The Importance of Measuring Lake Quinault Sockeye Salmon Stock and Ecosystem Health in Response to an Ever Changing Climate

Ecological Analysis and Restoration Plan

Emily Marraffa, 2023

In a warming world[1], ecological restoration is inescapable in my generation's lifetime. Although it is a new field of research in the climate change adaptation conversations, coined in the early 1900's by Aldo Leopold, with the Society of Ecological Restoration (SER) founded in 1988, it will be a colossal element of life by the time my future children experience our planet.

Across the spectrum of environmental scientific research focused on data collection, the intersectionality of humans and ecosystem services isn't at the forefront in the way it should be. Many researchers take pride in the methodical precision put into their work, understandably. While I strive to incorporate those strengths into my research, the core of my focus is people and wildlife. Restoration isn't *just* for the ecosystem at hand. We, as human beings, participate in and benefit from ecosystem services with every touch of a finger. A philosophical view of our daily interactions with the Earth is one I intend to bring to the world of scientific literature.

That being said, behind every sockeye salmon in the riverbed lies a strategic, ludicrous, ingenious life cycle. Those three words are not often tied together in one breath, but these fish have a story unlike any other. From afar in Amherst, Massachusetts, I have studied for years the economic and ecological impacts that sockeye bring to the Pacific Northwest in my undergraduate research; specifically, Alaska's Bristol Bay and the Wenatchee river system. In Alaska, fisheries amounted to $2.2 billion towards the economy in 2019, and supplied 62,000 workers, as well as 37,400 full time equivalent jobs. In fact, Alaskan salmon account for 57% of worldwide sockeye salmon. Outside of capitalism, sockeye and other salmon greatly contribute to subsistence practices by indigenous peoples in the state. Indigenous subsistence lifestyles are common in Alaska in comparison to the rest of the country, with indigenous lives equating to 19.7% of Alaska's total population.[2]

Life Cycle and Susceptibility

Due to their anadromous nature, sockeye salmon are particularly sensitive to environmental risks. Such risks include but are not limited to increasing river temperatures, drought, water turbidity, and general obstruction such as fallen biomass and dams. A current case study that represents these risks well is the Wenatchee river system in central Washington. Using GIS, I focused on the river's susceptibility to climate change by assessing the potential of riverbank erosion, natural disasters, and the like. Salmon migration routes can be observed in the

[1] Bradley and Jones, 'Little Ice Age' summer temperature variations: their nature and relevance to recent global warming trends
[2] U.S. Department of Health & Human Services. "American Indians and Alaska Natives - by the Numbers.

appendix, along with increasing river temperatures and a risk assessment map. Temperature stability is the most crucial element in spawning success, bringing about obvious challenges. The amount of oxygen found in water systems is directly correlated to the temperature. The higher the temperature, the lower the dissolved oxygen levels.[3]

New research in the Bristol Bay region of Alaska shows the fish that are caught in this region migrated from the river systems of Puget Sound, including the Wenatchee and Quinault rivers. So, these seemingly separate regions are directly connected to each other, meaning that the success of spawning salmon in far away areas has a direct link to the economic success of Alaska, and the availability of fresh Sockeye Salmon worldwide. Fisheries are aware of this and the endangerment, however, restoration events have not been abundant quite yet. As time prevails, ecological crashes are not out of the question. With consistent increases in frequency and intensity of storms and rising temperatures, back to back obstructions that cause insecurity are likely.

Ecological Impacts

When anadromous salmon release their eggs to be fertilized, they die shortly after. This carcass discharge has proven to be a valuable source of energy and nutrients to the river system, as well as the wildlife dispersed in it.[4] As the carcasses biodegrade, they release nitrogen and phosphorus to the ecological operation. Fish and other birds feed on juvenile salmon, bears, eagles and wolves feed on sockeye in freshwater, and sharks, lampreys and other marine mammals prey on sockeye in the ocean.

