Supplementation and Community Involvement as Drivers of Salmon Recovery: Summer Chum Salmon (Oncorhynchus keta) Populations in Union and Tahuya Rivers, Washington, United States

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SUPPLEMENTATION AND COMMUNITY INVOLVEMENT AS DRIVERS OF SALMON RECOVERY: SUMMER CHUM SALMON (Oncorhynchus keta) POPULATIONS IN UNION AND TAHUYA RIVERS, WASHINGTON, UNITED STATES

by

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A capstone report submitted in partial fulfillment of the requirements for the degree of

MASTER OF NATURAL RESOURCES

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ABSTRACT

Between the 1970s and late 1990s, Summer Chum salmon abundance in the Hood Canal basin declined significantly to the point the population was listed as “threatened” under the Endangered Species Act (1999), with multiple subpopulations extirpated. The Hood Canal Salmon Enhancement Group, in partnership with the Washington Department of Fish and Wildlife, developed and implemented a supplementation program to increase spawner abundance in the Union River so that supplementation could eventually take place in the Tahuya River, where Summer Chum had been extirpated. The program, which is only possible with intense volunteer efforts, reduced extinction risks for the Union River population while returning Summer Chum once again to the Tahuya River. Using von Bertalanffy growth models, contingency tables, and a linear regression model, this paper examines differences between supplemented and non-supplemented origin Summer Chum in terms of fork lengths, age class, and return timing. Results do not indicate significant differences in growth rates among populations, though populations demonstrate minor differences in age structure. Overall run timing results for the Union River population show no real change over the supplementation period. This paper also includes results from a survey of volunteers and their motivations for involvement in the effort, which include job training and giving back to the community and its natural resources. The economic benefits of a community-driven salmon recovery effort are also discussed. The Union/Tahuya River Supplementation Program can serve as a model to recover other salmonid populations while creating strong community buy-in and reducing operating costs.
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**GLOSSARY OF TERMS AND ACRONYMS**

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<tr>
<td>ALEA</td>
<td>Aquatic Lands Enhancement Account</td>
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<tr>
<td>ESA</td>
<td>Endangered Species Act</td>
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<td>ESU</td>
<td>Evolutionary Significant Unit</td>
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<tr>
<td>HCCC</td>
<td>Hood Canal Coordinating Council</td>
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<tr>
<td>HCSEG</td>
<td>Hood Canal Salmon Enhancement Group</td>
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<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NOR</td>
<td>Natural Origin Returner</td>
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<tr>
<td>NMFS</td>
<td>National Marine Fisheries Service</td>
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<tr>
<td>NWIFC</td>
<td>Northwest Indian Fisheries Commission</td>
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<tr>
<td>PIC</td>
<td>Pollution and Identification Correction</td>
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<tr>
<td>PNPTC</td>
<td>Point No Point Treaty Council</td>
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<td>SOR</td>
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<td>SRFB</td>
<td>Salmon Recovery Funding Board</td>
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<td>SRP</td>
<td>Summer Chum Salmon Recovery Plan</td>
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<td>VBGF</td>
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Introduction

For residents of the Pacific Northwest, salmon are of great importance. From marine-derived nutrients to recreational angling to ceremonial use among Washington tribes, salmon are one of the most important natural resources in the region (United States Fish and Wildlife Service, 2008). In 2011, it was estimated that nearly 1,000,000 individuals fished in Washington, equating to over 13 million days of effort and expenditures exceeding $1 billion (United States Fish and Wildlife Service, 2013). The same report noted a majority of effort and expenditures were related to salmon fishing. Unfortunately, a resource that was quite plentiful across all stocks has been dwindling over the last few decades due to numerous factors, such as poor water quality, hydroelectric development, and hatchery operations (Meador, 2014; Nickelson, 2003; Noakes, Beamish, & Kent, 2000).

As Washington’s population grew, more pressure was put on salmon fisheries. Between overfishing, loss of riparian and estuarine habitat, climate change, and hydroelectric development, stocks dwindled (Washington State Recreation and Conservation Office, 2010). Today’s returning salmon populations along the West Coast are just a tenth as large as they were a century ago, and it is estimated that more than 60% of those fish are of supplemented origin (Sims, 1994). Populations of some stocks, such as Columbia River Coho, have fallen so much that total closure of that marine fishery was seriously considered in 2016 (Mayor, 2016). Others, like Hood Canal Summer Chum, have been listed as threatened under the Endangered Species Act or have experienced extirpation (Ames, Graves, & Weller, 2000).
In this paper, I examine community-based supplementation efforts to recover threatened Summer Chum in Hood Canal, and the efficacy of this model for future salmon recovery efforts in the Northwest.

**Summer Chum Salmon**

Chum salmon (*Oncorhynchus keta*) are one of five types of Pacific salmon species, and have the widest geographic distribution among Pacific species. A distinct summer-run of Chum exists from the Yukon Basin in Alaska south to Washington. Summer Chum salmon are one of the most resilient salmonid species, having adapted to spawn when instream flows are at their lowest rate in the summer. The species is also the first to return to spawn, with most returning between August and mid-September (Sands et al., 2007; Tynan, 1997). After entering rivers, Summer Chum spawn quickly, building redds in the lowest three kilometers of rivers, a trait that may signal adaption to low river flows (Ames et al., 2000; Brewer, Watson, Christensen, & Brocksmith, 2005). Most alevin will emerge after four to five months in redds to immediately begin outmigration to estuarine waters, with fry often making the move in the same day (2005). Once Summer Chum fry reach a size of 45-50 mm, they will begin migrating from shallow estuarine waters to marine waters throughout Hood Canal (Ames et al., 2000; Brewer et al., 2005). Summer Chum will spend between two to four years in the Pacific Ocean before returning to spawn, with a majority of fish returning at three and four years old (Ames et al., 2000). Summer Chum have a higher rate of straying, which may be attributed to the quick out migration of fry after emergence, and thus a shorter imprinting period (Magneson, 2011). Given the unique life history of Summer Chum, stocks are susceptible to significant limiting factors, primarily climate change, low flows, flooding, exploitation as bycatch in net fisheries for Coho, and loss of
nearshore habitat and degradation of riparian habitat in the lower three kilometers of rivers (Brewer et al., 2005).

Chum salmon (*Oncorhynchus keta*), as well as Steelhead (*Oncorhynchus mykiss*), Chinook (*Oncorhynchus tshawytscha*), Coho (*Oncorhynchus kisutch*), Pink (*Oncorhynchus gorbuscha*), and Sockeye (*Oncorhynchus nerka*) naturally occupy Hood Canal, a large glacial fjord and sub-basin of the greater Puget Sound fed by numerous streams that originate in the Olympic Mountains or heavily forested upland areas (Biedenweg, et al., 2014). Kassler and Shaklee (2003), found that Summer Chum in Hood Canal are closely related to Strait of Juan de Fuca Summer Chum, and that both were genetically distinct from Puget Sound summer and Fall Chum populations, Fall Chum in Canada, and Chum in Sinclair Inlet, Washington (Sands et al., 2007). Summer Chum populations in Hood Canal were once strong, with runs of more than 27,000 fish in 1976. Returns declined rapidly throughout the 1980s and 1990s with escapements of less than 1,000 fish in 1989 and 1990 (Ames et al., 2000).

Declines in Summer Chum abundance have been attributed to a number of factors, most notably the loss of estuarine habitat, and overharvest as bycatch in terminal and pre-terminal Coho, Pink, Sockeye, Chinook, and marine mixed stock commercial fisheries (Brewer et al., 2005). Summer Chum in the Hood Canal have a run timing overlapping primarily with Chinook and Coho fisheries. Prior to regulation changes that limited the commercial Coho harvest, Summer Chum had a mean exploitation rate of 71% throughout the 1980s, and at one point, exceeded 90% in part of Hood Canal (Johnson, Grant, Kope, Neely, Waknitz, & Waples, 1997).
To limit the exploitation rate, WDFW began limiting commercial Coho fisheries in Hood Canal, and the immediate result was a mean exploitation rate of just 2.5% (1997).

