From Watershed to Waves: Restoring Estuaries for Salmon

Virtual Knowledge Exchange Workshop **|** *June 11, 2025*

Introductions and Welcome

Moderator Laura Weatherly (DFO) welcomed participants and outlined the workshop theme, objectives and context, noting:

- Workshop is co-hosted by Fisheries and Oceans Canada, Pacific Salmon Foundation and the Washington Governor's Salmon Recovery Office.
- Nearly 1,000 virtual participants attending from across Canada, the US and Mexico.
- This is the 8th workshop in the Knowledge Exchange series; the 9th workshop on tide gates is planned for September. The PSF website includes a full library of reports and resources from the workshop series.

Greer Maier, Washington, added brief welcoming remarks and co-moderator Jason Hwang, PSF, introduced the first speaker.

Estuaries as nursery habitat for salmon: from science to stewardship

Jonathan Moore, Simon Fraser University

Highlights of this presentation included (See PowerPoint for details):

- SFU Salmon Watersheds Lab: overview, research objectives.
- Importance of collaborations in this work, e.g. the Estuary Resilience Initiative led by Nature Trust of BC in partnership with First Nations.
- Estuaries as complex mosaics and among the most productive and most degraded habitats on earth.
    - There are a host of controls that impact and define estuary inputs from both watersheds and the ocean, with additional complexity added by various estuary processes.
    - Estuary changes can occur very fast or very slowly.
    - Diversity of fish found in estuaries: migratory and resident.
- Migratory salmonids may use multiple estuaries.
    - Estuaries function as a pinch point (like Grand Central Station) between their freshwater and marine habitats. What happens in estuaries can impact what happens to salmon in both near and distant environments.
    - Study: Survival rate of Chinook salmon is lower in more degraded estuaries.
    - Heiltsuk Coho study: Extensive estuary residence time and faster growth during that period, leading to 40% increase in marine survival due to estuary function.
- How estuaries shape salmon life-histories: Coho adapt to estuary habitat: e.g. migrating earlier and over a longer period with more enclosed and complicated estuaries.
    - Wild origin fish and fish that migrate earlier hang out longer in estuaries.

    - Estuaries are important on a population level to salmon.
- How salmon utilize estuary habitats:
    - Studies of juvenile Coho: More young Coho in cooler water and meadow habitat.
    - Importance of habitat type varies by context: Eelgrass in Flora Bank region contained far more salmon than other eelgrass habitats (importance of the right combination of factors, e.g. salinity, turbidity).
    - Study found salmon movement following tidal waves, which may link to the foods they are relying on (so food webs are complex, connected and dynamic).
- Work on stressors, past and emerging:
    - Stressors include warming waters, e.g. 2021 heat dome: complicated patterns mapped; these are driven by marine and watershed influences.
    - Projections to understand current and future heat stress for salmon.
    - Also effects of projected sea level rise on estuaries: estuary function can be adapted up-slope if there is connectivity (no dykes).
- Nursery function of estuaries is enabled by connected, diverse, dynamic estuary habitats.
    - This is driven by ocean, watershed and in-estuary processes.
    - These areas offer important “solution space” for salmon in their migratory life cycle.
- Estuary degradation varies significantly, driven by local and global factors.
    - Importance of protecting resilience of unaltered estuaries, restoring degraded estuaries where possible, especially connectivity, and focusing on enhancement for significantly altered ones.
    - Local actions can help estuaries cope with global influences.

Discussion

- Are there examples of successfully managing estuaries for the big changes expected (sea level rise and temperature)?
    - Rivers with intact sediment supply regimes appear more likely to be able to keep up with and adapt to ocean rise. Also restoring connectivity (e.g. Cowichan River example) to allow estuaries to migrate up-slope. Temperatures are driven in part by what’s happening up-stream, so protecting that riparian habitat. Complexity is a great solution for many of these challenges — e.g. pools or cool water pockets that salmon can find and utilize.
- What restoration strategies should we emphasize to improve complexity?
    - Removing dykes and hard edges, e.g. Skagit and Puget Sound examples, to let nature restore connectivity.
- How best to combine river and estuary restoration?
    - Integrated planning that looks at stressors from headwaters to the ocean, and that prioritizes actions, particularly those that will have cumulative benefits.

