# A Glimpse into the Loss of Salmon Populations in the Columbia River Basin and the Case for Incorporating Traditional Indigenous Management in Restoration

By

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## Abstract

Pacific salmon are at the heart of the ecosystems and communities that have lived in the Columbia River basin since time immemorial. Through centuries of reciprocity and reverence for salmon, Indigenous people developed systems of management through communal rules and spiritual rituals. In turn, they managed salmon populations sustainably and allowed large salmon runs to return year after year. Colonialism radically disrupted this intricate balance between humans and fish. In this time, tribal land was dispossessed, traditional Indigenous management practices were supplanted with western management, and salmon populations declined. In this thesis, I explore the legal and historical context of this issue to understand how salmon are governed and how co-management operates today. I then review Indigenous management of salmon based in traditional ecological knowledge (TEK) and explore how these time-tested practices can contribute to salmon restoration today. Comparing TEK practices with western management practices, I document the limitations of western management and suggest methods for the two knowledge paradigms to be bridged. Finally, I express that the re-incorporation of TEK practices in salmon management is feasible, will directly benefit the salmon, and provides an empowering resolution for Indigenous people.

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## List of Acronyms

**TEK:** Traditional Ecological Knowledge

**PNW:** Pacific Northwest

**CRITFC:** Columbia River Inter-Tribal Fish Commission

**PSC:** Pacific Salmon Commission

**NMFS:** National Marine Fisheries Service

**ODFW:** Oregon Department of Fish and Wildlife

**WDFW:** Washington Department of Fish and Wildlife

**CRC:** Columbia River Compact

**CRT:** Columbia River Treaty

**BPA:** Bonneville Power Administration

**PST:** Pacific Salmon Treaty

**MSA:** Magnuson-Stevens Act

**ESA:** Endangered Species Act

**PFMC:** Pacific Fisheries Management Council

**CTUIR DNR:** Confederated Tribes of the Umatilla Indian Reservation – Department of Natural Resources

**IEJ:** Indigenous Environmental Justice

## Acknowledgements

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# Introduction

For over 9000 years, the Indigenous communities of the Columbia River basin managed annual runs of salmon sustainably [1]. Through a system of management of communal rules and rituals, they allowed salmon to spawn and limited catch to just what the community needed [2]. Fishing rights were upheld through systems of community connections and public reciprocity, in which several stewardship responsibilities were mutually expected by all those who used the fishery [3,4]. Additionally, salmon was more important than just a source of food; it was central to the cultures, intertribal interactions, and even religions of the tribes [5]. The centuries of reciprocity between humans and salmon was impeded as Europeans started settling throughout the 1800s. In this time, Indigenous tribes were displaced, while salmon populations plummeted and fisheries collapsed [2].

Today, Columbia River salmon fisheries are primarily managed by United States (US) federal and state agencies, as well as tribal nations with treaty rights [6]. Despite years of many different conservation efforts, salmon populations remain at about 10% of historical numbers, and half of all Pacific salmon species are listed as endangered or threatened under the Endangered Species Act, with only 16% of populations considered stable [7]. On top of this, climate change is proving to be yet another major threat to salmon [8].

With a salmon population that is severely depressed when compared to pre-colonial times, it is in the interest of all users of the Columbia River basin to find solutions to restore and sustain salmon into the future. To this end, the importance of Indigenous practices in

current resource management has become increasingly recognized by western society over time, this project continues to show that importance. Many recent successful ecological restoration efforts have been a collaboration of western scientists and Indigenous scientists [9]. There is a long history of Indigenous people, Indigenous history, and Indigenous beliefs and governance practices being marginalized in the US [9–11]. Bringing attention to these issues while demonstrating the value of Indigenous ideas and knowledge is important to help bring justice to Indigenous people [12]. Reintegrating traditional ecological knowledge (TEK) and practices of reciprocity in Columbia River salmon management provides a promising and empowering conservation solution.

In order to understand how salmon populations have declined, and to identify solutions, this thesis explores two major research questions:

- How does US – Tribal co-management function and what have been the results?
- How can traditional Indigenous management practices be bridged with western science to help restore salmon populations in the Columbia River Basin?

# Background

*The Importance of Salmon to the Ecosystem*

The history of the Columbia River basin, and the history of the salmon that have inhabited the area for millions of years are so intertwined, it is impossible to imagine one existing without the other. Salmon are a keystone species in the area, meaning they support a wide variety of other species, from bears to birds to old-growth trees [13]. Due to salmon's

spawning behavior of swimming from the ocean up streams and rivers, they act as a nutrient-bridge between the ocean and land [14]. When predators and scavengers eat salmon, they carry the nutrients in salmon's bodies inland and deposit nutrient rich urine and feces onto the forest floor [14]. Up to 40% of nitrogen in streamside plants is traceable to salmon populations, in addition to lesser amounts of sulfur, carbon, and phosphorous [14].

Pacific salmon also benefit from the ecosystem in a reciprocal relationship. The coast of the Pacific Northwest (PNW) is unique for its upwelling, in which cold, nutrient-rich waters rise to surface [15,16]. This brings an abundance of plankton, which ultimately benefits the whole ecosystem, allowing salmon and many other species to thrive [15,16] The interactions between pacific salmon and the greater PNW ecosystem are critical for the survival of both, however the importance of salmon goes further than just ecosystem survival.

*The Importance of Salmon to the People of the Pacific Northwest*

Pacific salmon are not only a keystone species to their ecosystem, but have also been keystone to the diets and cultures of the people living in the area for millennia. Based on an excavation and subsequent study in the Columbia River basin, there is evidence of humans fishing for and eating salmon in the area that dates as far back as over 9,000 years [1]. The abundance of salmon bones not only indicated that salmon were fished, but that the humans living there depended on salmon heavily as a major part of their diet [1].

There are five distinct species of pacific salmon: chinook, sockeye, chum, coho, and pink, as well as steelhead which are a type of trout that behaves and is managed much like

a salmon [17]. Within each species there are specific populations which only swim upriver to spawn once annually, so the people living there developed complex ways of catching and storing them sustainably [18]. Salmon were caught using a variety of techniques including weirs, dip-nets, reef-nets, fish-wheels, and fish-traps [18]. Whatever was not eaten immediately was dried or smoked to keep it edible, providing a source of protein throughout the year [18]. Through these practices, it is estimated that Indigenous people harvested up to 44 million pounds of salmon per year [19,20]. However, despite over 9,000 years of fishing, they were able to do this without depleting salmon populations, allowing salmon to come back year after year [18,21].

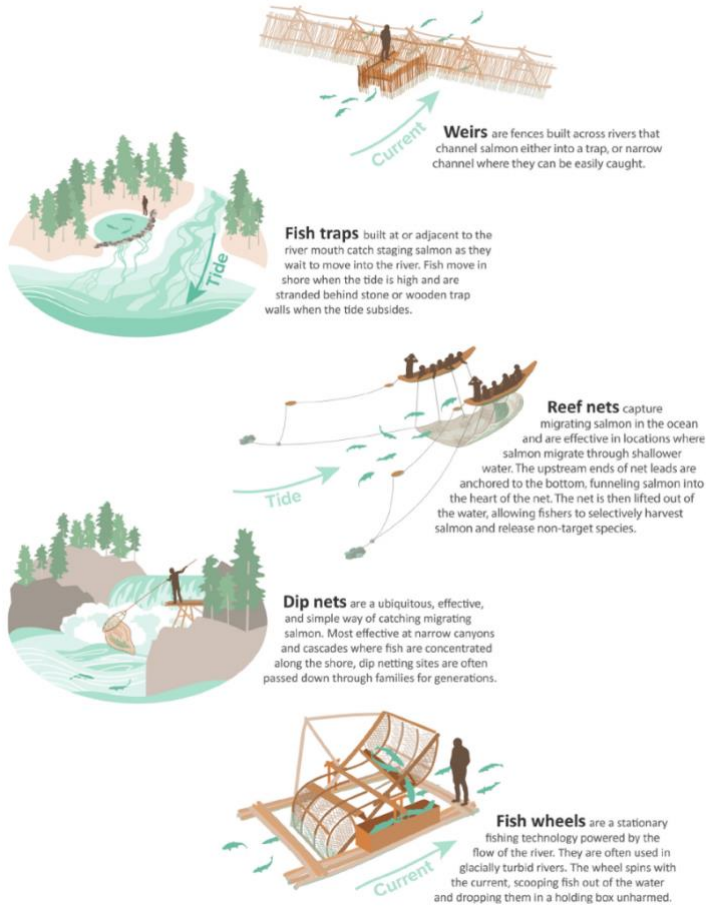


**Figure 1.** A depiction of common Indigenous fishing techniques used throughout the PNW. Source: Atlas et. al.

The many Indigenous communities of the Columbia River held varying laws, rules, and principles that governed their respective communities, and in turn guided salmon fishing [18]. Despite this variance, one commonality was that they each held a deep appreciation for and understanding of the connection between ecosystems and humans [18]. This understanding of interconnectedness is also known as traditional ecological knowledge (TEK) [21,22]. TEK is exclusive to many Indigenous communities in that it is typically place-based and grounded in multiple generations of a community living in and passing on knowledge from that local area [21,22]. Through TEK, sustainable fishing was and continues to be defined by protecting the health of all parts of the ecosystem, and ensuring that salmon will thrive and provide for generations to come [11,18,21]. Among the communities of the Columbia, management of fishing was typically employed through communal rules and rituals, and regulated by tribal elders and leaders [2,18]. These management principles flowed from TEK, and through this they caught what was needed for subsistence and trade, and restricted harvest once those needs were met [18].

This system of governance not only sustained the populations of salmon, but it also led to greater appreciation and respect for them. This reverence for salmon is evident throughout the cultures of tribes living along the Columbia River. The tribal communities living in the Columbia River basin, many of which now make up the Nez Perce, Umatilla, Warm Springs, and Yakama nations, refer to themselves collectively as “Wy-Kan-Ush-Pum”, which translates to “Salmon People” [23]. Indeed, salmon was, and continues to be integral to the lives of Indigenous people of the Columbia River basin. These overlapping ideologies of – respect and appreciation for the natural world and food sources, providing enough for the whole community, and not taking more than one needs – were central to all aspects of

Indigenous culture. In turn, it also led to the success of Indigenous communities and salmon populations living together in the Columbia River basin for thousands of years.

*The Colonial History of Pacific Northwest*

These ideological beliefs were notably absent in the cultures and economic systems of most European colonial nations at the beginning of the age of colonialism [18]. Most European colonial nations were highly exploitative societies in their relationships with other nations as well as the natural world [2,7,11,12]. These ideologies influenced how Europeans treated natural resources, seeing them as inexhaustible and meant for human consumption [2,7,12]. These factors led many European countries to look outward for new resources to exploit and people to subjugate [2,12].

The history of colonization in the PNW is not dissimilar from many other colonization stories, however this case is unique because it directly connects to the depletion of salmon populations [2]. The first known contact between Europeans and Indigenous tribes of the PNW was 1707, and by the late 18th and early 19th century there was established trade of fur and seal pelts [2]. The most devastating consequence of trade was the spread of diseases, especially smallpox [2]. It is estimated that between 1774 and 1874, the populations of Indigenous people living between modern southern Alaska and southern Oregon declined 80% [2,3]. The population on the Columbia plateau declined 48% between 1805 and 1870 [2]. In 1846, Britain and the US signed the Oregon Treaty, which officially designated the border between the US and what would become Canada; this paved the way for ethnic cleansing, the annexation of Indigenous land, and the exploitation of resources including salmon [2,24].

In the period between 1850 and the early 1900s, the Indigenous tribes of the Columbia River had much of their land dispossessed by settler populations, while new technologies enabled much larger catches of salmon [2,3]. In 1855, many of the tribes signed treaties which ceded away large tracts of their ancestral lands [25]. This empowered settler populations to take full control of the land and salmon fisheries [2,25]. In this period, there was close to zero regulation from the settler governments, and starting in the early 1900s salmon catch numbers plummeted and fisheries collapsed [2,3]. This was not only due to overfishing but also logging, farming, and damming [2,26]. Damming is especially destructive as it blocks off river passage and prevents salmon from going on their natural spawning runs [26]. During this time, governance of Columbia River fisheries remained lenient, the few regulations that were passed were not effectively enforced [2].