Following initial declines throughout the 1980s and early 1990s, multiple petitions were submitted to the National Marine Fisheries Service (NMFS) to list Hood Canal Summer Chum under the Endangered Species Act (ESA) (Johnson et al., 1997). Petitioning parties included Professional Resource Organization – Salmon (PRO-Salmon) and the Northwest Chapter of Trout Unlimited (TU). Both petitions argued that Hood Canal Summer Chum populations were genetically isolated from other summer and Fall Chum stocks, and spawned at significantly different times. Furthermore, the petitions identified overharvest and habitat loss as the primary factors for decline, including channelization, timber harvest, and shoreline armoring. In requesting that Hood Canal Summer Chum be given evolutionary significant unit (ESU) designation, petitioners argued that, “…various runs of Summer Chum salmon are part of a unique race of Chum salmon that has adapted to a specific niche in Hood Canal” (Trout Unlimited, 1994). An ESU can be defined in many ways, but according to Waples (1991), an ESU is, “A population or group of populations that…is substantially reproductively isolated from other conspecific population units, and represents an important component of the evolutionary legacy of the species.” Sands et al. (2007) concluded that 21 spawning aggregations of Summer Chum existed in Hood Canal, with 10 of those recently extirpated. Following the two petitions for listing, the NMFS carried out a status review of Summer Chum, which was completed in 1997 (Johnson et al., 1997).
In 1999, after continued declines in spawner abundance, Hood Canal Summer Chum were identified as an ESU (Figure 4) and were subsequently listed as a “threatened” species under the ESA (Adicks, Ames, & Johnson, 2007). Under the Endangered Species Act (1973), a “threatened” designation is meant to protect “any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.” The NMFS, in its status review, concluded Hood Canal Summer Chum were at risk of extinction. The Hood Canal Coordinating Council, a regional agency tasked with managing salmon recovery efforts in Hood Canal among co-managers, submitted the Hood Canal Summer Chum Recovery Plan (SRP) in 2005 to NFMS, which formally adopted the plan in 2007 (Hood Canal Coordinating Council, 2005). The SRP covers needs, goals, and recommendations for habitat restoration and regional policy, but also includes the co-managers (Federal, state, and tribal fisheries managers) criteria for recovery in terms of abundance. As a whole, the requirements for recovery in the Hood Canal ESU are as follows:

All six extant natural stocks (as of 2003) must meet all individual stock recovery criteria as outlined in the SRP. On average, abundance ESU-wide must meet or exceed the summer of individual stock thresholds. Natural escapement must meet or exceed the summer of individual stock escapement thresholds. ESU-wide natural productivity must meet or exceed 1.6 recruits per spawner (Brewer et al., 2005, p 18).

For subpopulations within the ESU, a series of criteria must be met, which include:

The mean natural origin abundance and spawning escapement shall meet or exceed the thresholds as outlined in the SRP over the most recent 12-year period. The natural origin abundance and escapements of each stock must be lower than the respective stock’s
critical threshold in no more than 2 of the most recent 8 years, and no more than 1 of the most recent 4 years. Natural recruits-per-spawner shall average at least 1.6 over the most 8 recent brood years for which estimates exist, and no more than 2 of the 8 years shall fall below 1.2 recruits per spawner (2005, p 18).

Figure 1. The Hood Canal Summer Chum evolutionary significant unit (ESU) stretches throughout Hood Canal and into the Strait of Juan de Fuca.
This project focuses on the Union and Tahuya Rivers, where the recovery escapement threshold is 340 natural-origin fish, the abundance threshold is 550 and the critical abundance threshold is 340 (2005, p 212; Figure 3). Natural-origin fish can be defined as summer chum produced by wild fish “spawning and rearing in the natural habitat, regardless of parentage,” whereas supplemented-origin fish can be defined as those spawned and reared in a hatchery (Washington Department of Fish and Wildlife, 2017).

Watershed Profiles of the Union and Tahuya Rivers

The Union River watershed originates from a spring in the Blue Hills, some 457 meters above Hood Canal, making its way through mostly undeveloped lowland hills before being impounded by Casad Dam, which supplies more than 60% of the City of Bremerton’s drinking water supply (Williams, Laramie, & Ames, 1975). The river above Casad Dam is relatively protected by the City of Bremerton for its water supply, though limited logging has been taking place in the upper watershed in recent years (Farley, 2014). Below the reservoir, the river runs through McKenna Falls, a natural barrier to salmon migration, and transitions into a low-gradient stream surrounded by a mix of coniferous and deciduous trees, primarily willow (Salix), red cedar (Juniperus virginiana), and maple trees (Acer) (Hood Canal Coordinating Council, 1999). In contrast to its upper reaches, the lower Union River is heavily developed and flows through dense residential and farmland areas (1999). The river meets Hood Canal just outside of Belfair, an urban growth area at the lower end of Hood Canal. In total, the watershed covers 62 sq. kilometers, with the river and its tributaries flowing more than 48 kilometers (1999).

Summer Chum escapement in the Union River has historically been low, but experienced sever declines in the early 1980s (Figure 2). Many factors have contributed to Summer Chum
declines in the Union River (1999; Lestelle, Blair, & Mobrand, 2005, including road crossings, levees, residential development, farming, water diversion, and faulty septic systems, among other things. Habitat degradation has led to the listing of the Union River as an impaired water body on the 303(d) List for dissolved oxygen, high temperatures, pH, bacteria, and ammonia (Department of Ecology, n.d.). Recent analysis and monitoring from Kitsap County Public Health notes that both short-term and long-term water quality in the river is stationary (Kitsap Public Health District, 2014).

In addition to Summer Chum, the Union River has populations of fall Chinook, Fall Chum, Coho, and Pink salmon, along with winter Steelhead, sea-run cutthroat trout (Oncorhynchus clarkii clarkii), and white sturgeon (Acipenser transmontanus) (Washington Department of Fish & Wildlife, n.d.).

The Tahuya River is the largest watershed in lower Hood Canal, with the main stem river running over 33 kilometers and tributaries making up an additional 77 kilometers (Bernthal & Rot, 2001). The Tahuya River is born just above Lake Tahuya on the Kitsap Peninsula, a dammed, private lake. Like the Union River, the Tahuya River is a moderate to low-gradient stream comprised of coniferous-dominated second-growth forests (Williams et al., 1975). Many small tributaries flow into the Tahuya River, though a majority of these dry up in the summer and winter (Hood Coordinating Council, n.d.). The watershed’s land use is primarily state and private forestland, with Tahuya State Forest surrounding much of the watershed. In addition to timber harvest, moderate rural development and agriculture activities currently take place (Hood Coordinating Council, n.d.; Bernthal & Rot, 2001). The lower river includes numerous wetlands
and beaver activity has created ponds, providing valuable rearing habitat for salmonids, primarily Coho salmon.

Salmon populations on the Tahuya River have faced declines due to numerous factors (Figure 1). Intensive shoreline development, timber harvest, a causeway, and a lack of large woody debris are just a few habitat issues within the watershed (Hood Canal Coordinating Council, n.d.). Within Tahuya State Forest lies an incredibly popular off-road vehicle area, which has also caused habitat issues. In 2013, a landowner attempted to alter the course of the Tahuya River to avoid potential flooding, impacting over 4,000 square meters of the river’s bed during the time in which threatened winter Steelhead spawn and occupy the river. The Tahuya River is listed as an impaired water body on the 303(d) List for bacteria, dissolved oxygen, temperature, ammonia, and pH (Department of Ecology State of Washington, n.d.) Recent analysis and monitoring from Kitsap County Public Health notes that while short-term water quality is stationary in the river, long-term water quality is worsening (Kitsap Public Health District, 2014).

In addition to Chum, the Tahuya River supports populations of Chinook and Coho salmon, along with Steelhead and sea-run cutthroat trout (Washington Department of Fish & Wildlife, n.d.).
Figure 1. Summer Chum escapement from 1974-2015 in the Tahuya River. Summer Chum populations declined rapidly in the 1990s to the point that the stock had been classified as “recently extirpated,” before supplementation efforts began in 2004. Retrieved from (Washington Department of Fish and Wildlife, 2013).

Figure 2. Summer Chum escapement from 1974-2015 in the Union River. Unlike other Hood Canal streams, Summer Chum in the Union River remained relatively stable prior to supplementation, which began in 2000 (2013).
Supplementation Background

There are many actions being taken in Washington to recover salmon populations, including habitat restoration, dam removal, and hatchery propagation (Washington State Recreation and Conservation Office, 2010). Historically, hatcheries have been utilized with the primary goal of producing fish for harvest, either to replace extirpated stocks, or to create a fishery where the wild stock is not harvestable (United States Fish and Wildlife Service, 2008). Often, hatchery programs are based on non-local broodstock (Krikeals & Ford, 2014). More recently, though, fisheries managers have developed supplementation programs, which differ from conventional hatcheries in that they utilize local broodstock with the overall goals of retaining some genetic diversity, breeding salmon that can survive and spawn in a natural environment, and intentionally stocking hatchery fish to spawn with natural-origin fish (Johnson, 2004). As the naturally-reproducing stock rebounds, programs are phased out. Supplementary
programs have the ability to reduce short-term extinction risk and rapidly stabilize recovering stocks (Trushenski, Flagg, & Kohler, 2010).

There is a deep history of supplementation and artificial propagation operations targeting Summer Chum in Puget Sound and Hood Canal. In Hood Canal, Summer Chum rearing operations started in 1911 on the Duckabush River, and in 1912 at the Quilcene National Fish Hatchery. However, both programs had ended by the 1940s (Johnson et al., 1997). Other smaller programs took place at varying times throughout the late 1900s, but 1992 marked the return of large-scale supplementation programs to Hood Canal for Summer Chum as a response to ongoing declines (Cook-Tabor, 1995). In southern Puget Sound, other supplementation programs came online in the mid to late 1900s. In 1976, the State of Washington and Squaxin Indian Tribe collaborated on supplementation programs to boost Summer Chum populations in Hammersley and Case inlets in Mason County (Ames & Adicks, 2003). Now, more than 20 Endangered Species Act-listed salmon stocks in Washington are part of supplementation programs (Washington Department of Fish and Wildlife, 2010). As traditional hatchery programs come under increased scrutiny for their impacts on genetics and fish with relatively lower fitness, supplementation, paired with other actions such as habitat restoration, may present a popular and viable path forward to aid depressed stocks of salmon, including Hood Canal Summer Chum (Gaston, n.d.).