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Tidal marsh restoration design: Then, now and tomorrow: What are we learning?

Greg Hood, Skagit River System Cooperative

Highlights of this presentation included (See PowerPoint for details):

- Presentation focusses on tidal marshes in the Pacific Northwest, and particularly on tidal channels at the heart of these systems.
- Examples:
    - Gog-li-hi-ti 1985 project: Aerial photos show evolution of the 6-acre site over almost 40 years to achieve a dynamic equilibrium.
        - Lessons learned: 1) It can take a long time for mash restoration to occur. 2) This was a relatively crude site design — our understanding and design of channels has evolved since then.
    - 1990 Chehalis mitigation slough: Excavation of tidal channel to mitigate for shipping channel. Aerial photos (2011 and 2021) show evolution of he site, including unusual tidal flows due to the weird shape.
        - This example demonstrated the importance of tidal channel shape and what we've subsequently learned about geomorphology.
        - It also highlights the importance of considering physical processes, land forms and biota, and how those interact in habitat restoration.
- Things have changed significantly since those earlier examples:
    - New quantitative predictive models (past models were more qualitative).
    - Also more sophisticated and accessible technology, (e.g. GIS, Lidar, drones), have significantly changed planning and how we do field work.
- How do we think about the geometry of forms: simple example of cubes and spheres:
    - Basic geometry of forms (body form, landform) to plot their volume and surface area. Key difference between cubes and spheres.
    - Lots of research on animal body forms, with a direct relationship between the animals' surface area and mass, regardless of size, and between their body mass and metabolic rate.
- We can apply the same relationships to landforms.
    - Allometry of marsh islands and channel geometry: allows prediction of a suite of useful channel geometries.
    - This shows that the relationship between size and results is non-linear: The bigger the area restored, the more bang for restoration bucks, so aim for larger areas covered by the project.
    - Exploration of factors affecting allometry: fetch, tidal range, sediment supply, vegetation density and vegetation species. (More details in Hood WG, 2015, *Geographic variation in Puget Sound tidal channel planform geometry*).

  - Applying this in designing tidal channel restoration. Spreadsheet available for Puget Sound channel restoration design: (Link: https://salishsearestoration.org/wiki/Tidal_Channel_Reference_Model)
  - Recommend using the 80% confidence limit (or even lower): this raises the bar to push you to not compromise too much, produces something closer to natural sites.
- What happens if you ignore allometry:
  - Tendency to under-estimate by five-fold the number of tidal channels needed in restoration projects. Under-estimation means reduced connectivity and utility for fish.
  - Qwuloolt and Fir Island Farms examples vs “Zis a ba” site: having too few channels also negatively affects seed retention, and restoration of desired vegetation.
  - Seed retention experiment showed differences in tidal velocity/dispersion of tidal energy, and less vegetation due to seed loss with higher tidal velocities.
  - Micro-topography associated with multiple channels results in different/offsetting tidal patterns and null zones that support seed retention.
- Biological implications of land forms: studies in Chehalis and Skagit deltas showed how channel and slough size impacts detrital insect flotsam density: Smaller channels had higher density, slower movement and thus more availability of food important to juvenile salmon.
  - Experiment with different coloured marshmallows to compare how fast detritus moved in tidal flows and also where organic content is more likely to get trapped within some channels, affecting the biology of those landscapes.
- Current and future challenges facing restorationists: sea level rise, warming, flood hydrography changes:
- Examples of research, monitoring and engineering innovations:
  - Research: Tidal beavers, better understanding of how to use wood, linking fish to channel geometry for better design, improved predictive models.
  - Monitoring: Better understanding of expected restoration trajectories and salmon response, and how to speed up recovery rates. Important to test hypotheses as part of monitoring programs to speed learning.
  - Engineering questions around use of vegetation mounds, the role of large wood, sediment supplementation, and Beaver dam analogues to engineer tidal water depth. So not getting ahead of the science and understanding “the devil in the details” of restoration design — e.g. what works in stream restoration may not work in estuaries.
- Current work on planform vs cross-section geometry: analysis of differences across regions (North Fork, South Fork and Bay Fringe) within the broader Skagit delta linked to changes in marsh elevation.
  - In low elevations, as the tide drops, it flows directly into the bay vs interacting with the marsh platform. At higher elevations, there is more interaction with the marsh platform and more resulting erosion.

