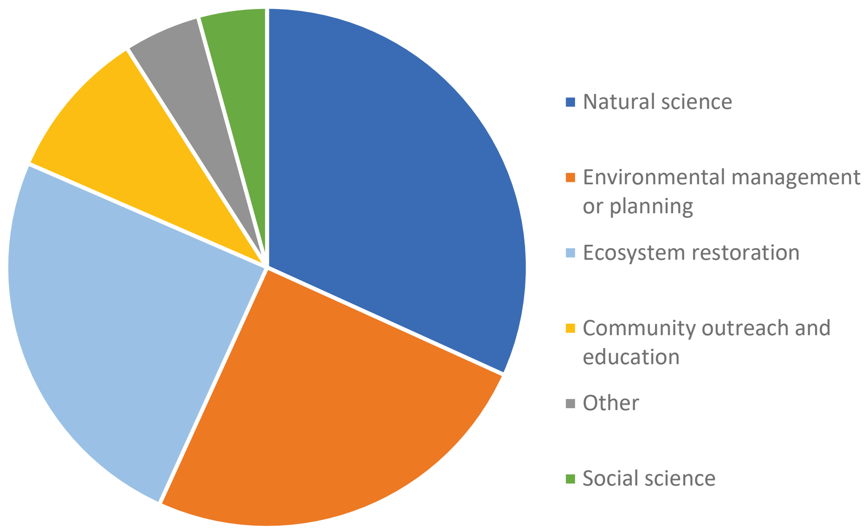

Figure 8-2. Primary field of Summit registrants.

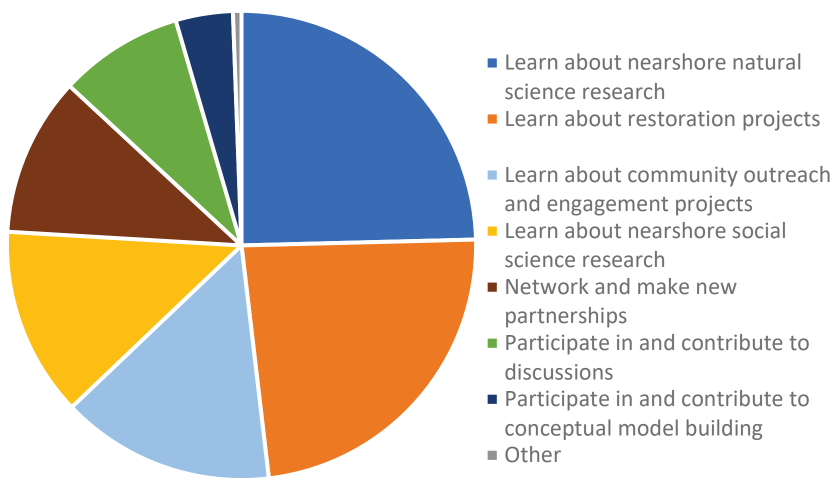

Figure 8-3. Expectations of registrants prior to the Summit.

8.2 Post-Summit survey

Following the Summit, the planning team created and implemented a post-Summit assessment survey. The survey was implemented using Qualtrics, a web-hosted survey program. The survey aimed to evaluate the Summit among participants. A small group of self-selected respondents (n=65) participated in the assessment (~12% of the total Summit attendees). Respondents primarily included general audience members (63%), presenters (14%), small group discussion participants (13%), conceptual model participants (5%), and learning/knowledge cycle participants (5%). Survey respondents also largely included natural scientists (40%), practitioners (37%), and others (18%) (e.g., recovery coordinator, volunteer committee member, and facilitator). Social scientists comprised the smallest group of respondents (5%). Respondents also primarily worked for state government (28%), local government (16%), private sector/business (16%), and non-profit organizations (12%), among other sectors or places of employment. Given the variation in respondent groupings, survey results are linked to respondents' roles in the Summit and do not fully capture the diversity of Summit participant roles and experiences. Respondents were asked to assess the success of the Summit. Success was linked to the Summit's prioritized six goals, including "develop and/or incorporate social science principles including Diversity, Equity, and Inclusion (DEI) into conceptual models for nearshore restoration," among other goals. Based on a scale from 1 (not very successful) to 5 (very successful), respondents' perspectives varied by goal. For example, 50% of respondents selected 5 (very successful) for meeting the "synthesize nearshore restoration work in Puget Sound," goal, while only 40% of respondents selected 4 (successful) and another 40% selected 5 (very successful) for meeting the "synthesize biophysical and social science research informing nearshore restoration in Puget Sound," goal (Table 8-1).