Salmon populations in the area continued to decline through the second half of the 1900s, despite renewed motivation to protect the fish [2,25,27]. This motivation was especially apparent on the part of tribal nations who witnessed salmon populations diminishing, while their own treaty fishing rights were being undermined [25,27]. In 1974, the tribe's treaty rights were preserved through court litigation, giving them much greater governance than previously held [25,27]. This ruling is known as the Boldt Decision, and it functionally mandated non-Indigenous and Indigenous people to govern a depressed salmon population together [25,27]. Nevertheless, by the 1990s, 18 distinct local salmon stocks had gone extinct and the average number of returning annual fish was down to 2.5 million [19].

Today, tribal nations have more say in the management of salmon, however many salmon populations are still struggling to recover and are much smaller than pre-colonial levels [17,18]. The 2021 Columbia River salmon return is estimated at about 1.14 million fish, which is lower than the 10-year average, and is only at about 10% of historical run estimates [28]. Despite many efforts over the years, including ongoing major undertakings by the treaty tribes to repopulate and protect the watershed, salmon populations have not significantly improved [23].

For thousands of years salmon populations thrived in the Columbia River basin while keeping the human inhabitants fed. Yet, in just over 150 years, these salmon populations have become widely depressed. While there has been considerable change during this period, salmon were managed sustainably for thousands of years prior. It is possible to learn from past success and failure to restore and sustain salmon in the future.

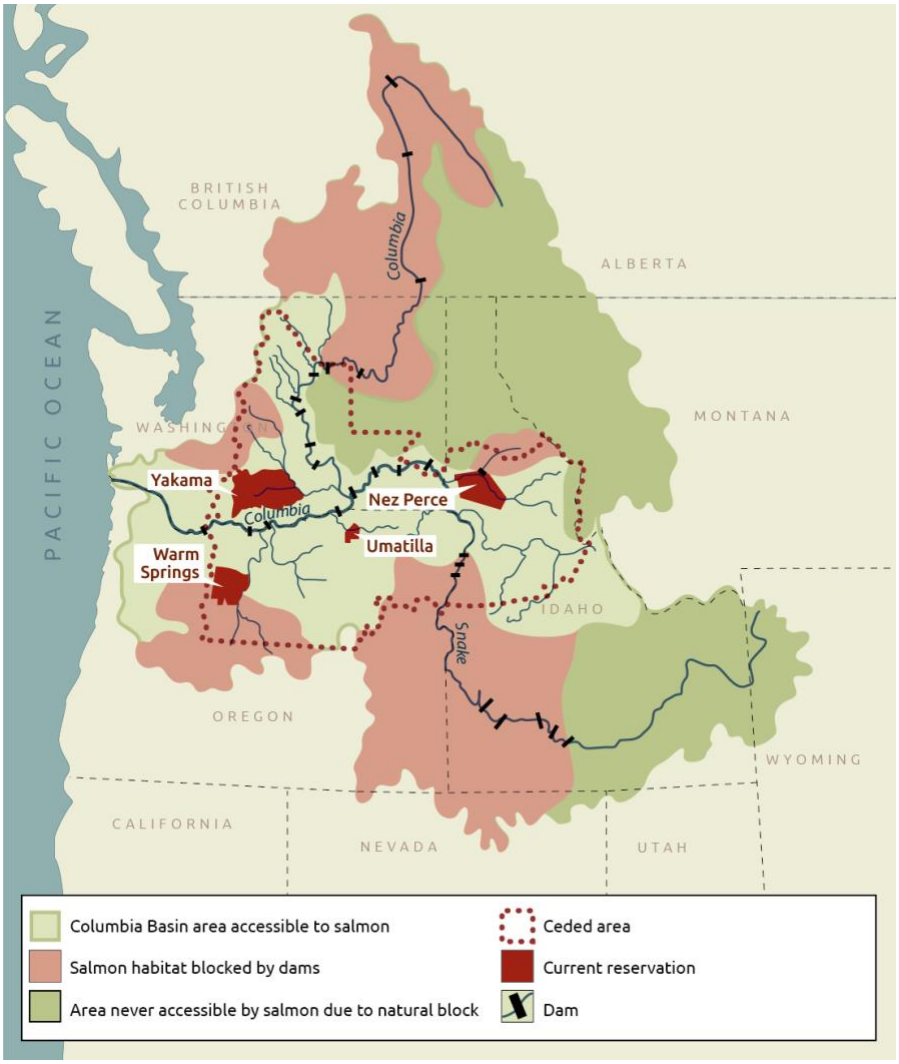


**Figure 2.** A map of the entire Columbia River Basin, including salmon accessibility, dams, ceded lands, and tribal reservations. Source: Columbia River Inter-Tribal Fish Commission

## Methods

To fully explore my research questions, I gathered data by examining secondary sources through means of literature review, and conducting semi-structured interviews to gain insights from primary sources. I then synthesized the information I gathered to draw conclusions from. This approach allowed me to utilize both the broad base of knowledge

provided in a literature review, with the deeper and more detailed insights provided from interviews, to draw conclusions from.

My first step of research was a thorough literature review in the form of a thematic synthesis. A thematic synthesis is a type of extending literature review involving a summary of previous research, and synthesis into newer constructs [29]. The sources involved in the literature review included peer-reviewed papers, history books, US agency reports, and tribal reports. These sources provided me with a base-level knowledge in three key areas. The first is historical Indigenous fishery management practices in the region. Through this I could understand the traditional methods used that sustained salmon fisheries for centuries and compare these to modern practices. The next major theme is the connection between colonialism and fish decline. To examine this, I reviewed literature on the history of colonialism, and the history of fish decline in the region. By looking at the overlapping history of these two pivotal events, I could make inferences about the connection between the two. This theme is key to understanding how the fish populations have declined and why they have never fully recovered. Lastly, I examined other examples of modern-day TEK practices being used to contribute to solving environmental issues. By reviewing these other case studies, I could look at consistencies from which to compare to how this might work in the Columbia River basin.

Overall, the literature review provided a base level of knowledge to utilize towards designing and conducting my interviews, and prepared me for the finer details delivered in those interviews. By developing my literature review first, I had the level of knowledge necessary to conduct thorough and detailed interviews.

After developing a solid knowledge-base of the context of the situation in the Columbia River basin, my next step was to hear from those directly involved in the management. To accomplish this, I solicited interviews with key individuals who are involved in salmon management in the Columbia River basin. To view the full management picture – a large agglomeration of management groups, government entities, and stakeholders – I wanted to speak with individuals representing the spectrum. I narrowed down to three primary subgroups: US federal agencies, US state agencies, and tribal managers.

On the US federal side, I sought interviews from a representative of the Pacific Salmon Commission (PSC) and a representative of the National Marine Fisheries Service (NMFS). The PSC is a non-governmental body designed to provide a space for representatives from both the US and Canada to design shared conservation and harvest objectives [30]. PSC directed me towards interviewing a NMFS correspondent who worked closely with them. NMFS, otherwise known as NOAA Fisheries, is the US agency that works with the PSC to manage salmon fisheries 3 to 200 miles off the west coast of the US [31]. While NMFS does not directly manage riparian salmon and steelhead fisheries in the Columbia River basin, they do work with state and tribal co-managers in accordance with PSC recommendations [32]. From NMFS, I interviewed Anadromous Harvest Management Branch Chief Jeromy Jording. On the US state side, I sought interviews from a representative of Oregon Department of Fish and Wildlife (ODFW) and a representative from Washington Department of Fish and Wildlife (WDFW). Each Fish and Wildlife Department is the state agency that is directly responsible for managing salmon fisheries in the Columbia River basin within their respective state jurisdiction [32]. From ODFW I

interviewed Columbia River Fisheries Manager Jeff Whisler. From WDFW I interviewed Columbia River Fishery Manager Ryan Lothrop.

On the tribal side of management, I solicited interviews from representatives of the Columbia River Inter-Tribal Fish Commission (CRITFC). Made up of the Umatilla Tribes, Warm Springs Tribes, Nez Perce Tribe, and Yakama Nation, the CRITFC has been working since 1977 to provide a unified voice for the member tribes in order to manage fisheries and protect treaty rights [23]. I sought to interview a few representatives with different roles in the CRITFC and with different individual experiences in salmon management on the tribal side. To this end I interviewed Fishery Biologist and member of the Umatilla Tribes Ryan Branstetter, Fisheries Management Director Mike Matylewich, and Fishery Scientist Kate Self.

By interviewing individuals representing the many primary groups of salmon management in the Columbia River basin, I could compare different perspectives and experiences to paint a clearer picture of management challenges and successes. These varied perspectives also allowed me to better explore my research questions and gain a more thorough understanding of the complicated system of management that exists in the Columbia River basin.

Finally, I thoroughly reviewed each of my interviews through a process of coding. My codes were primarily based on general themes I gathered from my literature review, though when new ideas were brought up in my interviews, I added them. I then rigorously combed through each of my interviews to discern new themes and separate the most important content. I then analyzed both the primary and secondary data I collected to draw

conclusions, in turn my results and discussion are a mixed collection of data gathered from literature review and interviews. This research received ethics approval from the University of Colorado Boulder's Institutional Review Board under Protocol 21-0550.

# Results and Discussion

## Part 1: The Legal, Historical, and Environmental Context of the Issue

*Governance of the Region and Resource*

The Columbia River basin area is 259,000 square miles, draining parts of seven states in the US and one Canadian province [33]. Due to the sheer size of the basin, there are numerous organizations involved in its management and numerous laws, treaties, and litigation that govern it and the fisheries within it. In total, there are 15 Tribal Nations in the US, three First Nations in Canada, four US State Fish and Wildlife Services, the NMFS, and the Department of Fisheries and Oceans Canada – Pacific Region involved in fishery management, within their respective jurisdictions [33]. Each organization manages different areas within the watershed and has different priorities for their fisheries. Additionally, some organizations are not bound to the same laws that others are, which can further complicate managing a single resource.

Following the Boldt Decision of 1974, several Tribal Nations in the PNW had their fishery management rights restored within ceded lands [23,33]. The four Tribal Nations making up the CRITFC were a part of this: the Confederated Tribes of the Umatilla Indian Reservation, the Nez Perce Tribe, the Confederated Tribes and Bands of the Yakama Indian

Nation, and the Confederated Tribes of the Warm Springs Reservation of Oregon [33]. Together, these Tribal Nations co-manage a 147-mile stretch of the Columbia River, from the Bonneville Dam to the McNary Dam [23,33]. Additionally, each of these Tribal Nations co-manages subbasins with the WDFW and ODFW, within their respective ceded lands [23,33]. These four Tribal Nations are the focus of this project, but they are not the only Indigenous communities with management rights. Further north, the Coeur d'Alene Tribe of Indians, Confederated Tribes of the Colville Reservation, Kalispel Tribe of Indians, Kootenai Tribe of Idaho, and Spokane Tribe of Indians manage about two million acres of on-reservation land [34]. In Canada, Ktunaxa Nation, Secwepemc Nation, and Okanagan Nation Alliance have management rights within their respective reserves and are heavily involved in salmon restoration efforts within Canada's jurisdiction [35].

In addition to the many organizations that govern the Columbia River basin are the laws, agreements, and treaties that guide these entities. Each significant agreement or law establishes a guideline for co-management of the watershed in some way.