    - Erosion of high marsh in bay fringe of Skagit delta (1937 to 2004), with lower SCPU marsh and loss of tidal channels, whereas In the North Fork, with more sediment delivery, channels are becoming bigger and more distinct as the marsh build up around them.
    - Cross section information is important for channel design but also has implications for how marshes will respond to sea level rise. Without compensatory sediment accumulation, our channels will become more indistinct as sea level rises.

Pocket estuary restoration design and implementation in the Salish Sea

Jessica Cote, Blue Coast Engineering

Highlights of this presentation included (See PowerPoint for details):

- Presentation focusses on small pocket estuaries, many of which have been filled historically, with residential development and sediment depletion.
- Such concerns led to the Puget Sound nearshore ecosystem restoration project, which developed design guidelines for sizing primary tidal channels and barrier embayments appropriately for the Puget Sound conditions.
    - Study sites: 10 sites with in situ data collection, 38 with desktop data analysis and field validation.
    - In addition to design guidelines, other lessons included:
        - Importance of understanding embayment geomorphology (where does the primary channel sit within a broader system).
        - Classification of habitat: Impoundment systems, tide flats, marsh — need further research on differences between such systems and what drives them.
    - This work supported development of a guidance document and online tool; caveats include that these guidelines are not applicable to freshwater dominated systems.
    - McSorley Creek: Drowned stream valley; importance of considering current context.
    - Similk: Good candidate to create a barrier embayment.
- Puget Sound case studies:
    - Rose Point: Historic barrier estuary: work included wind wave hindcast, sediment supply and transport, tidal and flow modelling.
        - Site design, construction challenges.
        - Resulting beaver activity, juvenile salmonid response monitoring, valuable lessons being learned.
    - Point No Point barrier estuary: site description.
        - 2022 flooding event created opportunity to combine restoration with protection against future events.
    - Blue Coast barrier embayment strategy decision tree.

Discussion

- Have the studies supported the value of this pocket estuary restoration work to salmon recovery and if so how do you prioritize them?
  - The studies/monitoring done have shown increased fish populations, with juveniles detected very soon after project completion in several cases.
  - Restoration design must be appropriate to the context, geomorphic features and processes to provide successful results.
- What techniques or approaches are best for highly-developed estuaries?
  - These will always require a levee or berm system, so maximizing tidal prism and going as big as you can. Also focus on quality of habitat, so good groundwater flow, ensuring a relatively intact watershed and good riparian corridor upstream to ensure cooler water flow. We also try to remove invasive vegetation, with planting of native species, and creating complexity, e.g. more smaller channels.

Assessing and enhancing estuary resilience to sea-level rise: Estuary restoration in action

Steve Henstra, Nature Trust of British Columbia

Highlights of this presentation included (See PowerPoint for details):

- Project background: estuaries comprise less than 3% of BC's coastline yet support over 80% of the province's coastal fish and wildlife; also important to First Nations communities and commercial fisheries.
- About Nature Trust and its role in procurement and conservation of key ecosystems.
- Marsh Resilience to Sea-Level Rise (MARS): Monitoring framework to ensure our work fit with Nature Trust's key objectives.
- Implementation of MARS in BC:
  - Applied in 22 different estuaries.
  - Project goals.
  - Partnerships — key to project strength.
  - MARS tool: a multi-metric index covering key resilience factors for sea-level rise.
  - MARS outputs and management implications.
  - MARS scoring; results for the 22 sites showed lots of room for improvement.
- Nature Trust is using the MARS output to guide restoration project planning.
  - 2022 Snuneymuxw Estuary: freshwater and sediment redistribution; ongoing monitoring.
  - Gwa'dzi Estuary: Roadway breach, tidal channel reconnection to restore lost habitat.
  - Xwesam Estuary: reconnecting tidal channels.