Table 8-1. Summit satisfaction in meeting prioritized goals (scale: not very satisfied (1) to very satisfied (5)).

Summit Goals	1	2	3	4	5
Synthesize biophysical and social science research informing nearshore restoration in Puget Sound.	0%	0%	20%	40%	40%
Synthesize nearshore restoration work in Puget Sound.	0%	0%	15%	35%	50%
Identify the most important science and restoration management questions that will guide actions that improve nearshore ecosystem condition.	0%	9%	17%	51%	23%
Update Puget Sound Nearshore Ecosystem Restoration Project (PNSERP) conceptual models for the ecosystem responses of specific restoration actions and best practices to incorporate new research (Clancy et al. 2009).	0%	13%	35%	29%	23%
Develop and/or incorporate social science principles including Diversity, Equity, and Inclusion (DEI) into conceptual models for nearshore restoration.	0%	12%	35%	26.5%	26.5%
Make connections with people, research, and ideas that will be reflected in your future work.	0%	3%	14%	37%	46%

Respondents were also asked to assess their satisfaction of the Summit, based on their own experiences (Table 8-2). Satisfaction was assessed per Summit component, including, general Summit organization, presentations, conceptual model activities, and lounge activities, among other components. Based on a scale from 1 (not very satisfied) to 5 (very satisfied), respondents largely responded positively to the satisfaction question with average responses ranging from 3 (other) to 4.8 (general Summit organization). Overall, respondents were more satisfied with the general Summit organization, Summit communications and outreach, and presentations, compared to other components.

Table 8-2. Summit satisfaction overall (scale: not very satisfied (1) to very satisfied (5)).

	1	2	3	4	5
General Summit organization	0%	0%	3%	14%	83%
Summit communications and outreach	0%	3%	3%	31%	63%
Presentations	0%	3%	0%	23%	74%
Small group discussions	5%	5%	9%	36%	45%
Conceptual model activities	7%	0%	40%	33%	20%
Ecocycle activities	8%	0%	17%	50%	25%
Lounge activities	5%	0%	17%	39%	39%
Other	33%	0%	33%	0%	33%

Respondents were also asked to assess how the Summit and its contents contribute to their nearshore restoration work, including what Summit component contributed most to their work. Overall, respondents demonstrated that the Summit and its contents contribute to their nearshore work and/or research with variations, including: "a little" (22%); "a moderate amount" (33%); "a lot" (25%); and "a great deal" (19%). Building upon participant satisfaction, respondents were asked to identify which specific Summit components (e.g., presentations, conceptual model activities, lounge activities, and others) contributed most to their nearshore work and/or research. While at least 2 respondents selected one component or more, overall, respondents demonstrated that presentations (62%) and small group discussions (16%) contributed most to respondents' nearshore work and/or research.

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Appendix C: Applied Geomorphology Guidelines and Hierarchy of Openings.

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10. Appendix A. Management measures and descriptions from Clancy et al. 2009

