Comprehensive Management Plan for Puget Sound Chinook:

Harvest Management Component

PUGET SOUND INDIAN TRIBES
AND
THE WASHINGTON DEPARTMENT OF FISH AND WILDLIFE

FEBRUARY 17, 2022

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Executive Summary

This Harvest Management Plan will guide the Washington co-managers in planning annual harvest regimes, as they affect listed Puget Sound Chinook salmon, for management years 2023-2024 through 2032-2033. Harvest regimes will be developed to achieve stated objectives (i.e., total or Southern U.S. exploitation rate ceilings, and / or abundance thresholds) for each of fifteen management units. This Plan describes how these guidelines are applied to annual harvest planning.

The Plan guides the implementation of fisheries in Washington, under the co-managers' jurisdiction, but also considers harvest impacts of other fisheries that impact Puget Sound Chinook, including those in Alaska and British Columbia, to assure that conservation objectives for Puget Sound management units are achieved. Accounting total fishery-related mortality includes incidental harvest in fisheries directed at other salmon species, and non-landed mortality.

The fundamental intent of the Plan is to enable harvest of strong, productive stocks of Chinook, and other salmon species, and to minimize harvest of weak or critically depressed Chinook stocks. Providing adequate conservation of weak stocks will necessitate foregoing some harvestable surplus of stronger stocks.

The Exploitation Rate (ER) ceilings stated for each management unit (Table 4-1) are not target rates. Pre-season fishery planning will develop a fishing regime which does not exceed the ER ceilings for any management unit. Projected exploitation rates that emerge from pre-season planning will, for many management units, be lower than their respective ceiling rates. While populations are rebuilding, annual harvest objectives will be intentionally conservative, even for relatively strong and productive populations.

To further protect populations, low abundance thresholds (Table 4-1) are set well above the critical level associated with demographic instability or with loss of genetic integrity. If escapement is projected to be below this threshold, harvest impacts will be further constrained, by lower Critical Exploitation Rate ceilings, to increase escapement. Additionally, for some management units in the Plan, a Point of Instability (or Lower bound) has been defined which requires further harvest constraints below the Critical Exploitation Rates to be developed, based on co-manager agreement.

Exploitation rate ceilings for some management units are based on estimates of recent productivity for component populations. Productivity estimates (i.e., recruitment and survival) are subject to uncertainty and bias, and harvest management is subject to imprecision. The derivation of ER ceilings considers specifically these sources of uncertainty and error, and manages the consequent risk that harvest rates will exceed appropriate levels. The productivity of each management unit will be periodically re-assessed, and harvest objectives modified as necessary.

Criteria for exemption of state / tribal resource management plans from prohibition of the 'take' of listed species, are contained under Limits 4 and 6 of the salmon 4(d) Rule (50 CFR 223:42476). The 4(d) criteria state that harvest should not impede the recovery of populations which exceed their critical threshold, and that populations below critical status should be guarded against further declines, such that harvest will not significantly reduce the likelihood of survival and recovery of the ESU. Specifically, the individual criteria in Limit 4 of the salmon 4(d) rules are addressed in the following locations:

- Criteria (A) – Chapter 3 addresses Population structure and identifies populations incorporated as Management Units. Additional information on individual populations and populations incorporated within a management unit can be located in Appendix A (Management Unit Profiles).
- Criteria (B) – Appendix A (Management Unit Profiles) describe current population status' in terms of critical and viable statuses consistent with VSP parameters.
- Criteria (C) – Escapement and/or exploitation rate objectives are defined for each population or Management Unit in Chapter 4 and Appendix A (Management Unit Profiles).
- Criteria (D) – Chapters 4 and 6 and Appendix A (Management Unit Profiles) describe the rationale describing the harvest management strategies expectation to not appreciably reduce the likelihood of survival and recovery of the ESU.
- Criteria (E) – A description of the monitoring components and evaluation are provided in Chapter 7.
- Criteria (F) – Chapter 7 also provides for expectations for reporting on monitoring requirements to evaluate harvest objectives and assumptions.
- Criteria (G) – Enforcement expectations are included in Chapter 5.
- Criteria (H) – Harvest objectives in Chapter 4 and implementation rules in Chapter 5 describe how harvest restrictions are utilized to minimize take of listed fish.
- Criteria (I) – Considerations for other Federal harvest plans, court proceedings, international obligations, are addressed in Chapter 2.

The abundance and productivity of all Puget Sound Chinook populations is constrained by habitat conditions. Recovery to substantially higher abundance is primarily dependent on restoration of habitat function. Therefore, the harvest limits established by this Plan must be complemented by the other elements of the Comprehensive Recovery Plan that address degraded habitat and management of hatchery programs (Shared Strategy for Puget Sound 2007).

1. Objectives, Principles, and Integration with Habitat Requirements

This Harvest Management Plan (Plan) establishes management guidelines for annual harvest regimes, as they affect Puget Sound Chinook Salmon, for management years 2023 -2024 through 2032 - 2033. The Plan guides the implementation of fisheries in Washington, under the co-managers' jurisdiction, and considers the total fishery-related impacts on Puget Sound Chinook Salmon from salmon, trout/char-, freshwater spiny-ray, hatchery steelhead-directed fisheries, and fisheries directed at ESA listed Puget Sound steelhead where approved under other plans, as well as including the impacts of salmon fisheries in Alaska, British Columbia, and Oregon. The Plan's objectives can be stated succinctly as an intent to:

> *Ensure that fishery-related mortality will not impede rebuilding of natural Puget Sound Chinook salmon populations, consistent with the capacity of properly functioning habitat, to levels that will sustain fisheries, enable ecological functions, and are consistent with treaty-reserved fishing rights.*

This Plan will constrain fisheries to the extent necessary to enable rebuilding of natural Chinook Salmon populations in the Puget Sound Chinook Salmon Evolutionarily Significant Unit (ESU), provided that habitat capacity and productivity are protected and restored to allow rebuilding of abundances through improved survival and productivity. This Plan includes explicit measures to conserve and maintain abundance while preserving the spatial structure and diversity across the ESU. The ultimate goal of this plan is to promote rebuilding of natural Puget Sound Chinook Salmon, to the extent possible in light of habitat constraints on productivity, so that natural Chinook populations will be sufficiently abundant and resilient to perform their natural ecological function in freshwater and marine systems, provide related cultural values to society, and sustain commercial, recreational, ceremonial, and subsistence harvest.

The parties to this Plan include the Lummi, Nooksack, Swinomish, Upper Skagit, Sauk-Suiattle, Tulalip, Stillaguamish, Muckleshoot, Suquamish, Puyallup, Nisqually, Squaxin Island, Skokomish, Port Gamble S'Klallam, Jamestown S'Klallam, Lower Elwha Klallam, and Makah Tribes, and the Washington Department of Fish and Wildlife (collectively, co-managers).

The co-managers and the National Marine Fisheries Service (NMFS) have adopted a Recovery Plan for Puget Sound Chinook Salmon (NMFS 2007, Ruckleshaus et al. 2005) that states quantitative abundance and productivity goals for each population for recovery of the ESU. The Recovery Plan also includes more qualitative guidance for diversity and spatial structure. These four parameters (i.e., Viable Salmonid Population parameters) provide the ultimate objectives for all aspects of recovery planning. The Recovery Plan addresses integrated factors affecting the survival and recovery, including the management of fisheries and hatchery production, and conservation and restoration of freshwater and marine habitat, all of which are necessary to achieve recovery goals.

1.1 Scope of the Plan

This Plan guides the implementation of fisheries in Washington, under the co-managers' jurisdiction, and considers the total fishery-related impacts on Puget Sound Chinook Salmon of salmon fisheries in Washington, Oregon, British Columbia, and Alaska, and the incidental impacts of co-managers' fisheries directed at resident/anadromous trout/char, spiny-ray, and hatchery steelhead in Puget Sound. Incidental impacts on Puget Sound Chinook Salmon from NOAA approved fishery plans directed at ESA listed Puget Sound steelhead will also be considered in the total fishery-related impacts (e.g. exploitation rate ceilings) under this Plan.

This Plan defines allowable levels of fishery-related mortality on Puget Sound Chinook Salmon. While impacts to Puget Sound Chinook Salmon are realized and accounted for over a broad geographic extent, the intended geographic scope of this Plan for Endangered Species Act authorization is focused on tribal Indian and non-Indian commercial, tribal ceremonial and subsistence, and recreational salmon, steelhead, and trout/char fisheries that occur in the Washington marine waters of Puget Sound, the Strait of Juan de Fuca (east of Cape Flattery), Rosario Strait and Georgia Strait, Hood Canal, and in rivers and streams draining into these waters when ESA-listed adult Chinook salmon could be encountered (Figure 1-1). The Plan also includes whitefish and spiny-rayed fresh water fisheries in those same freshwater systems when adult Chinook are potentially present; see below for clarification of spiny-rayed fisheries).

Ocean salmon fisheries that operate in Washington coastal Areas 1 – 4B, from May through September, involve harvest or encounters with Puget Sound Chinook Salmon. The Secretary of Commerce, through the Pacific Fisheries Management Council (PFMC), is responsible for management of these fisheries. As participants in the PFMC / North of Falcon planning processes, the Washington co-managers consider the impacts of these ocean fisheries on Puget Sound Chinook Salmon, and may request the PFMC to modify them, to achieve management objectives for Puget Sound Chinook Salmon (PSSMP Section 1.3).

Impacts in salmon fisheries in Alaska, British Columbia, and Oregon are accounted for to assess, as completely as possible, total fishing mortality on Puget Sound Chinook Salmon consistent with specified exploitation rate management objectives (see Table 4-1 for specific management objectives). Regardless of individual Management Unit objectives, exploitation rates for non-Washington fishery impacts are assessed within individual management unit profiles to provide a complete representation of fishery impacts (see Appendix A). Mortality of Puget Sound Chinook Salmon in other Washington, Oregon, and Alaska commercial and recreational fisheries, e.g. those directed at groundfish, halibut, or shellfish, are not directly accounted. NMFS provides ESA take authorization for these fisheries through consultation on separate resource management plans. The co-managers' long-term objective is to account for the incidental mortality that these fisheries have on Puget Sound Chinook Salmon.

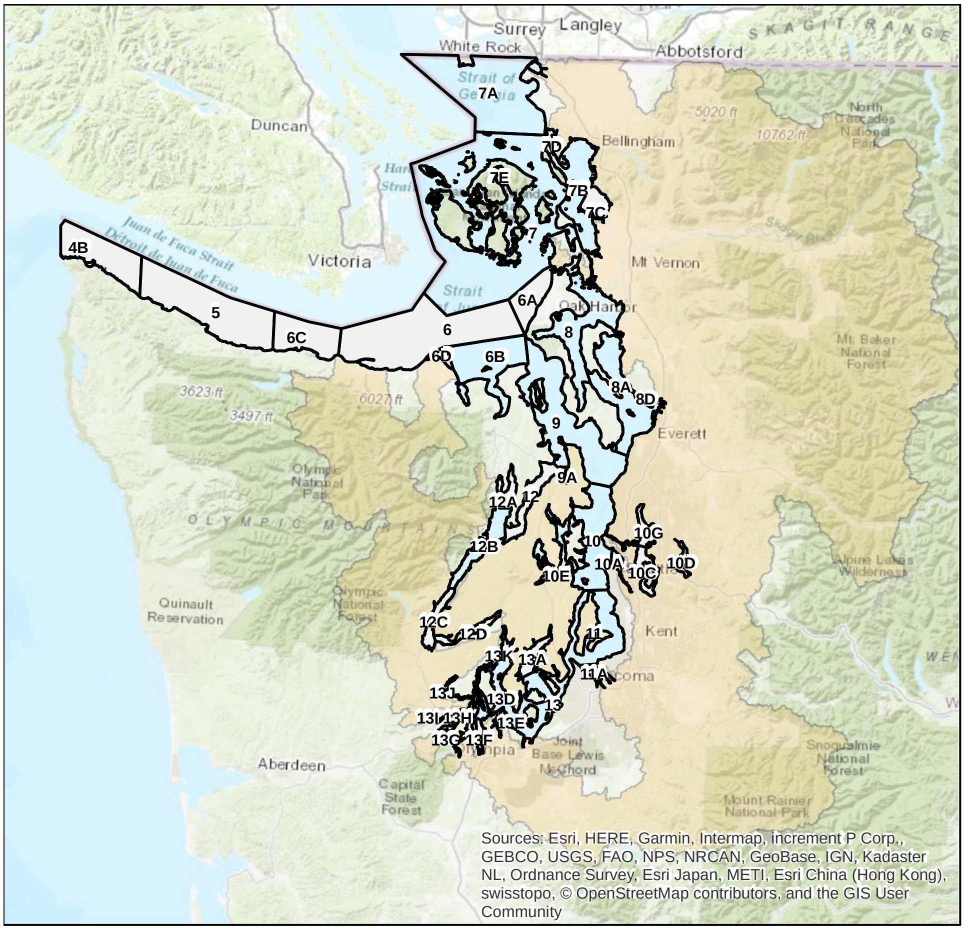

Figure 1-1. Geographic extent of action area including marine catch areas associated with the proposed harvest plan.

Trout/char and hatchery steelhead-directed fisheries in Puget Sound, including tribal and recreational fisheries in marine and freshwater areas as well as spiny-ray species (e.g. large and small mouth bass, northern pikeminnow, black crappie, yellow perch, etc,.) and whitefish fisheries in freshwater rivers/streams that occur during the period when ESA-listed adult Chinook are potentially in-river may involve incidental mortality of adult Chinook Salmon. Timing and location of these fisheries, and the types of gear deployed make the likelihood of encounters (and mortalities) of Chinook Salmon in most of these fisheries minimal and difficult to measure. Puget Sound Chinook Salmon exploitation rate estimates produced by the co-managers and the Chinook Technical Committee of the Pacific Salmon Commission to date have not estimated impacts in these fisheries. The effect of these fisheries, while likely relatively small, if not accounted for under this Plan's management objectives, would become an increasing portion of the fishery-related mortality should Puget Sound Chinook Salmon populations continue to decline. Co-managers will develop these impact estimates as accurately as possible and will include them in estimating exploitation rates on each Puget Sound Chinook Salmon management unit.

1.2 Objectives

To promote recovery, the Plan has the following objectives:

- Conserve the productivity and abundance within populations that make up the Puget Sound Chinook Salmon ESU as well as conserving the spatial structure and diversity of populations across the ESU.

- Achieve compliance with the ESA jeopardy standard, by meeting the requirements of the salmon and steelhead 4(d) rule, and over all provide a management framework that promotes conservation and potential for recovery of affected listed species (NMFS 2005a).

- Reduce the risks associated with harvest management imprecision and uncertainties in estimates of the productivity and survival of Puget Sound Chinook Salmon populations.

- Provide opportunity to harvest surplus hatchery Chinook Salmon from Puget Sound and the Columbia River, as well as harvestable abundance Puget Sound Sockeye, Pink, Coho, and Chum Salmon, hatchery steelhead, and other anadromous/resident trout/char, freshwater spiny ray species and the directed harvest of Sockeye, Pink, and Chum Salmon originating from British Columbia pursuant to the Pacific Salmon Treaty.

- Account for all sources of landed and non-landed fishery-related mortality, in all fisheries described in Section 1.1, when assessing fisheries relative to the management objective exploitation rates defined by this Plan, to the extent enabled by current and updated data and models.

- Adhere to the principles of the Puget Sound Salmon Management Plan (PSSMP), and other legal mandates pursuant to U.S. v. Washington (384 F. Supp. 312 (W.D. Wash. 1974)), and U.S. v Oregon, which provide the basis for co-management of the salmon resource by the treaty tribes and the State of Washington and mandates equitable sharing of fishery opportunity.

- Meet the fishery management obligations defined by the Treaty between the Government of Canada and the Government of the United States of America concerning Pacific salmon (the Pacific Salmon Treaty (PST)).

- Ensure exercise of Indian fishing rights established by treaties, and further defined by federal courts in U.S. v Washington and related sub-proceedings.

Responsible management of salmon fisheries requires accounting of all sources of fishery-related mortality in all fisheries. This is a complex task since directed, incidental, and non-landed mortality must all be taken into account, and since Puget Sound Chinook Salmon are affected by fisheries in a large geographical area extending from southeast Alaska to the Oregon coast. Management tools have been continually refined to better quantify harvest rates and catch distribution for Puget Sound Chinook Salmon.

The management regime of this Plan will be guided by the principles of the Puget Sound Salmon Management Plan (PSSMP), and other legal mandates pursuant to U.S. v. Washington (384 F. Supp. 312 (W.D. Wash. 1974)), and U.S. v. Oregon, in equitable sharing of fishery opportunity.

The Pacific Salmon Treaty defines limits to harvest in fisheries that take Puget Sound Chinook Salmon. It is anticipated that the renegotiation of the Chinook agreement and adjustments to the Aggregate Abundance Based Management (AABM) and Individual Stock Based Management (ISBM) regimes will result in improvements to sustain healthy stocks while addressing the conservation needs of depressed natural stocks through the Puget Sound critical stocks program.

Most of the harvest-related Puget Sound Chinook Salmon mortality in fisheries governed by this Plan will occur in fisheries directed at harvestable Chinook Salmon hatchery production, Sockeye and Pink Salmon (including stocks originating from the Fraser River), Coho Salmon and to a lesser extent Chum Salmon fisheries. Consequently, management plans and agreements pertaining to stocks from regions other than Puget Sound, and for species of salmon other than Chinook Salmon, are taken into account in developing this plan.

This Plan sets limits on annual fishery-related mortality for each Puget Sound Chinook Salmon management unit. The limits are expressed either as exploitation rate ceilings, escapement thresholds (hatchery and/or natural escapement), or changes to the number of spawners caused by Puget Sound fisheries as defined in the MUPs. Exploitation rate ceilings are expressed either as rates in all fisheries (Total), southern U.S. fisheries, or pre-terminal southern U.S. fisheries. For one management unit (mid-Hood Canal), objectives are specified as ensuring that Puget Sound fisheries do not reduce the number of spawning Chinook by more than seven. For some populations, terminal fishery management measures are specified that will achieve stated natural escapement thresholds. Exploitation rate ceilings for management units comprised of more than one population are defined with the intent of contributing to the rebuilding of each component population. Implementing this Plan requires assessing the effects of fisheries (i.e. the comparison of total production with the resulting escapement) on individual populations.

The Plan asserts a specific role for fishery management in contributing to the rebuilding of the Puget Sound Chinook Salmon ESU: to ensure that sufficient mature adults escape fisheries to utilize currently available spawning and rearing habitat to the optimum degree. For most populations, until habitat constraints to productivity are alleviated, the Plan’s constraints on fishery-related impacts may only assure that population abundance will remain stable (i.e., persist). For some populations, the Plan’s constraints on fishery-related impacts are designed to provide levels of natural escapement that exceed the number associated with maximum sustainable yield (MSY) under current habitat conditions (Appendix A). Providing these higher escapements will improve estimates of population productivity and will lead to increased production if habitat conditions improve or other survival factors are favorable. The Plan requires that fishery restrictions be implemented to promote larger escapements for those populations that are forecasted to be at or near critical abundance status (i.e. at or below LAT). For a small number of populations in critical abundance status, due to major survival impediments associated with habitat condition or the limited impact of fisheries under the management jurisdiction of the co-managers, the constraints on fishery-related mortality imposed by this Plan may not reduce their risk of extinction.

For some management units with quantified productivity, the Plan’s objectives directly incorporate the effects of uncertainty associated with deriving and implementing exploitation rate ceilings or spawning escapement objectives. Furthermore, the Plan commits the co-managers to ongoing monitoring, research and analysis, to collect data pertinent to refining management objectives, to better quantify and evaluate the significance of uncertainty and management error, and to modify the Plan as necessary to minimize associated risks. For some Management Units, the expectation is to review the data every five years (see Appendix A).

Concern over the declining status of Puget Sound and Columbia River Chinook Salmon has motivated conservation initiatives under the management authorities of the Pacific Salmon Commission and the PFMC. This Plan is designed to complement the conservation efforts of those management authorities and will continue to evolve to provide a coordinated, coast-wide fishery management response to address the conservation of Puget Sound Chinook Salmon.

1.3 Integration of Harvest and Hatchery Management with Habitat Requirements

The stock-specific management strategies outlined in this Plan were developed in the context of current and anticipated habitat status over the duration of this Plan. Within each watershed, Chinook salmon hatchery programs also are coordinated with harvest goals and objectives to accord with Puget Sound Chinook Salmon recovery. Hatchery production is managed to achieve conservation and harvest objectives, recognizing the status of habitat, and potential for restoring habitat function in each watershed (Tribal Hatchery Policy 2013).

In 2007, a coalition of tribal, state and local governments, business and private interests known as Shared Strategy (the forerunner of the Puget Sound Partnership) submitted a Salmon Recovery Plan for Puget Sound, which created a blueprint for restoring habitat in each watershed. NMFS adopted this Recovery Plan. Although habitat restoration is proceeding, key habitat protection components of the Recovery Plan are not being implemented and consequently habitat function is still declining in Puget Sound (Judge 2011, NWIFC 2012, NWIFC 2016). Tribal co-managers have continued to emphasize that we are losing critical salmon habitat faster than we are restoring it and that disparate conservation requirements are being applied to harvest actions compared to those necessary for habitat protection and recovery (NWIFC 2011).

Management of habitat, harvest, and hatcheries must be coordinated with commensurate levels of accountability to support recovery. There are biological and legal limits on the extent to which harvest and hatchery management can promote the recovery of ESA-listed species by compensating for degraded and declining habitat function. Current harvest and hatchery management plans can only react to loss of habitat function. Conservation of listed populations will ultimately necessitate improvements in habitat productivity to be successful.

2. Fisheries and Jurisdictions

Puget Sound Chinook salmon contribute to fisheries along the coast of British Columbia and Alaska, in addition to those in the coastal waters of Washington and the Puget Sound. Therefore, their management involves the local jurisdictions of the Washington co-managers, along with the jurisdictions of the State of Alaska, the Canadian Department of Fisheries and Oceans, the Pacific Salmon Commission (PSC), and the Pacific Fisheries Management Council (PFMC).

2.1 Southeast Alaska

Chinook salmon are harvested in commercial, subsistence, personal use, and recreational fisheries throughout Southeast Alaska (SEAK). From 1999 through 2020, total landed catch ranged from 164,742 to 499,300 (Table 2-1). The SEAK fishery is managed by Alaska Department of Fish and Game to achieve the annual all gear PSC allowable catch through plans established by the Alaska Board of Fisheries (see NPFMC 2018).

Table 2-1. Chinook salmon catch in southeast Alaska fisheries, 1999-2020 (CTC 2021)

Year	Troll	Net	Sport	Total
1999	146,219	32,720	72,081	251,020
2000	158,717	41,400	63,173	263,290
2001	153,280	40,163	72,291	265,734
2002	325,308	31,689	69,573	426,570
2003	330,692	39,374	69,370	439,436
2004	354,658	64,038	80,572	499,268
2005	338,451	68,091	86,545	493,087
2006	282,315	67,396	85,794	435,505
2007	268,146	53,644	82,849	404,639
2008	151,936	43,029	49,265	244,230
2009	175,644	48,438	69,585	293,667
2010	195,614	30,629	58,503	284,746
2011	242,193	48,230	66,575	356,998
2012	209,036	39,750	46,495	295,281
2013	149,541	51,319	56,392	257,252
2014	355,570	50,010	86,942	492,522
2015	269,862	53,718	79,759	403,339
2016	276,432	42,263	68,347	387,042
2017	129,649	25,097	52,306	207,052
2018	107,565	30,777	26,400	164,742
2019	109,364	36,032	29,700	175,096
2020	169,916	29,772	35,100	234,788

Commercial fisheries employ troll, gillnet, and purse seine gear. Commercial troll landings accounted for an average of 67% of total harvest from 1999-2015, while net gear accounted for 13%. The majority of troll catch occurs during the summer season, although winter and spring seasons are also scheduled from October through April. The summer season usually opens July 1st targeting Chinook salmon, then shifts to a Coho salmon directed fishery in August. Gillnet and seine fisheries within State waters target Pink, Sockeye, and Chum salmon, with substantial incidental catch of Coho salmon, and relatively low incidental catch of Chinook salmon.

Total Chinook salmon landed in SEAK recreational fisheries ranged from 26,400 to 86,942 from 1999-2020 (Table 2-1), accounting for an average of 20% of total landed catch. The recreational fishery occurs primarily in June, July, and August. The majority of the effort is associated with non-resident fishers, and is targeted at Chinook salmon. Fishing is concentrated in the vicinity of the major population centers of Ketchikan, Petersburg, Sitka, and Juneau, but also occurs in more remote areas like the coast of Prince of Wales Island.

Chinook salmon from the Columbia River, Oregon coast, Washington coast, west coast of Vancouver Island (WCVI), and northern B.C. contribute significantly to harvest in Southeast Alaska. Most Puget Sound Chinook stocks are subjected to very low or zero mortality in Southeast Alaska, but there are notable exceptions; on average since 1999, 46% of the fishery-related mortality of Hoko, 9% of Nooksack springs, 7% of Stillaguamish, 22% of Skagit summer Chinook, and since 2015 14% of Elwha Chinook occurred in Alaska (CTC 2021).

2.2 British Columbia

The Department of Fisheries and Oceans coordinates commercial and recreational marine and freshwater fisheries and ensures compliance with PSC obligations for Chinook salmon. In British Columbia (B.C.), troll fisheries occur on the northern coast and on the west Coast of Vancouver Island (WCVI). Commercial and test troll fisheries directed at Pink salmon in northern areas, and sockeye on the WCVI and the southern Strait of Georgia incur relatively low incidental Chinook salmon mortality. Net fisheries, including gillnet and purse seine gear in B.C. are primarily directed at Sockeye, Pink, and Chum salmon, but also incur incidental Chinook salmon mortality. Conservation measures have limited Chinook salmon retention in many areas.

Chinook salmon catch in the Northern B.C. and WCVI troll fisheries increased dramatically in 2002 (Table 2-2) resulting in high average catch during the first 10-years since listing and increased exploitation rates for many Puget Sound Chinook Salmon management units in these fisheries. Similarly, catch rates for Canadian tidal sport fisheries in the Salish Sea (Strait of Juan de Fuca, Georgia Strait, and Johnstone Strait) have had an increasing trend from 2008 to present, with the average catch being 5,000 greater than the time period of 1999 to 2007 (Table 2-2). Nooksack spring, Skagit summer/falls, Stillaguamish summer/fall, Hoko fall, and South Puget Sound fall stocks were most impacted by increasing B.C. fisheries, as can be seen in CWT distribution data presented in the management unit profiles in Appendix A.

Table 2-2. Chinook Salmon catch in British Columbia commercial troll and tidal sport fisheries, 1999 - 2020 (CTC 2021)

	1999-2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Aggregate Abundance Based Management (AABM) Fisheries													
NBC Area 1-5 Troll	94,939	75,470	90,213	74,660	80,256	69,264	172,001	106,703	147,381	97,730	72,276	72,826	30,096
WCVI Troll	104,823	58,191	84,123	129,023	69,054	49,526	133,499	68,522	60,478	60,356	36,056	36,841	24,184
WCVI Sport	37,729	66,426	54,924	75,209	66,156	67,345	59,209	50,452	42,615	57,060	49,265	36,641	19,397
Individual Stock Based Management (ISBM) Fisheries													
CBC Troll	256	0	0	0	0	0	0	0	0	0	0	0	0
Johnstone S Troll	198	0	2	0	0	0	0	0	0	0	0	0	0
Georgia S Troll	227	0	5	0	0	0	0	0	0	0	0	0	0
NBC Area 3-5 Sport	9,127	9,177	7,570	14,677	7,017	10,259	11,973	12,760	10,043	10,108	5,821	15,152	8,247
CBC Tidal Sport	7,920	3,239	4,043	7,701	5,861	4,457	7,800	10,597	5,769	6,679	7,704	10,750	1,387
WCVI Tidal Sport	35,926	31,921	24,687	52,131	26,693	23,152	28,756	34,838	23,843	40,107	33,631	42,876	32,248
JDF, GS, JS Sport	57,784	54,982	40,570	54,660	61,216	89,358	83,458	137,220	90,826	119,895	127,828	87,872	59,578

2.3 Washington Ocean

Tribal Indian and non-tribal commercial troll fisheries directed at Chinook, Coho, and Pink salmon, and recreational fisheries directed at Chinook and Coho salmon are scheduled from May through September[1] along the Washington Coast (Catch Areas 1-4B), under co-management by the WDFW and Treaty Tribes. The Pacific Fisheries Management Council (PFMC), pursuant to the Sustainable Fisheries Act (1996), oversees annual fishing regimes in these areas. Tribal fleets operate within the confines of their usual and accustomed fishing areas. Principles governing the co-management objectives and the allocation of harvest benefits among tribal and non-tribal users, for each river of origin, were developed under Hoh v Baldrige (522 F.Supp. 683 (1981)). The declining status of Columbia River origin Chinook salmon stocks (PFMC 2018) has been the primary constraint on coastal fisheries, though consideration is also given to attaining allocation objectives for troll, terminal net, and recreational harvest of coastal origin stocks from the Quillayute, Queets, Quinault, Hoh, and Grays Harbor systems. Ocean fisheries off Washington's coast primarily target Columbia River Chinook (CTC 2017). Puget Sound Chinook salmon make up a relatively low percentage of the catch, with South Puget Sound and Hood Canal stocks exploited at a higher rate than North Puget Sound and Strait of Juan de Fuca Chinook salmon.

The ocean troll fisheries have been structured, in recent years, as Chinook-directed salmon fishing in May and June, and Chinook- and Coho-directed salmon fishing from July into mid-September, to enable full utilization of tribal Indian and non-tribal Chinook and Coho salmon quotas. These quotas (i.e. catch ceilings) are developed in a pre-season planning process that considers harvest impacts on all contributing stocks. Time, area, and gear restrictions are implemented to selectively harvest the target species and stock groups. In general, the Chinook salmon harvest occurs 10 to 40 miles offshore, whereas the Coho salmon fishery occurs within 10 miles off the coast, but annual variations in the distribution of the target species cause this pattern to vary. The majority of the Chinook salmon catch has, in recent years, been caught in Areas 3 and 4 (which, during the summer, includes the westernmost areas of the Strait of Juan de Fuca – Area 4B). Since 1990, troll catch has ranged from 14,747 (2020) to 114,252 (Table 2-3).

Recreational fisheries in Washington Ocean areas are also conducted under specific quotas for each species, and guidelines to each catch area. WDFW conducts creel surveys at each port to estimate catch and keep fishing impacts within the overall quotas. Most of the recreational effort occurs in Areas 1 and 2, adjacent to Ilwaco and Westport. Generally recreational regulations are not species directed, but certain time / area strata have had Chinook non-retention imposed, as conservation concerns have increased, and to enable continued opportunity based on more abundant coho stocks. Since 1999, recreational Chinook catch in Areas 1 – 4 has ranged from approximately 7,508 to 57,821 (Table 2-3).

Puget Sound Chinook salmon stocks comprise less than 10 percent of coastal troll and sport catch (see below for more detailed discussion of the catch distribution of specific populations). The contribution of Puget Sound stocks is higher in northern fishery areas along the Washington coast. The exploitation rate of most individual Puget Sound Chinook salmon management units

[1] Directed fisheries for Chinook primarily target more abundant hatchery stocks. While directed fisheries are primarily prosecuted in spring and summer, there are incidental impacts year-round.

in these coastal fisheries is, in most years, less than one percent (CTC 2017). However, these exploitation rates vary annually in response to the varying abundance of commingled Columbia River, local coastal, and Canadian Chinook salmon stocks.

Table 2-3. Commercial troll and recreational landed catch of Chinook salmon in Washington Areas 1 - 4, 1999 - 2020 (PFMC 2021)

	Troll			
Year	Non-tribal	Tribal	Recreational	Total
1999	17,456	27,452	9,887	55,047
2000	10,269	7,638	8,478	26,536
2001	21,229	28,843	22,974	74,683
2002	53,819	39,846	57,821	151,941
2003	56,202	35,172	34,183	125,803
2004	35,372	49,735	24,907	126,182
2005	35,066	41,975	36,369	118,344
2006	16,769	30,545	10,667	58,677
2007	14,268	22,943	8,944	49,895
2008	8,636	20,907	14,635	46,261
2009	12,316	12,226	12,351	36,893
2010	45,099	32,376	36,874	114,349
2011	26,902	31,824	29,203	87,929
2012	36,855	54,789	33,729	125,373
2013	40,090	51,160	28,918	120,168
2014	38,707	61,761	40,025	140,493
2015	55,313	58,939	39,431	153,683
2016	17,344	23,101	16,907	57,352
2017	32,933	24,414	20,037	77,384
2018	23,556	23,903	9,913	57,372
2019	22,776	18,321	9,583	50,680
2020	12,310	2,437	7,508	22,255

Amendment 16 to the PFMC Framework Management Plan updated conservation of Chinook salmon stocks under the jurisdiction of the PFMC (i.e., coastal ocean fisheries between the borders of Mexico and British Columbia, including Washington catch areas 1 – 4) considered "in the fishery" to align with the Magnuson-Stevens Act and National Standard 1 guidelines. However, the PFMC must also align its harvest objectives with conservation standards required for salmon ESUs, listed under the Endangered Species Act. Additionally, this Plan, along with the Puget Sound Salmon Management Plan, commits the co-managers to explicit consideration of coastal fishery impacts, to ensure that the overall conservation objectives are achieved for all Puget Sound Chinook Salmon Management Units. This requires accounting all impacts on all management units, even in fisheries where contribution is very low.

2.4 Puget Sound

Tribal Ceremonial and Subsistence Fisheries

Indian tribes schedule ceremonial and subsistence salmon fisheries to provide basic nutritional benefits to their members, and to maintain the intrinsic and essential cultural values imbued in traditional fishing practices and spiritual links with the natural resources. All the tribes conduct ceremonial and subsistence fisheries, in pre-terminal and/or in terminal areas. Ceremonial fisheries occur at various times throughout the year, and are usually conducted by a small number of selected fishers when the need arises (e.g., for funerals and special celebrations). Subsistence needs are often met in conjunction with commercial fisheries; a portion of the catch taken in the commercial fishery is taken home by fishers. Some subsistence catches are taken in separately scheduled fisheries, i.e., when commercial fishing is not allowed, subject to the availability of allowable impacts. Chinook salmon catches taken by tribal Indians for ceremonial and subsistence purposes are counted against the applicable tribal allocation and impacts are included in exploitation rate estimates generated by FRAM validation runs for all relevant management units. The magnitude of ceremonial and subsistence harvest of Chinook salmon is small relative to commercial and recreational harvest, and is carefully monitored, particularly where it involves critically depressed stocks.

Commercial Chinook Salmon Fisheries

Several tribes conduct commercial troll fisheries directed at Chinook salmon in the Strait of Juan de Fuca. These fisheries include a winter troll season in Washington Catch Areas 4B, 5, 6, and 6C, and a spring/summer season in Areas 5, 6, and 6B. Washington Catch Area 4B is managed concurrently with the PFMC ocean troll fishery in neighboring areas from May through October. Annual harvest over the past 5 years (2015-2019) has ranged from 426 to 3,272 in the winter troll fishery, and from 143 to 1,646 in the spring/summer troll fishery in the Strait of Juan de Fuca (TOCAS 2022).

Commercial net fisheries, using set and drift gill nets, purse or roundhaul seines, beach seines, and reef nets are conducted throughout Puget Sound, and in the lower reaches of larger rivers. These fisheries are regulated, by WDFW (non-tribal fleets) and by individual tribes (tribal fleets), with time/area and gear restrictions. In each catch area, harvest is focused on the target species or stock according to its migration timing through that area. Management periods are defined as that interval encompassing the central 80% of the migration timing of the species, in each management area. Because the migration timings of different species overlap, the actual fishing schedules may be constrained during the early and late portion of the management period to reduce impacts on non-target species. Incidental harvest of Chinook salmon occurs in net fisheries directed at Sockeye, Pink, Coho, and Chum salmon.

Due to current conservation concerns, Chinook salmon-directed commercial fisheries are of limited scope and most are directed at harvestable hatchery production in terminal areas, including Bellingham/Samish Bay and the Nooksack River, Tulalip Bay, Elliott Bay and the Duwamish River, Lake Washington, the Puyallup River, the Nisqually River, Budd Inlet, Chambers Bay, Sinclair Inlet, and southern Hood Canal and the Skokomish River. Purse or roundhaul seine vessels operate in Bellingham Bay and Tulalip Bay, although these are primarily gillnet fisheries. A small-scale, onshore, marine set gillnet fishery is conducted in the Strait of

Juan de Fuca. Small-scale gillnet research or evaluation fisheries may also occur to acquire management and research data in the Skagit River, Elliott Bay and the Duwamish River, Puyallup River, and Nisqually River. Abundance assessment/test fisheries typically involve two or three vessels making a prescribed number of sets at specific locations, one day per week, during the Chinook salmon migration period.

Total commercial harvest of Chinook salmon in Puget Sound fell from levels in excess of 200,000 in the 1980's, to less than 100,000 in all years from 1993 to 2000 (Figure 2-1). Harvest has increased slightly in recent years, averaging 106,200 since 2000.

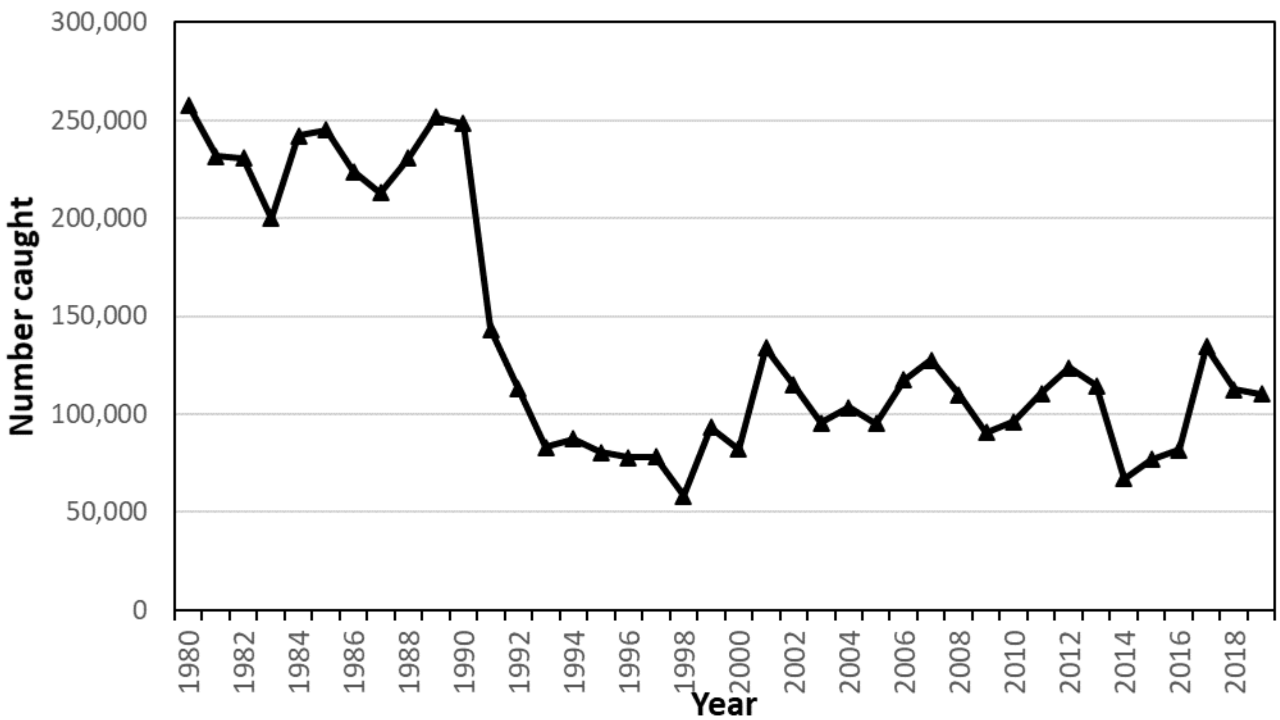

Figure 2-1. Commercial net and troll catch of Chinook in Puget Sound fisheries, 1980 – 2019 (WDFW WaFT database).

Commercial Sockeye, Pink, Coho, and Chum Salmon Fisheries

Net fisheries directed at Fraser River Sockeye salmon are conducted annually, and at Fraser River Pink salmon in odd-numbered years, in the Strait of Juan de Fuca, Georgia Strait, and the Straits and passages between them (i.e., catch areas 7 and 7A). Nine tribes and the WDFW issue regulations for these fisheries, as participants in the Fraser River Panel, under the Pacific Salmon Treaty Annexes. Annual management plans include sharing and allocation provisions, but fishing schedules are developed based on in-season assessment of the abundance of early, early summer, summer, and late-run Sockeye salmon stocks and Pink salmon.

Management has constrained Sockeye salmon harvest in recent years to account for lower survival and pre-spawning mortality of Sockeye salmon. Harvest averaged 213,119 between 2012 and 2020, ranging from 0 to 1,969,188 and typically peaks on a four year cycle (Table 2-4).

Fraser Pink salmon return in odd years, with odd-year catches averaging 1,301,394 over the same period. Recent Pink salmon harvest has increased substantially over the 2001-07 average (PSIT and WDFW 2010), but remains constrained due to concerns for co-migrating late run Sockeye salmon. Most of the Pink salmon harvest is taken by purse seine gear. Specific regulations to reduce incidental Chinook salmon mortality, including requiring release of all live Chinook salmon from non-treaty purse seine fishery hauls, have reduced incidental contribution to total catch. All salmon fishing-related Chinook salmon mortality is accounted.

Table 2-4. Net harvest of Sockeye, Pink, and Chinook salmon in Washington fisheries under Fraser Panel Management, 2012-2020

	Species	2012	2013	2014	2015	2016	2017	2018	2019	2020
Strait of Juan de Fuca	Chinook	1,568	620	1,300	820	258	48	2,200	40	73
	Pink	21	10,537	45	2,118	17	0	8	2	0
	Sockeye	15,682	4,510	4,012	1,040	1,453	0	60,170	0	0
Rosario and Georgia Straits	Chinook	432	3,913	6,835	4,781	19	2,565	3,348	3,640	39
	Pink	1,744	4,070,275	638	694,238	4	125,368	102	303,039	0
	Sockeye	103,605	22,884	709,840	51,653	68	1,531	941,151	470	0

Commercial fisheries directed at Cedar River Sockeye salmon stocks may occur in Shilshole Bay, the Ship Canal, and Lake Washington. The Cedar River stock does not achieve harvestable abundance consistently and has not had a significant fishery since 2006. Smaller scale commercial fisheries targeting Baker River Sockeye salmon occur in the Skagit River. These fisheries generally involve low incidental Chinook salmon mortality (PSIT and WDFW 2015, 2016, 2017, 2018, 2019, 2020, and 2021).

Commercial fisheries directed at Puget Sound-origin Pink salmon occur in terminal marine areas and freshwater in Bellingham Bay and the Nooksack River, Skagit Bay and Skagit River, Possession Sound / Port Gardner (Snohomish River system), and more recently in South Puget Sound rivers when abundance is projected to exceed escapement requirements. Because of the timing overlap of Pink and Chinook salmon in the Nooksack region, Pink salmon harvest is a bycatch taken in the fall Chinook salmon fishery that occurs after August 1, after the bulk of the Pink salmon run has passed. New Pink-targeted salmon opportunities occurred starting in 2007 in Marine Area 10 (Seattle Area), Elliott Bay, and the Duwamish, corresponding to the large increase in abundance of Pink salmon in the Green and Puyallup River systems in recent years. Terminal Pink salmon fisheries can involve significant incidental catch of Chinook salmon, due to the large overlap in run timing of the two species. Pink Salmon catches in each of the terminal areas have been variable since 2007 (Table 2-5), and largely reflect the patterns of Pink salmon abundances returning to those areas during that time.

Table 2-5. Commercial net harvest of Pink salmon from Nooksack, Skagit, Snohomish, and South Puget Sound terminal areas, 2007-2019.

Terminal Area	2007	2009	2011	2013	2015	2017	2019
Bellingham Bay/Nooksack	675	2,961	6,232	87,001	66,491	8,755	17,636
Skagit Bay/River	2,764	298,624	312,679	516,847	55,195	1,049	286
Stillaguamish/Snohomish	20,067	487,848	439,902	1,006,159	106,324	148	5,051
South Puget Sound	13,768	183,336	105,600	188,620	47,094	2,544	2,323

Commercial fisheries directed at Coho salmon also occur around Puget Sound and in some rivers. Coho salmon are also caught incidentally in fisheries directed at Chinook, Pink, and Chum salmon. From 2014-2020, total landed Coho salmon catches have been relatively stable around 200,000, with a lower catch of 18,503 occurring in 2015 and 91,925 in 2019 (Table 2-6). The largest catches occur in South/Central Puget Sound, with in-river fisheries targeting hatchery Coho salmon in the Green and Puyallup, and marine fisheries targeting net pen production in deep South Sound.

Table 2-6. Landed Coho salmon harvest in Puget Sound net fisheries, 2014-2020. Regional totals include freshwater catch.

	2014	2015	2016	2017	2018	2019	2020
Strait of Juan de Fuca	5,572	1,542	4,644	5,879	7,719	1,618	4,989
Georgia & Rosario Strait	19,697	3,530	4,056	3,310	3,800	1,886	5,195
Nooksack-Samish	29,431	15,169	51,753	29,752	55,220	28,950	40,921
Skagit	14,286	3,015	5,576	1,044	13,267	4,545	14,227
Stillaguamish-Snohomish	46,704	8,255	77,236	45,320	25,916	5,210	17,207
South Puget Sound	57,995	11,104	98,159	80,545	108,501	42,705	102,875
Hood Canal	27,904	5,888	26,234	22,476	22,317	7,011	11,281
Total	201,589	48,503	267,658	188,326	236,740	91,925	196,695

Marine and freshwater fisheries targeting fall Chum salmon occur in many areas of Puget Sound in most years. Since 2011, chum harvests in Puget Sound have been large, ranging from 996,187 to more than 1,700,000 although has decreased substantially in recent years (2018 and 2019) due to conservation concerns for meeting escapement of individual spawning stocks in South Sound and Hood Canal (Table 2-7). Due to the later migration timing of fall Chum salmon, most Chinook salmon caught incidentally in marine areas are immature ‘blackmouth’. Incidental Chinook salmon catch is low.

Table 2-7. Landed Chum salmon harvest in Puget Sound commercial fisheries, 2014 - 2020. Regional totals include freshwater catch.

Region	2014	2015	2016	2017	2018	2019	2020
Strait of Juan de Fuca	5,286	7,389	26,702	4,010	4,638	425	292
Georgia & Rosario Strait	147,022	124,774	118,461	123,282	66,444	612	87,551
Nooksack-Samish	32,665	39,846	45,827	17,885	5,298	6,503	6,408
Skagit	1,434	1,484	477	246	594	206	696
Stillaguamish-Snohomish	11,139	5,136	1,300	2,587	415	7	
Area 9	8,166	13,362	24,202	45,036	43,842	21,785	13,995
Hood Canal	569,473	639,395	564,355	828,889	446,726	181,424	99,650
South Puget Sound	393,780	337,079	214,490	389,837	281,216	73,388	66,726
Total	1,168,965	1,168,465	995,814	1,411,772	849,173	284,350	275,318

Recreational Fisheries

Recreational salmon fisheries occur in marine waters in Washington Catch Areas 5-13 and freshwater areas, under regulations promulgated by the Washington Department of Fish and Wildlife. In marine areas, the principal target species are Chinook and coho salmon. Since the mid-1980's the total annual marine harvest of Chinook has declined steadily from levels in excess of 100,000 in the late 1980's, to an average of almost 34,000 since 2002 (Figure 2-2). Marine area coho harvest has also decreased from an average of over 220,000 in the late 1980's, to an average of 74,000 since 2002.

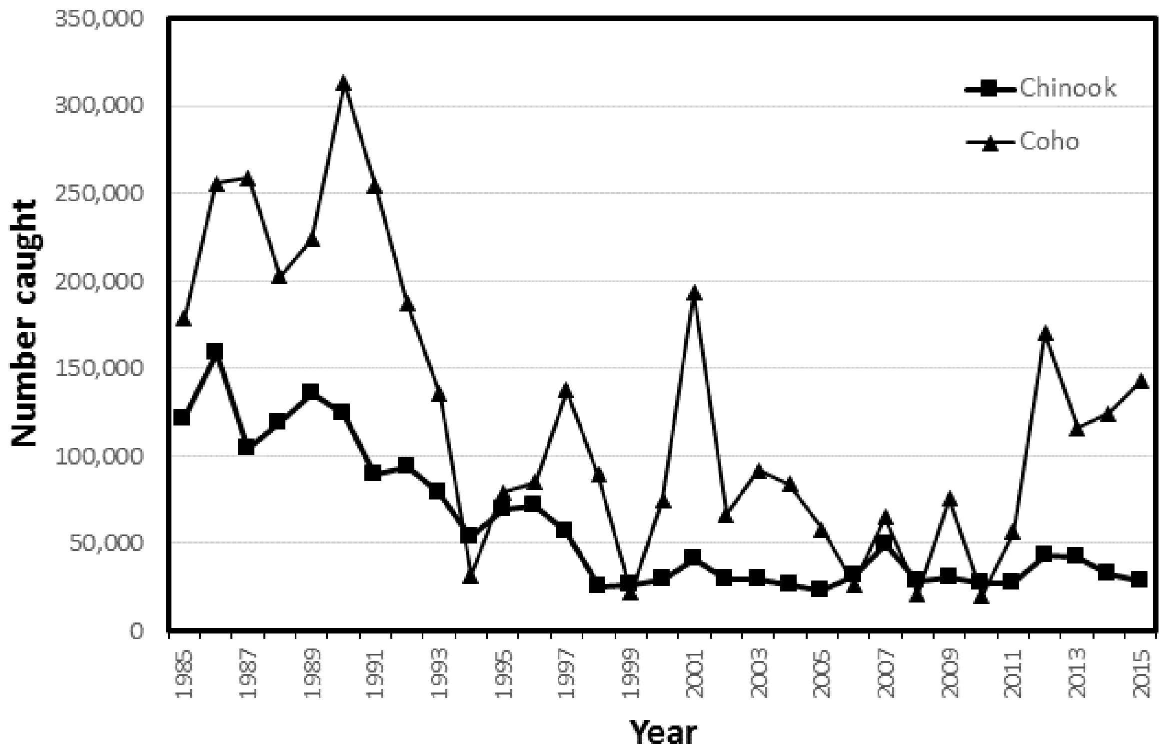

Figure 2-2. Recreational salmon catch in Puget Sound marine areas, 1985 - 2020 (WDFW CRC estimates, 2020 data are preliminary)

Freshwater recreational catch has shown an increasing trend since the late 1980's (Figure 2-3), likely in response to constraints placed on marine opportunity, and to the increasing abundance of some stocks. The number of ESA-listed adult Chinook encounters that occurs in non-directed salmon, trout/char, and spiny rayed fisheries vary by target species, the region fished, and the time period fished.

Recreational Chinook catch has been increasingly constrained in mixed-stock marine areas to avoid overharvest of weak Puget Sound populations. Time and area closures and mark-selective fisheries have been implemented to limit impacts on weak wild stocks. Recreational fishery mortality (landed and incidental) is accounted in exploitation rate estimates for Chinook and coho. In recent years, WDFW has allocated the majority of Chinook and coho mortalities in non-tribal fisheries to the recreational sector.

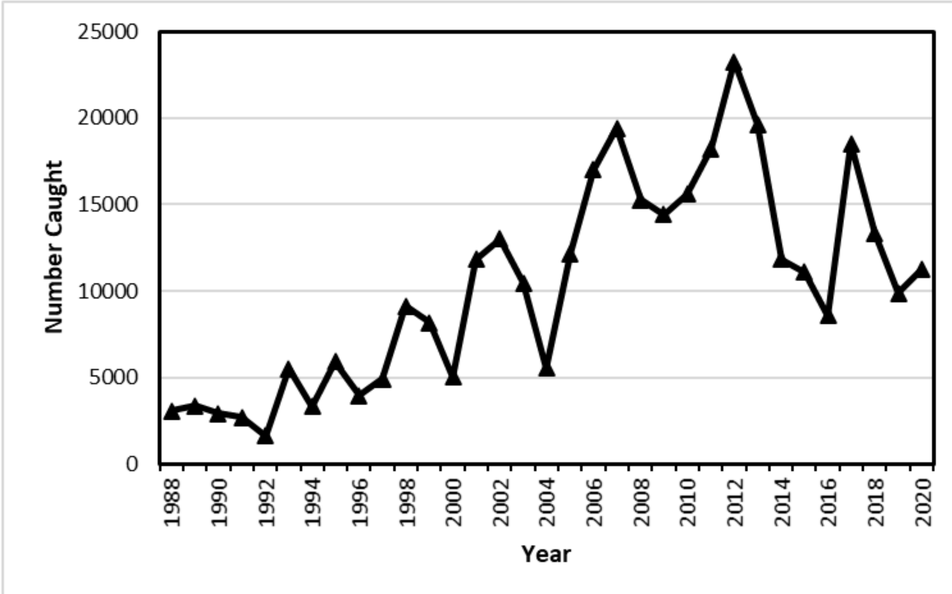

Figure 2-3. Recreational Chinook harvest in Puget Sound freshwater areas, 1988 – 2020 (WDFW Catch Record Card estimates; 2020 data are preliminary).

2.5 Fishery Impact Assessment

The Chinook Fishery Regulation Assessment Model (FRAM) is used by the co-managers and others to estimate the impacts of proposed fisheries on Chinook salmon stocks for a single management year. The model includes stocks from central CA to southern BC, and estimates impacts in fisheries from Southern California to Southeast Alaska. The model uses coded-wire tag (CWT) recoveries from brood years 2005-2008 to estimate maturation rates and rates of fishery impacts for each stock. These rates are estimated separately for each age group within the stock (age 2 to age 5). Each year, forecasts of terminal stock abundance and estimates of fishery catch and/or effort are input into the model to estimate the overall impacts on each stock of the proposed fishery package. Impacts are reported in many forms, including landed catch, release mortality for sublegal and unmarked fish, total fisheries mortality (catch and release mortality), net drop out, and adult equivalence (AEQ) total fisheries mortality which accounts for the chance a fish caught in a pre-terminal fishery would die of natural causes before spawning. Salmon fishing-related mortality from all the fisheries in the FRAM are included in the mortality estimates. Chinook FRAM is usually used with terminal area management modules (TAMMs) which split out FRAM stocks into finer stocks and model terminal area fisheries. The exploitation rates used by co-managers are calculated in the TAMM for each stock as total AEQ fisheries-related mortality divided by the sum of total AEQ fisheries-related mortality and escapement.

Chinook FRAM is also used for post-season runs, in which the two major FRAM inputs (forecasts and estimates of fishery catch/effort) are replaced by terminal run sizes and actual fishery catch. The impacts on each stock are then estimated using the base period-derived stock-, age-, and fishery-specific exploitation rates and maturation rates as in the pre-season model, although an identical comparison is often not possible given revisions that occur to the FRAM model framework from year to year. In 2017, the base period used for the FRAM model was updated to use CWT from recent years (brood-years 2005-2008), to better reflect current stock distributions and more contemporary fisheries. Other methods of post-season evaluation (cohort reconstruction using CWT recoveries, genetic stock identification[2] methods to identify the impacts of a given fishery) could provide alternate estimates of fisheries impacts to a stock that reflect distribution in the year of interest, rather than assuming that distribution is identical to the base period.

2.6 Non-Landed Fishery Mortality

Non-landed or incidental mortality occurs in almost all commercial and recreational fisheries that encounter Chinook salmon. For some fishing gears, studies designed to quantify the rate of mortality of this fishing related impact have produced a scientific basis for fishery managers to estimate and account for this source of mortality. For other fisheries, studies sufficient for quantifying non-landed mortality have not been conducted. Absent a scientific basis, fishery managers have agreed on assumptions about mortality rates to use for estimation and accounting of this mortality source. The rates currently agreed upon for estimation of non-landed mortality vary greatly by gear type as well as by the size or maturity of Chinook Salmon encountered (Table 2-8). These agreed rates are incorporated into FRAM and other management planning or assessment models. Hook-and-line fisheries are regulated by size limits, recreational bag limits, non-retention periods, and mark-selective periods, resulting in required releases of some Chinook Salmon. A proportion of the fish not kept will die from hooking injury or handling trauma. Rates are higher for commercial troll than for recreational gear, and higher for small fish.

As bag limits on recreational fisheries have decreased, and the use of mark-selective fishery strategies has expanded, the non-landed proportion of total mortality has risen. Literature on release mortality has been reviewed periodically by the Washington co-managers, as well as in the PFMC and Pacific Salmon Treaty forums. Non-landed mortality rates associated with hook-and-line fisheries have been adjusted, so that fisheries simulation models used in management planning express the best available science. For hook-and-line gear in Washington fisheries, the Co-managers have also agreed to incorporate an additional, possible source of non-landed mortality with fishery impact assessments. That possible source is termed “drop-off” mortality, and refers to fish that are hooked but escape before being brought to the boat. No scientific basis is available to estimate this mortality source but it is assessed as a proportion of the total landed catch.

Table 2-8. Chinook salmon incidental mortality rates applied to commercial and recreational fisheries in Washington.

Fishery: (designated by area, user group, and/or gear type)	**FisheryType**	**Comments**	**Release Mortality**	**"Other" Mortality**[a]
PFMC Ocean Recreational[d]	Retention MSF	 Barbless	n.a.[c] 14.0%	5.0% 5.0%
PFMC Ocean T-Troll PFMC Ocean NT-Troll	Retention Non-Retention MSF	 barbless	n.a.[c] 26.0% [b] 26.0%	5.0% 5.0% [b] 5.0%
Area 5, 6C Troll	Retention		n.a.	5.0%
Puget Sound Recreational[e]	Retention Non-Retention MSF	 barbless	n.a.[c] 10-20% [b] 10-20%	5.0% 5.0% 5.0%
WA Coastal Recreational	Retention		n.a.	5.0%
Buoy 10 Recreational	MSF MSF	barbed barbless	16.0% 14.0%	5.0% 5.0%
Gillnet and Setnet			100%	2.0%
PS Purse Seine			33-45 % [b]	2.0%
PS Reef Net			0.0%	0.0%
Beach Seine			n.a.[b]	n.a.
Round Haul			26.0% [b]	2.0%
Freshwater Net			n.a.	n.a.
Freshwater Recreational	Retention Non-Retention MSF		n.a. 10.0% [b] 10.0% [b]	n.a. n.a. n.a.

[a] The "other" mortality rates (which include drop-out and drop-off) are applied to landed fish (retention fisheries), thus FRAM does not assess "drop-off" in non-retention fisheries. Drop-off (and release mortality) associated with CNR fisheries are estimated outside the model and used as inputs to the model. For mark-selective fisheries (MSF), "other" mortality rates are applied to encounters of marked and unmarked fish.
[b] Recreational release mortality is 10 % for fish $\geq$ 22" and 20 % for fish < 22" (WDFW et al. 1993). Purse seine release mortality is 33 % or 45 % depending on season and maturity (CTC 2004). Rate assessed externally to FRAM.
[c] None assessed.
[d] Source: Salmon Technical Team (2000).
[e] Source: WDF et al. (1993).

The various types of net gear also exert non-landed mortality. Few studies have been conducted to quantify rates of non-landed mortality applying to net gear, as such studies are difficult to design and implement. Gillnet dropout is one source of non-landed mortality that results from fish killed as a result of encountering gear, but dropping out of the gear or succumbing to predation by marine mammals prior to successful collection. Absent a scientific basis for estimating these effects, the dropout incidental mortality is estimated assuming the effect is 3% of landed catch in pre-terminal areas and 2% in terminal marine fisheries. Purse seine regulations for the non-treaty fleet require a strip of wide-mesh net at the surface of the bunt to reduce the catch of immature Chinook salmon. Immature Chinook salmon caught by seine gear are assumed to have a higher mortality than mature Chinook salmon. Non-treaty seine fishers have been required to release all Chinook salmon in all areas of Puget Sound (7B/7C hatchery-Chinook salmon directed fishery excluded) in recent years. Mortality rates vary due to a number of factors, but work in British Columbia has shown that over two-thirds of Chinook salmon survive seine capture (Candy et. al, 1996). This is particularly true if the fish are sorted immediately or allowed to recover in a holding tank before release. Because catch per set is typically small for beach seine and reef net gear, it is assumed Chinook salmon may be released without harm. Conservatively higher release mortality is assumed for some beach seine fisheries (e.g. the Skagit Pink salmon fishery= 50% release mortality). Research continues into net gear that reduces release mortality, with promising results from recent tests of tangle nets (Vander Haegen et al. 2004, Ashbrook et al. 2005). In any case, non-landed mortality is accounted by managers, according to the best available information, to quantify the mortality associated with harvest.