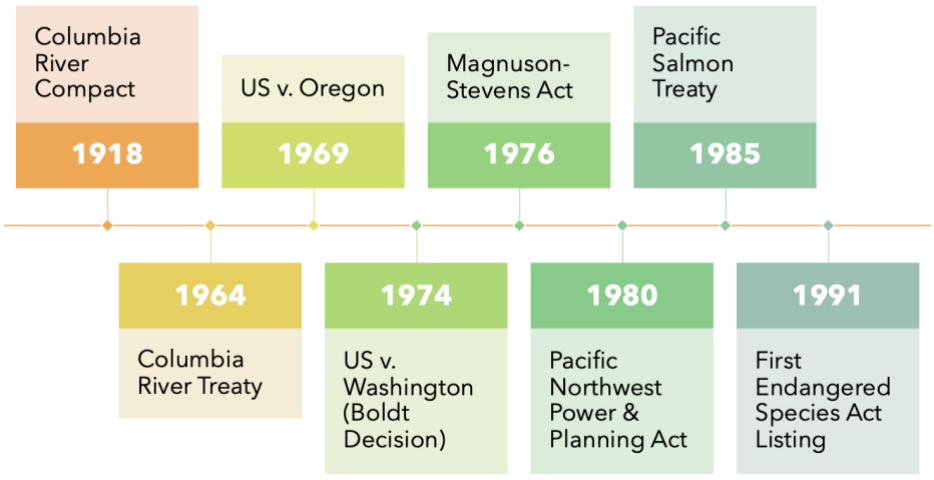


**Figure 3.** Timeline for reference of relevant legislation, litigation, and other agreements to Columbia River basin co-management. Created by Josh Lipson based on literature review and interviews.

In the early 20th century, as the salmon fisheries declined, fishing jurisdiction between Washington and Oregon was a major issue [25]. For years, the two states had been passing different laws legislating fishing seasons and gear [25]. This led to many conflicts between fishers in the two states, culminating in court cases [25]. In 1918, Washington and Oregon signed the Columbia River Compact (CRC) establishing concurrent management [25]. This became the first attempt at co-management in the watershed, though notably it excluded tribes.

The CRC eased tensions between Washington and Oregon around fishing, though from here the US began to focus on the hydroelectric potential of the Columbia. Throughout the massive basin, the average annual runoff is 200 million acre feet, meaning it has one of the largest average runoffs of North American rivers [36]. This potential energy producing resource, combined with the growing population of settlers, made the Columbia an enticing place for the US to unfurl one of its newest spectacles of engineering: hydroelectric dams [26]. In 1932 the first dam was built and by the late 1950s five more were added, though these dams had very low water storage capacity [26]. The Columbia has significant year-to-year variability in runoff, and this combined with low storage capacity to devastating consequence in 1948, when a large period of precipitation caused massive floods in Oregon [36]. This began a period of negotiations between the US and Canada, ultimately culminating in the Columbia River Treaty (CRT) in 1964 [26]. In the treaty, Canada agreed to build four new dams which would provide flood control and shared electricity to the US, in exchange the US paid Canada $64.4 million and also shared hydroelectric power [36]. Like the CRC, Tribal Nations in the US and First Nations in Canada were not consulted or accounted for in the creation of the CRT, though the effects on their ways of life were massive [26]. The CRT

paved the way for the rapid development of more dams which drastically changed the river basin; fish passage was completely blocked off in the upper parts of the river, Celilo Falls, an extremely important cultural fishing site was destroyed, and the construction of these dams simply violated many treaties [26]. The CRT is still the law of the land in the Columbia River basin and the construction of over 60 dams in less than 100 years has had a devastating impact on the fish of the basin.

The major turning point in reintegrating the Columbia River basin treaty tribes in fish management came from a series of court cases in the late 1960s. Between 1854 and 1855, the Governor of Washington Territory Isaac Stevens negotiated 12 treaties with tribes of the PNW [27]. In these treaties, the tribes ceded much of their lands in exchange for reservations, cash payments, and notably, "The right of taking fish at all usual and accustomed grounds and stations is further secured to said Indians in common with all citizens of the Territory" [27]. Many of these "usual and accustomed grounds" were of significant cultural value to the tribes, though they quickly became of significant economic value to settlers, and over the next 100 years settlers continually restricted tribal access to fishing places [25]. Throughout this time, state fish and game officials regularly expropriated Indigenous fishing boats and gear, and arrested and physically assaulted Indigenous people for fishing [37].

Beginning in 1887, the tribes of the PNW began filing court cases, calling on the states to uphold their treaty promises [25]. This resulted in the combined cases of *Sohappy v. Smith* and *US v. Oregon*, in which Judge Robert C. Belloni ruled in favor of the tribes [27]. This ruling meant that the tribes had the right to manage their own fishers, they had the right to

allocate their own share of fish, and that the states needed to ensure that the tribal nations received their "fair share" [27]. Despite the weight of this decision, little changed in the immediate as state agencies and non-Indigenous fishers resisted this decision, additionally there still needed to be a decision on what "fair share" meant [27]. The tribes then filed *US v. Washington* to further establish their treaty rights [37]. After three years of litigation, Judge George Boldt ruled that the phrase "in common with" meant that the tribes were entitled half of the harvestable returning fish in the region [37]. This landmark decision re-established agreed upon fishing rights, acknowledged tribal sovereignty, and effectively mandated the states and tribes into a state of co-management.

Beginning in 1977, the parties (including the State of Washington, Oregon, and Idaho, the US, the Shoshone-Bannock Tribes, the Warm Springs Tribes, the Umatilla Tribes, the Nez Perce Tribe, and Yakama Nation) have reached several agreements to meet their fishery goals. The first few agreements involved near yearly litigation and did not meet goals due to lack of enforcement in achieving salmon sharing and production, as well as a failure to account for ocean fisheries [25]. In 1988 the parties agreed to the Columbia River Fish Management Plan, which provided a stronger framework for habitat and fishery restoration, as well as allowing for yearly fishery management plans [25]. This agreement ended in 1998 and was followed by a series of more short-term agreements until 2008 when a ten-year US v. Oregon Management Agreement was signed between the parties [33]. A subsequent US v. Oregon Agreement was extended in 2017 and makes up the current management framework for the Columbia River basin [33]. The current agreement prioritizes ensuring fair sharing of fish between tribes and states, conserves and restores ESA-listed fish, and restores damaged habitats [17].

Beginning with the CRC in 1918, the first series of agreements, treaties, and litigation in the 20th century surrounding Columbia River basin fishing co-management primarily centered human interests. These interests included harvest rights, hydroelectric power, and flood control, among others. Notably, none of these agreements prioritized the declining fish themselves or the habitats they lived in, most in fact governed in spite of the fish. Following the Boldt Decision, however, this began to change. Throughout the next two decades, three new pieces of legislation, and an international treaty were enacted which better prioritized the still declining fish populations. These agreements still govern the region today.

In 1980, Congress passed the Pacific Northwest Electric Power and Planning Act, which after 50 years of hydropower development, gave precedence to the fish and their habitat "equal to that of the kilowatt" [25]. The act set up the Northwest Power Planning Council to work with state DFW agencies and treaty tribes to make decisions around hydropower [38]. Additionally, Bonneville Power Administration (BPA), the federal agency that operates the federal dams in the Columbia, was required to set up a fish and wildlife program to mitigate for the development and continued use of hydropower systems [17,38].

In 1985, the US and Canada adopted the Pacific Salmon Treaty (PST) which established the Pacific Salmon Commission (PSC), this has become the cornerstone of international co-management from southeast Alaska through southern California [39]. The signing of the PST was spurred by a drastic decline in chinook stocks up and down the west coast, due in large part to overharvesting in international waters [40]. The treaty's two foremost goals are to "prevent overfishing and provide for optimum production; and

provide for each Party to receive benefits equivalent to the production of salmon originating in its waters" [39,40].

The last two primary agreements that guide management of Columbia River basin salmon are the Magnuson-Stevens Act (MSA) and the Endangered Species Act (ESA). Both acts were implemented in the 1970s and they are the primary legislation that guides how the NMFS manages fisheries [32]. The MSA guides ocean fishing and puts intensive, stock specific limits on salmon when they are being fished in the ocean [17]. The ESA is more generalized towards the protection and recovery of all endangered species [17]. In 1991, the first two salmon stocks were listed by the NMFS under the ESA, today 13 stocks are listed [33] . It is important to note that while the MSA and ESA guide federal salmon management, they do not directly govern state and tribal management. That said, the states and tribes regularly cooperate with the NMFS regarding MSA and ESA listings to co-manage effectively [17].

Over the last 100 years, acts have been passed, treaties have been signed, and litigation has been won to better facilitate co-management of the Columbia River basin; a watershed that is critical to the lifeways of all those living in the PNW. The long-arching trend of these agreements has been towards co-management, to meet the needs of all parties involved, including the fish themselves.

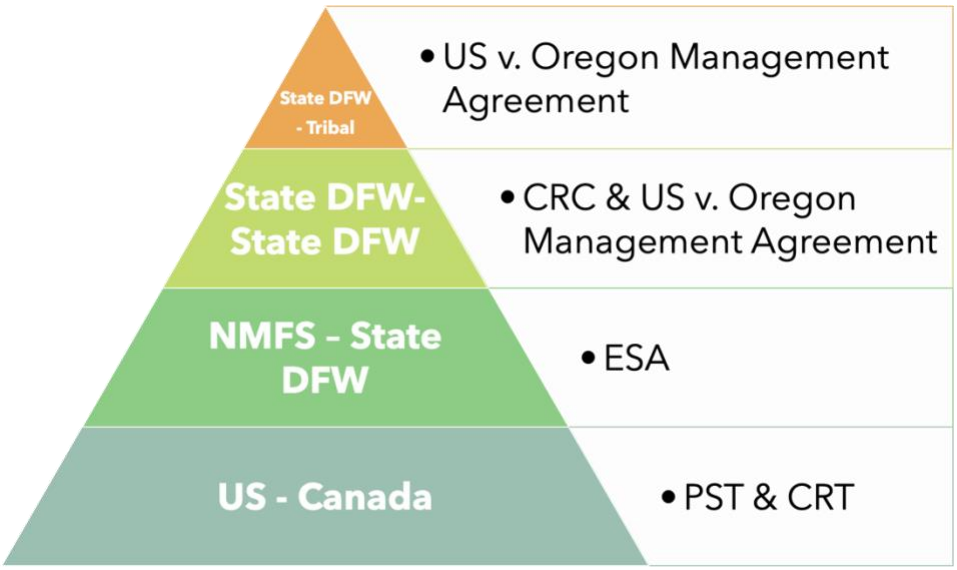


**Figure 4.** Visual depiction of Columbia River basin salmon governance on a spatial scale, including organizations and laws. From largest scale at the bottom to smallest at the top. Created by Josh Lipson based on literature review and interviews.

*Management Structure of the Columbia River Basin Salmon Fisheries*

Today, while there are many parties with management responsibilities in different subbasins and regions within the Columbia basin, one common theme throughout is cooperation and co-management. On smaller scales, such as specific tributaries like the Willamette River, there is cooperation. The ODFW works closely with the Confederated Tribes of Grand Ronde to manage the salmon and lamprey fisheries through a Willamette subbasin-specific management plan [41]. On the largest scale, the PSC provides avenues for each of the many parties involved to come together to make decisions regarding the complex region and resource, and to resolve conflicts that may arise [40]. Over the last 100 years, from the smallest scales to the largest and everything in between, agreements have been developed and committees have been formed to more effectively manage a waterway that is complex yet interconnected.


**Figure 5:** Map depicting management jurisdiction of different entities within Columbia River Basin. This map is intended to provide a general idea of management within the basin. Management jurisdiction is complex and in flux, therefore this map may not be 100% accurate. Data used to create figure obtained from CRITFC. Figure created by Nora Britton, 2022.

At the international level, the US and Canada manage within their respective countries and the ocean waters in which they have jurisdiction [30]. The two countries work together under the provisions in the CRT and PST, and by means of their respective members of the PSC in order to cooperate over management of a species which regularly migrates from one country to another [30]. NMFS (NOAA Fisheries) directly manages ocean fisheries from 3-200 miles off the coast of the US based on recommendations by the Pacific Fishery Management Council (PFMC) [31]. While NMFS does not directly manage within the states, they work with the states and tribes through the ESA [32]. At the state level, Washington, Oregon, and Idaho similarly have authority within their respective borders

[32]. The states cooperate through agreements such as the CRC and US v. Oregon Agreement, as well as the many committees established through these agreements to facilitate cooperation [32,41]. At the more local and regional scale, that state's DFW works with whatever Tribal Nation may have management authority in that region, typically subbasin specific and species-specific plans are developed [42].