Though managers utilize supplementation as a method for salmon recovery while minimizing declines in genetic diversity, there are concerns specific to straying (Small, Currens, Johnson, Frye, & Von Bargen, 2009). With increases in abundance of supplemented Summer Chum, expected strays may also increase, causing concern related to carrying capacity of certain
tributaries (Small et al., 2009). Past studies have shown that about 12% of supplemented adult Summer Chum have strayed to non-supplemented streams in Hood Canal (Small et al., 2009).

**Project Background**

To help reverse declines in populations of Summer Chum in Hood Canal, the Hood Canal Salmon Enhancement Group (HCSEG), in partnership with the Washington Department of Fish and Wildlife (WDFW), proposed a supplementation program to boost the Union River population while eventually working to reintroduce Summer Chum in the nearby Tahuya River, a river in which Summer Chum had been recently extirpated (Figure 5). The Union River was chosen for a donor stock due to its geographic proximity to the Tahuya River and genetic similarities (National Marine Fisheries Service, 2000).

The HCSEG installed a weir on the Union River in 2000 to collect data on adult escapement while also trapping a portion of returning fish for artificial propagation. Eggs and milt were collected and transported to George Adams Hatchery, a state facility where matrix spawning took place and eggs are incubated to the eyed stage (National Marine Fisheries Service, 2000). To identify the eggs as supplemented-origin, the eggs underwent otolith thermal marking, a process which helps managers identify a fish at any life stage (Volk and Hagen, 2001). Eyed eggs were then transferred to remote-site incubators along the Union River to develop and acclimate to the river. As the fish developed to fry, they were then reared in a raceway and fed until reaching one gram in weight (Johnson and Weller, 2003).
The goal of the project was to supplement the Union River to build a donor stock to revitalize the Tahuya River stock. Supplementation goals for the Union River were met in 2003 and fish releases in the Tahuya River began in 2004 (Johnson, Adicks, Weller, & Tynan, 2008). Broodstock collection efforts on the Union River continued through 2014, with the last fry release into the Tahuya River taking place in early 2015 (Hood Canal Salmon Enhancement Group, 2017).

This project is unique with regard to community involvement. Local volunteers monitor the Union River weir non-stop from August 15th to October 15th each year. While
supplementation was taking place, volunteers also assisted with egg and milt collection, fish feeding, and carcass surveys. This project has become a model for community-based salmon recovery efforts while providing opportunities for community members to give back to help salmon, socialize with friends and other family members, raise awareness in the community about the importance of Summer Chum, and job training.

**Goals of the Study**

The goal of my capstone study is to determine the success of supplementation efforts on the Union and Tahuya rivers in Hood Canal by examining and analyzing changes in the population, including fork lengths and growth rates, age structure, and escapement, potentially as a function of supplementation efforts. My capstone also examines community-based salmon recovery as a model for other projects by learning more about volunteers who participate in the supplementation program. Lastly, my study examines economic impacts, along with habitat restoration and policy efforts that also have played a role in recovering Summer Chum populations in both the Union and Tahuya rivers.

**Ecology and Quantitative Analysis Objectives.** The Hood Canal Summer Chum ESU was listed as threatened under the Endangered Species Act in 1999. Since then, a multitude of agencies, tribes and organizations have worked to recover Summer Chum populations. My study examines populations specifically on the Union and Tahuya rivers within the Hood Canal basin. Data has been analyzed to better understand how supplementation efforts have impacted age structure, run size, and run timing. Results of otolith analysis by the Washington Department of Fish and Wildlife are also discussed to understand the proportion of returning Summer Chum that are of natural origin, as opposed to supplemented origin (Barnett-Johnson, Pearson, Ramos,
Grimes, & MacFarlane, 2008). A discussion has also been included examining genetic diversity and changes throughout supplementation efforts.

Further, my study offers a brief examination of past restoration efforts that have occurred in the Union and Tahuya rivers throughout the supplementation phase, as well as a discussion on habitat issues that still exist in the rivers which may limit the success of Summer Chum populations.

**Human Dimensions Objectives.** I have analyzed qualitative and quantitative data regarding volunteer participation and motivations for the Hood Canal Salmon Enhancement Group’s volunteers that assist in Summer Chum recovery activities on the Union and Tahuya rivers, from collecting escapement data and carcass sampling to fish feeding. Volunteers are crucial to the success of the Union/Tahuya Summer Chum Project, and building a better understanding of motivators can lead to the creation and successful implementation of similar projects in other watersheds. Further, gaining a better understanding of what type of experience volunteers get and can help assign value to the role of communities in salmon recovery.

**Economic Objectives.** Summer Chum are not a valuable species of fish for commercial fishers, and are generally not intentionally targeted but rather incidentally caught as part of Coho and Sockeye harvest (Magneson, 2011). However, in Alaska, Summer Chum have become an important species for commercial harvest (United States Fish and Wildlife Service, 2009). Aside from harvest value, I have examined the economic benefits of community involvement. Part of the appeal of the Union/Tahuya Summer Chum Project is its low-cost method of salmon recovery, utilizing remote-site incubation sites, volunteers and interns to perform nearly all
associated tasks, as opposed to efforts involving more paid staff and traditional facilities, such as a hatchery.

**Policy Objectives.** My study identifies and discusses relevant policies and regulations that affect Summer Chum recovery in Hood Canal. This component includes a discussion of funding mechanisms, political partnerships, and state legislation affecting Summer Chum habitat. This component also addresses policy and programmatic goals identified in the SRP, such as reducing shoreline armoring through incentives, social marketing approaches, and regulation. A discussion on future needs and risks is also included as discussions on de-listing of Summer Chum begin.

**Literature Review**

Over the last decade, numerous studies have been done assessing the impacts of hatcheries and/or supplementation on salmonid stocks. Specifically, research has focused on genetic impacts, fitness levels, survival, age-structure, and fork lengths. Ford et al. (2006) examined, among other things, changes in fork lengths and mean spawning time among supplemented- and natural-origin Coho in Minter Creek, Washington, a stream that had been heavily supplemented for decades. Natural- and supplemented-origin fish were not significantly different in terms of fork lengths, which was more driven by sex and year. Supplemented-origin fish returned slightly earlier than natural-origin fish, though that is a result of sex, origin, and year. Overall, Minter Creek Coho were found to be returning more than a month earlier than previously observed. Supplemented-origin fish in the study were not significantly different than natural-origin fish in terms of spawning success and offspring production.
Ames and Adicks (2003) examined the success of supplementation efforts on Summer Chum stocks in southern Puget Sound. While supplementation alone did not return the populations to sustainability, efforts successfully decreased extinction risk and provided adequate escapement to ensure supplemented stocks could produce offspring following supplementation to be self-sustaining. Similarly, Adicks et al. (2007) studied supplementation efforts in Hood Canal and found that enhancement programs successfully reduced extinction risk of many stocks and also resulted in significant returns of supplemented and natural-origin fish. On the Union River specifically, extinction risk was lowered from moderate to low following the supplementation program. Further, recovery goals for the Union River stock in terms of escapement and abundance have been surpassed. They also found that reintroduction programs have been successful, restoring Summer Chum populations to streams where Summer Chum had been extirpated for over 10 years.

Johnson et al. (2008) expanded upon previous research on successes of supplementation in Hood Canal, concluding that enhancement programs were resulting in reduced extinction risk and increased escapement. On the Union River specifically, the recovery threshold of 550 returning adults was surpassed each year following supplementation efforts. Small et al. (2009) carried out research that represented the first dedicated effort to understand the interaction between supplementation of Summer Chum in Hood Canal and genetic diversity among baseline and supplemented populations. Utilizing allele frequencies, researchers separated Hood Canal and Strait of Juan de Fuca Summer Chum into four groups. Their results suggested most supplemented populations hadn’t experienced negative effects to genetic diversity. Small, Johnson, Bowman, & Martinez (2014) built on these previous findings, examining the impact of
supplementation on genetic diversity of Hood Canal Summer Chum. Overall, results showed supplementation had very little impact on genetic diversity, though genetic distances decreased among some supplemented streams. Specific to the Union River, genetic diversity increased from 2000 to 2008 slightly, and samples of supplemented- and natural-origin fish from 2000, 2003, 2004, and 2008 remained closely related to one another.

Dahl, Pettersson, Dannewitz, Jarvi, & Lof (2006) studied survival and growth among supplemented-origin, natural-origin, and hybrid anadromous brown trout and found no significant differences in survival and growth between each group. Further, offspring of supplemented and hybrid trout had equal fitness compared to offspring of natural-origin trout. Egg sizes among supplemented-origin and natural-origin trout were also analyzed, and no difference was found.