2.7 Regulatory Jurisdictions affecting Washington fisheries

Fisheries planning and regulation by the Washington co-managers are coordinated with other jurisdictions, in consideration of the effects of Washington fisheries on Columbia River and Canadian Chinook salmon stocks. Pursuant to U.S. v Washington (384 F. Supp. 312), the Puget Sound Salmon Management Plan (1985) provides fundamental principles and objectives for co-management of salmon fisheries.

The Pacific Salmon Treaty, originally signed in 1984, commits the co-managers to equitable cross-border sharing of the harvest and conservation of U.S. and Canadian stocks. The Chinook salmon Chapter of the Treaty, which is implemented by the Pacific Salmon Commission, establishes ceilings on Chinook salmon exploitation rates in southern U.S. fisheries. The thrust of the original Treaty, and subsequently negotiated agreements for Chinook salmon, was to constrain harvest on both sides of the border in order to rebuild depressed stocks.

The PFMC is responsible for setting harvest levels for coastal salmon fisheries in Washington, Oregon, and California. The PFMC adopts the management objectives of the relevant local authority, provided they meet the standards of the Sustainable Fisheries Act. The Endangered Species Act has introduced a more conservative standard for coastal fisheries, when they impact listed stocks.

Puget Sound Salmon Management Plan (U.S. v. Washington)

The Puget Sound Salmon Management Plan (PSSMP) remains the guiding framework for jointly agreed management objectives, allocation of harvest, information exchange among the co-managers, and processes for negotiating annual harvest regimes. At its inception, the Plan implemented the court order to provide equal access to salmon harvest opportunity to Indian tribes, but its enduring principle is to “promote the stability and vitality of treaty and non-treaty fisheries of Puget Sound… and improve the technical basis for …management.” It defined management units (see Chapter III, PSSMP), and regions of origin, as the basis for harvest objectives and allocation, and established maximum sustainable harvest (MSH) and escapement as general objectives for all units. The PSSMP also envisioned the adaptive management process that motivated this Plan. Improved technical understanding of the biological parameters of populations, and assessment of the actual performance of management regimes in relation to management objectives and the status of stocks, will result in continuing modification of harvest objectives.

Pacific Salmon Treaty

Public Law 99-5 established the Pacific Salmon Treaty Act of 1985 and initiated the coordination of management of Chinook salmon coast wide. The Pacific Salmon Commission is the administrative body for implementation of the treaty and has authority over Chinook originating from watersheds from Southeast Alaska, British Columbia, Washington, Oregon and Idaho. Domestic allocation decisions remain under the purview of each country and each party can take more conservative management action as necessary.

In 1999, negotiations between the U.S. and Canada resulted in a new, comprehensive Chinook salmon agreement, which replaced the previous fixed-ceiling regime with a new approach based on the annual abundance of stocks. It included increased specificity on the management of all fisheries affecting Chinook salmon, and sought to address the conservation requirements of a larger number of depressed stocks, including some that are now listed under the ESA.

The 1999 agreement established a two-tiered management approach which is still utilized. Fisheries are classified either as aggregate abundance-based management regimes (AABM) or individual stock-based management regimes (ISBM). The agreement defines “an AABM fishery (as) an abundance-based regime that constrains catch or total adult equivalent mortality to a numerical limit computed from either a pre-season forecast or an in-season estimate of abundance, and the application of a desired harvest rate index expressed as a proportion of the 1979-1982 base period” (PSC 2001). All Chinook salmon fisheries subject to the Treaty which are not AABM fisheries are classified as ISBM fisheries, including freshwater Chinook salmon fisheries. The agreement defines “an ISBM fishery is an abundance-based regime that constrains to a numerical limit the total catch or total adult equivalent mortality rate within the fisheries of a jurisdiction for a naturally spawning Chinook salmon stock or stock group” (PSC 2001).

All Chinook salmon fisheries within Washington State waters are classified as ISBM fisheries. The PSC agreement specifies that Canada and the U.S. shall manage their ISBM fisheries, for a specified list of indicator stocks, to contribute to the achievement of agreed to MSY or other biologically-based escapement objectives that are consistent with recovering and sustaining healthy and productive stocks and fisheries. In Puget Sound these include Nooksack early, Skagit summer/fall and spring, Stillaguamish, and Snohomish stocks.

Currently, the PSC Chinook agreements have a 10-year duration with the current agreement taking effect in 2019. Representatives for the United States and Canada agreed to continue with the current two-tiered management approach. It is anticipated that the renegotiation of the Chinook agreement will result in adjustments to the AABM and ISBM regimes as necessary to sustain healthy stocks while addressing the conservation needs of depressed natural stocks. A large focus of the 2019 negotiations have were directed at addressing the conservation needs of Georgia Strait and Puget Sound Chinook salmon including the Puget Sound critical stocks program. For Puget Sound stocks, these include a required 12.5% reduction in exploitation rates on Nooksack Springs, Skagit Springs, Skagit Summer/Falls, Stillaguamish, Snohomish relative to the 2009-15 average exploitation rate for Canadian ISBM fisheries. For Southern US ISBM fisheries, a 5% exploitation rate reduction relative to the 2009-15 average is required for Skagit indicator stocks, while remaining indicators stocks exploitation rates are consistent with the 2009-15 average CYER in US ISBM fisheries. For AABM fisheries, the agreement requires reductions relative to the past by a magnitude that varies depending upon estimated annual aggregate abundance metrics (see Chapter 3 of PST 2019 for additional details).

Distribution of Fishing Mortality

A significant portion of the fishing mortality on many Puget Sound Chinook salmon stocks occur outside the jurisdiction of this plan, in Canadian and/or Southeast Alaskan fisheries, based on recoveries of coded-wire tags from indicator stocks (Table 2-9). Of the Puget Sound indicator stocks, more than half of total mortality of Nooksack spring, Skagit summer/fall, Stillaguamish summer/fall, and Hoko fall Chinook salmon occurs in Alaska and Canada. Washington troll fisheries account for smaller portions of total exploitation, accounting for 6 to 10% for Samish, Skokomish, Nisqually, and South Puget Sound stocks. Puget Sound net and U.S. sport fisheries account for the majority of mortality on Skagit spring, Samish fall, Skokomish fall, Nisqually, and South Puget Sound fall stocks.

Table 2-9. 2009-2019 average distribution of fishery mortality, based on coded-wire tag recoveries, for Puget Sound Chinook salmon indicator stocks (CTC 2021).

Indicator stock	Alaska	Canada	US troll	US net	US sport
Nooksack spring fingerling	8.8%	67.0%	3.1%	11.1%	9.9%
Samish fall fingerling	0.6%	29.5%	7.4%	48.2%	14.3%
Skagit spring fingerling	2.1%	33.8%	0.9%	46.8%	16.4%
Skagit summer/fall fingerling	19.4%	49.2%	1.6%	18.3%	11.5%
Stillaguamish fall fingerling	5.8%	55.6%	2.6%	10.8%	25.3%
Skykomish fingerling	2.8%	48.5%	3.8%	2.2%	42.6%
White River spring	0.0%	4.2%	0.7%	75.7%	19.3%
South Puget Sound fall fingerling	1.1%	35.3%	10.8%	11.7%	41.2%
Nisqually fall fingerling	0.1%	15.1%	8.0%	42.2%	34.5%
Skokomish fall fingerling	0.3%	21.5%	6.7%	38.1%	33.5%
Hoko fall fingerling	34.6%	49.9%	3.5%	0.2%	11.8%

Trends in Exploitation Rates

Post-season FRAM ('validation') runs, which incorporate catch and stock abundance from post-season assessments, are available for management years 1992-2018, and can show trends in the total exploitation rate of Puget Sound Chinook salmon over that time. The base period for the FRAM model was updated in 2017, and validation runs for years prior to 1991 are not available using the newer base period. For these models, post-season abundances (total recruitment) are estimated from the observed terminal run sizes by using pre-terminal expansion factors estimated using CWT-based preterminal exploitation rates, or from fishing effort scalars.

For Category 1 populations (see Section 3.3), fisheries management has reduced exploitation rates steadily since the 1980's. Total exploitation rates on Skagit, Stillaguamish, and Snohomish units declined dramatically through the 1990's, to roughly one-third to one-half of earlier values by the late 90's, though Skagit has increased more recently (Figure 2-4). Exploitation rates on Nooksack, Skagit, and White river spring Chinook stocks have generally stabilized since the mid 90's (Figure 2-5).

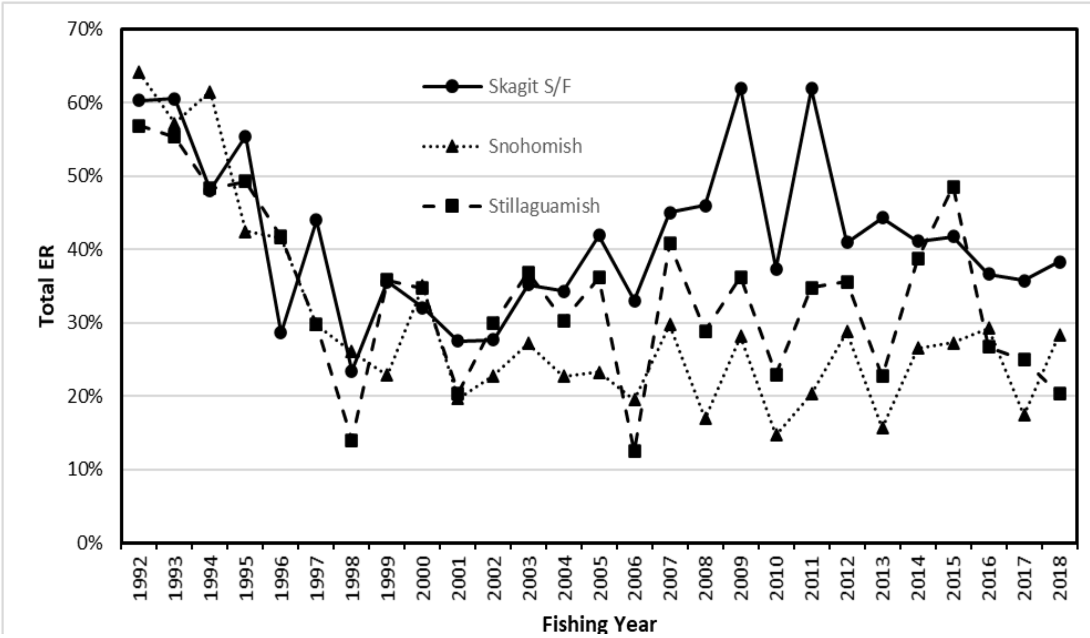

Figure 2-4. Total exploitation rate for Skagit, Stillaguamish, and Snohomish summer/fall Chinook salmon management units, 1992-2018 (based on 2021 FRAM validation run 7.1.1).

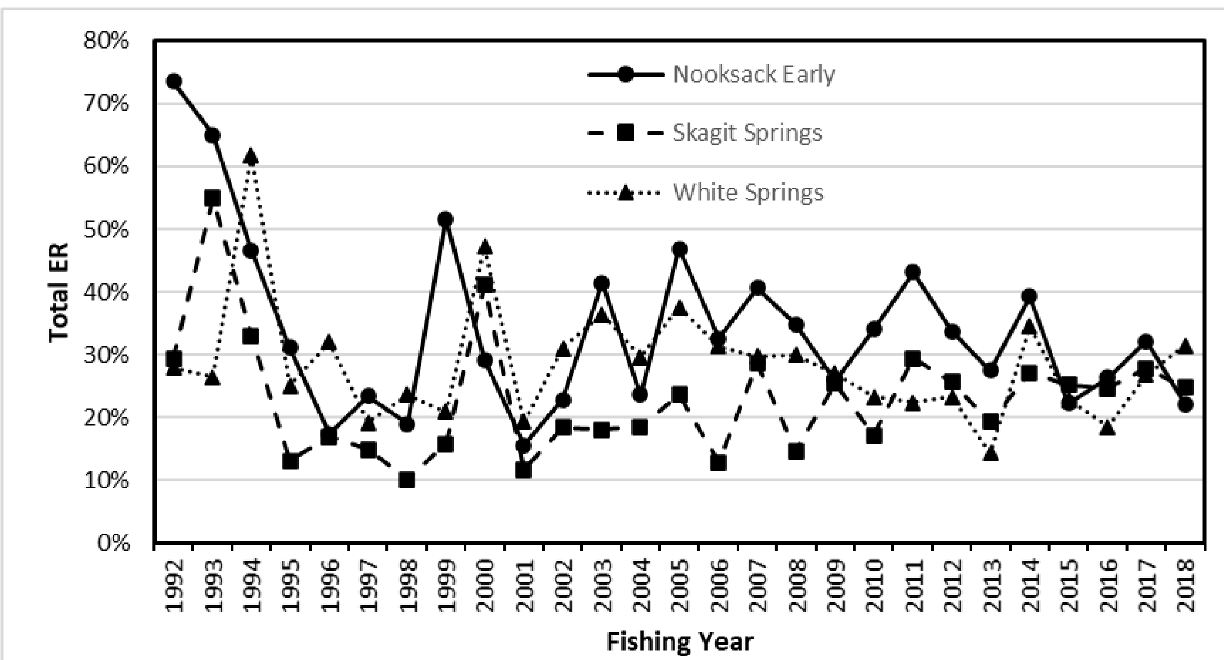

Figure 2-5. Total exploitation rate for Nooksack, Skagit, and White spring Chinook salmon management units, 1992-2018 (based on 2021 FRAM validation run 7.1.1).

3. Population Structure – Aggregation for Management

This section describes the population structure of the Puget Sound Chinook ESU, and how populations of similar run timing returning to similar terminal areas are aggregated into Management Units for the purposes of harvest management in some river systems (i.e. ESU spatial structure and diversity).

3.1 Population Structure

The Puget Sound Chinook ESU comprises 22 extant populations (Table 3-1) (also referred to as stocks in this document) originating in 12 river basins (PSTRT 2005). This Plan also includes management objectives for Chinook salmon originating in the Hoko River in the western Strait of Juan de Fuca and outside the Puget Sound Chinook Salmon ESU. The intent of the population structure of this Plan is to manage fishery-related risk, in order to conserve the spatial structure , genetic and ecological diversity in relation to run timing of populations across the ESU.

Extant Puget Sound Chinook salmon were delineated into stocks in the Salmon and Steelhead Stock Inventory (SASSI) (WDF et al. 1993); the 2001 Harvest Plan was generally based on the SASSI stock designation. Those stocks generally occurred in watersheds where independent populations existed historically. To assist their delineation of historical population structure, the Puget Sound Technical Recovery Team (TRT) further examined juvenile freshwater life history, age of maturation, spawn timing, and physiographic characteristics of watersheds (Ruckelshaus et al. 2006). The spatial structure of the stocks in this Plan for the most part conforms to the TRT population delineation (Ruckelshaus et al. 2006) that was developed as part of recovery planning.

Puget Sound Chinook Salmon populations in this Plan are classified according to their migration timing as spring-, summer-, or fall-run Chinook salmon (see Appendix A for further clarification), but specific return timing toward their natal streams, entry into freshwater, and spawning period varies significantly as ‘races’ within each of these run timings (Ruckelshaus et al. 2006). Run timing is an adaptive trait that has evolved in response to specific environmental and habitat conditions in each watershed. Fall Chinook salmon are present in the majority of systems including the lower Skagit, Stillaguamish, Snoqualmie, Cedar, Green, Puyallup, Nisqually, Skokomish, mid-Hood Canal, and Hoko rivers, and in tributaries to northern Lake Washington and Sammamish River[3]. Summer runs originate in the Elwha, Dungeness (spring/summer), upper Skagit, lower Sauk, Stillaguamish, and Skykomish rivers. Spring (or ‘early’) Chinook salmon are produced in the North / Middle and South Forks of the Nooksack River, the upper Sauk River, Suiattle River, and upper Cascade River in the Skagit basin , and the White River in the Puyallup basin.

[3] Data collected by the co-managers since 2006 indicate that 1) the Sammamish population, as defined by the TRT, is no longer distinct from the Cedar River population and 2) habitat conditions are unlikely to support a viable population. Consequently, this population should not be included in the list of 22 distinct stocks managed in the Puget Sound ESU. The Lake Washington management unit represents the independent population for this area.

Table 3-1. Natural management units for Puget Sound Chinook Salmon and their component populations and subpopulations. The production category (see Section 3.3) of each population is noted in parentheses.

Management Unit	Component Populations
Nooksack Early	North/Middle Fork Nooksack River (1) South Fork Nooksack River (1)
Skagit Summer / Fall	Upper Skagit River Summer (1) Lower Sauk River Summer (1) Lower Skagit River Fall (1)
Skagit Spring	Upper Sauk River (1) Suiattle River (1) Upper Cascade River (1)
Stillaguamish Summer / Fall	Stillaguamish Summer (1) Stillaguamish Fall (1)
Snohomish	Skykomish River Summer (1) Snoqualmie River Fall (1)
Lake Washington	Cedar River Fall (1) Sammamish Fall (2)
Green	Green River Fall (1)
White	White River Spring (1)
Puyallup	Puyallup River Fall (2)
Nisqually	Nisqually River Fall (2)
Skokomish	North and South Fork Skokomish River Fall (2)
Mid-Hood Canal [1]	Hamma Hamma River Fall (2), Duckabush River Fall (2), and Dosewallips River Fall (2)
Dungeness	Dungeness River Spring/Summer(1)
Elwha	Elwha River Summer (1)
Western Strait of Juan de Fuca [2]	Hoko River Fall (1)

[1] The various spawning aggregations in these rivers are considered one population.
[2] The Hoko River is not part of the listed Puget Sound ESU.

Juvenile Puget Sound Chinook salmon populations primarily exhibit a sub-yearling (‘ocean type’) smolt life history (i.e. spending a few weeks or less in freshwater). A small (less than 5 percent) proportion of juvenile fall Chinook salmon and a larger and more variable proportion of juvenile spring and summer Chinook salmon in some systems rear in freshwater for 12 to 18 months before emigrating. Expression of this ‘stream-type’ life history is believed to be influenced more by environmental factors than genotype (Myers et al. 1998). Refer to Appendix A for further information on early life-history *diversity metrics* for each management unit.

The oceanic migration of Puget Sound Chinook salmon typically proceeds north into the coastal waters of British Columbia, and for some stocks, extends to southeast Alaska. For many stocks a large proportion of their harvest occurs in the southern waters of British Columbia (i.e., in Georgia Strait and the west coast of Vancouver Island). Adult Chinook salmon become sexually mature at the age of three to six years; most Puget Sound Chinook salmon mature at age-3 or 4. A small proportion of males mature precociously during their freshwater residence, or after shorter ocean residence (i.e. 'jacks'). Refer to Appendix A for specific information on age at maturation *diversity metric* for each management unit.

Puget Sound Chinook salmon are genetically distinct and adapted to the local freshwater and marine environments of this region. Retention of their unique characteristics depends on maintaining healthy and diverse populations across the ESU. A central objective of this Plan is to assure that the abundance of each population is conserved, at a level sufficient to protect its genetic integrity.

Allozyme-based analysis of the genetic structure of the Puget Sound ESU indicates six distinct genetic clusters: 1) Strait of Juan de Fuca, 2) Nooksack River early, 3) Skagit spring, summer, fall, and Stillaguamish River summer (formerly North Fork Stillaguamish summer-run)[4], 4) Snohomish River and Stillaguamish River[4] fall-runs (formerly South Fork Stillaguamish fall-run), 5) central and southern Puget Sound and Hood Canal late, and 6) White River early (Figure 6 in Ruckelshaus et al. 2006). The genotypes of populations in South Puget Sound and Hood Canal reflect use and establishment of Green River-origin fish from large-scale hatchery production in those areas. Indigenous early- and/or late-timed populations were extirpated in the Nooksack (late run), Stillaguamish (early run), Snohomish (early run), Lake Washington-Sammamish basin (late run), Green/Duwamish (early run), Puyallup (early and late run), Nisqually (early and late run), Skokomish (early and late run), Mid-Hood Canal (early and late run[5]) and Elwha (early run) (Table 6 in Ruckelshaus et al. 2006). Genetic analyses of extant returns to these systems do not detect continued distinct, indigenous genotypes. .

This Plan does not establish harvest objectives where Chinook salmon return solely due to local hatchery production or as strays from other systems (e.g., the Samish River, Gorst Creek and other streams draining into Sinclair Inlet, Deschutes River, and several independent tributaries in South Puget Sound).

3.2 Management Units

The availability and quality of data to inform management of individual populations varies. For some populations, the only directly applicable data are spawning escapement estimates. In such cases, estimates of migratory pathways, entry patterns, age composition and maturation trends, age at recruitment, catch distribution and contributions must be inferred from the most closely related population for which such information is available. This Plan aggregates populations returning to the same terminus rivers and exhibiting similar run timing into management units for the purpose of managing harvest (Table 3-1). This is due largely to the spatial and temporal

[4] Analysis of subsequent data gathered since this initial work indicates that the geographic distinction for the Stillaguamish River populations is not warranted. Genetic analysis of this data indicates that while two distinct run-timings populations still exist, the populations overlap spatially within the basin and are not geographically isolated. The comanagers now view this as a summer/fall management unit, with two populations, a summer-run population and a fall-run population, distinguished exclusively by run timing.

[5] The TRT was inconclusive as to whether an independent, indigenous fall-run stock occurred in the Mid-Hood Canal rivers, although one was included in the PS Recovery Plan. Regardless, the current extant stock is indistinguishable from Skokomish River hatchery and wild Chinook and from other stocks established from use of Green River origin fish for hatchery production.

commingling of these populations throughout their harvest distribution as well as current utilization of coded wire tags (CWT) in representative hatchery indicator stocks intended to represent the similar run timing of the component populations as one unit, and not each population independently. For these management units, a technical means for planning or implementing differential harvest of single populations does not exist.

Prior to the conclusion of U.S. v Washington in 1974, almost all fisheries on Puget Sound salmon were conducted in marine waters, with no explicit management units or escapement goals. The Boldt decision, however, mandated that fish be allowed to return to tribal fishing areas near the mouths of Puget Sound rivers. This stipulation, combined with the need for improved stock-by-stock management, required the delineation of management units and the development of spawning escapement goals. The Puget Sound Salmon Management Plan (PSSMP) established the basis for management units, escapement goals, management periods, and other elements of an effective harvest management plan. In general, management units have been established for one or more stocks of a single species returning over a similar duration to a single river system that flows into saltwater, or as otherwise agreed by the co-managers. While the PSSMP called for escapement goals for these natural management units to be the level associated with maximum sustained harvest (MSH), in practice most natural Chinook salmon escapement goals for Puget Sound were based on recent year average observed escapement (Ames and Phinney, 1977).

Of the 15 management units covered in this Plan (Table 3-1), six contain more than one population. The other nine management units are comprised of one population only. One management unit, Mid-Hood Canal, is composed of a single population with spawning aggregations in three distinct rivers. This Plan includes management measures intended to conserve the genetic and run-timing characteristics of each population across the ESU until habitat is restored to levels that can support viable populations and sustainable harvest (see Chapter 6, and the management unit profiles for Nooksack, Skagit, Stillaguamish, Snohomish, and Lake Washington[6] in Appendix A). . Escapement goals can differ for individual population within a management unit and the exploitation rate objective (ERC or CERC) for a management unit is determined according to the abundance status of the weakest population component to avoid or reduce its risk of extinction.

3.3 Population Categories

The co-managers' Comprehensive Management Plan for Puget Sound Chinook salmon categorizes populations according to the origin of naturally reproducing adults, presence of indigenous populations, the proportional contribution of artificial production, and the origin of hatchery broodstock (Table 3-1):

- Category 1 - natural production is predominantly of natural origin, by native / indigenous stock(s), or enhanced to a greater or lesser extent by hatchery programs that utilize indigenous broodstock.

- Category 2 – natural production by a non-native stock, introduced for use in local hatchery production, and influenced by ongoing hatchery contribution. The indigenous

[6] See Chapter footnote 1

population is functionally extinct. Habitat conditions may not currently support self-sustaining natural production and/or may not match the life-history characteristics of the current extant stock.

- Category 3 – an independent natural population was not historically present; natural production may occur, involving adults returning to a local hatchery program, or straying from adjacent natural populations or hatchery programs.

Category 1 and 2 populations comprise the remaining extant populations among those delineated by the Puget Sound TRT (Ruckelshaus et al. 2006) as making up the historical legacy of the ESU. Conservation of Category 1 populations is the first priority of this plan, because they comprise what are currently considered endemic, genetically and ecologically unique components of the ESU. They include populations in the Nooksack, Skagit, Stillaguamish, Snohomish, Cedar, Green, White, Dungeness, and Elwha rivers (Table 3-1). The Hoko River population, outside of the ESU, is also designated Category 1.

Natural production of Category 2 populations in the Sammamish, Puyallup, Nisqually, Skokomish, and mid-Hood Canal systems are comprised of Chinook salmon now genetically indistinguishable from those used for local hatchery production because of extensive interbreeding, and from each other since they are derived from the Green River stock which was used to initiate and perpetuate many hatchery programs in many of these systems. While included as part of the Puget Sound ESU, these ‘introduced’ stocks may not be well suited to the introduced watersheds such that there is uncertainty of their potential to achieve viability or recovery standards (abundance and productivity) in those systems.

Hatchery recovery programs are essential to protecting the genetic and demographic integrity of critically depressed populations in the Nooksack, Stillaguamish, White, Dungeness, and Elwha rivers. Hatchery produced fish in these systems were included in the original ESA listing, because they are essential to the recovery of the ESU (NMFS 1999). The NMFS subsequently listed hatchery produced Chinook Salmon from Skagit River, Snohomish River, Tulalip Bay, Issaquah Creek, and in the Green, Puyallup, Nisqually, Skokomish, and mid-Hood Canal rivers, because these hatchery stocks were not significantly divergent from naturally-spawning fish in those systems and part of the evolutionary legacy of the ESU (NMFS 2005a, NMFS 2005b).

The listed, ‘production’ hatchery programs were historically initiated with the primary objective of enhancing fisheries, thereby mitigating the decline in natural production resulting from loss of habitat function. Hatchery production was seen as a solution to the increasing demand for fishing opportunity, particularly following the resolution of U.S. v. Washington, and the rapid human population increase in the Puget Sound region. Some programs operate under legally-binding mitigation agreements associated with hydropower projects. Formerly, the harvest management strategy for these programs was to fully utilize this increased hatchery production, and constrain harvest only to the extent necessary to ensure that escapement was adequate to perpetuate the hatchery program. However, high exploitation rates were not sustainable for commingled natural Chinook salmon populations.

Category 2 populations that are heavily influenced by hatchery programs established from stocks not native to the watershed, and where current habitat conditions limit population productivity and may prevent recovery, generally have higher levels of harvest than Category 1 populations under this Plan. Because of the degraded habitat conditions and endemic populations replaced by introduced hatchery stocks, the consideration of hatchery-origin fish as part of the abundance objectives is intended to maintain subsequent natural-origin production. For both the Nisqually and Skokomish populations, exploitation rate limits were first implemented under the 2010 version of this Plan. Based on recent updates to their respective Recovery Plans, harvest considerations are further adjusted to align with the current recovery strategies (see respective MUPs).

Specific harvest objectives have not been established for Category 3 populations in this Plan, so their status is not discussed here in detail. Some hatchery programs operate in systems where there is no evidence of historical native Chinook salmon production. These include programs in the Samish River, Glenwood Springs (East Puget Sound), Gorst Creek and Grovers Creek, Chambers Creek / Garrison Springs, Minter Creek, Deschutes River, and Hoodsport. In these areas, terminal harvest is frequently managed to remove a very high proportion of the returning Chinook salmon, while providing sufficient escapement to the hatchery to perpetuate the program. However, if the harvest falls short of this objective, excess adults may spawn naturally, or be intentionally passed above barriers to utilize otherwise inaccessible spawning areas. Straying from non-local hatchery programs may results in some natural Chinook salmon production, but these streams cannot support independent populations.

4. Management Thresholds and Exploitation Rate Ceilings

4.1 Upper Management Thresholds

An upper management threshold (UMT) is set for most MUs (Table 4-1), consistent with the PSSMP, as the escapement level associated with achieving optimum production (i.e. maximum sustainable harvest (MSH)), unless agreement has been reached by the co-managers on an alternative definition. Escapement to each MU is projected during pre-season harvest planning, after accounting for fishing mortality in all fisheries modeled in FRAM. If spawning escapement is projected to substantially exceed the UMT, higher levels of fishing impact may be allowed for some MU's, subject to conditions further specified in Chapter 5.2. The UMT is generally used as a benchmark for evaluating annual population status, either pre-season or post-season. The annual population status informed by abundance alone in this Plan differs from the VSP viability status (i.e. a 100-yr extinction risk; McElhany et al. 2007) which accounts for other parameters (productivity, spatial structure, and diversity) and is not expected to vary substantially on an annual basis .

For some management units, UMTs are quantitatively derived by a two-step process. An initial quantitative value of MSH is obtained using population recruitment functions or associated simulations of population dynamics models which incorporate, among other parameters, population recruitment functions. Then, considering the uncertainty in quantifying recruitment and recent productivity, UMTs were set at a level greater than the estimated MSH level, to reduce the risk of not obtaining MSH escapement before potentially implementing directed fisheries. UMTs for the Skagit summer/fall, Skagit spring, Snohomish, Lake Washington, Green River, Puyallup, and White River MUs were derived in this manner.

For some MUs, where data are not available to quantify recruitment and productivity using population dynamic models or the co-managers thought it inappropriate, MSH is estimated by habitat-based productivity modeling, using the EDT method to emulate current habitat condition or through application of the Parken Model (Parken et al. 2004). Considering uncertainty in these habitat-based model estimates, the UMTs for these MUs were set at a level greater than the estimated MSH.

For the remaining MUs, UMTs were set at a level equal to their historical escapement goals, which in some cases were derived from historical spawner density and spawning habitat area, and in other cases based on historically high escapements. These UMTs are probably higher than the levels associated with MSH under current degraded habitat condition.

Setting the UMT at the current MSH escapement level or higher is a conservative strategy intended to reduce the risk that harvest will impede recovery. This risk averse practice accounts for uncertainty in population dynamic models and provides for escapement projections that would be expected to produce the greatest number of natural-origin recruits before directed fisheries could be considered (see Section 5 for Implementation Rules). It is expected that UMTs developed using spawner-recruit models will be adjusted in the future as habitat conditions change, to account for different productivity and/or capacity estimates. The methods used for each MU are described in more detail in their respective Management Unit Profiles (Appendix A).

Table 4-1. Exploitation rate ceilings, low abundance thresholds and critical exploitation rate ceilings for Puget Sound Chinook management units. Exploitation Rates are Total ER's, unless specified (i.e. SUS or Pre-terminal SUS).

Management Unit	Upper Exploitation Rate Ceiling	Upper Management Threshold	Exploitation Rate Ceiling or Moderate Management Exploitation Rate	Low Abundance Threshold	Critical Exploitation Rate Ceiling	Point of Instability
Nooksack River [4] North/Middle Fork South Fork		 1,000 [2] 500 [2]		 400 [2] 200 [2]	10.9% SUS ER, 14.1% SUS ER[1]	
Skagit Summer/Fall Upper Skagit summer-run Sauk summer-run Lower Skagit fall-run		14,500 [2]	52%	7,844 [2] 2,200 [2] 400 [2] 900 [2]	15% SUS even-years/17% SUS odd-years	4,800
Skagit spring-run Upper Sauk Upper Cascade Suiattle		2,000 [2]	36%	1,024 [2] 130 [2] 170 [2] 170 [2]	10.7% SUS	470
Stillaguamish River [3]	13% SUS	1,500	9% SUS	900	see MUP [3]	
Snohomish River Skykomish summer-run Snoqualmie fall-run	10.3% SUS	4,900 [2] 3,600 [2] 1,300 [2]	9.3% SUS	3,250 [2] 2,015 [2] 1,132 [2]	8.3% SUS	 1,745 700
Lake Washington – Cedar River fall-run [4]	14%-15% PT SUS[5]	500	18% SUS	200	12% SUS	
Green River fall-run [4]	14%-15% PT SUS[5]	4,500	18% SUS	1,098	12% SUS	
White River spring-run		1,000	22% SUS	400	15% SUS	
Puyallup fall-run [4]	14%-15% PT SUS[5]	1,538	30% SUS	468	15% SUS	
Nisqually			47%	6,300 [6]	see MUP [6]	
Skokomish fall-run [7]		3,650	50% [7]	1,300	12% PT SUS	
Skokomish River spring-run [8]						
Mid-Hood Canal [9]		1,250	See MUP	200	See MUP	
Dungeness		925	10% SUS	500	6% SUS	
Elwha		5,789	10% SUS	2,000	6% SUS	1,500
Western Strait of Juan de Fuca – Hoko River		916	10.6% SUS	633	6.3% SUS	

[1] SUS ER will not exceed 14.1% in 4 out of 5 years
[2] Natural-origin spawners.
[3] See Stillagumaish MUP for critical guideline implementation below the low abundance threshold as well as SUS ceilings on hatchery-origin recruits.
[4] Hatchery Escapement goals are an additional management consideration for harvest of these stocks. See respective MUPs (Appendix A) for greater information on hatchery escapement expectations.
[5] The Upper Management ER ceiling of 15% PT SUS for Lake Washington, Green River, and Puyallup River is triggered if Puyallup River and Green River Management Units meet the additional upper management thresholds (UMT #2) stipulated in each MUP (see Appendix A) and Lake Washington meets its UMT of 500, otherwise the Upper Management ER ceiling is 14% PT SUS when all three meet their UMT 1 (See MUPs in Appendix A for further description).
[6] Nisqually River LAT is comprised of all adults escaping fisheries and returning to either of the hatchery facilities and to spawning grounds, regardless of mark status. See Nisqually MUP for fisheries considerations for abundance estimates below the LAT.
[7] Skokomish LAT is escapement of 800 natural spawners and 500 escapement to hatchery while the UMT is escapement of 1,650 natural spawners and 2,000 escapement to hatchery.
[8] See Skokomish Recovery Plan for Skokomish River spring-run Chinook harvest expectations.
[9] See Mid-Hood Canal MUP (Appendix A) for exploitation rate and critical exploitation rate expectations.

4.2 Low Abundance Thresholds (LAT)

The Low Abundance Threshold (LAT) set for each MU (Table 4-1) triggers additional conservation measures in fisheries. The LAT is set at a level greater than the critical threshold (see 'Point of Instability' below) to provide increased responsiveness with the management of fisheries in order to reduce the risk of population instability. The derivation of the LAT varies by MU, similar to the derivation of UMTs, depending on the availability of information, associated uncertainty about population dynamics, and in some instances concern for declining stock status.

For the Skagit River spring-run Chinook and summer/fall-run MUs, the LATs were established based on consideration of the median MSY escapement estimates. These calculations accounted for the difference between forecast and actual escapement in recent years, as well as data uncertainty and variance in estimating recruitment parameters.

For Green River, Puyallup River, and White River, the LATs are set at 40% of the respective MSY estimates. For Lake Washington, the LAT is set at 200 or 71% of estimated MSY escapement for Cedar River Chinook. In other cases, where such population-specific data were lacking, published literature was used to set the LAT above the values of the minimum effective population size to reduce the risk of demographic instability or loss of genetic integrity (e.g., Franklin 1980; Waples 1990; Lande 1995; McElhany et al. 2000). For further details on specific methods used to derive LATs, refer to the respective MUPs (Appendix A).

4.3 Point of Instability

If the spawning population abundance falls to a very low level, there is a high risk of demographic instability, loss of genetic integrity, and extinction. This point of biological instability has not been quantified for all salmon populations, but genetic and demographic theory have attempted to define its boundaries (McElhany et al. 2000). At very low spawner abundance, ecological and behavioral factors may cause a dramatic decline in productivity. Low spawner density can affect spawning success by reducing the opportunity for mate selection or finding suitable mates. Depensatory predation can significantly reduce population productivity. However, the abundance level at which these factors exert their effect probably differ markedly between populations.

For some Management Units in this plan, the co-managers have defined a level of spawner abundance termed the Point of Instability (POI). The POI is set at a spawner abundance level below the LAT in order to provide further conservation protections when stock abundance falls to an extremely critical level, although the management POI abundance for most MU's is likely conservatively higher than the true point of instability where depensation will affect the MU. When pre-season escapement is expected to fall below the POI for those MUs, SUS fisheries would be managed by exploitation rate limits to be determined during the annual pre-season planning process through co-manager discussions. The POI ER ceilings would not exceed, and are expected to be more constraining than, the respective critical exploitation rate ceiling (CERC) set for that MU. Additionally, on a case by case basis and consistent with expectations spelled out in respective MUPs, triggering of the POI would require co-managers (the Tribes and WDFW), to develop of a stock management rebuilding plan, unless co-managers, by agreement, consider such a plan unnecessary.

The determination of the Point of Instability varies by Management Unit. For the Elwha River MU and Skykomish population component of the Snohomish MU, the POI is based on LATs defined in previous Chinook Harvest Management Plans. For the Snoqualmie population component of the Snohomish MU, the POI is based on an average of recent poor returns. For Skagit River stocks, the POI is set at the lowest observed escapement that resulted each management unit replacing itself (see respective MUP's for further detail).

4.4 Exploitation Rate Ceilings

This Plan sets fisheries exploitation rate (ER) ceilings as the principle mechanism for achieving spawning escapement objectives that are consistent with current habitat function. Exploitation rate management was first employed by the co-managers in the late 1990s for Puget Sound Chinook. The former harvest management strategy based on meeting spawning escapement goals, was not adequately conservative particularly when uncertainty in forecasted abundance was considered and was not consistently applicable across all fisheries when run sizes were lower than escapement goals. As noted by Lande et al. (1995, in Fieberg 2004), a harvest strategy based on harvesting all surplus above a certain level (i.e. escapement goal management) maximizes the long-term yield assuming no uncertainty in the forecasted population size. When there is uncertainty in the forecasted abundance, a proportional threshold strategy, which attempts to harvest a constant fraction (i.e. ER management) of the forecasted abundance above a population threshold outperforms a pure threshold strategy (i.e. escapement goal management), both in long-term yield and variability in yield (Engen et al. 1997, in Fieberg 2004). For harvest management objectives to be practical, they must be suited to available data and be consistent with technical capabilities for estimating fishery impacts with acceptable accuracy and precision. The co-managers determined that management objectives based on exploitation rates were more averse to risk (e.g. overharvest, extinction probabilities, etc.) than objectives based on spawning escapements (see Fieberg 2004 for evaluations of harvest strategies) because of uncertainties associated with forecasting abundance estimates and because exploitation rates can be evaluated by independent estimates derived from CWT recovery data. Estimates of spawning escapement rely on pre-season and post-season stock abundance estimates that are both known to have various sources of error.

In this Plan, ER ceilings are the maximum level of fishing-related mortality allowed for a MU. ER ceilings are established for each MU and are specified at different levels depending on forecast abundance. ER ceilings may apply to all fisheries (Total), only to southern U.S. fisheries (SUS), or only to pre-terminal southern US fisheries (PT SUS) (Table 4-1).

The ER ceilings for the Skagit summer/fall, Skagit spring, and Snohomish management units were derived from risk analysis based on quantified productivity from population dynamics modeling reflective of existing habitat conditions (see below).

For mid-Puget Sound Chinook Management Units (Lake Washington, Green River, and Puyallup River), Moderate Management exploitation rates are implemented. These rates define the maximum level of fishing-related mortality when escapements are forecasted between the LAT and UMT. Additionally, when forecasted escapement exceeds the UMT for these MU's, a pre-terminal exploitation rate ceiling will be implemented and terminal fisheries, supported by in-season update (ISU) models of terminal runsize (see MUPs in Appendix A), will be managed to achieve natural spawning escapements at, or above, the MSY estimates in addition to meeting hatchery escapement goals. The implementation of ISU models provides co-managers greater certainty in terminal run-size abundance relative to pre-season forecasts and alleviates the concern noted earlier regarding use of ER objectives where forecast uncertainty may be substantial. Ultimately for these mid-Puget Sound MUs, annual terminal fisheries management will be based on results of ISU (see MUPs, Appendix A).

When escapement is projected to be less than the LAT, fisheries are managed by a lower ER ceiling, termed the critical exploitation rate (CER) ceiling. For some MUs, CER ceilings were chosen with reference to pre-season FRAM estimates of fishery impacts for the years 1999-2001, reflecting very restrictive harvest regimes adopted by the co-managers in response to observed poor status for a number of Puget Sound populations. During those years, impacts on these MUs were incidental to fishing directed at healthy salmon species and stocks.

The CER ceilings for all MUs are intended to maintain fishing opportunity directed at abundant hatchery-origin Chinook, and sockeye, pink, coho, and chum stocks originating in Puget Sound, and sockeye, pink, and chum stocks originating in the Fraser River. The opportunity on these other stocks, however, is conditioned on careful time and area management to limit the cumulative impact of SUS fisheries on Chinook management units in critical abundance status to be below the CER ceilings. In recent applications of the co-managers' Plan, these CER ceilings have severely constrained fishing opportunities directed at harvestable species and stocks.

If exploitation rates for the CER ceilings were reduced further towards zero, then critical abundance status for even one management unit would result in no allowance for any fishing for salmon in all times and places where that stock is known to occur, effectively closing most salmon fisheries within the geographic scope of this plan. Critical ER ceilings in this Plan balance the co-manager's interest in minimizing additional demographic and genetic risk from fisheries activities to stocks in critical abundance while providing some fishing opportunity on healthy, harvestable stocks and species. An important outcome of this Plan's approach to defining fishing limits on stocks in critical abundance status is preservation of a portion of the fishing opportunity reserved by the tribes under the Stevens treaties with the United States. However, improvement of these stocks' condition will not occur without significant actions to correct reductions in natural productivity and capacity due to loss and degradation of habitat. Further harvest management action beyond the Plan's critical abundance status response, including complete closure of all fisheries, is unlikely to improve the status of any MU that is below critical abundance. The CER ceilings in this plan will not significantly increase the risk of further decline. Other profound actions must be put in place to reverse the declines.

The CER ceilings (Table 4-1) are defined as SUS ceiling exploitation rates for most management units. For the Skokomish, the CER ceiling applies only to pre-terminal fisheries with additional terminal fishery conservation measures detailed in it's MUP (Appendix A).

Derivation of Exploitation Rate Ceilings

ER ceilings applying to all fisheries (Total ER) are established for the Skagit summer / fall, Skagit spring, and Snohomish management units. The ER ceilings for these MUs were selected based on consideration of the highest exploitation rate that met the more restrictive of the following two risk criteria:

- The probability that escapement will fall to or below the critical threshold will increase by no more than five percentage points relative to the probability estimated under a zero fishing regime; or,
- The probability that escapement will be equal to or greater than the UMT at least 80% of the time, or, the probability that escapement is less than the UMT will not increase by more than 10 percentage points relative to a zero fishing regime.

The risk assessment procedures used to derive the ER ceiling first relied on detailed information about the current productivity of the population(s) comprising the MU, including estimates of annual spawning escapement, maturation rates, and harvest-related mortality. Harvest related mortality parameters for the Skagit River MUs harvest related mortality parameters are based on FRAM modeled exploitation rates. The Snohomish MU ER ceiling utilized both the CTC model and FRAM model to independently inform the final ER ceiling selection. These estimates provide a basis for reconstruction of historical cohort abundance and variability in marine and freshwater survival enabling development of spawner-recruit models. Population dynamics were simulated, with initial escapement specified, using the spawner-recruit function to predict natural-origin recruitment, and a specified annual exploitation rate to predict escapement. Typically, simulations at each exploitation rate level were run to represent a time series of 25 years, incorporating variation in annual natural mortality, uncertainty about estimated model parameters and management error. Management error in the simulations reflected estimated differences between anticipated and actual Chinook catch, and between forecasted and post-season abundance. Simulations were iterated across a range of exploitation rates, from 0% to 80%. The time series of annual escapements output from the simulations were compared with the risk criteria, stated above, to select the ER ceiling. The methods used for derivation of the recruitment functions, selection of upper and lower threshold values, and selection of the ER Ceiling, for each of the four management units, are detailed in Appendix A.

The simulations involved in the risk assessment procedure indicate that the risk criteria will be met if actual annual exploitation rates are at the level of the ER ceiling. However, we expect annual exploitation rates will be lower than the ER ceiling for some MU units, providing further assurance the populations will be protected (Figure 2-4 and Figure 2-5). Further, the simulation process of the RER exercise relied exclusively on NOR fish as the only contributor to spawning abundance and natural-origin production, when in reality HOR natural spawning contributes to total natural-origin production in every system.

For MUs lacking data to quantify productivity, ER ceilings and CER ceilings were set by reviewing fisheries regimes implemented in 1998 through 2003, and their spawning escapement outcomes relative the best available values for optimum escapement or spawning habitat capacity for each population. For these MUs, ER and CER ceilings were not set based on the likelihood of achieving escapement thresholds. The potential benefits of higher escapement (i.e. under lower ceilings), particularly for populations in critical or near-critical abundance status, was balanced with maintaining harvest opportunity on surplus hatchery-origin Chinook, coho, sockeye, pink, and chum. For some management units, SUS CER ceilings were established; for other MUs, pre-terminal SUS CER ceilings were established, combined with specific harvest measures for terminal-area fisheries. Since this Plan precludes directed fisheries targeted at MUs without harvestable abundance, these ceilings allow the spawning escapements for these units to benefit from the recent reductions in Canadian and U.S. fisheries, in some cases providing terminal runs which may exceed the upper management threshold.

5. Implementation

Pre-season harvest planning will develop a SUS fisheries regime that achieves the management objectives for all MUs, using FRAM projections to check compliance with ER ceilings and abundance thresholds. Pre-season planning will also shape the fisheries regime to meet allocation objectives and optimize fishing opportunity for all user groups within the constraints of forecasted abundance and management objectives.

The regulatory regime developed for pre-terminal, mixed-stock fisheries will be substantially influenced by achieving the conservation objectives of populations in critical abundance status, because more productive populations and management units are commingled with the less productive natural populations and management units with correspondingly lower ER ceilings.

This Plan prohibits directed harvest (defined below) on ESA protected populations of Puget Sound Chinook Salmon, unless there is a robust forecast or other evidence of harvestable surplus. If a management unit does not have a harvestable surplus, then fishery-related mortality will be constrained to incidental impacts. Fisheries directed at harvesting a surplus for a specific population will occur in terminal areas, and will be implemented cautiously. Should they occur, directed fisheries will be designed to maintain hatchery-origin and/or natural-origin natural spawning escapement at or above the UMT.

The Plan reflects the PSSMP mandate for equitable sharing of the conservation burden. Southern US fisheries will continue harvesting more abundant salmon stocks, and harvestable Puget Sound hatchery Chinook Salmon. Criteria defining minimal harvest opportunity and management responses to these situations (including exceedance of ER ceilings due to high northern fishery interceptions) is further detailed below.

5.1 Rules for Allowing Fisheries

The co-managers' primary intent is to control impacts on listed Chinook salmon populations, to avoid impeding their rebuilding, while providing sufficient opportunity for the harvest of other species, abundant returns of hatchery-origin Chinook salmon, and available surplus from stronger natural Chinook salmon stocks. For the duration of this Plan, directed fisheries that target ESA protected Chinook salmon populations are precluded, unless a harvestable surplus exists (as defined below in Chapter 5.2). Except for very small scale tribal ceremonial and subsistence fisheries, and research fisheries in a few areas, we expect directed fisheries to occur infrequently for the duration of this Plan.

For the purposes of this Plan, "directed" fisheries are defined as those in which more than 50 percent of the total fishery-related mortality is made up of ESA protected, Puget Sound-origin Chinook Salmon. Total mortality includes all landed and non-landed mortality.

Landed and non-landed incidental mortality of ESA listed Chinook Salmon will occur in fisheries directed at other salmon species. Additional impacts will occur as a result of fisheries directed at hatchery-origin Chinook salmon, including mark-selective fisheries. In both cases the fisheries will be strictly constrained by harvest limits that are established expressly to conserve naturally-produced Chinook salmon.

The annual management strategy, for any given Chinook salmon management unit, shall depend on whether a harvestable surplus is forecast. This Plan prohibits directed harvest on natural-origin populations of Puget Sound Chinook Salmon, unless they have harvestable surplus. If a management unit does not have a harvestable surplus, fishery-related mortality will be constrained to incidental impacts. Similarly, in some cases constraints will be imposed to protect escapements of hatchery populations for broodstock needs. Directed and incidental fishery impacts are constrained by specified exploitation rate ceilings or escapement goals for each management unit. The following rules define how and where fisheries can operate:

- Fisheries may be conducted where more than 50 percent of the resulting fishery-related mortality will accrue to management units and species with harvestable surpluses.

- Within this constraint, the intent is to limit harvest of ESA protected Chinook salmon populations or management units that lack harvestable surplus and develop a fishing regime that will not exceed specified ceiling exploitation rates or escapement goals for all Management Units.

- Incidental harvest of weak stocks will not be eliminated, but to avoid increasing the risk of extinction of weak stocks, fishery-related impacts will be reduced to the minimal level that still enables fishing opportunity on non-listed and non-ESA protected Chinook and other species, when such harvest is appropriate.

- Exceptions may be provided for tribal ceremonial and/or subsistence fisheries, and research fisheries that collect information essential to management.
- Where it is not possible to effectively target productive natural-origin stocks or hatchery production, without exceeding specified harvest controls for runs without a harvestable surplus, use of the above rules will likely necessitate foregoing the harvest of much of the surplus from those more productive management units.

5.2 Rules That Control Harvest Levels

The co-managers' will use the following guidelines when assessing the appropriate levels of harvest for proposed annual fishing regimes:

- ER ceilings are allowable maximums, not annual targets for each management unit. The annual fishing regime will be devised to meet the conservation objectives of the weakest, least productive management unit or component population. Because these units commingle to some extent with more productive units, even in terminal fishing areas, meeting the needs of these units may require reduction of the exploitation rate on stronger units to a significantly lower level than the level that would only meet the conservation needs of the stronger units.

- An ER management ceiling may be defined and measured as either a Total ER, SUS ER, or Pre-terminal SUS ER. A management unit shall be considered to have a harvestable surplus if, after accounting for expected Alaskan and Canadian fishery-related impacts, as well as incidental, test, and tribal ceremonial and subsistence catches in southern U.S. fisheries, that MU is expected to have a spawning escapement, or terminal runs destined for the spawning grounds for some MUs, greater than its UMT and the projected ER is less than its ER management ceiling. In these cases, additional fisheries may be implemented consistent with the type of ER management ceiling attached to a management unit. These additional fisheries (including directed fisheries) may be implemented within the constraints imposed by the UMT, consistent with the rules for allowing fisheries in Chapter 5.1 and described in individual MUPs. The array of fisheries that may harvest the surplus can be widened to include terminal-area, directed fisheries. However, expanded fisheries will not exceed the ER management ceiling, and escapement will exceed the UMT objective, except for Lake Washington, Green River, and Puyallup River MUs escapement will exceed the MSY escapement goal.

- Directed fisheries targeting harvestable surplus for any management unit will be implemented conservatively and will require reasonable assurances that abundance has increased to a level that will support a fishery. They would only occur contingent on consistent forecasts of abundance which exceed the respective management unit's management objectives above the upper management threshold, and confirmed by in-season modeling and/or post-season assessment. Alternatively, a terminal area in-season update model with consistent performance may be used to identify abundance above the upper management threshold. In practice, a substantial harvestable surplus must be available, so that the directed fishery is of practical magnitude (i.e. there is substantial harvest opportunity and the fishery can be managed with certainty not to exceed the harvest target). A directed fishery would not be planned to remove a very small surplus above the UMT. The decision to implement a directed fishery will also consider the uncertainty in forecasts and fisheries mortality projections.

- If a MU does not have harvestable surplus, then, consistent with the rules for allowing fisheries (above), only incidental, test, and tribal ceremonial and subsistence harvests of that MU will be allowed in Washington areas.

- The projected ER for MUs with no harvestable surplus will not be allowed to exceed their ER ceilings. In the event that the pre-season projected ER exceeds the ceiling ER, the incidental, test, and tribal ceremonial and subsistence harvests must be further reduced until the ceiling ER is not projected to be exceeded. An exception to this rule, however, applies for management units that are managed for a total ER ceiling, in cases where the combined northern fisheries ER is projected to be greater than the difference between the ER ceiling and the Critical Exploitation Rate (CER) ceiling. In such cases, the CER ceiling becomes the applicable ER ceiling for that stock, and that stock's total projected ER may exceed the ER ceiling (see "Implementing CER ceilings in response to northern fisheries interceptions", below).

- Pre-season planning will bring the SUS fishing regime into compliance with the current Pacific Salmon Treaty Chinook Agreement, such that the SUS ISBM Fishery impacts will not exceed the Treaty-mandated obligation (see Chapter 3, Pacific Salmon Treaty). The SUS ISBM Fishery comprises the aggregate of Washington/Oregon coastal, inside marine, and freshwater fisheries, including Idaho (Snake River Basin) freshwater fisheries.

- After accounting for anticipated Alaskan and Canadian interceptions, test fisheries, ceremonial and subsistence harvest, and incidental mortality in southern U.S. fisheries, if the spawning escapement for any management unit, or a component population of an aggregate MU, is expected to be lower than its Low Abundance Threshold (LAT), Washington fisheries will be further shaped until either the escapement for the management unit, or component population of an aggregate MU, is projected to exceed its LAT, or its projected ER does not exceed the CER ceiling and, if applicable, abundance is above the point of stock instability (see section 5.3, below).

- The co-managers may implement additional fisheries conservation measures, where analysis demonstrates they will contribute significantly to recovery of a management unit, in concert with other habitat and enhancement measures.

5.3 Response to Critical Abundance Status

The CER ceiling for any MU will be implemented if natural escapement is projected to be less than the LAT. The point of stock instability defines the escapement range under the LAT in which incidental impacts up to the CER ceiling are allowed. For the Nooksack spring, Skagit summer/fall, Skagit spring, and Snohomish management units, each with more than one population, the management unit LAT is greater than the sum of the component population LATs. The MU LATs are set at these levels to minimize the risk of going below any of the component population LATs when managing for the pooled populations as a unit. For the Stillaguamish MU, given the constraints for forecasting individual component population abundances, the MU LAT is set at a level nearly double the estimated rebuilding escapement threshold (RET) defined in NOAA's RER analysis (NOAA 2018), to provide greater certainty of protecting both the summer-run and fall-run populations. As described in Chapter 4, the CER ceilings for each MU reflect baseline harvest opportunity for surplus hatchery-origin Chinook, Coho, Pink, Sockeye, and Chum Salmon.

Appendix B provides a qualitative description of baseline tribal fisheries that virtually excludes harvest directed at natural Chinook Salmon (with exceptions for ceremonial and subsistence harvest), and shapes fisheries directed at other species to reduce incidental mortality of natural Chinook Salmon. Reducing tribal fisheries to those specified in the minimum fishery regime (Appendix B - MFR), while requiring significant sacrifice of the fishing opportunity guaranteed by treaty rights, represent the minimum level of fishing that allows some exercise of those rights. The tribal MFR details regional variation in essential fisheries. It is not guaranteed all fisheries described in the MFR will occur when a MU is in critical abundance status.

As described in Chapter 1.3, restriction of harvest will not, by itself, enable recovery and rebuilding of populations that have all suffered severe decline in abundance, productivity, spatial structure and diversity, resulting from loss and degradation of properly functioning habitat conditions as well as restricted passage to historically utilized habitat. Restriction of fishing below the level defined in this critical response would reduce treaty and non-treaty fishing opportunity for abundant hatchery-origin Chinook salmon, and non-listed species.

The CER ceilings are defined as SUS exploitation rates for the Nooksack, Skagit Summer/Fall, Skagit Spring, Snohomish, Lake Washington, Green, White, Puyallup, Nisqually Dungeness, Elwha, and Hoko Chinook Salmon MUs. For the Skokomish Chinook Salmon, the ceiling rate applies only to pre-terminal fisheries. For this management unit, additional terminal fishery conservation measures are detailed in the management unit profile (Appendix A).

During pre-season planning the co-managers may, by agreement, set the management objective for any MU not meeting its LAT, below the specified CER ceiling. Fishing patterns and regulations vary between years and the impacts on critical abundance management units in individual fisheries will also vary. To ensure that SUS ERs for critical abundance MUs do not exceed the CER ceiling, fisheries that incur projected impacts on critical abundance MUs shall be shaped to achieve the management objectives outlined in this Plan or more constraining objectives if agreed to by co-managers pre-season. As fisheries become increasingly constrained or precluded altogether, conservation measures will focus on needed contributions to spawning escapement[7].

If circumstances dictate that co-managers must agree to target a spawning escapement level below a MU's point of stock instability, the annual North of Falcon process will be utilized to identify an appropriate conservation response, including the level of any harvest opportunity, not to exceed the CERC, that may be permitted. Associated with this action is a requirement for the affected co-managers to agree upon a recovery plan and / or suite of management actions, consistent with any language stipulated in the respective MUP, to rebuild future spawning levels of the MU back above its LAT. This agreement must be included in the Co-Managers List of Agreed to Fisheries document. Subsequently, the effects of these management actions on critical abundance MUs will be carefully assessed post-season, for reference in subsequent pre-season planning.

Implementing CER ceilings in response to northern fisheries interceptions

In recent years the impact of some fisheries in British Columbia (notably those on the west coast of Vancouver Island) on some populations of Puget Sound and Columbia River Chinook increased substantially (CTC 2016). The 2008 PST Chinook Agreement was intended to address conservation of ESA listed populations, but reductions in northern fisheries stipulated in the Agreement were only expected to reduce exploitation rates on Puget Sound MUs by about 2 – 3%, and did not offset the increase in mortality on some Puget Sound stocks that occurred in 2003 – 2005 (CTC 2006). Fishery performance under the 2008 Agreement through 2015, however, resulted in an increase in the average ER for Puget Sound Chinook salmon stocks (CTC 2016). The new PST Chinook Agreement is anticipated to restructure the coast wide fishery to reverse this trend and increase escapement for these Puget Sound stocks over the duration of the agreement.

For Puget Sound MUs with total ER Ceiling objectives, their interception rate in northern fisheries may cause their total ER ceiling to be exceeded. To avoid exceeding the ER ceiling, SUS fisheries would have to be constrained to a lower ER than would have been necessary if the MU was at critical abundance status. For Puget Sound MUs with a total ER ceiling (i.e. Skagit Summer/Falls, Skagit Springs, Nisqually, and Skokomish), if the ER associated with northern fisheries on that MU is projected to exceed the difference between the MU's ER ceiling and CER ceilings, the constraint for that MU in that year will be its CER ceiling. Recent experience has demonstrated that the potential for this circumstance to result in a Puget Sound Chinook salmon MU to fall into critical abundance status is unlikely over the duration of this plan. Unless impacts in Northern Fisheries exceed more than 20% ER on any of the four MU's noted above with Total ER objectives, implementation of this guideline is unlikely to occur. While this

[7] These conservation actions may involve a coordinated management plan with other fishery management entities with authority over the relevant fisheries MU developed within the Pacific Salmon Treaty forum and consistent with the principles set forth in *United States v Washington*.

measure may impose a further conservation burden on Washington fisheries, pursuant to the underlying rationale for the MFR, it maintains access to the harvestable surplus of non-protected Chinook Salmon, and other species.

Because of annual variability in abundance among the various populations, there is no single fishing regime that can be implemented from one year to the next to achieve the management objectives for all Puget Sound Chinook units. The co-managers have, at their disposal, a range of management tools, including gear restrictions, time / area closures, catch or retention limits, and complete closures of specific fisheries. Combinations of these actions will be implemented in any given year, as necessary, to insure that management objectives are achieved.

Discretionary conservation measures

The co-managers may, by mutual agreement, implement further conservation constraint on SUS fisheries, in response to critical abundance status of any management unit, or in response to declining status or heightened uncertainty about status of any management unit, or to achieve allocation objectives. In doing so, they will consider the most recent information regarding the status and productivity of the management unit or population, and past performance in achieving its management objectives. The conservation effect of such measures may not always be quantifiable by the Chinook FRAM, but will be informed based on the best available information on the distribution of stocks, the available analysis, and the rationale that indicates the measure(s) to have beneficial effect.