While federal and state jurisdiction over management is generally straightforward, tribal authority over specific areas tends to be a more complicated picture. Mike Matylewich, illustrated a "kind of hierarchy" in tribal authority over different regions [17].

> "On the reservations themselves the tribes have pretty much total say so. Then there's a concept called ceded lands, so those are the historical areas that they ceded to the United States government back in 1855. So, they have more co-management authority there. And then there's off-reservation off-ceded lands which include some additional custom fishing places as well as all of the ocean. The tribes have more control on the reservation, less control as you move further away." [17]

These varying levels of management authority can complicate certain issues, but Matylewich emphasized that tribes still have their voices heard in regions where their legal authority is not as robust, "We talk to people. Wherever the fish are affected that's where we go to talk to people" [17]. Ryan Lothrop of WDFW, Jeromy Jording of NMFS, and Jeff Whisler of ODFW each underscored this same point, describing the many committees that tribal members sit on, and important management positions that tribal members hold [41,43,44]. Whisler, who sits on a few of these committees, believes that bringing all parties together including tribal members leads to a "wealth of expertise" and "foster[s] a real kind of cohesive learning environment" [41].

The foundation of tribal co-management is the continuing jurisdiction of the US v. Oregon case. Following the Boldt Decision of 1974 which upheld the rights laid out in the treaties of 1855, the states and treaty tribes have been co-managers in the region [25]. The parties have continuously entered into management agreements since the first one in 1988 [25]. The previous and current agreement are both 10-year agreements, they are set up this way in order to incorporate new elements that have been learned from the previous management period and to ensure parties are coming back to the table and communicating [44]. The first agreement of 1988 solely delt with in-river harvest allocation; since then, ocean catch, hydropower factors, hatchery production elements, and updates in fishing and monitoring technologies have been added to the agreements [17,43]. A few interviewees were involved in the negotiation of the latest agreement in 2017, and each emphasized the importance of having a collectively agreed upon framework by all parties involved [17,41,43,44]. Jeff Whisler, who was one of those involved, recounted his experience:

> "Having been deeply involved in the negotiation of the last agreement in managing the fisheries really demonstrated to me the utility and the power in bringing all these parties to the same table and trying to hammer out something that everyone can live with. And it's not perfect, it's a negotiated agreement, everybody didn't get what they wanted. But at least there's a common framework there that all the parties are all on the same page." [41]

Having so many voices at the table can delay certain processes and everyone doesn't get what they want, however, the semi-recent inclusion of Indigenous people in salmon management is not only just, but strengthens the overall management structure [11,41,44].

The US v. Oregon Agreement also sets up committees that meet regularly to share information, evaluate how objectives are going, and to resolve conflicts that may arise. One of these is a policy committee which meets quarterly and is made up of policy and legal

representatives from each of the parties [41]. There are also two advisory committees which meet more often depending on need: a technical advisory and a production advisory committee [41]. The technical advisory committee forecasts runs in the preseason, reconstructs runs in the postseason, and describes fishery impacts [41]. The production advisory committee coordinates hatchery production [41]. Tribal members are also increasingly involved in organizations that operate outside of the Columbia basin such as the PFMC and PSC [43]. Each year, tribal representatives testify at the PFMC when they are setting ocean fisheries [43]. Additionally, Ryan Branstetter described how today "we have [tribal] representatives at big major federal decision-making levels" [11]. Branstetter hoped this will "pull more tribal members up and we'll have more of a tribal voice in the federal government to advocate for us and advocate for salmon" [11]. With the Boldt Decision and the continuing US v. Oregon case as the basis of tribal co-management, tribal members have increasingly become involved in major decision-making and management in and outside of the Columbia River basin.

In this 50-year period, there have been several co-management success stories. Through smaller-scaled subbasin specific plans, riparian habitat protection and enhancement has been prioritized [11,17]. For example, the Colville Tribes have done significant habitat work to increase and protect spawning grounds in the upper Columbia, and the Umatilla Tribes have worked to reestablish the natural meanders and flows of their regional tributaries [17,43] Hatcheries have been more effectively managed to align with conservation and harvest goals, tribal hatcheries specifically have spearheaded a number of reintroduction projects [17]. Most notably, there have been successful collaborative efforts throughout the Columbia River basin to reintroduce coho, a species that had been

historically abundant but driven to near extinction [41,45]. Additionally, there have been improvements in water management, specifically plans with BPA to safely get fish in and out of the Columbia and its tributaries [17]. Each of these projects have led to tangible results seen in the improvement of coho, sockeye, and fall chinook stocks [17].

These co-management successes have not been without challenges along the way. One persistent issue brought forward by Jording and Whisler who manage for the US and Oregon respectively, is the debate around mark-selective versus full-retention fisheries [41,43]. Most of the hatchery produced salmon in the region have a small fin removed as a visual cue that confirms that fish is of hatchery origin [41]. This helps fishers distinguish a hatchery fish from a wild fish and only keep the hatchery fish [43]. This harvest management strategy is commonly used by non-tribal fisheries, especially with species that are ESA listed [43]. Tribes typically do not adhere to mark-selective fishing and instead believe that a captured fish should be retained and fully utilized, fish release is a waste and is in opposition to tradition [41,43]. On the other hand, both Branstetter and Matylewich who work for CRITFC described how the tribes tend to look at fish management more holistically than the state and federal agencies and how this can lead to persistent issues [11,17]. State and federal agencies are typically much larger and more bureaucratic than the fish management branch of tribes which can lead to breakdowns in communication [17]. In addition, these agencies must report to larger political entities that do not necessarily prioritize habitat, water, or fish [17]. All of this said, despite the expected turbulence that comes with different entities co-managing a complex resource, each of my interviewees agreed that the parties have made significant progress in effective cooperation [11,17,41,43,44].

By establishing more forums for communication, valuing different perspectives and areas of expertise, and working towards compromise, there have been many successes despite some challenges. Branstetter believed that at the end of the day, everyone involved wants the same thing, "In general I think we can agree that we all want a place that has wild fish, and that they'll be there hopefully well into the future" [11]. This point was echoed throughout other interviews. While a lot of progress has been made in establishing effective co-management and restoring fish populations and habitats, more work will be necessary to continue improvement into the future.

*Current Status of Salmon*

The status of salmon populations in the Columbia River basin varies by stock [17,43]. Within the total salmon population, there are specific stocks that have made major improvements over the last 50 years, but there are also stocks that have declined and many that fluctuate or stay consistent [43]. Within the context of the last 50 years (since the Boldt Decision), there are many victories to point to in terms of salmon population restoration and enhancement. However, despite years of efforts, when the temporal scale is extended to the pre-colonial era, today's numbers fall short

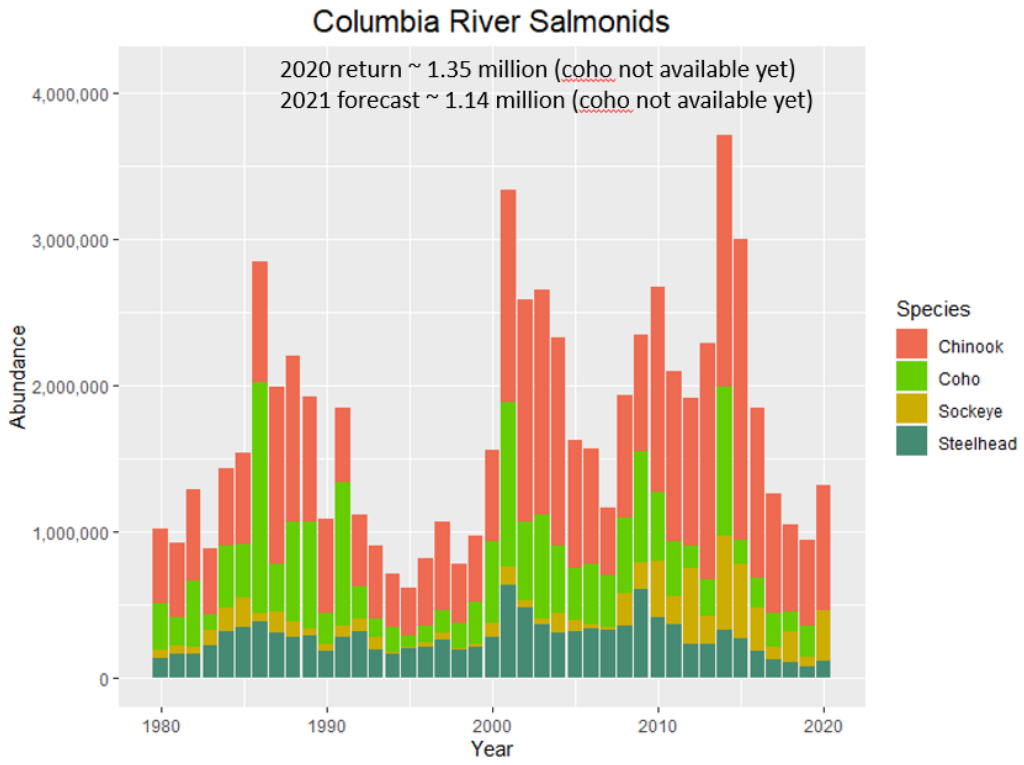


**Figure 6.** Chart of total returns of salmon, broken down by species, to the Columbia River basin each year since 1980. 2021 forecast developed by US v. Oregon Technical Advisory Committee. Source: Washington Department of Fish and Wildlife

When the total salmon population is broken down by species, there is a wide range in how each species is doing. Chinook overall tend to fluctuate, though when separated into their spawning periods, spring chinook tend to be more depressed, while fall and summer chinook have done better [17,43]. There are many populations of coho that are ESA listed, though restoration projects have improved many populations [17,43]. Steelhead survival and returns have experienced a downturn over the last 10 years [17]. Chum, which are not listed in the figure as their populations are low in the river are doing poorly [43]. Sockeye populations tend to fluctuate, they have increased in the last 10 years, though there are some populations that are the most endangered fish in the river [17,43].

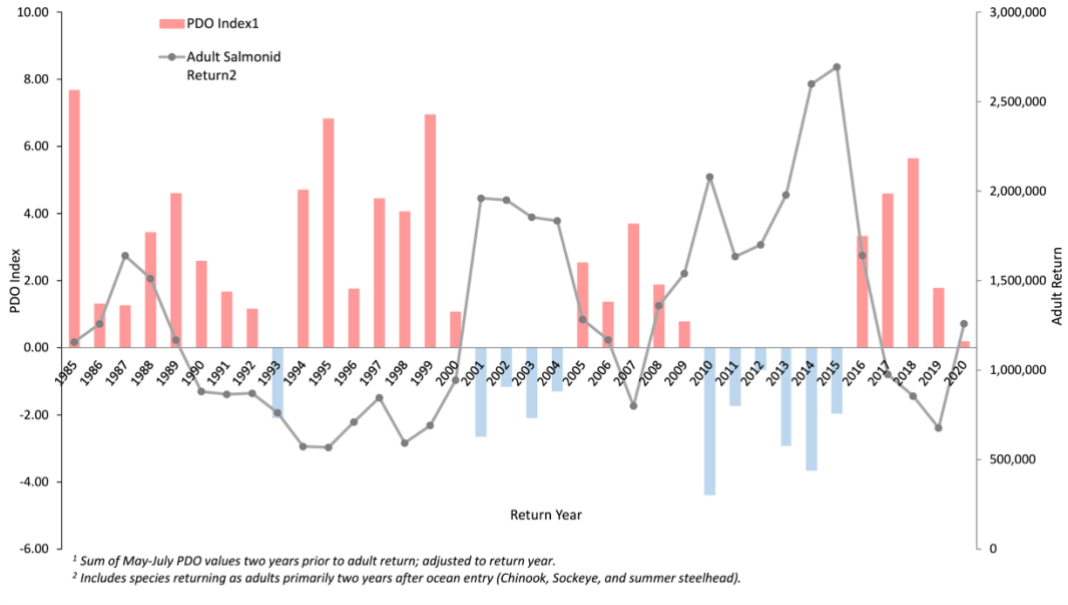


**Figure 7.** Chart of total salmon returns to the Columbia River mouth since 1985, overlayed with PDO Index of annual ocean conditions. Positive (red) PDO represents warmer ocean conditions while negative (blue) PDO represents cooler ocean conditions. Note that this chart only includes chinook, sockeye, and summer steelhead. Source: Oregon Department of Fish and Wildlife – Columbia River Management Program

This range in status of species populations contributes to an overall oscillating cycle in abundance of total annual salmon. While there are many factors that go into this, Figure 7 indicates that ocean conditions are among the most important. [16]. As an anadromous fish that spends most of its life in the ocean, this is a crucial element to the life of a salmon [16]. Over the last 40 years, the fluctuation in ocean conditions tends to have a very strong correlation with salmon returns in the Columbia River [28]. There are record periods such as from 2010 to 2015 when it appears that populations are significantly improving, though these periods are often followed by a downturn, such as from 2016 to 2019 [28]. The implications of this are that when assessing the improvement of salmon populations over time, it is important to look at long term trends rather than 2–3-year changes. When long term trends are examined, salmon populations are in a similar place to where they were in

1980. On the whole, the period of 1980 through 2020 had an average of about 2 to 2.5 million fish returning per year [28].