Berejikian, Scheurer, Bush, & Van Doornik (2009) studied relative reproductive success among supplemented-origin and natural-origin Summer Chum on Big Beef Creek, Washington. Results indicated no reduced reproductive performance among supplemented fish in comparison to natural-origin fish. They concluded Hood Canal Summer Chum recovery partners “should reasonably expect” that supplemented-origin fish have a sufficient reproductive success rate to aid in recovering and rebuilding depressed or extirpated stocks, in conjunction with other fisheries management tools, such as habitat restoration and harvest reduction. In regards to age structure, researchers found that natural origin fish returned to spawn at a slightly greater age throughout the study.
The Washington Department of Fish and Wildlife and Point No Point Treaty Tribes (2007) compared mean fork lengths of supplemented and natural-origin Summer Chum in Hood Canal (Figure 6). Length data was collected on the Union River from 2000 (the beginning of supplementation efforts) to 2004. WDFW data suggested that supplemented-origin fish were slightly larger in fork length than natural-origin fish across both sexes, with the lone exception of four-year old natural-origin males, larger than their supplemented counterpart.

![Figure 6](image-url). Mean fork lengths and 95% confidence intervals for Summer Chum returning to the Union River between 2000 and 2004. Plot retrieved from Washington Department of Fish and Wildlife and Point No Point Treaty Tribes (2007).
Methods

Data Collection

Over the last 16 years, staff from WDFW and HCSEG, along with volunteers, have collected data for this project. Utilizing a weir on the Union River, which is operated 24/7 between August 15th and October 15th, escapement data is collected by capturing all returning salmon. Volunteers determine the species and sex of each fish before releasing all fish upstream to spawn. Escapement estimates for the Tahuya River have been derived from area-under-the-curve (AUC) estimates (Johnson et al., 1997). WDFW describes AUC estimates as a method where, “live Chum observations (are) collected through the season in each index are plotted on a graph, and a line is fit by eye through the counts. The area described under the curve is calculated (fish x days), and this value is divided by the assumed average residence time of the fish on the spawning grounds (usually 10 days) to derive an estimate of total spawner abundance in the surveyed reach (Washington Department of Fish and Wildlife, n.d.; Millar, McKechnie, Jordan, & Hilborn, 2012).

The HCSEG and WDFW staff also conduct carcass surveys on both the Union and Tahuya rivers, with the goal of collecting length and condition information for at least 150 fish in each river, and 100 otolith samples in each stream (C. David, personal communication, November 5, 2017). For each carcass found, staff determine sex through observation of the mouth, measure fork length, collect scales for genetic monitoring and age structure analysis, extract the otolith to check for thermal marking from a hatchery, and are categorized by condition for the purposes of estimating total escapement. Based on the samples collected, the
data is extrapolated to estimate the escapement proportion of natural-origin fish and supplemented-origin fish.

Data for this report was gathered from WDFW and HCSEG. In total, 4,272 carcass samples have been completed on the Union and Tahuya rivers. A number of surveys have incomplete data, missing either fork length measurements, age structure, otolith mark status, or sex. Limited data organization has taken place. Fork lengths have all been converted to centimeters. Otolith mark status originally were coded as 0 (natural-origin), 1 (supplemented-origin), and 999 (failed otolith extraction or lost sample), but have been recoded to change 999 observations to “n/a.” Further, a handful of observations were assumed to be incorrect, such as an 11.11 cm fork length, which would more characteristic of a Summer Chum smolt, which would not be present during spawning and thus were marked as “n/a.” Outliers were identified and removed using Tukey’s interquartile range method (Tukey, 1977). Utilizing Tukey’s rule, fork lengths above 83 cm and below 51 cm were considered outliers and were removed.

**Fork Lengths: Methodology and Results**

A primary component of my study is to determine the effect supplementation has had on Summer Chum lengths in the Union and Tahuya rivers. Chen, Jackson, and Harvey (2011) compared the accuracy of von Bertalanffy and polynomial growth functions, and found that the von Bertalanffy growth function (VBGF) was the most accurate model for all tested populations in estimating length-at-age values for 16 freshwater fishes.

To compare fork lengths (FL) and growth rates among four populations (supplemented-origin male, natural-origin male, supplemented-origin female, natural-origin female), a VBGF
was fitted to age-at-length data for each population using Beverton and Holt’s (1957) parameterization: 

\[ L_t = L_\infty \left[ 1 - e^{-k(t-t_0)} \right] \]

where \( L_t \) represents length at age \( t \) (years), \( L_\infty \) represents the asymptotic length, \( k \) represents the rate at which fish reach \( L_\infty \), and \( t_0 \) is the theoretical age at which the fish would have a length of 0 cm (Allen & Hightower, 2010). Initial estimates for the starting parameters were as follows for each population: \( L_\infty = 75 \text{ cm}, k = 0.3, t_0 = -0.4 \). Using the Fisheries Stock Assessment package in R (Ogle, 2017), the nonlinear least-squares estimate was determined for each parameter for each population, providing actual values for use in the von Bertalanffy models (Ogle, 2015). From these values, model predictions were made for each age class (0 to 5) and 95% confidence intervals.

The VBGF between natural- and supplemented-origin fish do not appear to differ significantly (Figure 7). All populations (male and female; supplemented and natural origin) appear to be similar in size at age two, then begin to diverge. Male fish prior to age two grow at slightly different rates, but both populations appear to match one another at age three through age five (Figures 8,9). For females, Tables 3 and 4 demonstrate that supplemented origin fish appear to grow at a slightly faster rate \( (k = 0.734) \) than natural origin fish \( (k = 0.429) \), but both of these populations equal out at age four through age five (Figures 10, 11). One possible explanation for the difference in growth rates between female and male Summer Chum is how energy is allocated for growth. In this study, females are likely allocating a significant amount of their energy towards gonad growth and egg development, while males are putting energy towards developing reproductive traits, such as a kype (Allen & Hightower, 2010; Enberg, Dunlop, & Jorgenson, 2008). As shown in Tables 1 and 2, supplemented-origin male fish have a similar growth rate \( (k = 1.155) \) to that of natural-origin fish \( (k = 1.107) \). Both male populations are also
similar in asymptotic length (for supplemented-origin fish, $L_{inf} = 74.002$ cm; for natural-origin fish, $L_{inf} = 74.074$ cm).

Overall, these models show supplementation has had little impact in fork lengths and growth patterns. Due to a lack of age data on fish younger than 2, however, these models for younger-age fish should be interpreted with caution.

*Figure 7. Von Bertalanffy growth function by origin and sex.*
Figure 8. Von Bertalanffy growth function for natural origin males.

Figure 9. Von Bertalanffy growth function for supplemented origin males.
Figure 10. Von Bertalanffy growth function for natural origin female.

Figure 11. Von Bertalanffy growth function for supplemented origin females.
Table 1.
*Von Bertalanffy Parameter Estimates Natural-Origin Male (n = 809)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>2.5%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>(L_{\text{inf}})</td>
<td>74.074 cm</td>
<td>72.661 cm</td>
<td>75.487 cm</td>
</tr>
<tr>
<td>(k)</td>
<td>1.107</td>
<td>0.848</td>
<td>1.366</td>
</tr>
<tr>
<td>(t_0)</td>
<td>0.641</td>
<td>0.306</td>
<td>0.976</td>
</tr>
</tbody>
</table>

Table 2.
*Von Bertalanffy Parameter Estimates Supplemented Origin Male (n = 578)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>2.5%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>(L_{\text{inf}})</td>
<td>74.002 cm</td>
<td>72.246</td>
<td>75.758</td>
</tr>
<tr>
<td>(k)</td>
<td>1.155</td>
<td>0.703</td>
<td>1.607</td>
</tr>
<tr>
<td>(t_0)</td>
<td>0.5777</td>
<td>-0.091</td>
<td>1.247</td>
</tr>
</tbody>
</table>

Table 3.
*Von Bertalanffy Parameter Estimates Natural-Origin Female (n = 818)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>2.5%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>(L_{\text{inf}})</td>
<td>72.680 cm</td>
<td>64.235</td>
<td>81.124</td>
</tr>
<tr>
<td>(k)</td>
<td>0.429</td>
<td>0.008</td>
<td>0.851</td>
</tr>
<tr>
<td>(t_0)</td>
<td>-1.599</td>
<td>-4.445</td>
<td>1.247</td>
</tr>
</tbody>
</table>
Table 4.  
*Von Bertalanffy Parameter Estimates Supplemented Origin Female (n = 594)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>2.5%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L_{\infty}$</td>
<td>68.860 cm</td>
<td>64.834</td>
<td>72.887</td>
</tr>
<tr>
<td>$k$</td>
<td>0.734</td>
<td>-0.023</td>
<td>1.493</td>
</tr>
<tr>
<td>$t_0$</td>
<td>-0.552</td>
<td>-3.256</td>
<td>2.150</td>
</tr>
</tbody>
</table>

**Age Structure: Methodology and Results**

Another primary objective of my study was to examine how supplementation has impacted age structure in the Union and Tahuya rivers. To compare the age class distributions of natural origin and supplemented origin salmon, I created a contingency table for both observed and expected values using the “gmodels” package in R statistical package (R Core Team, 2013; Warnes, Bolker, Lumley, & Johnson, 2015). Expected values were calculated by multiplying row and column totals and dividing by $n$. The null hypothesis is that both groups are not significantly different in terms of age structure. The alternative hypothesis is that both groups are significantly different.