  - Kw’a’luxw Estuary: Shoreline and coastal process restoration: removed seawall, concrete, rubble and riprap.
  - Cowichan Estuary: Dike removal and food systems revitalization: multi-phased project to increase estuary resilience through the restoration of lost estuarine marsh, with significant emphasis on indigenous food systems revitalization.
  - Shoal Estuary: acquisition to facilitate landward migration of marshes.
- Keys to success: indigenous and other partnerships; stable, ongoing funding, including for monitoring and adaptive management; using assessment tools that are easily scalable; linkages, opportunities to support concurrent research.

Discussion

- How did these restoration projects deal with the need to address flood protection/mitigation?
  - An engineering firm addresses such considerations. The dike removal permit process addresses modelling and mitigation to address various flood risk scenarios.
- How did you deal with the costs of removing materials, including contaminants?
  - We prefer to re-use materials on site wherever possible, e.g. for constructing new berms and dikes, or thin layer placement, which reduces trucking costs. We also partnered with the LaFarge cement company, which contributed trucking costs to support the projects. Involving local players wherever possible is always encouraged and the firms are often receptive to such involvement.

Morning Panel

- Are there examples/models for a watershed wide plan, from headwaters to estuary?
  - Moore: There are a number of different models. In Canada, DFO uses life-cycle modelling approaches for some salmon populations, as do some Washington species recovery plans. The most exciting models are co-governance tables such as the Nicola table, which is looking at the entire watershed, with input from the entire community in order to consider values important to various groups. There is lots of work that can be done to build on these.
  - Agree. I see some of the elements of such a comprehensive approach partly in place, but there still remains lots of work to be done.
- What are some of the challenges of working on restoration in urbanized areas and what strategies are effective in such settings?
  - Cote: Human resistance to change is a challenge. Washington has a program called Shore Friendly that does outreach to residents and provides education on coastal processes, sea level change, moving homes, and best practices. Also bringing in tribal communities, which can be powerful in some situations.
  - Hood: My past experience with a small Seattle project years ago initially felt futile, i.e. to be doing small projects in highly-degraded systems, but the funding was tied to SuperFund. However the project turnout out really well and it inspired support for further work. So success stories can snowball.

- These highly-altered estuaries are also where most people live so it's about reconnecting people and nature and ecosystems, which is an important way to ensure ecosystems are valued.
- Agree: Engage people in ways that resonate with them. We won't always be able to restore it to the historical state, so we need to be creative and open to hybrid approaches in order to achieve successes where you can.
- Getting people interested and passionate is a powerful resource for driving change.

- Does the dynamic nature of estuaries make them easier or more difficult to restore?
    - Hood: The fast-changing nature of estuaries is helpful, although engineers and stakeholders who may want to create a more certain solution can view that as a challenge. But that dynamism is what creates the mosaic. It's also helpful to learning, when you see dramatic changes occurring very rapidly.
    - Cote: The hope is that engineers are adapting to improved understanding of these systems and the value of their dynamism.
    - Henstra: Agree. The fast-changing nature of estuaries is an advantage in restoration work.
- Have you had pushback to using traditional ecological knowledge and if so, how did you deal with it?
    - Henstra: The Cowichan project really challenged traditional notions about agriculture.
    - Cote: A restoration project in the Skagit valley faced concerns about loss of local farmland. There are no easy solutions, but options include offering new agriculture land in exchange, or re-thinking our understanding of what is farming.
    - Hood: There have been contentious relationships between farming and tribal communities in Skagit. One point that helps bridge the gap is that such restoration still produces food (fish), just in a different way.
- What else do we need to do besides building channel networks to jumpstart salmon habitat?
    - Hood: Estuarine channels are really important, but we need to consider other areas such as eelgrass, upper basins and other delta areas such as tidal shrub and forest communities. We really need to think of the habitat continuum on an entire landscape scale, and how different parts of the landscape interact.
    - Cote: There's been a lot of focus on channels because tidal currents aren't powerful enough to carve channels on their own, whereas vegetation can self-establish or can always be done later.
    - Moore: Channels set the stage for everything else that happens. But there is a diverse portfolio of opportunities and those should be tailored to the stressors that the estuary is facing. In some estuaries the key stressors could be Canada geese or Harbour seals.
- Closing thoughts?