No.[1]	Management Measure	Description[2]
1	Armor Removal or Modification	Removal, modification, or relocation of coastal erosion protection structures such as rock revetments, bulkheads, and concrete walls on bluff-backed beaches, barrier beaches, and other shorelines.
2	Beach Nourishment	The intentional placement of sand and/or gravel on the upper portion of a beach where historic supplies have been eliminated or reduced.
3	Berm or Dike Removal or Modification	Removal or modification of berms, dikes and other structures to restore tidal inundation to a site that was historically connected to tidal waters. Includes dike/berm breaching and complete dike/berm removal.
4	Channel Rehabilitation or Creation	Restoration or creation of channels in a restored tidal wetland to change water flow, provide habitat, and improve ecosystem function.
5	Contaminant Removal and Remediation	Removal or remediation of unnatural or natural substances (e.g., heavy metals, organic compounds) harmful to the integrity or resilience of the nearshore. Pollution control, which is a source control measure, is a different measure.
6	Debris Removal	The removal of solid waste (including wood waste), debris, and derelict or otherwise abandoned items from the nearshore.
7	Groin Removal or Modification	Removal or modification of groins and similar nearshore structures built on bluff-backed beaches or barrier beaches in Puget Sound.
8	Habitat Protection Policy or Regulations	The long-term protection of habitats (and associated species) and habitat-forming processes through zoning, development regulations, incentive programs and other means.
9	Hydraulic Modification	Modification of hydraulic conditions when existing conditions are not conducive to sustaining a more comprehensive restoration project. Hydraulic modification involves removing or modifying culverts and tide gates or creating other engineered openings in dikes, road fills, and causeways to influence salt marsh and lagoon habitat. This measure is used in managed tidal systems (as opposed to naturally maintained systems).
10	Invasive Species Control	Eradication and control of nonnative invasive plants or animals occupying a restoration site and control measures to prevent introduction or establishment of such species after construction is complete.
11	Large Wood Placement	Installment of large, unmilled wood (large tree trunks with root wads, sometimes referred to as large woody debris) within the backshore or otherwise in contact with water to increase aquatic productivity and habitat complexity.
12	Overwater Structure Removal or Modification	Removal or modification of overwater structures such as piers, floats and docks to reduce shading and restore wave regimes.
13	Physical Exclusion	Installation of exclusionary devices (fences, barriers, mooring buoys, or other devices) to direct or exclude human and/or animal use of a restoration site.
14	Pollution Control	Prevention, interception, collection, and/or treatment actions designed to prevent entry of pollutants into the nearshore ecosystem.
15	Property Acquisition and Conservation	Transfer of land ownership or development rights to a conservation interest to protect and conserve resources, enable restoration or increase restoration effectiveness.
16	Public Education and Involvement	Activities intended to increase public awareness of nearshore processes and threats, build support for and volunteer participation in restoration and protection efforts, and promote stewardship and responsible use of nearshore resources.
17	Revegetation	Site preparation, planting, and maintenance to manipulate soils and vascular plant populations to supplement the natural development of native vegetation.
18	Species Habitat Enhancement	Installation or creation of habitat features (sometimes specific structures) for the benefit of native species in the nearshore.
19	Reintroduction of Native Animals	Reestablishment of native animal species at a site where they existed or as replacement for lost habitat elsewhere.
20	Substrate Modification	The placement of materials to facilitate establishment of desired habitat features and improve ecosystem functions, structures, or processes.
21	Topography Restoration	Dredging, excavation and /or filling to remove or add layers of surface material so that beaches, banks, tidal wetlands, or mudflats can be created.

[1] The management measures are listed in alphabetical order. No hierarchy or priority order should be inferred.

[2] See Clancy et al. 2009 for a complete definition.

11. Appendix B. List of all Summit speakers and affiliations

Beach Speakers	
Natural Scientists	
Name	**Affiliation**
Andrea Maclennan	Herrera Environmental
Bart Christiaen	Washington Department of Natural Resources
Bianca Perla	Vashon Nature Center
George Kaminsky	Washington Department of Ecology
Hannah Faulkner	Washington Department of Fish and Wildlife
Hugh Shipman	Washington Department of Ecology, retired
Ian Miller	Washington Sea Grant
Jason Toft	University of Washington
Megan Dethier	University of Washington
Tessa Francis	Northwest Fisheries Science Center, Puget Sound Institute
Practitioner/Planners	
Name	**Affiliation**
Brian McTeague	Squaxin Island Tribe
Christina Kereki	Kitsap County
DG Blair	Stewardship Centre for British Columbia
Jamie Michel	Coastal Watershed Institute
Jim Johannessen	Coastal Geologic Services
Karin Strelioff	Thurston Conservation District
Kollin Higgins	King County Natural Resources
Lisa Kaufman	NW Straits Foundation
Tina Whitman	Friends of the San Juans
Social Scientists	
Name	**Affiliation**
Aimee Kinney	Puget Sound Institute
Brittany King	Oregon State University
David Trimbach	Oregon State University and Washington Department of Fish and Wildlife
Melissa Schutten	Washington Sea Grant
Steve Dundas	Oregon State University
Sydney Fishman	Ecology
Delta Speakers	
Natural Scientists	
Name	**Affiliation**
Amy Borde	Pacific Northwest National Lab
Chris Ellings	Nisqually Indian Tribe
Correigh Greene	Northwest Fisheries Science Center
Emily Howe	The Nature Conservancy
Eric Grossman	United States Geological Survey
Frank Leonetti	Snohomish County
Gary Slater	Ecostudies Institute