The results in Table 5 show that the distribution of age classes among both supplemented and natural-origin fish are moderately similar. Row and column totals demonstrate that a majority of fish in both populations return as 3-year fish, followed by 4-year fish. However, the proportion of fish that return as 3-year fish is nearly 10% higher for supplemented-origin fish. Similarly, the proportion of 4-year natural-origin fish is more than 6% higher than supplemented...
origin fish. The results also indicate a slightly higher number of natural-origin fish return as 2-year fish (2.5%) compared to just 0.9% for supplemented-origin fish.

To test whether there were any significant differences between mark status and age, I performed a Pearson chi-square test (Tang, He, & Tu, 2012).

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

The results, $$\chi^2 (3, n = 2,999) = 29.57, p < .05$$, suggest that mark status does not significantly influence age structure.

**Table 5.**
*Observed and Expected Ages of Return for Natural-Origin (NOR) and Supplemented-Origin (SOR) fish (N = 2,999)*

<table>
<thead>
<tr>
<th>Age</th>
<th>NOR</th>
<th>SOR</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Observed</td>
<td>Expected</td>
<td>Row Total (%)</td>
</tr>
<tr>
<td>2</td>
<td>44.0</td>
<td>32.0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>11.0</td>
<td>23.0</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>1183.0</td>
<td>1243.0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>953.0</td>
<td>893.0</td>
<td>44.6</td>
</tr>
<tr>
<td>4</td>
<td>502.0</td>
<td>454.0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>279.0</td>
<td>327.0</td>
<td>35.7</td>
</tr>
<tr>
<td>5</td>
<td>16.0</td>
<td>16.0</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>11.0</td>
<td>11.0</td>
<td>40.7</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Total</td>
<td>1745.0</td>
<td>1254.0</td>
<td>58.2</td>
</tr>
</tbody>
</table>
Mean Run Timing: Methodology and Results

Another primary component of my research is to determine if the mean return date (defined as days after August 14th – the first trap day historically) has changed over the years as supplemented fish were added to the river. Analysis was performed solely on Union River samples (n=36,822), since it’s the only stream with a weir. Volunteers are not able to identify a supplemented fish as different from a natural-origin fish due to the otolith mark being the indicator (Volk and Hagen, 2001); however, data is still collected on the timing of the fish run in addition to the total number of fish that return annually to spawn. As Table 5 shows, we have observed no fish return before reaching age two, so an assumption can be made that 2002 would be the first year with supplemented fish. The age structure data also indicates the maximum age is five, so an assumption can be made that no fish of supplemented origin returned after 2008, five years after supplementation efforts ended on the Union River.

A mean return date was determined for each year based on the data collected by volunteers (Table 6). Overall, the mean return date from 2000 to 2015 on the Union River was day 26.56, or approximately September 10th, and the mean return date has trended slightly earlier. To test the effect of trap year on the average return date, a linear regression model was created to examine the relationship between mean return date and year (Figure 12; Table 7).
Figure 12. Boxplot demonstrating means and observations relating to return timing of summer Chum to the Union River.

Table 6
Mean Return Date by Year

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean Day Trapped</th>
<th>Date</th>
<th>Year</th>
<th>Mean Day Trapped</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>25.90</td>
<td>September 9</td>
<td>2008</td>
<td>27.04</td>
<td>September 10</td>
</tr>
<tr>
<td>2001</td>
<td>27.95</td>
<td>September 11</td>
<td>2009</td>
<td>22.90</td>
<td>September 6</td>
</tr>
<tr>
<td>2002</td>
<td>31.96</td>
<td>September 15</td>
<td>2010</td>
<td>24.37</td>
<td>September 7</td>
</tr>
<tr>
<td>2003</td>
<td>26.04</td>
<td>September 9</td>
<td>2011</td>
<td>23.52</td>
<td>September 7</td>
</tr>
<tr>
<td>2004</td>
<td>29.95</td>
<td>September 13</td>
<td>2012</td>
<td>24.94</td>
<td>September 8</td>
</tr>
<tr>
<td>2005</td>
<td>29.48</td>
<td>September 12</td>
<td>2013</td>
<td>25.76</td>
<td>September 9</td>
</tr>
<tr>
<td>2006</td>
<td>28.21</td>
<td>September 11</td>
<td>2014</td>
<td>26.93</td>
<td>September 10</td>
</tr>
<tr>
<td>2007</td>
<td>17.96</td>
<td>September 1</td>
<td>2015</td>
<td>22.92</td>
<td>September 6</td>
</tr>
</tbody>
</table>
The results of the regression analysis (Table 7) suggest that Summer Chum are returning slightly earlier as each year passes (0.3 days earlier), but not to the point of statistical significance \((p < 0.05)\). However, 2007 appears to play a larger role in the decline of the mean return date (Table 8).

### Table 7
*Regression Analyses for Mean Return Date as Dependent Variable (\(n = 15\))*

<table>
<thead>
<tr>
<th>Variable</th>
<th>(\beta)</th>
<th>SE</th>
<th>(t)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>657.6711</td>
<td>337.0785</td>
<td>1.951</td>
<td>0.0714</td>
</tr>
<tr>
<td>Year</td>
<td>-0.3147</td>
<td>0.1679</td>
<td>-1.874</td>
<td>0.0820</td>
</tr>
<tr>
<td>(R^2)</td>
<td></td>
<td></td>
<td>0.1434</td>
<td></td>
</tr>
<tr>
<td>(F)</td>
<td></td>
<td></td>
<td>3.512</td>
<td></td>
</tr>
</tbody>
</table>

*Note. * \(p < .05\) (two-tailed). ** \(p < .01\) (two-tailed).*

When excluding data from 2007, the model was statistically significant \((R^2 = 0.4347, F(1, 13) = 9.997, p < 0.01)\), explaining an additional 24.78% of the variance in mean return date. The effect of year remains similar, though, with fish returning about a third of a day earlier annually. I performed additional analysis to examine trends prior to and after 2007. Prior to 2007, the mean
return date was trending later, but that relationship was not significant. Following 2007, the mean return date appeared to decline slightly, but that result was also not significant. Overall, the annual distribution of spawn timing is fairly similar (Figure 13).

Figure 13. Annual histograms representing the mean return date of Summer Chum to the Union River. Differences between years appear very minimal, with the peak of the run occurring by day 30 or earlier.
Community Involvement

Limited research has been done in determining motivators for volunteers to become involved in habitat and/or fisheries restoration. Copeland, Baker, Koehn, Morris, & Cowx (2017) examined motivators for recreational anglers to become involved in fish and habitat restoration projects. The major motivator among survey respondents was to “put something back into their sport.” In terms of benefits, helping fish was the top response, along with being outside and social obligation. Ryan, Kaplan, & Grese (2001) argued that natural resource stewardship projects are very different than other environmental volunteer opportunities in that participants are able to see the impact of their work in a shorter timeframe, and thus have a, “more immediate, tangible result” than larger environmental causes. Researchers surveyed environmental stewardship volunteers to determine initial and current motivations for volunteering. They concluded that social interaction is an important initial motivator for service, but a commitment to stewardship of the resources sustained involvement over time. Bruyere and Rappe (2007) surveyed 401 volunteers and found that “helping the environment” was the most important motivation for getting involved, followed by secondary motivators such as social interaction and continued learning.

The Hood Canal Salmon Enhancement Group’s supplementation project is unique in that volunteers have been involved in every component of the project since it began in 2000. Primarily, volunteers monitor the weir on the Union River twenty-four-seven to collect escapement data, but also have assisted with carcass surveys, spawning efforts, and feeding fry in raceways. By utilizing volunteers, HCSEG is able to not only keep costs for the project low and sustainable, but also create support and buy-in amongst community members for salmon
recovery. Illustrating the community reach of the program, HCSEG tracked interactions between volunteers and the general public at the weir site through 2017 and recorded 1,200 visits. Given the historical decline of Hood Canal Summer Chum due to primarily anthropogenic impacts, this support and awareness is crucial if Summer Chum are to one day become a de-listed species. This is also important as new threats arise to Summer Chum and their habitat, including but not limited to increasing development in riparian areas, nonpoint source pollution such as storm water, and non-permitted changes to habitat (Dempsey-Hall, 2015).