Migration habitats extend in scale from small inland streams to the vast North Pacific Ocean, thus including multiple habitats in the process. These include freshwater, estuarine, and saltwater habitats, with sockeye traveling up to 1,000 miles in some regions. Because of the multiple habitats and consistent degradation, many species have been listed under the Endangered Species Act.[5] With this extensive travel, they are not a keystone species, but they influence a range of other species, and their nutrient contributions are an important element to ecosystem balance.

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[3] Watershed Academy Web, U.S. Environmental Protection Agency . “The Effect of Climate Change on Water Resources and Programs | Watershed Academy Web | US EPA.” *Cfpub.epa.gov*, 2023,
[4] Fisheries, NOAA. “Sockeye Salmon | NOAA Fisheries.” *NOAA*, 17 Apr. 2020,
[5] Cederholm, C. J., D. H. Johnson, R. E. Bilby, L.G. Dominguez, A. M. Garrett, W. H. Graeber, E. L. Greda, M. D. Kunze, B.G. Marcot, J. F. Palmisano, R. W. Plotnikoff, W. G. Pearcy, C. A. Simenstad, and P. C. Trotter. 2000. Pacific Salmon and Wildlife - Ecological Contexts, Relationships, and Implications for Management. Special Edition Technical Report, Prepared for D. H. Johnson and T. A. Oâ€™Neil (Managing directors), Wildlife-Habitat Relationships in Oregon and Washington. WDFW, Olympia, Washington.

Terrestrial bird species and many others that feed on salmon are especially vulnerable due to their largely nutritious food source facing extinction. The domino effect would quickly take over and cause collapses in ways we haven't yet witnessed in human history. Ecosystem health directly affects ecosystem services, leading to catastrophic food scarcity not only locally and to indigenous lives, but globally in terms of marine catch and distribution. To involve food science, the omega 3's in salmon are essential to the human diet, helping the cells in our body function correctly and efficiently. More specifically, they supply vital cell membrane structure concentrated in the brain and eyes.[6] A lack of nutritious food can cause more problems in times of long term scarcity.

Case Study | Lake Quinault

In my chosen focus area, the Quinault river system and lake, I aim to study a plethora of aspects impacting the ecosystem. Fish need healthy water to succeed in spawning, but they also need critical nutrients, a healthy surrounding ecological community and a food chain for feeding. The streams connected for migration and spawning of sockeye salmon are critical. Observing the current health of these regions, and ecological shifts in response to climate change, including warming waters with emphasis on shallow streams, more frequent storms, and excessive pollutive runoff are all important. Focusing on a smaller scale spawning system for tag and release, one that is prominent in spawning, will bring much important data. Many fisheries and scientists do this work, but not within the bounds of restoration ecology that includes biotic factors. Other researchers focus on the fish and the ocean interactions, so my focus will be on the plant and wildlife interactions happening in the warming streams and lakes.

Quinault sockeye are traditionally referred to as blueback, and they are one of seven evolutionary significant units of sockeye salmon in the Pacific Northwest.[7] Their life history has evolved specifically to this system. Known for its resiliency, consistent declines in bluebacks have been observed since the 1950's, and environmental impacts caused by clearcutting historic forests, removing woody debris, and logjams have thrown this habitat off its course. Based on a study from 2008, the Alder Creek side channel was named to be one of the few spawning areas left in this river system.[8] The Olympic Peninsula has been continuously affected by humans,

[6] Cleveland Clinic. "Omega-3 Fatty Acids." *Cleveland Clinic*, 2019
[7] Howk, Lori. 2010. "Bringing Back the Blueback." Wild Salmon Center. September 5, 2010.
[8] Howk, Lori. "Restoring the Quinault." *Wild Salmon Center*, 28 Dec. 2008

and soon our impacts driving climate change will cause further fluctuations of temperatures, precipitation, storm intensity, and water acidification, all only adding flames to the fire. Forest fires in areas of drought are likely too, with thousands of acres burning in the region yearly. Some fires are beneficial to the environment, especially in boreal regions where permafrost protects the topsoil and organisms hiding out below it. However, as permafrost melts, releasing more methane, the feedback loop furthers the entire problem, and many issues are likely to exponentially evolve.