Greg Hood	Skagit River System Cooperative
Heida Diefenderfer	Pacific Northwest National Lab
Jason Hall	Cramer Fish Sciences
Josh Chamberlin	Northwest Fisheries Science Center
Katrina Poppe	Western Washington University
Lisa Belleveau	Skokomish Tribe
Melanie Davis	Oregon State University
Mike LeMoine	Skagit River System Cooperative
Roger Fuller	Padilla Bay National Estuarine Reserve
Sandie O'Neill	Washington Department of Fish and Wildlife
Shelby Burgess	Cramer Fish Sciences
Todd Zackey	Tulalip Tribes
Trina Bayard	Audubon Washington
Planner/Practitioners	
Name	**Affiliation**
Catherine Corbett	Lower Columbia Estuary Partnership
Daniel Elefant, and	Environmental Science Associates
Bennett LaFond	Snohomish Conservation District
Cindy Dittbrenner	Dittbrenner Consulting
Jason Griffith	Stillaguamish Tribe of Indians
Jenna Friebel	Skagit County Drainage and Irrigation District Consortium
Jenny Baker	Washington Department of Fish and Wildlife
Joseph Pavel	Skokomish Tribe
Kurt Nelson	Tulalip Tribes
Loren Brokaw	Washington Department of Fish and Wildlife
Mike Rustay	Snohomish County
Monte Marti	former Snohomish Conservation District
Social Scientists	
Name	**Affiliation**
Kelly Biedenweg	Oregon State University
Sara Breslow	University of Washington
Steven Scyphers	Northeastern University
Embayment Speakers	
Natural Scientists	
Name	**Affiliation**
Doris Small	Washington Department of Fish and Wildlife
Pad Smith	Washington Department of Fish and Wildlife
Eric Beamer	Skagit River System Cooperative
Hans Daubenberger	Port Gamble S'Klallum Tribe
Jeff Gaeckle	Washington Department of Natural Resources
Jessica Cote	Blue Coast Engineering
Micah Wait	Wild Fish Conservancy
Paul Schlenger	Environmental Science Associates
Practitioner/Planners	
Name	**Affiliation**

Alicia Olivas	Hood Canal Coordinating Council
Kathy Ketteridge	Blue Coast Engineering
Kristin Williamson	South Puget Sound Salmon Enhancement Group
Mendy Harlow	Hood Canal Salmon Enhancement Group
Peter Bahls	Northwest Watershed Institute
Sarah Heerhartz	Mid-Sound Salmon Enhancement Group
Social Scientists	
Name	**Affiliation**
Jennifer Arnold	Reciprocity Consulting
Althea Wilson	Lummi Indian Tribe
Brian Katz	Oregon State University
Colin Grier	Washington State University

12. Appendix C. Discussion participants, leaders, and notetakers

Beach Discussions (Dinner Parties and Conceptual Models or Ecocycle)	
Name	Affiliation
Kay Caromile+	Recreation and Conservation Office
Tish Conway-Cranos*	Washington Department of Fish and Wildlife
Jessica Cote	Blue Coast Engineering
Megan Dethier	University of Washington
Lindsay Desmul	Washington Department of Fish and Wildlife
Simone Des Roches*	University of Washington
Nicole Faghin	Washington Sea Grant
Hannah Faulkner	Washington Department of Fish and Wildlife
Sydney Fishman	Washington Department of Ecology
Roger Fuller	Padilla Bay National Estuarine Research Reserve
Jennifer Griffiths+	Washington Department of Fish and Wildlife
Kollin Higgins	King County
Sarah Heerhartz	Mid-Sound Salmon Enhancement Group
Alexia Henderson+	Washington Department of Fish and Wildlife
Jim Johannessen	Coastal Geologic Services
Jenna Jewett	Washington Department of Fish and Wildlife
Jenna Judge*	Puget Sound Partnership
Lisa Kaufman	Northwest Straits Foundation
Christina Kereki	Kitsap County
Brittany King	Oregon State University
Aimee Kinney	Puget Sound Institute
Mary Krauszer	Pierce Conservation District
Jay Krienitz*	Washington Department of Fish and Wildlife
Andrea MacLennan	Herrera Environmental
Ian Miller	Washington Sea Grant
Bianca Perla	Vashon Nature Center
Dave Price	National Oceanic and Atmospheric Administration
Katrina Radach+	Puget Sound Partnership
Paul Schlenger	Environmental Science Associates
Doris Small	Washington Department of Fish and Wildlife
Karin Strelioff	Thurston Conservation District
Anna Toledo	Island County
David Trimbach*	Oregon State University
Chris Waldbillig	Washington Department of Fish and Wildlife
Tina Whitman	Friends of the San Juans
Daron Williams+	Washington Department of Fish and Wildlife