When compared to estimates of historical salmon runs, modern runs are meager. Pre-colonial salmon runs are estimated to have ranged from about 10 to 16 million fish per year [19,20]. Researchers estimate that the Columbia Basin tribes caught up to 44 million pounds of salmon per year, which would come out to 4.5 – 6.3 million individual salmon [20,46]. This number would vastly surpass any annual catch in recent times, and even surpass many of the total catches in the height of commercial fishing [19]. In this period, between 1883 and 1919, the industrial fishery maximum harvest only surpassed 41 million pounds nine times [19]. Despite the tribes' historically high harvest rates, the salmon fisheries remained stable [33].

There are many explanations offered for how the tribes sustainably managed the salmon fisheries while harvesting in substantial amounts, as compared to European setters who could not. One explanation is that tribal fishing was well-adapted to the area and was spread across the basin rather than concentrated just in the lower Columbia, unlike commercial fisheries [19]. Jeromy Jording added that the development of the river was a major difference [43]. He explained that Bonneville Dam, the first dam built on the Columbia in 1937, was built without fish ladders [43]. From here, the continued damming of the basin resulted in salmon habitat decreasing from about 14,666 to 10,073 miles of stream [20]. Finally, Kate Self offered TEK as an explanation of sustainability:

> "Ten thousand years of information that had been honed and revised and adapted to the changing environment over those thousands of years. It should still be listened to and valid and try to be applied to this highly modified environment" [47].

Perhaps the true reason is a complex combination of each of these explanations, and perhaps it's something else entirely. Regardless, the fact remains that the Indigenous communities managed the Columbia River basin fisheries sustainably. Turning to their descendants, those still in possession of that knowledge, provides a promising solution.

## Part 2: Bridging TEK and Western Science in Co-Management

### *The Importance of TEK*

Indigenous resource management systems offer an alternative to western resource management in both their goals and foundation. Western colonial societies generally created systems based on control of people and resources, focused on expansion and extraction for short-term profit without the concept of limit or sustainability [4,11,48]. Conversely, Indigenous societies tended to create systems based on a centuries-long relationship with their local environment, with the goal of emphasizing reciprocity with the natural world and multigenerational sustainability [11,48].

PNW Indigenous principles are centered in many ways around the deep connection between humans and the greater natural world, this has led to long-held beliefs and management systems stressing respect and protection for the non-human world [4,48]. The historical abundance of natural resources in the PNW allowed for larger populations and permanent settlements, while at the same time creating awareness among the precolonial Indigenous people of the pressures these resources faced when being used by many people [48]. The way they organized their societies directly connected to how they viewed the rest of the world and the natural resources around them. Tribal ceremonies and traditions reflect their values of reverence for the natural world and gratitude for the natural

resources provided for them [21] These principles were the primary driver of thousands of years of conservation practices in the Columbia River basin, which contributed to the success of salmon populations [18].

The Indigenous land ethic of placing humans within the complex, integrated system of the natural world, flows from their traditional ecological knowledge (TEK); this vast array of knowledge allowed them to build successful yet sustainable societies. TEK is defined as "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission" [21]. TEK is much more than an empirical list of facts; it includes skills and strategies to address dynamic environmental situations and is applied by expressing these in the context of present environmental conditions [9]. Through thousands of years of living along the Columbia River, Indigenous people came to understand the interconnection between all things in the biophysical world, in that it is all one system in which each part affects everything else [9]. Therefore, humans must respect, show appreciation for, care for, and maintain the harmony of this system [9]. A land ethic born out of TEK led to a governance system of natural resources that prevailed for thousands of years, and allowed for successful, sustainable societies along the Columbia River.


**Figure 8.** Visual depiction of the levels and holism of TEK. Based on Berkes, 1999.

This time-tested land ethic guided stewardship and appreciation of the salmon that sustained Indigenous societies, and centered salmon in spirituality as the irreplaceable keystone species that they are. Oral histories are a central part of many Indigenous communities, these stories typically provide social rules including guidance on how to care for the non-human natural world [49]. In the PNW, salmon appear in many of these tribal stories and myths including the origin stories of humans. As stated by the CRITFC:

"From tribal legend, we learn that when the Creator was preparing to bring forth people onto the earth, He called a grand council of all creation. From them, He asked for a gift for these new creatures – a gift to help the people survive, since they would be quite helpless and require much assistance from them all. The very first to come forward was Salmon, who offered his body to feed the people. The second was Water, who promised to be the home to the salmon… In accordance with their sacrifice, these two receive a place of honor at traditional feasts throughout the Columbia Basin" [50].

Spiritual stories such as this serve to help societies remember to treat the environment and resources such as salmon with respect, and to foster an emotional connection with them [21,48].

Other stories teach honoring salmon through a spiritual ritual known as the "First Salmon Ceremony" [21]. From northern California through Alaska, the First Salmon Ceremony has been a nearly ubiquitous ritual for salmon-fishing Indigenous communities [21,48]. Historically, fisheries would not be open to tribal fishers when the first salmon runs of the year appeared in the river, everyone had to wait for the permission of tribal elders and the conduction of the First Salmon Ceremony [5,21]. While there were many specific variations to the process, typically one or many tribal ritual leaders would make the decision on exactly when to conduct the ceremony, and mark the opening of the fishery [21]. The ceremony itself honored the return of salmon and reflected the spiritual belief that salmon give their lives to support the people, as is conveyed in the origin story [5,48].

While the First Salmon Ceremony is important solely as a spiritual ritual, it has value as a resource management tool as well. Using TEK, an experienced observer could assess the strength of a particular salmon run in a given year [5,21]. Based on this, that leader could adjust the timing of the opening of the fishery to allow a sufficient number of fish to continue upstream to their spawning grounds [5,21,48]. This process was often conducted through the use of a fish weir – the most widespread fishing technology used by Indigenous communities in the PNW [2,18]. The weir spanned the width of the river and funneled fish into one point, allowing an observer to view fish passage and make a determination on fishing [18]. If used by an unaware fisher a weir can quickly decimate a salmon population, therefore there were typically strictly enforced rules highlighting conservation, all based in

TEK [2,5,18]. Additionally, weirs were often used by many families or communities within a single river location, requiring cooperative management of weir use up and down the river [2,18]. This process supported the practice of terminal fishing – the targeting of a single healthy stock of fish based on in-river monitoring (as opposed to mixed-stock fishing which targets fish regardless of health of stock) [5,18]. The leader administered this management process through a ritual, and it was enforced socially, all of which was consistent with cultural values and beliefs [5,21].

This process, excluding the spiritual elements, is not dissimilar from how US fishery biologists and managers today assess and regulate salmon fisheries. US fish biologists generally use population models and counting fences, and managers set fishery opening dates and monitor daily harvest to allow enough fish to escape and spawn upstream [21]. While western management methods are more quantitative and reliant on previously collected data, and traditional Indigenous methods are more qualitative and reliant on generational observational knowledge, they resemble each other closely. The results are quite similar as well; according to several tribal biologists in Oregon who were asked as part of a study, an experienced observer can conduct an accurate qualitative assessment of a salmon run [51]. Many tribal fishery biologists still know the traditional system, and it continues to be implemented in a few places – such as the Karuk Tribe on the Klamath River in Northern California [21]. The Karuk people have traditional fishing sites where the Klamath narrows, and salmon can be visually assessed by experienced tribal fishers, they then make harvest decisions based on those qualitative observations [21]. Nevertheless, while the First Salmon Ceremony is still widely practiced for spiritual purposes, it has

mostly been supplanted by western biological management, even in areas where Indigenous communities manage their own fisheries [21].

*Bridging TEK and Western Science*

While much is clearly different about the Columbia River basin from the last time Indigenous communities had full governance power, there is still lots to learn and incorporate from TEK. Bridging TEK and western science to address new problems is an example of "co-production" of knowledge [21]. Coproduction of knowledge is defined as "the collaborative process of bringing a plurality of knowledge sources and types together to address a defined problem and build an integrated or systems-oriented understanding of that problem" [22]. Coproduction of knowledge is typically most effective when employed to address issues of which neither individual knowledge system can adequately deal with [21]. That said, in general the two knowledge systems are created and communicated in vastly different ways. Western science is typically conducted through the scientific method and transmitted via literature, while TEK is generally conducted and transmitted orally or through hands-on experiences and demonstrations [21]. Therefore, the most effective way to bridge TEK and western science for conservation is by empowering tribes to be directly involved in these efforts [9].

While the increased integration of TEK into modern conservation is certainly a positive step, it is important to remain respectful, and maintain awareness of the history of colonialism and continuing power imbalance between Indigenous people and western settlers. As the value of TEK has gained greater recognition by westerners, western researchers have advocated for TEK to be documented and stored to mitigate for the erosion of the knowledge over time [9]. This has led to concerns of knowledge being

appropriated and used while the Indigenous knowledge keepers see no benefit [9]. This also represents a fundamental misunderstanding of what TEK is. TEK is grounded in worldview and is based in generational local knowledge, something typically only accessible to Indigenous peoples [21]. Hence, specific pieces of knowledge cannot be simply stored and used in absence of those interconnections and direct experiences [9,21]. Additionally, the "combination" of knowledge systems between Indigenous people and a colonial power (as opposed to bridging them) typically ends up being a disadvantage to the Indigenous people, due to power imbalances [21]. These issues can lead to mistrust and reluctance to share TEK, Ryan Branstetter explained that due to many factors, "There's some issues about sharing this knowledge, within our tribal cultures, with outsiders" [11]. This underscores the need for diligent respect and contextual awareness in co-production.

There are a number of approaches and models that have been used to effectively bridge TEK and western science in a way that is respectful and acceptable to Indigenous knowledge holders. The four primary models that have been used within the US are: "collaborative species-specific management", "co-management for landscape-scale ecological restoration", "integrated scientific panels", and "formal institutional liaisons" [9]. Collaborative species-specific management occurs when western scientists and environmental managers work with Indigenous knowledge holders to bridge TEK with western management practices, typically to protect or enhance a species that is of significance in the local area [9]. Co-management for ecological restoration is when an official, power-sharing partnership is established between a state institution and an Indigenous community to share decision-making and resource management authority [52]. An integrated scientific panel is an official panel made up of both western scientists and

Indigenous people with TEK who work together to analyze environmental problems and recommend solutions based on their respective knowledge bases [9]. Formal institutional liaisons serve as a third-party educational organizations between Indigenous people possessing TEK, and others interested in learning about TEK to apply to environmental issues [9]. There are real-world examples of each of these practices occurring with success in various parts of the world [9]. Many of these inter-cultural conservation efforts have only been applied on a small scale, but nevertheless, they have the potential to be implemented on a larger scale to create much greater change [9].