5.4 Pre-season Planning

- Annual pre-season planning of Puget Sound fisheries proceeds concurrently with that of coastal fisheries, from February through early-April each year, in the Pacific Fishery Management Council and North of Cape Falcon (NOF) forums. These offer diverse stakeholders access to information about forecasted salmon abundance, stock status, expected fishing seasons, and opportunity to interact with the co-managers in developing annual fishing regimes. Conservation concerns for any management unit are identified early in the process. The steps in the planning process that occur in February are:
    - Abundance forecasts are developed for Puget Sound, Washington coastal, and Columbia River Chinook salmon management units in advance of the pre-season planning process.
    - Forecasting methods are detailed in documents available from WDFW and tribal management agencies.
    - Preliminary abundance forecasts for Canadian Chinook stocks, and expected catch ceilings in Alaska and British Columbia, are obtained through the Pacific Salmon Commission or directly from Canada Department of Fisheries and Oceans.

- The Pacific Fishery Management Council's annual planning process begins in March by establishing a range of allowable catch ('options') for each coastal fishery. For Washington fisheries, this involves recreational and commercial troll Chinook catch quotas for Areas 1 – 4 (including Area 4B from May-October in the western Strait of Juan de Fuca). FRAM runs incorporating forecasted Chinook and Coho Salmon abundance for California, Oregon, Idaho, Washington and British Columbia stocks are constructed to simulate the three options.

- An initial regime is evaluated for Puget Sound fisheries that utilize the previous year's recreational and commercial Chinook and Coho Salmon fisheries with the current year's forecasted abundance. For this model run, pre-terminal and terminal net fisheries directed at other salmon species are initially set to meet management objectives for those species.

- The Chinook FRAM is configured to simulate this initial suite of regulations for all Washington fisheries, based on forecasted abundance of all contributing Chinook salmon management units. Estimated spawning escapements, terminal run size destined for the spawning grounds, or forecasted abundance for each population and/or management unit, and total and SUS exploitation rates, projected by this model run, are then examined for compliance with management objectives summarized in Chapter 4 for each Puget Sound Chinook salmon management unit and their component populations. This initial model run reveals conservation concerns for any MUs in critical abundance status (i.e. where escapement or forecasted abundance depending on management unit, falls short of the low abundance thresholds), and a more general perspective on the achievement of management objectives for all other management units.

- As the fishing regime is refined during March and April, a sequence of Chinook FRAM model runs are constructed through the pre-season planning process to develop a final package that achieves the management objectives for all Puget Sound Chinook Salmon MUs and component populations. In accordance with the preceding rules that control harvest levels, regulations governing directed and incidental Chinook Salmon harvest impacts are adjusted, through negotiation among the co-managers, then modeled, to develop a fishery regime that addresses the conservation concerns for weak stocks, ensures that exploitation rate ceilings are not exceeded and / or escapement objectives are achieved. The early model runs may utilize season structure from the previous year for some fisheries. Recent catch and effort provide a basis for adjusting quotas or fishery exploitation rate scalars. Incidental Chinook Salmon mortality will depend on the scale of Sockeye, Pink, and Coho Salmon fisheries in some areas.

The fishing regime developed by the pre-season planning process will comprise fishery-, time- and area-specific regulations for which fishing mortality can be modeled with acceptable accuracy, can be monitored to verify their impacts, and can be practically enforced. These conditions are intended to improve the potential to achieve management objectives and reduce management errors.

5.5 Compliance with Pacific Salmon Treaty Chinook Agreements

The fishing regime developed through the Pacific Fishery Management Council and North of Falcon pre-season planning processes will be examined for compliance with the current PST Chinook Agreement. The fisheries managed under this RMP comprise part of the US Individual Stock Based Management (ISBM) Fishery under the provisions of the PST. The US Individual Stock Based Management (ISBM) Fishery will not exceed the Treaty-mandated obligation. If fishery-related impacts associated with the US ISBM Fishery are projected to exceed PST obligations, then these fisheries must be further reduced until the PST obligation is achieved. Not withstanding, the PST defers to any more restrictive limit mandated by the Puget Sound Chinook Harvest Management Plan, or otherwise implemented by the co-managers.

The parties to the Pacific Salmon Treaty agreed to implement a revised 2008 abundance-based Chinook Salmon management regime for fisheries in the United States and Canada. Southern U.S. fisheries will be conducted, in their aggregate, as an ISBM fishery keyed to specific stocks. With respect to Puget Sound Chinook Salmon, this agreement refers to the abundance status (i.e. spawning escapement) of certain indicator stocks with respect to their identified escapement goals[8]. The summer/fall indicator stocks include the Hoko, Skagit, Stillaguamish, and Snohomish, MUs; the spring indicator stocks include Skagit spring and Nooksack spring MUs. Stock specific exploitation rates and escapements projected by the Chinook FRAM, at the conclusion of pre-season planning, will be compared to PST obligations. This action will ensure that the proposed fishery related impacts will comply with the pass through provisions and obligations for individual stock-based management regimes (ISBM) pursuant to the Chinook chapter within the US/Canada Pacific Salmon Treaty.

5.6 Regulation Implementation

Individual tribes promulgate and enforce regulations for fisheries in their usual and accustomed fishing areas, and WDFW promulgates and enforces non-Indian fishery regulations, consistent with the principles and procedures set forth in the PSSMP. To achieve conservation and sharing objectives all fisheries shall be regulated based on four fundamental elements: (1) acceptably accurate determinations of the appropriate exploitation rate, harvest rate, or numbers of fish available for harvest; (2) the ability to evaluate the effects of specific fishing regulations; (3) a means to monitor fishing activity in a sufficient, timely and accurate fashion; and (4) effective regulation of fisheries, and enforcement, to meet objectives for spawning escapement, harvest sharing, and fishery impacts.

The annual fishing regime, when developed and agreed-to by the co-managers through the PFMC and NOF forums, will be summarized and distributed to all interested parties, at the conclusion of annual pre-season planning. This document will summarize regulatory guidelines for Tribal Indian and non-Indian fisheries (i.e. species quotas, bag limits, time/area restrictions, and gear requirements) for each marine management area on the Washington coast and in Puget Sound, and each freshwater management area in Puget Sound. Regulations enacted during the season will implement these guidelines, but may be modified, based on catch and abundance assessment, by agreement between parties. In-season modifications shall be in accordance to the procedures specified in the PSSMP and subsequent court orders.

Further details on fishery regulations may be found in the respective parties' regulation summaries, and other WDFW and tribal documents. The co-managers maintain a system for transmitting, cross-indexing and storing fishery regulations affecting harvest of salmon. Public

[8] Escapement goals for the Puget Sound indicator stocks, equivalent to the upper management thresholds stated in this plan, will undergo review by the Joint Chinook Technical Committee of the Pacific Salmon Commission for incorporation into the Chinook Agreement.

notification of fishery regulations is achieved through press releases, regulation pamphlets, and telephone hotlines.

5.7 In-season Management

Fishery schedules and regulations may be adjusted or otherwise changed in-season, by the co-managers or through other operative jurisdictions (e.g. the Fraser Panel, Pacific Fisheries Management Council). Schedules for fisheries governed by quotas or total encounters, for example, may be shortened to avoid exceedance. Commercial net fishery schedules in Puget Sound may be modified to achieve allocation objectives or in reaction to in-season assessment of the abundance of target stocks, or of stocks harvested incidentally. In each case, the co-managers will assess the effect of proposed in-season changes with regard to their impact on natural Chinook Salmon management units, and determine whether the management action is compliant with the harvest limits stated in this plan. Particular attention will be directed to in-season changes that impact MUs or populations in critical abundance status, or where the pre-season plan projections indicated that total impacts were close to ceiling exploitation rates or projected escapement close to the respective escapement goals.

The co-managers will notify the NMFS when in-season management decisions cause an increase in ER, or lower escapement, for a particular MU, relative to the pre-season projection. The notification will include a description of the regulatory change, an assessment of the resulting fishing mortality, and technical or other demonstration that the management action is in accordance with harvest guidelines (i.e. ER ceilings, thresholds, and/or escapement objectives) and principles established by this Plan.

5.8 Enforcement

Non-tribal commercial and recreational fishery regulations are enforced by the WDFW Enforcement Program. The Enforcement Program’s general-authority for commissioned fish police officers is to provide protection for the state’s fish and wildlife habitats and species, prevent and manage human/wildlife contacts, and conduct outreach and education activities for both the citizens and resource users of Washington State. The mission and responsibilities of the Enforcement Program originate with statutes promulgated in several titles of the Revised Code of Washington (RCW) and Washington Administrative Code (WAC). Primary among these is RCW Title 77 - Fish and Wildlife, and Title 10 - Criminal Procedure.

Commissioned Fish and Wildlife Officers (FWOs) stationed in six regions throughout the state work with a variety of state and federal agencies to enforce all fish and wildlife laws, general authority laws, and WDFW rules. FWOs hold commissions with the United States Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration’s Office of Law Enforcement (NOAA-OLE), and therefore have jurisdiction over specific federal violations. The most important of these are the Endangered Species Act (ESA) and the Lacey Act. Officers work joint patrols and coordinate with these federal agencies as well as with the United States Coast Guard (USCG), United States Forest Service (USFS), Federal Bureau of Investigation (FBI), Bureau of Land Management (BLM), tribal police, and the Department of Homeland Security (DHS).

Each tribe maintains their own enforcement program and exercises authority to enforce tribal fishing regulations, whether fisheries occur on or off their reservation. Enforcement officers of one tribal agency may be cross-deputized by another tribal agency, where those tribes fish in common areas. Some tribes have increased enforcement activity to reduce illegal fishing in some areas. Tribal and WDFW agencies coordinate enforcement for some fisheries. Prosecution of violations of tribal regulations occurs through tribal courts and governmental structures.

We anticipate WDFW and tribal enforcement activity will continue similar to recent years for the duration of this Plan, under similar funding support. Outreach and education will continue to complement enforcement. High compliance with fishing regulations is expected to continue, and contribute to achieving the biological objectives of the Plan.

6. Conservative Management

This chapter summarizes the conservative rationale and technical methods underlying harvest management objectives established by this Plan, notes how they have changed from previous management practices, and explains how they are integrated with the hatchery and habitat components of the co-managers' Puget Sound Chinook Salmon Recovery Plan and achieve the conservation standards of the ESA.

Co-managers Harvest Management Plan and ESA Conservation Criteria

This plan protects the natural Chinook salmon management units from seventeen major river systems within Puget Sound. The intent is to maintain the continued existence of these natural management units in these watersheds and in turn, maintain the twenty-three[9] associated component populations of Chinook salmon throughout the 5 biogeographical regions that comprise the Puget Sound Chinook ESU. This is consistent with the basic intent of the Endangered Species Act to provide a frame work to conserve and protect endangered and threatened species and their habitats (16 U.S.C. Section 1531 et seq. 1973) and conforms to the TRT's population diversity and spatial distribution guidelines (Ruckelshaus et al. 2006) that were developed as part of recovery planning.

This Plan constrains harvest of all natural management units so that fishing mortality does not impede rebuilding and eventual recovery of the Puget Sound Chinook ESU. Harvest constraint will play a role by providing escapement to support natural production under existing habitat conditions, and maintaining the existing diversity of population run-timings that make up the Puget Sound Chinook ESU, by stabilizing, and in some cases increasing natural spawning escapement. However, rebuilding and recovering populations depends on successful management of other factors affecting productivity, including hatchery reform and, most importantly, the restoration of habitat function and adequate protection of intact, functioning habitat.

Current estimates of optimum or MSH escapement levels are highly uncertain, particularly where data are limited. Given this uncertainty, a fishery management regime that allows escapement to range upward from the point estimate of MSH will capitalize on favorable environmental conditions and enable measurement of recruitment across a broader range of escapement, leading to improved estimates of productivity and MSH. This strategy assumes that the potential downside risk of exceeding MSH (reduced productivity due to density dependence) is acceptable.

Additional conservation measures defined by the Plan are anticipated to increase escapement for populations at critical abundance or near-critical abundance status. Hatchery recovery programs are in place for some of the populations at high risk of extinction to ensure their persistence in the natural environment and are included as components of their abundance thresholds. Additional constraints of SUS harvest, beyond the ER limits in this Plan, will not materially improve the likelihood these populations will survive in the long term.

[9] The Hoko River is not part of the listed Puget Sound ESU.

6.1 Harvest Objectives Based on Natural Productivity

Prior to 1998, Chinook Salmon harvest objectives were stated as escapement goals for many Puget Sound management units. The PSSMP states “For primary management units returning to natural spawning areas, the escapement goal shall be the maximum sustained harvest (MSH) escapement level”, which implies the availability of information to adequately quantify MSH escapement and to estimate natural productivity with the use of population dynamics models (i.e. spawner – recruit functions). However, the PSSMP also provides exceptions to MSH based escapement goals if agreed to by affected parties. Escapement goals originally established by the co-managers to meet the objectives of the PSSMP for most ‘primary’ management units did not have a strong technical basis; most were simply an average of escapements during a period of relatively high abundance (e.g. 1968 - 1977 for summer fall stocks, 1959 - 1968 for Skagit River spring stocks). That co-managers’ management regime for Puget Sound Chinook salmon defined by the PSSMP was in effect until the late 1990s. Continuing decline in stock status, failure to meet agreed spawning escapement goals, and the subsequent ESA listing of Puget Sound Chinook Salmon prompted re-assessment of that regime and development of new fishery management strategies designed to assure protection and conservation of Category 1 and Category 2 (see Section 3.3) populations.

This Plan sets fishery impact limits (i.e. exploitation rates) or escapement objectives for all natural management units and their component populations, including some hatchery components, consistent with the best available estimates of current or recent natural productivity. Specifying fishery impact limits as exploitation rate ceilings (ER ceilings) applying to all fisheries and reflecting the status of natural production based on abundance thresholds represents a significant change from fishery management practices prior to ESA listing. These impact limits and escapement objectives will be refined if new data are available and analyses indicate the existing values are in error.

Accounting for Uncertainty and Variability

Uncertainty and annual variability are present in all estimates of productivity of salmon populations. To manage the associated risk, uncertainty and variability in the data or management systems is incorporated into the technical methods (i.e. viability risk assessment) used to derive escapement thresholds and exploitation rate ceilings for the Skagit summer / fall, Skagit spring, and Snohomish MUs. Derivation of these ER ceilings is outlined in Chapter 4 and is described in more detail in Appendix A. Accounting for uncertainty and variability may be summarized as follows:

- To the extent possible with available data, errors in estimates of freshwater and marine survival rates were estimated and parameterized in spawner – recruit functions;

- Simulations of population dynamics to derive ER ceilings incorporated variance in estimates of recent-year productivity and freshwater or marine survival. Recent estimates were employed assuming these parameters provided the most likely depiction of population performance over the duration of this plan.

- Imprecision and inaccuracy in forecasting abundance and the associated potential errors in annual harvest management decisions were incorporated into population simulations.

- The productivity of populations and our ability to accurately estimate impacts of fishing on natural management units will be monitored. At any time during the period of implementation, if significant changes are detected, then the harvest objectives of this Plan will be adjusted accordingly.

6.2 Protection of Individual Populations

In specifying criteria for determining whether actions affect the probability of ESU recovery, the salmon 4(d) rule states that for populations whose VSP status is currently not at viable population status, rebuilding to a viable status must not be impeded, unless ESU recovery would not be appreciably reduced by greater risk to that individual population. Improvement in VSP status will require improvement not only in abundance but in all four VSP categories including productivity, which has a direct relationship to abundance, as well as spatial structure and diversity (McElhany et al 2000). Increases in natural-origin abundance will be impossible for populations whose average productivity is not greater than one (i.e. not replacing themselves) and restricted for populations with average productivity near one. The long-term goal for recovery of the ESU envisions restored functionality and adequate protection of habitat resulting in much higher than current productivity, with proportionately higher harvest potential, and higher escapement suited to restored habitat function. Viable thresholds defined under those conditions involve naturally produced Chinook salmon. Previous versions of this Plan, and NMFS evaluations of them, have utilized the concept of viable thresholds by defining them exclusively based on abundance and in the context of current habitat capacity. Neglecting other VSP parameters, especially productivity, places exceptional burden on harvest actions to rebuild natural-origin abundance which is not possible where productivity, after accounting for harvest in run-reconstructions, is below replacement (less than 1.0).

For some MUs (Skagit summer/fall, Skagit spring, and Snohomish), ER ceilings were derived based on a risk assessment procedure (RER or VRAP, see Sec. 6.1 and Appendix A) with the intention of having a high probability of achieving their MSH thresholds consistent with current habitat conditions. The recruitment functions underlying the risk assessment procedure used to determine the ER ceilings were based on the available estimates of stock productivity of natural and hatchery origin adults spawning naturally[10]. Thresholds are stated in terms of natural-origin adults for many of these MUs, but hatchery-origin adults contribute to natural spawning and to production of subsequent natural-origin recruits for all MUs. The risk assessment analyses do not account for natural spawning hatchery supplementation contributing to natural-origin production in the simulation process. Upper thresholds used for the ER risk assessment, and UMTs are intentionally set higher than point estimates of MSH escapement for these MUs, in part to accommodate for the uncertainty in quantifying productivity and MSH escapement, but also to produce escapements higher than MSH in years of relatively high survival. This feature of the Plan is designed to enable measurement of recruitment under a broad range of conditions and improve estimation of productivity.

For other MUs (i.e., the Elwha, Skokomish, and Dungeness MUs), UMTs were established absent quantified estimates of current productivity and MSH escapement. The Dungeness UMT

[10] While ERs are generally specified for natural origin fish, both natural and hatchery origin productivity is considered in setting management objectives for integrated systems.

is based on assessment of available spawning habitat area and spawner density (see Dungeness MUP; Appendix A). The UMT for the Skokomish MU is 3,650, including 1,650 natural spawners and 2,000 returns to the George Adams Hatchery (HCSMP 1986).

Under this Plan, harvest limitations are not specifically designed to produce escapements that will consistently exceed the UMTs for all MUs. With reference to recent years, spawning escapements are expected to meet or exceed UMTs in some years for the Lake Washington-Cedar River, Green, White, and Puyallup MUs, accounting the aggregate of natural- and hatchery-origin adults that spawn naturally. For these MUs, harvest is not managed to achieve the UMTs exclusively with natural-origin adults, although programs are in place to sample spawners to determine their origin and to monitor the abundance of first-generation hatchery-origin and natural-origin returns. Along with severely degraded and altered freshwater and estuarine habitats in these highly urbanized systems, they also have hydropower or diversion dam structures within the spawning and migratory reaches of listed Chinook salmon, altering stream hydrology as well as sediment and wood transport and recruitment. Passage at some facilities is available while lacking or severely impactful at others. Even with available fish passage, these structures will continue to affect passage timing by delaying migrations, and in some cases, increasing predation opportunities by marine mammals taking advantage of these migratory impediments.

Potential risks exist to genetic integrity and fitness of natural populations related to interbreeding between hatchery- and natural-origin Chinook Salmon. Domestication selection and other changes in genetic diversity occur in the hatchery environment, though improved culture practices are being implemented to mitigate these risks. Chinook salmon hatchery programs have been operating for decades in these watersheds as mitigation for lost natural productivity due habitat destruction (NMFS 2014a). We lack empirical estimates of hatchery-related fitness loss, relative to the pristine state of populations, or of potential further decline in fitness. Indigenous populations have been extirpated in the Puyallup, Nisqually, Skokomish, and Mid-Hood Canal systems. Recovery potential is uncertain because these populations will depend on the adaptability of an introduced stocks. Available estimates indicate that current natural productivity of the populations in these systems is low (see Appendix A). There is strong evidence that freshwater and to some extent marine habitat conditions are a significant cause given stable, if not declining trends in returns of natural-origin fish despite relatively strong returns of hatchery-origin fish to the respective systems/facilities (see Appendix A). The additive risk of hatchery-related fitness loss is uncertain, but we assume that population productivity will not recover significantly until the freshwater and marine habitat constraints are addressed. Habitat restoration and protection efforts, are ongoing in most watersheds and reliable assessments of the effectiveness of such actions will not be available for decades. However, the expectations of ‘no net loss’ of habitat for the Puget Sound Chinook Salmon ESU in the recovery plan (NMFS 2006b, Shared Strategy for Puget Sound 2007) have not been realized to date (Judge 2011, NWIFC 2012, NWIFC 2016) and co-managers, while continuing to support and implement habitat protections and restoration, have no indication that all appropriate jurisdictions will effectively address habitat declines to improve population productivity, as well as within population spatial structure and expression of diverse life-history strategies, for populations throughout the ESU.

With these circumstances in mind, the strategy of this Plan is to maintain current abundance for all populations. For more healthy and productive MUs (average $\lambda \gg 1.0$), the Plan seeks to promote natural-origin escapements trending towards optimum levels defined by productivity associated with current habitat condition and assuming consistent freshwater and marine survival rates observed in recent years. For less productive MU's (average $\lambda \leq 1.0$) and especially those in highly urbanized environments, spawning abundance is expected to be maintained by mixed-origin spawning aggregates, both hatchery-origin and natural-origin fish, as a precautionary approach to ensure continued natural-origin recruits for recovery potential. The Plan provides more restrictive fishery impact limits when the abundance of a population is forecast to be below their threshold defining critical abundance status (also referred to as Low Abundance Threshold). Absent immediate and effective measure to address habitat constraints on with-in population productivity, spatial structure, and diversity to recover natural-origin abundance, additional constraints to fisheries beyond those defined by this Plan for fisheries under the direct jurisdiction of the Puget Sound co-managers will not materially lower the risk of extinction for these populations.

The prudent course is to experimentally implement different recovery strategies suited to local conditions and population status. Fundamental to these approaches is our intent to adjust the ER ceilings defined in this Plan in logical sequence, informed by demonstrated improvements in productivity resulting from the restoration of habitat function and improvements in fitness due to local adaptation of natural production resulting from hatchery reform for stocks in each watershed. For two populations dependent on introduced stocks for recovery, we have begun implementing two experimental recovery strategies.

In the Nisqually watershed, comprehensive habitat restoration and protection measures have already been implemented. With near-term improvement in habitat function likely to improve juvenile survival, harvest rates have been sequentially reduced, and harvest management measures implemented in the terminal fishery to enable achieving a specific MSY escapement objective, defined in terms of natural-origin fish, that will be developed as result of the implementation of the 2017 Nisqually Fall Chinook Stock Management Plan. The strategy for Nisqually Chinook envisions higher harvest rates on hatchery-origin production as the total exploitation rate on natural-origin production transitions to a lower ER ceiling during the recolonization phase of recovery. The differential for natural-origin production will be achieved by selective fisheries and re-structuring of the in-river tribal net fishery regulatory regime, possibly involving selective fishing methods based on evaluations with various selective gear types. Subsequent further adjustments in the ER ceiling may be implemented if the initial strategy is shown to result in higher productivity or conversely if escapements are demonstrated to not fully utilize habitat capacity.

A markedly different strategy has been initiated to recover historical Chinook life histories in the Skokomish watershed. There is substantial evidence the introduced Green River-origin stock may not achieve recovery objectives (Appendix A, Skokomish MUP). An early-timed, spring-run, stock is being introduced initially into the North Fork Skokomish, then subsequently into the South Fork, supported by a hatchery recovery program. Harvest on the extant, introduced summer/fall-timed Skokomish Chinook will vary consistent with the recovery strategy to experimentally delay the stocks run and spawn timing to later in the year (September-October) to sync more appropriately with the local hydrograph.

Management Units in Critical Abundance Status

Annual pre-season fisheries planning will respond to the annual abundance status (i.e., projected spawning escapement) of individual populations at or near critical annual abundance, based on FRAM estimated spawning abundance for the management unit and/or population level. If these projections indicate the escapement for any management unit or component population will be lower than its Low Abundance Threshold (LAT), then harvest will be constrained to increase escapement above the LAT or the annual fisheries regime will be designed to not exceed the critical ER ceiling (CERC). Given that most MUs have substantial impacts from northern (Alaskan and Canadian) fisheries, and that the fishery management regimes affecting those fisheries are not responsive to annual changes in abundance for individual Puget Sound MUs or populations, management efforts made by the co-managers with fisheries under their jurisdiction to address critical abundance status are limited and may even be compromised by lack of response in those northern fisheries.

Critical or near-critical abundance status is expected to persist for the Dungeness, Nooksack, Stillaguamish, and Mid-Hood Canal populations, requiring constraint of SUS fisheries consistent with this Plan and, except for mid-Hood Canal, ongoing hatchery recovery programs to ensure their persistence. Chinook-directed fisheries in the terminal areas for these populations have been closed, except for minimal tribal C&S harvest in the Nooksack River and Stillaguamish River. Pre-terminal SUS fishery impacts from 2010 to 2018 have been held to low levels: 3 – 7% for the Nooksack, 9 – 20% for the Stillaguamish, 8 – 15% for Mid Hood Canal, and 2– 8% for the Dungeness MUs based on New Base period (Round 7.1.1) post-season runs. Recent declines in escapement for these populations is most likely due to factors other than mortality in SUS fisheries.

Exploitation Rates and Escapement Trends

In the mid-1990s, prior to ESA listing, the co-managers implemented harvest conservation measures in response to declining returns of certain stocks including closing some terminal fisheries. Total or SUS ER ceilings were implemented with previous versions (2001, 2004 and 2010) of this Plan. Since 2010, SUS ERs for 11 of 14 MUs have been declined relative to the late 1990s, while the remaining three MUs indicate increases as a result of severe restrictions and in some cases complete closure of the terminal fisheries (e.g. Nooksack River and Skokomish terminal fisheries) between 1994 and 1998 (Table 6-1).

Table 6-1. Average Southern U.S. fishery exploitation rates for Puget Sound Chinook Salmon management units based on 2021 FRAM post-season runs version 7.1.1.

Management Unit	1992-98 Avg	2001-09 Avg	2010-18 Avg
Nooksack Spring	6.9%	4.7%	6.6%
Skagit Summer/Fall	16.0%	12.0%	16.4%
Skagit Spring	10.8%	7.2%	10.6%
Stillaguamish	18.1%	9.0%	8.4%
Snohomish	25.7%	9.8%	7.8%
Lake Washington	29.7%	17.6%	14.4%
Green	36.4%	38.2%	19.8%
White River Spring	25.1%	19.1%	18.1%
Puyallup	44.3%	38.0%	33.0%
Nisqually	64.4%	59.2%	40.0%
Skokomish	32.3%	45.3%	42.0%
Mid-Hood Canal	24.2%	12.3%	11.6%
Dungeness	11.4%	6.1%	5.0%
Elwha	13.7%	5.6%	5.2%

Analysis of escapement trends for Puget Sound Chinook demonstrates changes in population status during the period 2001-2015 using the Geiger and Zhang (2002) method (Table 6-2). This method detects relatively short-term trends of biological significance, but analysis of much longer time series is required to identify changes in abundance status. Based on this method, three populations exhibit biologically significant declining trends. Negative slopes are evident in 6 other populations or management units, but are not considered biologically significant. Eight populations exhibit biologically significant increasing trends, with positive slopes evident in four other populations. From the preceding analysis, biologically significant declining trends or decline of lesser magnitude, are not associated with changes in harvest mortality. Harvest constraint cannot reverse these declines. Some declines are circumstantially linked to floods or similar events; more robust populations can rebound from these effects. However, in many systems habitat conditions are so degraded that natural production cannot rebound. Hatchery programs are playing an essential role for these populations to perpetuate natural production until habitat conditions improve. Concern for these populations is growing as several analyses indicate the habitat conditions continue to worsen (NWIFC 2012, 2016 and Judge 2011), despite ongoing efforts to restore and protect habitats.

Table 6-2. Fifteen-year (2006-2020, except Nooksack covers 2004-2018;Skagit, Stillaguamish, Nisqually, Skokomish, and Hoko covers 2005-2019; Mid-Hood Canal covers 2007-2021) trends in natural spawning escapement for Puget Sound Chinook populations. Light-red highlights depict biologically significant declines and light-green depicts biologically significant increases consistent with criteria expressed in Geiger and Zhang (2002).

		15-year series	
MU	Population	slope	slope/y_0
Nooksack	North / Middle Fk	18.0	0.012
	NF/MF NORs	-22.5	0.052
	So. Fork Total	59.2	-0.245
	So Fork NORs	15.7	-0.403
Skagit spring	Suiattle	37.2	0.230
	Upper Sauk	113.5	5.007
	Cascade	-15.0	0.038
Skagit S/F	Lower Sauk	-13.2	0.024
	Upper Skagit	31.0	0.003
	Lower Skagit	-72.0	0.027
Stillaguamish [1]	Summers and Falls	-30.9	0.021
Snohomish	Skykomish	40.0	0.015
	Snoqualmie	-57.6	0.033
Lake Washington	Sammamish	-28.3	0.065
	Cedar River	-55.0	0.043
Green		259.0	0.039
White		206.6	0.289
Puyallup		-69.9	0.030
Nisqually		12.6	0.006
Skokomish		113.1	0.169
Mid Hood Canal		-10.9	21.517
Dungeness		43.0	0.211
Elwha		197.2	0.151
Hoko		133.2	0.788

[1] GMR adjusted escapements used for Stillaguamish MU.

6.3 Equilibrium Exploitation Rates

Managing fisheries under this Plan using exploitation rate ceilings that are defined based on current estimates of natural productivity, are intended to promote stable or increasing escapements of natural-origin returns for those management units with brood year productivities consistently greater than one. By setting the fishery exploitation rate ceilings conservatively and all else remaining constant, the Plan anticipates an increase in the probability that natural-origin escapement will trend toward maximum sustainable yield (MSY or MSH) over time for management units with productivity greater than one. The following analysis illustrates this concept for the Skagit River spring management unit.

The equilibrium exploitation rate at each level of spawning escapement (i.e., the exploitation rate that would, on average, maintain the spawning escapement at the same level) for Skagit River spring Chinook were calculated from the Ricker spawner-recruit parameters used in the ER ceiling derivation. These equilibrium rates are represented by the curve that forms the border between the shaded and white regions in Figure 6-1. Note that the equilibrium ER decreases as escapement increases due to declining productivity at higher abundances. In the region below the curve (i.e., the exploitation rate is lower than the equilibrium rate that applies to that level of spawning escapement), escapement should, on average, increase in the next cycle. In the region above this curve, escapement should, on average, decrease in the next cycle.

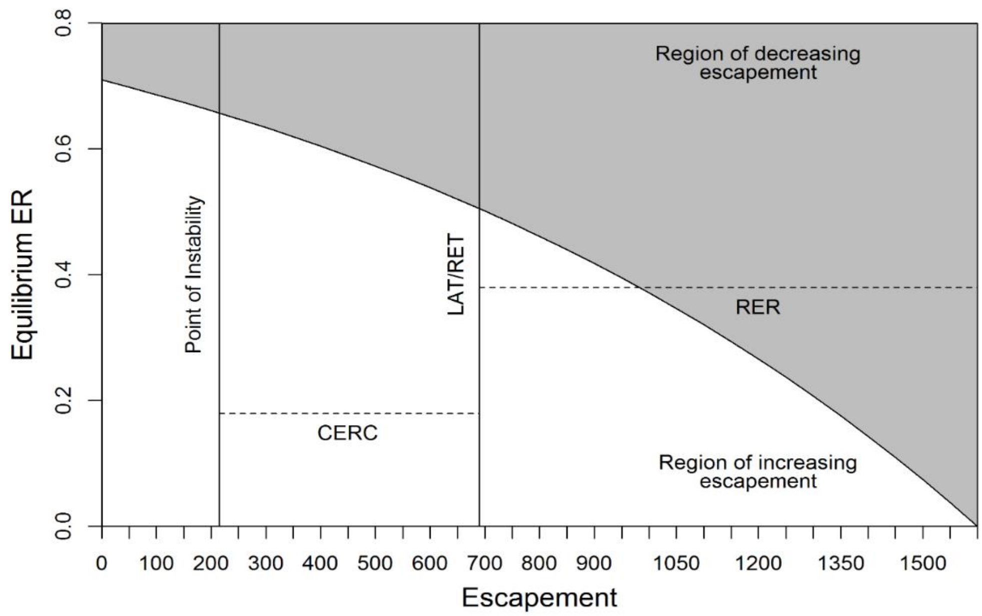

Figure 6-1. The equilibrium exploitation rate, at each escapement level, for Skagit spring Chinook.

For Skagit spring Chinook, where management unit productivity is generally greater than 1.0 and spatial diversity and population diversity are generally sufficient to reduce risk of extinction from small scale perturbations, although improvements in habitat complexity (reactivation of floodplain habitat and removal of migration barriers) would improve the overall status (see Appendix A), the NMFS Limit 6 "viable status" is comparable to the "rebuilding escapement threshold" (RET) used in the ER ceiling analyses[11]. The RET is also the estimated MSY escapement level of about 823 derived from the Ricker spawner-recruit parameters (Figure 6-1). The NMFS Limit 6 "critical threshold", however, is NOT comparable to the "critical abundance threshold" (Low Abundance Threshold; LAT) defined in this Plan. The NMFS Limit 6 "critical threshold" is a level of spawner abundance below which the spawner-recruit relation destabilizes and the 100 year risk of extinction increases greatly. The low abundance threshold in this Plan, in contrast, is set above the point of instability to reduce that the risk of developing population instability through management error or uncertainty. The critical abundance threshold, or LAT, for Skagit spring Chinook in this Plan is 823 spawners, more than double the point of instability calculated using the Ricker parameters from the ER Ceiling analysis and Peterman's (1977) rule-of-thumb (about 215 spawners).

[11] Where productivity, spatial structure, and diversity limit the long-term extinction risk of a population, abundance thresholds are not viable surrogates for determining VSP status.

The plan mandates that, if escapement is projected to fall below the LAT, SUS fisheries will be constrained to exert an exploitation rate less than or equal to the CER ceiling, though the total exploitation rate may range higher due to northern fisheries. For Skagit spring Chinook, when abundance is between the point of instability and the viable abundance threshold, this plan's ER ceiling is well within the region of increasing escapement (Figure 6-1), which satisfies the criterion that the plan must not appreciably slow the population's achievement of viable abundance status. In fact, even ER's significantly above the ER ceiling satisfy this criterion.

For escapements greater than the viable abundance threshold, the ER ceiling allows for increasing escapements up to the point where the ER ceiling intersects the equilibrium ER curve. This occurs at an escapement of about 1,000 (Figure 6-1). For escapements above that level, if harvest met the ER ceiling each year, escapements would tend to decrease in the next cycle; however, they would be expected to stabilize around an escapement of about 1,600, which is well above the viable abundance threshold. Thus, the plan also satisfies the criterion that, for escapements above the viable abundance threshold, abundance will, on average, be maintained in that region of the productivity curve.

For escapements below the demographic point of instability, recruitments will, by definition, be inconsistent and largely unrelated to the escapement level. This means that harvest management cannot be used effectively to increase escapements above the demographic point of instability. Rebuilding above this level could only be accomplished through fortuitous returns, naturally spawning hatchery fish, or increased natural productivity. This plan addresses risks associated with abundances below the management point of instability largely by minimizing the impact of fishing to avoid such extreme low abundance levels. For Skagit springs, the trigger for reducing SUS impacts to a critical abundance regime occurs at a threshold of 690, which is over three times higher than the calculated point of instability, and, at that threshold and exploitation rate, is well within the region of increasing escapement (Figure 6-1). In the event that abundance falls below the management point of instability, and then was followed by a fortuitous recruitment that exceeded that level, the critical ceiling exploitation rate is low enough that equilibrium momentum will tend to increase the escapement further, rather than reduce it to below the point of instability again. Thus, this plan should not increase the genetic and demographic risk of extinction for Skagit springs. In practical application, the lowest observed Skagit spring Chinook escapement has been 470 (in 1994 and 1999), which is over two times higher than the calculated point of instability – escapements have exceeded 1,000 during each of the last five years, which is higher than the viable abundance threshold, and again indicates that this plan should not increase the genetic and demographic risk of extinction for Skagit springs.

Exploitation rates below the curve should, on average, result in higher escapements on subsequent cycles; exploitation rates above the curve should, on average, result in lower escapements on subsequent cycles. Equilibrium rates were calculated from the Ricker parameters that were used for the ER Ceiling analysis used to set the ER ceiling for the Skagit spring Chinook management unit. The MSY exploitation rate (MSY ER), ER ceiling, and CER ceiling, and three escapement levels – the calculated point of instability, the low abundance threshold (LAT), and the rebuilding escapement threshold (RET), are marked for reference (Figure 6-1).

6.4 Recovery Goals

The Washington State Shared Strategy process identified recovery goals for 16 Chinook salmon populations, based on assessment of the potential productivity associated with recovered habitat conditions (Table 6-3). These interim planning targets are intended to assist local governments, resource management agencies, and public interest groups with identifying harvest and hatchery management changes, and habitat protection and restoration measures necessary to achieve recovery in each watershed and the ESU as a whole. Recovery goals are expressed as a range of natural-origin or natural spawning escapement and associated recruitment rates (i.e. adult recruits per spawner). The lower boundary represents a number of spawners that will provide relatively high surplus production (i.e. MSH) under properly functioning habitat conditions, assuming recent marine survival rates. The prudent course is to experimentally implement different recovery strategies suited to local conditions and population status. Fundamental to these approaches is our intent to set or adjust ER ceilings in logical sequence, informed by demonstrated improvements in productivity resulting from the restoration of habitat function and improvements in fitness due to local adaptation of natural production resulting from hatchery reform for stocks in each watershed.

Table 6-3. Escapement levels and recruitment rates for Puget Sound Chinook populations, at MSH and at equilibrium, under recovered habitat conditions (Ruckelshaus et al. 2005).

	High Productivity Target (R / S)	Equilibrium Target	Equilibrium Abundance Range
NF Nooksack	3800 (3.4)	16,000	16,000 - 26,000
SF Nooksack	2000 (3.6)	9,100	9,100 - 13,000
Lower Skagit	3900 (3.0)	16,000	16,000 - 22,000
Upper Skagit	5380 (3.8)	26,000	17,000 - 35,000
Lower Sauk	1400 (3.0)	5,600	5,600 - 7,800
Cascade	290 (3.0)	1,200	1,200 - 1,700
Suiattle	160 (2.8)	610	600 - 800
Upper Sauk	750 (3.0)	3,030	3,000 - 4,200
NF Stillaguamish	4000 (3.4)	18,000	18,000 - 24,000
SF MS Stillaguamish	3600 (3.3)	15,000	15,000 - 20,000
Skykomish	8700 (3.4)	39,000	17,000 - 51,000
Snoqualmie	5500 (3.6)	25,000	17,000 - 33,000
Sammamish	1000 (3.0)	4,000	4,000 - 6,500
Cedar	2000 (3.1)	8,200	8,200 - 13,000
Green	N/A	27,000	17,000 - 37,700
Puyallup	5300 (2.3)	18,000	17,000 - 33,000
Skokomish	N/A	N/A	N/A
Mid Hood Canal	1,300 (3.0)	5,200	5,200 - 8,300
Nisqually	3400 (3.0)	13,000	13,000 - 17,000
Elwha	6,900 (4.6)	17,000	17,000 - 30,000
Dungeness	1200 (3.0)	4,700	4,700 - 8,100

For most MUs, the upper management thresholds, recent escapements, and estimates of productivity at MSH are substantially below the lower end of the recovery range (Table 6-3), reflecting the different points of reference with regard to habitat quality and quantity. Notable exceptions include the Lower Skagit fall and Suiattle spring populations, where some recent escapements, but not productivity, have exceeded the lower abundance boundary of the recovery goals. These examples notwithstanding, UMTs established in this plan, based on considerations of uncertainty around MSH escapement, and the productivity estimates at MSH under current habitat conditions, demonstrate that current habitat conditions limit the potential for most populations to achieve viable status and eventual recovery of the ESU.

With the exceptions noted above, these population recovery goals are not of immediate relevance to current harvest management objectives because the Shared Strategy goals are based on recovered habitat and high productivity (Shared Strategy for Puget Sound 2007), where the co-manager's harvest management objectives within this Plan are based on *current* habitat and productivity conditions. Therefore, these recovery goals are high enough to support substantial harvest, they may exceed the abundance levels required to delist the ESU. From an ESA perspective, ESU recovery and delisting requirements are governed by NOAA and may be possible under more than one combination of viable populations.

6.5 Harvest Constraint Cannot Effect Recovery

Recovery for most populations cannot be accomplished solely by constraint of harvest. For the immediate future, harvest constraint will assist in providing optimal escapement, suited to current habitat condition. Productivity is constrained by habitat condition, and is not influenced by harvest, providing harvest does not reduce escapement to the point of demographic or genetic instability. The quality and quantity of freshwater and estuarine environment determines embryonic and juvenile survival, and oceanic conditions influence survival up to the age of recruitment to fisheries and spawning populations. Physical or climatic factors, such as stream flow during the incubation period, will vary annually, and have been shown to markedly reduce smolt production in some years. The capacity of Chinook salmon to persist under these conditions is primarily dependent on their diverse age structure and life history, and habitat factors (e.g. channel structure, off-channel refuges, and watershed characteristics that determine runoff timing/magnitude) that mitigate adverse conditions. However, these physical habitat attributes continue to be limiting in Puget Sound watersheds (NWIFC 2012, NWIFC 2016) as a result of ineffective regulatory measures to protect functioning habitat.

For several Puget Sound populations, mass marking of hatchery production has enabled more accurate accounting of the contribution of natural- and hatchery-origin adults to natural escapement. Sufficient data has accumulated to conclude that a significant reduction of harvest rates, and increased marine survival in some years, has increased the number of hatchery-origin fish that return, whereas returns of natural-origin Chinook salmon, though stable, have not increased (see next sentence). For instance, abundance (escapement) data for the North Fork Nooksack, Skokomish, and Dungeness rivers shows NOR returns have remained at very low levels, while total natural escapement including hatchery-origin spawners has either increased or held stable where hatchery supplementation programs exist (see Appendix A). Skokomish River spawner abundance data is presented as an example of this trend (Figure 6-2). It is evident that natural production has not increased under reduced harvest pressure, and is constrained primarily by the condition of freshwater habitat. Therefore, the harvest rates governed by this plan are not impeding recovery.

Harvest constraint has, for most populations, contributed to stable or increasing trends in escapement. For many populations this includes a large proportion of hatchery-origin adults. But stable or negative trends in NOR returns strongly suggests that recruitment will not increase substantially unless constraints limiting freshwater survival are alleviated.

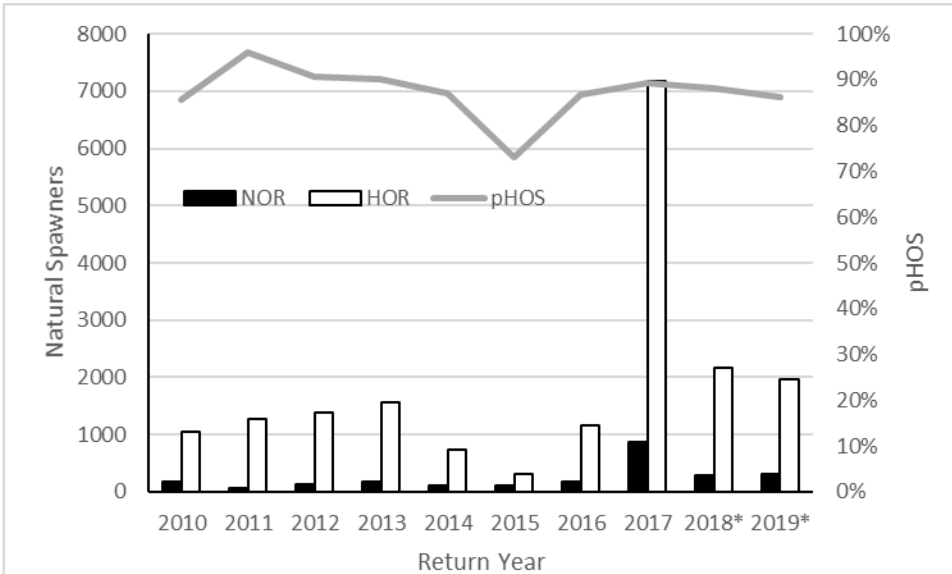

Figure 6-2. Natural and hatchery origin spawner abundance on the Skokomish River for 2010 – 2019. Note: Return year 2018 and 2019 are preliminary estimates (*); see Skokomish MUP (Appendix A).

6.6 Integration of harvest and hatchery management with habitat status

This section describes the framework for integrating the top priorities of protecting and recovering habitat with the actions associated with harvest and hatchery management to manage the level of acceptable risk for populations during recovery. An extensive body of science supports the principle that improvements in all management sectors must occur for salmon to be recovered (Ruckelshaus et al. 2002, Good et al. 2007). Impacts from habitat, hatchery, and harvest management sectors all affect salmon survival at different life stages as salmon complete their life history (Quinn 2011).

Managing those impacts must consider interactions of the viable salmon population (VSP) attributes of abundance, productivity, spatial structure, and diversity at different time scales (Scheuerell et al. 2006). Properly managed harvest actions focus on response of abundance over time periods of a generation or two whereas habitat degradation affects population productivity, spatial structure, and diversity parameters with leading multi-generational impacts on abundance that can be permanent if habitat is lost or severely degraded (Figure 6-3). These impacts are not limited exclusively to physical habitat structure and function (e.g., flood plain connectivity, impervious surfaces, large woody debris, etc.) but also include the ecological communities that affect salmon, whether those be the ever increasing abundance of pinniped predators (Chasco et al. 2017), invasive species (Sanderson et al. 2009), or changing pelagic food web from nitrogen pollution (Krembs et al. 2014). Focusing on risks and impacts in one sector without similar focus on related impacts from other sectors restricts the effectiveness of any one approach. Alternatively, integrating protection and recovery approaches across all management sectors means protection and/or recovery actions in any one sector are more likely to succeed.

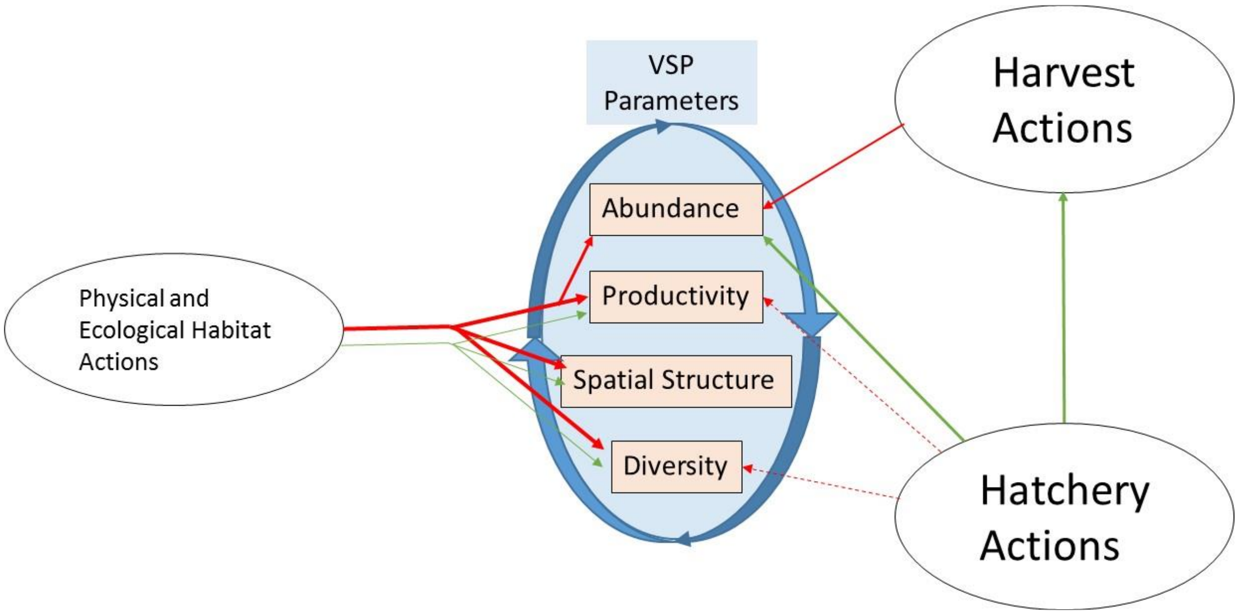

Figure 6-3. Effects of habitat, harvest, and hatchery management sectors on viable salmonid population (VSP) attributes.

Key Principles of Integration

This integration is based on five fundamental scientific and legal principles.

- Protecting functioning habitat is one of the top priorities and first steps for achieving a viable ESU (NMFS 2006a)
- Different factors interact to affect overall risk to the listed populations (NMFS 2007)
- Interactions and tradeoffs between risk factors change depending on the stage of recovery (HSRG 2012)
- The level of acceptable risk to populations and roles of populations in recovery may vary (NMFS 2006a, 2007) and should be implemented with respect to the uniqueness in available opportunities and constraints realized across the ESU.
- The proportional burden of conservation to different groups must be consistent with legal and scientific principles.

There is ample evidence indicating that salmon cannot survive and recover unless threats and limitations to their habitat needs are protected and improved, as necessary to allow rebuilding and improvement in VSP status. Loss of habitat is associated with over 90% of the extinction and declines of Pacific Salmon (Nehlsen et al. 1991, Gregory and Bisson 1997). All of NOAA's Pacific salmon recovery plans (http://www.westcoast.fisheries.noaa.gov/protected_species) identify protecting and restoring habitat as the key strategy for recovery of the species. In fact, Pacific salmon rivers have the highest density and extent of stream habitat restoration efforts in the United States (Bernhardt et al. 2005), but the lack of evaluation and integration of these efforts into other management actions weakens the potential progress towards recovery (Bernhardt et al. 2007). The importance of considering all the "H's" together is underscored by the manner in which NMFS has conducted its risk assessment for Puget Sound Chinook stemming from harvest actions:

> The results of this evaluation [NMFS' risk assessment] also highlight the importance of habitat actions and hatchery conservation programs for the preservation and recovery of these populations specifically, and to the ESU in general. The status of many of these stocks is largely the result of reduced productivity in the wild from habitat loss and degradation and from other sources of human induced mortality. The analysis in this evaluation suggests that it is unrealistic to expect to achieve substantive increases in Chinook population abundance and productivity and population recovery through harvest reductions alone without also taking substantive action in other areas to improve the survival and productivity of the populations. Recovery of the Puget Sound Chinook ESU depends on implementation of a broad-based program that addresses the identified major limiting factors of decline.[12]

The H-Integration Framework

Finding an equitable distribution of the conservation burden is the most difficult challenge for conservation in general (Hanich et al. 2015, Campbell and Hanich 2015, Azmi et al. 2016) and salmon recovery in particular. The federal government has recognized some of these challenges for Pacific salmon but has not yet provided a consistent, scientifically defensible solution (NWIFC 2011). In contrast, this framework addresses that gap and provides a practical and scientifically sound way of moving forward.

The cornerstone of this approach is that changes in harvest-hatchery strategies for populations, which are intended to protect populations for recovery, will be based on:

- the opportunity for habitat recovery (i.e., the adequacy of habitat protection);
- the current status of the habitat; and
- the productivity and capacity of the population.

This approach provides for consistency and coordination between the protection and recovery of salmon habitat, and the protection and recovery of salmon populations. Until recently, salmon conservation obligations have largely focused on protecting salmon populations via harvest restrictions on tribal and non-tribal fishers. As data on the status of the Puget Sound Chinook Salmon populations and habitat reveal, this focus is ineffective when habitat degradation and land use management limit the capacity of habitat to improve population viability (i.e. productivity, spatial structure, and diversity). Conservation by all sectors that affect salmon population viability is necessary to protect and recover salmon. Ignoring the population viability

[12] *See* NMFS, Endangered Species Act Biological Opinion and Magnuson-Stevens Act Essential Fish Habitat Consultation Regarding Impacts of Programs Administered by the Bureau of Indian Affairs that Support Puget Sound Tribal Salmon Fisheries, Salmon Fishing Activities Authorized by the U.S. Fish and Wildlife Service, and Fisheries Authorized by the U.S. Fraser Panel in 2014, NMFS Consultation No.: F/WCR-2014-578 (May 1, 2014) at 92. *See also id*. at 26 ("In addition to being a factor that contributed to the present decline of Puget Sound steelhead populations, the continued destruction and modification of steelhead habitat is the principal factor limiting the viability of the Puget Sound steelhead DPS into the foreseeable future").

impacts of poor habitat management, and simply relying on harvest restrictions and hatchery supplementation to maintain remnant populations of salmon unlikely to persist in the long-term, unfairly places the conservation burden on the treaty right to take fish.

For harvest, the conservation mandate is to constrain harvest to allow sufficient escapement of adults returning to their stream of origin to fully use the existing habitat. Harvest constraints affect both natural-origin and hatchery-origin fish, which affects the management of hatchery programs that are either providing fish to the habitat and/or for harvest. As habitat conditions improve or degrade, leading to changes in the productivity and capacity of salmon populations, managers will need to revise harvest management objectives and hatchery strategies accordingly.

The conservation mandate for harvest cannot be used to mitigate for failure to address non-harvest impacts on salmon. If habitat conditions fail to improve, for example, this points to a failure of land and/or water managers to address habitat threats and limiting factors and not a failure of harvest management. The Endangered Species Act identifies two categories of listing factors that the National Marine Fisheries Service (NMFS) must assess and address. One is the present or threatened destruction, modification, or curtailment of a species' habitat or range; the other is inadequacy of existing regulatory mechanisms for protecting habitat and fish populations. This framework attempts to directly incorporate these factors, along with the treaty rights conservation necessity principles discussed above.

Figure 6-4 illustrates the conceptual relationship between the status of the habitat and the population status for management purposes across different trajectories and phases of recovery. Where populations have a low likelihood of persistence without demographic help, habitat protection is fundamental to providing the opportunity for sustainable habitat restoration and recovery. This restored and protected habitat provides the opportunity for salmon to use the habitat and for natural-origin abundance to increase. Without habitat protection and restoration, hatchery and harvest management to recover salmon are inefficient, slower, and wasteful. As natural-origin salmon abundances in protected habitat increases, demographic risks to small populations decrease, thereby allowing for management protection of natural-origin fish to promote local adaptation and productivity of natural-origin salmon.

This approach incorporates three different concepts consistent with the principles described above:

- Current and future status of functioning habitat for salmon
- Role and status of different populations in recovery, and
- Phases of recovery.

These are described below.

Current and Future Status of Habitat

Extensive scientific research worldwide shows that the status of natural populations depends on their habitat and the effectiveness of actions to protect habitat from further degradation and provide opportunities for habitat recovery. Currently, numerous threats to habitat across Western Washington limit the ability of salmon populations to persist at high or very high probabilities of persistence (NMFS 2017; NWIFC 2016). NMFS identified the qualities of salmon habitat necessary to assess the threatened destruction, modification, or curtailment of a species' habitat or range and approved a plan to implement regulatory mechanisms to prevent habitat losses so that habitat recovery strategies could be effective (NMFS 2006a). Although NMFS has not yet assessed salmon habitat based on the qualities they identified (Beechie et al. 2017), a report published by the National Marine Fisheries Service in 2011 concluded that without a better assessment of how well habitat protections were working salmon habitat was likely to continue to decline thereby adversely affecting the status of fish populations (Judge 2011). In 2015, NMFS provided some evidence this was the case. NMFS scientists concluded that although the rate of development of impervious land cover (an indicator of lack of habitat protection and impacts to salmon) had slowed in some areas, habitat continues to be lost across the Puget Sound (Bartz et al. 2015).

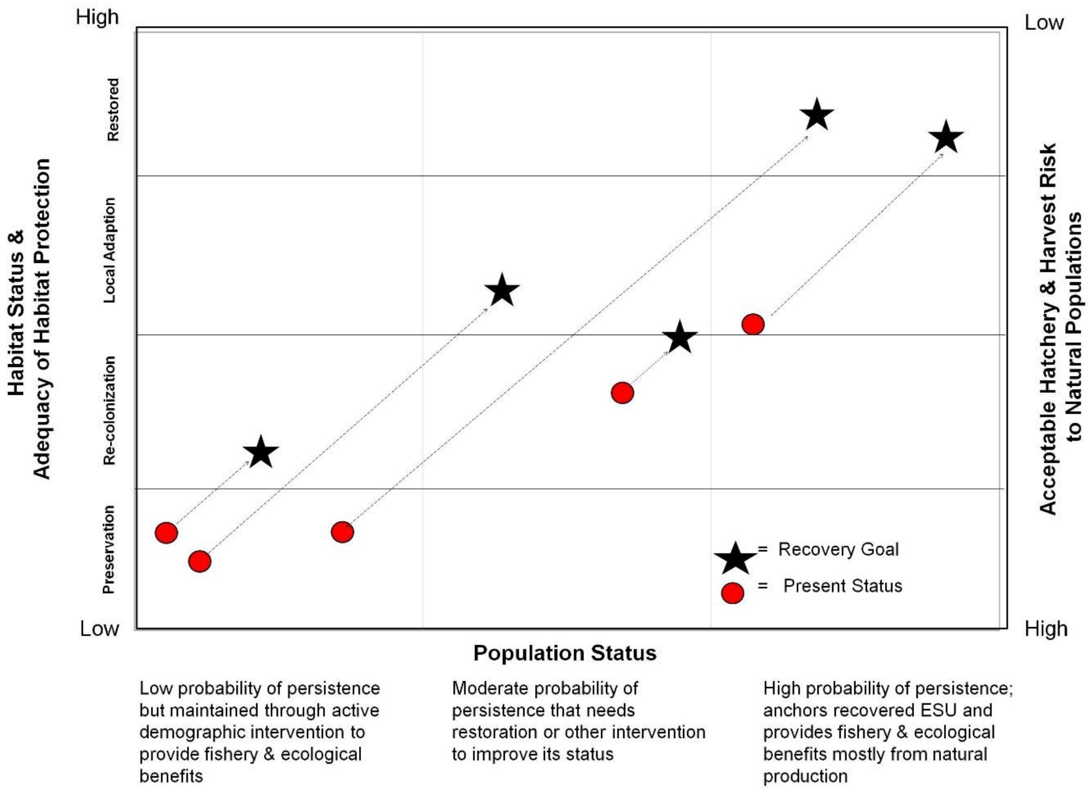

Figure 6-4. Pathways for changing harvest and hatchery management based on habitat status and the adequacy of regulatory protection for habitat. Circles indicate current status; stars indicate possible population roles in a recovered ESA; and dotted lines indicate recovery trajectories.

Portfolio of Populations

The roles and acceptable risk to different populations may vary across the listed species or ESU (NMFS 2006a, 2007, 2010). Not all populations need to reach a high or very high probability of persistence for the ESU to be recovered. In fact, some populations in the Puget Sound Chinook

ESU are not expected to improve from current status as a result of historical and ongoing habitat alterations by humans.

In this Plan, *population status* means the current state of the population based on likelihood of persistence associated with active intervention in the demographics of the population. This may change over time. For example, where habitat extent, quality, and protection are poor, the probability of persistence and recovery is low. Management activities for harvest and hatcheries will be consistent with maintaining the population but this will require active intervention in the demographics of the population using transportation, hatcheries, and other tools because this increases the overall likelihood of persistence until habitat can improve. This intervention may provide fishery and ecological benefits but without intervention the natural population is unlikely to persist at baseline levels. Under more improved habitat conditions and protections that increases population abundance and productivity, management activities will be consistent with maintaining the population and promoting natural production with less active forms of intervention. Finally, where habitat is functioning well, populations require little or no demographic intervention to be viable. These populations will ultimately anchor a recovered ESU and provide fishery and ecological benefits mostly from natural production.

If habitat cannot be protected and restored (Figure 6-4), recovery is biologically not possible even with restrictions on harvest and hatcheries. For some populations (e.g., central Puget Sound populations in urbanized watersheds such as the Cedar, Green and Puyallup rivers), there may be little opportunity to improve status given historical land alterations for development, transportation, and agriculture and projected human population growth and climate change (Cuo et al. 2011). Consequently, these populations will need to be constantly supported by hatcheries and other management activities to provide ecological and social benefits.

The *roles of populations* refer to status of populations necessary for a recovered ESU. The *Final Supplement to the Shared Strategy's Puget Sound Salmon Recovery Plan*, for example, specifies that to recover the Puget Sound Chinook Salmon ESU, 2-4 populations in each biogeographical region must be at their target recovery goals with little demographic intervention. These "primary" populations are those that need to have the highly functioning habitat so that they can reach high or very high probabilities of persistence. In the Puget Sound, three of the five biogeographical regions have only two populations each. Other populations may be self-sustaining at levels lower than the target recovery goals or rely on demographic and continual restoration to maintain their abundance and productivity.