Ecological Restoration Efforts

With intensifying heat waves, droughts, forest fires, and severe storms, ecological restoration is going to require constant engagement. Thus, abundance of data collected, while consistently zooming in and out on an ecological and a chemistry based scale will prove to be significant. While I plan to create restoration options and efforts in my graduate studies, incorporating them isn't the main goal just yet. Delving into both options and solutions needs to come first. Jumping directly into restoration is inefficient, as it is the last step of the entire process. That being said, the marine and coastal ecosystems will be most greatly affected in this region. With the planet's makeup of ~71% water, this is not an easy clean up, and there is not one easy solution. Many efforts of critical design and scale will be vital, working in conjunction with one another.

Some of these efforts may include but are not limited to; consistent water salinity and turbidity monitoring, YSI monitoring[9], frequent chemical property monitoring for oxygen, nitrogen, and phosphorus levels, dredging and lining streams with large stones to decrease sediment transport, monitoring photosynthesis of aquatic and terrestrial plants in the system, introducing local plant species with thick rhizome structures that strengthen riverbed structure to combat bank erosion, measuring water levels and the shifting of watersheds often, and many more. Introducing microorganisms and local species that strengthen the ecosystem is a topic I hope to dive into more in my studies as well. To tie all of this together, the goal is to do this kind of monitoring through GIS in order to provide clear visual representation. With an easily digestible map that can be referred to and updated, the climate crisis will be workable, rather than a deep set fear based topic of discussion. To enhance visuals, I plan to work towards my drone license and record aerial footage of the ecosystem at hand. The use of Lidar (Light Detection and Ranging) is

[9] "YSI - A Xylem Brand." About YSI: https://www.ysi.com/about#:~:text=We%20often%20get%20asked%2C%20what,and%20manage%20our%20water%20resources.

another aspect to implement. My photographer for my music portfolio has also made a plan to join me in Washington and record the process of research for their own portfolio.

Indigenous knowledge incorporation (TEK)

Indigenous peoples have been observing the land for centuries and they live in harmony with it, viewing themselves as part of the ecosystems they inhabit. They know the ins and outs from facing the elements, and watching their shifts year after year. Living in a world outside of capitalism, focused on tribal health and prosperity, as well as ecological symbiosis, this subgroup of our population has it "figured out". I do not wish to come in with science technology and walk over previous observations with a close minded approach. Incorporating the voices of those who are immersed in the land, the generational knowledge that comes with that, and combining science with people is the heart of life. Indigenous peoples are the original scientists. Every decision they make is out of experience working with the elements. Working against the grain of colonialism by validating this knowledge and strengthening together rather than creating polarity brings us full circle. Kelsey Leonard expresses this concern and story well, with first hand experience and knowledge specifically with water rights. As an indigenous water rights lawyer and scientist, and the first indigenous woman to earn a science degree from the University of Oxford in 2012, she leads the way in this research with a powerful message.[10]

Conclusive takeaways

Expanding the limits of science within ecology is inevitable. To overcome human-caused, human-centric issues like global climate change will take the breaking of walls and shifting of perspectives. Incorporating more women in STEM is a fantastic way to push through, highlighting voices that have yet to be heard on a large scale. The science produced thus far has created a wonderful foundation in terms of logical thinking and research. By bringing a wider variety of voices, we will prevail.

Furthermore, the lives of salmon, while delicate and intricate, aren't too far off from our own. Each of us resemble only a fraction of our lives when we interact with one another, we travel far and wide to pursue our dreams, we even embody a similar resiliency with various habitats in our lifetimes.

[10] Leonard, Kelsey. 2019. "Why Lakes and Rivers Should Have the Same Rights as Humans." Www.ted.com. December 13, 2019. https://www.ted.com/talks/kelsey_leonard_why_lakes_and_rivers_should_have_the_same_rights_as_humans?language.