- Hood: We need to have confidence that we know what we're doing in undertaking these projects but also humility in acknowledging that many projects are often learning experiences.

Lunchtime Slideshow

See workshop resources page for slideshow featuring a range of restoration project examples.

Resource-based habitat coverage targets and climate actions in the Columbia Estuary

Catherine Corbett, Lower Columbia Estuary Partnership

Highlights of this presentation included (See PowerPoint for details):

- Description of the Lower Columbia and key features.
- Overview of 3 approaches used to identify critical areas for inclusion in a reserve network.
- "Stepping stone" approach to provide refuge sites along the salmonid migratory route.
- Objective was to restore the historic habitat mosaic, which would be protective of the native species that evolved in those conditions.
    - Started with habitat change analysis comparing 1870s habitat to 2010:
    - Found Lower Columbia had lost 50% of its historic habitat, with more losses for certain types of habitat. Prioritized restoration for the latter, along with other rare habitat types.
- Methods for setting measurable targets for restoration: used an ecosystem-based approach to protect a percentage of historic habitat that would be protective of native species.
    - What percentage? Different guidance on what's needed.
    - The goals were to achieve no net loss of native habitats relative to the 2009 baseline and to recover 30% of historical priority habitats by 2030 (40% by 2050), to achieve 60% native habitat coverage.
- Assessing progress: To track progress, they reach out to all partners annually and update project inventory.
- Climate change: These approaches are insufficient to protect species from such impacts so they started adding climate smart strategies to their work. Traditional practices are insufficient; you need forward thinking goals that manage for change, not just persistence.
    - Climate adaptation framework (Schmitz et al 2015): identifies things they're already doing, plus additional requirements to help native species adapt and survive, e.g. start protecting anticipated future habitat needs, provide climate refugia, identify key species vulnerabilities.
    - Examples of climate adaption measures in the Lower Columbia.
    - Project-specific climate adaptation measures: Steigerwald Flood plain reconnection project (e.g. 500-year flood event as the new standard).

- Integrating climate mitigation at a program scale: protecting intact forests, wetlands to help meet Paris Accord commitments to reduce emissions. LCEP working to track land conversions and GHG sequestration/emissions in their habitat work.
- Carbon-methane flux research: addressing knowledge gaps to ensure future access to carbon markets as a funding source for this work.

- Next steps for Columbia River: Identify methods for improved carbon sequestration, including inventory, monitoring of carbon stores/methane emissions, and work with agencies to explicitly fund carbon sequestration and provide resources to expand conservation to working lands.

Discussion

- Q/A: Re the program budget and timeframe. Steigerwald project cost ~$32 million, with 10 years to design and 3 years to construct. Another project was ~$20 million. Bonneville funds much of this work (about $15 million/year), plus there is additional funding from state and federal agencies. The analysis of current vs. historical land coverage was critical to planning and prioritizing the work being undertaken.
- How are biological factors considered, e.g. pinnipeds and invasive species?
  - We didn't tackle pinnipeds and are not very prescriptive regarding quality of habitat.
- Given the importance of scale, how is the work prioritized to ensure effectiveness?
  - We have a good inventory of work underway, so we can compare that to our targets. Bigger is always better, but not always possible, so only smaller restoration sites will be possible sometimes.
- Q/A: Regarding connectivity, there is no simple answer, but the stepping stone strategy is a useful approach. We've also focused on restoring an entire watershed as a steelhead stronghold. We are trying to work on different projects that leverage each other, e.g. improving water flows upstream of Steigerwald.