It is not unusual for regulators to want to focus on increasing the pace of recovery for primary populations. Scientifically, the pace of recovery depends on changes to the current status of the populations and their habitats. Habitat necessary to attain viable population status will need to be well protected and highly functional to recover the ESU. Based on the principle that protecting functioning habitat is one of the top priorities and first steps for achieving a viable ESU (NMFS 2006a), regulatory actions focusing on primary populations need to begin with protecting their habitat and assessing effectiveness of protection so that changes in harvest and hatchery management sectors can be successful. Just as the kinds of habitat protections needed in each watershed are not expected to be identical because the watersheds are not identical, harvest actions for management units with similar population roles in the ESU are not expected to be uniform. Rather, they will vary depending on evaluation of a variety of considerations: current and potential habitat recovery opportunities, origin of the stock for recovery, geographic location of the stock and fishery opportunities, and exercise of Treaty rights.

Phases of Recovery

Phases of recovery refer to the different ecosystem conditions that require different objectives to balance the various risks and opportunities for recovery that occur as the ecosystem changes. For example, the tradeoff between extinction when population abundances are very low and losing a characteristics for local adaptation and genetic diversity by protecting a population in a hatchery is starkly obvious in the preservation phase (Busack 2012, HSRG 2012) but less important in other phases of recovery. This plan uses the four phases identified by the Hatchery Scientific Review Group (HSRG 2014): preservation, re-colonization, local adaptation, and full restoration. Table 6-4 contains narrative descriptions of the ecosystem conditions and objectives for each phase.

Pace of Recovery

Phases of recovery do not have an implicit pace of recovery. In most cases it will likely take many decades for populations to move from one phase to another as the ecosystem changes, although this can be frustrating to restoration activists and regulators. For example, NMFS's analysis of the population abundance trends and growth rates (lambda) for most Chinook Salmon populations indicate there is little improvement in the long-term trend and most populations are barely replacing themselves (NMFS 2011). This indicates that many populations are in the preservation phase and may require significant intervention with hatcheries to prevent extinction and provide fishery and ecological benefits unless and until habitat is sufficiently protected and restored. Similarly, where lack of habitat protection and funding means that habitat restoration is slow, populations may be in the re-colonization or preservation phase for many decades. In most cases, opportunities to provide access to functioning habitat through passage improvements where fish can re-colonize rapidly are limited and represent special cases of re-colonization. This pace of recovery for habitat is consistent with other expectations for the pace of recovery from other management sectors. Scientific analyses show that NMFS's regulatory efforts to encourage local adaptation by managing the proportion of natural-origin and hatchery-origin fish may take centuries or more before the potential fitness gain and transition to a fully restored phase are realized (Ford 2004, NMFS unpublished analyses).

Table 6-4. Biological phases of restoration and objectives for different ecosystem conditions as described by the HSRG (2014) and biological, social, and economic trade-offs at different stages.

Biological Phases	**Ecosystem Conditions**	**Objectives**	**Conflicting Objectives and Trade-Offs**
Preservation	Low population abundance; habitat unable to support self-sustaining populations; ecosystem changes pose immediate threat of extinction	Prevent extinction; retain genetic diversity and identity of existing population	• Adaptive value of natural habitat versus the pace of habitat restoration that will be fast enough to prevent extinction • Using hatcheries to increase abundance to prevent extinction versus the potential short-term loss of diversity and productivity • Using hatcheries to increasing spatial structure (by splitting vulnerable populations among multiple hatcheries) and avoid large catastrophic loss from ecosystem changes in the wild versus increasing the exposure of fish to smaller catastrophic losses in hatcheries. • Using hatcheries to increase abundance to prevent extinction versus the loss of ecosystem benefits that natural salmon provide (e.g., predator-prey interactions, marine drive nutrients, etc.). • Using hatcheries increase abundance to prevent extinction versus the constraints on harvest because of low abundance of natural origin fish
Re-colonization	Underutilized habitat available through restoration and improved access	Re-populate suitable habitat from pre-spawning to smolt outmigration (all life stages)	• Long-term cost, pace, and certainty of protecting and restoring degraded conditions to allow successful re-colonization – especially given human population growth projections and climate change - versus the short-term cost of producing larger numbers of fish in hatcheries • Cost of monitoring re-colonization to improve its effectiveness versus coast of habitat protection and restoration • Natural productivity associated with the quality of new restored and accessible habitat versus the productivity of hatchery fish in the wild • Protection and restoration of habitats that favor the most abundant and

Biological Phases	Ecosystem Conditions	Objectives	Conflicting Objectives and Trade-Offs
Re-colonization (cont.)			successful life-history types versus protection and restoration of habitats that increase overall diversity of life-history types • Using hatcheries to increase abundance for re-colonization versus the loss of ecosystem benefits that natural salmon provide (e.g., predator-prey interactions, marine drive nutrients, etc.). • Using hatcheries to increase abundance for re-colonization versus providing those fish for harvest
Local adaptation	Habitat capable of supporting abundances that minimize risk of extinction as well as tribal harvest needs; prevent loss of genetic diversity; and promote life history diversity	Meet and exceed minimum viable abundance for natural-origin spawners; increase fitness, reproductive success and life history diversity through local adaptation	• Long-term cost, pace, and certainty of protecting and restoring degraded conditions to allow successful local adaptation – especially given human population growth projections and climate change - versus the short-term cost of producing larger numbers of fish in hatcheries • Cost of monitoring local adaptation to improve effectiveness of hatchery and harvest management strategies versus coast of habitat protection and restoration • Natural productivity associated with the accessible habitat versus the productivity of hatchery fish in the wild • Using natural production to increase abundance to provide for ecosystem benefits that natural salmon provide (e.g., predator-prey interactions, marine drive nutrients, etc.) versus using hatcheries • Using natural production to increase abundance for harvest versus using hatcheries
Full restoration	Habitat restored and protect to allow full expression of abundance, productivity, life-history diversity, and spatial structure	Maintain viable population based on all viable salmonid population (VSP) attributes using long-term	• Long-term cost, pace, and certainty of protecting habitat for natural production of salmon versus using the same habitat to support human population

Biological Phases	Ecosystem Conditions	Objectives	Conflicting Objectives and Trade-Offs
		adaptive management	

It is the intent of this plan that scientific analyses will inform how tradeoffs between different risks and benefits occur at different phases of recovery and how to implement recovery actions consistent with those that will be legally sound. The concept has already achieved some legal support. For example, the Ninth Circuit Court of Appeals recently supported the National Marine Fisheries Service scientific conclusion that the value of using hatchery fish to prevent extinction and recover Elwha River salmon runs as the dams were removed and fish were reintroduced outweighed the genetic and ecological risks of using hatcheries during the preservation and re-colonization phases.

Demographic Support

Demographic support for populations may involve a number of management tools, including but not limited to transportation, translocation, predator removal, prey enhancement, and hatcheries. Demographic support depends on the status of the population and the ability to protect and restore habitat (Figure 6-4). Because the pace of recovery is expected to be slow, demographic support using hatchery programs will play a key part of the integration across the management sectors for a considerable time to come.

The conservation mandate for hatcheries is to support salmon populations demographically, consistent with the status of the population and phase of recovery while maintaining opportunities for fishing and the future recovery of natural populations as habitat improves. Demographic benefits of using hatcheries to allow populations to persist can come at a cost to other genetic and ecological characteristics of the population (Naish et al. 2007) but understanding the potential long-term loss of fitness from hatchery production relative to the impacts of habitat changes during phases of recovery is important. Degraded habitat can lower the survival and reproductive success of naturally spawning fish even more than hatchery effects. For example, the expected incidence of floods leading to 0% egg-to-fry survival of Chinook Salmon in the Stillaguamish River has increased from zero in 50 years to once every 10 years from changes in habitat (Beamer et al. 2005). With projected climate change the likelihood of losses of this magnitude will increase even more (Snover et al. 2013 and citations therein). No analyses predict a similar level and pace of loss from hatcheries. Similarly, over 78% of the juvenile salmon in the Green/Duwamish estuary and nearshore had PCB levels associated with adverse effects on growth and survival and 45% and 35% of Puyallup and Snohomish juveniles, respectively, had PBDE levels associated with increased susceptibility to diseases (O'Neill et al . 2015). In addition, recent reviews suggest that the lower reproductive success of hatchery Chinook Salmon in the wild may actually reflect environmental effects rather than genetic changes from the hatchery (Christie et al. 2014 and citations therein).

These data point to a key reason for linking the demographic support of populations to the status of their habitat: habitat protection and restoration can mitigate for effects of both habitat loss and hatchery production. Ford's (2002) seminal analysis of the potential genetic effects of integrated hatchery programs noted that conserving or restoring a population's habitat may be the most effective way of preventing the phenotypic changes that are concerns in hatchery programs. This is an example of the synergistic benefits of integrating approaches across management sectors that is at the core of this plan.

6.7 Protecting the Diversity of the ESU

This Plan conserves the diversity (in terms of run timing) of populations across Puget Sound by enabling some populations to reach their current viable abundance thresholds, hold others at stable abundance levels well above their critical abundance thresholds, and contributing to persistence of those at or near critical abundance. Harvest mortality in SUS fisheries will not significantly increase the risk of extinction for any population.

Conservative management objectives are established for the eight indigenous populations in the Skagit and Snohomish systems where natural production is not dependent on hatchery augmentation. These populations inhabit large watersheds that support diverse life histories. The Plan emphasizes protection of these populations.

Exploitation rate ceilings for the Skagit summer/fall, Skagit spring, and Snohomish populations reflect low risk of decline to critical abundance status and high probability of achieving MSY escapement. Should abundance of any of these populations decline to the LAT, ceiling exploitation rates for SUS fisheries would be reduced. This lower exploitation rate would be well below the equilibrium ER (see Section 6.3) that applies to escapements between the LAT and the point of instability, so, on average, equilibrium pressure would result in increased escapement. The ER ceiling approach of this plan provides similar assurance that escapement will achieve the level associated with optimum productivity (MSH). Escapement will increase, even at exploitation rates higher than the ER Ceiling, according to the equilibrium exploitation rate assessment, so the ER ceiling assures the Plan will not impede rebuilding, contingent on sufficient functioning habitat. Furthermore annual fishing regimes are expected to result in target exploitation rates for these populations that are lower than their respective ER ceilings, further improving the probability that escapement will increase or remain at optimum levels.

Abundance is supplemented by hatchery production for indigenous populations in the North/Middle Fork and South Fork Nooksack, Stillaguamish, Skykomish, White, Green, Elwha, and Dungeness rivers. Local hatchery production assures persistence of non-indigenous populations in the Puyallup, Nisqually, and Skokomish rivers. Hatchery programs maintain natural production and in many areas provide harvest opportunity, while natural production is severely constrained by habitat condition. Fishery constraints are expected to maintain the current status of most of these populations.

For the populations whose abundance has been at critical or near-critical abundance levels in recent years (i.e. in the North/Middle Fork and South Fork Nooksack, Stillaguamish, Mid Hood Canal, and Dungeness) harvest constraints will reduce extinction risk. The resulting low harvest mortality in SUS fisheries will not influence the potential for these populations to rebuild given the poor population productivity (average $\lambda>1.0$) limiting rebuilding (Appendix A). Hatchery recovery programs are operating in these systems to ensure persistence. Rebuilding the naturally-produced components of these populations to a highly viable status requires alleviating significant habitat constraints.

The Plan's constraints on harvest assure that the majority of increase in abundance associated with favorable survival will accrue to spawning escapement. Implementation of the Plan will enable escapements higher than the current MSH level, to capitalize on the production opportunity provided by favorable, higher freshwater survival conditions. For populations with more uncertain current productivity, implementation of this Plan will provide stable natural escapement (in many cases considerably higher than the optimum level likely under current conditions) to preserve options for recovering production throughout the ESU in the long term.

In summary, the Plan provides assurance that most populations will continue to rebuild or persist at their current abundance. The recovery potential for introduced populations to achieve recovery is uncertain. Two innovative strategies have been implemented under this plan, to improve the fitness of the introduced stock in the Nisqually, and to introduce a stock with higher recovery potential in the Skokomish. Critically depleted populations are subject to higher extinction risk, but the harvest constraints of this plan and local hatchery recovery programs will enable a higher likelihood of assuring their persistence.

6.8 Summary of Fishery Conservation Measures

- Exploitation rates have been substantially reduced from past levels (i.e. in the 1990s). The ER ceilings and implementation rules in this Plan will perpetuate these lower ER's.

- Exploitation rate ceilings established for each management unit have resulted in stable spawning escapement for most populations under current habitat constraints

- Exploitation rate ceilings are allowable maximums, not annual targets for each management unit. Under current conditions most management units are not producing a harvestable surplus, as defined by this plan, so weak stock management procedures implemented to conserve the least productive MUs will result in ERs below the ER ceilings for other MUs. Given the mixed-stock nature of many of the fisheries affecting Puget Sound Chinook Salmon, the Plan's intent to prevent exceeding ER ceilings for all MUs will result in ERs below the ER ceilings for many of the MUs.

- If a harvestable surplus is projected for any management unit, that surplus will only be harvested if a fishing regime can be devised that is expected to exert an appropriately low incidental impact on weaker commingled populations, so that their conservation needs are fully addressed.

- Total exploitation rate ceilings are set for four MUs: Skagit spring, Skagit summer/falls, Nisqually fall, and Skokomish fall run. If interceptions in Canadian and/or Alaskan fisheries cause exceedance of those ceilings, the lower SUS Critical ER ceilings, otherwise implemented due to critical status, will be implemented.

- If escapement is projected to be below the low abundance threshold, SUS fisheries will be managed to not exceed a lower critical exploitation rate ceiling for that Management Unit. The low abundance thresholds are intentionally set at levels substantially higher than the point of biological instability and the associated CER ceilings are set so that fisheries conservation measures are implemented to reduce the likelihood of abundance falling further to below the critical abundance threshold.

- Under all abundance status conditions, whether critical or not, the co-managers maintain the prerogative to implement, by agreement, additional conservation measures that reduce fisheries-related mortality farther below any management ceiling stated in this Plan. Responsible resource management will take into account recent trends in abundance, freshwater and marine survival, and management error for any unit.

7. Monitoring and Assessment

Harvest management will be informed primarily by monitoring escapement to track abundance trends and monitoring fisheries-related mortality to assess management performance. These data are also applicable to planning and monitoring the effectiveness of habitat restoration, and to hatchery management.

Mortality associated with certain monitoring and research activities (e.g. test fisheries and update fisheries), that primarily inform in-season harvest management decisions, will be accounted with other fishery related mortality as part of the ER ceiling limits defined for each MU. Mortality associated with other research and monitoring, which have broader applicability to stock assessment, will not be accounted as part of the ER ceilings. At the discretion of the co-managers and NOAA Fisheries, the take associated with this latter category will not exceed a level equivalent to 1% of the estimated annual abundance (i.e. 1% ER) for any MU. Co-managers will submit proposals to NOAA Fisheries for monitoring or research to obtain authorization under the research and monitoring ER budget 30 days in advance of starting field work.

7.1 Catch and Fishing Effort

Landed catch in commercial, ceremonial, subsistence, and test fisheries, in Washington catch areas 1 – 13, and associated subareas and freshwater areas, is recorded on sales receipts ('fish tickets'), and compiled in a jointly maintained database[13]. Harvest during these fisheries typically occurs between May and November (with the exception of tribal winter troll harvest in the Strait of Juan de Fuca). Catch is monitored in-season for all fisheries.

The WDFW estimates recreational landed catch by analysis of Catch Record Cards (CRC) returned from a randomly selected subset of CRCs issued annually to all recreational license holders. The baseline sampling program for recreational fisheries in marine waters provides auxiliary estimates of species composition, effort, and catch per unit effort (CPUE) to the Salmon Catch Record Card System. The baseline sampling program is geographically stratified among marine Areas 5-13 in Puget Sound. For this program, the objectives are to sample 120 fish per stratum for estimation of species composition, and 100 boats per stratum for the estimation of CPUE. This analysis also utilizes data collected by angler interviews in marine areas. Compilation and analysis of these data (WDFW 2012) produces preliminary estimates of management year (May – April) catch by July of the following year.

For most salmon directed recreational fisheries, catch, encounters, and effort are monitored by creel surveys. In-season catch estimates are produced for coastal areas 1 – 4, most Puget Sound marine areas (varies by year), and certain freshwater Chinook Salmon fisheries including, in recent years, fisheries in the Skagit, Skykomish, Carbon, and Nisqually rivers. Creel sampling regimes and analytical methods have been developed to meet acceptable standards of variance for estimates of weekly landed catch and mortality where full-murthy sampling is employed. For

[13] An electronic fish ticket system is currently being implemented and coordinated by the NWIFC.

detailed information on data collected and methods used in both baseline monitoring of and in enhanced monitoring of Puget Sound Marine selective fisheries, see WDFW's Methods Report (WDFW 2012). The report explains ongoing collection of data on species, mark status, fork and total length, scales, and CWTs (when present) for landed catch. This report, along with a comprehensive set of reports on results is available on the WDFW website (wdfw.wa.gov).

Non-landed mortality of Chinook Salmon is estimated for commercial troll and recreational hook-and-line fisheries. Regulations for these fisheries may require release of sub-legal Chinook Salmon, un-marked Chinook Salmon, or all Chinook Salmon, during certain periods. Studies are conducted to estimate encounter rates and retention rates for legal and sub-legal Chinook Salmon, in order to estimate mortality for these fisheries. Estimates of encounter rates and retention rates are derived from on-board observations, angler interviews at landing ports or marinas, and remote observation of some recreational fisheries. These findings are used to validate, or adjust, the encounter rates, and sub-legal and legal non-retention rates used in the FRAM.

The co-managers acknowledge that previous efforts to quantify incidental impacts in freshwater recreational fisheries have varied in scope and precision. The co-managers convened regional technical workgroups in Summer 2021 to inventory where and how incidental impacts in the freshwater are being accounted for. Beginning in 2021, WDFW committed to large scale freshwater monitoring to validate salmon and gamefish fisheries which could have incidental impacts on adult Chinook when they are potentially present in-river. In pre-season 2021 and in post-season runs that will occur in 2022, the co-manager technical team commits to reviewing and evaluating incidental impacts in light of any new data collected via new monitoring programs.

Release mortality rates in Puget Sound marine recreational fisheries are based on a 1993 co-manager technical review of evaluations that were available at the time (WDF et al. 1993). At that time, no evaluation studies or monitoring programs had been developed for Puget Sound estuarine or freshwater recreational fisheries (WDF et al. 1993). For these latter recreational fisheries, an assumed release mortality rate of 10% has been adopted consistent with the marine release mortality rate for Chinook greater than 22" total length (Table 8, Chapter 2). 'Drop-out' mortality in gillnet fisheries is accounted as 3% and 2% of landed catch in pre-terminal and terminal fisheries, respectively, but is currently not estimated by monitoring programs or evaluation studies. Chinook Salmon non-retention regulations govern certain non-Treaty seine fisheries; WDFW monitors Chinook Salmon encounters in these fisheries to estimate release mortalities during these fisheries.

Terminal-area commercial fisheries are sampled to collect biological information about mature Chinook Salmon, including Age-2 'jacks'[14], and recover coded-wire tags. Collection of scales, as well as otoliths in some terminal areas, determination of sex, mark status, and length data supplement commensurate information collected from spawning ground carcasses to characterize the origin, age, and size composition of local populations.

[14] Although terminal commercial fisheries sample Age-2 'jacks', the FRAM model does not account for Age-2 jacks returning to the terminal area.

7.2 Spawning Escapement

Chinook Salmon escapement is estimated annually for each population. For most populations, estimates are based on a cumulative redd count, expanded by a sex ratio of 2.5 adults (1.5 males to 1.0 females) per redd (Orrell 1976 in Smith and Castle 1994). Other sampling and computational methods are used to estimate escapement for some populations, including integration under escapement curves drawn from a series of live fish or redd counts, peak counts of live adults or carcasses, cumulative carcass counts, and genetic mark-recapture methods. A trap is operated in the White River to count, sample, and transport Chinook Salmon above Mud Mountain Dam, however operational standards of this trapping facility result in substantial uncertainty in return estimates for the later proportion of the run. Chinook Salmon survey protocols and estimation methods used for Puget Sound Chinook Salmon are described in annual reports (see Section 7.5).

The proportions of hatchery- and natural-origin adults among natural spawners are estimated for all populations. These estimates depend primarily on sampling carcasses on the spawning grounds, although carcass recovery rates vary by watershed depending on hydrological and physical habitat conditions. Sampling of available carcasses, terminal-area catch, returns to hatchery racks, and at traps or weirs also provides information to characterize age composition, sex ratio, and origin of returning fish. Recovery of CWTs, analysis of otoliths, and/or visual observation of external marks (i.e. clipped adipose or ventral fin clips) are used to identify hatchery-origin adults. Sex, length, and fecundity estimated from a subsample of adults used for hatchery broodstock is used to further characterize adult returns.

Estimates of the proportions of first generation hatchery recruits on spawning grounds may, with caution, be utilized for cohort reconstruction, but do not quantify the extent of inter-breeding or genetic introgression among hatchery and natural origin spawners. Direct genetic analyses are required for such purposes.

7.3 Abundance and Exploitation Rates

After accounting for natural mortality, estimates of spawning escapement, age composition, and age specific fishery mortality enable reconstruction of cohort abundance. Cohort reconstruction estimates allow estimates of the recruitment rate (i.e. productivity) for each brood year to be developed. A recruitment function may be fit to a lengthy time series of recruitment estimates, and may be utilized to derive maximum sustainable yield (MSY) and/or exploitation rate ceilings that achieve stated risk criteria. However, it is not certain that productivity is stationary across the long-term time series, perhaps violating the assumption underlying recruitment functions. Some harvest management objectives in this Plan, are based on current population productivity estimates, but data gaps (e.g., sufficient and representative CWT data) preclude cohort reconstruction for all Puget Sound Chinook Salmon populations. Where possible, sampling programs collect data to enable monitoring of recruitment and changes in productivity to track the status of populations relative to their recovery goals. In response to changes in productivity, exploitation rate ceilings may be adjusted.

Indicator stock programs, using local hatchery production, have been developed for many Puget Sound populations, as part of a coast-wide program established by the Pacific Salmon Commission. Among other information, these CWT-indicator hatchery programs provide data necessary to estimate fishery related mortality distribution. Indicator programs include

Nooksack River early (Kendall Creek Hatchery), Skagit River spring and summer (Marblemount Hatchery), Stillaguamish River summer (Harvey Creek Hatchery), Skykomish summer (Wallace River Hatchery), Green River fall (Soos Creek Hatchery), White River spring (White River Hatchery), Nisqually River fall (Clear and Kalama Creek Hatcheries), Skokomish River fall (George Adams Hatchery), and Hoko River fall (Hoko Hatchery) stocks. Indicator stocks are assumed to have the same genetic and life history characteristics as the natural populations that they represent. Indicator stock programs are intended to release 200,000 tagged juveniles annually, so that tag recoveries will be sufficient for acceptably precise estimation of harvest distribution and fishery exploitation rates. The indicator stock programs depend on achieving target sampling rates in all fisheries that each stock encounters. Because catch in Alaska and British Columbia is not electronically sampled to detect coded-wire tags, indicator stock releases are also expected to be adipose clipped.

Commercial and recreational catch in all marine fishing areas in Washington is sampled to recover coded-wire tags. For commercial fisheries, the objective is to sample at least 20% of the catch[15] in each area, in each statistical week, throughout the fishing season. For recreational fisheries, the objective is to sample 10% of the catch in each month / marine area stratum. Based on recent performance, sampling objectives will be consistently achieved for most catch area / time strata, and shortfalls addressed, contingent on staff resources (WFDW and PSIT 2008, WDFW and PSIT 2009). Mass marking of hatchery-produced Chinook Salmon, by clipping the adipose fin, has necessitated electronic sampling of (freshwater?) catch and escapement to detect coded-wire tags. Creel and carcass surveys have been instituted in watersheds with large production hatchery programs (e.g., Snohomish, Puyallup, and Nisqually).

Standardized procedures enable calculation of a stock's total, age-, and fishery specific mortalities, if there are sufficient tag recoveries. The FRAM incorporates estimates of mortalities derived from CWT data from a historical base period, limiting the model's sensitivity to changes in stock distribution and fishery regimes. It is recognized that the FRAM cannot perfectly simulate the outcome of the coast-wide Chinook Salmon fishing regime, so, periodically, performance of simulation modeling using the FRAM will be assessed. In 2017, the FRAM base period CWT data was updated, in part to address bias suggested by recent CWT-based mortality estimates..

Mark-selective fisheries, if implemented on a large scale, will exert significantly different landed and non-landed mortality rates on marked and unmarked Chinook salmon populations. Accurate post-season estimation of age- and fishery-specific fishery mortality in coast-wide non-selective and mark-selective fisheries, represents a daunting technical challenge, particularly due to the complex age structure of Chinook Salmon. Release of double index CWT groups (i.e. equal numbers of marked (adipose clipped) and unmarked fish containing distinct tag codes) has been initiated for many indicator stocks as a means of estimating total fishery mortality associated with mark-selective fisheries, maintaining the objectives of the coast-wide CWT indicator stock programs. As described in Section 7.1, additional data will be obtained by monitoring mark-selective fisheries to estimate encounters of legal/sub-legal, marked/unmarked Chinook Salmon.

[15] May not necessarily result in 20% sampling of Chinook incidentally caught in other salmon (Sockeye, Coho, Chum) directed fisheries given how/when Chinook catch might recruit to those fisheries.

Collaborative analyses of these data will be reported outside of the annual and periodic performance assessment reports.

7.4 Annual Management Review

The co-managers will develop an annual review of the previous seasons' fisheries. A concise summary of the previous year's available preliminary escapement and landed catch, compared to pre-season projections, will be distributed in March for reference during pre-season planning. A more detailed annual report providing a narrative of regional fisheries, noting changes from the pre-season regime, describing escapement surveys and estimation methods, fisheries monitoring (creel surveys, other monitoring of recreational and commercial fisheries), and coded-wire tag sampling rates for the preceding year will be completed in July. The July detailed annual report will include:

Summary of landed net and troll catch and in-season management

Tables will compare expected and observed catch for commercial, ceremonial and subsistence, and test fisheries in coastal areas and Puget Sound (Areas 1 – 13, associated sub-areas and freshwater areas), by area, for the preceding management year. Accompanying narratives will describe in-season management decisions, particularly any significant deviations from pre-season regulatory structure.

Recreational landed catch

Tables will compare projected and observed landed catch for the previous management year, for areas where creel surveys have generated catch estimates (i.e. typically, Areas 1 – 6 and certain freshwater fisheries). Due to analytical time requirements for Catch Record Card analysis, and complete analysis of creel survey data, the report will compare projected catch with preliminary CRC estimates, and creel-survey estimates, for all areas for the preceding management year.

Non-landed mortality

The annual report will include estimates of encounter rates and non-landed mortality, and associated analyses for recreational and commercial troll fisheries included in this Plan. Preliminary analyses for fisheries in the preceding year will be included in the July annual report, but full analyses will be reported the next year.

Spawning Escapement

Natural spawning escapement for all management units and populations will be compared to pre-season projections and the management thresholds established by this Plan. The July annual report will include a tabulation of escapements for the preceding ten years. Available estimates of the hatchery- and natural-origin proportions of natural escapement, from carcass or terminal fishery sampling, will be included in the annual report.

CWT Sampling Rates

A preliminary summary of CWT catch sampling rates for commercial and marine recreational fisheries, with a one-year time lag, will be included in the annual report. These mark – sample files, downloaded from the PSMFC RMIS data system, are subject to subsequent revision as data are regularly updated.

7.5 Retrospective Performance Assessment

- Harvest management performance will be assessed by a retrospective analysis of accumulated data and information related to population abundance and productivity, harvest rates, sampling and monitoring objectives. A harvest management performance assessment will be completed in 2023 covering fishing years 2011-2019 (i.e. covers performance of previous harvest plans). Subsequent harvest management performance assessments will be scheduled for completion every six years (e.g. a second performance assessment will occur in 2029, covering years 2020-2026). .. Although post-season FRAM runs are compiled every two years, runs do not account for the two most recent years due to timing of CRC data availability. In recognition of the constraining interactions of stock abundance and fisheries harvest, especially in pre-terminal fisheries,on interpreting post-season FRAM results relative to pre-season FRAM results, performance assessments will be supplemented with CWT analysis based on PSC Chinook Technical Committee work or other independent analysis, where available and warranted. The retrospective performance assessment will compare FRAM ER estimates with CWT or other ER estimates and discuss the significance of differences to successful achievement of the harvest plan objectives.

The reports will include:

- A comparison of post-season estimates of exploitation rates in northern and SUS fisheries to rates projected during pre-season planning, and to exploitation rate ceilings set by the Plan. This analysis will examine fishery-specific ERs to identify patterns of divergence from pre-season projections.
- Quantify the trends in escapement for each population.
- Compare pre-season forecasts with the respective observed terminal abundance for each management unit, and identify possible problems with forecast accuracy that may be contributing to management error.
- Compare pre-season projected to observed landed catch by fishery to identify consistent projection errors.
- Compare pre-season and post-season estimated encounters for mark-selective fisheries, by fishery, to identify consistent projection errors.
- Description of biological sampling (i.e. collection of scales, otoliths, DNA, and sex and size data) of catch and escapement.
- Age structure of populations from escapement (carcass) or terminal fishery sampling.

FRAM generates estimates of ERs for each management unit that are assumed to accurately reflect impacts from the ever-changing regime of fisheries that Puget Sound Chinook Salmon encounter. Significant changes in stock distributions and fishery regimes may cause changes in ERs that are not detected by the FRAM, due to its use of CWT data from a historical period. For stocks with representative CWT indicator programs, cohort reconstruction ER estimates can also be generated and used to periodically compare to FRAM estimates and to evaluate accuracy of the management model. This comparison is not direct, because of some differences in methods incorporated in the FRAM and CWT-based cohort reconstruction, and caution should be used interpreting such comparisons given errors in both estimate procedures. Comparisons made for a period of years will reveal systematic problems with accuracy and provide a basis for considering revision of the FRAM or re-interpretation of its output.

An update of the base-period CWT data that are the basis for FRAM fishery exploitation rate scalars was completed in 2017, and the revised model adopted by the co-managers and the PFMC for use in managing coastal fisheries. This revision was motivated by an analysis of bias in the FRAM in comparison to annual exploitation rates estimated directly from CWT recoveries (cite McHugh, Hagen-Breaux, et al 2013 cited in PSIT and WDFW 2013)). Similar periodic bias analysis is recommended to validate FRAM projections.

7.6 Marine-Derived Nutrients from Salmon

Adult salmon provide essential marine-derived nutrients to freshwater ecosystems; directly as a food source for juvenile and resident salmonids and invertebrates, and indirectly as their decomposition supplies nutrients to the food web. A body of scientific literature reviewed in Appendix D of the 2004 Plan (PSIT and WDFW 2004) supports the contention that the nutrient re-cycling role played by salmon is particularly important in nutrient-limited, lotic systems in the Northwest. Some studies assert that declining salmon abundance and current spawning escapement levels exacerbate nutrient limitation in many systems (Gresh et al. 2000). Controlled experiments to test the effect of fertilizing stream systems with salmon carcasses or nutrient compounds show increased primary and secondary productivity, and increased growth rates of juvenile coho and steelhead, two salmonid species with extended freshwater juvenile life histories. However, marine-derived nutrients have received little attention in recent primary literature, suggesting no, to minimal, additional information is readily available to inform this Plan’s management strategy.

The role in nutrient supplementation by spawning Chinook Salmon must be examined in the broader context of spawning salmon of all species. In large river systems that support Chinook Salmon, escapements of pink, coho, and chum salmon comprise a large majority of total nutrient input, so changes in Chinook Salmon escapement expected as a result of this Plan’s implementation are not expected to result in a significant change to nutrient loading. Natural escapements of Chinook Salmon, and of substantially more abundant pink and chum salmon, have varied widely without apparent correlation with survival of Chinook Salmon during their freshwater life history. Currently, information is not available to suggest that marine-derived nutrient limitation affects Puget Sound Chinook Salmon population productivity, this may be because many Puget Sound Chinook Salmon express sub-yearling migrant strategies and therefore are not exposed to freshwater environments, where MDN-cycling impacts would be realized, for extended periods. Post-emergent survival of juvenile Chinook Salmon is undoubtedly affected by a complex array of other biotic and physical factors. The incidence and magnitude of peak flow during the incubation season, for example, is correlated very strongly with outmigrant smolt abundance in the Skagit River and other Puget Sound systems (Seiler et al. 2000).

Manipulating spawning escapement or supplementing nutrient loading with surplus hatchery returns will require resource management agencies to consider potential benefits and risks from a wider policy perspective. Artificial nutrient supplementation, despite its potential benefits to salmon production, contradicts the long-standing effort to prevent eutrophication of freshwater systems. However, just as habitat modifications are limiting Chinook salmon productivity throughout Puget Sound, we speculate that those same habitat modifications are interfering with nutrient cycling in the riparian and terrestrial ecosystems. Considering the influence flow and channel structure, including LWD loading, have on the length of time carcasses and nutrients can be retained, habitat modifications that limit flood-plain connectivity, reduce riparian forest function, decrease channel complexity, and increase peak flow events are likely to limit nutrient retention for complete ecosystem utilization.

Use of surplus carcasses from hatcheries also has potential implications for disease transmission. As a result, co-managers updated their Salmonid Disease Control Policy in 2006 with requirements related to the use of hatchery carcasses for nutrient supplementation to address potential disease risks from carcass supplementation (The Salmonid Disease Control Policy of the Fisheries Co-managers of Washington State 2006).

7.7 Selective Effects of Fishing

Commercial and recreational salmon fisheries exert some selective effect on the age, size, and sex composition of mature adults that escape to spawn. The location and schedule of fisheries, the catchability of size and age classes of fish associated with different gear types, and the intensity of harvest determine the magnitude of this selective effect. In general, hook-and-line and gillnet fisheries are thought to selectively remove older and larger fish. To the extent maturation and growth rates are genetically determined, subsequent generations may be include fewer older-maturing or faster-growing fish. Fishery-related selectivity has been cited as contributing to long-term declines in the average size of harvested fish, and the number of age-5 and age-6 spawners. Older, larger female spawners are believed to produce larger eggs, and dig deeper redds, which may improve survival of embryos and fry. A recent analysis by Ohlberger et al. (2018) suggests that Chinook salmon populations across the entire Northeast Pacific Ocean have experienced shifts in age structure as well as size at age. Given the large geographic extent from California to Alaska of Ohlberger et al. (2018) analysis, the observed shifts in size-at-age and varying fishery size limits regualtions by state, variation in gear selectivity, and range of estimated harvest impacts across the populations, the authors hypothesize that harvest is unable to explain the overall trend (Ohlberger et al 2018).

There is no strong evidence of long-term or continuing trends in declining size or age at maturity for Puget Sound Chinook Salmon. Available data suggest that the fecundity of mature Skagit River summer Chinook Salmon has not declined from 1973 to the present (Orrell 1976; Musselwhite and Kairis 2009). The age composition of Skagit summer / fall Chinook Salmon harvested in the terminal area has varied widely over the last 30 years, particularly with respect to the proportions of three and four year-old fish, but there is no declining trend in the contribution of five year-olds, which has averaged 15 percent (Henderson and Hayman 2002; R. Hayman, SSC December 9, 2002, personal communication). Further, while ocean age-4 Chinook salmon have decreased in size across the west coast over the past 30+ years, Puget Sound stocks, along with California and southern Oregon stocks, showed little to no relationship to the declining trend compared with Columbia River, Northern Oregon and Washington Coast, Alaksa, and British Columbia stocks (Ohlberger 2018). More detailed discussion and analysis of size-selective effects on Puget Sound Chinook Salmon were included in Appendix F of the 2004 Puget Sound harvest plan (PSIT and WDFW 2004) and the NEPA EIS developed by the NMFS (NMFS 2004) in review of the 2004 plan.

8. Amendment of the Harvest Management Plan

The Plan will continue to evolve. It is likely that monitoring and assessment methods and tools will improve to more accurately quantify population abundance and productivity. As new information becomes available, the co-managers will periodically, in some cases every five years, reassess management guidelines and harvest strategies, in response to changes in the status and productivity of Chinook salmon populations. If the Plan is amended, changes will be submitted to the NMFS for evaluation, well in advance of their implementation.

9. Glossary

Adult Equivalence (AEQ) – Discount of fishing mortality of age 2, 3, and 4 fish that would otherwise succumb to natural mortality before they mature.

Cohort Analysis - Reconstruction of brood-year recruits, conventionally as the abundance of a population or management unit prior to the occurrence of any fishing mortality. The calculation sums spawning escapement, fisheries-related mortality, and adult natural mortality.

Low abundance threshold (LAT) - A spawning escapement level, set above the point of biological instability, which triggers extraordinary fisheries conservation measures to minimize fishery related impacts and increase spawning escapement.

Diversity - Diversity is the measure of the heterogeneity of the population or the ESU, in terms of the life history, size, timing, and age structure. It is positively correlated with the complexity and connectivity of the habitat.

Escapement – The number of adult salmon that survive fisheries and natural mortality, comprising potential natural spawners or returns to a hatchery.

Exploitation Rate (ER) - Total mortality in a fishery or aggregate of fisheries divided by the sum of total fishing and natural mortality plus escapement.

Fishery – Harvest by specific gear type(s) in a specific geographical area (sometimes comprised of more than one salmon Catch Area, during a specific period of time. A fishery if often characterized by its principal target species.

Harvest Rate (HR) - Total fishing mortality, in some cases of a specific stock divided by the abundance in a given fishing area at the start of a time period.

Management Period – Based on information about migration timing, the management period is the time interval during which a given species or management unit may be targeted by fishing in a specified area

Maximum Sustainable Harvest (MSH) or Maximum Sustainable Yield (MSY)- The maximum number of fish of a management unit that can be harvested on a sustained basis, such that spawning escapement will optimize productivity.

Non-landed Mortality – Fish not retained that die as a result of encountering fishing gear. It includes a proportion of sub-legal fish that are captured and released, hook-and line drop-off, and net drop-out mortality.

Point of instability - that level of abundance (i.e., spawning escapement) that incurs substantial risk to demographic or genetic integrity.

Population – For the purposes of the Plan, equivalent to the stocks (see below) delineated by the NMFS Technical Recovery Team as distinct, historically present, independent demographic units within the ESU.

Pre-terminal Fishery- A fishery that harvests significant numbers of fish from more than one region of origin.

Productivity - Productivity is the ratio of the abundance of juvenile or adult progeny to the abundance of their parent spawners; or the rate of change of abundance of a given life stage (usually adults) over time.

Recruitment – Production from a single parent brood year (e.g. smolts or adult returns per spawner).

Stock - a group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season.

Terminal Fishery - A fishery, usually operating in an area adjacent to or in the mouth of a river, which harvests primarily fish from the local region of origin, but may include more than one management unit. Non-local stocks may be present, particularly in marine terminal areas.

Viable – In this plan, this term is applied to salmon populations that have a high probability of persistence (i.e. a low probability of extinction) due to threats from demographic variation, local environmental variation, or threats to genetic diversity. This meaning differs from that used in some conservation literature, in which viability is associated with healthy, recovered population status (see McElhany et al. 2000).

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11. APPENDIX A: Management Unit Profiles (MUPs)

Nooksack River Management Unit Status Profile

Component Populations

North/Middle Fork Nooksack early Chinook
South Fork Nooksack early Chinook

This profile has been prepared and submitted to obtain coverage for a process that does not align with the harvest and recovery objectives of the Lummi Nation and the Nooksack Tribe. The Nooksack River early Chinook populations have been decimated as a result of decades of habitat loss and degradation, and a failure to reverse this damaging progression. Despite the tribes' commitment to rebuilding the early Chinook populations, including no directed fisheries on natural-origin Nooksack early Chinook since 1978, things are no better today than they were 40 years ago. The fact that habitat preservation and restoration have not outpaced continued habitat decline, or led to higher Chinook productivity, is of great concern to the tribes. Adhering to the harvest management objectives within this profile will not lead to the recovery of meaningful and sustainable harvestable surpluses of natural Chinook populations without significant actions to protect and restore habitat and water quality and quantity within the basin, which is the main cause of salmon decline. Natural populations of early Chinook may never be able to recover to historic levels due to the ecological impacts of climate change. Decreases in marine survival of west coast salmon have been linked to marine heatwaves and other ecological changes in the ocean (Sobocinski et al. 2013, Crozier et al. 2019). Climate induced changes in hydrologic regime as well as stream temperature in the Nooksack River watershed will also limit the ability of natural origin stocks to recover. At the same time, there is growing evidence of the correlation between increasing seal predation and decreasing wild Chinook salmon populations (Nelson et al. 2019). Finally, as long as fisheries outside the jurisdiction of this plan continue to account for approximately 80% of the exploitation rate on Nooksack early Chinook populations, restrictions on fisheries in the southern US will have little effect on "recovery". At this time, the co-managers reluctantly endorse the management objectives described in this plan, based on the anticipated support and flexibility of NOAA to work with the co-managers on the implementation of a strategic regional hatchery production plan that will contribute to the co-managers' interim harvest goals and begin to address the harvest needs of Lummi and Nooksack tribal communities.

Geographic description

The Nooksack River Chinook management unit is comprised of two early-returning, native Chinook populations that are genetically distinct, and exhibit different migration and spawn timing from one another (SSDC 2007).

The North and Middle Forks drain high altitude, glacier-fed streams. North Fork/Middle Fork Nooksack early Chinook (NF/MF Chinook) spawn in the North Fork and Middle Fork, including tributaries, from the confluence of the South Fork (RM 36.6) up to Nooksack Falls at RM 65, and in the Middle Fork downstream of the diversion dam, located at RM 7.2. A diversion dam on the Middle Fork, installed in 1960-1961, created a fish passage barrier that cut off approximately 16 miles of former Chinook habitat. According to an Ecosystem Diagnosis and

Treatment model run in 2003, restored passage at this site should yield a 31% increase in natural origin (NOR) Chinook abundance, 12% increase in NOR productivity, and 48% increase in diversity index for the North/Middle Fork Nooksack NOR early Chinook population (SSDC 2007).

The South Fork drains a lower-elevation watershed that is fed by snowmelt and rainfall, but not by glaciers. Consequently, river discharge is relatively lower and water temperature relatively higher in the South Fork mainstem than the North and Middle Forks during summer and early fall. South Fork Nooksack early Chinook (SF Chinook) spawn in the South Fork and South Fork tributaries from the confluence with the North Fork to the cascades at RM 30.8, although use is much lower upstream of Sylvester's Falls at RM 25 in recent decades.

For both the NF/MF and SF populations, the amount of tributary spawning varies considerably from year to year depending on whether discharge is sufficient to allow entry to the spawning grounds. Climate induced changes in watershed flow regimes have likely altered spawning distributions. Spawning ground survey data appears to confirm a recent decline in tributary habitat use, coinciding with dry late summers.

Life History Traits

River Entry

Previous studies indicate that Nooksack early Chinook populations are characterized by entry into freshwater beginning in March, slow upstream migration and lengthy holding periods in the river prior to spawning (Barclay 1980, Barclay 1981). However, this early work never extended lower river tagging beyond June, included very few Chinook that went up the South Fork, and it does not provide a solid basis for river entry distribution or timing, leading to the hypothesis that the SF population may exhibit slightly later run timing than the NF/MF population.

Restrictions on sampling the migration between mid-June and the end of July have diminished the ability to clearly establish river entry timing for SF Chinook. Recent CWT recoveries (2015-2020) from the Skookum Creek early Chinook population recovery program in the terminal area fisheries appear to support the hypothesis that the behavior of the SF population is different than of the NF/MF population. The NF/MF population typically peaks in mid- to late-May, then diminishes into August. South Fork Chinook river entry timing appears to continue through August, though more data is needed to determine peak timing.

Spawning

In the North and Middle Forks, spawning is estimated to occur from July through September, peaking in August. South Fork Chinook begin spawning in August and continue into early October, with peak spawn timing in late September and at least 2-3 weeks after NF/MF Chinook. However, the increased incidence of storms and high flows during early fall diminishes the ability to make observations and collect carcasses after mid-October that would allow a more accurate determination of the spawn timing and distribution, especially in the South Fork.

Outmigration

Nooksack Chinook exhibit all three out-migrant life history patterns (ocean-type fry, ocean-type parr and stream-type yearlings) as evidenced by adult scale pattern analysis, sampling and analyzing catches of juvenile out-migrants at a lower river screwtrap, and beach seine sampling through the lower river, delta and nearby estuaries (Beamer et al. 2016; Lummi Natural Resource juvenile salmon database and analyses). Ocean-type age 0 Chinook fry migrate out early from late winter through March rearing in the river delta or pocket estuaries until they are large enough to undergo the physiological shift to salt water. Ocean-type age 0 parr rear for a few months in freshwater before migrating out directly to estuaries and near-shore regions; outmigration peaks in May and June. Yearlings rear over summer and overwinter in freshwater and outmigration occurs over two main periods. One period occurs in April through May preceding the main parr outmigration. The second period starts in late fall and extends into late the winter ending in February prior to the out-migrant fry peak.

Analysis of juvenile salmon captured at a rotary screw trap, operated in the lower main stem of the Nooksack River, confirms that, from 2005-2015, fry comprised 5.5%, parr 90% and yearling 4.5% of the total NOR Chinook out-migrant population (Beamer et al. 2016). The outmigration of yearlings is likely an underestimate at 4.5%, due to the lack of sampling during some of the outmigration and lower catchability of yearlings compared to parr. Scales collected from NOR spawners show the NF/MF spawning population to consist of 29% yearlings while the SF spawning population consists of 38% yearlings (SSDC 2007).

Age Composition

Available information on the age composition of adults returning to the NF/MF and the SF suggest a predominance of age-4 returns. The NF/MF population age data were derived from natural origin adults sampled on the spawning grounds from 1999 through 2014. There is less confidence in estimates of SF age structure, due to the low number of carcasses sampled on the spawning grounds. Estimated age composition for natural origin returns for both populations are shown in Table 1; however, there is a high degree of uncertainty in these estimates due to low sample sizes.

Table 1. Estimates of the age composition of returning adult natural origin Nooksack early Chinook by population 1999-2018 (co-manager unpublished data).

Population	Age 2	Age 3	Age 4	Age 5	Age 6
NF/MF NOR	<1%	20%	54%	16%	0%
SF NOR	2%	20%	69%	9%	0%

Hatchery Recovery Programs

Two hatcheries in the Nooksack River watershed operate early Chinook programs; the Kendall Creek Hatchery and the Skookum Creek Hatchery. Both the Kendall and Skookum programs are key components in the recovery of native Nooksack Chinook populations and are operated to buffer demographic and genetic risks while improvements to habitat quantity and quality occur.

The Kendall Creek and Skookum Creek hatcheries are intended to assist in recovery of the NF/MF and SF populations by significantly increasing population abundances and natural production.

Kendall Creek Hatchery – North Fork/Middle Fork Chinook Program
Since 1981, a population recovery program for the NF/MF Chinook population has operated at the Kendall Creek Hatchery. At peak production, up to 2.3 million fingerlings, 142,500 unfed fry and 348,000 yearlings were released into the North Fork, or at various acclimation sites. The yearling release program was discontinued after the 1996 brood because survival rates were lower than those of sub-yearling release groups. In 2001, fingerling releases into the Middle Fork were initiated. Since 1992, all Kendall Chinook have received thermal otolith marks and 200,000 (single index) or 400,000 (double index) have received coded-wire tags to evaluate release strategies, estimate contribution to natural production, and estimate contribution to fisheries. Double-index tag groups were discontinued after the release of brood year 2011 fingerlings.

The production strategy for the NF/MF program was adjusted in 2003 to reduce straying into the South Fork. On-station releases were reduced from 900,000 in 1998, ranging from 630,000 to 424,000 in 1999-2002, and were further reduced to 200,000 in 2003, which remained the on-station release goal until 2018. The total off-station release was reduced in 2003 from a peak of approximately 1,730,000 fingerlings in 1999 (all in the North Fork or its tributaries) to 400,000 fingerlings in the North Fork, 200,000 in the Middle Fork, and 50,000 fry to remote site incubators in the North Fork. The remote site incubator releases were discontinued after the 2004 release. Reductions to the NF/MF program's release objectives were primarily made as a precautionary measure to reduce potential genetic effects on South Fork Chinook. However, preliminary data suggests minimal overlap in spawn timing between the two populations (D. Kruse and A. Spidle, personal communication), and the South Fork population abundances have increased substantially. As part of the most recent hatchery production plan, the co-managers have agreed to annual releases of up to 2,000,000 NF/MF sub-yearling Chinook from Kendall Creek Hatchery and Middle Fork Nooksack release sites; 100% of these will be adipose-clipped and thermal marked with 200,000 also receiving coded-wire tags. Additional production will be released directly from Kendall Creek Hatchery. In an effort to expedite the recolonization of the Middle Fork, 100,000 of the 200,000 Middle Fork release group will be planted above the former diversion dam site, with the remainder continuing to be released from McKinnon Pond.

Skookum Creek Hatchery – South Fork Chinook Program
In 2007, a captive brood South Fork population recovery program was initiated using NOR juveniles captured from the South Fork and reared at WDFW's Kendall Creek hatchery and the NOAA Fisheries Manchester Research Station. Since the program was initiated, there has been extensive genetic stock identification of captive brood and returning adults from captive brood progeny released from the hatchery. Key priorities for the program are to maintain genetic diversity of the population and expand the effective population size. Beginning in 2017, all of the program broodstock have come from Hatchery Origin Broodstock (HOB) adult returns from the program (Table 2.). The co-managers have agreed to a release objective for Skookum Creek Hatchery of 2,000,000 sub-yearling juveniles, of which up to 500,000 will be released in the upper South Fork prior to smoltification to promote future natural production.

Table 2. Captive Brood South Fork Chinook spawned and total adult Chinook recruits to Skookum Creek Hatchery Brood Years 2010-2020 (unpublished data).

Brood Year	Captive Females Spawned	Captive Males Spawned	Total Returned Females	Total Returned Males
2010	2	10	0	0
2011	15	15	0	0
2012	91	91	0	0
2013	285	171	0	0
2014	194	160	0	23
2015	144	123	12	949
2016	175	108	114	1,547
2017	0	0	482	1,123
2018	0	0	511	1,836
2019	0	0	276	1,106
2020	0	0	454	2,572

All juvenile Chinook released from the Skookum Creek Hatchery have been coded-wire tagged to improve evaluation of the program. In 2018, the coded wire tag program transitioned to include a release of 200,000 CWT-adipose clipped fish; 10% of the program size. Of the 2 million juvenile Chinook annual release objective for the program, 1.3 million will not be adipose marked but will be coded-wire tagged and the remaining 700,000 will be adipose marked (including 250,000 with CWTs [Ad+CWT]). Due to the rapid evolution of this program it is anticipated that the proportion of marked and tagged fish will be gradually modified over time as further developments are made, however future modifications will likely result in an increase to the proportion of adipose marked juveniles and a reduction in the use of CWTs. Beginning in 2017, all release groups have been 100% thermally otolith marked to improve estimation of returning adult abundance, particularly from spawning ground surveys.

Habitat

Habitat loss and degradation have resulted in substantially reduced spawning and rearing habitat capacity and quality, which in turn limits the potential abundance and productivity of Nooksack Chinook populations. At present, reduced capacity of and survival in freshwater habitat are considered key factors limiting recovery. The last estimate of current capacity is 2,723 in the North Fork and 1,215 in the South Fork (SSDC 2007). In 2005, the productivity was estimated to be 1.8 in the North Fork and 1.4 in the South Fork (SSDC 2007). In 2017, a NOAA produced RER analysis suggested the capacity of the management unit was 1,529 (Ricker) and 457 (Beverton Holt) (NWFSC 2017).

Land uses contributing to habitat degradation include agriculture throughout much of the lowlands, timber harvest in the upper watershed, rural residential development in the valleys, and urban and industrial development in the lower watershed and along the shoreline south of the Nooksack River delta (SSDC 2007). Climate change will exacerbate the negative effects of habitat loss and degradation by increasing summer temperatures, sediment loads, the frequency and magnitude of peak flows, and by reducing summer flows (Dickerson-Lange and Mitchell 2013; Murphy 2015; EPA 2016; Kuhlman et al. 2016).

Habitat degradation in the Nooksack River Forks, which contains the majority of Nooksack early Chinook spawning and rearing habitat, substantially limits both populations (SSDC 2007). In the North Fork, high channel instability, which is associated with frequent channel shifting, reduces egg-to-emergence survival due to increased scour or burial of redds (Hyatt and Rabang 2003). Reduced channel stability has been linked to the loss of forested islands and associated stable side channels for spawning and rearing in the North and Middle Forks (Hyatt 2007). The Middle Fork Diversion Dam, built in 1960-1961 to divert water to Lake Whatcom to augment the City of Bellingham's water supply, was removed to restore fish passage in 2020.

In the South Fork, Chinook are limited by low habitat diversity and lack of deep holding pools, along with high water temperatures and low instream flows, due to instream wood loss and removals and degraded riparian conditions coupled with extensive bank hardening, water use, and wetland loss through the South Fork valley (Maudlin et al. 2002; Soicher et al. 2006). Adult migration of immigrant spring Chinook has been shown to be thermally blocked at a range of 21^0-22^0 C (Alabaster 1988, Stabler 1981, Bumgardner et. al, 1997). For Chinook salmon, an upper incipient lethal temperature of 24.9-25.1 ^{0}C has been recorded (Brett 1952, Orsi 1971, Brett 1982). Hicks (2000) recommended that in order to protect Chinook from acute lethality, daily maximum temperatures should not exceed 22^0 C.

Pathology analysis of Chinook pre-spawn mortalities in the South Fork in 2003, 2006, 2009 and 2013 confirmed the presence of *Flavobacterium columnare* (Columnaris), a pathogen associated with high temperatures; corresponding 7-day average of the daily maximum temperature in the lower South Fork for those years were 23.1 °C, 23.0 °C, 23.8 °C, and 22.1 °C, respectively (EPA 2016). Temperatures in the South Fork continue to exceed 20 °C at times. In October 2021, a mass pre-spawn mortality event occurred in the South Fork. Pathology reports found evidence of Columnaris, *Ichthyophthirius multifiliis* (ICH), and freshwater diatoms present in multiple samples. It is believed that high water temperature in conjunction with low water, resulted in a lethal proliferation of Columnaris and other pathogens. Pre-spawn mortalities like this are vexing because fisheries are limited to pass these fish through, yet they do not survive to reproduce. There have also been land management-induced increases in fine sediments relative to natural conditions, due to past and ongoing forest practices, riparian forest clearing, and floodplain disconnection (Brown and Maudlin 2007).

Rearing habitat in the main stem Nooksack River and associated floodplain and tributary habitats is limited by extensive bank hardening and levees, especially through the lower 25 miles, clearing of the floodplain forest, and ditching and draining of floodplain wetlands (SSDC 2007). An instream flow rule was established for the Nooksack watershed in 1985, and much of the watershed was either fully closed (lower Nooksack watershed) or seasonally closed (much of the North and South Fork watersheds) to further appropriation at that time (WAC 173-501). Nonetheless, established instream flows are frequently not met in many areas of the watershed, and there is no mechanism to ensure that instream flow needs can be met (Blake and Peterson 2005). Finally, the impacts of pollution from agricultural and household chemical use, as well as urban stormwater runoff, on Nooksack Chinook have not been fully evaluated.

Estuarine habitat connectivity in the Nooksack is limited by fish passage barriers, floodplain disconnection, and lack of forested cover (Brown et al. 2005; Beamer et al. 2016). The Lummi River, formerly the primary distributary channel of the Nooksack River, was cut off in the late 1800s and remains largely disconnected except at the highest flows. The Nooksack River delta has prograded significantly into Bellingham Bay since the 1930s, creating diverse and productive estuarine environments. Much of the nearshore south of the delta is urbanized, and legacy industrial uses on the waterfront have contaminated sediments and water quality in Bellingham Bay (SSDC 2007). Stormwater runoff associated with Bellingham also negatively impacts water quality in the bay and in independent tributaries that can provide non-natal rearing habitat.

Climate change impacts to the hydrologic regime (Nooksack River watershed) and stream temperature (South Fork Nooksack River watershed) have been modeled, and vulnerability of salmon in the South Fork assessed. Hydrologic modeling indicates that, by 2025, median August flows are estimated to drop 25%, 14%, and 40% relative to the historic average (1950-2010) for the North, Middle, and South Forks, respectively (Murphy 2015). Projected changes in flood frequency are more challenging to model, but increases in annual flood peak is projected, such that the magnitude of the historical 10-year flood in the mainstem Nooksack River is projected to have a return interval of 3 years by 2050 (Dickerson-Lange and Mitchell 2013). Critical condition temperatures (i.e. those experienced during hot, dry summers) in the South Fork are expected to increase 2.5-3.6 °C by the 2040s, and 3.4-5.9 °C by the 2080s (Butcher et al. 2016). Sediment loads are likely to increase under climate change due to loss of snowpack and increased intensity of precipitation events (EPA 2016). Potential impacts of sea level rise, wave-generated erosion, and sediment load increases on tidal and near-shore habitats are being evaluated (USGS 2017).
Habitat status has been updated through development of the Nooksack Chinook monitoring and adaptive management framework (PSP and WRIA 1 SRB 2014; Coe 2015). Watershed-wide, status of floodplain connectivity, channel migration, floodplain forest, riparian forest stand age, main stem habitat connectivity, and turbidity (South Fork) is considered fair. Status of instream large wood, pool frequency, forested islands, forest road density, and summer water temperature (South Fork) are considered poor. While restoration has improved habitat conditions in some reaches of the Forks, watershed-wide habitat condition continues to decline (NWIFC 2016). Between 2012 and 2016, floodplain status, tributary habitat connectivity, shoreline hardening and South Fork water temperature conditions all declined. Recent habitat declines include 350 feet of new hardened marine shoreline added (since 2011), 99 additional fish passage barriers identified (since 2010), 1.5% loss in wetlands (2006-2011), and 565 new permit-exempt wells (2008-2014; NWIFC 2016).

Population Status

The current status of both Nooksack early Chinook populations is extremely depressed (SSCD 2007), with significantly degraded habitat contributing to consistently poor returns of natural-origin Chinook and low productivity.

Escapements

Between 1999 and 2018 escapement of NF/MF natural-origin spawners (including NF/MF spawners in the South Fork) ranged from a low of 85 to a high of 453, with an average of 268 spawners. During this time period, two of the highest and two of the lowest natural-origin escapements occurred in the most recent four years, 2015-2018. The escapement of NF/MF HOR Chinook to the spawning grounds in all forks ranged from a low of 556 to a high of 3,806 (Figure 1). There has been no indication that years of above average escapements lead to above average NOR returns in the subsequent three to five years.

Between 1999 and 2018, SF Chinook natural-origin escapement ranged from a low of 7 to a high of 408, averaging just 98 spawners per year (Figure 1). The very low NOR escapements from 2013 and 2015 can be explained, at least partially, by the survey conditions in those years. Pink salmon spawn concurrently with South Fork Chinook, and the 2013 and 2015 Nooksack pink escapement estimates (224,000 and 247,000 respectively) were the highest and third highest since 1959, when the methodology was developed. Consequently, the South Fork Chinook estimates for those years were reported as minimum estimates due to redd superimposition. In 2014, the SF had an unusual high flow event that coincided with peak population spawn timing, where discharge rose from a low of 133 cfs September 23rd to a high of 3,830 cfs September 24th at the South Fork USGS Saxon Gauge. This freshet obscured redds and also flushed carcasses which would skew the stock assignment results to underrepresent the population. Similar situations occurred in 2013 and 2015, with a minimum discharge September 27, 2013 of 226 cfs rising to a peak of 13,300 cfs September 28. In 2015 the minimum discharge was 163 cfs on September 18 but that rose to 9,480 cfs by September 20. This is a very flashy river and visibility rarely recovers after the first strong fall freshet. Skookum Creek HOR Chinook adults were first observed in the South Fork in 2014 and escapements had increased to 920 by 2018. There has been a concurrent increase in NOR escapement in this timeframe as well, leading to two of the most productive years (2016 - 334 and 2018 - 408) since 1999.

Productivity

For the most recently completed brood years, 2009-2013, average productivity for the combined NF/MF and SF populations was 0.71 (Table 3). Productivity for the individual forks was not estimated due to a high degree of uncertainty resulting from consistently low abundance of SF natural-origin spawners. Although the number of SF natural-origin spawners is regularly below 100, the total number of spawners in the SF is expected to increase significantly in coming years as the SF recovery program operating from the Skookum Creek hatchery continues to develop and progress according to program objectives.