*Discussion Lead
+Notetaker

Delta Discussions (Dinner Parties and Conceptual Models or Ecocycle)	
Jenny Baker	Washington Department of Fish and Wildlife
Trina Bayard	Audubon Washington
Seth Ballhorn+	Washington Department of Fish and Wildlife
Eric Beamer	Skagit River Systems Cooperative
Amy Borde	Pacific Northwest National Laboratory
Sarah Breslow	University of Washington
Richard Brocksmith	Skagit Watershed Council
Loren Brokaw	Washington Department of Fish and Wildlife
Laura Brophy	Institute for Applied Ecology
Laura Brown	Washington Department of Fish and Wildlife
Shelby Burgess	Cramer Fish Sciences
Paul Cereghino*	National Oceanic and Atmospheric Administration
Joshua Chamberlin	Northwest Fisheries Science Center
Dave Cline	Shannon and Wilson
Tish Conway-Cranos*	Washington Department of Fish and Wildlife
Catherine Corbett	Lower Columbia Estuary Partnership
Kit Crump	Snohomish County
Melanie Davis	Oregon State University
Lindsey Desmul+	Washington Department of Fish and Wildlife
Simone Des Roches+	University of Washington
Daniel Elefant	Environmental Science Associates
Hannah Faulkner*	Washington Department of Fish and Wildlife
Jenna Friebel	Skagit County Drainage and Irrigation District Consortium
Roger Fuller	Padilla Bay National Estuarine Research Reserve
Gretchen Glaub	Snohomish County
Jason Griffith	Stillaguamish Tribe of Indians
Jennifer Griffiths	Washington Department of Fish and Wildlife
Correigh Greene	National Oceanic and Atmospheric Administration
Eric Grossman	United States Geological Survey
Cynthia Harbison+	Washington Department of Fish and Wildlife
Jason Hall	Cramer Fish Sciences
Alexia Henderson+	Washington Department of Fish and Wildlife
Emily Howe	The Nature Conservancy
Gary Johnson*	Retired Pacific Northwest National Laboratory
Aimee Kinney	Puget Sound Institute
Jay Krienitz	Washington Department of Fish and Wildlife
Bennett LaFond	Snohomish Conservation District
Monte Marti	Retired Snohomish Conservation District
Jamie Michel	Coastal Watershed Institute
Ian Miller	Washington Sea Grant
Alicia Olivas	Hood Canal Coordinating Council
Sandie O'Neill	Washington Department of Fish and Wildlife
Joseph Pavel	Skokomish Indian Tribe
Dawn Spilsbury Pucci	Island County

Katrina Radach+	Puget Sound Partnership
Si Simenstad	University of Washington
Gary Slater	Center for Natural Lands Management
Doris Small	Washington Department of Fish and Wildlife
Padraic Smith	Washington Department of Fish and Wildlife
Jason Toft*	University of Washington
David Trimbach*	Oregon State University
Micah Wait	Wild Fish Conservancy
Daron Williams+	Washington Department of Fish and Wildlife
Isa Woo	United States Geological Survey
Todd Zackey	Tulalip Tribes

*Discussion Lead
+Notetaker

Embayment Discussions (Dinner Parties and Conceptual Model or Ecocycle)	
Jennifer Arnold	Reciprocity Consulting
Eric Beamer	Skagit River System Cooperative
Kay Caromile+	Recreation and Conservation Office
Tish Conway-Cranos*	Washington Department of Fish and Wildlife
Jessica Cote	Blue Coast Engineering
Logan Daniels	Snohomish County
Hans Daubenberger	Port Gamble S'Klallum Tribe
Lindsey Desmul+	Washington Department of Fish and Wildlife
Simone Des Roches	University of Washington
Megan Dethier	University of Washington
Hannah Faulkner*+	Washington Department of Fish and Wildlife
Sydney Fishman	Washington Department of Ecology
Roger Fuller	Padilla Bay National Estuarine Research Reserve
Jeff Gaeckle	Washington Department of Natural Resources
Eric Grossman	United States Geological Survey
Mendy Harlow	Hood Canal Salmon Enhancement Group
Sarah Heerhartz	Mid-Sound Salmon Enhancement Group
Jenna Judge+	Puget Sound Partnership
Brian Katz	Oregon State University
Aimee Kinney	Puget Sound Institute
Jay Krienitz*	Washington Department of Fish and Wildlife
Brian McTeague	Squaxin Island Tribe
Theresa Mitchell+	Washington Department of Fish and Wildlife
Alicia Olivas	Hood Canal Coordinating Council
Dawn Spilsbury Pucci	Island County
Katrina Radach+	Puget Sound Partnership
Paul Schlenger	Environmental Science Associates
Doris Small	Washington Department of Fish and Wildlife
Padraic Smith	Washington Department of Fish and Wildlife
Jason Toft*	University of Washington
David Trimbach*	Oregon State University
Micah Wait	Wild Fish Conservancy
Daron Williams	Washington Department of Fish and Wildlife
Kristin Williamson	South Puget Sound Salmon Enhancement Group
Todd Zackey	Tulalip Tribes