Restoring connectivity and habitat for juvenile salmon in the Fraser River estuary

Dave Scott, Raincoast Conservation Foundation

Highlights of this presentation included (See PowerPoint for details):

- Overview of the Lower Fraser River and estuary — highly developed area, lots of flood control structures.
- Chinook are the most estuary-reliant salmon species in the Fraser.
- Status of salmon habitats in the Lower Fraser river and estuary.
- Raincoast has been working in the Fraser estuary annually since 2016 to learn more about juvenile salmon habitats.
  - Sampling sites and methods.
  - Results from the first four years show the most intensive use is of marsh habitat.

    - Otolith study for Harrison Chinook showed they spent about 42 days in the estuary (March to June), during a period of rapid growth.
    - Stream-type fish don't rear in the estuary as much, neither do hatchery juveniles.
    - Stomach contents for juvenile Chinook in eelgrass habitats show they switch from eating insects in the marsh to fish prey, so fast growth is essential to support a successful transition.
    - Investigation of juvenile sub-yearling Sockeye migrations in the Fraser estuary.
- Fraser estuary habitats and barriers: project to provide access through jetty structures built along shipping channels — Steveston and Fraser North Arm jetty breaches.
    - Hydraulic modelling work and engineering required to demonstrate that these breaches don't negatively affect the shipping channels.
    - Evolution of breach channels and juvenile sampling: Sampling showed the highest densities of the smallest Chinook juveniles at these sites, along with some stream-type Chinook, hatchery samples and ocean-type Chinook later in the season.
    - Conclusions: breaches significantly improved connectivity for juvenile Chinook, with no impact on adjacent shipping channels. Channel development occurred at varying rates.
- Next steps: Addressing habitat gaps in the Lower Fraser (also taking a stepping stone approach), with a focus on marsh restoration. Issues include geese over-grazing, log booms, vessel wakes.
- Woods Island marsh project: removal of invasive cattails, removed barriers, excavation to make the site more conducive to native plant species, followed by planting. Subsequent monitoring showed a 25-fold increase in juvenile salmon.
- Other projects currently being advanced, partnering with government and First Nations.

Discussion

- Q/A: In terms of estuary restoration priorities, one of the most important things is the off-channel habitat that has been lost, especially in the Lower Fraser.
- Q/A: Flood protection barriers to protect low-lying areas are a key obstacle, so a key challenge is figuring out how to balance flood protection with habitat needs, or identifying low-value lands that can be utilized for restoration.
    - Hope to speak more about flood/tide gates in the next mini-workshop.
- What were the logistical challenges to creating the breaches and how did you deal with it?
    - A key challenge is cost of bridges where needed to maintain truck/rail connectivity.
- Q/A: We have been working with Ducks Unlimited and others who have had success with eco-cultural fencing for geese exclosures or potential harvest to control goose populations.
- Q/A: The breaches are just 30 - 50 metres wide in structures that are kilometres long. The cross current impacts are minimal relative to the size of ships moving by. And the movement of water is primarily from the river to the mud flats, as was modelled.

Restoration Monitoring in the Nisqually River Delta

Melanie Davis, United States Geological Survey

Highlights of this presentation included (See PowerPoint for details):