**Community Involvement: Methodology and Results**

To understand why community members get involved with the supplementation project, and to better manage the volunteer effort moving forward, HCSEG created a survey to learn from its volunteers. More specifically, HCSEG wanted to better understand motivators for community involvement, levels of satisfaction among volunteers, whether or not project volunteers felt their actions make a difference, and identify associations between recreational activities or residence and volunteering. The survey was administered to volunteers who participated in the supplementation program any time between 2000 and 2016 via e-mail, mail, phone, and intercept interviews at the Union River weir (See Appendix A). In total, 74 volunteers responded over a six-month period. It is not possible to know how many volunteers saw the survey, as HCSEG advertised it online through social media and its comprehensive contact email list. Results were compiled and coded into common groups for analyses and graphical presentation. Below are key results from each question:

**Level of Involvement.** Respondents were asked how long they had been involved with the Summer Chum monitoring program, which began in 2000 (Figure 14). The mean length of
involvement in years was 5.2. Seventeen percent of respondents indicated they had been involved for ten or more years, and 20% were first-time volunteers. Respondents were also asked about their level of involvement during the monitoring season. Volunteers for this program often spend one day per week assisting with the program, though involvement can vary from once per year to multiple times weekly. Sixty-three percent of respondents volunteer once per week, with 14% volunteering once per month and the remainder split between once per year, twice per week, or three or more times per week.

![Pie chart showing volunteer involvement levels](image)

*Figure 14. Volunteer level of involvement with Summer Chum monitoring program*

**Demographics.** In terms of age, HCSEG volunteers vary greatly. As a whole, HCSEG’s volunteer base is skewed towards older, retired individuals. However, efforts have been made over the past four years to diversify in terms of age. Respondents were asked to identify their age group. Thirty-eight percent of respondents fall into the 56+ age category, with 28% made up of individuals age 26-40. Eighteen to twenty-five-year-old volunteers made up 16% of respondents,
with the remaining 18% in the 41-55 category. In terms of gender, 50% of respondents were female, and 49% male.

Geographically, respondents were well spread out, with the most significant pockets being Port Orchard (20%), Bremerton (14%), Shelton (14%), and Belfair (12%). More than 24% of respondents traveled an hour or more to volunteer, coming from Pierce, King, and Thurston counties or locations beyond Puget Sound (Figure 15).

![Geographical location of volunteers](image)

*Figure 15. Geographical location of volunteers*

HCSEG was interested in determining if individuals who worked in a natural resource-related field volunteered at higher rates. Just 27% of volunteers work in natural resources. Similarly, respondents were asked if they had ever lived along a salmon-bearing stream in order to test if that was a primary motivator for involvement on this project. 77% of volunteers had never lived along a salmon-bearing stream, indicating that living among salmon is not necessarily a predictor for involvement. Respondents were also asked what recreational activities
they took part in (Figure 16). 43% of respondents fish, with other significant activities being birding, camping, and boating.

![Pie chart showing recreational activities](image)

**Figure 16. Volunteer engagement with recreational activities.**

**Perception of Success.** Respondents were asked two questions pertaining to perceptions about success of the project. The first question asked returning volunteers whether or not they felt the project as a whole had been successful. Ninety-five percent responded that they had seen success on the project, with 5% uncertain. Nobody felt as if the program was a failure.

As a follow-up, volunteers were asked if they felt their own involvement had made a difference on Summer Chum populations (Figure 17). Seventy-eight percent indicated that they felt their involvement had positively impacted Summer Chum populations. Volunteers who believed their involvement had made a difference were asked to expand on their answer. A majority of respondents pointed to increased returns as the reason, with others pointing to their
direct involvement with trapping, spawning, and rearing activities, as well as increased awareness of Summer Chum in the Union and Tahuya rivers.

**Figure 17.** Volunteer perception of whether their involvement impacted Summer Chum populations.

**Motivators and Benefits.** Volunteers were asked why they initially decided to get involved in the project (Figure 18). Twenty-six percent indicated the hands-on nature of the project was their initial motivator. Other significant reasons included job training and a way to give back to the community and its resources.
Returning volunteers were asked what keeps them involved year to year (Figure 19). A majority (36%) of respondents indicated that giving back to the salmon resource is their top motivator. Fifteen percent indicated continued progress as their motivator, with the remainder choosing factors such as “being outdoors,” “taking part in a family opportunity,” “hands-on involvement,” or “social interaction.”
Volunteers were also asked what they felt was the most significant personal benefit from their involvement in the project (Figure 20). Nearly 40% of respondents indicated the satisfaction of helping fish was the most significant benefit from service, followed by increased knowledge and/or job skills.
Communication Channels. To assist HCSEG in efforts to reach prospective volunteers, respondents were asked how they first heard about the project. Nineteen percent learned about the project by visiting the trap site and talking with an on-site volunteer. Sixteen percent learned about the opportunity through an online source (e.g. social media, HCSEG website). Fifteen percent learned about the project through one of the various outreach events HCSEG attends annually. To a lesser extent, volunteers learned about the opportunity through visiting the HCSEG office, word of mouth, local newspapers, prior HCSEG involvement, partner organizations, HCSEG’s newsletter, and the local radio station.

Restoration Efforts in Study Area

Given the importance of both the Union and Tahuya Summer Chum stocks, habitat restoration in both watersheds has been a significant priority since Hood Canal Summer Chum
were first listed as threatened under the Endangered Species Act. Since 2000, more than $24 million has been invested into habitat and salmon recovery in the Union and Tahuya watersheds (Habitat Work Schedule, n.d.). Projects funded include barrier removals, floodplain restoration, estuary restoration, large woody debris placements, riparian plantings, and invasive species control.

To help guide investments from state and federal agencies, the Washington State Legislature created the Lead Entity Program, an effort to ensure local partners and stakeholders direct salmon recovery funding by writing their own priorities and strategies (Washington State Recreation and Conservation Office, n.d.). For the Hood Canal basin, the Hood Canal Coordinating Council (HCCC) acts as the Lead Entity. The HCCC has existed since 1985 and is comprised of a Technical Advisory Group (TAG) and Citizens Advisory Group (CAG). Project sponsors apply to carry out restoration actions and the TAG and CAG rank projects for funding (Hood Canal Coordinating Council, n.d.).

Of the major restoration efforts completed in lower Hood Canal, two have had significant impacts on Summer Chum recovery. In 2013, the HCSEG completed a multi-year effort to restore the Union River Estuary (Habitat Work Schedule, n.d.). Eighty years previous to restoration, a large dike had been constructed, eliminating estuarine habitat in the name of hay and cattle production (Washington Fish and Wildlife Office, n.d.) funding from state and federal sources, the HCSEG breached the dike in two locations, opening up nearly 12.94 hectares of important habitat for rearing salmonids and other anadromous species in transition (Washington State Recreation and Conservation Office, n.d.; Figure 21). Numerous wood structures were
placed in the new tidal channels. This project was the final piece of a larger effort to restore and protect over 202 hectares of the lower Union River and its estuary (Washington State Recreation and Conservation Office, n.d.).

![Figure 21. An aerial image of the restored Union River Estuary (Washington Department of Fish and Wildlife, 2014.).](image)

Beyond recent large-scale restoration activities, recent restoration proposals for the Union River have focused on assessments of the lower reaches of the river (Habitat Work Schedule, n.d.). The Hood Canal Summer Chum Recovery Plan identified sediment load and habitat diversity as the most pressing freshwater issues to resolve (Brewer et al., 2005; Figure 22).
A variety of restoration actions for the Tahuya River and its estuary have been proposed recently. Aside from habitat assessments throughout the main stem Tahuya River, the most notable interest as of late has been in restoring the estuary. Historically, the Tahuya River had a larger estuary, but over time, habitat has been lost through land use and a large embankment (Puget Sound Nearshore Ecosystem Restoration Project, 2012). The embankment has altered and limited tidal flow and creation of new tidal channels. Through the Puget Sound Nearshore Restoration Project, the WDFW and Army Corps of Engineers have proposed replacing the embankment with a bridge, removing fill material to restore former estuarine habitat, and cleaning up a former mill site. The WDFW hypothesizes these actions would benefit Summer Chum as well as shellfish populations. The Skokomish Indian Tribe has also been monitoring stream temperatures in the Tahuya River and its tributaries to prioritize future restoration efforts.

Given that the river’s source is a lake, the stream is warmer than many other Hood Canal
systems, and therefore, riparian restoration is a priority on the Tahuya River (Northwest Treaty Tribes, 2017; Washington State Conservation Commission, 2003).

**Policy and Programmatic Approaches to Recovery**

A large collaborative effort drives salmon recovery in Washington, both in terms of policy and funding (Figure 23). The Puget Sound Partnership (PSP) is a state agency but receives most of its funding from the EPA’s National Estuary Program, which it allocates to various projects and programs that address habitat, water quality, ecosystems, and human well-being (Puget Sound Partnership, n.d.). In addition to funding critical projects, PSP leads efforts to coordinate regional partners in the recovery of Puget Sound and Hood Canal. One of the primary tools for this coordination is the Puget Sound Action Agenda (PSAA), which is a ranked list of necessary strategies and actions for ecosystem recovery. On a biennial basis, PSP solicits project proposals utilizing these strategies and actions and ranks proposals for inclusion on the PSAA, as required to receive National Estuary Program (NEP) funds. Another important resource statewide for salmon recovery is the network of 14 regional fishery enhancement groups established in 1990 by the State Legislature. The goal of these watershed groups is to engage local communities in habitat restoration, salmon and Steelhead recovery, and environmental education. The Hood Canal Salmon Enhancement Group was founded in 1990 and is one of the 14 organizations, working in communities and waters throughout the entirety of Hood Canal (Hood Canal Salmon Center, n.d.).