*Discussion Lead
+Notetaker

13. Appendix D. Conceptual model discussions

D.1 Starting conceptual models

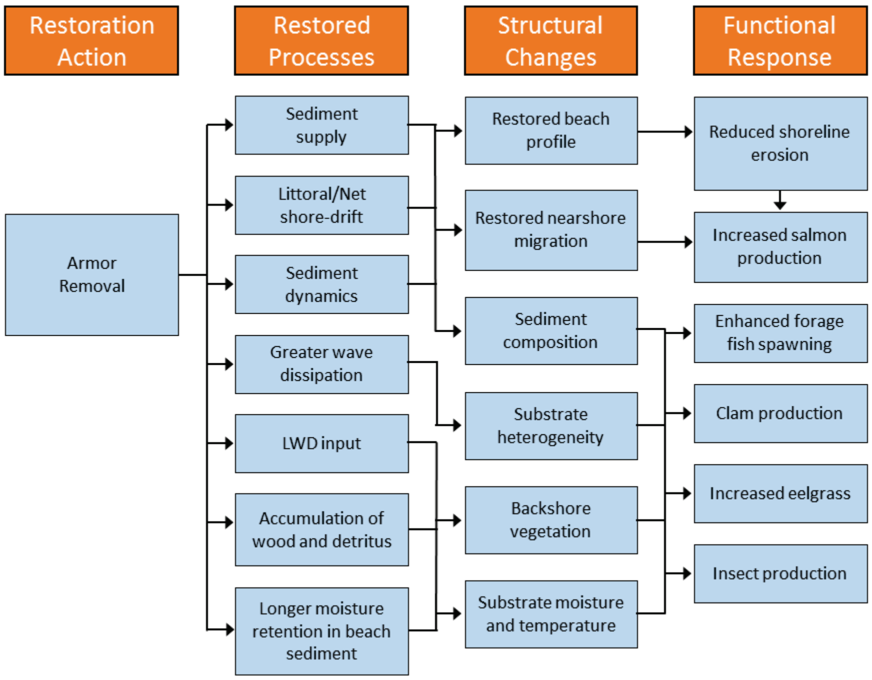

Figure D-1. Conceptual model for Armor removal from Clancy et al. (2009), used in Beach Discussions.

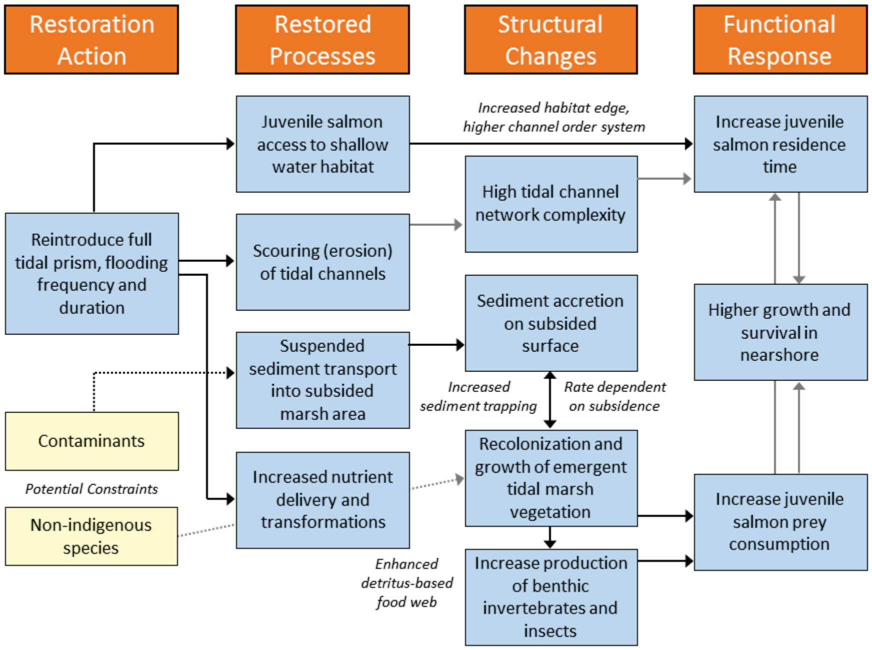

Figure D-2. Conceptual model for berm or dike removal or modification from Clancy et al. (2009), used in Delta discussions.