Collaborative species-specific management is particularly intriguing as, more than the other models, it incorporates TEK directly into natural resource management. Equally intriguing is that a successful example of collaborative species-specific management has occurred in a region that neighbors the Columbia River basin. Beargrass is a plant that is native to the PNW and is historically important to the Skokomish and Quinault people of the Olympic Peninsula [53]. Beargrass is important for use in basketry and spiritual practices, and the Skokomish and Quinault people would traditionally conduct controlled burns to maintain open-canopied beargrass [53]. Following the treaties of 1855, in which the Skokomish and Quinault people ceded much of their lands, controlled burning largely stopped, this has resulted in the decline of beargrass [53]. In 1995, the Olympic National Forest started a project to restore beargrass populations [53]. To coordinate this project, forest managers and University of Washington scientists collaborated with Skokomish and Quinault knowledge holders to incorporate traditional land management practices based in TEK [53]. This resulted in a successful 13 hectares of forest burns and revegetation with further burns planned at 3–5-year intervals [53]. As of 2009, these TEK-guided prescribed

burns have spread to other areas within western Washington, and results have shown improvement in beargrass populations [54].

The case study of beargrass demonstrates that collaboration between western natural resource managers and Indigenous knowledge holders can have successful results and be beneficial for all involved. By bridging TEK with western forestry management practices, through already established avenues of co-management (the Skokomish Indian Tribe and the Quinault Indian Nation have similar treaty rights to the Columbia basin tribes), the parties were able to successfully work towards a shared goal [54]. It also serves as a potential model for management of salmon in the Columbia River basin, as collaborative species-specific management has not yet been attempted there.

## Part 3: TEK and Co-Management in the Columbia River Basin

### *The Context of Co-Management Today*

Until relatively recently, co-management of the Columbia River basin between tribal nations and the US did not exist. From the time that most tribal lands were ceded in 1855 and the rapid infusion of white settlers, until the Boldt Decision of 1974, the basin was managed by the dominant colonial society. As examples such as the CRC and CRT demonstrate, co-management was not absent in the region, but it did not include the original managers of the land. It is imperative to acknowledge the colonial history of the region and recognize that co-management rights were only gained through a long social and legal struggle. Even since 1974, there have been periods of pushback against tribal inclusion, lack of ability of the parties to come to effective management agreements, and

perhaps most importantly many of the salmon populations have not substantially improved [11,17]. Today, there continues to be a power imbalance between the Tribal Nations and the US, as tribes do not have the same rights as a true sovereign nation [11]. That said, a lot has improved over the last 50 years, and today co-management between the Tribal Nations and the US is stronger than ever.

Following the passage of the Boldt decision, the states spent years pushing back legally against the ruling, and Fish and Game Departments simply ignored the new rules [37]. Between 1974 and the first long-term management agreement in 1988, there was a period of gridlocked litigation where yearly plans were only implemented through legal supervision, and there was a distinct lack of cooperation [37]. Even after 1988, Branstetter described the attitude of many of the previous generation of state fishery managers as "hat[ing] natives, they didn't like the tribes, they didn't feel like the tribes had a role to play, they shouldn't have a seat at the table" [11]. This paints a picture of a hostile and reluctant co-management structure between two groups with a contentious history. Even so, over the next 30 years, that cultural strife was reduced due to the older generation moving on and new generations coming in with more desire to set a paradigm of better co-management [43].

Since then, the aforementioned "co-management for ecological restoration" has been the most notable model that has been implemented in Columbia Basin salmon management. Through the ruling of the US v. Oregon case, the treaty tribes and US states have a formal power-sharing relationship over salmon management and decision-making. With US v. Oregon as the basis for upholding tribal management rights, Indigenous

managers are not only deeply involved in the US v. Oregon agreements, which are the most important management agreement in the region. But they are now involved in the PSC, the PFMC, sit on the committees established under US v. Oregon, and are increasingly taking important positions in federal and state management agencies [11,43]. Additionally, through this formal power-sharing model, the states and tribes work together on various programs such as fish stock monitoring and predation management [41,44]. This all represents progress made in productive co-management, justice for Indigenous people, and has led to tangible improvements.

These improvements are notable and significant, and while Indigenous people have their voices heard far more today than 50 years ago, the fisheries are still managed solely according to western scientific principles [21]. In many cases, the tribes are required to use western scientific management due to co-management agreements [55]. While cooperative management is legally mandated, the specific management practices are not defined, therefore western science remains the standard [18,21]. While many tribal members still possess TEK, and customs such as the First Salmon Ceremony and traditional fishing methods are still practiced for cultural purposes, TEK is not something that has been widely incorporated into management of salmon in the Columbia River basin [11,41,43]. Two interviewees who manage for the US confirmed that TEK was not something they had been exposed to in management of fisheries [41,43]. Nevertheless, with an already legally established and long-running co-management structure already in place, the potential to implement TEK conservation practices is undoubtedly there.

*Efforts to Bridge TEK and Western Science in the Columbia River Basin*

For decades, the CRITFC and its member tribes have been at the forefront of advocating for the incorporation of TEK into salmon management in the Columbia River basin. In 1995, the CRITFC put forward a holistic plan to restore the declined runs of salmon, protect tribal sovereignty and treaty rights, emphasize natural and traditional management practices, and protect the resource for future generations [23]. The plan is called "Wy-Kan-Ush-Mi Wa-Kish-Wit", meaning "Spirit of the Salmon" [23]. It is comprehensive and covers the numerous facets of the issue, including an emphasis on the collaboration of modern western science with TEK as a basic guideline of the plan [23]. Within this inter-cultural integration, the plan especially stresses four TEK concepts for use in salmon management: documentation of natural conditions prior to colonization, holistic management based on existing relationships between tribal members and natural resources, an adaptive management framework, and recognition of the relationship between place and community [23]. The plan lists several specific TEK principles, identifies their practical application in management and restoration, and provides examples of that principle being used historically or today [23]. Since 1995, the CRITFC and its member tribes have continued to push for the holistic goals of their management plan, including the incorporation of TEK.

In 2008, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) Department of Natural Resources (DNR) came out with the *Umatilla River Vision*, which outlined their vision for managing and restoring habitats within the Umatilla River Basin through a "First Foods" approach [56]. A First Foods approach brings traditional

management practices and spiritual beliefs into management [56]. In tribal creation belief, salmon was the first food to offer to take care of humans, followed by deer, cous, and huckleberry, each of these are considered "First Foods" [56]. These First Foods represent categories of ecologically interconnected species, each of which supports and relies on one another [56] By focusing on protecting, restoring, and enhancing First Foods, CTUIR takes a holistic approach which considers the ecosystem as a whole and the way that each component affects another [56]. As opposed to common western management practices which often focus on a single species with limited spatial and temporal scales, the *Umatilla River Vision* looks beyond anadromous fish to "five fundamental 'touchstones': hydrology, geomorphology, connectivity, native riparian vegetation, and native aquatic biota" [17,23,56].

Since its development in 2008, the *Umatilla River Vision* has succeeded in bridging TEK with western science, facilitating co-management, and tangibly improving ecosystems. In addition to being based in TEK, the *River Vision* provides an implementation framework that is scientifically based [57]. This framework uses the five fundamental touchstones to implement restoration and enhancement efforts in order to create more resilient ecosystems in support of the First Foods [57]. This scientific framework allows the DNR to empirically link the First Foods to ecological processes and restoration approaches [57]. Additionally, it allows the DNR to communicate their approaches and efforts to other tribal, federal, state, and local managers [57]. Since the Umatilla River basin and range of First Foods is much larger than the Umatilla Reservation, the CTUIR DNR must collaborate with tribal, federal, state, and local agencies to achieve their goals [57]. The First Foods approach allows the CTUIR to clearly communicate the cultural importance of First Foods, as well as the scientific processes that affect First Foods [57]. This provides co-managers with an

understanding of the importance of protecting First Foods, and lays out clear ways that they can help [57]. This has all led to greater management capacity of resources by the CTUIR, and concrete improvements in their riparian habitats and the species themselves [57].

By taking an approach that emphasizes holism and cultural significance through science, the CTUIR can connect to all parties involved in management, which has led to tangible results. While the *Umatilla River Vision* solely concerns scales to which the Umatilla River basin is relevant, there is no reason it cannot be applied elsewhere. With the *River Vision* as a guide, the First Foods approach can be exported from the Umatilla River basin, across the whole Columbia River basin [23].

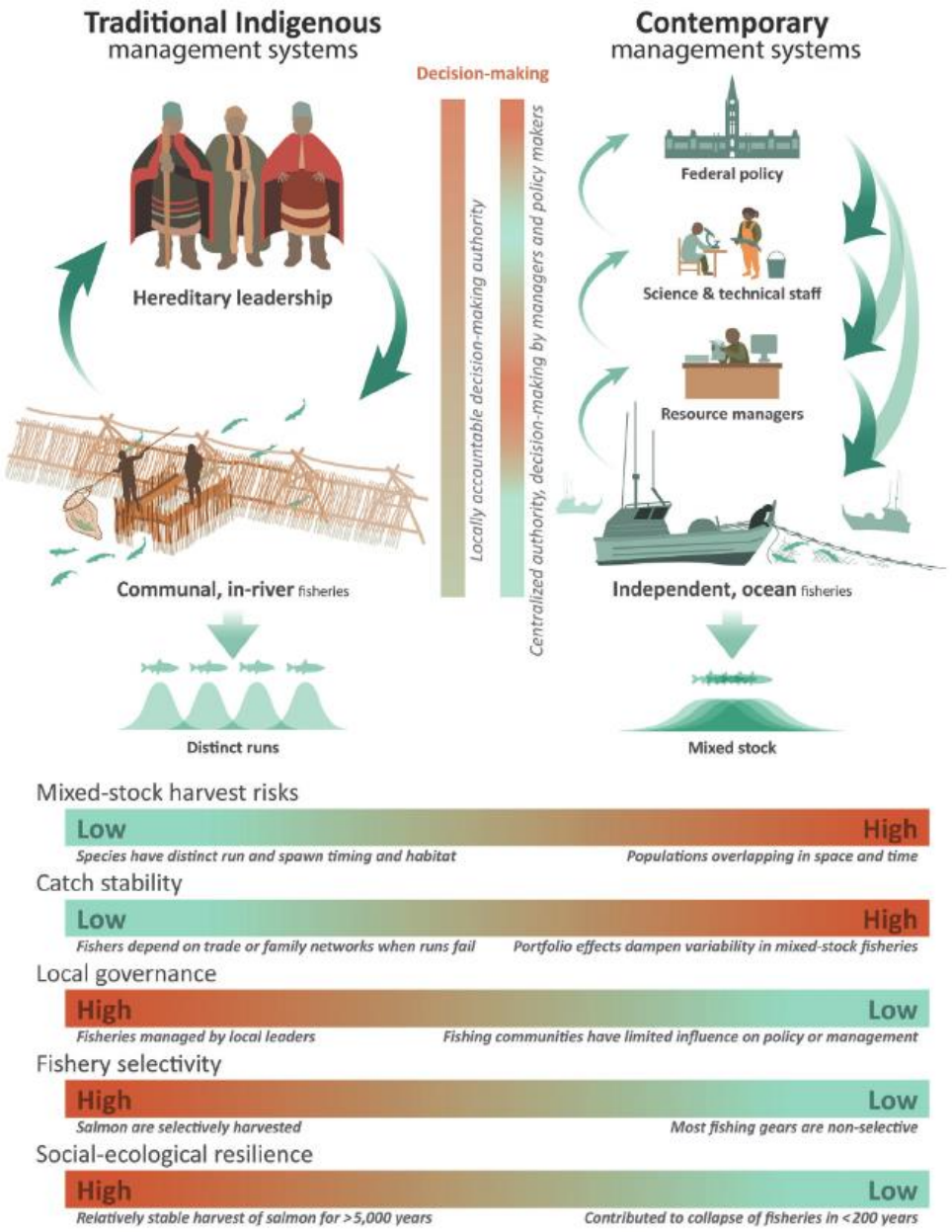


**Figure 9.** A visual comparison of traditional Indigenous and contemporary management systems in regard to decision making and evaluated across five important social-ecological parameters. Source: Atlas et al., 2021

*Impediments to Incorporating TEK*

While the CTUIR's First Foods approach has the potential to be applied in other places throughout the Columbia River basin, this approach still has not gone mainstream, especially in areas where Tribal Nations have less management power. There are a variety

of impediments to the greater incorporation of TEK into fishery management, and many obstacles are specific to local areas. In my research I have found there to be three primary obstacles in the Columbia River basin: erosion of TEK over time, lack of trust and comfortability in sharing knowledge with non-Indigenous people, and US resistance to major change.