At the regional level, Washington’s Salmon Recovery Funding Board, part of the Recreation and Conservation Office, guides state investments in habitat and salmon recovery projects and programs (Washington State Recreation and Conservation Office). To ensure
regional needs are being addressed, Washington’s Legislature established lead entity organizations in major watersheds (Washington State Recreation and Conservation Office, n.d.) Lead entities craft localized salmon recovery plans, and also solicit recovery and restoration programs. These projects are ranked and recommended to the Salmon Recovery Funding Board for funding. The Hood Canal Coordinating Council (HCCC) serves as the lead entity for Hood Canal, bringing together Hood Canal’s county and tribal governments, as well as citizens and technical experts. The HCCC lead the development of the SRP as required by the Endangered Species Act (Washington Department of Fish and Wildlife, n.d.).

Figure 23. Funding mechanisms for salmon recovery and habitat restoration in Washington.

The SRP (Brewer et al., 2005) identifies a number of programmatic, financing, and policy objectives and solutions, both regionally and at the county level. For generating revenue, the SRP suggests special fees could be charged for day use of boat launches or for services such
as pump outs of boats and trailers. Further, the SRP suggests revenue for habitat remediation could be generated by fines levied for pollution and/or habitat degradation in permitted projects. One of the more unique ideas identified in the SRP is the creation of an environmental credit market, where participants can exchange and transfer development rights and emissions permits to concentrate harmful environmental effects in areas less susceptible to critical habitat loss.

Programmatic goals identified in the SRP include increased enforcement of regulations on private lands, property acquisition (voluntary or through eminent domain), conservation easements, and increased education and outreach efforts. Given the life history of Summer Chum, a significant priority was placed on protecting and better understanding nearshore areas, realizing the connection between Summer Chum, other salmonids, and forage fish. The HCCC operated a pilot program, the Community Nearshore Restoration Program, which revolved around incentives for voluntary shoreline restoration along private parcels. The program found success in terms of outreach (nearly 250 landowners engaged with about restoration, resources, and regulations) and on-the-ground restoration (more than 20 projects completed) (Brewer et al., 2005). In recent years, Washington State’s environmental agencies have formulated a social marketing approach to increased stewardship of Puget Sound and Hood Canal shorelines through the Shore Friendly campaign (Colehour & Cohen, 2014). Utilizing traditional marketing tactics to “sell” behavior change, grants are provided to local partners to engage with shoreline landowners, contractors, and realtors in an attempt to remove or reduce hard armoring.

The lower Hood Canal watershed, as shown in Figure 24, is one of the most altered shorelines within Puget Sound, nearly completely devoid of a connection between the shoreline
and natural feeder bluffs (Hirschi, Labbe, & Carter-Mortimer, 2003). More than 60% of lower Hood Canal’s northern shore is armored, and more than 70% of the south shore is armored (Mason County Project Management Team, 2012). Between 2005 and 2014 alone, Mason County and WDFW approved over 200 shoreline modifications, resulting in a net increase of 2.4 kilometers of modified shoreline (Skokomish Tribe, 2016).
Figure 24. The shoreline of the lower Hood Canal is heavily armored (2016).
State, county, and local agencies have a few principal regulatory mechanisms important to habitat restoration and salmon recovery. To help regulate development impacting state waterways, and to protect fish and marine resources, the Washington State Legislature created a hydraulic code (Washington State Legislature, 2014). Projects such as bulkheads, bank stabilization, water crossings, and culverts require a Hydraulic Project Approval (2012), administered by the Washington Department of Fish and Wildlife.

Under Washington’s State Environmental Policy Act (SEPA), passed in 1971, state, county, and local entities must identify and address environmental impacts of project proposals and engage with the community and stakeholders (Washington State Department of Natural Resources, n.d.). In concert with the passage of the SEPA, the Washington State Legislature passed the Shoreline Management Act (SMA) the same year, with the purpose of regulating shoreline development and protecting natural resources in marine waters, many rivers and lakes, and a number of wetlands (Washington State Legislature, 1971). Under the SMA, counties and cities that use the Washington Growth Management Act for planning must develop local management objectives for land use and water resources, known as a Shoreline Master Program (SMP) (Washington State Legislature, 2011).

In the SRP, policy and programmatic recommendations are made to each of the counties within the Hood Canal Summer Chum ESU. Specific to Mason County, the SRP called for an updated SMP to include “guidance that discourages hard armoring of the nearshore” (Brewer et al., 2005). Additional recommendations for Mason County include incentive programs to promote low-impact development, establishing outreach campaigns to reverse the trend of forest
cover loss, and the creation and implementation of best management practices (BMPs) to control
the growing threat of storm water pollution throughout Mason County (Brewer et al., 2005). To
further aid Summer Chum recovery in the Union and Tahuya rivers, the SRP calls for developing
storm water facilities and BMPs in the greater Belfair area, in order to address water quality and
flow. Furthermore, the SRP calls for Mason County to update and strengthen its Critical Areas
Ordinance, increasing protection for riparian habitat and channel complexity. Scott Brewer,
executive director of the Hood Canal Coordinating Council (HCCC), feels that Mason County
has made progress towards many of the original policy goals outlined in the SRP, specifically in
terms of the establishment of the Belfair Urban Growth Area and its sewer system (S. Brewer,
personal communication, January 19, 2018). Looking ahead for Mason County specifically,
Brewer calls for a continued examination of the nearshore and water quality in lower Hood
Canal. To accomplish this, the HCCC has developed a Hood Canal-wide Pollution and
Identification Correction (PIC) program. With full support from Mason County, the PIC program
will help to identify and restore waters impacted by fecal coliform. Brewer points to the PIC
program as a way in which Summer Chum recovery partners can work more closely with
shellfish producers to build support for improved water quality, creating a win-win for salmon,
shellfish, and forage fish (S. Brewer, personal communication, January 19, 2018).

Economic Advantages to Community-Driven Recovery Efforts

Investments in salmon recovery efforts throughout Washington have led to very
substantial results for local communities. The Governor’s Salmon Recovery Office (GSRO),
which is responsible for allocating state salmon recovery funding, notes that a $1 million
investment in recovery and habitat restoration can create or sustain over 30 jobs, resulting in over
$2.2 million in economic benefits (Governor’s Salmon Recovery Office, 2010). Additionally, GSRO notes that over two-thirds of grant monies are expended in restoration communities. Since 1999, the agency reports that their investments have created or sustained more than 4,000 jobs and have generated $650 million in economic benefits for restoration communities. Similarly, NOAA Fisheries has invested more than $1 billion through the Pacific Coastal Salmon Recovery Fund and leveraged $1.3 billion from state and local partners (NOAA-NMFS, 2014).

One of the most attractive factors of the Union/Tahuya Summer Chum Project is the ability to significantly leverage grant monies and perform duties at a cost much lower than a traditional hatchery operation (Table 9). From 2000 to 2015, the period in which Summer Chum were being trapped, spawned, and incubated primarily by HCSEG staff and volunteers, associated costs annually averaged approximately $23,976. This is derived from 686 hours for a biologist at a current rate of $26/hour, which includes the cost of benefits; 72.75 hours for a volunteer coordinator at a current rate of $27/hour, which includes the cost of benefits; and two research interns, which cost approximately $1,175 for the duration of the project. Additional costs include mileage ($1,400 at current rate of $0.54/mi), and utilities/supplies ($1,600). In comparison, if the program were operated by the WDFW or another agency, without volunteer help, personnel costs alone would total approximately $56,635, which accounts for nine temporary full-time natural resource technicians during trapping, and one part-time natural resource technician during incubation and rearing at a rate of $14.25/hour, and $0.38/hour for overhead related to each employee (Washington Office of Financial Management, 2017; Pew Charitable Trusts, 2016). Additional mileage in excess of $1,400 would also have to be included in operational costs if the WDFW were to manage the program, as the agency’s Summer Chum
hatchery is 35 kilometers away from the HCSEG’s office. Altogether, this volunteer-driven approach resulted in approximate cost savings of at least $34,059 annually during the height of the project. Estimates for WDFW consist solely of costs associated with trapping, whereas HCSEG estimates account for carcass surveys, trapping, feeding, incubation, and trap install/removal.