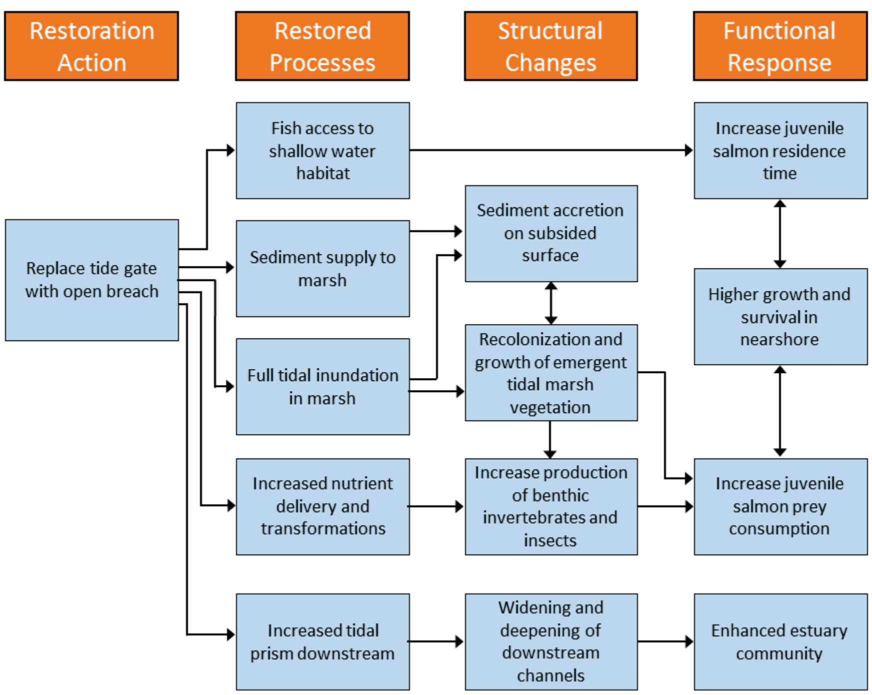

Figure D-3. Conceptual model for hydraulic modification from Clancy et al. (2009), used in Embayment in discussions.

D.2. Commonly identified human/social themes from conceptual model workshop activities:

Access and use: site access and human use (e.g., recreation).

Climate change: climate change related (e.g., SLR).

Management: management or planning related.

Broad drivers: broad or vague drivers, usually used as an overarching category with more detailed subcategories.

Broad response: broad or vague responses, usually used as an overarching category with detailed subresponses.

Engagement and education: education, outreach, and engagement focused item; emphasis on engagement as it relates to two-way interaction compared to one-way outreach activities

Economics: cost/benefit or economics related content.

Diversity, equity, inclusion (DEI): equity, DEI, JEDI, or EJ related content.

Hazard reduction: hazard reduction content.

Values, beliefs, & norms (VBN): human perceptions, attitudes, opinions, values, beliefs, perspectives, and norms – use of values, beliefs, norms as theme category name due to wide use within environmental social sciences.

Human wellbeing (HWB): human wellbeing content, includes key non-economic wellbeing components or dimensions, including those included in the HWB Vital Signs, like stewardship, local foods, and sense of place.

Individual and community change: individual and social change focused (relates to an action taking place that triggers some sort of human change response, whether individual, community, or even institutional).

Knowledge: knowledge content.

Ecological (+/-) benefits, contributions, and services: content that includes multiple benefits, contributions, and ecosystem services as outputs or outcomes, including primarily natural.

Negative human impacts: negative human impacts directly related to human behaviors or actions.

Property and land use: content associated with private property, land values, and land use.

Regulations and governance: content associated with regulations, politics, laws, or governance in some form.

Time and context: broad or specific content associated with underlying time or context.

14. Appendix E. Glossary of terms

Glossary of Social Science terms:

***Diversity**: Illustrates the differences present within a particular collective, group, setting, or place. An individual is not diverse. Differences are often associated with social identities, including able-bodiedness, age, class, ethnicity, gender, race, religion, or sexual orientation.

Equity: The ability to develop, enhance, and support procedural, distributional, contextual, and recognitional fairness in systems, resource management or distribution mechanisms, governance, and procedures to foster more equitable opportunities for all people.

***Human dimensions**: The full spectrum of ways in which people relate to the environment including actions and behaviors that affect the health of the Sound as well as the ways in which people benefit from engagement with the natural environment of Puget Sound (i.e. human wellbeing).