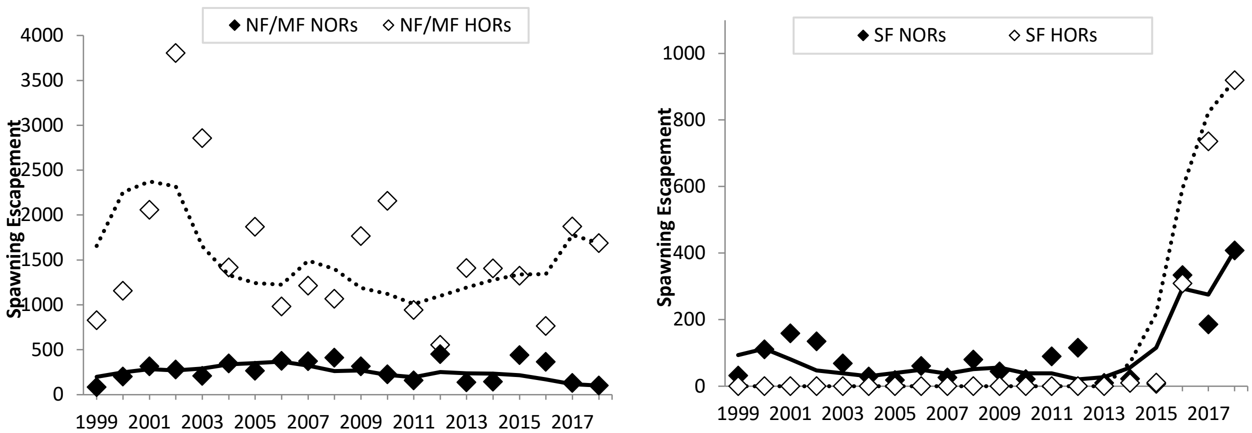

Figure 1. Spawning ground escapement estimates for the NF/MF (left graph) and SF (right graph) Nooksack early Chinook populations (1999-2018). The filled and unfilled diamonds represent point estimates, while the solid and dashed lines represent the four-year geometric means. Note: 2016-2018 represent genetic-based total basin escapement estimates.

Table 3. Spawning ground escapement estimates for the NF/MF and SF Nooksack natural origin and hatchery origin components of the early Chinook populations (1999-2018). Starting in 2016, estimates are genetic-based total basin escapement for each population. Note: NF/MF estimates include pre-spawn mortalities, SF exclude pre-spawn mortalities.

Return Year	NF/MF Natural Origin Spawners	NF/MF Hatchery Origin Spawners	SF Natural Origin Spawners	SF Hatchery Origin Spawners	R/S NF/MF & SF
1999	85	828	32	0	0.56
2000	202	1156	111	0	1.10
2001	315	2059	159	0	0.07
2002	279	3806	135	0	0.38
2003	210	2857	69	0	0.17
2004	347	1419	29	0	0.99
2005	266	1869	19	0	0.62
2006	377	981	61	0	0.26
2007	372	1213	26	0	0.68
2008	412	1068	80	0	0.67
2009	318	1767	45	0	0.21
2010	229	2157	21	0	0.11
2011	160	942	90	0	1.34
2012	453	556	116	0	1.00
2013	139	1409	10	0	0.89
2014	147	1406	22	10	
2015	440	1325	7	11	
2016	366	767	334	302	
2017	131	1873	186	736	
2018	102	1687	408	920	

Source: A&P01NF+SF_MUNooksackV7.2b_RER_2018b

Enumeration Methods

Current escapement estimate methodologies for the South Fork are redd-based, calculated by multiplying the total number of redds by the standard 2.5 adults per redd. Beginning in 2017 the methodology explicitly includes the following assumptions:

1) All redds are accurately counted in all geographic spawning areas utilized
2) No spawning Chinook after October 8 are early returning Chinook
3) Chinook that spawn through October 8 die within 1 week (by October 15)

Prior to 2017 assumption #2 only included the redds that were built through September 30 and carcass recoveries through October 7. However, new coded wire tag (CWT) recoveries and DNA results indicated spawning occurred later than was understood when the escapement estimates were much smaller, and Nooksack co-managers agreed to amend the assumption.

In the North/Middle Forks, a predominance of unfavorable viewing conditions support utilizing a carcass-based methodology for estimating the number of natural origin and Kendall Creek Hatchery origin early Chinook in the North/Middle Forks and their tributaries. A methodology was developed using redd data from five years (1991, 1992, 1995, 1996, and 2000) considered to have good viewing conditions. Redd counts from these five years were multiplied by 2.5 fish to estimate total population abundances. The total carcass counts in each of these five years was expanded to match the respective redd based total population abundance estimates. The individual year results ranged from a low of 3.22 to a high of 3.95, and the averaged expansion was 3.48 fish per recovered carcass to match redd-based estimates. As such, a 3.48 expansion factor for carcasses was adopted.

Beginning in 2010, carcasses observed in proximity to the Kendall Creek Hatchery were not expanded, and instead were considered the total counts. Unexpanded counts from Kendall Creek and Kendall Slough, areas of high carcass density, frequent surveys and favorable viewing conditions, were considered to more accurately reflect total abundance in recent years in this area. Prior escapement estimates were not recalculated with the change in methodology. Due to the very low number of NORs typically found in this reach (0-10, mean 5.86) the change in methodology does not appreciably affect estimates of NORs, nor does it dramatically change estimates of HORs. If anything, productivity (recruit per spawner) estimates from the early 2000s would be biased low due to potentially over-estimating the number of fish spawning naturally in the area and contributing to future NOR returns during years of expanded counts. In the Middle Fork, the escapement methodology has shifted between carcass-based methodology in years with poor survey viewing conditions (with a carcass expansion factor initially being 3.48, but later adjusted to 1.91) and a redd-based methodology in years with good survey viewing conditions. For select years, unexpanded carcass counts from low-flow, clear-water, and frequently surveyed Middle Fork tributaries were considered to more accurately reflect total Chinook spawners in those areas.

Stock Allocation

In the South Fork, DNA extracted from tissue samples from carcasses is used to determine a primary, secondary, and tertiary stock assignment with a posterior probability assigned to each level. The three stocks with unique genetic baselines that have been used are the NF/MF baseline, the SF baseline, and a Nooksack/Samish Fall stock baseline. Population of origin for each carcass is determined by simple majority (posterior probability of individual assignment >50%). The posterior assignments are generally very high for the Nooksack stocks averaging over 80% for all stocks and with a low percentage of ambiguous results.

In the South Fork, hatchery origin fish were identified based on adipose fin clip marks, otolith marks and/or CWT presence and subsequently assigned to their respective hatchery origin stock. These data are used to estimate respective hatchery contributions to the estimated total number of spawners through Oct 8, as determined by multiplying the total redd count by 2.5. The DNA results for the sampled natural origin carcasses are proportionally applied to the total estimate of wild Chinook (those without marks indicating hatchery origin) as expanded from the total number of redds in the South Fork.

Harvest Distribution and Exploitation Rate Trends

In the Fishery Regulation Assessment Model (FRAM), the NF/MF and SF populations are managed as a single unit as an indicator stock, based on coded wire tags from Kendall Creek

Hatchery. Kendall Creek Hatchery represents both the NF/MF and SF populations because the Skookum Hatchery Spring Chinook program was not operational during most of the base period for FRAM 7.1.

From 1992-2018, northern fisheries, conducted in Alaska and British Columbia, have consistently accounted for a majority of fishing-related mortality on Nooksack early Chinook, averaging an exploitation rate (ER) of 28.1%. Pre-terminal and terminal fisheries conducted in the southern US averaged 4.7% and 1.3% ER, respectively, for the same time period (Figure 2). Viewed another way, northern fisheries averaged 82.5% of the total annual exploitation rate between 1992 and 2018, while pre-terminal and terminal fisheries averaged 13.8% and 3.8% of the total annual exploitation rate on Nooksack early Chinook, respectively (Figure 2).

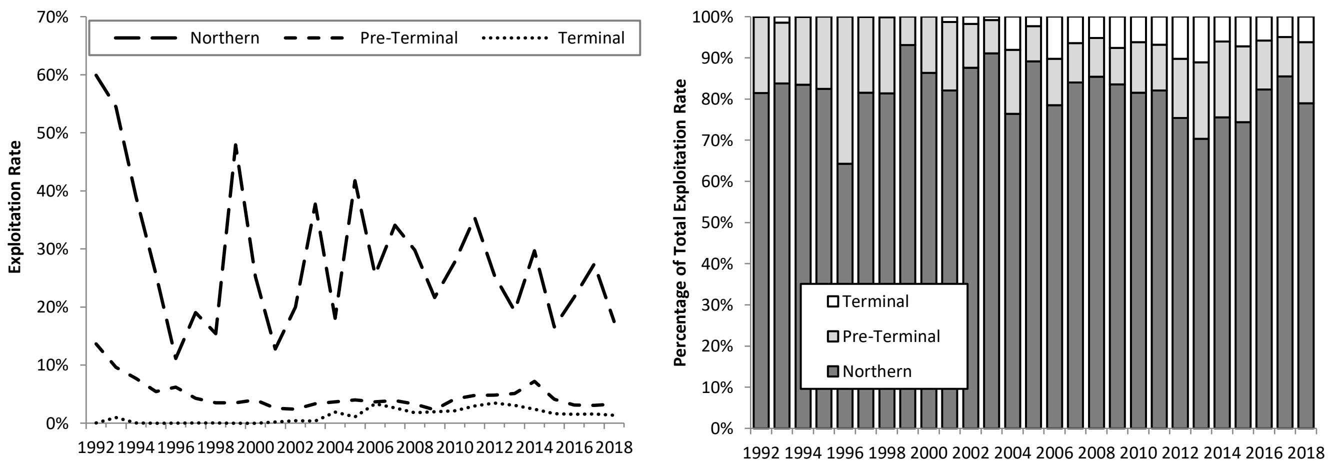

Figure 2. Northern, Pre-Terminal and Terminal exploitation rates on natural-origin Nooksack early Chinook from 1992-2018 (left graph), and the percentage of the total annual exploitation rate attributed to the Northern, Pre-Terminal and Terminal fisheries (right graph). Both graphs are based on post-season model runs using FRAM 7.1.

Management Objectives

The Kendall Creek and Skookum Creek hatchery programs are key components in the recovery of native Nooksack Chinook populations, playing a critical role in sustaining and increasing population abundances and buffering demographic and genetic risks while improvements to habitat quantity and quality occur.

The management objectives for Nooksack early Chinook were developed to ensure that Southern US harvests do not impede recovery or jeopardize the genomes of the NM/MF and SF populations, to maintain supplementation production from the Kendall and Skookum hatcheries until habitat capacity might be restored to a level that will sustain viable populations and to allow the exercise of treaty-reserved tribal fishing rights and non-tribal fishing opportunities on harvestable salmon. Both the NF/MF and SF Nooksack early Chinook populations will be managed for escapement of natural origin spawners.

The Nooksack management unit has been managed under a critical exploitation rate ceiling (CERC) under past management plans, with Upper Management Thresholds (UMTs) of 2,000 and Low Abundance Thresholds (LATs) of 1,000 for both populations, and with no allowable exploitation rate ceiling higher than the CERC identified. The co-managers will continue to manage using a CERC response at the onset of this plan regardless of expected abundance, but have attempted to define UMTs and LATs more representative of the current status of the populations and their habitat. In recent analyses of Nooksack early Chinook populations' abundance and productivity, a rebuilding threshold of 500 adult natural-origin spawners was identified for the combined NF/MF and SF populations (NMFS 2003; NMFS 2017; NWFSC 2017). Until recently the SF NOR population typically made up a very small proportion of the total spawners returning to the Nooksack River; therefore 400 natural-origin spawners is a reasonable reference point for establishing a conservative LAT for the NF/MF population. The UMT for the NF/MF population will be set at 1,000 natural-origin spawners (Table 4). Although an allowable exploitation rate higher than the CERC at higher abundances is not identified in this plan, setting the UMT for the NF/MF population at a level that is twice the rebuilding threshold of 500 natural-origin spawners is a very conservative approach to defining escapement thresholds.

The SF population has shown promising return trends from 2016-2018. Prior to this trend chronically low NOR abundance estimates and highly uncertain productivity estimates limited our the ability to produce a recruit-per-spawner curve or establish escapement reference points. Because of low confidence in biologically-based population metrics for the SF population, a LAT was established utilizing a habitat-based model (Parken et al. 2006) that estimates spawners at MSY based on watershed area and dominant life history type (ocean-type, stream-type). For the South Fork watershed, 25% of the watershed is considered inaccessible due to natural falls and cascades, and based on previous EDT model-based estimates the current capacity of accessible spawning habitat is 7.5% of historic levels (WRIA 1 SRB 2005). Using the method established by Parken et al. (2006) results in 157 spawners at MSY. Following logic for taking a conservative approach similar to that used for the NF/MF population, a LAT for the SF population is set at 200 natural origin spawners, and the UMT is set at 500 natural origin spawners (Table 4). Setting both thresholds at levels higher than the best available estimate of MSY escapement is a very conservative approach to defining escapement thresholds. These escapement thresholds are consistent with the goals of the Skookum Creek SF early Chinook program of increasing natural-origin spawner abundance and preserving genetic diversity of the SF population.

When preseason FRAM outputs of projected natural spawning escapement for one or both Nooksack early Chinook populations are below the LAT, fisheries in the Southern US will be planned so as not to exceed the CERC. The CERC will be 10.9% SUS ER on the natural-origin components of the combined populations (Table 4). However, to allow some flexibility in conducting directed fisheries on harvestable surplus of healthy stocks, the SUS ER ceiling may increase to 14.1% in one out of five years. These ceilings are not viewed as targets, but rather as limits within which tribal and non-tribal fisheries will be prosecuted. Northern fisheries continue to account for the majority of harvest-related mortality on Nooksack early Chinook (Figure 2), and further reductions of fishery impacts in Washington waters below the CERC limits used for management in the past would not materially influence spawning escapement. In fact, closing all Puget Sound fisheries would only allow, on average (2014-2018), an additional 9 NF/MF NORs and 7 SF NORs to the reach the spawning grounds (FRAM v7.1.1). In contrast, any further harvest limitations in Puget Sound would have real and significant impacts on tribal and non-tribal fisheries and fishing communities. Ultimately, the limited amount of SUS harvest permitted under the CERC limits will not appreciably reduce the likelihood of survival and recovery of the Nooksack early Chinook populations, or the Puget Sound Chinook ESU, consistent with criteria C for FMEPs in the 4(d) rule.

The CERC has changed through time as data and models have evolved. The original CERC was based on a Minimum Fisheries Regime which at the time was calculated to be 7% SUS ER, and 9% SUS ER once every 5 years. When FRAM 6.2 was developed, these reference points were adjusted to fit the terms required for the new base-period. For each year from 1992-2016, a conversion factor was calculated by dividing the FRAM 6.2 post season estimates by the old-FRAM post season estimates. The mean conversion factor across years was 1.5, so 7% and 9% SUS ER in the old model equates to 10.5% and 13.5% SUS ER in FRAM 6.2, respectively. A similar process was completed to convert the FRAM 6.2 terms into base-period FRAM 7.1.1 terms (years used = 1998 to 2016[16]). The updated CERC values under FRAM 7.1.1 are 10.9% SUS ER and 14.1% SUS ER once every 5 years.

Table 4. Upper Management Thresholds (UMT) and Low Abundance Thresholds (LATs) of natural origin spawners for the NF/MF and SF Nooksack early Chinook populations. The Critical Exploitation Rate Ceiling (CERC) and Exploitation Rate Ceiling (ERC) are applied to the two populations combined.

Population	ER Ceiling	UMT	LAT	Critical ER Ceiling
NF/MF	N/A	1,000	400	10.9% SUS ER; 14.1% 1 out of 5 years
SF		500	200	

Achieving hatchery rack goals for the Kendall and Skookum hatcheries are an essential component of increasing the populations of the Nooksack management unit. However, hatchery rack goals were not incorporated into the LATs and UMTs for each population. Instead, the co-managers will meet pre-season to discuss and agree upon appropriate hatchery rack goals to use for the upcoming season. Hatchery rack and release goals are expected to increase over the term of this plan as the status of terminal hatchery programs move towards production goals developed by the co-managers.

As hatchery production in the Nooksack watershed continues to progress, particularly for the Skookum program, the abundance of NOR spawners are expected to grow relative to recent escapements. For the Nooksack management unit, it will be particularly important to have the ability to revisit established management objectives over the term of this plan to ensure they remain relevant in light of harvest and recovery objectives. Triggers for revisiting the management objectives could include, but are not limited to, increases in the population to the

[16] 1998 to 2016 were chosen as the years for the CERC translation because earlier years (1992 to 1997) had higher average ratios of Round 7.1.1 SUS ERs to Round 6.2 SUS ERs than later years (1992 to 1997 average = 1.17; 1998 to 2016 average = 1.04). More recent years are more likely to portray recent trends in escapement and fishing regimes. 2016 was the final year used to examine ratios because it is the latest available year of post-season runs for base period Round 6,2.

point where an ER Ceiling needs to be developed, or the development of improved reference points based on biologically derived assessment models for the stock.

There have been no directed commercial fisheries on Nooksack early Chinook in Bellingham Bay and the Nooksack River since the late 1970s. Incidental harvest of Nooksack early Chinook in fisheries directed at fall HOR Chinook in Bellingham Bay and the lower Nooksack River was reduced in the late 1980s by significantly restricting fisheries in July. In addition, release, marking and acclimation strategies on fall hatchery Chinook further reduced incidental impacts on early Chinook and reduced straying into early Chinook spawning areas. Since 2010, there have been limited C&S fisheries in the Nooksack River between April and June. All fish in these C&S fisheries are sampled and any NOR mortalities are counted towards the overall take limit. In addition, there is limited recreational fishing in the Nooksack River which is monitored and managed by WDFW.

Tribal treaty-right fisheries on Nooksack early Chinook in the Nooksack River are the highest priority in the tribal terminal area fishing regime. These fisheries will occur throughout the lower river, no higher than the lowest ¼ mile of the North Fork, will target Kendall Creek and Skookum Creek Hatchery returns and may utilize selective gear to enable the release of NOR Chinook. As changes in terminal abundance occur, the tribes may target early Chinook in other terminal fisheries, as negotiated through the North of Falcon process. Fisheries that occur in the terminal area targeting Nooksack early Chinook HORs will be closely monitored; all impacts will be accounted for and will not exceed agreed-to harvest limits.

Although most terminal area fishing impacts on early timed Chinook stocks occur between mid-March and mid-June, the development of a successful south fork Chinook hatchery program at Skookum Creek warrants additional monitoring of stock composition, migration timing and distribution by conducting fisheries between mid-June to the end of July. Taking into consideration the current forecasts, recent-year run size, and spawning escapement trends for Nooksack early Chinook populations, the co-managers and NOAA will discuss the opportunity for fishing between mid-June and the end of July annually during the North of Falcon preseason planning process. Planning fisheries so as not to disproportionally impact any Nooksack early Chinook population will be considered. The co-managers and NOAA will agree on fishing and reporting guidelines, conditions and timelines to use for the season prior to any fishing during the mid-June to end of July time period. The total impacts of all terminal area fisheries on Nooksack early Chinook will be managed so as not to exceed the preseason agreed limits.

In recent years, the portions of the mainstem Nooksack from the confluence of the North and South forks to the yellow boundary marker approximately 1.3 miles downstream, and of the South Fork Nooksack from the confluence to the mouth of Wanlick Creek have been closed to all recreational fishing during much of the trout season (through September 30) to protect holding and spawning Chinook. Similar closures are expected to remain in place given the status of the Chinook population and environmental conditions likely to persist in the near future but recreational fisheries planned each year will be included in the annual discussions with NOAA referenced in the prior paragraph.

Data Gaps

- Improve abundance and productivity estimates based on information gathered by evaluation of limitations of current program.
- Continue to improve understanding of NF/MF and SF Chinook freshwater entry and migration.
- Chinook life cycle model
    - The Chinook life cycle model will identify, prioritize and estimate the temporal and spatial aspects of population productivity and factors limiting recovery, including survival estimates by life stage. This work is currently in development.
- Improvements in the outmigrant population estimates from smolt traps will provide new information to update productivity estimates including smolt-to-adult returns.
    - Skookum Creek Hatchery early Chinook survival
        - Metrics continue to be developed to evaluate this new program.
- Recolonization of Middle Fork after removal of diversion dam in 2020
    - Surveys planned to assess presence/absence, distribution, and spawning activity beginning in 2021.

Skagit River Management Unit Status Profile

Component Populations

Summer/fall Chinook salmon management unit

Lower Sauk River (summer)
Upper Skagit River mainstem and tributaries (summer)
Lower Skagit River mainstem and tributaries (fall)

Spring Chinook salmon management unit

Upper Sauk River
Suiattle River
Upper Cascade River

Geographic and Habitat Description

The Skagit River watershed is the largest river system in Puget Sound and includes 3,100 mi^2 of watershed area and 126 mi^2 of freshwater tidal delta and estuary (SRSC and WDFW 2005). The upland freshwater ecosystem includes the mainstem Skagit River and four large secondary basins: the Baker, Cascade, Sauk, and Suiattle rivers and a number of smaller streams. The upper Skagit River watershed that includes the Suiattle and Cascade rivers is characterized by a snowmelt hydrology, whereas the Sauk River and main-stem Skagit River are characterized by a transitional hydrology which consist of combination of rain-on-snow and snowmelt driven peak flow (Beechie et al. 2006). Hydroelectric projects occur on the upper-Skagit River near Newhalem, WA and on the Baker River near Concrete, WA. Most of Skagit River watershed is forested with the lower watershed dominated by agriculture and urban development. The cities of Sedro Woolley, Burlington and Mount Vernon are adjacent to large sections of the lower Skagit River. Governing bodies in the Skagit system include three treaty Indian tribes; two federal and three state land management agencies; Canadian federal, provincial and municipal governments; three county governments; various local municipal governments; and private property owners.

Two Skagit River Chinook salmon management units (MU's) occur in the Skagit River watershed. Within these two MU's the co-managers assumed contributions from three summer/fall and three spring timed populations, which was later supported by the Puget Sound Technical Review Team through their assessment of historical population structure (Ruckelshaus et al. 2006). Juvenile Chinook salmon from either the Skagit River spring Chinook MU or the Skagit River summer/fall Chinook MU rear throughout the Skagit River basin and estuary and exhibit five distinct life history strategies including: 1) delta fry: following emergence, rear in the Skagit River delta for a period of 0.5 – 2 months prior to migrating to marine nearshore habitats; 2) fry migrants: migrate directly to marine areas following emergence spending very little time in nearshore refuge areas; 3) nearshore refuge rearing fry migrants: migrate directly to marine areas following emergence but spend some period of time in rearing in non-natal estuarine habitat 4) parr migrants: exhibit extended freshwater rearing prior to migrating directly to marine areas; and 5) yearlings: migrate to marine nearshore habitat's following one year of freshwater rearing spending very little if any time in estuarine habitats (Beamer et al. 2005, Greene et al. 2016, Zimmerman et al. 2015). Diversity of life history strategies appears to be a density dependent response to the availability of freshwater and estuarine habitat (Greene et al. 2016, Zimmerman et al. 2015).

Spawning and incubation potential of juvenile Skagit River Chinook salmon has been limited by instream barriers, sedimentation and hydrograph regimes. In year 2000, over 600 barriers to fish passage that limit access by spawning adults and by rearing juvenile Chinook salmon were identified in the Skagit River basin (SRSC and WDFW 2005). Many of these barriers were associated with road crossings from undersized culverts that limit overall carrying capacity of Skagit River Chinook salmon. In addition, roadways produce a significant source of sediment that smothers incubating eggs, decreasing egg to fry survival and altering productivity. A number of roads in the Skagit River basin have been identified as sources of sediment that are likely impacting Skagit River Chinook salmon. Stream hydrographs, which indicate the frequency and severity of peak flows, have shown direct relationships to juvenile Chinook salmon survival (Zimmerman et al. 2015). Furthermore, humans have altered the landscape through urban and rural development and stream engineering (straightening, diking, and bank armoring) that results in loss of floodplain connectivity and increase the peak flow severity.

The Skagit River mainstem has seen extensive flood control. Currently, 31% of large river floodplain area and 98% of non-tidal delta area have been lost relative to historical conditions basin (SRSC and WDFW 2005). These freshwater areas have been isolated from natural habitat forming processes by levees and armored banks, resulting in degradation or complete loss of limiting channel and floodplain habitats important for juvenile Chinook salmon rearing. Freshwater habitats in the Skagit River consistently produce around 1.3 million migrants, regardless of escapement levels, providing evidence of limited habitat capacity and reductions to population productivity.

Loss of freshwater habitat within the Skagit River continues to occur. A recently completed inventory of hydro-modified banks (i.e. armored with riprap) within the known area of Skagit River Chinook salmon distribution documented over 32 miles of impacted riverbank; with 2.2 miles newly armored since 1998 (USIT unpublished data). A change detection analysis from the period 2006 to 2009 for the lower portion of the watershed indicated an annual rate of change to permanent development (e.g. new roads or buildings) of 0.08%. Furthermore, 290 miles of fish-bearing streams had permanent development in 67.5 acres and non-permanent development (e.g. forest clearing) in 53 acres.

Annually, a large proportion of juvenile Chinook salmon fry rely on estuarine habitat for rearing (Beamer et al. 2005). The total number of Chinook fry that migrate directly to Skagit Bay without utilizing the estuary for rearing purposes is likely a density dependent response to habitat limitation in freshwater and the estuary (Zimmerman et al. 2015). This reduced rearing opportunity often results in smaller size at marine entry for juveniles, which in turn, could lead to poorer marine survival although the positive relationship between the quality and quantity of estuarine habitat and marine survival of Chinook salmon has only been observed for a few coastal populations (Magnusson and Hilborn 2003). In the Skagit River, much of the estuary has been isolated by diking. Specifically, 73% (8,365 hectares) of tidal delta has been disconnected from floodplain and tidal processes and 24% of Skagit Bay has been armored (SRSC unpublished data). From 2004 to 2014, a total of 122 hectares of tidal delta and estuary habitats have been restored (SRSC unpublished data), and ongoing monitoring efforts are determining the system wide response of Skagit River spring Chinook salmon and Skagit River summer/fall

Chinook salmon to these recovery efforts in terms of increased juvenile rearing capacity, growth, and early marine survival (Greene et al. 2016). Despite recent gains in estuarine habitat, a combination of human land use practices and natural processes have resulted in a loss of 67 hectares of habit in the Skagit River tidal delta for the same period (SRSC unpublished data).

Recent years of above average temperatures in the Northeast Pacific Ocean have resulted in extended periods of little to no precipitation and high stream temperatures during summer months throughout the Puget Sound region (Bond et al. 2015, Mote et al. 2016). Ocean conditions have been linked to growth and survival of Puget Sound Chinook salmon during ocean rearing (Wells et al. 2008) where the first months at sea are believed to be the most critical for salmon survival (Daly and Brodeur 2015). However, Puget Sound Chinook salmon populations have exhibited higher inter-population variability in long term trends in early marine survival compared to coastal populations (Ruff et al. 2017). Therefore, the localized effects of these anomalous high ocean temperatures on both freshwater productivity and early marine survival of Skagit Chinook salmon populations remain uncertain.

Skagit River Chinook salmon populations are under threat of contemporary climate change and broad scale habitat loss. For the Skagit River, future climate scenarios are projected to change the seasonal hydrological cycle from a rain and snowmelt driven cycle to primarily a rain driven cycle resulting in a single rain-dominated peak in early winter, which overlaps with the egg incubation period for Chinook (Lee et al. 2016). These changes will likely result in reductions in egg to fry survival and further limit the rearing capacity of juvenile Chinook salmon due to low summer flows. More concerning, however, the Puget Sound Region and the Skagit River basin is seeing rapid population growth. The Skagit River basin is in three counties: Whatcom County, Skagit County and Snohomish County; each has seen 7.8%, 5.8% and 10.4% increase in human population size from 2010 to 2016, respectively. Population growth inherently leads to increased impervious surface, habitat loss, and more habitat fragmentation. Further loss of freshwater and estuarine habitat may reduce the overall resilience of Skagit River Chinook salmon in the face of climate change and may increase management uncertainty.

Component Populations and Management Units

There are two natural origin Chinook MU’s originating in the Skagit River system—summer/fall and spring Chinook salmon. The co-managers initially identified three summer/fall and three spring timed populations. Ruckelshaus et al. (2006) supported the co-managers delineation of the historical population structure with some caveats. Geographic distance was the primary inference in distinguishing populations; however, genetic analysis suggests strong differentiation between lower Sauk River and Suiattle River and Cascade, but weak differentiation between the lower Sauk River, upper Sauk River and lower Skagit River groups.

Dispersal and thus gene flow between groups is still not known, but out of basin straying tends to be high suggesting some connection between populations. Ruckelshaus et al. (2006) identified further genetic work is needed to reconcile uncertainty in population structure (see data gaps). In addition, a better understanding of dispersal rates between populations is needed to evaluate connectivity and demographic influence on population structure (Schtickzelle and Quinn 2007).

Spring Management Unit

The Skagit River spring Chinook MU includes: the upper Sauk River, the Suiattle River, and upper Cascade River.

- The upper Sauk River spring Chinook salmon stock spawns in the mainstem to the forks, in the lower North Fork Sauk River to the falls, and the South Fork Sauk River to river mile 3.5, although redds have recently been seen to river mile 5. Included in this population are fish spawning in the White Chuck River, and tributaries Camp, Pugh and Owl Creeks.
- The Suiattle River spring Chinook salmon stock spawns in several tributaries including Buck, Downey, Sulphur, Tenas, Lime, Circle, Straight, Milk and Big creeks.
- The Cascade River spring Chinook salmon stock spawn in the mainstem above RM 8.1, to the forks, in the lower North and South Forks, and in tributaries Marble, Found and Kindy Creeks. They are thus spatially separated from the Upper Skagit River summer Chinook which use the lower 5 miles of the Cascade River.

Spring Chinook salmon begin entering freshwater in April. The Cascade River stock and Suiattle River stock currently spawn from early August through the third week of September. The upper Sauk River stock currently spawns from mid- August to mid- October. Annual observations of population specific spawn timing indicate that there is considerable overlap in the spawn timing between each of the three spring Chinook populations.

Adult spring Chinook salmon returning to the Skagit River reach sexual maturity at ages 3 – 5 years with the majority of individuals from each population reaching maturity after 4 or 5 years (Figure 1), similar to that observed for Skagit summer/fall Chinook. Analysis of scales collected from adults on the spawning grounds indicates that the proportion of spawners that outmigrated as yearlings ranged from 20% to 85% from the Suiattle, 35% to 45% from the Upper Sauk, and 10% to 90% from the Upper Cascade system.

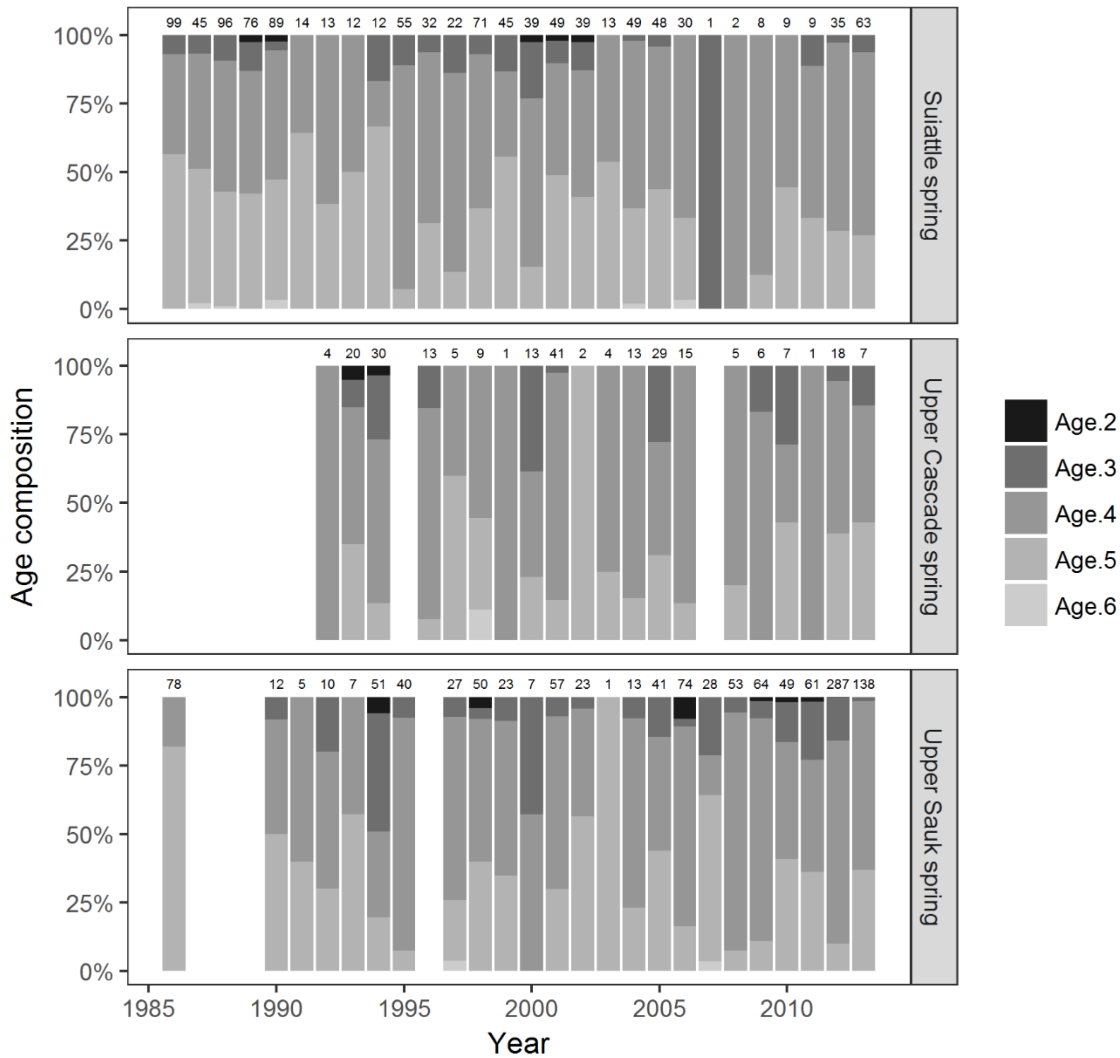

Figure 1. Annual age composition of natural origin Chinook salmon spawners from each of three populations comprising the Skagit spring Chinook management unit. The number of annual samples is noted above each bar.

Summer/fall Management Unit

The Skagit River Chinook salmon summer/fall MU includes: Upper Skagit River summers, Lower Sauk River summers, and Lower Skagit River falls.

- Upper Skagit River summer Chinook salmon spawn in the mainstem and certain tributaries, from above the confluence of the Sauk River to Newhalem. Spawning also occurs in the lower five miles of the Cascade River, and in Diobsud, Bacon, Falls, Goodell, and Illabot, creeks. Gorge Dam, a hydroelectric facility operated by Seattle City Light, prevents access above river mile (RM) 94,

- The lower Sauk River summer Chinook salmon stock spawns primarily from the mouth of the Sauk to RM 27—separate from the upper Sauk spring spawning areas above RM 31.
- The lower Skagit River fall Chinook salmon stock spawns downstream of the mouth of the Sauk River and in the larger tributaries including Hansen, Alder, Grandy, Pressentin, Jackman, Jones, Nookachamps, O'Toole, Day, and Finney creeks.

The upper Skagit River summer Chinook salmon stock and lower Sauk River summer Chinook salmon stock spawn from early September through October. Upper Skagit River summer Chinook salmon spawn in the mainstem and certain tributaries, from above the confluence of the Sauk River to Newhalem. Spawning also occurs in the lower five miles of the Cascade River, and in Diobsud, Bacon, Falls, Goodell, and Illabot creeks. Hydropower operational constraints imposed by the Federal Energy Regulatory Commission on the Skagit Hydroelectric Project's operation have, to some extent, mitigated the effects of flow fluctuations on spawning and rearing in the upper main stem, and reduced the impacts of high flood flows by storing runoff from the upper basin. Glacial turbidity from the Suiattle River and Whitechuck River may limit egg survival in the lower Sauk River.

The lower mainstem fall stock spawns downstream of the mouth of the Sauk River and in the larger tributaries including Hansen, Alder, Grandy, Jackman, Jones, Nookachamps, O'Toole, Day, and Finney creeks. The lower river fall Chinook salmon enter the river and spawn from mid- September to mid- November. Fall Chinook salmon tend to spawn later than the summer Chinook salmon but there is considerable overlap in spawn timing between Skagit summer and fall Chinook salmon.

Adults reach sexual maturity at ages 3 - 5 years with the majority of individuals from each of the three populations returning to spawn after 4 years (Figure 2). Although most summer/fall Chinook salmon smolts emigrate from the river as sub-yearlings, considerable variability has been observed in the timing of downstream migration and residence in the estuary, prior to entry into marine waters (Hayman et al. 1996). Analysis of scales collected from adults on the spawning grounds indicates that the proportion of spawners that outmigrated as yearlings ranged from 0% to 2% for Upper Skagit summer Chinook, 11% to 26% for Lower Sauk summer Chinook, and 0% to 32% for Lower Skagit fall Chinook (Skagit co-managers unpublished data).

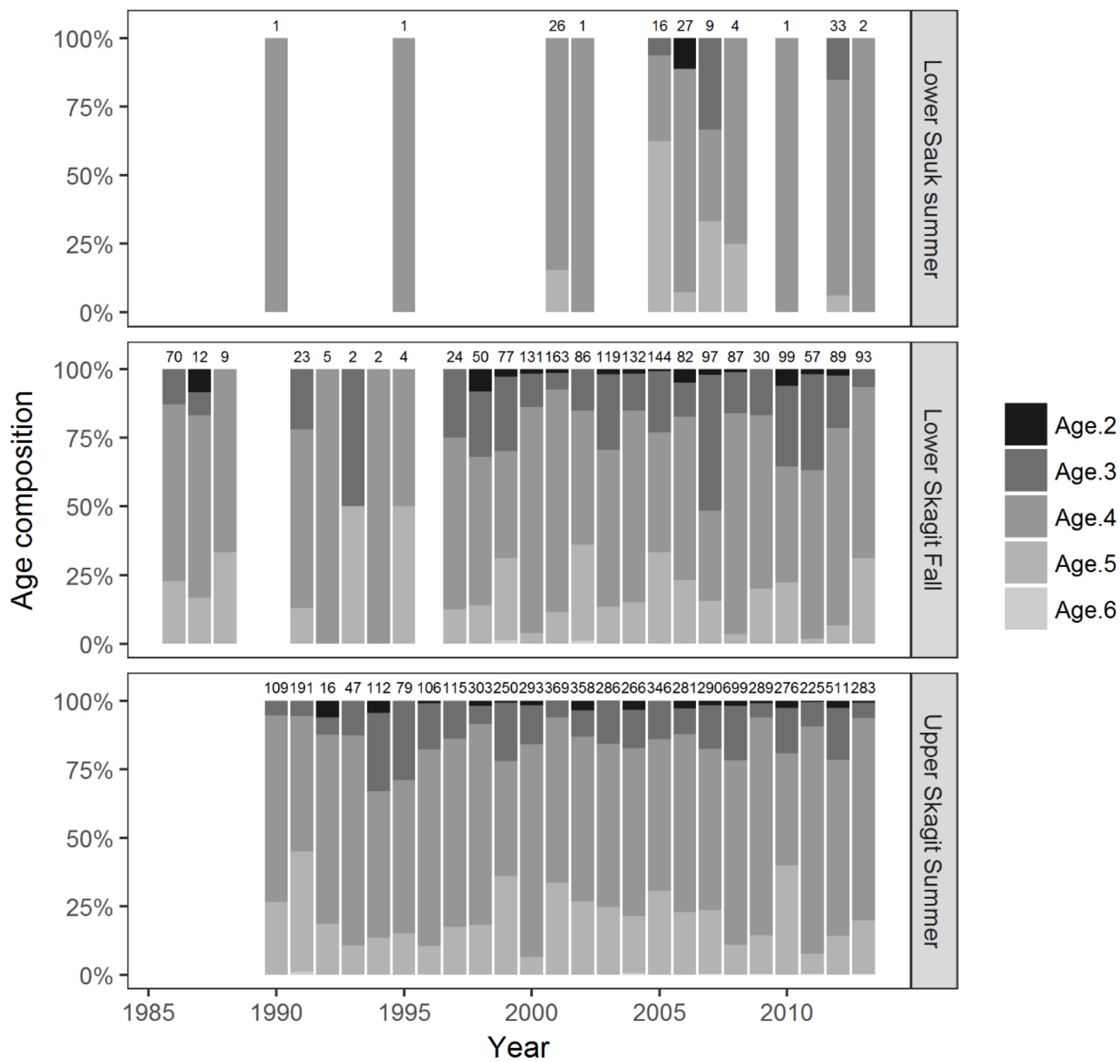

Figure 2. Annual age composition of natural origin Chinook salmon spawners from each of three populations comprising the Skagit summer/fall Chinook management unit. The number of annual samples is noted above each bar.

Hatchery programs

The Skagit River summer Chinook salmon integrated research hatchery program is a Pacific Salmon Commission (PSC) wild indicator stock program and has been operating since 1994. Prior to this program, Samish hatchery fall fingerling releases were considered to be an accurate surrogate for the distribution of Skagit River summer/fall Chinook salmon, but the Skagit local indicator stock has since been developed. The Skagit River summer Chinook salmon indicator stock program collects unmarked and untagged summer broodstock (up to 61 spawning pairs per year) from the upper Skagit River. Eggs and juveniles are reared at the Marblemount Hatchery prior to being released as fingerlings into acclimation ponds in the Upper Skagit River. The objective of the program is an annual release of 200,000 adipose-clipped and coded-wire tagged fingerlings. The indicator stock program supplies information essential to PSC fishery assessment (e.g. Chinook Technical Team 2016) and ongoing research (Ruff et al. 2017).

The Skagit River fall Chinook salmon indicator program that provided fishery distribution information specific to Lower Skagit Falls operated from 1999 to 2008, but was terminated due to funding constraints. This program is being reinitiated (HGMP currently under review, 2019); this program is also designed and sized as an indicator stock program for PSC fishery assessment and other research. In order to achieve the goals of this program, 110 natural origin adults will be collected annually for hatchery broodstock to provide 200,000 sub-yearlings for a program release goal. The sub-yearlings will be released from Stress Relief Ponds into Baker River (WRIA 04.0435) in two groups; 100,000 Adipose-clipped +CWT and 100,000 CWT only. This release is expected to return 720 adults. Fish in excess of hatchery broodstock needs will provide a buffer for bycatch to in-river fisheries targeted at non-listed species. Returning hatchery fish to the Baker River Upstream Fish Trap will be intercepted and removed from the system to control pHOS.

Skagit River spring Chinook salmon are supplemented by a segregated hatchery production program with broodstock originating from the Suiattle River. Eggs and juveniles are reared to fingerlings, which are acclimated in the Marblemount hatchery before they are released. The program serves as both a partial mitigation for lost production and harvest and is designated as a PSC indicator stock program, essential to management of the Skagit River spring Chinook MU. The annual release goal is currently 587,500 sub-yearlings (fingerlings), all of which are coded-wire tagged (CWT) and/or marked by adipose clip (AD). Of these releases, the goal is for 110,000 adipose clipped only, 200,000 CWT only, and 277,500 both adipose clipped and coded-wire tagged (AD+CWT). The AD+CWT and CWT only fish comprise the double index tag (DIT) group which enables estimates of non-landed mortality of wild Skagit Spring Chinook salmon encountered in mark-selective fisheries targeting marked hatchery Chinook salmon in mixed stock areas throughout Puget Sound.

Management Unit Status

Spring Chinook management unit

Although none of the three spring populations have exhibited a predominant long-term trend in productivity during this same period, each population has experienced moderate declines in productivity over the most recent five year period (brood years 2008 – 2012), according to NOAA’s analysis (NOAA Fisheries et al. 2018a). The estimated temporal variability in aggregate productivity for Skagit Spring Chinook generally translated to an increasing trend in escapement for each of the three spring Chinook populations from 1993 – 2018, with Upper Sauk spring Chinook exhibiting the largest magnitude in increased escapement over the period (Figure 3). Comparing the most recent ten year observed escapements to NOAA’s population specific rebuilding thresholds (RET; See NOAA Fisheries et al. 2018a), Suiattle Spring Chinook have exceeded NOAA’s RET of 223 spawners in nine out of the last ten years; Upper Sauk spring Chinook have exceeded NOAA’s RET of 470 spawners in eight out of the last ten years; and Upper Cascade spring Chinook have exceeded NOAA’s RET of 148 spawners in nine out of the last ten years. Based on the estimated linear relationship between aggregate escapement and resulting population specific escapements (Figure 3), Suiattle spring Chinook have generally exceeded NOAA's RET of 223 when aggregate escapements have exceeded 490 spawners; Upper Sauk spring Chinook have generally exceeded NOAA's RET of 470 when aggregate escapements have exceeded 1,100 spawners; and Upper Cascade spring Chinook have generally exceeded NOAA's RET of 148 when aggregate escapements have exceeded 470 spawners.

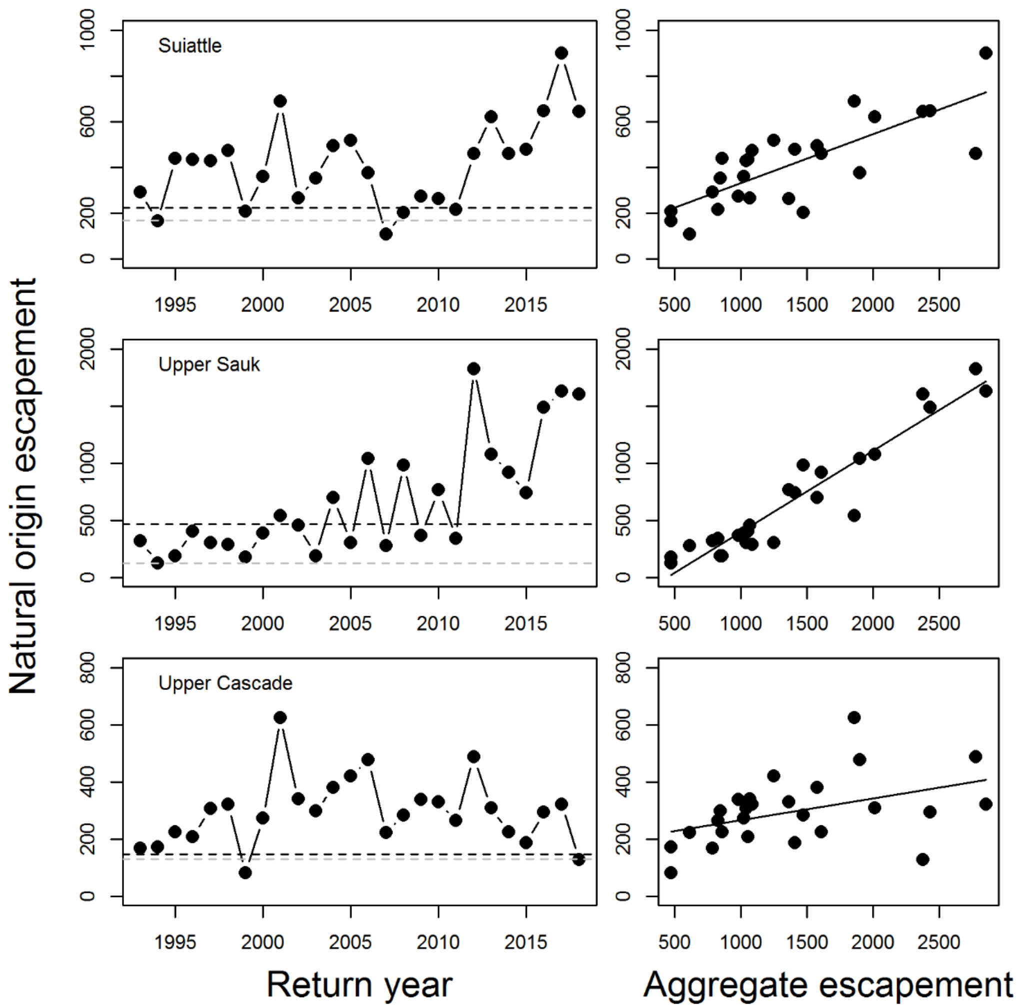

Figure 3. Natural origin spawning escapement of Skagit River Spring Chinook salmon populations for return years 1993 - 2016. Right hand panels show the linear relationship between population specific escapements and aggregate escapements of natural origin spawners for the spring Chinook management unit. In the left-hand panels, horizontal dashed lines represent population specific abundance thresholds developed by NOAA fisheries including the rebuilding escapement threshold (black line), and critical threshold (grey line).

Summer/Fall management unit

Each population within the Summer/Fall management unit exhibited an increasing trend in productivity from brood year 2006 – 2012, according to NOAA's analysis (NOAA Fisheries et al. 2018b), with productivity rates for each of the populations approaching greater than average values seen during the period back to the early 1990s. The estimated temporal variability in productivity for the Skagit summer/fall Chinook generally translated to an increasing trend in escapement for each of the three populations over the most recent ten-year period (Figure 4). Comparing the most recent ten year observed escapements to population specific rebuilding thresholds (RET; See NOAA Fisheries 2018b), Lower Skagit fall Chinook have exceeded NOAA's RET of 2,131 spawners in three out of the last ten years; Lower Sauk summer Chinook have exceeded NOAA's RET of 371 spawners in four out of the last ten years; and Upper Skagit Summer Chinook have exceeded NOAA's RET of 5,470 spawners in eight out of the last ten years. Based on the estimated linear relationship between aggregate escapement and resulting population specific escapements (Figure 3), Lower Skagit fall Chinook have generally exceeded NOAA's RET of 2,131 when aggregate escapements have exceeded 12,300 spawners; Lower Sauk summer Chinook have generally exceeded NOAA's RET of 371 when aggregate escapements have exceeded 5,683 spawners; and Upper Skagit summer Chinook have generally exceeded NOAA's RET of 5,740 when aggregate escapements have exceeded 7,400 spawners.

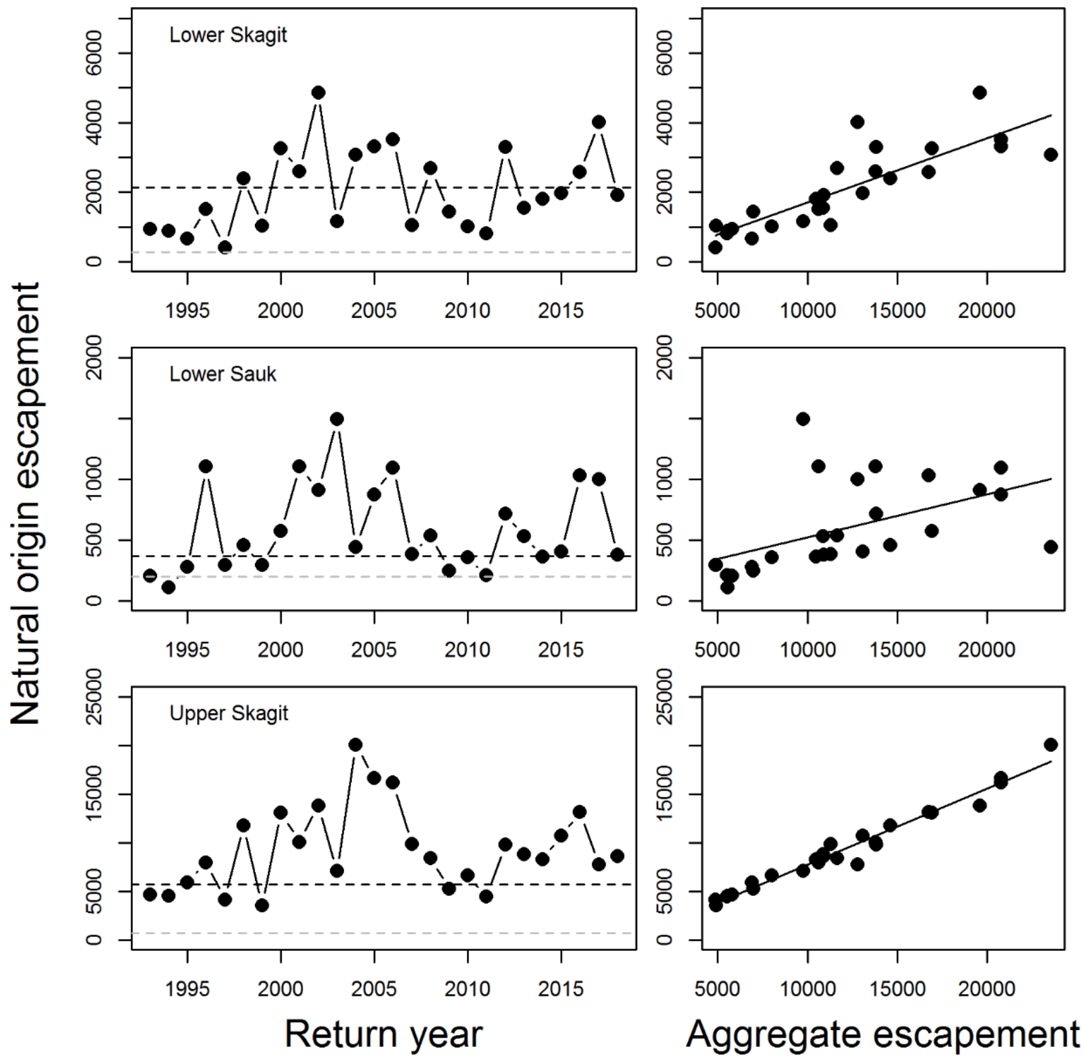

Figure 4. Natural origin spawning escapement of Skagit River Summer/Fall Chinook salmon populations for return years 1993 - 2016. Right hand panels show the linear relationship between population specific escapements and aggregate escapements of natural origin spawners for the spring Chinook management unit. In the left-hand panels, horizontal dashed lines represent population specific abundance thresholds developed by NOAA fisheries including the rebuilding escapement threshold (black line), and critical threshold (grey line).

Exploitation Rate Trends and Harvest Distribution

FRAM validation runs were recently completed for fishing years 1992 – 2018. Although there has been no discernable long-term trend in total annual exploitation rate for the Skagit Spring Chinook MU (Figure 7), there was a sharp drop in the total exploitation rate beginning in 1995 where the total exploitation rate averaged below 19% through fishing year 2016. This trend is partially caused by reductions in Areas 5, 6, and 8 sport, as well as West Coast Vancouver Island troll fishery reductions that began in 1994. Total exploitation rates for the Skagit Summer/Fall Chinook MU exhibited a declining trend from 1992 - 2002 followed by an increasing trend through 2011, finally leveling out at an average of 40% through year 2018 (Figure 7).

Skagit River Chinook salmon are commonly caught in Alaskan, Canadian fisheries, in addition to Southern US fisheries. Over the most recent 10 year period included in the FRAM validation runs 7.1.1 (2009-2018), exploitation rates on the Skagit Spring Chinook MU have averaged 14% in northern fisheries (Alaska and Canada) and 11% in southern US fisheries. Over the same period, exploitation rates on Skagit summer/fall Chinook MU have averaged 26% in northern fisheries and 18% in southern US fisheries.

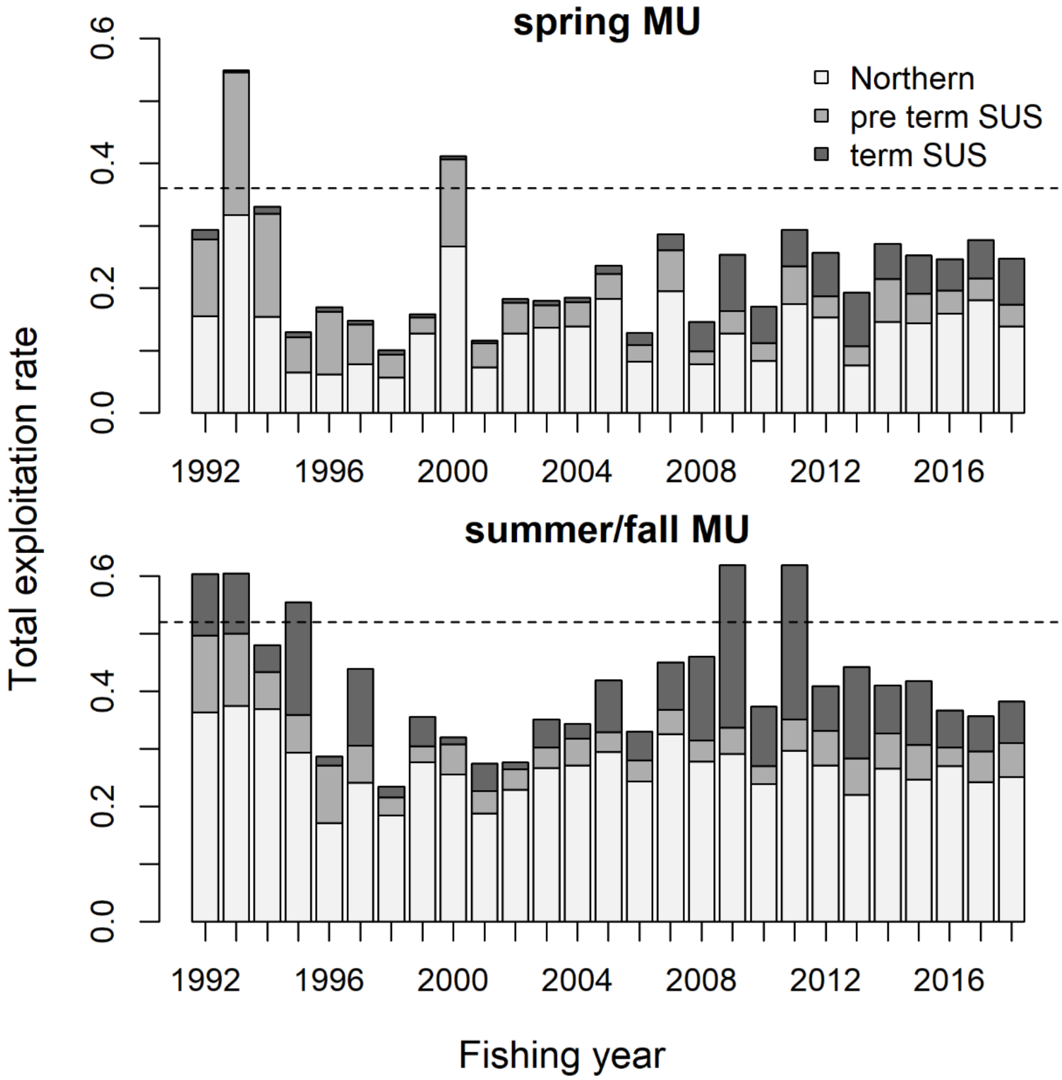

Figure 7. Annual exploitations rates apportioned by northern and southern fisheries for Skagit spring and summer/fall Chinook MU's estimated from post-season FRAM runs for management years 1992-2018. Horizontal dashed lines indicate the proposed exploitation rate ceilings of 37.5% for Skagit spring Chinook MU and 48% for Skagit summer/fall Chinook MU.

Management Objectives

We utilized results from the updated spawner-recruit and RER analysis (see Appendix A) to guide proposed updates to the abundance and harvest rate objectives for wild Skagit River summer/fall Chinook MU and Skagit River spring Chinook MU (Table 1). Each of the reference points were established according to the estimated variance in the spawner recruit parameters estimated for each MU including intrinsic productivity (α) and the magnitude of density dependence (β) which are required for estimating important management reference points such as the number of spawners required to produce maximum sustainable yield (Smsy).

Table 1. Harvest management thresholds and objectives for natural origin Skagit River Chinook MU's.

Management Unit	POI	CERC (SUS)	LAT	ERC	UMT
Skagit Spring	**470**	**10.7%[1]**	**1,024**	**36%**	**2,000**
Upper Sauk			130		
Upper Cascade			170		
Suiattle			170		
Skagit Summer/Fall	**4,800**	**17%/15%**	**7,844**	**52%**	**14,500**
Upper Skagit			2,200		
Sauk			400		
Lower Skagit			900		

1 95% of the average 2009 – 2015 Southern US exploitation rate

Point of instability (POI)

For the purposes of this plan, the point of instability is defined as spawning abundance below which there may be significant genetic or demographic risk to the management unit while accounting for uncertainty. Similar to how NOAA Fisheries derived critical escapement thresholds for the three Skagit Spring Chinook populations (NOAA Fisheries et al. 2018a, NOAA Fisheries et al. 2018b), we set the point of instability for each management unit equal to the lowest observed escapement over the time period analyzed that resulted in the management unit replacing itself (1986 - 2018 for Skagit Spring Chinook MU, and 1983 - 2018 for Skagit Summer/Fall Chinook MU). For Skagit River spring Chinook MU, the point of instability for management purposes is 470 spawners. For Skagit River summer/fall Chinook MU, the point of instability for management purposes is 4,800. These are conservative estimates of points of instability, as these units have fallen to levels this low in the past and rebuilt to higher abundance. If spawner abundance for either management unit is forecast below the POI during the pre-season harvest planning process, the following management actions will be implemented:

1) Limited terminal area treaty C&S fisheries may occur (Sauk, Swin, USIT);
2) Incidental impacts on the management unit during fisheries directed at other stocks and species will be reduced to levels below the CERC with the goal of escapement exceeding the POI. Fisheries reductions will be negotiated during the North of Falcon process;
3) Terminal area co-managers will develop a rebuilding plan (Chapter 5 RMP);
4) Terminal area co-managers will set an escapement goal for the year, which will be consistent with an exploitation rate ceiling lower than the CERC. Southern US fisheries will be reduced to meet that escapement goal.