Becoming one with the forests, the rivers, and the sockeye is a direction we ought to head in, strengthening symbiotically.

Ecology isn't inherently political, but the topics that have wormed their way into politics to encourage debate have made it so. Defeating the stigmas that lie behind women, the climate crisis, the natural world and its complexities, gender expression, indigenous voices, and all the rest are a great starting point to harboring success and strength in habitats. Everything is interconnected, and intersectionality is an important conversation in science. To overcome such a devastating turn of events, we must remove polarity and encourage everybody who wants to be involved to have a seat at the table. As for the fish, they deserve to carry out happy, healthy lives, and to have a spot at the table as well, maybe even on our plates in the end.

Appendix:

Effects of Climate Change on Wenatchee River Sockeye Salmon

Emily Marraffa

Introduction:

Sockeye Salmon face an array of challenges in their lifetime due to climate change. From recreation to industrialization, pollution of aquatic habitats is inevitable. In this region specifically (Fig. 1), sockeye populations reside and migrate depending on the season.

Temperature is the most important factor in sockeye salmon spawning success. As shown in the temperature of planet hockey stick graph (Fig. 2), humans have made quite the impact on the natural cycle of our planet's climate. Due to our emissions of greenhouse gasses (GHG) such as CO2 and methane, rather than entering an interglacial to glacial period, we're heading the opposite direction. This can be observed at the end of the Holocene epoch.

With increasing temperatures, many cold water fish species face challenges. Salmon face an added interference when they travel into freshwater to spawn, earning the title anadromous, meaning that they migrate from the ocean into rivers and lakes to breed. Because of the nature of this spawning habitat, the shallow waters are sensitive to thermal radiation as the planet warms. With higher sediment loads and increased rainfall leading to flooding and erosion, this species is at high risk.

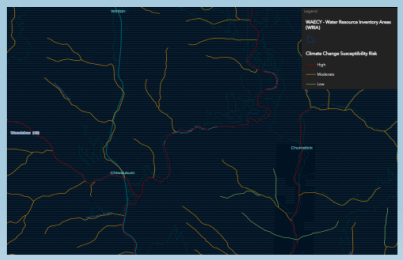

Figure 4. Water Resource Inventory Areas (WRIA) – Climate Change Susceptibility Risk. Found on ArcGIS Data Hub.

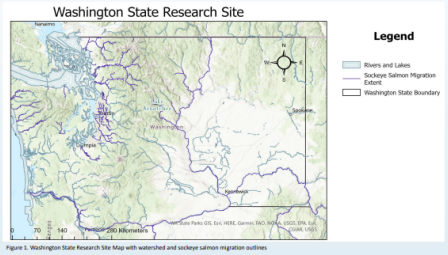

Figure 1. Washington State Research Site Map with watershed and sockeye salmon migration outlines

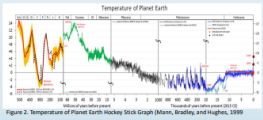

Figure 2. Temperature of Planet Earth Hockey Stick Graph (Mann, Bradley, and Hughes, 1999

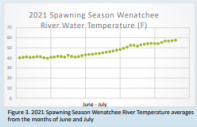

Figure 3. 2021 Spawning Season Wenatchee River Temperature averages from the months of June and July

Methods:

The Pacific Northwest holds most sockeye salmon populations internationally, with Alaska's fisheries at the forefront of production and stock health records. So, I chose my study site accordingly with a focus on wild sockeye.

Through NOAA watershed geospatial data in ArcGIS pro, I outlined the sockeye spawning grounds, and the neighboring lakes that the anadromous fish enter throughout their migration journey. Further, I had the Wenatchee River system outlined via watershed data, and current environmental risks on the system (Fig. 5) Alongside this data, I used stream temperature reading data during spawning season (June-October)

Lastly, the upper Columbia salmon recovery board data portal has a climate change susceptibility risk map (Fig 3.) that concludes the Wenatchee River is at high risk, shown in red.