***Human wellbeing**: An interdisciplinary perspective on what allows humans to thrive. It includes familiar topics such as physical and psychological health, as well as governance, social, cultural, and economic wellbeing. Within the context of Puget Sound recovery, human wellbeing relates to people's engagement with the natural environment of Puget Sound, as reflected in the Partnership's Human Health and Quality of Life goals and associated Vital Signs.

Inclusion: Practices and strategies aimed at promoting meaningful interactions among individuals or groups with differing backgrounds, experiences, worldviews, and traits.

Social-ecological systems: Refers to the integration of humans and nature into one complex, unified system. The social-ecological framework can help us understand how governance systems, people within a resource system, resource systems, and resources all come together to create the specific geographic context of situations. The framework also provides context for understanding influences from external ecological or human factors (for example, climate change or economic development).

***Social sciences**: The academic body of theory, knowledge, and research methods aimed at understanding social systems. The foundational social sciences based on empirical study include anthropology, economics, geography, political science, psychology and sociology. Social science helps us understand the human dimensions of natural resource management.

Glossary of natural science terms. Adapted from Clancy et al 2009, Schlenger et al. 2012 and Cereghino et al. 2012, CGS et al. 2020 Beach Strategies Phase 2 glossary

Accretion: The gradual addition of sediment to a beach or to marsh surface as a result of deposition byflowing water or air. Accretion leads to increases in the elevation of a marsh surface, the seaward building of the coastline, or an increase in the elevation of a beach profile (the opposite of erosion).

Barrier type embayment: A barrier estuary, barrier lagoon, or closed lagoon or marsh landform (as per Shipman 2008) which depends on a barrier beach for wave protection, and thus, is linked through sediment supply and transport to the updrift beach system.

Beach: The gently-sloping zone of unconsolidated sediment along the shoreline that is moved by waves, wind and tidal currents.

Bluff: A steep bank or slope rising from the shoreline, generally formed by erosion of poorly consolidated material such as glacial or fluvial sediments.

Conceptual model: A model, either numerical or diagrammatic, that summarizes and describes the relationships and interactions between specified model components.

Delta: A deposit of sediment formed at a stream or river mouth, or other location where the slowing of water flow results in sediment deposition.

Drift cell: A segment of shoreline that encompasses a single system of sediment input, transport, and deposition. The structure of beaches within a drift cell is anticipated to be strongly affected by sediment input and sediment transport processes. Generally consists of a zone of sediment erosion (Feeder Bluff), zone of sediment transport (Transport Zone) and a zone of sediment accretion (Accretion Shoreform) (MacLennan et al. 2013).

Embayment: Open coastal inlet, barrier estuary, barrier lagoon, closed lagoon, and marsh.

Ecosystem process: Any interaction among physiochemical and biological elements of an ecosystem that involve changes in character or "state" (NRC 1992). Processes like primary production or tidal flux alter structures that inturn provide ecosystem functions goods and services.

Ecosystem structure: Refers to the composition and configuration of the physical and biological components of an ecosystem at a moment in time, including water, sediments, gases, and biota. Roughly synonymous with ecosystem state but perhaps more exclusive of process, and without any assumption of equilibrium.

Ecosystem functions: Any phenomena in an ecosystem that results from the interaction of the structures and processes of that ecosystem (e.g., an animal acquiring food, flood stage changing slowly, a beach remains cool on a sunny day). All the ways that humans recognize value in ecosystems are collectively described as ecosystem functions, goods, and services.

Erosion*:* The wearing away of land by the action of natural forces. On a beach,the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation (wind action; opposite of accretion) (Shipman 2008).

Nearshore ecosystems: Nearshore ecosystems include those ecosystems within a narrow strip where the land and rivers meet the sea. The nearshore extends from the waterward depth of light penetration (estimated as 10 meters below Mean High Water) across the shoreline to the uplands that directly influence or are influenced by the shoreline (estimated as 200 meters landward of the shoreline). Includes streams and rivers to the upstream extent of tidal influence, and their riparian areas.

Puget Sound: Defined here to include all inland marine waters of Washington State inside of the entrance to the Strait of Juan de Fuca and including Georgia Strait south of the Canadian border.

Shoreform/landform: A nearshore structure like a beach, river delta, or an embayment created and maintained through the action of physiographic processes. The term shoreform and landform are used alternately among PSNERP publications and are essentially synonymous.

Tidal wetlands: Wetlands where hydrology is influenced by tides. Simenstad et al. (2011) divides tidal wetlands into four classes based on potential vegetation structure as controlled by salinityregime: euryhaline unvegetated (EU), estuarine marsh (EM), oligohaline transition (OT), and tidal fresh (TF).