From an efficiency and leverage standpoint, this project serves as an effective model for distributing grant monies while making a significant impact towards salmon recovery. Each year, the HCSEG receives funds from the WDFW and USFWS, which supports this project, though a small grant from the Washington Department of Fish and Wildlife’s Aquatic Lands Enhancement Account (ALEA) helps to cover costs such as mileage and supplies. From 2000 to 2015, volunteers averaged approximately 3,000 hours of service on the project through trapping, survey, and rearing activities. (C. David, personal communication, August 5, 2017). The current match rate utilized for Washington state volunteers is $31/hour (Independent Sector, 2016). Research interns generated an additional 600 hours annually of volunteer time through carcass surveys and other support efforts, resulting in a match value of $17,425 (calculated as match value of 600 hours minus stipends paid to interns). At that rate, HCSEG volunteers generated $110,425 in match annually.
Table 9

**Comparison of HCSEG Summer Chum Volunteer-Driven Monitoring Efforts and Traditional Hatchery Operations in Terms of Associated Annual Costs and Generated Match Dollars**

<table>
<thead>
<tr>
<th>Personnel</th>
<th>Associated Costs</th>
<th>Match Generated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish Biologist</td>
<td>$17,836</td>
<td>---</td>
</tr>
<tr>
<td>Volunteer Coordinator</td>
<td>$1,965</td>
<td>---</td>
</tr>
<tr>
<td>Research Interns</td>
<td>$1,175</td>
<td>$17,425</td>
</tr>
<tr>
<td>Monitoring Volunteers</td>
<td>---</td>
<td>$93,000</td>
</tr>
<tr>
<td>Supplies/Materials</td>
<td>$1,600</td>
<td>---</td>
</tr>
<tr>
<td>Mileage</td>
<td>$1,400</td>
<td>---</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$23,976</td>
<td>$110,425</td>
</tr>
</tbody>
</table>

| Natural Resource Technician      | $56,635          | ---             |
| Mileage                          | $1,400 +         | ---             |
| TOTAL                            | $58,035          | ---             |

*Note: HCSEG personnel costs include all tasks in the process, from installing weir, trapping, conducting carcass and otolith sampling, incubation, feeding, and release. WDFW costs are estimated for trapping alone.*

Past research examined the public’s willingness to pay (WTP) for down-listing species by utilizing surveys to determine contingent valuation. Wallmo and Kew (2012) surveyed nearly 8,500 individuals to determine WTP to down-list various mammals and marine fish, including Upper Willamette River Chinook salmon and Puget Sound Chinook salmon, both of which are threatened under the Endangered Species Act (National Marine Fisheries Service, 1999). Results indicated that initially, a majority of respondents (73%) valued down-listing threatened species, slightly lower than the support for protecting endangered species (81%). However, when presented with eight marine taxa that were either threatened or endangered, support for recovering threatened species with much stronger than support for down-listing endangered species. Specific to salmonids, the mean willingness to pay for recovery of threatened Chinook
stocks ranged from $40.49 for Puget Sound Chinook to $40.65 for Willamette River Chinook. Wallmo and Kew (2012) concluded that overall, the public finds value in recovering threatened species.

Bell, Huppert, and Johnson (2003) studied the willingness to pay of coastal communities for Coho enhancement efforts. Using contingent valuation methods, 2,209 residents responded to a survey, indicating significant support for enhancement programs. The subset of residents in Grays Harbor, Washington, indicated a mean WTP of $97.56 for enhancement efforts, an amount that was not significantly impacted by participation in recreational fishing.

In the case of Hood Canal Summer Chum, these findings indicate there may be a willingness to financially support recovery, especially given the low cost of the Union/Tahuya River Summer Chum Project relative to its benefits and in comparison to traditional hatchery programs.

Discussion

Given the increased abundance and escapement of Summer Chum in the Union River, the return of Summer Chum to the Tahuya River, and limited evidence of a loss in genetic diversity (Small et al., 2009), HCSEG’s project has been successful in meeting its goals and contributing to the overall objectives of the SRP (Point No Point Treaty Tribes and Washington Department of Fish and Wildlife, 2014). Many consider supplementation efforts on the Union River successful in terms of how enhancement actions have sustained relatively strong returns annually, though the Tahuya River has not seen the same level of success (S. Brewer, personal...
communication, January 21, 2018). Equally important, the project has had a significant impact in the human dimensions arena, serving as a tool to educate and engage the public in salmon recovery.

Fork lengths and growth appear to show little difference among natural origin and supplemented origin fish. All groups were relatively close in size at age two, with slight differences through age five. Rather, growth appears to be much more related to sex, bioenergetics, and reproductive traits. However, results from this analysis must be accepted with caution, as no data exists for younger (<2 year) fish. In 2018, the HCSEG is implementing an outmigration monitoring component to this project, which can help fill in data gaps and provide a clearer picture of growth rates, as well as the health of food sources.

Analysis of age-class data demonstrates that natural-origin and supplemented-origin fish do differ slightly in terms of age at reproduction, and that the difference between the two populations is statistically significant. However, the distribution of ages is fairly similar across both populations: more than 65% of fish return as age-3 fish, followed by age-4, age-2, and age-5. While the difference in ages is statistically significant, there is not strong evidence supporting significant biological differences in age at reproduction for fish in both groups.

Results from the analysis of peak run timing demonstrates little change over the project’s history. Each year, Summer Chum are returning to the Union River about one-third of a day earlier. Other factors may be better predictors of mean return dates for Summer Chum salmon on the Union River, such as weather factors (rain, flows, temperatures) and oceanic conditions, such
as the Pacific Decadal Oscillation (PDO), though previous studies have concluded that the Union River is impacted minimally by ocean conditions in comparison to all other Summer Chum salmon-bearing streams in Hood Canal (Lestelle et al., 2005; Small et al., 2009). The effects of climate change on Summer Chum salmon are already being observed, though, through significantly earlier outmigration patterns (Weinheimer, Anderson, Downen, Zimmerman, & Johnson, 2017). Further future analysis of other factors, such as outmigration timing and climatic conditions, would aid in explaining the slight trend towards earlier returns. Additional analysis of 2007 data in terms of returns and climatic conditions also could provide interesting insights as to why the return skewed much earlier that year, as opposed to ongoing trends before and after 2007.

Results from the volunteer survey provide some interesting insights, demonstrating the success of the project in terms of community involvement. These results will allow HCSEG to continue to grow and improve its volunteer program for this specific project. With a majority of volunteers residing within close proximity to the project area and Hood Canal, and just 23% of respondents living along a salmon-bearing stream, the project appears successful in building interest and awareness among Hood Canal communities and individuals who may lack much of a connection to salmon. Additionally, among volunteers who’ve been involved for more than one year, there is a strong perception of success, both for the project as a whole, but also due to their hands-on involvement. Much of the perception of success is driven by seeing increased returns of Summer Chum to the Union and Tahuya rivers. Moving forward in recruiting and building its volunteer base, HCSEG would be well served to make special efforts to engage with the fishing community, which represents over 40% of the respondents. Additionally, gearing recruitment
efforts towards the themes of helping fish in a hands-on, social environment would likely lead to increased growth and satisfaction among all project volunteers.

Economically speaking, the supplementation program has proven to be an efficient way to recover ESA-listed stocks, support local non-profit organizations, and leverage funds through volunteer involvement. With approximate cost savings of more than 80% annually, this model can be implemented in other watersheds as budgets for natural resource programs continue to dwindle (Mooney, 2017).

Conclusion

As salmon and Steelhead stocks throughout Puget Sound and Hood Canal face increased pressures and threats of ESA listing, supplementation programs can continue to help rebuild and boost abundance. The prospectus for de-listing of Summer Chum is positive, with managers hoping to begin the formal process of delisting with the NMFS in the mid-2020s (Hood Canal Coordinating Council, 2017). In the interim, there is still much to do. Co-managers are examining the potential to create similar supplementation programs on the Dewatto River and Big Beef Creek on the Kitsap Peninsula using Union River fish as broodstock (2017). To reverse salmon declines, it’s going to take more than supplementation, though. This program serves as a model for developing lasting community buy-in, which ultimately hopefully will lead to increased awareness and care for the salmon resource. When Summer Chum are eventually removed from ESA protections, it will be in large part because of this citizen-driven supplementation effort.
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Summary_of_Summer_Chum_Assessment_in_HC-4-3-05.pdf


APPENDIX A: Survey Instrument

1. How long (in years) have you been volunteering on the supplementation project?
2. If you have been volunteering for more than one year, what keeps you coming back?
3. If you’ve been involved for more than one year, do you feel like you’ve seen success?
   1. Yes
   2. No
   3. Unsure
4. How did you learn about this volunteer opportunity?
5. What is your level of involvement each season on average?
   1. Once per week
   2. Two times per week
   3. Three or more times per week
   4. Once/Month
   5. Once/Year
6. If you’ve been involved for more than one year, what keeps you coming back?
7. Why did you decide to volunteer on this project initially?
8. What do you consider to be the top benefit to you personally from your volunteer work on this project?
9. Do you feel like your volunteer actions are making a difference on Summer Chum populations?
   1. Yes
   2. No
   3. Unsure
10. If you answered yes, why?
11. Which of the following recreational activities do you take part in?
   1. Fish
   2. Hike
   3. Hunt
   4. Birdwatch
   5. Boating/Kayaking
   6. Other

12. Do you live, or have you lived, along a salmon-bearing stream?

13. What is your age group?
   1. 18-25
   2. 26-40
   3. 41-55
   4. 56+

14. Do you work in a natural resource-related field?
   1. Yes
   2. No

15. What is your gender?
   1. Male
   2. Female
   3. Prefer not to answer

16. Where do you reside?