The comanagers will plan fisheries during the North of Falcon process consistent with these management actions. The effects of these management actions will be carefully assessed post-season, to inform co-manager actions in subsequent pre-season planning under this RMP.

Low abundance threshold (LAT)

To ensure consistency with the Chinook chapter of the Pacific Salmon Treaty, the low abundance threshold (LAT) for each management unit is set equal to the median estimate of escapement that would produce the maximum sustained yield (Smsy). Under this management plan, this abundance is not considered a fixed target. Rather, based on how aggregate exploitation rate ceilings were derived (see appendix A), it is the intent of this plan that there is an 80% or more probability of exceeding the aggregate LAT over the course of a 25-year period. Observed aggregate escapement levels for each management unit have exceeded estimated aggregate Smsy escapement levels for 18 out of the last 25 years for Skagit summer/fall Chinook and 22 out of last 25 years for Skagit spring Chinook. For Skagit River spring Chinook salmon MU, the median estimate of Smsy is 1,024. For Skagit River summer/fall Chinook salmon MU, the median estimate of Smsy is 7,844. Population specific LAT's for Skagit River Chinook populations have been in place since the implementation of the 2004 Co-manager Puget Sound Chinook Resource Management Plan (PSTIT and WDFW, 2004), and represent estimated pre-season forecast escapement for which there is a 95% probability that the post-season escapement will exceed the point of instability, given management error and uncertainty in population specific estimates of the point of instability. Due to data limitations, the co-managers will continue to use these historical population specific LAT's for the duration of this plan (Table 1). We intend to fund and implement further research during the period of this plan to develop appropriate monitoring and analytical methods for reevaluating population specific LAT's. Implementation of total exploitation rate management (ERC) for either management unit requires that 1) projected aggregate escapement exceeds aggregate LAT for a management unit, and 2) projected escapement exceeds the population specific LAT's (Table 1) for all populations comprising each management unit. If either of these criteria aren't satisfied, then Southern U.S. fisheries will be constrained so as not to exceed the critical exploitation rate ceiling (CERC; see section below).

Critical exploitation rate ceiling (CERC)

The CERC's for each management unit were established to be consistent with the general obligation for Southern US fisheries identified in the Chinook chapter of the 2019 - 2028 Pacific Salmon Treaty. Specifically, as stated in the chapter, the general obligation for each U.S. stock encountered in U.S. ISBM fisheries will be set at 95% of the 2009 – 2015 average exploitation rate. For stocks with biologically based abundance thresholds (Smsy) where CTC concurrence has been reached, U.S. ISBM fisheries would be limited to the general obligation for stocks that aren't meeting biologically based management objectives. For the Skagit River spring Chinook MU, the CERC is set to 10.7% in U.S. ISBM fisheries which will be triggered when the aggregate abundance is projected to fall below 1,024 or any of the component populations are projected to fall below their low abundance threshold. For Skagit River summer/fall Chinook MU, the CERC is set at 15% during even years and 17% during odd years in U.S. ISBM fisheries, which will be triggered when the aggregate abundance is projected to fall below 7,844 or any of the component populations are projected to fall below their low abundance threshold. The 15%/17% SUS CERCs have been in place since the implementation of the 2004 Co-manager Puget Sound Chinook Resource Management Plan (PSTIT and WDFW, 2004), and represent estimated exploitation rates associated with implementing minimal SUS fisheries in even (non-pink) and odd (pink) return years as described in the 'Minimum Fisheries Regime' in that Plan. Analysis of changes to exploitation rate estimates associated with recent updates to FRAM (through version 7.1.1) show relatively small changes to estimates of SUS exploitation rates for the management unit, so the CERCs remain unchanged from previous plans. Therefore, fishery impacts in excess of the CERC will only be allowed for either management unit if a management unit and its component populations are projected to exceed their low abundance thresholds. The average northern exploitation rates for the Skagit springs and Skagit summer/fall MUs are 12.9% and 26.2%, respectively (2009 – 15; Round 7.1.1 FRAM validation runs). It is anticipated that, under the new obligations of the PST agreement, northern exploitation rates would decrease on average by 0.9% for Skagit springs and by 1.7% for Skagit summer/falls in low AI years. Therefore, if managing to the CERC, the average total exploitation rate for the Skagit spring MU in this plan is expected to range from 19.6% (low AI; 87.5% reduction to Southern BC ISBM fisheries) to 20.5% (no northern fishery changes). Similarly, if managing to the CERC, the average total exploitation rate for the Skagit summer/fall MU in this plan is anticipated to range from 39.2% (low AI; 87.5% reduction to Southern BC ISBM fisheries; even year) to 42.9% (no northern fishery changes; odd year).

Exploitation rate ceiling (ERC)

The resulting median RER values were 36% for the Skagit River spring Chinook MU and 52% for the Skagit River summer/fall Chinook MU. Fisheries will be planned to minimize the risk of exceeding the median exploitation rate ceilings for either management unit.

Upper management threshold (UMT)

The UMT is set to ensure a high probability of achieving Smsy while considering the significant level of uncertainty in the spawner recruit relationship for each management unit in the event of limited directed harvest. Specifically, it is the escapement level used to determine whether harvestable surplus exists. In years where escapements are projected to exceed the UMT for either management unit, limited directed harvest may occur on abundance in excess of the UMT and will not exceed the ERC of 36% for Skagit Spring Chinook or 52% for Skagit Summer/Fall Chinook. For Skagit River spring Chinook MU, the current UMT of 2,000 spawners is between the median and the upper 95% CI for Smsy. Therefore, the UMT for the Skagit River spring Chinook MU will remain at 2,000. For the Skagit River summer/fall Chinook MU, the current UMT of 14,500 spawners is between the median and upper 95% CI for Smsy. Therefore, the UMT for Skagit River summer/fall Chinook MU will remain at 14,500.

Data Gaps

Priorities for filling data gaps to improve understanding of the population dynamics of Skagit River Spring Chinook MU and Skagit River Summer/Fall Chinook Mu which are necessary for testing and refining harvest management objectives include:

- Develop and implement new monitoring and analytical methods to reevaluate management reference points for each of the 6 Skagit River Chinook populations including three spring Chinook populations (Upper Cascade, Suiattle, and Upper Sauk), and three Summer/Fall Chinook populations (Lower Sauk Summer, Upper Skagit Summer, and Lower Skagit Fall).

- Incorporate genetic stock identification (GSI) methods into long term juvenile monitoring programs within the Skagit River system including the mainstem smolt trap and delta/estuary/nearshore monitoring to generate annual estimates of freshwater productivity for each Skagit River Chinook management unit. If GSI methods allow, confirm current population delineation and estimate annual variability in freshwater productivity for each population. This will help to improve understanding of the population dynamics of each management unit, and the effects of specific recovery actions including restoration of freshwater, delta, and estuarine habitat on freshwater productivity and marine survival of Skagit Chinook management units.

- Estimate natural dispersal between potential populations to understand connectivity between populations. Dispersal will also improve GSI understanding and further inform if populations are demographically independent.

- Consistent release of coded-wire tagged indicator stocks representative of primary freshwater life history types exhibited by each Skagit Chinook management unit including sub-yearling and yearling freshwater life history types. There are fingerling indicator stock release groups for both Skagit Spring and Summer Chinook. The Skagit River Spring yearling indicator program has been discontinued due to budget constraints which may result in inaccurate assessments of total fishery impacts on Skagit Spring Chinook.

- Assess the effectiveness of each indicator stock program in accurately representing the life history pathways of each management unit. A simple approach would be to utilize long term catches from nearshore juvenile monitoring programs throughout Skagit Bay and the San Juan Islands paired with existing GSI data to determine whether there are differences in the spatial and temporal distribution between wild Skagit Chinook management units and their indicator stock conspecifics. A more complicated approach would be to select a suite of representative fisheries where Skagit Chinook indicator stocks are encountered and conduct GSI analyses on unmarked Chinook encountered in those fisheries.

- Continue assessing life stage component survivals across the stream to ocean continuum, including: continuing delta restoration Chinook life history assessments (see Beamer et al. 2005, Greene et al. 2015), begin assessing the loss of mainstem river habitat on Skagit River Chinook salmon survival, and improved understanding of high flow events on egg to fry incubation. This will require continued collaboration between State and Tribal co-managers and federal and academic partners.

Appendix A: Developing management reference points for Skagit River Spring and Summer/Fall Chinook management units.

Swinomish Indian Tribal Community, Upper Skagit Indian Tribe, and Sauk Suiattle Indian Tribe.

Introduction

The purpose of this study was to conduct a reassessment of stock recruit relationship for both Skagit Spring Chinook and summer/fall Chinook management units to help inform updates to abundance and harvest management reference points for each management unit. Specifically, we conducted a spawner recruit analysis for both Skagit Spring and Summer/Fall Chinook by fitting an integrated population model to time series of age, escapement, and total exploitation rate (derived using FRAM 7.1.1) including years 1992 – 2018. Because FRAM is the widely accepted model used to guide the preseason planning process and assess post season fisheries impacts on Puget Sound Chinook stocks, we utilized the updated estimates of the spawner recruit relationship for each management unit to evaluate a range in exploitation rate ceilings that would that would minimize the risk of overfishing each management unit. Finally, we utilized updated stock recruit relationship for each management unit to help inform changes if, if any, to the abundance based management reference points used to guide management of Skagit Chinook spring and summer/fall management units including the point of instability (POI), low abundance threshold (LAT), and the upper management threshold (UMT).

Methods

We used a Bayesian state-space model developed to estimate the population dynamics for each aggregate Skagit River Chinook management unit including Skagit Spring Chinook and Skagit River Summer/Fall Chinook (Scheuerell et al. *in review*). State-space models have been used to evaluate general monitoring schemes for estimating extinction risk (e.g., Dennis et al. 2010, See and Holmes 2015), and assessing the outcomes of conservation and harvest management options for salmon (e.g., Fleischman et al. 2013, Scheuerell et al. 2015). A state-space model comprises two major components: a process model describing the production of age-specific recruits, and observation models to account for errors in the estimates of spawning escapement and age composition. Similar to other traditional analyses of Pacific salmon population dynamics, this modeling framework assumes no consistent bias in estimates of adult spawners or age composition of returning adults. The primary inputs to the model are annual estimates of escapement, age composition, and harvest. Available data encompassed years 1992 – 2018 for each management unit.

We begin with our process model where we assume that the relationship between spawning adults and offspring born in year t that survive to adulthood (R_t) and spawning adults (S_t) follows a general Ricker model (Ricker 1954), such that

$$\ln(R_t) = \ln(S_t) + \alpha - \beta S_t + \varepsilon_t. \quad (1)$$

For this analysis, we assumed that time varying stochastic errors, ε_t, follow a Gaussian distribution with a mean zero and an unknown variance.

The estimated numbers of fish of age a returning in year t ($N_{a,t}$) is then product of the total number of brood-year recruits in year $t - a$ from Equation (1) and the proportion of mature fish from that brood year that returned to spawn at age a ($\pi_{a,t-a}$), such that

$$N_{a,t} = R_{t-a}\ \pi_{a,t-a}. \quad (4)$$

Adult Chinook from the Skagit River return predominantly as 2-6 year-olds, and therefore the vector of all age-specific return rates for brood year t is $\boldsymbol{\pi}_t = [\pi_2, \pi_3, \pi_4, \pi_5, \pi_6]_t$, which we modeled as a hierarchical random effect whereby $\boldsymbol{\pi}_t \sim \text{Dirichlet}(\boldsymbol{\eta}\,\tau)$. The mean vector $\boldsymbol{\eta}$ is also distributed as a Dirichlet; the precision parameter τ affects each of the elements in $\boldsymbol{\eta}$ such that large values of τ result in $\boldsymbol{\pi}_t$ very close to $\boldsymbol{\eta}$ and small values of τ lead to much more diffuse $\boldsymbol{\pi}_t$.

The spawner-recruit models above describe a process based on the true number of spawners, but our estimates of the numbers of spawning adults necessarily contain some sampling or observation errors due to incomplete censuses, pre-spawn mortality, etc. Therefore, we assumed that our estimates of escapement, the number of adult fish that "escape the fishery" and ultimately spawn (E_t), are log-normally distributed about the true number of spawners (S_t):

$$\ln(E_t) \sim \text{Normal}(\ln(S_t), \sigma_s). \quad (5)$$

We cannot estimate the observation variances for both the escapement and harvest. Therefore, we assume the harvest is recorded without error and calculate S_t as the product of the estimated total run size (N_t) and the proportion of fish escaping fisheries (1 - H_t)

$$S_t = N_t * (1 - H_t), \quad (6)$$

and N_t is the sum of $N_{a,t}$ from Equation (3) over all age classes. Here, H_t is the total calendar year exploitation rate derived from the most recent set of FRAM validation runs incorporating fishing years 1992 – 2018 (FRAM 7.1.1)

We obtained observations of the number of fish in each age class a in year t ($O_{a,t}$) from scale-pattern analyses of adults captured in both terminal area fisheries and recovered on spawning grounds. These data were assumed to arise from a multinomial process with order Y_t and proportion vector $\mathbf{d}_t$, where

$$\mathbf{O}_t \sim \text{Multinomial}(Y_t, \mathbf{d}_t). \quad (7)$$

The order of the multinomial is simply the sum of the observed numbers of fish across all ages returning in year t:

$$Y_t = \sum_{a=2}^{6} O_{t,a}\ . \quad (8)$$

The proportion vector $\mathbf{d}_t$ for the multinomial is based on the age-specific, model-derived estimates of adult returns in year t ($N_{a,t}$) such that

$$d_{a,t} = \frac{N_{a,t}}{\sum_{a=2}^{6} N_{a,t}}. \quad (8)$$

We used Bayesian inference to estimate all model parameters and the unobserved true numbers of spawners over time. We used the freely available **R** v3.2.3 software (R Development Core Team 2015) combined with the JAGS v4.2.0 software (Plummer 2003) to perform Gibbs sampling with 4 parallel chains of 2×10^5 iterations. Following a burn-in period of 1×10^5 iterations, we thinned each chain by keeping every 100th sample to eliminate any possible autocorrelation, which resulted in 4000 samples retained from the posterior distributions. We assessed convergence and diagnostic statistics via the CODA package in **R** (Plummer et al. 2006). Specifically, we used visual inspection of trace plots and density plots, and verified that Gelman and Rubin's (1992) potential scale reduction factor was less than 1.1, to ensure adequate chain mixing and parameter convergence. See supplementary information for details on model priors and instructions for replicating our analysis.

Additionally, we estimated two biological reference points of interest to harvest managers. Specifically, we calculated the number of spawners expected to produce the maximum sustainable yield (S_{MSY}) as

$$S_{MSY} = \frac{1-W(e^{1-\alpha})}{\beta}, \tag{2}$$

where parameters α and β come from equation 1, and $W(\cdot)$ is the Lambert function (see Scheuerell 2016). We also estimated the capacity of adult spawners (K) beyond which population productivity declines below replacement as

$$K = \frac{\log(\alpha)}{\beta}. \tag{3}$$

Results

We estimated considerable uncertainty in the spawner recruit relationship for both Skagit River Chinook management units (Figures 1-2; Table 1). For Skagit spring Chinook, the median of the intrinsic productivity was 2.48 offspring per spawner (95% credible interval = 1.46 – 6.2) and the median of the carrying capacity was 2,403 (95% credible interval = 1,534– 15,042). For Skagit summer/fall Chinook, the median of the intrinsic productivity was 4.09offspring per spawner (95% credible interval = 2.41 – 7.44) and the median of the carrying capacity was 19,881 (95% credible interval = 15,197– 36,387).

Except for a few years, model estimates of escapement for each management unit appeared to track annual observations well (Figures 3 – 4). Neither management unit exhibited a discernable long-term trend in productivity for the period included in the study (Figures 5 – 6).

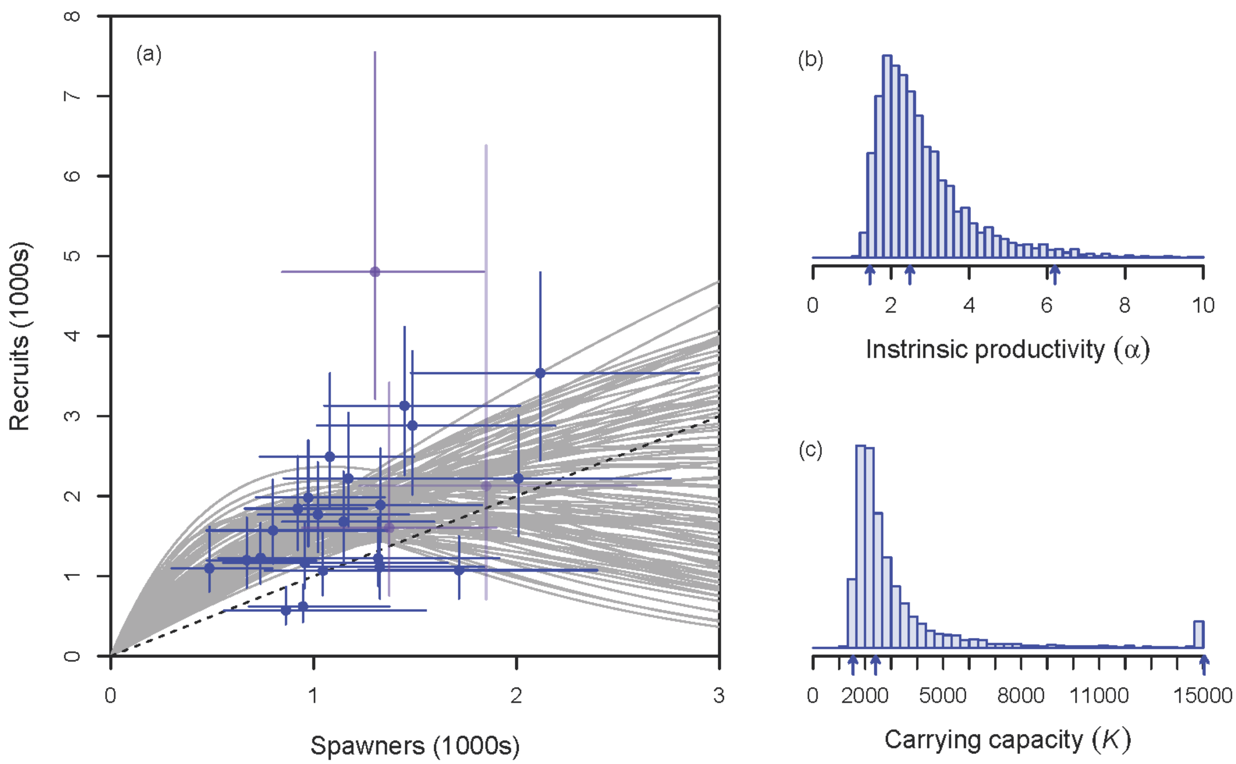

Figure 1. Skagit Spring Chinook spawner recruit relationship. Relationship between the number of spawning adults and their subsequent surviving offspring (recruits) (a). Points are medians of the posterior estimates; error bars indicate the 95% credible intervals. Blue points are for estimates with complete broods; purple points are for the most recent years with incomplete broods. Gray lines show100 random paired samples from the posterior distribution of the spawner recruit parameters. Note that for plotting purposes only in (b) and (c), the density in the largest bin for each parameter contains counts for all values greater than or equal to it. Vertical arrows under the x-axes in (b) and (c) indicate the 2.5th, 50th, and 97.5th percentiles.

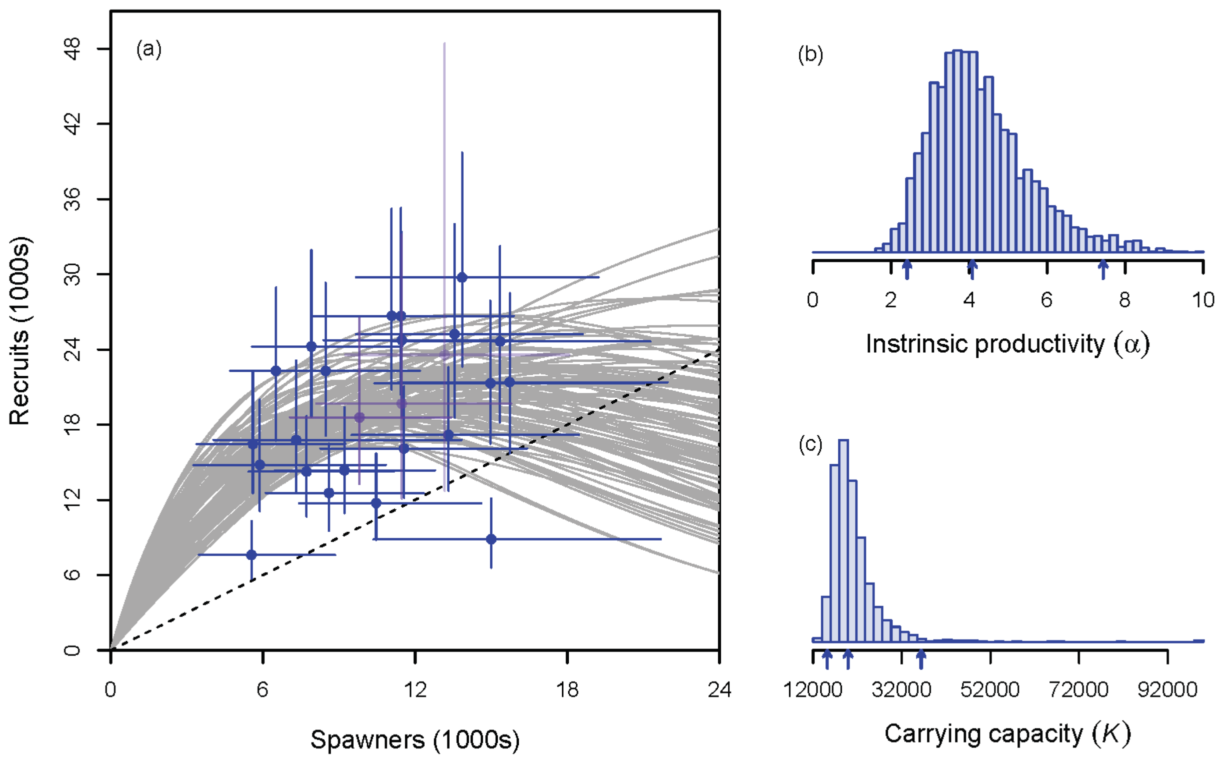

Figure 2. Skagit Summer/Fall Chinook spawner recruit relationship. Relationship between the number of spawning adults and their subsequent surviving offspring (recruits) (a). Points are medians of the posterior estimates; error bars indicate the 95% credible intervals. Blue points are for estimates with complete broods; purple points are for the most recent years with incomplete broods. Gray lines show100 random paired samples from the posterior distribution of the spawner recruit parameters. Note that for plotting purposes only in (b) and (c), the density in the largest bin for each parameter contains counts for all values greater than or equal to it. Vertical arrows under the x-axes in (b) and (c) indicate the 2.5th, 50th, and 97.5th percentiles.

Table 1. Summary of the posterior distributions for relevant management reference points derived from the Ricker spawner recruit relationship estimated for Skagit River Spring and Summer/Fall Chinook.

	Spring	Summer/Fall
Intrinsic productivity (α)	2.48 (1.46 – 6.2)	4.09 (2.41 - 7.44
Carrying capacity (K)	2,403, (1,534– 15,042)	19,881 (15,197 - 36,387)
Spawners at MSY (Smsy)	1,024 (576 – 6,987)	7,844(5,542– 15,508)

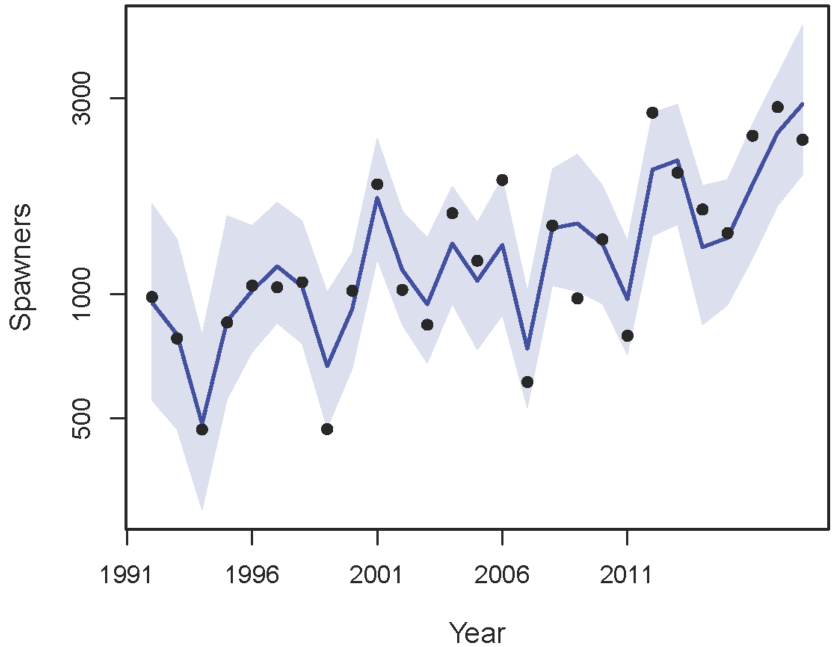

Figure 3. Time series of the estimated escapement for Skagit Spring Chinook. The observed data are the points; the solid line is the median estimate and the shaded region represents the 95% credible interval.

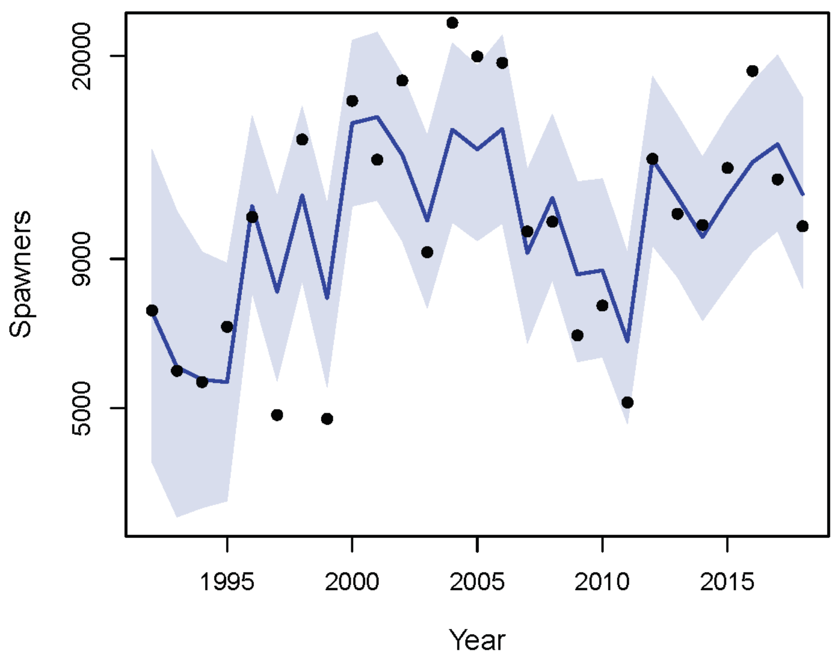

Figure 4. Time series of the estimated escapement for Skagit Summer/Fall Chinook. The observed data are the points; the solid line is the median estimate and the shaded region represents the 95% credible interval.

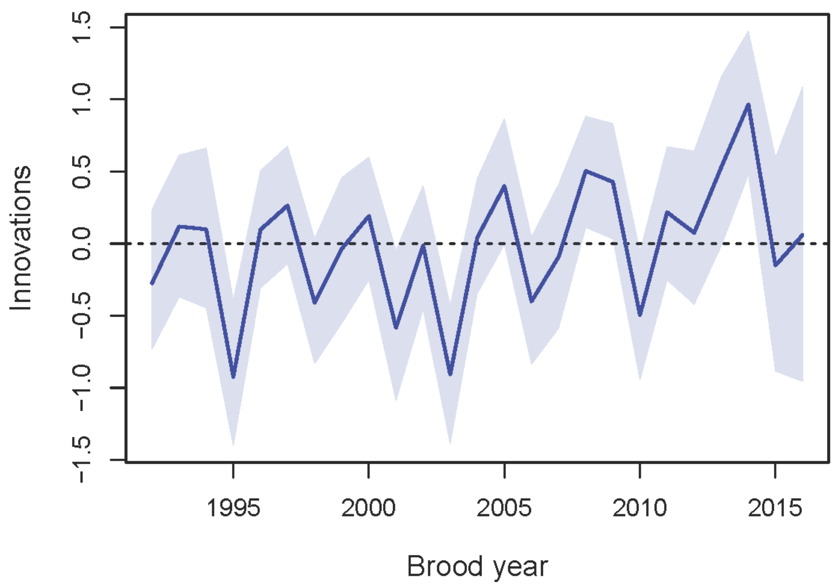

Figure 5. Time series of the estimated productivity for Skagit Spring Chinook for the period 1992 - 2016. The solid line is the median estimate and the shaded region represents the 95% credible interval.

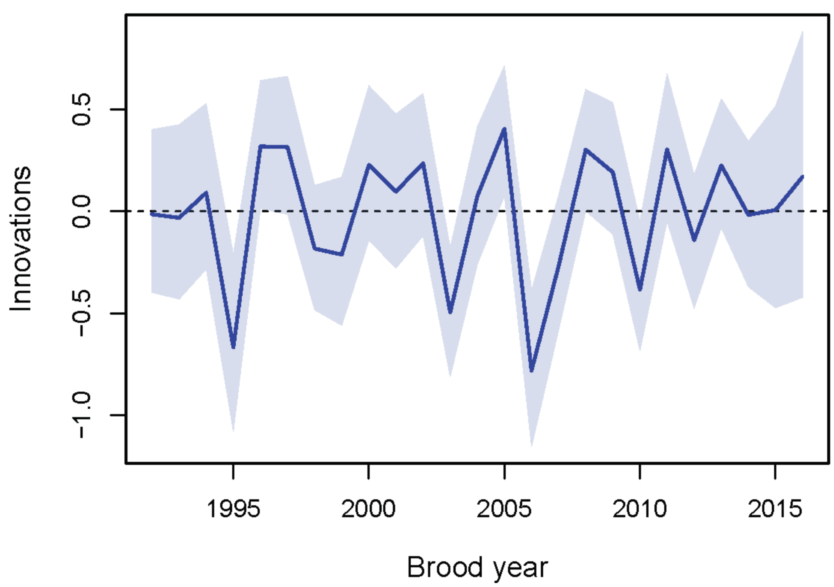

Figure 6. Time series of the estimated productivity for Skagit Summer/Fall Chinook for the period 1992 - 2016. The solid line is the median estimate and the shaded region represents the 95% credible interval.

RER derivation

We utilized a basic simulation framework to evaluate the probability of meeting or exceeding specific abundance-based management reference points derived from the spawner recruit analysis for each management unit over a user specified period of time across a range in target exploitation rates (0% – 80%). In practice, the RER is defined as the maximum allowable exploitation rate resulting in simulated escapements that: (1) are less than the lower escapement threshold at most 5% of the time relative to a baseline exploitation rate of 0%, and (2a) are greater than the upper escapement threshold for years 23-25 at least 80% of the time, or, less than the upper escapement threshold at most 10% of the time relative to a baseline exploitation rate of 0%. For the purposes of deriving the RER for each management unit, we identified an upper and lower escapement threshold for each management to evaluate each of the three criteria. Specifically, we specified the lower threshold for each management unit the lowest observed aggregate escapement and the upper threshold as the median of the posterior distribution of MSY escapement (Table 4). For Skagit Spring Chinook, we set the lower escapement threshold at 470, and the upper threshold at 1,024. For Skagit Summer/ Fall Chinook, we set the lower escapement threshold at 4,800 and the upper threshold at 7,844.

The simulation framework utilizes the posterior distributions of the spawner recruit parameters for each management unit to simulate brood year recruitment, fishing year AEQ run size, and escapement across a 25- year period. For each target exploitation rate evaluated, 1,000 25- year simulations were conducted using a paired sample of the spawner recruit parameters that was randomly drawn from the posterior distribution. Each 25- year simulation was seeded with the last 5 years of observed escapements for each management unit. To incorporate uncertainty in the spawner recruit relationship into derivation of the RER, we utilized 100 random paired samples of the spawner recruit parameters for each target exploitation rate evaluated to generate a credible interval of the RER for each management unit. Because there was little to evidence for autocorrelated error’s in the spawner recruit relationship for both Skagit Spring Chinook and Summer/Fall Chinook management unit, annual residual variation was modeled following a gaussian distribution with a mean of 0 and the posterior median of the residual standard deviation estimated for each management unit. To estimate age specific recruitment for each brood year, we applied the average maturation schedule estimated for each management unit. We did not include management error in the simulations because recent updates to the FRAM base period preclude a direct comparison of the updated post-season runs which were conducted using the new base period with pre-season model runs that utilized the old base period.

The posterior median RER for Skagit Spring Chinook was 36% with a 95% credible interval of 7% - 54% (Figures 7-8). For Skagit Summer/Fall Chinook, the posterior median RER was 52% with a 95% credible interval of 39% - 62% (Figures 9-10).

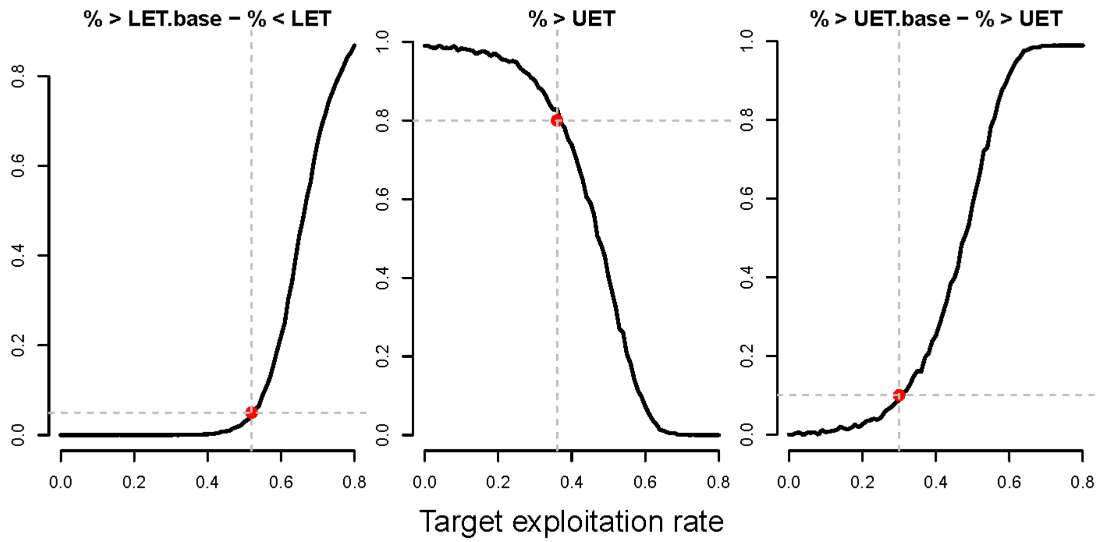

Figure 7. The probability of each of the three RER criteria being met across a range in target exploitation rates for Skagit River Spring Chinook.

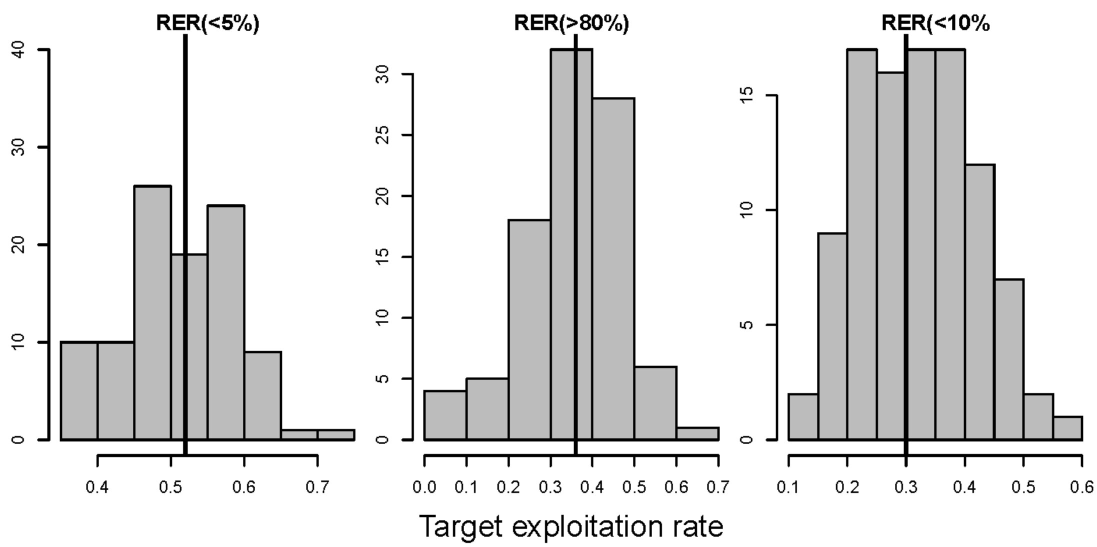

Figure 8. RER range for Skagit Spring Chinook. Histograms show the frequency in which each of the three RER criterion were met for each target exploitation rate. The thick black line shows the median exploitation rate that satisfies each RER criteria.

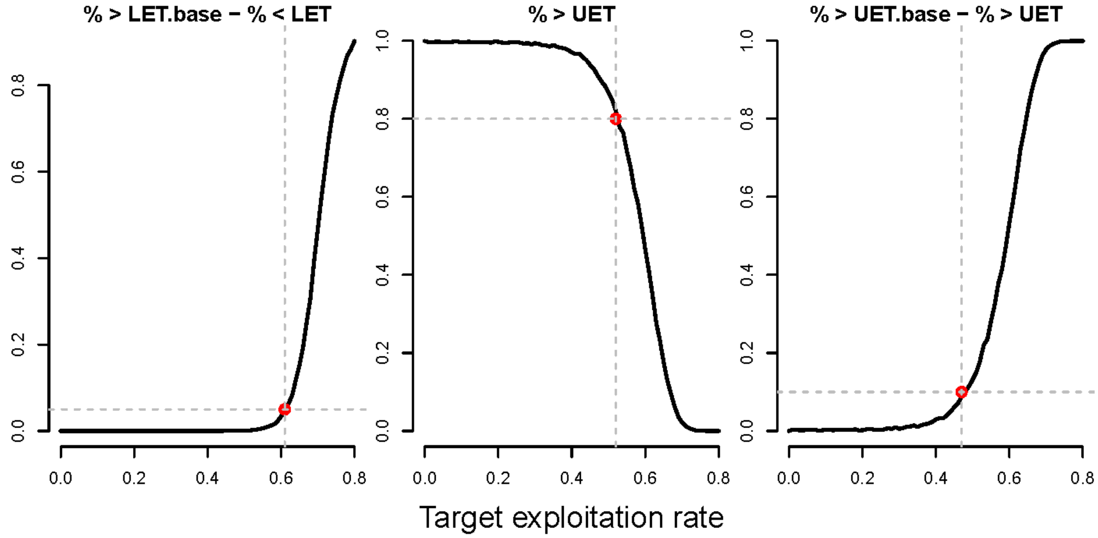

Figure 9. The probability of each of the three RER criteria being met across a range in target exploitation rates for Skagit River Summer/Fall Chinook

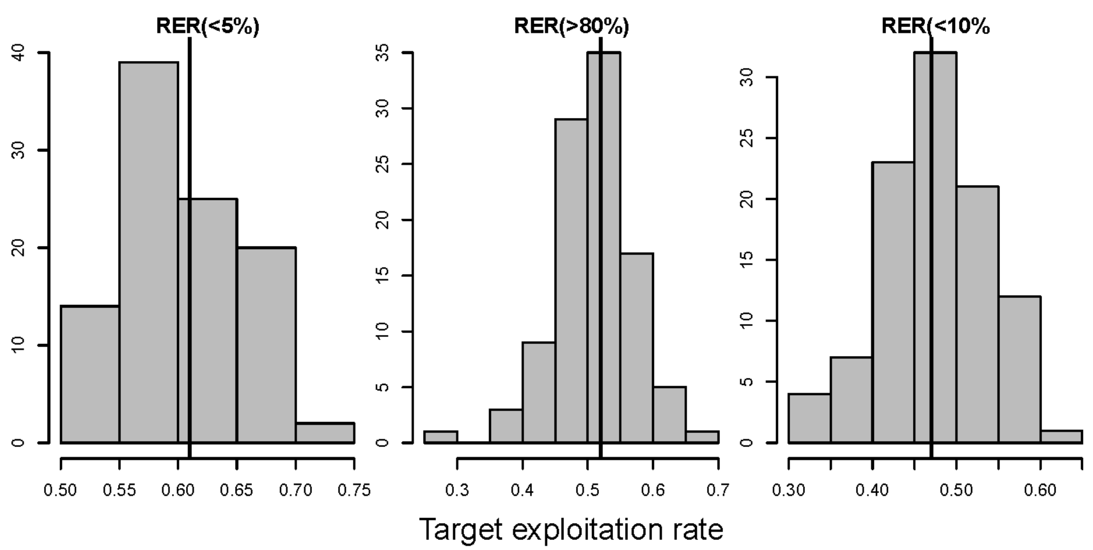

Figure 10. RER range for Skagit Summer/Fall Chinook. Histograms show the frequency in which each of the three RER criterion were met for each target exploitation rate. The thick black line shows the median exploitation rate that satisfies each RER criteria.

Stillaguamish River Management Unit Status Profile

Component Populations

Stillaguamish summer Chinook
Stillaguamish fall Chinook

Geographic Description

There are two populations of Chinook in the Stillaguamish River, distinguished by differences in migration, spawn timing, and genetic characteristics. Among 22 Puget Sound Chinook salmon populations, the Stillaguamish summer run is most closely associated by Bayesian lineage clustering of microsatellite DNA genotypes with spring and summer running populations from the Skagit and Skykomish Rivers. In the same analysis, the Stillaguamish fall run is associated with North/Central Puget Sound fall populations (Skagit and Snoqualmie) more closely than to the cluster of fall populations associated with South Puget Sound hatchery releases (Ruckelshaus et al. 2006). Summer and fall populations in the Stillaguamish remain significantly differentiated from each other (Fst =0.88%, p≈0.0, permutation test after Excoffier et al. 1992, A.P. Spidle, NWIFC, unpublished data 2019).

Previous assignments of independent populations of Chinook in Puget Sound had classified the two populations in the Stillaguamish based on geographic separation (Ruckelshaus et al 2006). However, recent analysis proved such geographic separation is not apparent, although the populations, a summer-run population and a fall-run population, are still genetically distinct despite some overlap in spawning distribution. The summer run population spawns in the North Fork (NF), South Fork (SF), as well as the larger tributaries. The majority of the summer adults primarily spawn in the NF between river mile (RM) 14.3 and 30.0; locations known as Deer Creek and Swede Heaven Bridge. Boulder River and Squire Creek are the two most important spawning tributaries, although summer Chinook adults are also found in French, Deer, and Grant creeks; particularly when flows are high. The fall run population also spawns throughout the watershed, with genetic analysis indicating a substantial presence of fall run in the NF and comprising a higher percentage of the limited spawner abundance in the SF and tributaries (Small et al. 2016).

Life History Traits

Summer run adults are seen in the NF from late May, increasing through July and August. Spawning activity begins in late August, peaking usually around mid-September, and continues through late-October.
The timing of river entry of fall adults is not known, although it presumed to be later than that of the summers. Spawning typically takes place from mid-September through early November, with peak activity in early to mid-October. Genetic sampling indicates that fall adults account for an estimated 15% of total adult Chinook NF spawners, and an estimated 50% of the Chinook spawning in the SF, which equates to on average 20% of the total management unit (MU) escapement.

Table 1. **Age Structure Estimates for Stillaguamish MU* from Stillaguamish Chinook scales and coded wire tag recoveries, 2007-2020.**

AGE	Avg. %
2	5.9%
3	35.5%
4	50.6%
5	7.8%
6	0.2%

*Samples includes both summer and fall populations
Source: Stillaguamish Tribe Fisheries Database (Konoski)

The scale analysis also indicated that 98.6% of the Chinook adult returns during this period were sub-yearling juvenile outmigrants, which is supported by data collected on the Stillaguamish smolt screw trap during same period (Stillaguamish Tribe, unpublished data).

Hatchery Recovery Programs

A small (releases of approximately 33,000 - 100,000 sub-yearlings per year) hatchery program using native summer-timed broodstock was initiated with the 1980-1983 brood years and restarted with the 1986 brood year as an integrated recovery program for the summer-timed Chinook stock. Initial spawning and rearing occurs at the Harvey Creek Hatchery (NF tributary, RM 15.3), followed by acclimation and release from Whitehorse Ponds Facility (NF tributary, RM 28). The proposed annual fish release is 220,000 fingerlings, with releases coded wire-tagged (CWT) and adipose fin clipped. The program serves two purposes – to protect the critically depleted population from extinction, and as a Pacific Salmon Commission (PSC) indicator stock to monitor exploitation rates in Canadian and U.S. ISBM fisheries as required by Annex IV, Chapter 3, Attachment I of the Pacific Salmon Treaty (PST). To assess compliance with PST fishery obligations, clipping of the adipose fin of each juvenile fish is essential so that it can be identified in fisheries, primarily in Canada, that rely upon this clip to identify tagged fish. During 2011-2020, broodstock spawning ranged from 105 to 125 summer adults, averaging around a 1:1 ratio of natural origin (NOR 45%) to hatchery origin (HOR 55%) adults (Stillaguamish Tribe, unpublished data). Genetic testing has confirmed that program fish are indistinguishable from the wild-origin fish (Eldridge and Killebrew 2008).

An integrated fall-timed Chinook recovery program has operated since 2007, predominately as a Captive Brood program. Attempts to collect adult broodstock were insufficient to meet the release objective, therefore since 2009; outmigrant juveniles are being collected in river for captive rearing. Each juvenile is genetically sampled upon capture and is genotyped to verify its stock assignment. Juveniles assigned fall are retained for the recovery program, with summer assigned juveniles released back into the river system. Adults genotypically assigned as fall-timed population that are incidentally acquired through collection of summer-timed population broodstock seining activities are also utilized in the fall spawner program. All hatchery activities for fall stock from spawning to release occur at Brenner Creek Hatchery (SF RM 31). The proposed annual fish release is 200,000 fingerlings, with releases coded wire-tagged and adipose fin clipped. First captive brood spawning began in 2013, with current levels of release above

100,000. This program also attempts to alleviate the extinction risk, as well as to develop a PSC indicator stock for this critically depleted population.

Population Status

The status of both Stillaguamish summer and fall Chinook populations is critical given that in recent years, productivity for the MU consistently falls below 1.0. Only one year out of the last ten exceeded productivity of 1.0 (2006-2015), averaging 0.77 (NOAA Stillaguamish RER Analysis GMR 2018, A&P Table). Stillaguamish MU NOR escapement estimates (EE) also show a sustained decline in abundance since 1988, with a negative trend also observed in the total natural spawner escapement, but starting later in the 1990s (Figure 1). The hatchery recovery programs provide critical protection to stabilize and maintain the natural spawning abundance, for populations suffering from extremely poor habitat production and survival.

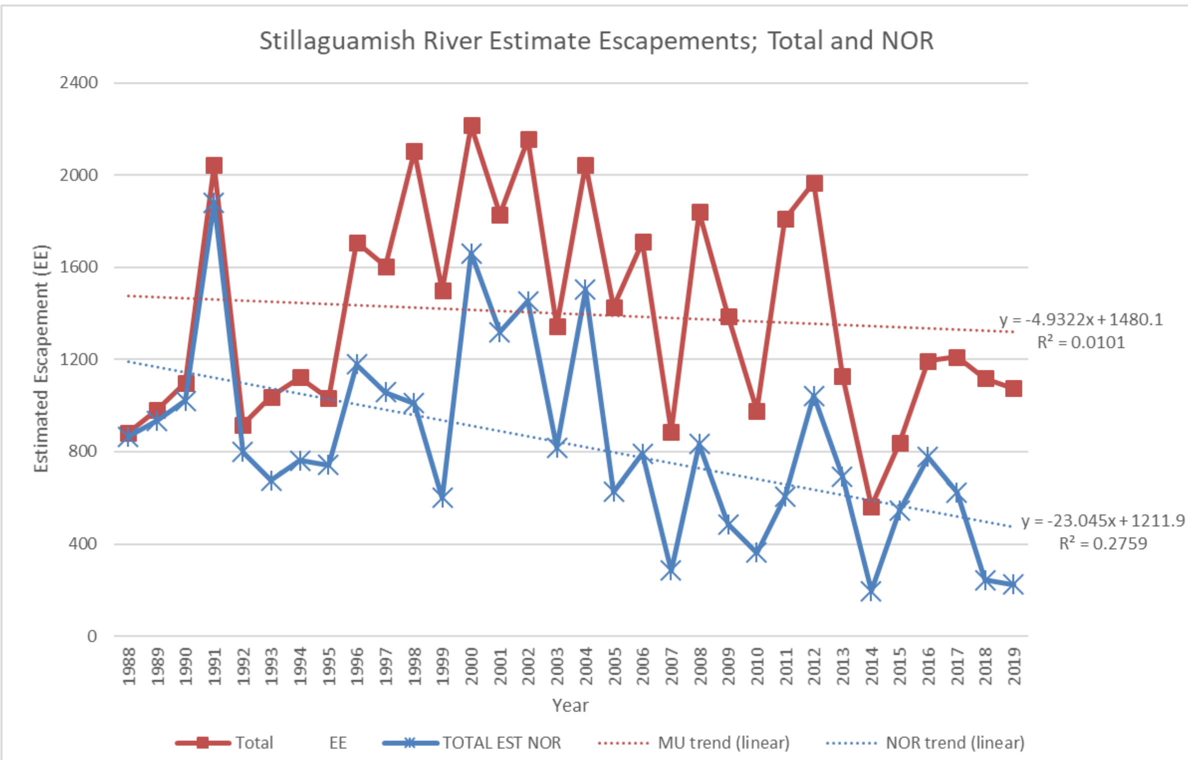

Figure 1. Stillaguamish Management Unit annual GMR adjusted estimated escapements for years 1988 through 2019.

Escapement estimates were derived from a combination of foot and aerial spawning ground redd surveys, expanded by a factor of 2.5 fish per redd. These estimates are likely biased low during years of poor survey conditions (i.e. reduced river visibility due to turbidity, high flow events, and increased carcass predation). Recently, a Genetic Mark Recapture (GMR) study was completed to calibrate (expand) historic and future estimates of escapement based on spawning ground surveys, to account for loss of survey data from poor survey conditions (Table 2).   Over the last ten years (2010 – 2019), the number of total adult spawners, in watershed has ranged from 563 to 1966 (Table 2). To estimate NORs, HOR spawners are derived from CWT and adipose fin clipped fish recoveries and subtracted from total escapement. During the same period, NOR spawners ranged from 197 to 1043 NORs and HOR spawners ranged from 295 to 1205. In 2018 and 2019 estimated NOR spawners were below NOAA's defined Critical Escapement Threshold of 400.

Table 2. GMR adjusted spawning escapement estimates (EE) of Stillaguamish summer and fall-timed Chinook, 1988-2019. Total EE including both populations, from spawning ground (SGS EE) and broodstock data. Total estimated NOR and HOR compiled from SGS EE and broodstock data based on CWT recoveries and ad clip status sampling. The Co-Managers continue to collect tissue samples for genetic analysis and are developing methods to estimate escapement by population. Source: WDFW & Stillaguamish Tribe Fisheries Data (Verhey, Konoski)

YEAR	Total EE	SGS EE	BROOD STOCK	TOTAL EST NOR	TOTAL EST HOR
1988	883	867	16	865	18
1989	983	956	27	934	49
1990	1098	1032	66	1021	77
1991	2044	1948	96	1880	163
1992	917	764	153	798	119
1993	1039	870	169	675	364
1994	1122	941	181	763	359
1995	1033	944	89	744	289
1996	1708	1563	145	1178	529
1997	1604	1447	157	1058	545
1998	2103	1959	144	1009	1094
1999	1501	1370	131	601	901
2000	2215	2092	123	1661	554
2001	1829	1702	127	1319	510
2002	2156	2017	139	1453	703
2003	1346	1224	122	818	527
2004	2045	1908	137	1502	543
2005	1427	1287	140	625	802
2006	1709	1576	133	792	917
2007	887	721	166	284	603
2008	1840	1711	129	833	1007
2009	1388	1239	149	486	902
2010	977	837	140	362	615
2011	1810	1637	173	605	1205
2012	1966	1787	179	1043	923
2013	1129	997	132	693	436
2014	563	419	144	197	366
2015	838	709	129	543	295
2016	1194	1053	141	778	416

2017	1212	1070	142	624	588
2018	1118	966	152	243	875
2019	1075	944	131	224	851

Habitat Limiting Factors
Current Phase of Recovery: Preservation, Current Habitat Condition: Low

Degraded spawning and rearing habitat currently limit the productivity of Chinook in the Stillaguamish River system (i.e. the continuing degradation of water quantity and quality, floodplain and riparian processes, marine shoreline and habitat conditions (SOW 2016)). From 2005 to 2013, permit exempt wells increased by 24 percent (from 666 to 827), riparian forest remains unchanged at 23 percent coverage and is less than a third of that expected for primary functioning condition in the Salmon Recovery Plan, while net addition of bank armoring resulted in 0.22 miles (0.21 miles removed and 0.43 miles added). These habitat-limiting factors affect abundance and productivity. Lower water flows during the late summer due to drier summers and exacerbated by exempt wells reduce rearing habitat and juvenile survival. Lack of floodplain connectivity, exacerbated by bank armoring, confines peak winter flows caused by long-term increases in rainfall (but proportionally less snowfall) to the active channel, scouring redds and mobilizing bed material needed during future spawning events, leading to significant egg/alevin losses during the incubation period and available spawning habitat. Figure 3 shows egg-to migrant survival decreasing linearly as daily peak freshwater flows increase during the incubation period, noticeably when flows exceed 18,000 cubic feet per second (cfs). Naturally spawning Chinook have also faced higher frequency of peak flows in recent years (50% probability compared to the historic 10%). As habitat deteriorates in diversity and complexity, it is unable to support the Chinook early life stages.

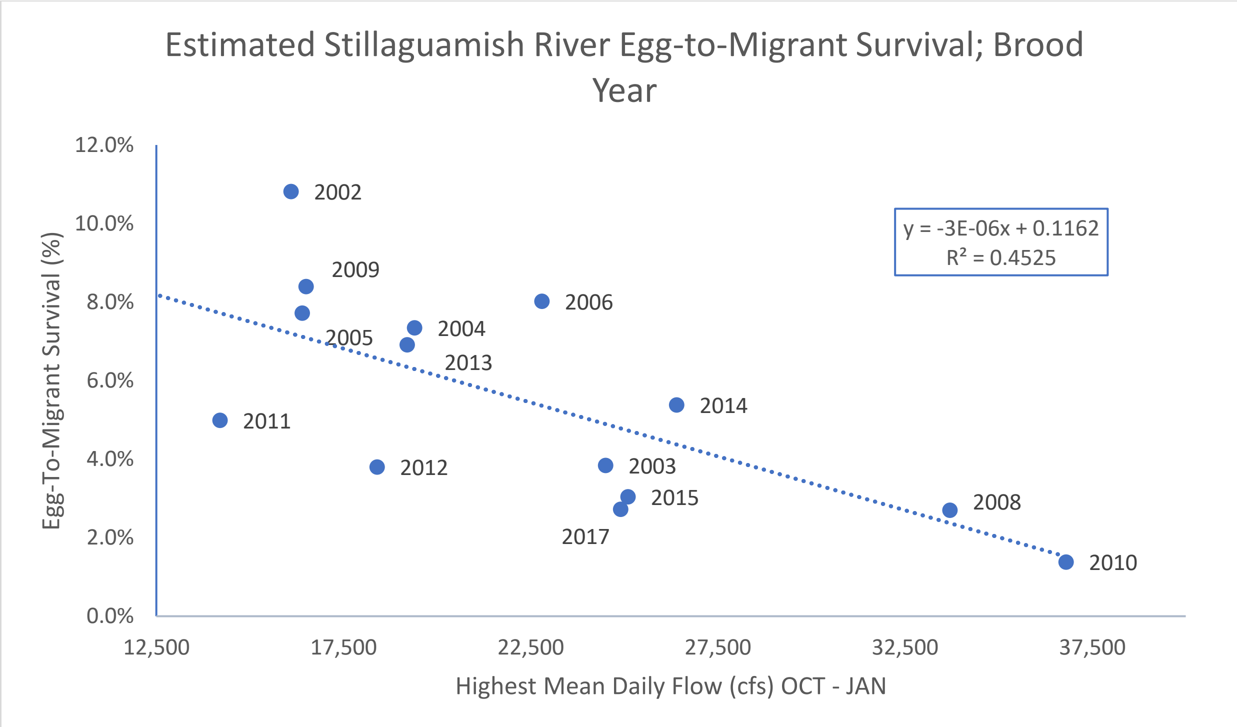

Figure 3. Stillaguamish Natural Origin (NOR) Egg-to-Migrant survival vs Stillaguamish River Peak Flows. Egg-to-Migrant survival calculated by dividing estimated Chinook smolt outmigration by number of females that spawned naturally in the given brood year and their associated fecundity.

Harvest distribution

Post-season analyses from the Fishery Regulation Assessment Model (FRAM) are utilized to infer harvest distribution among fisheries of Stillaguamish Chinook. From 2007 through 2018, Northern fisheries in Alaska (AK) and British Columbia (BC) accounted for an average of 65.2% of total marked and 75.0% of total unmarked harvest mortalities. Southern United States (SUS) Troll and Net combined accounted for 9.2% of marked and 9.9% of unmarked, and SUS Sport accounting for 25.5% of marked and 15.1% of unmarked mortalities (Table 4).

Table 4. Average distribution of total fishery-related mortality Stillaguamish River Chinook, 2007-2018. (FRAM_Rnd 7.1.1 post-season reports).

Fishery Related Mortality - Distribution by Mark					
	AK	**BC**	**SUS Troll**	**SUS Net**	**SUS Sport**
MARKED	4.3%	60.9%	4.5%	4.7%	25.5%
UNMARKED	4.8%	70.2%	4.9%	5.0%	15.1%

Table 5. Annual exploitation rates of Stillaguamish Chinook, 2007-2018. (FRAM_Rnd 7.1.1 post-season reports).