Several case studies over the last couple decades have provided evidence of the rapid erosion of TEK worldwide [10]. There are a number of reasons for the loss of TEK over time, and most of them trace their roots to the effects of colonialism, including: loss of access to traditional lands and resources, the prohibition of traditional management practices, and the genocide of Indigenous people worldwide [9,10]. Many of these issues continue to contribute to the loss of TEK today [10]. These effects are just as apparent in the PNW as anywhere else in the world that has been altered by colonialism. [11] Branstetter detailed these effects:

> "Because of disease, poverty, the boarding school system – a lot of our cultures, a lot of our histories are damaged. Some of that stuff was lost, was straight up gone because of those things. It's like if I took a book and ripped out random pages out of it, and trying to figure out how it goes together. That's very much a similar situation that a lot of tribal people face themselves growing up, and our culture have been in some ways irreparably damaged. And trying to figure it out and piece those things together is a study within itself. It might take a lifetime to piece it back together" [11].

TEK is a holistic and evolving bank of knowledge that that has been built up over thousands of years, fostered by and in concert with the local environment. [21,23]. As western settlers moved in with a different land ethic and enforced new management structures of natural resources, that local environment with which tribal social, economic, and cultural practices were based, declined [9]. As those environments decline, so does the TEK that is closely tied in; and as TEK erodes, culturally important species continue to decline, in a feedback loop

[9]. Addressing the numerous threats to TEK degradation is necessary to protect this knowledge system, as well as to provide justice to Indigenous people.

Among Indigenous people who do possess TEK, there are many who are understandably reluctant to share this knowledge with non-Indigenous agencies and individuals. There is a long history of non-Indigenous people and agencies forcefully excluding Indigenous communities from river management, while at the same time exploiting the foods, resources, and knowledge of the original people [27,57]. Even in recent times as the value of TEK has been more recognized by non-Indigenous people, there are concerns about others using the knowledge irresponsibly or inappropriately [9]. Of high concern is the practice of the "mining" of TEK, in which non-Indigenous people have knowledge shared with them, and proceed to use it as data for science, often out of context [21]. Often these people will not credit the Indigenous knowledge-holders, or may not return compensation from where it is acquired [9,21]. As mentioned earlier, even when TEK is simply "combined" with western science, this can be to the disadvantage of Indigenous people [21]. Due to these long-running and continuous exploitative colonial practices, many Indigenous communities are distrusting of non-Indigenous agencies and reluctant to share important traditional knowledge [11,57].

Despite justified distrust and wariness to share TEK, the CTUIR DNR emphasizes the importance of collaborating with non-Indigenous agencies and sharing knowledge in order to apply the First Foods approach [57]. The CTUIR DNR continues to outline a variety of steps that Indigenous communities can take to protect themselves against exploitation when sharing sensitive information [57]. As co-management is necessary, each of these steps

are ones that CTUIR has had success with in implementing the *River Vision* [57]. While over 200 years of exploitation cannot be undone or forgotten, there are methods to rebuild trust, and Indigenous agencies like CTUIR DNR are at the forefront.

In addition to impediments to sharing TEK from Indigenous communities, there is also resistance from non-Indigenous people to change and the incorporation of TEK. As has been outlined in this paper, from the moment the treaties were signed in 1855, Indigenous people have had their lands, resources, rights, and ways of life taken away [25,27]. Even for many years following the Boldt Decision in 1974, non-Indigenous agencies made every effort to continue excluding Tribal Nations from being involved in management [11,27]. It was not until very recently that the value of TEK began to be recognized by non-Indigenous people, Branstetter explained that "For a long-time native belief and native education was not looked at, as at the same level as western education" [11]. Even as a great deal of active resistance to incorporation of TEK has subsided, there is still abundant passive resistance.

There are a number of beliefs and institutions, based in exploitation and unsustainability, that are deeply imbedded in the structural fabric of the US colonial state [7,11,56]. These beliefs and institutions are in many cases incompatible with TEK practices, and often stand in the way of co-management [7,11]. Two of the pillars of western capitalism and in turn the US, are the commodification of natural resources and the protection of private property [7]. Beginning in the late 19$^{th}$ century, each of these pillars guided the way that salmon and water were managed. Dollar values were assigned to salmon and hydroelectric power, producers were granted private use, and these resources were extracted for global markets [7,48]. Branstetter summarized this:

> "The settler-colonial mentality here was just that it was full on extraction, and the idea that God's going to provide and it's an unlimited resource. You look at what had been done to Europe, and then been done to the east coast is kind of the story. Wash-rinse-repeat where they took everything and wiped everything out and kept on going with no thought for the future. It was all about getting as much wealth as you could and extract as quickly as possible" [11]

The characterization of river resources as commodities for extraction encouraged overfishing, dam-building, and managing according to economic interests, rather than prioritizing a functional watershed to support human and ecosystem processes [7,56].

While a number of measures have been taken over the years to mitigate for the incentives of private property rights and commodification of natural resources, these concepts are contradictory to Columbia basin Indigenous cultures and TEK management practices [48,56]. These firmly entrenched concepts in the US stand as major obstacles to truly incorporating TEK as well as restoring ecosystems.

The history of and continuing effects of the hydroelectric dam system in the Columbia River and its tributaries serve as a poignant case study in the divergence between Indigenous and western ideology. As outlined in the description of the CRT, the hydroelectric dam building project throughout the 20$^{th}$ century had the goals of nation-building, flood protection, job creation, and producing electricity for a growing settler population [26]. The Columbia hydroelectric project both commodified and privatized the river resource, dams are not only about electricity but also represent human control over nature [26]. The construction of dams notably did not prioritize taking a holistic approach to maintain a healthy watershed for the humans and ecosystems that rely on it, and in turn Tribal and First Nations were not consulted [23,26]. The dams have had the environmental effects of massively altering the flow of the river, and eliminating upstream populations

where fish passage was not provided [23,26]. At its maximum, this led to a blockage of over 55% of historical anadromous fish habitat [23]. The cultural effect on Indigenous communities was just as large as the environmental effect. Economically and spiritually significant sites such as Celilo Falls were inundated, Indigenous communities were forcibly displaced, and upstream fish populations which maintained many communities' way of life were eliminated [26]. The decision to prioritize economic benefits over the health of the ecosystem, was also a calculated choice to continue the cultural genocide of Indigenous people [26]. The deliberate disruption of an ecosystem that maintained the way of life for many communities, not only damaged the ecosystem, but served the colonial project of dispossession [26].

Today, dams are a living representation of the history of colonialism in the region, while continuing to impede habitat and fish restoration. Most current restoration efforts are focused on developing technology to help with fish passage, and there have been successes, especially with dam spillovers [17,23,44]. This has restored over 15,000 square miles of habitat [23]. That said, over 80,000 square miles of historical habitat remain inaccessible, mostly due to failure to achieve fish passage in the upper Columbia and Snake Rivers [23]. The feasibility of maintaining dams has decreased over time, as many dams are reaching the end of their operational design life, and renewable alternatives like wind and solar have become more economical [47,58]. As a result, many groups, including Indigenous communities, have been advocating for dam removal. While the practice of dam removal has been occurring since the 1990s and has true scientific basis, it is also in many ways based in TEK [23,58]. Through TEK, many Indigenous people believe that given the opportunity, the ecosystem will heal itself; the removal of dams is seen as a way to allow

the river to return to its natural state, and for fish to restore their own upstream populations [17,59].

Incorporating TEK with western science through the practice of dam removal has gained increasing support in recent years, though the idea is still often met with resistance due to economic or western cultural reasons [59]. One place where a fight over dam removal has existed for over 20 years are four dams located on the lower Snake River [60]. Proponents claim that breaching the dams would improve the ecosystem, return traditional fisheries to Tribal Nations, and even benefit the economy [60]. Opponents argue that this would decimate the economy of the PNW [60]. This debate around these specific four dams epitomizes the same difference in worldview that has existed since the first dam was built: one that values ecosystem processes and one that values commodification.

In spite of resistance, two major dam removal projects in the PNW were conducted in 2011: the Condit Dam on the White Salmon River and two dams on the lower Elwha River [23,58]. Each project took years of advocating and planning and in each case, local Tribal Nations were heavily involved in advocation and planning [23,58,59]. As the rubble was cleared and the rivers began to regain their flow, salmon quickly began repopulating tributaries that they had not been to in almost a century [23,58]. Evidence was provided for the concept of getting rid of the obstacle and letting the river do the rest. As stated by Matylewich:

> "In both of those, the Elwha and the White Salmon, we have seen fish come back on their own. So as tribal members often told me; listen to the fish and give the fish half a chance and they will show you what to do, and they will do a lot of the work on their own" [17]

While each of these dam removal sites will need to continue to be monitored, the early success of both suggests success in other areas of the PNW.

The three major impediments: loss of TEK over time, Indigenous resistance to sharing TEK, and US resistance to incorporating TEK are all major issues, none of which will disappear in the near future. Still, there are strategies to mitigate or work around these impediments. Indeed, there are success stories in which TEK and western science have worked together despite the obstacles that stood in the way. These case studies and strategies can be used to help guide co-management in the Columbia River basin into the future.

*Benefits to Incorporating TEK*

Based on the current status of US-Tribal co-management in the Columbia River basin, documented success stories of TEK incorporation, and the ambition of the Columbia basin Tribal Nations, I have gathered that the bridging of TEK with western science is feasible and would create widespread benefits for fish, habitat, and people.

The current paradigm of cooperation in management between the US and Tribal Nations in the Columbia River basin sets a robust foundation for moving to also incorporate tribal management practices based in TEK. As previously stated, the current co-management structure most closely resembles "co-management for landscape-ecological restoration", in that the two parties have a legal, power-sharing partnership [9]. Through a common desire to protect the salmon, and backed by litigation, the parties work together to set a comprehensive management framework [17,41]. Additionally, the parties collaborate through policy committees, advisory committees, and several other

collaborative efforts within and outside of the Columbia River basin [17,41,43] However, this power-sharing partnership still exists within the western economic and scientific management regime [48]. With a goal to move towards a management regime that is based in both western science and TEK, the current foundation of cooperation can help ease this transition.

The previously discussed case study of cooperation between the Skokomish and Quinault Tribes, and the Olympic National Forest Service provides an apt example of this. The Boldt Decision of 1974, which legally upheld the right to fish and hunt at "usual and accustomed places", and required 50% of fish harvest to go to the Columbia basin tribes, similarly held the same rights for twenty total tribal nations, including the Skokomish and Quinault [27,55]. Through a similar process to the Columbia tribes, the Skokomish Tribe and Quinault Nation gradually built co-management structures with the state of Washington and federal agencies [27,55]. It was within this paradigm of cooperation that the Tribal Nations were able to promote a restoration project that incorporated TEK. In a very similar manner, the Lower Elwha Klallam Tribe worked with state and federal agencies to facilitate the removal of the Elwha River dams [59]. It is important to note that the Tribal Nations referenced above continue to face many of the same obstacles as the Columbia River basin tribes, and still must co-manage within the western economic and scientific paradigm [9,27,59]. However, these case studies demonstrate the importance of an already established co-management relationship to facilitate the greater incorporation of TEK into resource management. Additionally, given that both case studies occurred in close proximity and under similar circumstances to the Columbia River basin, they represent replicable models.