- This project reflects decades of co-management work by Nisqually Tribes, USGS, state, federal and other partners.
- General overview of the delta, geographic context.
- Focus of the restoration work was to benefit Chinook juvenile salmon for Nisqually tribes.
- Recovery phases and objectives.
- The Nisqually delta work is one piece of the broader work involving collaboration with multiple partners in the Nisqually watershed.
- Physical description of the delta area: complex mix of habitats utilized by juvenile Chinook during their out-migration.
- Historical context: Brown farm dike construction (early 1900s). Diked area became highly degraded, over-run by invasive grasses, blocking access for juvenile salmon, migratory waterfowl and other species.
- 2009 dike removal with restoration to tidal influence: caused massive outflow of invasive vegetation, leaving degraded mudflats.
    - Over time, salt-tolerant marsh vegetation gradually re-grew.
    - Not pristine, so the question is whether this still had benefits for salmon.
- Overview of monitoring program: success criteria and related questions addressed by the monitoring program.
    - Found juvenile salmon were benefitting, with growth rates comparable to reference sites.
    - Sampled the full habitat mosaic to build a detailed food web model for the delta. Found not just direct benefits for Chinook juveniles but also for other elements (prey insects, sediments) that indirectly benefitted Chinook.
- Built on the lessons learned by also exploring expected future impacts of climate change.
    - Sea level rise marsh accretion model: this projected the future loss of significant marsh habitat, and identified the most vulnerable areas.
    - Temperature model showed a 10% increase in the amount of time that temperatures would be untenable for juvenile salmon.
    - Bioenergetics model for fish: provided a clear message of an expected decrease in growth potential for salmon without mitigation.
    - This is a sediment-starved system; modelling showed that by doubling sediment entering the system, the marsh would be able to keep pace with sea level rise.
    - Also looked more broadly at other systems in Puget Sound — other sediment-rich systems are expected to be more resilient to climate change.

- Next steps: Integrating this work in an H-integrated framework (i.e. integrating habitat and monitoring with strategies for hatcheries, hydro, harvest, etc); Integrated population model intended to promote efficient data use and collection in Puget Sound/Salish Sea. Hope to produce an H-integrated resource guide in the next year.

Discussion

- How was the co-management structure developed? Canada would benefit from something similar but we have not yet seen the necessary long-term commitment from governments and others?
    - Co-management has been intrinsic to the Billy Frank Jr Nisqually wildlife refuge since the 1970s. The tribe has an important role facilitating these relationships, and it's helped to have many people at the table committed to co-management and also having that regulatory framework to begin with. There have been occasional challenges, but I can't think of another system in the area that has been co-managed so effectively, or of a more effective system for data collection and usage. Hope to publish a paper shortly on Nisqually as a case study for effective co-management.
- Q/A: We haven't trialed different processes for sediment recruitment in this work but Eric Grossman with USGS has done very detailed sediment modelling exercises. One idea was to create a sediment bypass channel to route sediment to some of the higher-elevation areas. But Eric's model showed that while it was somewhat effective, there just wasn't enough sediment to begin with, so we need to find ways to get that sediment past the dams. We are discussing alternate drawdown strategies with the hydro companies to increase sediment transport, but all the sediment is basically trapped up in the mountains.
- What restoration actions do you recommend to prioritize salmon foraging opportunities?
    - One of the main take-aways is that even if the restoration area doesn't look pretty or anything like the original — drop your expectations about what is right in terms of structural goals and focus instead on functional benefits for salmon. We're also working on a proposal for tidal forested habitat restoration, which has major benefits for salmon.

Afternoon Panel

- Which projects/types should be prioritized?
    - Scott: The Fraser is such a big estuary, so it's hard to decide. We see mostly Chinook using eelgrass in the outer areas, but should we focus there or in the sloughs where we have also seen juveniles hanging out to escape the mainstem?
- Given the importance of healthy sediment supply to salmon and the impediments (dredging, concrete berms), is that message getting through to the powers that be?
    - Scott: There is definitely discussion of how to start re-using sediment dredged from the Fraser. It costs a lot to move, so we're looking at ways to keep the material on site, but we need government to step in and mandate what's needed.
    - Davis: It's a social science question of bridging the divide between dirt and fish. People are looking at more immediate things like riparian vegetation, whereas sediment has longer-term benefits.

- Corbett: We've tried beneficial re-use of sediment. If it's mostly sand, you need to consider the need for organic material as well for planting vegetation.