FRAM Post Season ERs on Stillaguamish Chinook, by Fishery & Mark													
MARKED	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**AVG ER**
AK	3.0%	2.2%	1.1%	2.2%	1.5%	1.4%	1.1%	1.9%	1.1%	1.6%	1.2%	1.0%	**1.6%**
BC	29.0%	27.0%	15.5%	20.0%	21.2%	26.1%	18.8%	24.2%	21.8%	19.0%	28.4%	18.6%	**22.5%**
SUS Troll	2.5%	1.5%	0.9%	2.3%	1.3%	2.0%	3.4%	3.4%	0.9%	1.2%	0.7%	1.3%	**1.8%**
SUS Net	1.0%	1.6%	1.0%	1.1%	3.1%	1.1%	2.1%	1.6%	1.2%	1.0%	1.4%	2.9%	**1.6%**
SUS Sport	9.9%	9.8%	4.5%	7.1%	8.6%	7.6%	11.0%	16.6%	11.1%	7.4%	12.4%	12.3%	**9.8%**
TOTAL ER	45.3%	42.0%	23.0%	32.7%	35.7%	38.2%	36.3%	47.7%	36.1%	30.3%	44.1%	36.1%	**37.3%**
SUS ER	13.3%	12.9%	6.4%	10.5%	13.0%	10.7%	16.4%	21.7%	13.1%	9.7%	14.5%	16.6%	**13.2%**
UNMARKED	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**AVG ER**
AK	2.9%	1.7%	2.0%	1.7%	1.7%	1.5%	0.8%	1.9%	1.7%	1.7%	0.8%	0.7%	**1.6%**
BC	28.2%	20.4%	26.4%	15.6%	23.1%	27.0%	13.6%	23.9%	33.8%	19.8%	18.6%	12.5%	**21.9%**
SUS Troll	2.4%	1.1%	1.8%	1.7%	1.4%	2.1%	2.2%	3.3%	1.5%	1.3%	0.4%	0.8%	**1.7%**
SUS Net	1.1%	1.6%	1.0%	1.2%	3.2%	1.2%	2.3%	1.9%	1.3%	1.1%	1.6%	3.3%	**1.7%**
SUS Sport	6.2%	4.2%	5.0%	2.8%	5.4%	4.0%	3.9%	7.9%	10.3%	2.9%	3.6%	3.0%	**4.9%**
TOTAL ER	40.8%	28.9%	36.3%	22.9%	34.8%	35.6%	22.7%	38.8%	48.5%	26.8%	25.0%	20.3%	**31.8%**
SUS ER	9.7%	6.8%	7.9%	5.7%	10.0%	7.2%	8.4%	13.1%	13.0%	5.3%	5.6%	7.1%	**8.3%**

Exploitation rate trends

Post-season FRAM validation total exploitation rate (ER) estimates during 2007 – 2018 ranged from 23.0% to 47.7% on marked, 20.3% to 48.5% on unmarked; SUS ERs ranged from 6.4% to 21.7% on marked and 5.3% to 13.1% on unmarked (Table 5). In most recent years until 2018, harvest in SUS fisheries has been managed under the 2010 RMP critical ER ceiling (15% SUS ER) for NOR (unmarked) Stillaguamish adults and were below that level in all years, although exceeded or met the total ER ceiling of 25% in 7 of the recent 10 years. HOR (marked) Stillaguamish adults did not have defined management objectives. In 2018, Co-Managers adopted a total ER ceiling of 22% on NOR, with SUS ER ceilings adjusted based on forecasted terminal run size, including an SUS ER ceiling on HOR adults. In the only post year available, 2018, the total NOR ER was 20.3%, with SUS ER estimated at 7.1% NOR and 16.7% HOR which met the Co-Managers objectives.

Table 6. Total MU and SUS exploitation rates (ER) for Stillaguamish Chinook, by mark status (FRAM_Rnd 7.1.1 post-season Reports).

	MARKED		UNMARKED	
YEAR	TOTAL	SUS	TOTAL	SUS
2007	45.3%	13.3%	40.8%	9.7%
2008	42.0%	12.9%	28.9%	6.8%
2009	23.0%	6.4%	36.3%	7.9%
2010	32.7%	10.5%	22.9%	5.7%
2011	35.7%	13.0%	34.8%	10.0%
2012	38.2%	10.7%	35.6%	7.2%
2013	36.3%	16.4%	22.7%	8.4%
2014	47.7%	21.7%	38.8%	13.1%
2015	36.1%	13.1%	48.5%	13.0%
2016	30.3%	9.7%	26.8%	5.3%
2017	44.1%	14.5%	25.0%	5.6%
2018	36.1%	16.6%	20.3%	7.1%
AVG:	37.3%	13.2%	31.8%	8.3%

Management Thresholds & Actions

The sampling methodology and compilation of data for Stillaguamish Chinook are currently based on total watershed spawning escapement, including both HOR and NOR spawners, with continued development of genetic testing to assess summer and fall population composition. As an integrated recovery program, HOR adults are vital to the spawning abundance and natural outmigrant production. Genetic studies have shown that the broodstock production strategy has resulted in limited to no difference in genetic characteristic of natural and hatchery origin Chinook during the length of the integrated recovery program (Eldridge and Killebrew 2008). Migration timing and CWT data have also shown that HOR spawners may be considered representative of the timing and life history of NOR spawners. When genetic-based population escapement estimates become available, management thresholds and objective will be reviewed accordingly.

Forecasted terminal run size as projected by the Environmental Model Predicting Adult Returns (EMPAR) will be compared to thresholds to determine what management actions will be triggered. Co-Managers commit to reviewing any proposed changes to the EMPAR, for the duration of the plan, with agreement of changes completed by December for use in January for pre-season forecasting.

The management thresholds for Stillaguamish Chinook will change from the 2010 Harvest Plan to address the long-term decline in natural-origin spawners and the importance of the hatchery conservation programs in maintaining the populations. Two abundance thresholds are specified, a lower abundance threshold and an upper management threshold, both of which are expressed in terms of natural spawners.

An SUS ER ceiling will also be implemented for HOR Stillaguamish Chinook below the upper management threshold (UMT). This will ensure that the integrated recovery hatchery program provides a continued demographic boost to the natural origin population, thus reducing the likelihood of an even greater conservation concern in the subsequent cycle. The details of the management strategy are discussed in the following sections.

Lower Abundance Threshold

NOAA defines the critical escapement threshold (CET) as a boundary below which uncertainties about population dynamics increase substantially. For Stillaguamish Chinook, NOAA assessed the CET using two criteria. First was by finding the lowest spawner abundance resulting in positive recruit, determining 400 natural spawners for the Stillaguamish MU. The escapement year referenced for the determination was 1984, prior to implementation of the summer integrated hatchery program and not included in the GMR adjustment of historic estimates. NOAA secondarily applied the viable spawning population (VSP) criteria of 200 per spawning aggregate (equaling 400 for aggregate of summer- and fall-timed Stillaguamish Chinook) since it is slightly larger than the value of 374 produced by the first method. Given the Co-Managers acknowledge the referenced escapement estimate for CET determination pre-dates the time series of GMR adjusted estimates, it is not comparable to recent escapement estimates. Using the GMR adjusted EE, an estimated natural spawning escapement (combined NOR and HOR) of 764 is the lowest escapement with positive recruitment (brood year 1992; Table 7). However, in the last 10 years, only one year had positive recruitment (BY 2009) with an estimated natural spawning escapement of 1239. From 2010-2019, NORs averaged 44.4% (range of 20.9% - 65.2%) of the estimated escapement (EE). Multiplying the average NOR percentage (44.4%) and the 900 spawners as defined by the threshold (LAT) results in 400 NOR spawners, which is equal to the CET. Based on this, a LAT for a forecasted terminal run size of <900 will be implemented for the MU.
Should the forecasted TRS fall below the LAT, additional measures will be taken to attempt to prevent further declines in abundance. The Co-Managers will discuss development of a rebuilding plan and implement actions that will contribute to increasing abundance back to levels above the LAT. As potential actions are considered, the Co-Managers will consider factors including whether the MU has been at abundance below the lower bound for two or more consecutive years, or for consecutive brood returns. To the extent practicable, actions will be taken to prevent escapement from falling below the previous low value observed. Due to the limited productivity of existing habitat, it is unlikely that fishery actions alone can rebuild abundance of Stillaguamish Chinook to higher levels. The Co-Managers are committed to habitat protection and recovery in accordance with the Stillaguamish Watershed Salmon Recovery Plan.

When the forecasted TRS is less than the LAT, the Parties will meet as necessary prior to the March meeting of the Pacific Fishery Management Council to develop an agreed framework for consideration of management actions during the North of Falcon (pre-season) process. The following guidelines will be used in the development of the framework:

- Given the extraordinarily poor status of the projected return of Stillaguamish Chinook salmon, the SUS exploitation rate limits (NOR: 9%, HOR: 14%) will be on the table for necessary discussion regarding fishery actions to address conservation needs.
- The Co-Managers shall review projected exploitation rates in Canadian and Southeast Alaska fisheries (northern fisheries) and consider requesting that the U.S. Commissioners

invoke paragraph 7(f) (i.e., "extraordinary circumstances") of Chapter 3 of the Pacific Salmon Treaty.

- Further conservation actions will be necessary if the recent available post-season estimated terminal run size was less than the LAT.

Table 7. Recruits per Spawner estimates, Completed Brood Years 1990 – 2009 (GMR EE).

Year	Total Recruits	Total Spawners	R/S
1990	1192	1032	1.15
1991	1168	1948	0.60
1992	1372	764	1.80
1993	1361	870	1.56
1994	1209	941	1.29
1995	1031	944	1.09
1996	1651	1563	1.06
1997	1754	1447	1.21
1998	1631	1959	0.83
1999	1443	1370	1.05
2000	1500	2092	0.72
2001	1253	1702	0.74
2002	994	2017	0.49
2003	527	1224	0.43
2004	855	1908	0.45
2005	1078	1287	0.84
2006	619	1576	0.39
2007	637	721	0.88
2008	1244	1711	0.73
2009	1275	1239	1.03
2010	501	837	0.60
2011	570	1637	0.35
2012	1253	1787	0.70
2013	900	997	0.90

Source: Stillaguamish Tribe Fisheries Data, K. Konoski

Upper Management Threshold

NOAA analyses estimated a maximum sustainable yield (MSY) escapement of 484 and 520 natural origin spawners using two different spawner recruit models. NOAA determined the rebuilding escapement threshold (RET) to be 502 for the total MU, as an average between the two models. NOAA states in the derivation documentation that "the RETs are well below the escapement levels associated with recovery, but achieving these goals under current conditions is a necessary step to eventual recovery, under which habitat and other conditions are expected to become more favorable".

Recognizing the uncertainty in the estimates of MSY, and that MSY is a variable that can approach zero, the Co-Managers agree to implement strong SUS conservation measures with an upper management threshold (UMT) defined as greater than a forecasted TRS of 1,500 . This implements an UMT above the recent estimate of positive recruitment (1239 spawners, 2009), with the Co-Manager's objective to exceed the UMT annually for the duration of the plan. The UMT was calculated as double the recent 20-year average of NOR escapement (754) from 2000-2019, rounded to the nearest hundred to account for HOR adult returns in total natural spawners. If the forecasted TRS is below UMT, total impacts to NORs in SUS fisheries will be constrained to an ER ceiling of 9% (Table 8). This is expected to provide sufficient escapement to the spawning grounds considering recent exploitation rates in northern fisheries. This management action was developed after Co-Manager discussion and reviewing multiple sources of information and was chosen to ensure that fisheries do not impede the recovery of Stillaguamish Chinook salmon and work towards achieving the management objective of exceeding 1500 spawners annually for Stillaguamish Chinook salmon. The FRAM is considered a tool by which Co-Managers use in planning and evaluating fisheries, and updates to the FRAM base period or any mechanisms of the model do not automatically promote a change in management objectives. Currently genetic analysis (2007-2017) suggests that of the total watershed escapement, 20% is estimated to be of the fall Chinook population. Assuming the same proportion for the UMT of 1500 spawners, including both hatchery and natural-origin, 300 on average are fall-run Chinook. The Co-Managers are committed to developing genetic population based estimates to further understand the implications in harvest management.

If the forecasted TRS is above UMT, total impacts to NORs in SUS fisheries will be constrained to an ER ceiling of 13%.

HOR management

Impacts to HOR (marked) Stillaguamish Chinook in SUS fisheries will be limited to an ER ceiling of 14% when forecasted TRS is below the UMT threshold levels. If forecasted TRS is above UMT, HOR impacts will not be constrained.

Table 8. Management Thresholds and applicable actions.

Forecasted TRS	SUS NOR ER	SUS HOR ER
Below LAT <900	Guidelines implemented	
Above LAT 900-1500	9%	14%
Above UMT >1500	13%	No Constraint

Management Precision and Accountability

The Co-Managers recognize the importance of continuously improving our fishery management and ensuring effective implementation of our management actions to conserve and rebuild Stillaguamish Chinook salmon. The following measures will be implemented to advance the achievements of these objectives.

Sampling protocols:

The following fishery sampling will occur for any fishery estimated in final agreed-to pre-season FRAM run associated with the List of Agreed Fisheries (LOAF) to have equal to or greater than 0.1 adult equivalent (AEQ) mortality of impact on Stillaguamish Chinook.

- Puget Sound marine non-recreational fisheries will be monitored in a manner consistent with the Puget Sound Commercial Sampling Plan, Pacific Salmon Treaty sampling recommendations, and other documented sampling protocols.
- Puget Sound marine recreational fisheries (including fisheries directed at coho, pink, or chum salmon) with a pre-season predicted impact, both incidental and directed, on Stillaguamish Chinook salmon will be monitored using a full Murthy estimator. The full Murthy sample design is defined as including two sample days from Monday through Thursday and sampling on Friday, Saturday, and Sunday.
- The Non-Treaty freshwater recreational fishery in the Stillaguamish River will be monitored extensively for full catch accounting of Chinook impacts for fisheries directed at coho salmon, pink salmon, or gamefish. The design of the creel survey will include sampling during 3 weekdays and 2 weekend days per week of monitoring during the period when Chinook salmon are present in the river, unless otherwise agreed by the Co-Managers.
- The freshwater Treaty fisheries in the Stillaguamish River extensively for full catch accounting of fishery impacts, both incidental and directed, on Stillaguamish Chinook salmon. Sampling will occur weekly, with collection of bio-data, genetic samples, and CWTs at a minimum rate of 20% of total Chinook mortalities.

Conservation Payback:

The Co-Managers recognize that in-season management is essential to ensure that exploitation rate limits, catch quotas, and encounter estimates are not exceeded and that fisheries are implemented consistent with the management strategy developed during the annual North of Falcon pre-season planning process and described in the List of Agreed Fisheries. If through management imprecision, more than the planned mortality of Stillaguamish Chinook salmon occurs in Puget Sound and Stillaguamish River fisheries, impacts will be reduced in the following year by an equal amount to ensure that management imprecision does not impede the rebuilding of Stillaguamish Chinook salmon. For example, the allocated share of the SUS adult equivalent impacts (50%) in the subsequent year will be reduced by the amount of the conservation payback. No negative Conservation Payback shall occur.

A Co-Manager technical team will develop and utilize a management tool that comparatively assesses pre-season estimates to in-season estimates to determine if estimated mortality of Stillaguamish Chinook salmon was exceeded during the fishery. The methodology for this management tool will incorporate the following concepts:

- The ratio of in-season to pre-season estimates of impacts (across all FRAM stocks) of the four existing categories (legal-sized marked, sublegal-sized marked, legal-sized unmarked, sublegal-sized unmarked) are used to estimate the in-season adjusted estimates of Stillaguamish Chinook mortalities.
- The in-season to pre-season ratio adjusted estimates of Stillaguamish Chinook adult equivalent mortalities (in all four monitoring categories) are summed by non-Treaty and for Treaty fisheries occurring in Puget Sound and the Stillaguamish River.
- The Conservation Paybacks are computed separately for Treaty and non-Treaty fisheries and are the difference between the pre-season and in-season adjusted estimates.

This management tool and the methods employed will be documented and implemented as developed and agreed to by the Co-Managers.

Pacific Salmon Treaty

FRAM estimates that in recent years (2014-2018) on average over ~70% of total fishery mortality of natural origin Stillaguamish Chinook salmon occurs in northern fisheries under the jurisdiction of the Pacific Salmon Treaty (PST) in Canada and Alaska. In order to accrue the benefits anticipated with the 2019 update to the Chinook Chapter, it is essential that management entities fully implement the new obligations. These obligations are to be assessed and any necessary remedial measures implemented as required by the PST. To ensure equitable sharing of the conservation burden, and to advance rebuilding of Stillaguamish Chinook salmon populations, the Co-Managers will strongly advocate to NMFS, and to the U.S. representatives to the Pacific Salmon Commission, to seek further reductions in exploitation rates on Stillaguamish Chinook salmon in northern fisheries.

Data gaps

Priorities for filling data gaps to improve understanding of stock / recruit functions or population dynamics simulations necessary to testing and refining harvest management objectives include:

- Development of an unbiased estimate of the total MU spawning escapement for the summer and fall run populations, regardless of geographic region.

- Development of an unbiased estimate of HOR and NOR composition within the summer and fall run populations.

- Development of exploitation rate indicators (CWT or DNA) for the Stillaguamish fall population to determine if fishery impacts on this population are being correctly modeled in FRAM.

Snohomish River Management Unit Status Profile

Component Populations

There are two populations of Chinook salmon in the Snohomish basin; Skykomish summer Chinook and Snoqualmie fall Chinook, as delineated by the Puget Sound Technical Recovery Team (Ruckelshaus et al. 2006).

Summer/Fall Chinook Management Unit

Skykomish
Snoqualmie

Spawning Distribution

Skykomish summer Chinook spawn in the mainstem of the Skykomish River and its tributaries including the Wallace and Sultan Rivers, Bridal Veil Creek, the South Fork of the Skykomish River between RM 49.6 and RM 51.1 and above Sunset Falls (fish have been transported into the upper south fork above the falls since 1958), and in the North Fork of the Skykomish River up to Bear Creek Falls (RM 13.1). Relative to spawning distribution in the 1950's, a much larger proportion of summer Chinook currently spawn higher in the drainage, between Sultan and the forks of the Skykomish. In the most recent years, a greater proportion of spawners are being produced from the Sultan basin, attributed to increased flows of cold water drawn from Spada Lake by PUD. Fish spawning in the Snohomish mainstem and in the Pilchuck River are currently considered to be part of the Skykomish population. Snoqualmie fall Chinook spawn in the mainstem Snoqualmie River and its tributaries, including the Tolt and Raging Rivers, and Tokul Creek.

Life History Traits

Summer Chinook enter freshwater mostly from May through July, with a second upstream migration mode from mid-September though early October in response to stream flow. They spawn primarily early September through mid-October in the Skykomish basin whereas fall Chinook spawn from mid-September through early November annually in the Snoqualmie basin. Peak spawn timing in Bridal Veil Creek occurs during the second week of October (i.e. slightly later than the peak for fish spawning in the mainstem of the Skykomish). Natural spawning in the Wallace River occurs throughout September and October.

The age composition of returning Chinook to both systems is very similar, with 2-, 3-, 4- and 5-year-old fish comprising, on average, 3.0, 16.3, 62.4, and 18.3% in the Skykomish, and 3.1, 19.5, 61.6, and 15.8 in the Snoqualmie (years 2006-2018).

Analysis of scales and otoliths collected from natural-origin adult returns indicates that on average (years 2006-2018), 16% to 20% of the Snoqualmie and Skykomish populations, respectively, exhibit a yearling smolt life history, relatively high proportions for such a rare trait among the listed populations comprising the Puget Sound Chinook salmon ESU. Restoration and protection of rearing habitats that support both yearling and subyearling smolt life history traits is vitally important to the recovery of these stocks.

Management Unit / Stock Status (Abundance and Productivity)

While escapement for the Snoqualmie and Skykomish Chinook populations and the basin total showed a positive trend from the mid-1990s through 2004, in more recent years, overall escapements (natural and hatchery) have exhibited a downward trend (Figure 1), particularly from 2004 through 2011. In those years, the total natural (HOR and NOR) spawning escapement for the Skykomish population declined from 7,614 to 1,180, and from 2,988 to 700 in the Snoqualmie population, due to an abrupt decline in productivity observed for broods 2003-04, followed by a particularly low productivity in 2006 (Figure 1.2). Natural escapement improved moderately from 2012 through 2017. In 2019 however, the Snohomish Chinook experienced its record low natural escapement.

Natural-origin spawners also declined recently (years 2006-2011), from an average of 4,642 to 881 in the Skykomish and from 2,161 to 479 in the Snoqualmie (Table 1), resulting from a declining productivity trend for brood years 2000-2008 (Figure 1.2). Escapements from 2012 through 2017 increased moderately, but decreased to a record low in 2019 of only 1,012 fish (569 in the Skykomish and 443 in the Snoqualmie).

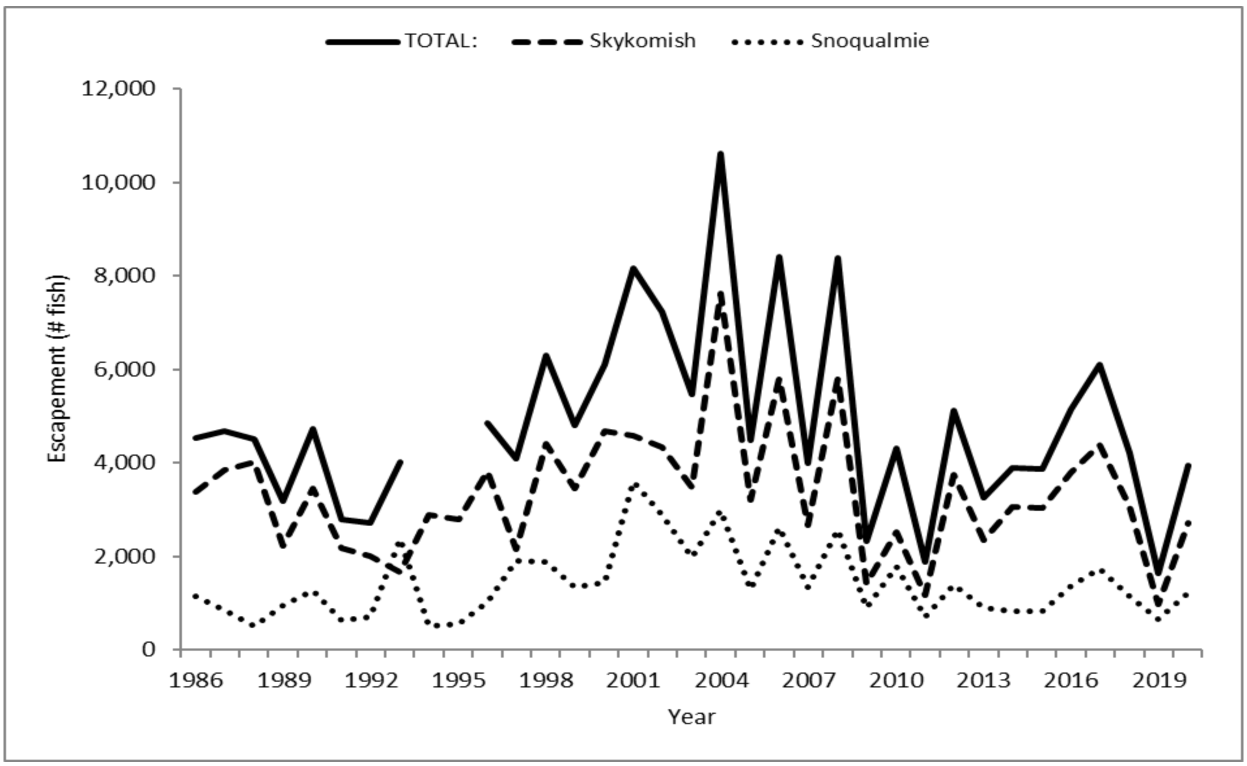

Figure 1. Total (HOR and NOR) Snohomish Chinook salmon escapements for the two listed populations and the basin total (1986-2020). No estimates are available for the Snoqualmie population in 1994 and 1995.

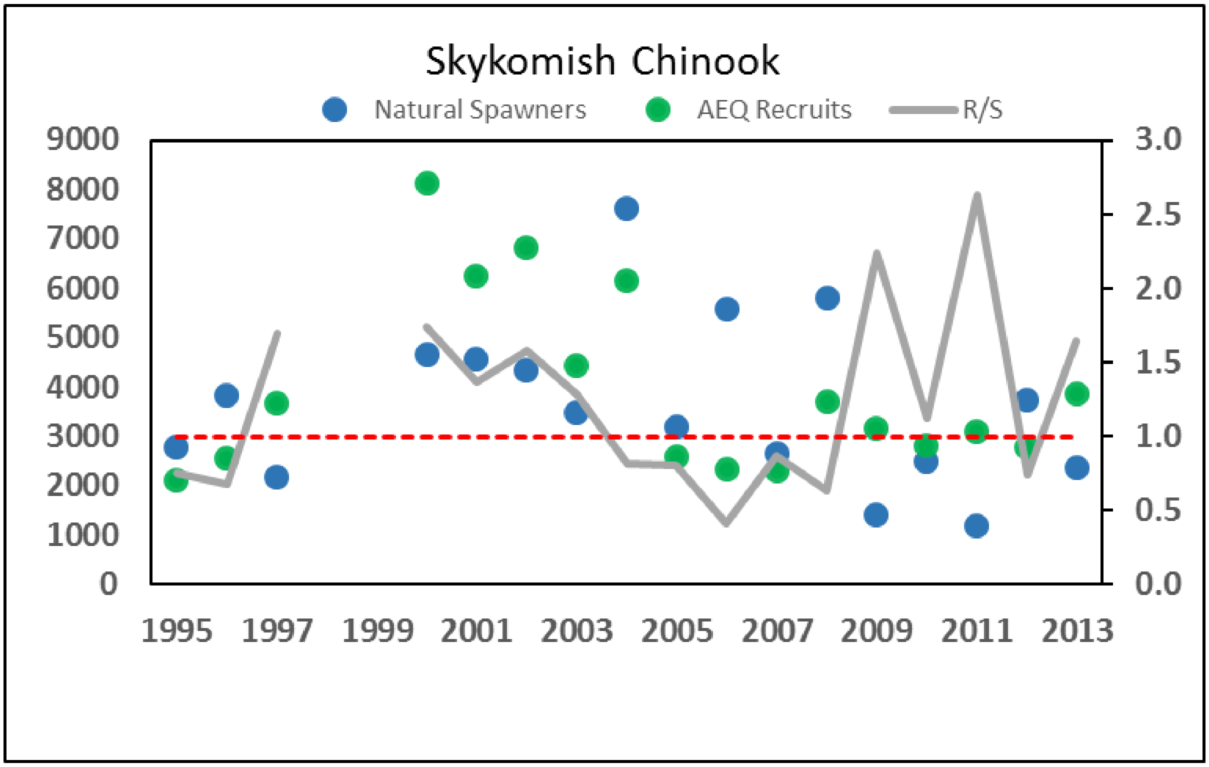

Figure 1.2. Natural Skykomish Chinook spawners (blue circles) and their progeny (AEQ recruits, green circles). Grey line shows the R/S by brood year, with the replacement line in red (Rawson and Crewson, 2017(a); Alexandersdottir and Crewson 2019).

Naturally-produced Chinook comprise a majority of natural spawners, averaging 71.3% for the basin in recent years (2006-2020, Figure 2), which is up from an average of 61.1% from 1997 to 2001 (M. Crewson Tulalip Tribes and Pete Verhey WDFW, unpublished data). Although the average hatchery-origin fraction of the Skykomish Chinook population since 2006 (31.1%) is still lower than during 1997-2001 (49.9%), it increased during 2014-2016 to an average of 43.8%. The hatchery-origin fraction of the naturally spawning Snoqualmie Chinook population during 2005-2020 has averaged 22.7%, which is slightly higher than the 1997-2001 average of 15.6% (Table 1).

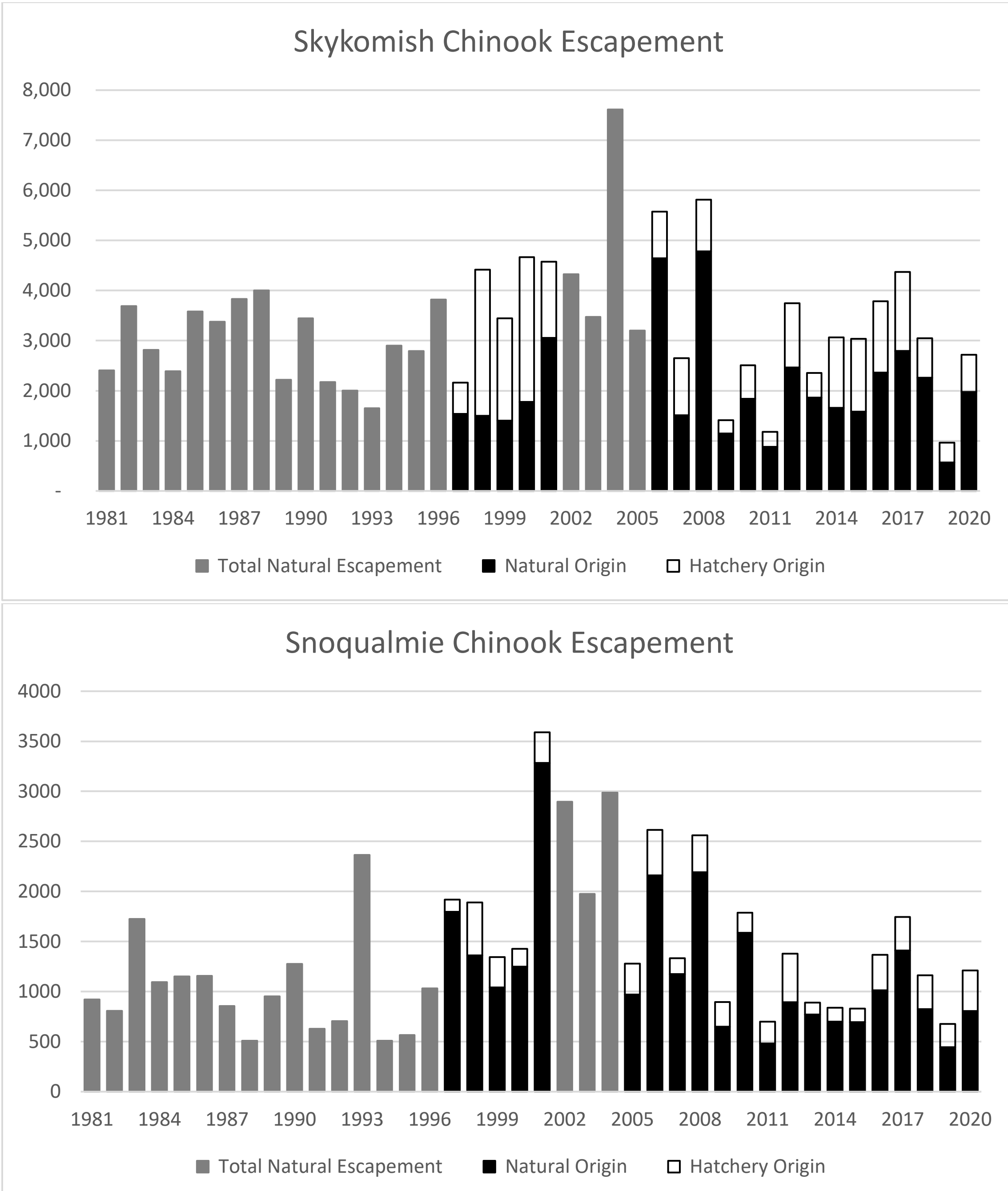

Figure 2. Skykomish (top) and Snoqualmie (bottom) Chinook natural escapements (1981-2020). Since 1997, natural and hatchery origin fractions have been estimated, except during the period 2002-2005 in the Skykomish.

Table 1. Chinook salmon escapement to the Snohomish basin, 2003-2020. HOS/NOS fractions were not estimated from 2002 to 2004 due to unmarked Chinook releases from Wallace River Hatchery, nor in 2005 for the Skykomish when HOS/NOS sampling was not conducted in the Wallace River.

	Skykomish		Snoqualmie	
Year	HOR + NOR	NOR	HOR + NOR	NOR
2003	3,472		1,975	
2004	7,614		2,988	
2005	3,201		1,279	968
2006	5,573	4,642	2,615	2,161
2007	2,648	1,510	1,334	1,174
2008	5,813	4,780	2,560	2,190
2009	1,414	1,146	895	649
2010	2,511	1,836	1,788	1,585
2011	1,180	881	700	479
2012	3,745	2,462	1,379	891
2013	2,355	1,860	889	770
2014	3,063	1,654	838	698
2015	3,034	1,585	829	694
2016	3,785	2,363	1,368	1,013
2017	4,374	2,790	1,745	1,409
2018	3,048	2,259	1,162	823
2019	966	569	676	443
2020	2,721	1,975	1,211	804

Hatchery Production

Local, natural-origin Chinook salmon have been incorporated into the broodstock at Wallace River Hatchery since brood-year 2005. The current production objective for on-station releases from Wallace River Hatchery is 1,000,000[17] subyearling and 500,000 yearling smolts. Wallace River Hatchery production is double index-tagged (DIT) and is designated as a PSC indicator stock, so 200,000 subyearlings (0+) are coded-wire tagged and adipose fin-clipped while an additional 200,000 subyearlings are coded wire-tagged only (no clip) annually to monitor harvest rates, catch distribution and the effects of selective fisheries. In addition, currently about 1/3 of the Wallace yearling (1+) juvenile production is also clipped and coded wire-tagged, with the remainder being clipped only. This tagging program has become increasingly relevant as the yearling life-history component also comprises a large fraction of the adult returns to Wallace River Hatchery as well as of both listed natural-origin Chinook populations.

Production at the Bernie Kai-Kai Gobin Salmon Hatchery ("Tulalip Hatchery") adjacent to Tulalip Bay also utilizes native summer Chinook broodstock[1]. The production goal is 2.4 million subyearling Chinook smolts released annually, which are also double index-tagged but

[17] Beginning with the 2018 brood year, additional sub-yearling production was initiated to benefit Southern Resident Killer Whales.

with 100,000 AD + CWT and 100,000 CWT only. Since this program switched to summer Chinook broodstock in brood year 2004, straying rates[18] declined substantially, as well as the contribution rate[19] of Tulalip Hatchery Chinook to the spawning grounds. In the earlier portion of that period, the reduction in the contribution rate was also partially due to smaller Tulalip Chinook run sizes, although in 2014-2015, when Tulalip Hatchery-origin Chinook returns were been stronger, the contribution rates to the Snohomish basin still remained under 3% (Figure 3).

Released Chinook at both hatcheries are thermally otolith-marked, which enables accurate monitoring of the presence of these stocks on spawning grounds in the Snohomish system. Adipose fin clips also help to generically identify hatchery-origin fish externally (non-lethally) on the spawning grounds along with wanding of coded-wire tagged fish, but marking alone is not useful for identifying the brood year or hatchery of origin needed to evaluate program effects on listed fish.

This overall reduction in hatchery-origin Chinook contribution rates by ~50% in recent years in the Skykomish population is thought to be related, in part, to declining survival rates (and resultant straying rates) of the regional hatchery stocks. However, it is also hypothesized that the recent reductions in hatchery straying may be mainly related to the change in broodstocks from exogenous fall, to local summer stocks. While the overall hatchery fraction of the Snoqualmie Chinook escapement has remained relatively similar in recent years, with only a moderate increase, the Tulalip Hatchery contribution rate dropped substantially (~10-fold) in recent years (2005-2013). While the cause(s) for reduced hatchery-origin Chinook contribution rates to the Skykomish population and basin total remains unclear, a major reduction in the contribution rate of Tulalip Hatchery Chinook to the Snoqualmie population has occurred in recent years coinciding with the change in broodstock at Tulalip Hatchery.

The proportion of Tulalip Hatchery Chinook (THC) among natural spawners has dropped significantly since the conversion to summer Chinook, particularly in the Snoqualmie (Figure 3). It averaged 12.2% and 2.2% for the Snoqualmie and Skykomish populations, respectively, before the program converted 100% to summers in 2004 (affecting returns after 2006), but averaged only 2.9% and 0.7% for the Snoqualmie and Skykomish populations, respectively, since summer production began to return in 2007. The THC straying rates to the Snohomish basin decreased from an average of 3.8% (1997-2001) to 2.0% (2007-2016). The majority of hatchery-origin Chinook on the spawning grounds in the Skykomish basin are from Wallace River Hatchery, which is expected because it is located in the Skykomish system. While insufficient numbers of recoveries are available to accurately determine the contribution rates of other hatchery-origin Chinook stocks on the Snohomish spawning grounds, based on CWT recoveries, it appears that while the Tulalip Hatchery fraction dropped, hatchery contributions from a number of other out-of-basin stocks have moderately increased in recent years.

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[18] The number of Tulalip Hatchery origin fish that stray to the target naturally-spawning population divided by the Tulalip Hatchery origin terminal run size.

[19] The number of Tulalip Hatchery origin fish that stray to the target naturally-spawning population divided the natural spawning escapement.

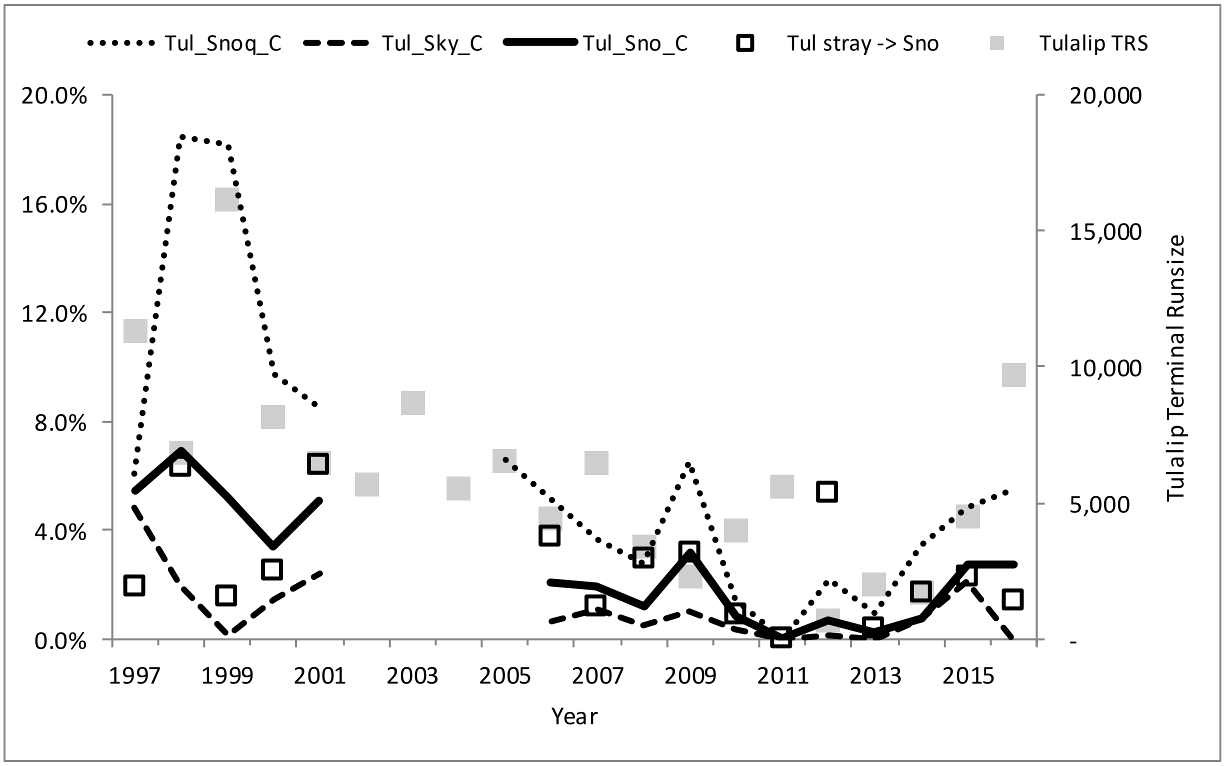


Figure 3. Tulalip Hatchery Chinook (Tul) contributions (C) to escapement in the Snohomish system (Sno), Skykomish (Sky) and Snoqualmie (Snoq) basins, straying rates to the Snohomish (hollow squares), and terminal run size (filled squares).

Harvest distribution and exploitation rate trends:

The coded-wire tag-derived exploitation rates for Wallace River Hatchery Chinook (indicator stock for the natural-origin Skykomish population) show that fisheries in British Columbia and SUS sport fisheries comprise the bulk of harvest of this stock, averaging 48.0% and 42.8% of the total fishing mortality respectively, while Alaska, preterminal SUS troll and net fisheries (mostly in Puget Sound) account for only 2.6%, 4.4% and 2.2% respectively (Table 2).

Table 2. Recent (2009 – 2018) distribution of Exploitation Rate from recovery of Wallace River Hatchery coded-wire tags (PSC CTC 2021).

AK	B.C.	SUS troll	SUS net	SUS sport
0.089	0.1620	0.0147	0.0074	0.1447

Post-season FRAM estimates of the total ER and SUS ER for Snohomish Chinook were on average lower (3.5% and 2.5% respectively) during 2013-2018 than pre-season estimates (Table 3a.; FRAM calibration version 7.1) . In 2014 and 2018 however, both the post-season total ER and SUS ER were higher than pre-season estimates.

From 2004 to 2018, SUS fisheries were managed in most years under the critical ER ceiling because pre-season planning indicated the Rebuilding Exploitation Rate (RER) would be exceeded due to northern fisheries.

Table 3a. Exploitation rates for Snohomish Chinook estimated by pre-season and post-season FRAM (BP version 7.1) models.

	Total ER			SUS ER		
Year	Pre-season	Post-season	Pre - Post	Pre-season	Post-season	Pre - Post
2013	27.3%	15.7%	11.6%	11.6%	5.5%	6.0%
2014	23.8%	26.6%	**-2.8%**	9.2%	11.0%	**-1.8%**
2015	39.8%	27.3%	12.5%	16.3%	10.1%	6.1%
2016	30.9%	29.3%	1.6%	12.7%	8.6%	4.1%
2017	19.5%	17.4%	2.1%	7.8%	5.0%	2.8%
2018	24.4%	28.4%	**-4.0%**	9.4%	11.7%	**-2.3%**

Table 3b. Exploitation rates for Snohomish Chinook estimated by post-season FRAM (BP version 7.1.1) models.

Year	Total ER	SUS ER
2013	15.3%	5.1%
2014	26.4%	10.8%
2015	27.3%	10.1%
2016	29.2%	8.5%
2017	17.1%	4.7%
2018	28.2%	11.5%

Integration of Harvest, Hatchery and Habitat Actions within the Basin

The Puget Sound Salmon Recovery Plan (Shared Strategy Development Committee 2007), the federal supplement to this plan (NMFS 2007), and the Snohomish River Basin Salmon Conservation Plan (Snohomish Basin Salmon Recovery Forum 2005) all emphasize that recovery of Chinook salmon populations will require significant management actions in all of the respective "Hs" (habitat, harvest, and hatchery management). Because the outcome of salmon recovery efforts depends on the combined and cumulative effect of hatchery, habitat, and harvest management, the effectiveness of actions in any of these areas cannot be evaluated without knowing the status of actions in the other areas.

The Snohomish River Basin Chinook Conservation Plan ("Snohomish Recovery Plan") is based on the premise that restoration and protection of habitat to properly functioning conditions will result in the basin's Chinook salmon populations moving to levels of abundance, productivity, diversity, and spatial distribution that reflect long-term population sustainability with harvestable surplus. Recovery goals for the populations are based on achieving levels of these four parameters, known as viable salmonid population (VSP) levels, associated with robust sustainable populations (McElhany et al. 2000).

There has been little to no joint and concurrent consideration of the Hs, even though their successful implementation would change baseline conditions. Because Chinook salmon recovery in the Snohomish watershed now includes a harvest management plan, a hatchery management plan, and a strategic habitat restoration program, and because key watershed stakeholders and the federal government are preparing to seriously consider harmonizing of regulatory habitat protection with other recovery efforts, a new H-integration framework was developed (Rawson and Crewson (b), Tulalip 2017). This approach describes hatchery guidelines and management actions based on the Phase of Recovery, which is derived from Habitat Condition + Population, building on the approach described by the Hatchery Scientific Review Group (HSRG 2014), which only determined Phase of Recovery based on population abundance. However, because habitat drives recovery, both the condition of habitat and the status of population parameters (primarily abundance and productivity) must be considered in determining the current Phase of Recovery (Figure 4), as well as the appropriate management response for moving toward full restoration (Table 4).

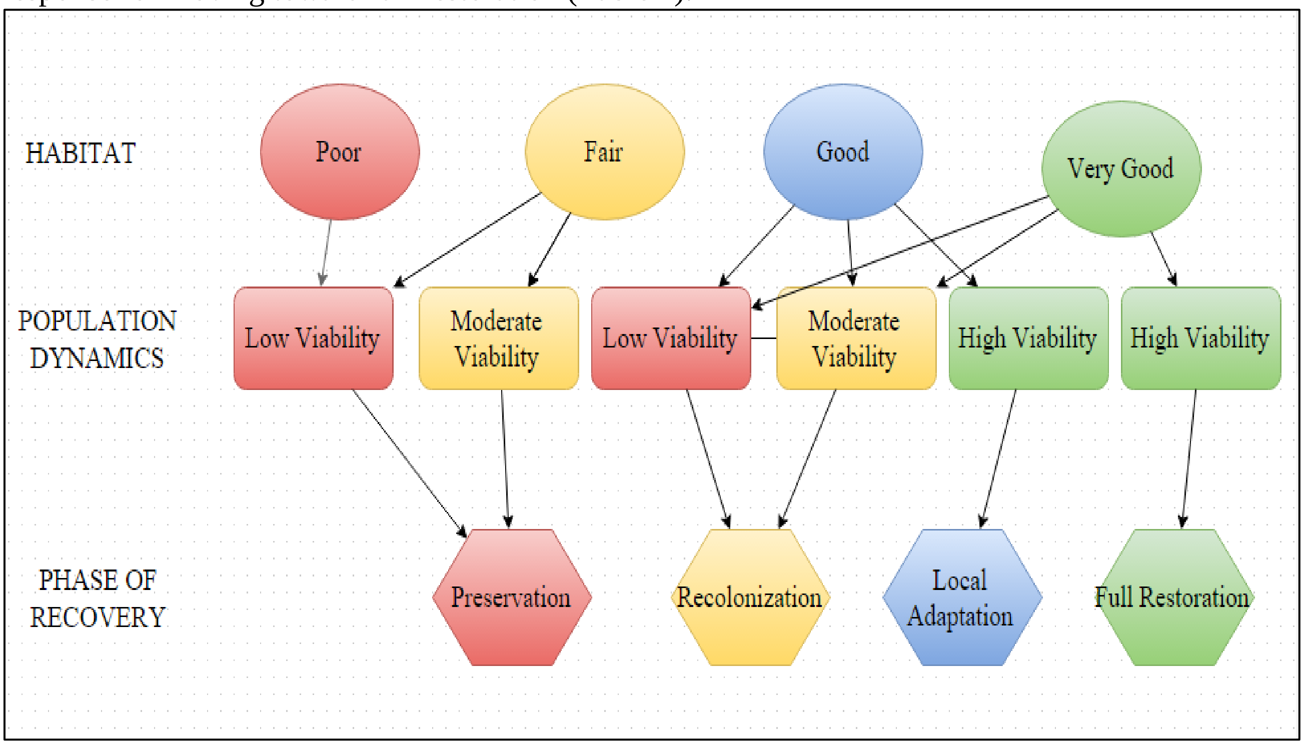


Figure 4. Phase of Recovery depends on both population viability and habitat status

Table 4. Table showing appropriate management objectives depending on both population viability status and habitat condition.

		Population Viability		
		Low	**Moderate**	**High**
Habitat Status	**Very Good**	Maintain Habitat	Maintain Habitat	Maintain Habitat
	Good	Improve VSP	Improve VSP	Maintain VSP
	Fair	Restore Habitat	Restore Habitat	Restore Habitat
	Poor	Preserve Population	Improve VSP	Maintain VSP

We developed a simple viability model incorporating both population abundance and productivity to determine Population Status for the two listed Snohomish Chinook units as:

- **High Viability** = VSP, as defined in PS recovery planning, i.e. a probability of 95% or greater of persisting for more than 100 years,
- **Moderate Viability** = 40 year persistence probability of 95% or higher, and
- **Low Viability** = Any population that fell below the Moderate standard

We estimated the distribution of the number of years to extinction based on observed rates of natural origin spawners (NOS) per natural origin spawner and age distributions (Figure 5):

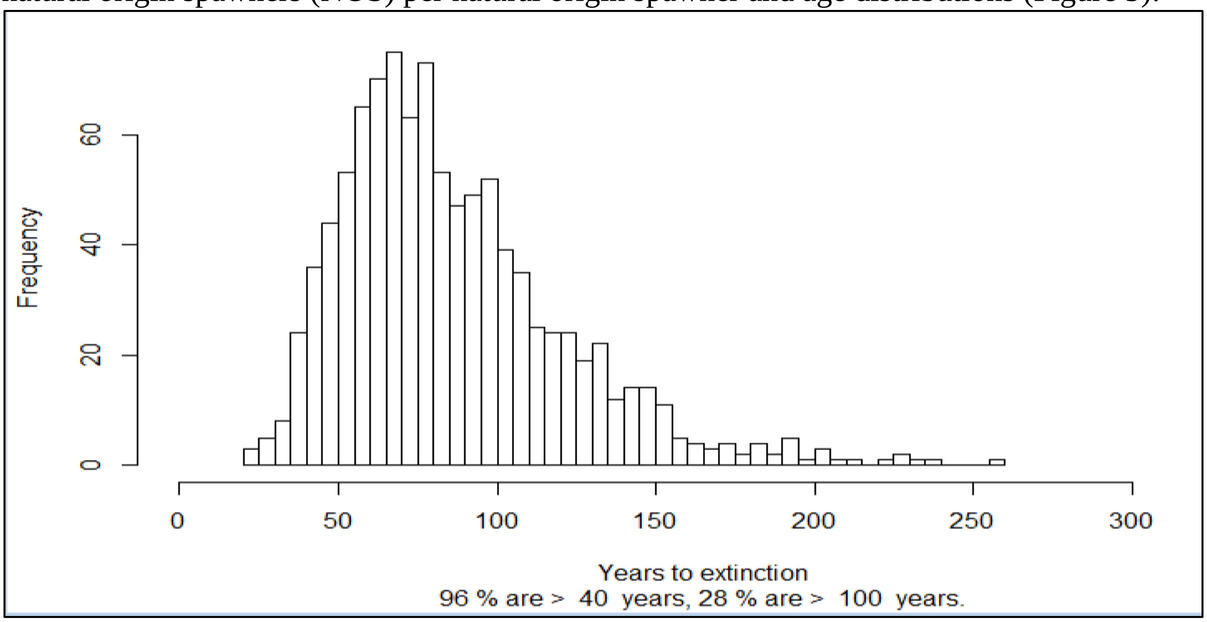


Figure 5. Frequency distribution of the number of years to quasi-extinction in 1,000 simulations for the Skykomish Chinook population.

The simulation for the Skykomish population showed approximately a 96% probability of persisting for more than 40 years and much less than a 95% probability of persisting for 100 years or more (Figure 5). Therefore, this population is potentially transitioning between a “Moderate” to a “Low” viability status, and on the border of Preservation and Recolonization phases of recovery, based on low to moderate population viability and fair or poor habitat status (Figure 4). Using the arbitrary 40-year persistence criterion for moderate viability, this population is barely above the 95% probability threshold, which emphasizes that a cutoff of 40 years exact is arbitrary. For example, if we had used a 50-year persistence criterion, then the persistence probability would have been < 90%, and this population would have been classified as being in low Population (viability) Status. Also, the analysis supporting placing this population in moderate, as opposed to low, Population Status, is mainly dependent on the productivity of 2.0 observed for the 2009 brood year (Rawson and Crewson, Tulalip 2017(b)). Most other recent brood years’ productivity has been less than 1.0. Unless freshwater and marine habitat conditions are meeting minimum properly functioning conditions that Chinook salmon from this population can utilize to increase Population Status by taking advantage of improved conditions, this population is expected to hover between ”Low” and “Moderate” viability status leading the population to be in the “Preservation” and “Recolonization” phases.
For Snoqualmie Chinook, the probability of persisting for 40 years is much less than 95% (Figure 6). Therefore, this population is classified as currently being in low viability status.

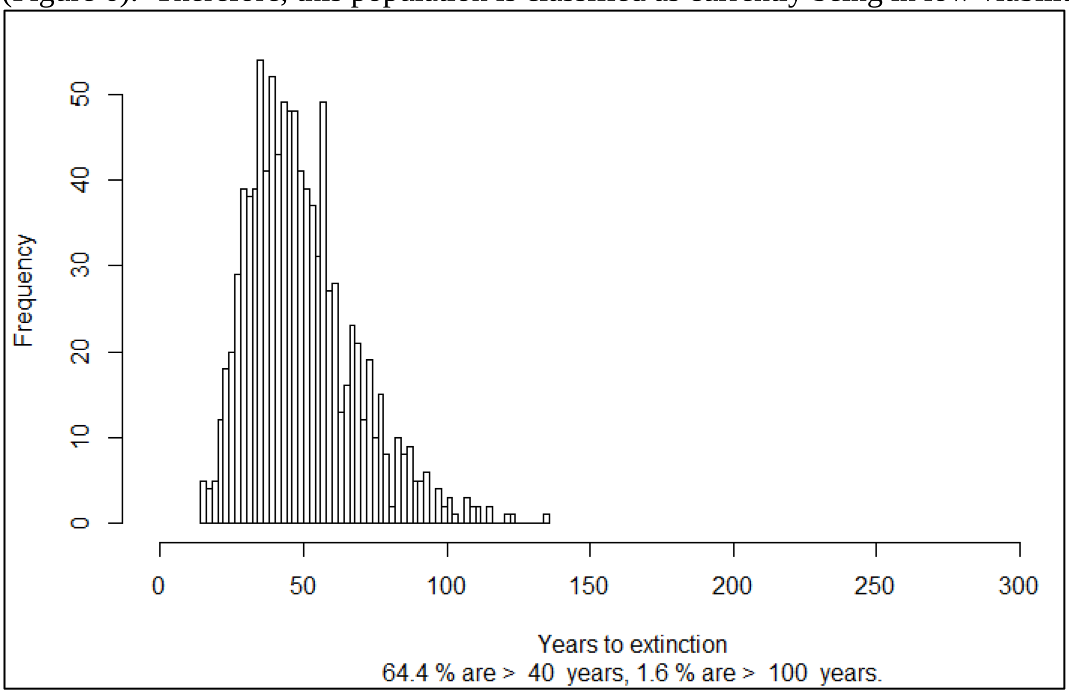


Figure 6. Frequency distribution of the number of years to quasi-extinction in 1,000 simulations for the Snoqualmie Chinook population.

The Snoqualmie population is definitely in the Preservation Phase, based on low population viability and poor habitat status.

The Skykomish population cannot remain in the Recolonization Phase unless both 1) productivity is above 1.0 in some brood years and 2) there is sufficient habitat of good quality available to support the increased production in those years, leading to recolonization. In years of higher abundance and productivity, management actions respond accordingly, but concurrent habitat actions must also be undertaken if the population is to actually grow when productivity is good. If this does not happen, then future productivity will remain below 1.0, and the population will revert into unambiguous low viability status and the Preservation Phase of recovery. Although marine conditions and their variability are not currently part of this modelling framework, we continue to develop and improve our marine survival assessment capabilities to better categorize Marine Habitat Condition under "Low" and "Normal" regimes (both in Puget Sound and ocean), so they can be incorporated into the overall habitat condition and classification of the Phase of Recovery. So, for example, if freshwater habitat improves, we would expect to see a gradual improvement in population viability status, all other management factors being equal. However, when marine survival drops from a normal to a low regime as it has currently, population performance is expected to decline throughout the low regime. It will be important to distinguish declines in population performance due to lowered marine survival from declines due to habitat degradation or inappropriate harvest or hatchery management. We are still working on this aspect of the framework. However, Rawson and Crewson (2017(b)) demonstrated that the recent productivity of the Skykomish population would have declined even in the absence of any fishing, as well as after recently implementing several important hatchery improvements (e.g. switching to the native Skykomish broodstock as the sole source of eggs for both Snohomish regional hatchery programs, integrating natural-origin fish into the broodstock, and greatly increasing both juvenile and adult monitoring efforts).

Management Thresholds and Objectives

Management objectives for the Snohomish populations in this RMP are applicable to natural-origin fish. They will be reviewed and potentially revised once information on the 2019 brood productivity, including estimated escapement in the years 2022-2024 becomes available. These objectives consist of:

Reference Point	Skykomish	Snoqualmie	Management Unit
Lower Bound Threshold (LBT)	1,745	700	
Lower Abundance Threshold (LAT)	2,015	1,132	3,250[20]
Upper Management Threshold (UMT)	3,600	1,300	4,900
Rebuilding Exploitation Rate	23%[21]		
Total Exploitation Rate Ceiling	20%		
Southern US Exploitation Rate Ceiling	**LBT** 8.3% **LAT** 9.3% **UMT** 10.3%		< 3,250

Management objectives for Snohomish summer/fall Chinook salmon include an upper limit on total exploitation rate, to ensure that harvest (*i.e.* all mortalities related to fisheries, including

[20] See derivation in Table 5.
[21] See derivation in Pages 22-27

direct take, incidental take, release mortality, and drop-off mortality) does not impede the recovery of the component stocks, and a low abundance threshold (LAT) for spawning escapement to trigger reduced fishing effort under low returns to maintain the viability of the stocks. We also identified a Lower Bound Threshold (LBT) to further minimize the impact of SUS harvest related mortality when the management unit is expected to return at very low levels. This additional precautionary step in managing fisheries, responds to the persistent decline for the Snohomish populations during recent years with no indications yet of a recovery from it. The lowest natural origin Chinook escapement was observed recently for both populations: in 2019 only 569 natural-origin Chinook returned to the Skykomish, and only 443 to the Snoqualmie. Very low abundance levels have persisted for up to three consecutive years in two recent periods: 2013-2015 and again 2019-2021 for both the Skykomish and the Snoqualmie populations.

The total exploitation rate ceiling (ERC) for Snohomish Chinook will be set at 20%. The ERC for Snohomish in the past has been set at the Rebuilding Exploitation Rate as estimated by NOAA analysis (conducted in cooperation with the comanagers), translated into a FRAM-based ER, such that the populations are unlikely to fall below a Critical Escapement Threshold (CTE, as defined for VRAP analysis). In 2017, that translation resulted in an ERC of 21%. Subsequent revisions to FRAM adjusted the translated FRAM value to 19% in 2019. A translation of the RER to FRAM version 7.1.1 results in an ER value of 23%. The comanagers have set the total ERC for the Snohomish MU at 20% as a conservative measure due to concerns with the relatively flat nature of the relationship between ERA-based and FRAM-based exploitation rates, and the need to update the RER analysis with data from more recent brood years.

The Critical Exploitation Rate Ceiling (CERC) for Snohomish was set at 8.0% SUS in the Co-manager's 2017 plan. This ceiling was meant to represent a rate that would limit SUS fisheries years when abundance was projected below the LAT but still allow minimal fisheries directed at other stocks and species to be implemented using the modeling tool in use at that time (FRAM 6.2). Comparison of FRAM rates between subsequent versions of the model have shown that an estimated rate of 8.0% in version 6.2 is roughly equivalent to a rate of 8.9% in version 7.1.1. As a conservative measure in part due to concern for the low escapement observed in 2019, the comanagers have adjusted the CERC to 8.3%. Although this rate is slightly higher numerically, changes to FRAM and its ER estimates mean that this rate should limit planned fisheries when abundance is below the LAT to levels below those allowed under the 8.0% CERC from the 2017 plan. The Co-managers may revisit the exploitation rate limits once the effects of the low escapement experienced in 2019 on future returns are better understood.

We have delineated reference points to ensure that harvest does not impede the recovery of the Snohomish Management Unit (or its component stocks), while prosecuting limited fisheries directed on other stocks and species. Northern fisheries can have a variable but significant impact on the Snohomish MUP, making planning fisheries below a total exploitation rate ceiling difficult and subject to much uncertainty as those fisheries change from year to year. For example, using pre-season models run using the new FRAM base period for 2013 to 2018, exploitation rates in Northern fisheries ranged from 12.20% in 2017 to 20.7% in 2016. If the MU had been managed to a total RER/ERC of 20% in those years, this would have left ERs ranging from 7.8% to 0% available for SUS fisheries. Exploitation rate limits this low in SUS fisheries would put an unreasonable conservation burden on SUS fisheries, requiring massive closures to treaty and non-treaty fisheries in some years. In recognition of this, the MU will be managed in a manner that allows total ER's that may exceed the total of 20% at some northern fishery levels, while limiting SUS ER's to lower levels that are dependent on projected escapement relative to the LAT and UMT.

When escapement is projected to be above the UMT for the aggregate unit and for both populations, fisheries will be planned so that the total ER does not exceed 20% for the MU. However, because northern fisheries could potentially eliminate most if not all harvest opportunity in SUS fisheries in some years, SUS fisheries may be planned to have an ER of up to 10.3% should northern fisheries be projected to have an ER of more than 9.7%, meaning that the total ER may exceed 20% in years with higher expected northern fishery impacts.

When escapement is projected to be above the LAT for the aggregate unit and for both populations, fisheries will be planned so that the total ER does not exceed 20% for the MU. However, because northern fisheries could potentially eliminate most if not all harvest opportunity in SUS fisheries in some years, SUS fisheries may be planned to have an ER of up to 9.3% should northern fisheries be projected to have an ER of more than 10.7%, meaning that the total ER may exceed 20% in years with higher expected northern fishery impacts.