Results and Discussion:

Sockeye need cold freshwater temperatures around 40-55ºF to spawn and thrive. Though temperature is the center of this research, various other climate change factors negatively affect the success of spawning. Fecundity of the stock faces a negative decline as numbers decrease, the overall survivorship, length, and weight follows suit.

The wild population aspect is important here. Hatchery salmon that have been released have trouble in the early phases of their life cycle, namely they cannot imprint on a specific tributary water source, therefore their historical migration and returning to spawning grounds is disrupted. (Murdoch, 2009).

As various species experience climate change and adaptation, the habitats of today are deemed temporary. Once the compounding effect of climate change sets in, many species and populations similar may experience unrecoverable crashes, and major habitat changes as a result. With consistent crashes and endangerment of species, ecosystems risk collapse.

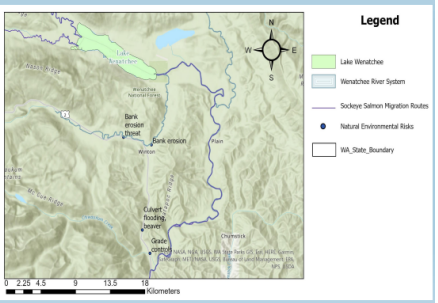

Figure 5. Lake Wenatchee and Wenatchee River study site outlined with sockeye migration routes back to the ocean, natural environmental threats, and the river system.

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Figure 1: GIS Final Project by Emily Marraffa, Sockeye Salmon Case Study

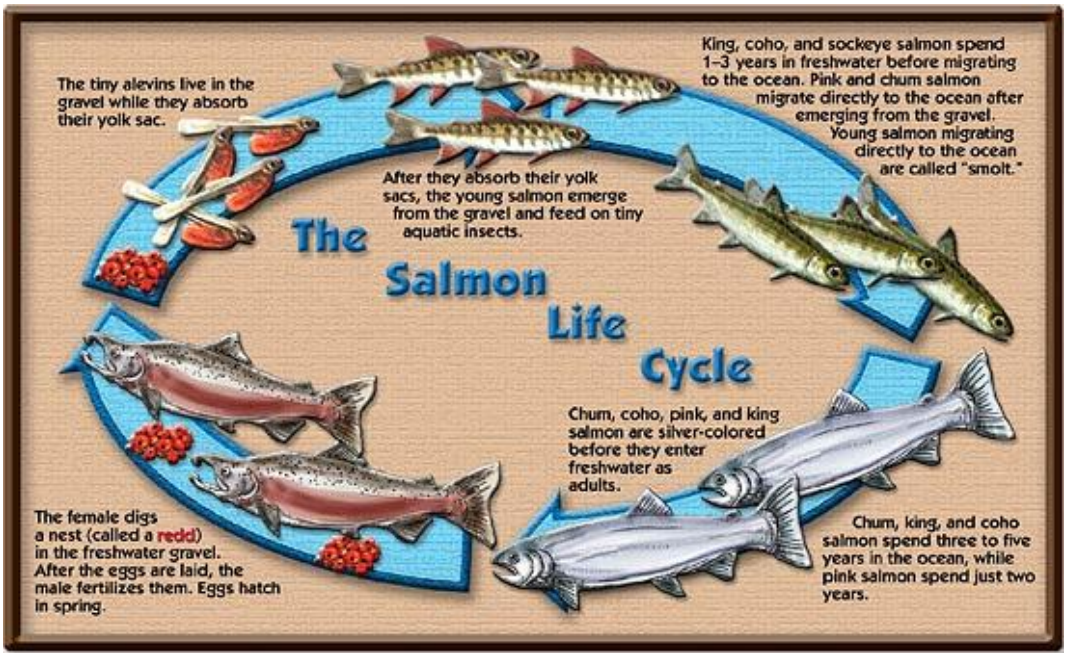

Figure 2: Salmon Life Cycle "Tongass National Forest - Home." 2023. Usda.gov. 2023.

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