Since the CRITFC's Wy-Kan-Ush-Mi Wa-Kish-Wit plan was published in 1995, they have affirmed that bridging TEK with western science is a basic principle of the plan [23]. They emphasize that the two knowledge systems share a lot in common, "including the need to make sense of a seemingly chaotic world, the desire to conduct both practical and curiosity-driven investigations, a non-static view of facts based on continuously updated information, and the use of experiments and quantitative thinking" [23]. While they still differ in many ways, the CRITFC is confident that the two viewpoints are complementary, and can be used in conjunction to solve modern problems [21,23]. The CTUIR underscores this same point in constructing their First Foods vision with the express purpose of being used in co-management and being relatable to non-Indigenous people [57]. All throughout the Columbia basin, from the Canadian First Nations and Colville Tribes in the north, to the Nez Perce Tribe in the east, and the Umatilla Tribes in the south, efforts are being made to promote TEK-based management [17,41,44]. It is clear that the Tribal Nations of the Columbia River basin are ambitious, motivated, and prepared to lead in the effort to re-incorporate the TEK management practices that sustained the salmon for centuries.

In addition to being feasible, the incorporation of holistic TEK management practices is equipped to provide simultaneous tangible benefits to habitat, fish, and humans. For habitat restoration and enhancement, Indigenous managers use passed down knowledge of what the historical habitat looked like and how natural processes functioned [23,48,56]. Through an approach that looks at the ecosystem as a whole, they can address and monitor all the limiting factors of habitat and examine through a longer period of time. Past examples of this include the restoration of the natural pattern and flow of tributaries and flood-plains which had been channeled, rerouted, or eliminated, in order to be more in tune

with natural processes and benefit the local riparian species [17,57]. The removal of harmful obstructions such as dams, dikes, and culverts to restore the natural habitat also provides a relevant example of this [23].

While harvest is generally not considered to be a primary limiting factor for salmon anymore, the incorporation of TEK practices can also improve harvest management of fish [43]. Traditional practices such as the First Salmon Ceremony can be implemented in true widescale management. Through this, the concepts of subsistence fishing, closed fishing periods for salmon migration, prioritizing terminal fisheries, and annual adaptive management can be implemented [21,41]. This ties in with the use of sustainable traditional fishing methods such as the use of weirs, traps, and dip nets. These traditional methods, when used within the framework of the above-mentioned concepts, provide a sustainable way to harvest fish and communicate with other river-based communities [48]. One example of this is the Lake Babine Nation, a First Nation that operates a weir on the Skeena River in British Columbia [48]. Lake Babine Nation members use traditional methods to monitor the fish that pass through the weir, and work with upriver communities to trigger commercial opening [48]. Harvest management practices based in TEK, such as this one, have the potential to be implemented in the Columbia River basin to benefit both the fish and the communities reliant on them.

For humans in the PNW as a whole, the benefits of incorporating TEK into management are clear through its effect on relationship with nature, and the widespread benefits of healthier ecosystems and fish populations. But the benefits to Indigenous people run deeper than that. As previously stated, one major difference between Indigenous and

settler societies is an enduring and deeply important relationship to ancestral lands [12,48]. This place-based connection was present throughout the culture and traditions of Indigenous communities in the PNW, and led to the development of TEK and sustainable ways of interacting with that environment [48]. Therefore, the dispossession of land and destruction of ecosystems throughout the US can be viewed as both cultural genocide and environmental injustice [12]. Additionally, each of these practices were an integral part of the US colonial project [12]. Given the extensive scale of this topic, exploring the relationship between setter-colonialism, cultural genocide, and environmental injustice is beyond the scope of this paper. The important takeaway, however, is that given Indigenous people's relationship to ancestral land– settler-colonialism, cultural genocide, and environmental injustice are one and the same, and must be treated as such in reparation [12]

Experts on this topic claim that for Indigenous people, social justice and environmental justice are not separate issues, the two issues can only be addressed together – this is known as Indigenous Environmental Justice (IEJ) [12]. The Boldt Decision was one step in IEJ, as Tribal Nations had their sovereignty rights upheld while also regaining management authority over their life-giving river. Even with co-management in place, the river is still managed according to western science and knowledge. A logical next step to further promoting IEJ is to incorporate TEK practices into management. These management practices had been used for centuries to maintain tribal ways of life, and were part of a deep relationship of reciprocity with the natural world [21,23]. When they were supplanted with western science and management practices, or in some cases outright banned, this was an attack on both the environment and tribal culture [48]. Implementing practices that connect Indigenous people to their ancestral lands and traditional lifeway

practices while repairing these environments, is a form of IEJ [12]. This would not solve all the issues that tribal communities face, and many other efforts would still need to be made in the pursuit of IEJ and decolonization. Still, re-incorporating TEK practices is a logical and feasible step that would be of direct benefit to Indigenous communities through IEJ.

While benefits of TEK incorporation to habitat, fish, and humans can be investigated independently of one another, in truth each are reciprocally connected to each other. The decline of habitat, fish, and Indigenous people in the PNW occurred simultaneously and due to the same processes. In the same way, the restoration and protection of habitat, fish, and humans are inherently tied together. Due to this, holistic means of managing and monitoring this system must be pursued. To this end, TEK provides a relevant and practical resolution.

*Future Considerations*

Going forward, considering IEJ when making decisions around salmon management is an important way to assess the efficacy of those decisions. Indigenous communities of the PNW have a unique connection to the land and have a unique colonial relationship to the US state. This means that justice for them looks different than for other groups. It is important to consider these facts, and actively pursue paths that make reparation for these ills.

IEJ reaches a lot further than just salmon management, and in turn TEK does as well. As stated, TEK is much more than an empirical list of facts or a simple way of managing fish. TEK influences everything from cultural values and stewardship principles, to worldviews and societal organization [21,23]. Due to this holistic nature of TEK, it can be

applied to more than just salmon management. From local scale resource management to large scale societal organization, TEK is relevant. For example, in the *Umatilla River Vision*, they discuss moving from a commodified view of resource management to a usufruct and stewardship approach [56]. They are careful to mention that replacing the current US economic system may not be feasible or even desirable, but they maintain that colonial systems have something to learn from TEK [56].

The adaptive nature of TEK and the fact that it is a process as well as content, will be pertinent to the upcoming challenge of climate change. Each of my interviewees identified climate change as the most significant upcoming challenge for salmon management. Branstetter put the challenge into context, "A lot of the stuff that we're working on, trying to do, and that we've done to try to help salmon populations maybe just gets undone by climate change" [11]. For salmon in the Columbia River basin, the most important considerations regarding climate change are water temperature, water availability, and ocean conditions [8]. Salmon are cold water fish, so as river waters warm, it becomes more of a challenge for them to survive [8,17]. Additionally, a lowering snowpack means that rivers and tributaries will not have the same sustained flow level, making them more prone to warming in later months [8,41]. In early 2015, a drought event combined with abnormally warm water temperatures led to a loss of a huge percentage of the sockeye run in the Columbia basin [41,44]. As depicted in the earlier chart overlaying salmon runs with ocean conditions, the temperature of the ocean is a critical element to the strength of salmon runs [16,28]. Similar to rivers, warming ocean waters will have a detrimental effect on salmon [8,16].

Climate change is a global problem that cannot be resolved solely within the Columbia River basin, however, TEK can be used collaboratively with western science to address the effects of climate change in the Columbia. An integral way to look at TEK is that it is both content and a process [21]. As content it is information that can be transmitted from one person to another, but as a process it is a way of observing, understanding information, and making adaptive decisions [21]. Climate change is the type of problem that has no historical parallel, therefore information based on previous experience may not be so relevant. However, since TEK is also a way of thinking, it can be applied in this way to address the effects of climate change [21]. In addition, adaptive management is a basic principle of TEK, meaning that it is open to change and builds upon previous knowledge with direct observation [23]. As a management structure that is versatile, it is prepared to respond to a variety of ecological surprises [23]. Many of the effects of climate change will likely be unexpected and require a diligent response, to this end TEK can be significantly valuable.

Over the last 50 years, many steps forward have been taken in the co-management of salmon in the Columbia River basin. This has resulted in improvements in harvesting and habitats, as well as the management of hydropower facilities and hatcheries. Still the greatest challenge may be ahead – climate change. Implementing TEK practices to address present and future challenges is both just and beneficial.

## Limitations:

In a system as large and complex as the Columbia River basin, there are many stakeholders who I did not get a chance to speak to. Each of my interviews was immensely informative and helpful for my research. But additionally, each one provided novel information to me in a way that suggested that if I had continued interviewing other stakeholders, I would have gained other valuable information. I especially would have liked to have spoken with other tribal members to gain their perspectives. Just one of my six interviewees was a tribal member, in a paper so focused on Indigenous people and knowledge it would have been valuable to speak with more Indigenous people. Additionally, COVID-19 limited my research. I had initially planned to travel to the area to conduct research, and this proved to be too ambitious and difficult due to the COVID-19 pandemic.

## Conclusions

The salmon fisheries of the Columbia River basin are a complex and dynamic resource that have sustained the plants, animals, and humans of the area for millennia. Today, pacific salmon are facing several threats to their long-term sustainability. As a resource that is vital to its ecosystem and extremely important to the livelihoods and cultures of all users, it is crucial to ensure the success of salmon. Throughout the results and discussion section of this paper, I use literature review and first-person interviews to

explore two major themes: the context and status of salmon and co-management in the Columbia River basin today, and TEK's role in co-management.

Within the first theme I have found that the status of fish has improved from its lowest point, and today nearly all management agencies are united in their efforts to improve fish populations. Still, while improvements are gradually made with specific populations in specific places, overall, the total population has not increased much over 40 years. When compared to historical records, today's fish return numbers do not come close. Examining the context of US-Tribal co-management, I have found massive steps forward in tribes being included in river management in the last 50 years. Not only do the tribes have their co-management rights enforced through legal processes, but through my interviews I have found that current US managers value working with tribal members and think that tribal voices strengthen river management. Today, tribal members from all over the Columbia basin are heavily involved in management of salmon all over the PNW and work extensively with international, federal, state, and local agencies. At the same time, I have found that Columbia River basin fish are predominantly managed according to western science and economics. While TEK is still used for spiritual practices and influences some Tribal Nation's local management, it is not substantially used on larger scales in co-management.

In my exploration of TEK in the Columbia River basin, I found that, based in thousands of years of living harmoniously with the ecosystem, TEK co-evolved with the development of sustainable management systems of salmon. Through practices such as the First Salmon Ceremony, the Indigenous people of the PNW managed massive runs of

salmon for millennia. I then investigated methods of bridging TEK and western science in co-management, specifically through the case study of the beargrass restoration project in the Olympic Peninsula. This case study suggested potential for similar success in the Columbia River basin, and by examining the efforts of the CRITFC and the CTUIR I found that a framework for TEK re-incorporation had already been established. The First Foods approach of the CTUIR serves as a particularly intriguing framework, especially as they have had local success with this approach. I followed this by addressing the major obstacles to incorporating TEK, though at the same time I convey viable solutions to these obstacles.

Through these findings, I suggest that approaches to salmon management that are more grounded in Indigenous TEK can promote more resilient and sustainable salmon populations. Indigenous salmon management is based in generations of understanding the interconnection between fish, ecosystems, and humans. This understanding has promoted sustainable salmon fishing for centuries. Today, a growing body of evidence has demonstrated how re-incorporating TEK into resource management can be beneficial for restoration, management, and harvest [21,48]. By emulating the previously successful case studies and following the guidance of Tribal Nations and agencies, re-incorporating TEK can be done in a successful and just way.

The history of salmon fishing in the Columbia River basin serves as a compelling case study of a resource that was managed sustainably for centuries by Indigenous governance, and subsequently managed unsustainably by western governance. During this time, much has changed in the Columbia River basin; from physical transformations in the ecosystems and fish populations, to shifts in the very worldviews and societal structures

that predominate. Still, amid these deeply entrenched changes, a knowledge system built on over 9,000 years of salmon fishing persists. A growing body of literature suggests that reinvigorating this time-honored knowledge should be pursued to restore and maintain the health of the salmon. As recounted by Branstetter, “The old story is that we take care of the fish, and they will take care of us". Today, as new challenges approach, it is even more critical to promote TEK and listen to those who have been ‘Salmon People’ for generations. In doing so, salmon will remain at the heart of the cultures and ecosystems of the Columbia River basin for centuries to come.

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