- Is there a strategy currently to protect "restorable" lands in the Columbia?
    - Corbett: There are laws to protect remaining habitat but we end up having to purchase lands in order to restore it.
    - Scott: In the Fraser, much of the area is fully developed, though remaining marsh habitat is protected. So developers are finding it very hard to find potential areas for offsetting. And with agricultural lands, the strategy is still to raise the existing dikes to protect them, instead of restoring those lands.
    - Davis: There is a bit more flexibility in the Nisqually, with more agricultural land left than in other Puget Sound estuaries. But many Puget Sound estuaries have very steep topography, so there's not much room for expansion. Tribes are discussing with government the possibility of lifting the I-5 highway to permit expansion.
- We are seeing big development projects that include estuary restoration. If you had $50 million is there potential to look at offsetting instead of sticking to what nature already put there?
    - Corbett: We have a project to protect cold water in the Columbia Gorge. The only places with cold water refuges are tributary confluences, but that's immediately subsumed by warmer water in the mainstem. So we are looking at potentially engineering cooler water pockets upstream. There may be room to explore solutions that while not perfect or natural, may still help to support salmon.
    - Scott: In the Fraser, we don't have much opportunity to do "restoration" and it's often not feasible to try to put things back the way they were, so there is potential to do things differently and there are unique opportunities, e.g. to speed up natural marsh establishment.
- Are principles of natural asset management and assignment of values to ecosystem services of estuaries being used to offset capital and maintenance costs for those projects?
    - Davis: We haven't done formal analyses but a colleague has done ecosystem services valuation research. One issue with valuing salmon as an ecosystem service is the Tribes don't want a dollar value placed on their salmon fishery.
    - Corbett: We look at the value that these restoration projects contribute to the local economy, including local jobs, services used, etc.
- Any insights on prioritizing under-restored tidal shrub/forest habitats to benefit salmon?
    - Davis: Laura Brophy has worked on quantifying that type of habitat loss, which is greater than estuarine habitat loss — it's a huge knowledge gap.
    - Scott: In the Fraser, so much has been lost that you don't see much left. We are working on one site in the Lower Fraser.
    - Corbett: There is some work in the Columbia, but it's the kind of habitat that will take decades to restore, so they are looking at ways to jumpstart it.
    - Davis: An estimated 90% of this habitat type has been lost so it's hard to find existing reference sites.

- Morning speakers referenced the importance of a headwaters to ocean strategy. Is the All-H integration focused just on the estuary or the whole watershed? We haven't seen any good whole system models to inform management decisions.
    - Davis: The Nisqually is intended as a whole-system approach, because for salmon it's been death by a thousand cuts. We are looking at smolt to adult recruitment models and the effects of adjusting all these factors. Nisqually isn't data deficient, but such models require an immense amount of data. More challenging, however, is the organizational silos.
    - It's similar in Canada, and we tend to oversimplify how difficult that is to overcome.
- How can we effectively involve municipalities, landowners and stewardship groups?
    - Scott: Raincoast relies on landowners and municipalities to do our projects, where we come in, do the work and leave. It can be challenging to get their attention, so you have to be persistent, but once you have their attention, especially if you can bring funding to the table, and get them excited, it's easier. It's important to come with a serious proposal, good data and science to get their buy-in.
    - In Canada, indigenous entities can play an important role in serving as a catalyst (bringing a very important legal, moral or rights based authority) to the table.
- How much do we need, how much is enough? The answer is definitely linked to other factors but how do we answer this question, both for individual and multiple estuaries that can provide enough rearing capacity.
    - Davis: It's a very difficult question to answer, as the success of these projects is a tiny signal in a lot of noise in terms of detecting population-wide effects, given everything else that salmon face. In Nisqually we focused on local factors like growth rates, diets, body size etc instead of relying on population-wide parameters.
    - Corbett: With climate change and large-scale disturbances, you want a lot and nothing is ever large enough so you do want redundancy.
    - Scott: In the Fraser, it's very hard to gauge the population benefits of our breaches, so we focus on what results we can observer locally. But it would be great to work with others across the whole watershed on relative needs, e.g. for spawning and rearing habitats.

Co-hosts thanked all the presenters, participants and support staff for their role in supporting a success full day.

Adjourned: 3:30 pm