When escapement is projected to be below the LAT for the MU or either of its populations, fisheries will be planned so that the total ER does not exceed 20% for the MU. Again, northern fisheries could potentially eliminate most if not all harvest opportunity in SUS fisheries that encounter Snohomish Chinook in some years. As a more conservative approach at lower abundances, SUS fisheries may be planned to have an ER of up to only 8.3% should northern fisheries be projected to have a rate of more than 11.7%, meaning that the total ER may exceed 20% in years with higher expected northern fishery impacts.

There is some uncertainty in expected ERs in Northern fisheries as the new PST agreement enters its first years of implementation, and as Canadian fisheries are structured to deal with conservation issues with Canadian stocks, but northern rates have averaged 15.5% over the 2013-2018 period (Table 3b).

Should the projected escapement fall below the lower bound of 1745 for the Skykomish or 700 for the Snoqualmie, then additional SUS harvest measures will be taken that season to attempt to prevent further declines in abundance. The comanagers will discuss and implement a contingency set of actions (*e.g.* closure of in-river mark-selective fisheries, significant reductions or closures to SUS marine fisheries impacting Snohomish chinook), that will contribute to increasing abundance back to levels above the LAT. As potential actions are examined both during pre-season planning as well during as in-season management, the comanagers will consider for factors including environmental factors such as water flow and temperature), and recent natural origin Chinook escapements (*i.e.* whether escapement has been below the lower bound in the previous three years).

Lacking direct information on the extent to which the current fisheries regime may disproportionately harvest any single stock (*i.e.* Skykomish *vs* Snoqualmie), the spawning escapement of each stock will be carefully monitored for indications of differential harvest impact. Average escapement during the period of 1965 – 1976 will be the benchmark for this monitoring (Snohomish Basin Salmonid Recovery Technical Committee (SBSRTC) 1999).

Abundance Threshold for Management

The lower bound value proposed for the Skykomish (1745) was the LAT in the previous plan, while the 700 for the Snoqualmie is the rounded average of the escapements during the three consecutive years of extreme poor return (2013-2015). This lower bound will provide a buffer for additional protection to a population in a low viability status (see section Integration of Harvest, Hatchery and Habitat Actions within the Basin).

A low abundance threshold of 3,250 spawners (natural origin, naturally spawning fish) for the Snohomish management unit is established as a reference for pre-season harvest planning. In addition, lower bound abundance thresholds of 1745 and 700 (natural origin, naturally spawning) for the Skykomish and the Snoqualmie populations respectively. If escapement is projected to fall below these thresholds under a proposed fishing regime, additional stepwise measures depending what threshold was triggered will be adopted to minimize harvest mortality. Directed harvest of Snohomish natural origin Chinook stocks (net and sport fisheries in the Snohomish terminal area or in the river) has already been eliminated. Further constraint, thus, depends on measures that reduce incidental take.

The low abundance threshold for the management unit was derived from Critical Observed Escapement (COE) for each of the Snoqualmie and Skykomish populations in a two-step process, following the same approach as in the 2010 Management Plan (described below), but updating key parameters derived from an extended dataset including more recent information on productivity and escapement (as recent as 2016).

Critical Observed Escapement are levels that we do not want to go below under any circumstances. For each population, the critical observed escapement was determined and then expanded to an adjusted level for management use according to the following formula, and summarized in Table 5:

$$E_{man,\mathbf{p}} = E_{crit\ obs,\mathbf{p}} / [(R/S)_{low,\mathbf{p}} * (1-RER_{mu})]\ [1]$$

Where $E_{man,\mathbf{p}}$ is the lower management threshold for population ***p;***

$E_{crit,obs\ \mathbf{p}}$ is the critical observed escapement for population ***p*** (lowest observed escapement producing a greater than 1:1 return per spawner*;*

$(R/S)_{low,\mathbf{p}}$ is the average of recruits/spawners for population ***p*** under low survival conditions; and

RER_{mu} is the RER established for the management unit

Table 5. Derivation of the Reference Points of the Snohomish Chinook salmon populations (see text for details).

Reference Points	Skykomish (years)	Snoqualmie (years)
Critical Observed Escapement	881 (2011)	400
$(R/S)_{low,p}$	0.54 (1996, 2006, 2008)	0.48 (2006, 2008, 2010)
Rebuilding Exploitation Rate	0.23	0.23
$Low_{threshold}$	2015	1132
NOR_{stock}/NOR_{tot}	0.62	0.38
MU LAT = Max (NORstock/NORtot)	**3250**	

Maximum Exploitation Rate Guideline

The rebuilding exploitation rate (RER) is the highest allowable ("ceiling") exploitation rate for a population under recovery given current habitat conditions, which define the current productivity and capacity of the population. This rate is designed to meet the objective that, compared to a hypothetical situation of zero harvest impact, the impact of harvest under this plan will not significantly impede the opportunity for the population to grow towards the recovery goal. Since recovery will require changes to harvest, hatchery, and habitat management and since this plan only addresses harvest management, we cannot directly evaluate the likelihood of this plan's achieving its objective. Therefore, we evaluate the RER based on Monte Carlo projections of the near-term future performance of the population under current productivity (environmental effects in marine and freshwater habitats on survival remain as they are now), as well under similar hatchery production levels.

WDFW and Tulalip Tribes collaborated with NOAA in reviewing and editing the A&P tables including (escapement, age composition, hatchery return data, fishing rates calculated by the Pacific Salmon Commission Chinook Technical Committee) needed for a revision of the Rebuilding Exploitation Rate estimates for the two populations of the Snohomish System. Also, co-managers reviewed NOAA's modelling work on the productivity of the Skykomish and Snoqualmie stocks, as well as their RER analysis. Here (pages 16-27), we present an abbreviated version of the original analysis.

Both a Ricker and Beverton-Holt spawner-recruit models were examined within a Bayesian modeling approach, with assumptions about the model parameters described by prior distributions, before data were introduced are described by the prior distributions.

For productivity a log normal distribution was used with mode=1.5, sigma=0.75, and truncated at 5 (equivalent to a mean of 2.35 and standard deviation of 1.17). For capacity a lognormal distribution with upper bound and median derived from an Ecosystem Diagnosis and Treatment analysis describing current conditions in 2004 (SBSRTC 2004) was recommended by co-managers as the best estimates available. The adult spawner capacity estimates for the

Skykomish and Snoqualmie populations were 12,604 and 7,204 fish respectively, which summed to approximately 20,000 Chinook salmon for the basin (SBSRTC 2004). For the upper bounds the basin 20,000 was expanded to 25,000 to account for uncertainty, and then apportioned this to the individual basins using the percentages from the original values, 64% and 36% (SBSRTC 2004), resulting in upper bounds of 16,000 and 9,000 for the Skykomish and Snoqualmie, respectively. A lower bound of 500 and a lognormal sigma of 10 was used.

Both the Ricker and Beverton-Holt functions appeared to fit the spawner-recruit data fairly well for both the Skykomish and Snoqualmie summer/fall Chinook populations (Figures 7-8). Estimated intrinsic productivity (posterior median) was 1.79 (Ricker) and 2.58 (Beverton-Holt) for the Skykomish summer/fall Chinook population, and 2.2 (Ricker) and 3.07 (Beverton-Holt) for the Snoqualmie summer/fall Chinook population (Table 6). Equilibrium population size was 3,773 (Ricker) and 3,512 (Beverton-Holt) for the Skykomish fall Chinook population, and 2,092 (Ricker) and 2,016 (Beverton-Holt) for the Snoqualmie fall Chinook population.

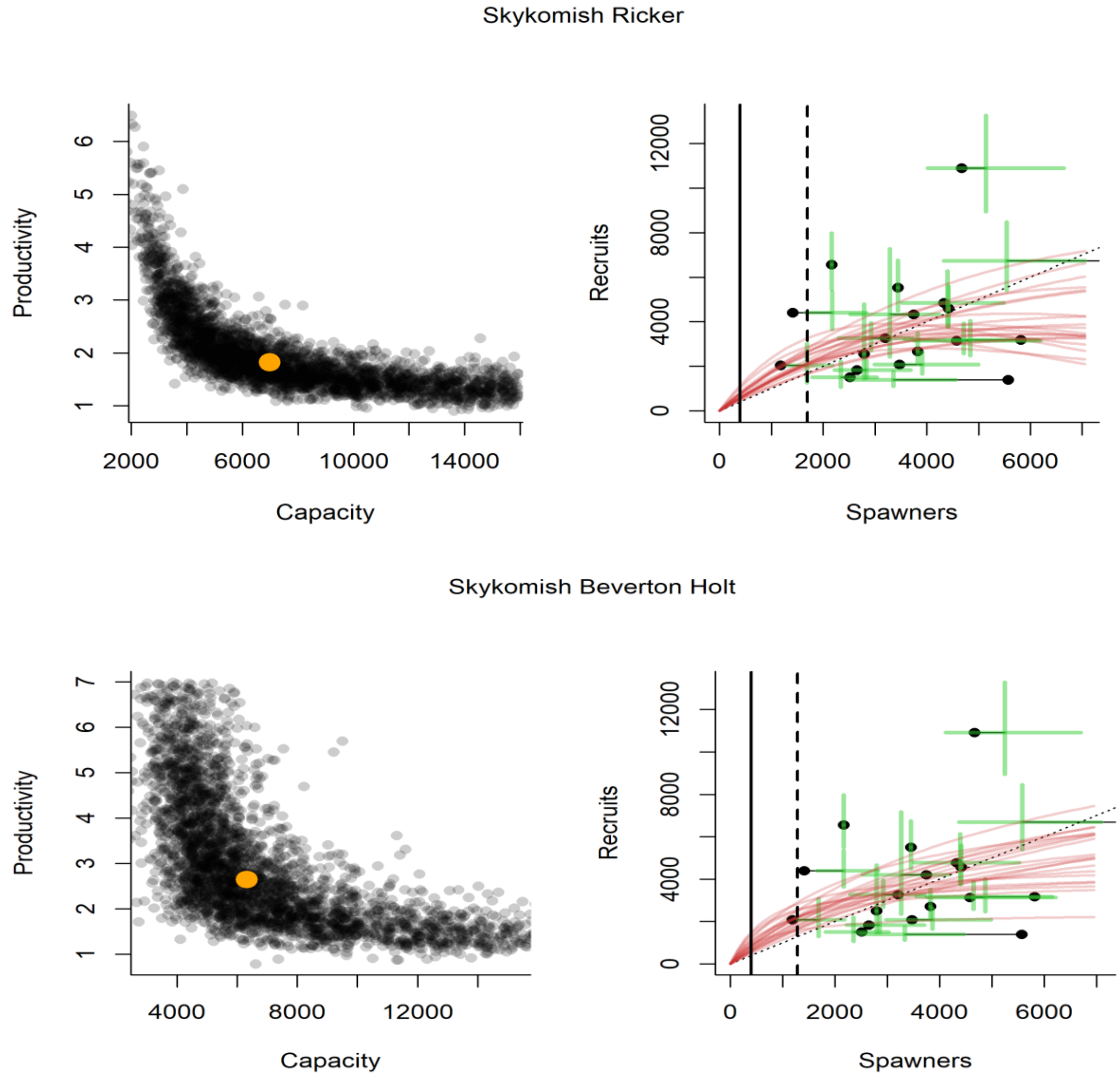


Figure 7. Posteriors of the Ricker and Beverton-Holt spawner-recruit parameters and fits to the spawner-recruit data for the Skykomish summer/fall Chinook population. The upper panels describe the Ricker fits and the lower panels describe the Beverton-Holt fits. The left panels represent the joint posterior distribution for the productivity and capacity parameters of the spawner-recruit relationship. The grey dots represent individual samples from the posterior distribution. Thus darker regions represent higher probability. The orange point is the posterior median. The right panels are total spawners age-3 to -5 versus estimated adult equivalent recruits. The vertical green lines represent uncertainty in recruitment (80% credible intervals) and the horizontal green line represent observation uncertainty in the spawner numbers (80% credible interval). The black lines represent the shift from the observed spawners to the predicted spawners. The red lines represent the spawner-recruit function for 20 samples from the posterior distribution (i.e. 20 plausible fits based on the assumptions and data). The solid and dashed vertical lines represent the critical and rebuilding thresholds used for defining the RERs respectively.

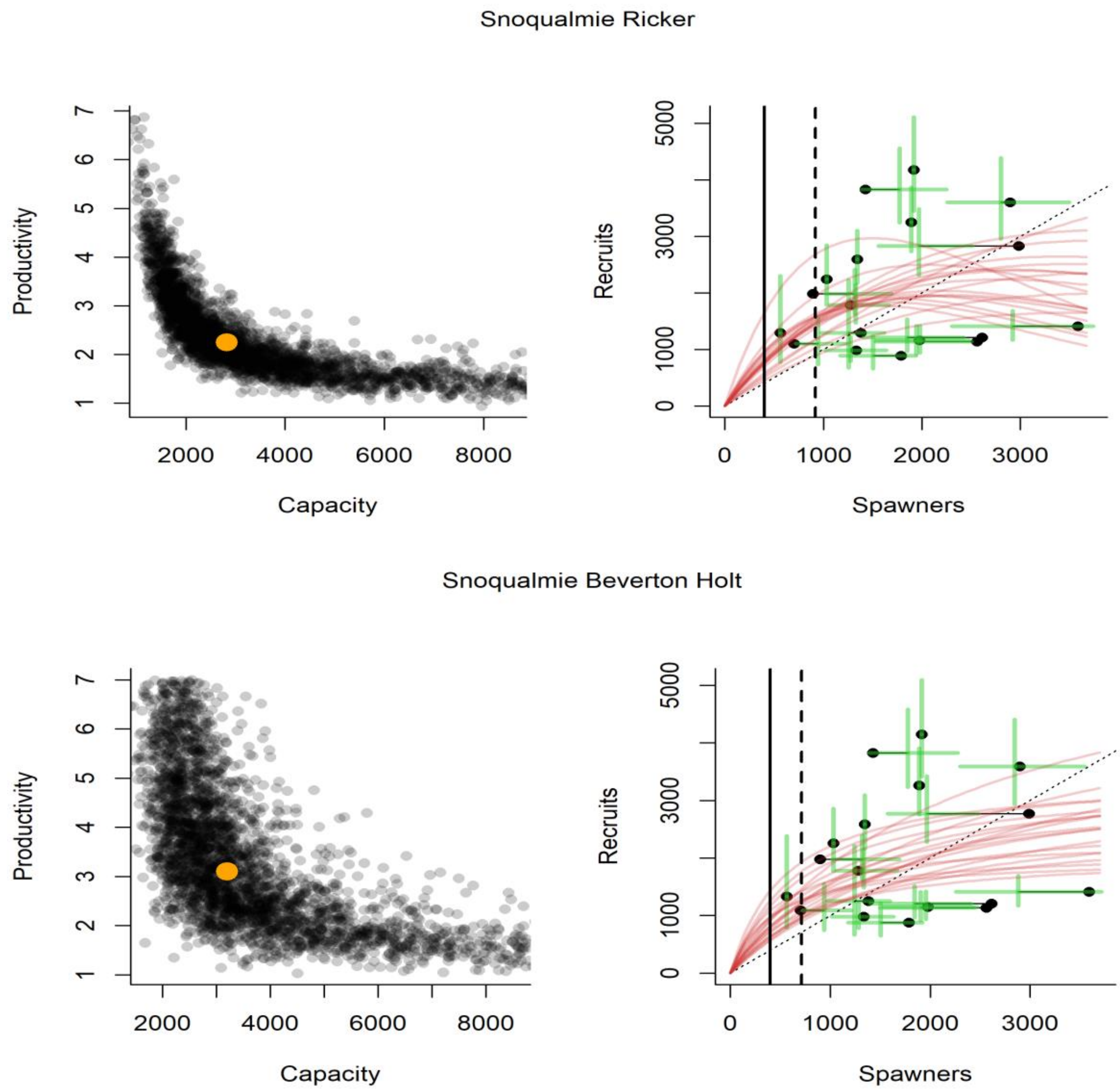


Figure 8. Posteriors of the Ricker and Beverton-Holt spawner-recruit parameters and fits to the spawner-recruit data for the Snoqualmie summer/fall Chinook population. See Figure 7 for details on the elements of the figure.

Table 6. Summary of the posterior distributions of the population dynamics model parameters. The values represent the median of the posterior distribution and an 80% credible interval.

	Skykomish Ricker	Skykomish Beverton Holt	Snoqualmie Ricker	Snoqualmie Beverton Holt
Productivity	1.79 (1.29,2.97)	2.58 (1.47,5.17)	2.2 (1.5,3.62)	3.07 (1.72,5.55)
ProductivityHist	2.39 (1.76,4.15)	3.56 (1.99,7.46)	3.13 (2.15,5.16)	4.4 (2.46,8.14)
ProductivityRecent	1.63 (1.24,2.68)	2.37 (1.39,4.79)	1.72 (1.23,2.72)	2.45 (1.41,4.45)
ProductivityAtCT	1.68 (1.25,2.68)	2.2 (1.39,3.51)	1.9 (1.38,2.83)	2.16 (1.5,2.9)
Capacity	6674 (3533,13089)	5901 (3969,11585)	2687 (1559,5917)	3066 (2126,5812)
Equilibrium	3773 (2463,5344)	3512 (2435,4944)	2092 (1617,2876)	2016 (1479,2841)
SmsyAll	1698 (1169,2466)	1284 (898,1962)	919 (716,1305)	712 (509,1116)
ProcessSD	1.833 (1.595,2.204)	1.818 (1.588,2.193)	1.745 (1.543,2.083)	1.736 (1.535,2.089)

Patterns in the recruitment residuals and recruits per spawner

There is some indication of a negative trend in recruitment residuals (Figures 9 and 10), for both the Snoqualmie River populations. The average productivity in the last ten years for the Skykomish is 1.63 and for the Snoqualmie is 1.72 (based on the Ricker model) compared to the entire time series average of 2.39 and 3.13 respectively.

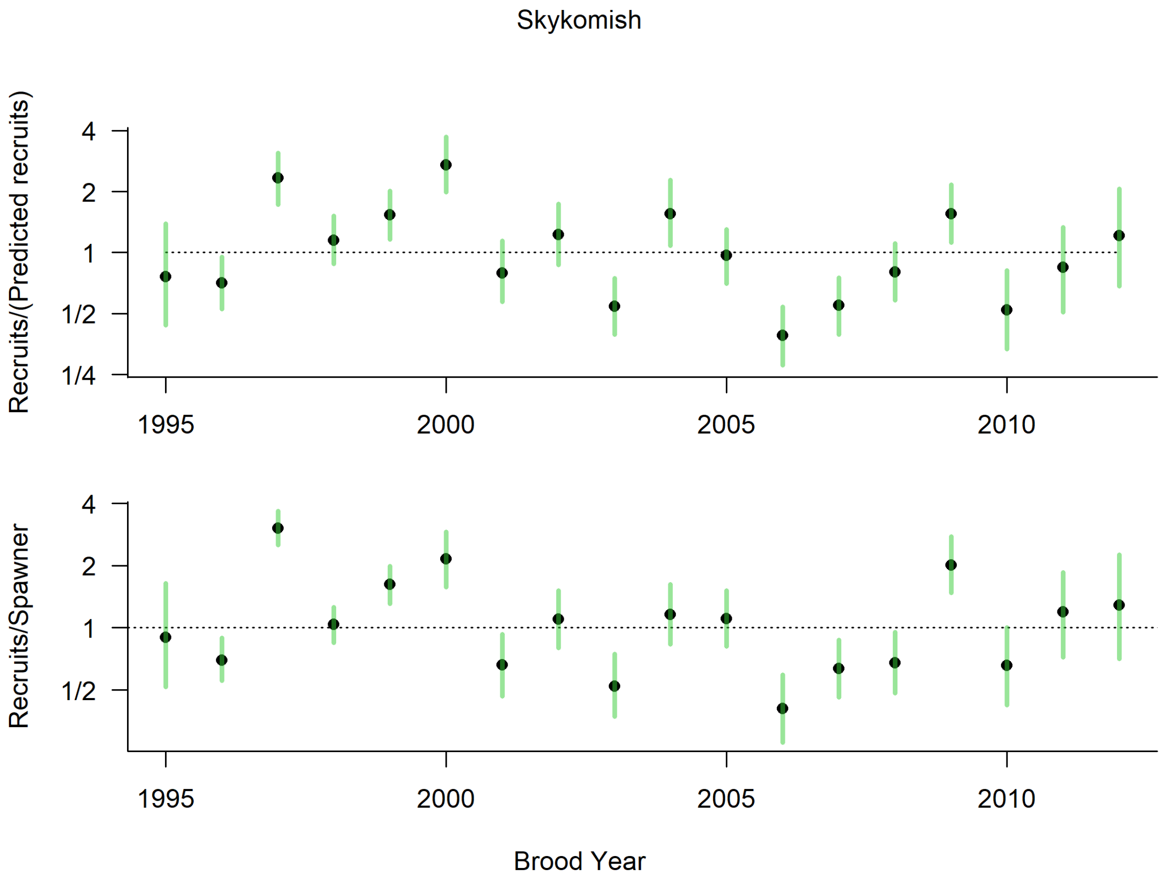


Figure 9. Patterns in recruitment by year for the Ricker fit for the Skykomish River summer/fall Chinook population. The upper panel represents the recruitment residuals, which are log recruits minus log predicted recruits. The green lines represent 80% credible intervals for the standard residuals. The bottom panel is log adult equivalent recruits divided by total spawners age-3 to age-5. The green bars represent 80% credible intervals.

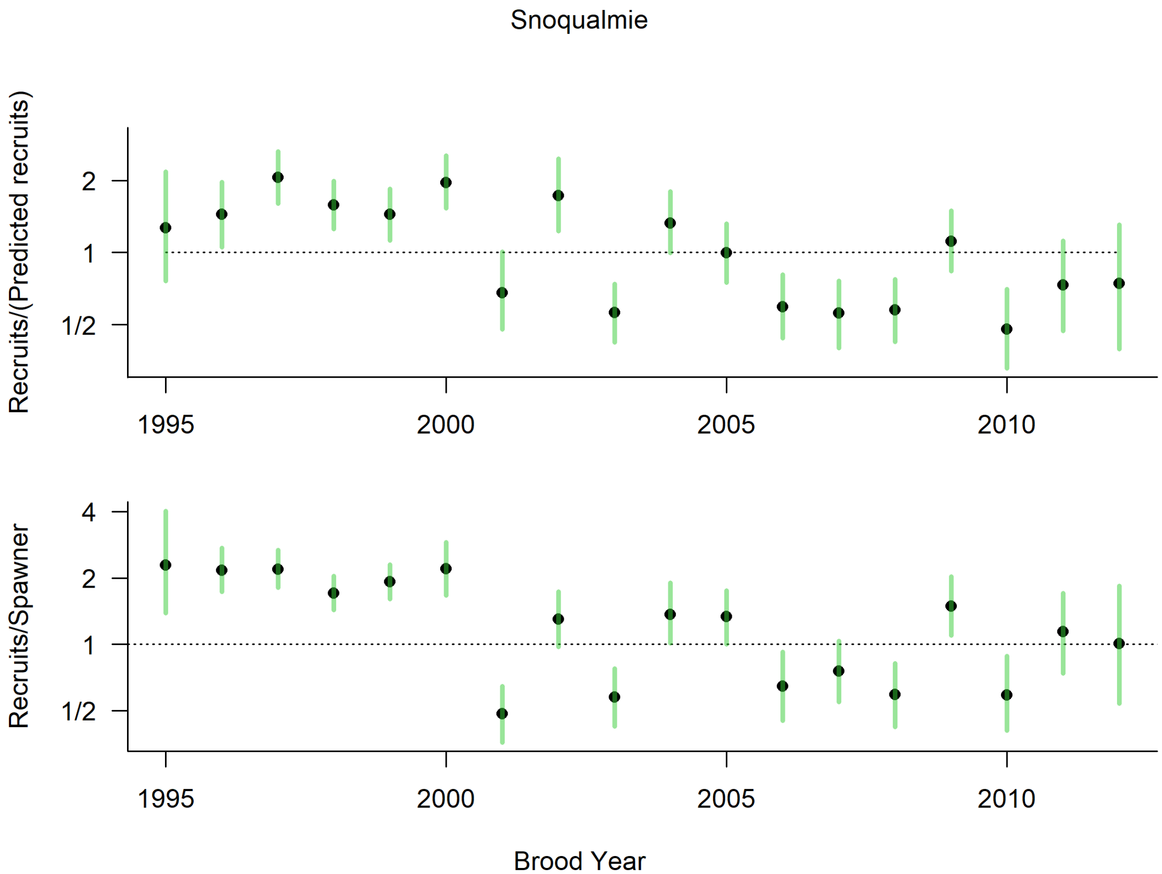


Figure 10. Patterns in recruitment by year for the Ricker fit for the Snoqualmie River summer/fall Chinook population. The upper panel represents the recruitment residuals, which are log recruits minus log predicted recruits. The green lines represent 80% credible intervals for the standard residuals. The bottom panel is log adult equivalent recruits divided by total spawners age-3 to age-5. The green bars represent 80% credible intervals.

Calculating RERs using VRAP

Once the population dynamics model (DM) was fit to the data, the Viability Risk Assessment Procedure (VRAP) was used to simulate 25 years into the future, 1,000 times each, for a range of target exploitation rates. For each target exploitation rate, the 1,000 runs were then summarized based on the percentage of times the simulated escapement fell below the critical escapement threshold (CET) and above the rebuilding escapement threshold (RET). Specifically, the RER is defined as the maximum harvest rate that satisfies both of the following conditions:

(1) The percent simulated escapement values less than the critical escapement threshold for the 25 year period differs from the baseline (i.e. % above at zero exploitation rate) by less than five percentage points.

(2) Simulated escapement values are either above the rebuilding escapement threshold at least 80% of the time for years 23-25, or if this criteria cannot be met, the percent simulated escapement values less than the rebuilding escapement threshold in years 23-25 differs from the baseline (i.e. % above at zero exploitation rate) by less than 10 percentage points.

For the CETs, NOAA's RER analysis evaluated 400 adult spawners for both populations (Method 1, NMFS 2000). The RETs were defined as the median of the posterior distribution for spawners at Maximum Sustainable Yield (Smsy) and are specific to the population and spawner-recruit function. For the Ricker functions these were 1,698 (Skykomish) and 919 (Snoqualmie). For the Beverton-Holt they were 1,284 (Skykomish) and 712 (Snoqualmie). Because the functions fit the data comparably (see above), for the purposes of management, we averaged the results of the two spawner-recruit analysis and rounded to the nearest 100 to determine the RET for each population: 1,491 (Skykomish), 816 (Snoqualmie). However, the RERs were calculated based on the spawner-recruit function specific values.

Recruitment variability was modeled using a gamma distribution with CV equal to 0.617 for the Skykomish and 0.521 for the Snoqualmie based on the Ricker fits and 0.61 and 0.524 for the Beverton-Holt fits. The difference between the target and actual exploitation rates was simulated using management error estimates derived from pre- and post-season exploitation rate estimates from the FRAM model. A gamma distribution was used to simulate the ratio of the actual to target exploitation rates (mean = 0.778, stdev = 0.231). The initial population size was calculated as the average of the last three age-specific cohort sizes calculated in the A&P Table. Average maturation rates were calculated using the median of the posterior distribution for the year and age-specific maturation rates estimated in the population dynamics model and then averaged over years. The average age-specific exploitation rates for the mixed-maturity and mature fisheries were calculated for the last five years to allocate exploitation rates across the different ages and fisheries.

The VRAP process was repeated 1000 times based on 1000 random draws from the posterior distribution. This allowed the uncertainty in the model parameters (e.g. productivity and capacity) to be propagated into the RER values. This produces a distribution of RER values (based on the 1000 draws) as opposed to a single value. Results are therefore summarized using the median and an 80% credible interval (the Bayesian analogue to the confidence intervals).

This is of course all conditional on the data and all of the model assumptions (including the priors).

RER results

Recovery Exploitation Rates (A&P) were calculated for both the Ricker and Beverton-Holt spawner-recruit functions since they fit the data comparably (see above). For both spawner-recruit functions and populations the RERs were constrained by the RET (Skykomish-Ricker = 31%, Skykomish-BH = 44%, Snoqualmie-Ricker = 40%, Snoqualmie-BH = 47%, Skykomish combined=0.37, Snoqualmie combined=0.44 Figure 11). Using draws from the posterior distribution to incorporate uncertainty into the RERs produces histograms that represent the posterior distribution of the RERs (Figure 12, also summarized in the third and fourth column of Table 7 with their median values and 80% credible intervals for FRAM calibration version 6.2 and 7.1.1 models respectively).

To make the RERs compatible with modeled exploitation rates used in fishery planning (the FRAM model[22]), the RERs derived from data in the A&P tables were converted to FRAM equivalent RERs, as these two estimates of exploitation rates are substantially different from the FRAM exploitation rates used in domestic management. These values were converted to FRAM equivalents using a logit-logit model fit to historic values of both exploitation rates.

[22] NOAA Fisheries Services (email from James Dixon on July 15th 2021). Snohomish River Chinook Salmon RER Results (new conversion). See Figure 12 and Table 7 below.

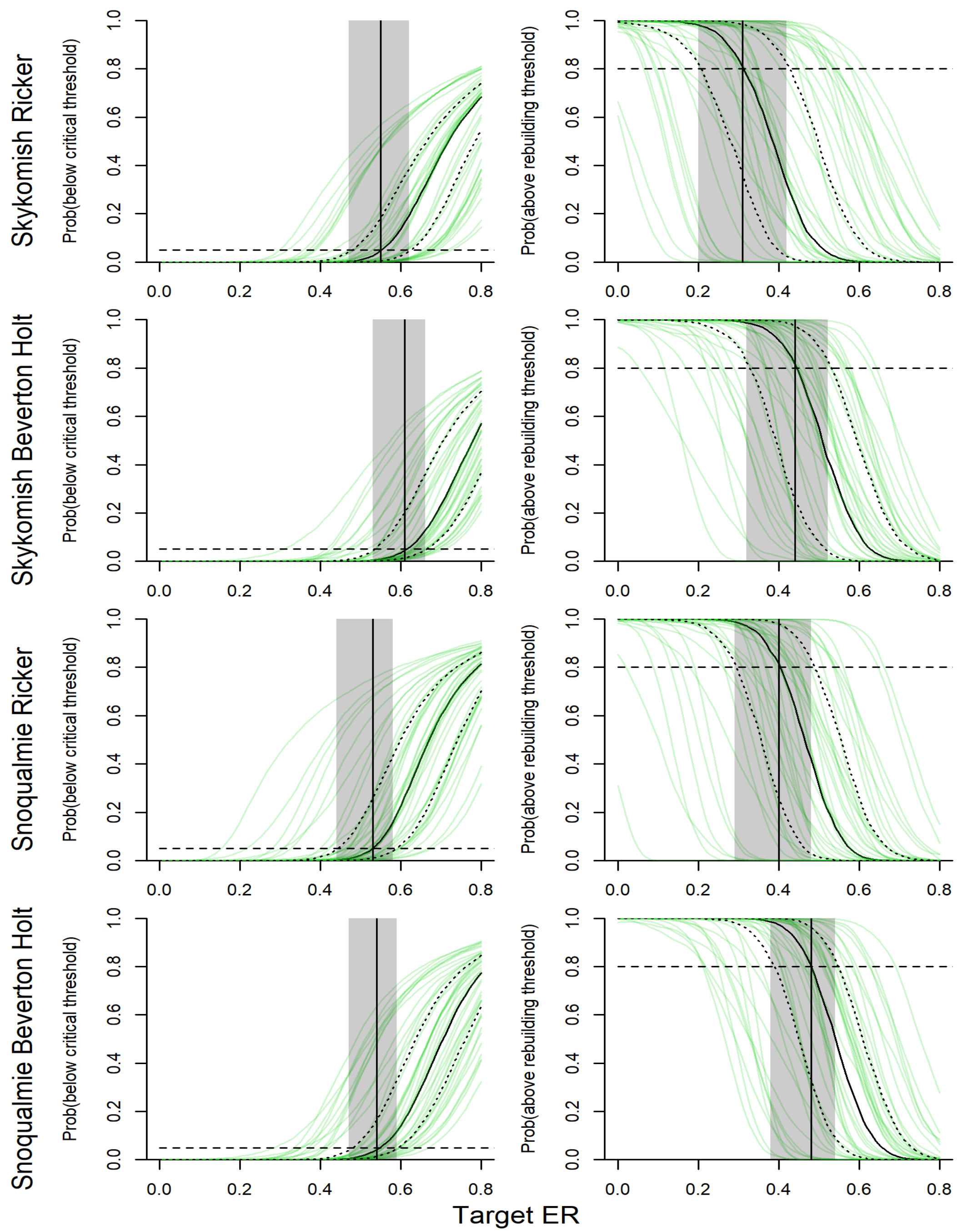


Figure 11. Probabilities of falling above and below the critical and rebuilding thresholds for the Skykomish and Snoqualmie River Chinook populations. The green lines are different plausible fits (taken from the posterior distribution). The dotted lines describe the pointwise 50% credible intervals for the probabilities while the gray bar is the 50% credible interval for the RER. The dashed lines are at 5% and 80% respectively.

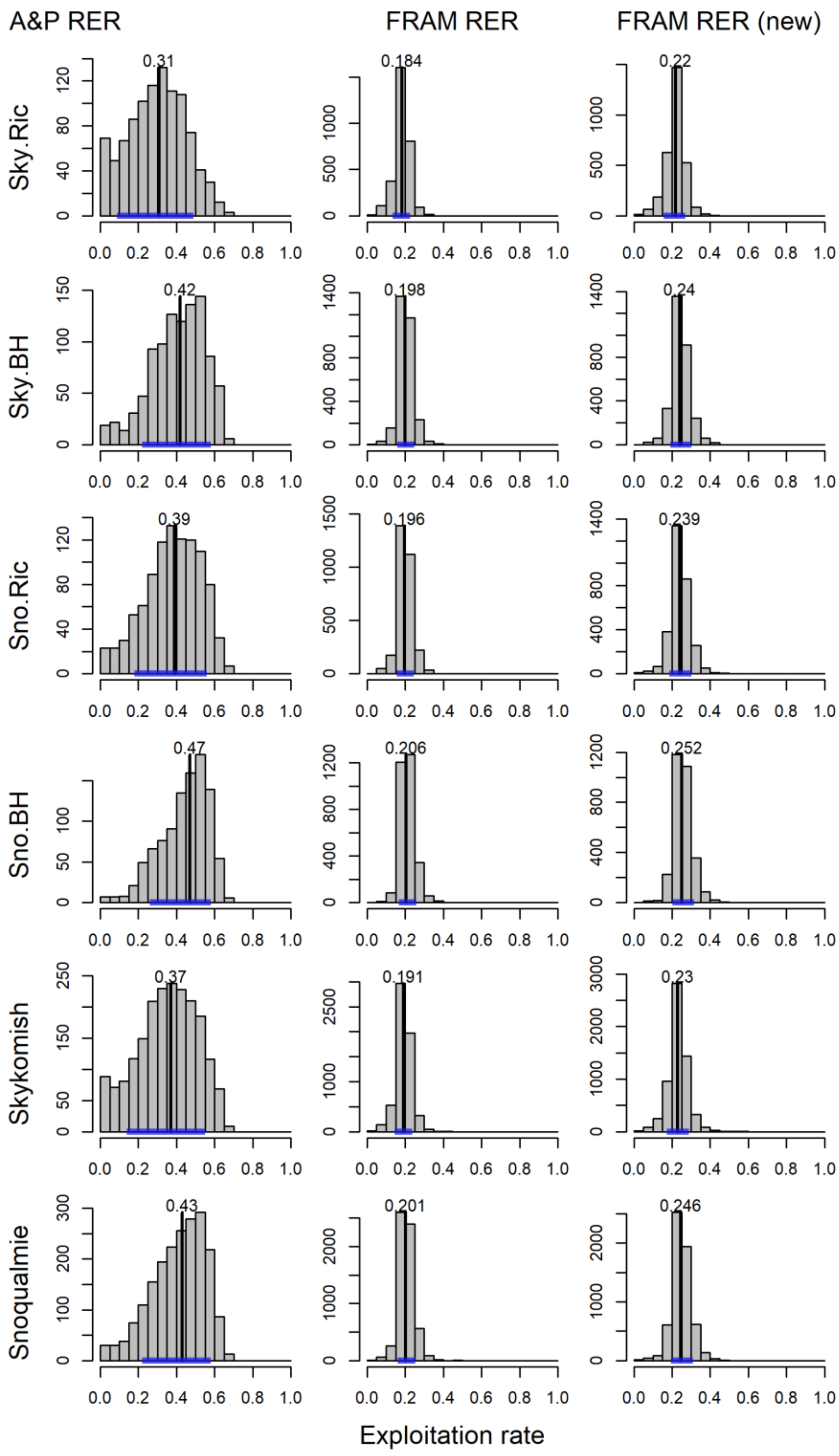


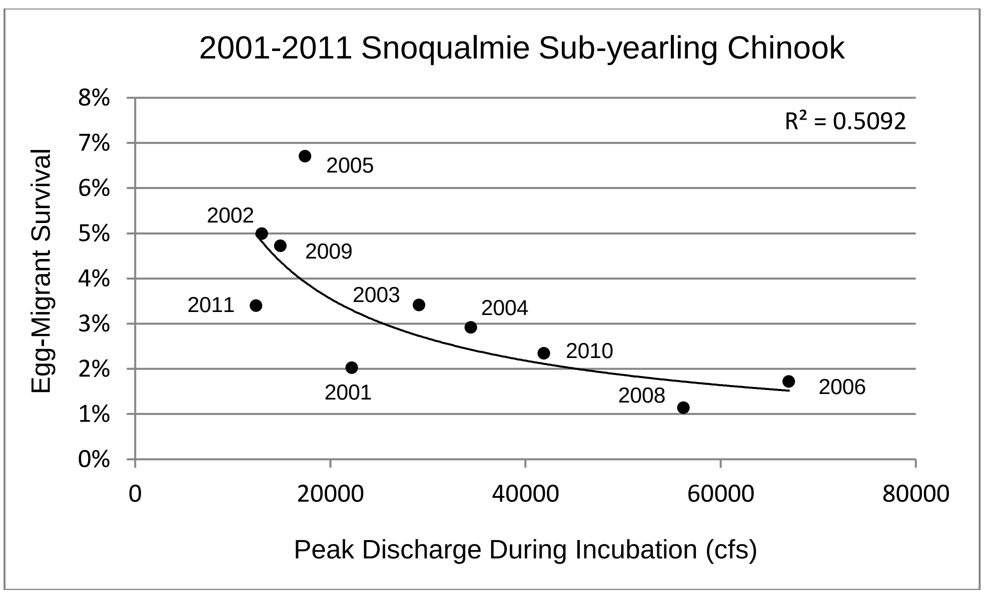
Figure 12. Posterior distributions for A&P RERs and post-conversion, FRAM, RERs for the Skykomish and Snoqualmie River Chinook populations. The vertical lines represent the median RERs and the horizontal blue bars represent 80% credible intervals.

Table 7. A&P and post-converted FRAM RER values (post-conversion) for the Skykomish and Snoqualmie River Chinook populations. Parentheses include 80% credible intervals.

	A&P	FRAM (post-conversion)	FRAM (new post-conversion)
Skykomish Ricker	0.31(0.09,0.49)	0.184(0.135,0.225)	0.22(0.156,0.271)
Skykomish Beverton Holt	0.42(0.22,0.58)	0.198(0.159,0.247)	0.24(0.192,0.302)
Snoqualmie Ricker	0.39(0.18,0.56)	0.196(0.156,0.245)	0.239(0.187,0.302)
Snoqualmie Beverton Holt	0.47(0.26,0.58)	0.206(0.168,0.259)	0.252(0.203,0.317)
Skykomish	0.37(0.14,0.55)	0.191(0.147,0.238)	0.23(0.174,0.29)
Snoqualmie	0.43(0.22,0.58)	0.201(0.161,0.253)	0.246(0.195,0.31)

Habitat Conditions

Analysis of subyearling smolt outmigration concluded that in both the Skykomish and Snoqualmie Rivers, outmigrant abundance was negatively correlated with peak winter flow (Kubo et al. 2013), particularly in the Snoqualmie (Figure 13)



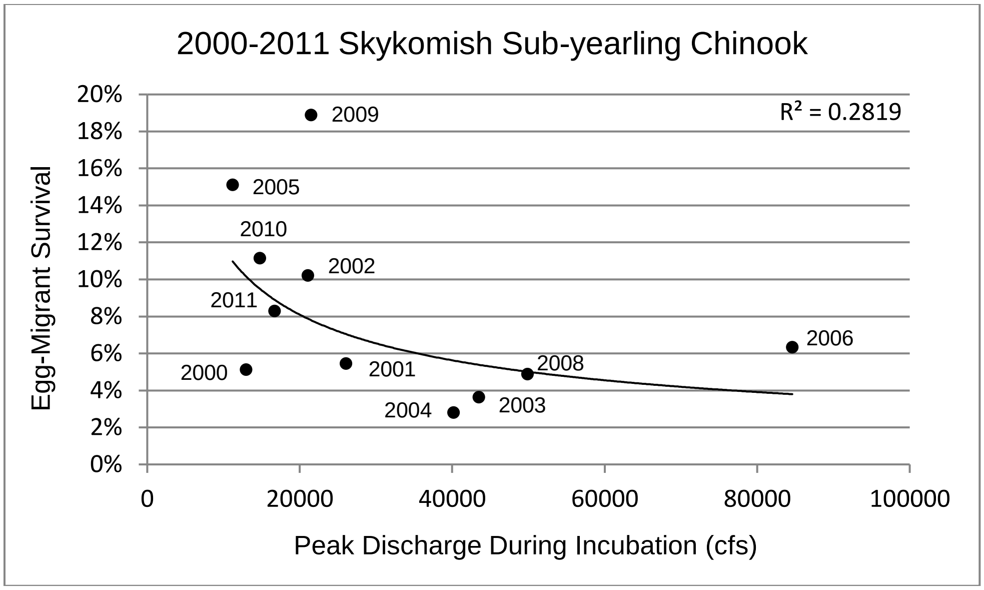


Figure 13. Egg-to migrant survival plotted against peak discharge during incubation for sub-yearling Chinook in the Snoqualmie and Skykomish Rivers from brood year 2001-2011 (Tulalip unpublished data 2015). The incubation period was estimated using a three-month period, which started 15 days before peak spawning (peak spawner/redd counts).

Basin position and channel cross-sectional profiles (e.g., gradient, confinement and bankfull width) in the Snoqualmie are much different in the Snoqualmie than in the Skykomish, which may differentially affect red scour and sedimentation of incubating eggs and thus differentially affect egg-to-smolt productivity as measured here. Lower summertime flows in the Snoqualmie relative to the Skykomish may exacerbate the magnitude of flow change and thus redd scour. Peak flows have the potential to kill large numbers of deposited eggs either through suffocation from sediment deposition or by displacement from gravel scour (Healy 1991). The observed variation in egg-to-migrant smolt abundance and survival appears to be more strongly influenced by peak flows during incubation in the Snoqualmie than in the Skykomish basins (R^2= 0.31 for the Skykomish and 0.63 for the Snoqualmie; Figure 13). Peak flows have the potential to kill large numbers of deposited eggs either through suffocation from sediment deposition or by displacement from gravel scour (Healy 1991).

These and other habitat perturbations may also limit available refuge from peak temperature and events more so in the Snoqualmie than in the Skykomish. This high survival may be a result of low discharge, relative change in discharge, or one of the other factors described here. It should be noted that variability across sub-basins in the timing and magnitude of peak discharge, and their effect during incubation and early rearing, may not be fully captured in these analyses due to differences in precipitation regimes and hydrologic responses between sub-basins.

There are other known differences in the quality and quantity of freshwater and riparian habitat conditions in the Snoqualmie vs the Skykomish that may differentially affect freshwater productivity and relative reproductive success. For example, the Snoqualmie has much more simplified habitat with more bank-armoring and less riparian vegetation (reduce shading), known to exacerbate water temperatures. During the summer of 2015 (under the effects of the 2015 “Blob”), record high temperatures exceeding 24°C were recorded in the Snoqualmie (Joshua

Kubo King County, unpublished study 2015; Figure 14), that greatly exceeded state standards for salmon in all life stages, but particularly for adult fish holding, maturation and spawning (see green dotted line in Figure 14).

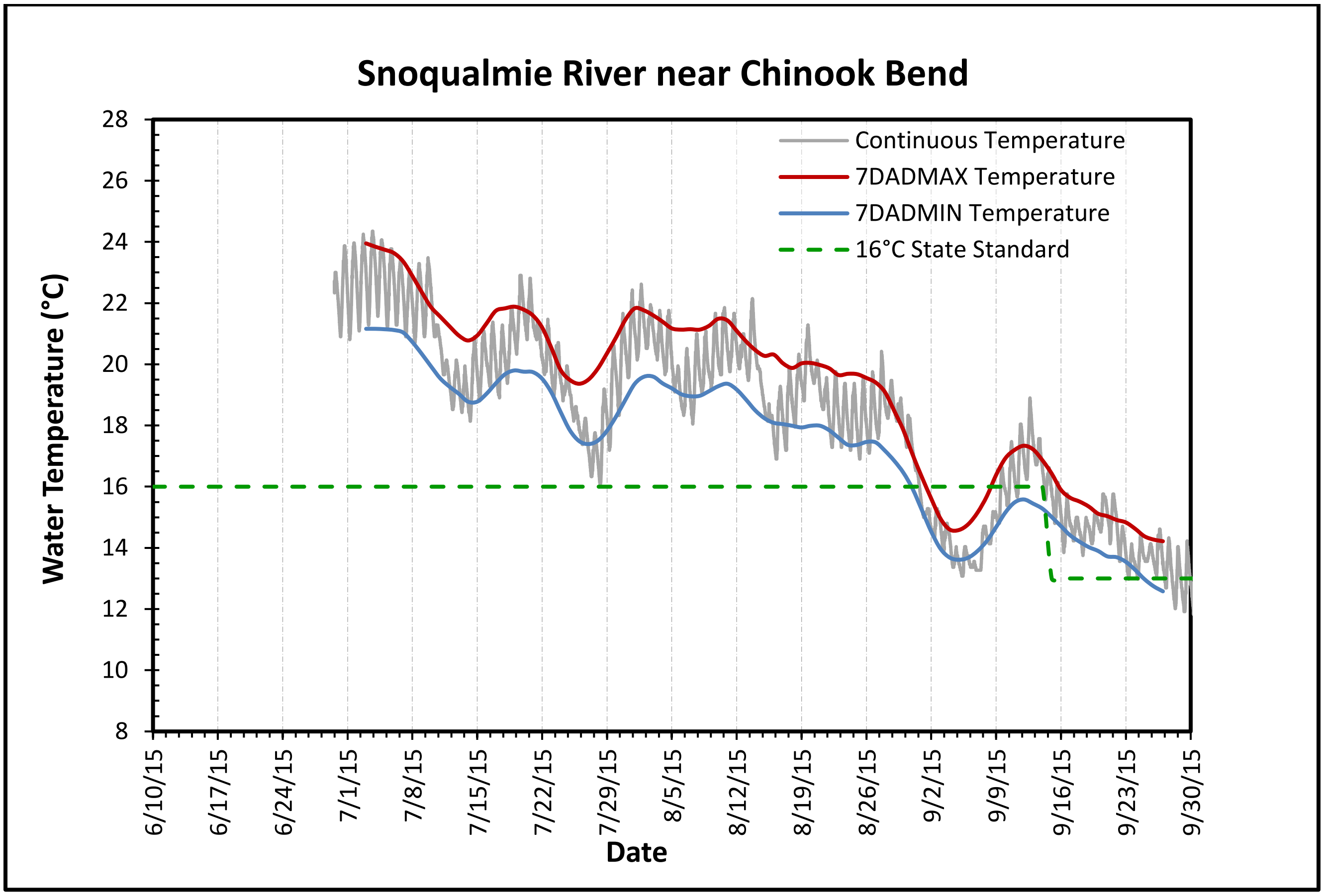


Figure 14. Record high temperatures in the Snoqualmie River basin in 2015 exceeded state standards for salmon in all life stages. Figure provided by Joshua Kubo, King County, and the Snoqualmie River Watershed 2015 Water Temperature Study.

Available refuge from peak temperature and flow events may also be more limiting in the Snoqualmie than in the Skykomish. It may be possible that lower summer and fall flows during adult holding, redd-building, and spawning in the Snoqualmie than in the Skykomish could magnify these effects by forcing Chinook to spawn almost exclusively in mainstem thalweg areas on low flow years that are becoming increasingly frequent, and exacerbating the vulnerability of eggs and juvenile fish to the effects of peak flows, which are becoming more frequent and of higher magnitude, leading to reduced egg survival. These hypotheses are supported by the observations reported above for the Snohomish and other watersheds (e.g., Skagit and Stillaguamish) (Figure 9).

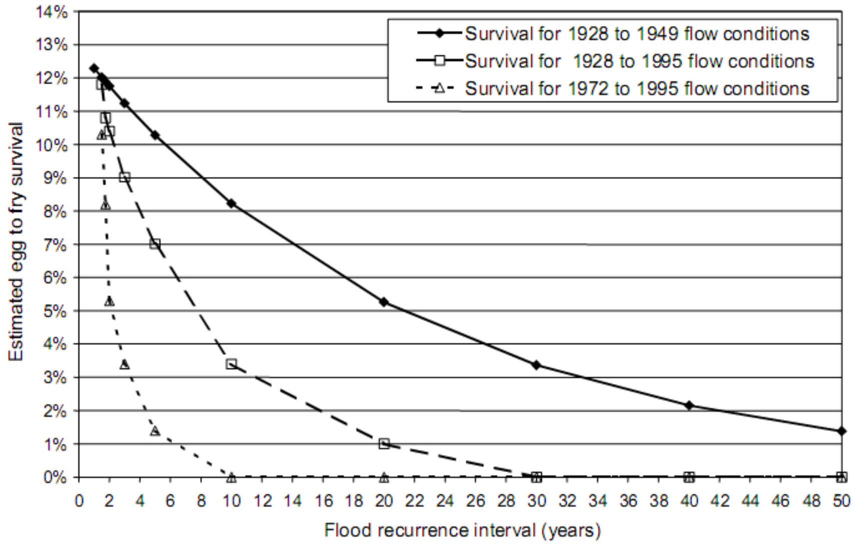


Figure 15. Reduction in egg-to-fry survival related to peak flow recurrence interval. Source: Beamer and Pess (1999).

Monitoring and Research Priorities

Hatchery Tagging and DIT Groups

Wallace River Hatchery Chinook have been coded-wire tagged since brood year 2000 with CWT releases for subyearlings starting in 2001 and yearlings in 2002. The subyearling stock is utilized as a DIT US-Canada Indicator Stock. The Tulalip Hatchery subyearling summer Chinook program was initiated in broodyear 1998, though the program did not convert to 100% summer Chinook until broodyear 2004. While this hatchery stock has been coded-wire tagged since its inception, double-index tagging was only recently initiated in broodyear 2010. It is thought that the Tulalip subyearling and Wallace yearling stocks may have different distributions and contributions to fisheries than the Wallace subyearling stock so the goal is to develop both of these as Indicator Stocks in the future.

Juvenile Monitoring

Juvenile salmonid outmigrant trapping in both the Snoqualmie and Skykomish systems has been ongoing since 2001 by the Tulalip Tribes. All of the efforts and data were summarized in a comprehensive report by Kubo et al. (2013). In addition, the Tribes and NOAA Fisheries have conducted intensive monitoring of juvenile salmonid use of Snohomish estuary since 2001, and the Tribe, in collaboration with Skagit River System Cooperative (SRSC) and NOAA Fisheries, has been monitoring juvenile salmonids in nearshore marine habitats since 2008. NOAA Fisheries is currently working with Tulalip to provide a summary report of the estuary work while SRSC, Tulalip and NOAA recently produced a comprehensive report documenting non-natal juvenile salmonid rearing in 32 out of the 63 small coastal streams that have been systematically monitored mostly since 2008 (Beamer et al. 2013).
New offshore monitoring efforts are underway by the Snohomish regional comanagers in partnership with multiple cooperators. These efforts link the extensive, existing monitoring efforts in the region with others in offshore marine areas under the Salish Sea Marine Survival Project (SSMSP). The SSMPSP is a collaborative, US-Canada international effort among the

tribes, state, federal, educational and non-profit agencies and entities to better understand the widespread variability and declines in marine survival across a variety of salmonid species in the Salish Sea. Several new studies started in 2014 in the Whidbey basin and elsewhere in Puget Sound and the Salish Sea (e.g., SeaGrant, SRFBD juvenile fish and plankton monitoring studies in key watersheds and adjacent marine areas of Puget Sound that include the Snohomish region). A Puget Sound-wide zooplankton and ichthyoplankton monitoring study linked with cooperative Canadian projects in the Strait of Georgia was initiated in 2014). These studies will provide better information on the level of interaction among species of salmonids and other fish species, and between salmonid stock components (such as hatchery vs wild, or subyearling vs yearling stocks), while also providing valuable information on food availability and fish growth that are known to affect survival.

These studies, envisioned to continue annually and be refined into the future, afford unique opportunities to gain insight on the biology of juvenile salmonids during their early marine residency that will improve management (e.g., forecasting abundance and survival). This will also enable comanagers to assess the extent to which overlap occurs with juvenile hatchery program fish and other fish, including other species of other fish species, and other salmon species including ESA-listed juvenile Chinook and steelhead in freshwater, estuarine, and marine environments.

The new marine monitoring will link existing freshwater, estuarine and nearshore monitoring with offshore studies of all fish species encountered to track natural- and hatchery-origin salmonids as they move offshore by examining their entire community of predators and prey, including plankton and numerous physical and oceanographic indicators that are thought to affect marine survival (e.g. salinity, upwelling, temperature, and freshwater flow inputs among others).

Monitoring of Adult Escapement and HOR/NOR

Escapement estimates of naturally spawning Chinook salmon returning the Snohomish watershed are calculated from cumulative redd counts made from physical surveys of all known spawning grounds, and from counts of adult fish passed at Sunset Falls. Survey methods include ground-based foot and float surveys, and aerial surveys done from a helicopter. Every carcass encountered on the ground is checked for adipose fin mark status and CWT presence and scales and otoliths are collected as well as tissues for DNA analysis. The proportion of hatchery-origin fish is estimated for each reach using a combination of mark status, CWT presence and otolith mark status. Because the relative proportions of hatchery contribution vary greatly among the sub-basins, the proportion of hatchery- and natural-origin fish in each reach is applied to the escapement estimates for that reach to derive the stratified NOR/HOR escapement estimate.

Genetic-Based Monitoring

Standard, demographic-based estimates of abundance and productivity are known to include several types of biases and variability that are not quantifiable. This is further complicated when trying to parse out hatchery- vs natural-origin stock components or understand, e.g., genetic interactions. For example, the presence of hatchery-origin fish on spawning grounds does not necessarily comport to gene flow because the degree of temporal-spatial sympatric spawning among natural- and hatchery-origin stock components is known to affect gene flow and reproductive success. Live fish and redd counts have inherent biases. Redd identification, carcass detection, and distinguishing marks on carcasses all have unknown associated errors and the variability of these demographic-based estimates cannot be quantified with accuracy.

Demographically-derived abundance methods (e.g., live fish passed, live spawner counts, redd surveys) are being compared to genetically-derived abundance estimates in the basin, e.g., genetically-effective population size (Ne) or the effective number of breeders. Demographic-based productivity estimates (e.g., smolts per female or per spawner, adult replacement rates) are being compared to genetically-effective migrants per generation (Nm).

Snohomish region comanagers are using transgenerational genetic mark-recapture (tGMR) to estimate census population size at the time of spawning and the effective number of breeders. The genetic-based abundance estimate will be partioned for natural spawning Chinook by origin, sex, and age, and compared to demographic-based estimates. This research might help in developing a redd expansion calibration factor that could potentially be used to adjust historical (or future) redd-based escapement estimates. In combination with system-wide production estimates from the smolt trapping efforts, this ongoing research will allow the estimation of relative productivity for hatchery- and natural-origin spawners, (“effective” proportions of natural- and hatchery-origin fish ($pNOS_G$ and $pHOS_G$) and the expansion estimates to each Snohomish Chinook population.

The comanagers also plan to compare demographic-based estimates of relative productivity of natural- and hatchery-origin fish to more direct, DNA-based, quantifiable estimates of relative productivity and gene flow (Nm/Ne; effective migrants per generation/effective population size). Demographic estimates of the proportions of hatchery-origin spawners ($pHOS_D$) are being compared to proportions of genetically-effective hatchery-origin spawners ($pHOS_G$) and used to derive a DNA-based estimate of gene flow, known as the Proportion of Natural Influence (PNI_G) that can be compared to the demographic-based estimate of gene flow (PNI_D).

Lake Washington Management Unit Status Profile

Component Populations

Cedar River Fall
Sammamish River Fall[23]

Geographic Distribution

The Lake Washington basin (Figure 1) is one of the most altered and degraded basins in Washington State. Lake Washington lies within King County Washington which has over 2.0 million residents. Historically, the basin drained through the Black River into the Duwamish River. Chinook had access to the Cedar River from the confluence of the Black and Duwamish rivers upstream to Cedar Falls at RM 34.5. In 1901 Landsburg Dam was constructed at RM 21.8 and blocked access to the upper Cedar River watershed. In 1916, the Cedar River was diverted away from the Black River and into Lake Washington when the Hiram M. Chittenden Locks and Ship Canal was completed. These actions resulted in the lake elevation being lowered 9 feet and all discharge from the basin exiting through the newly constructed locks.

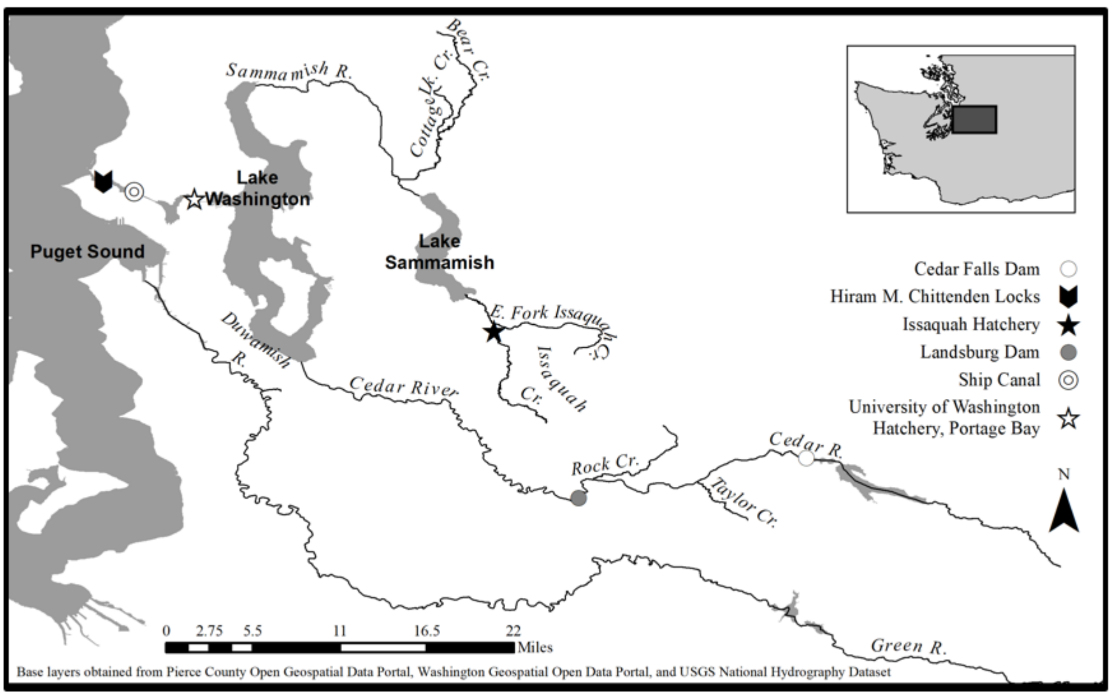


Figure 1. Location of the Lake Washington watershed and associated prominent features discussed throughout this Management Unit Profile.

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[23] TRT defined population. Recent genetic and demographic data indicates that this is not a viable population and the historical population, if one existed, was extirpated.

Cedar River

Fish passage facilities were completed at Landsburg Dam in 2003, and Chinook may now access suitable spawning areas upstream to Cedar Falls (Figure 2). The majority of spawning still occurs in the mainstem Cedar River upstream of RM 5.0 to Landsburg Dam (Figure 1), but Chinook also spawn in two Cedar River tributaries, Rock Creek and Taylor Creek.

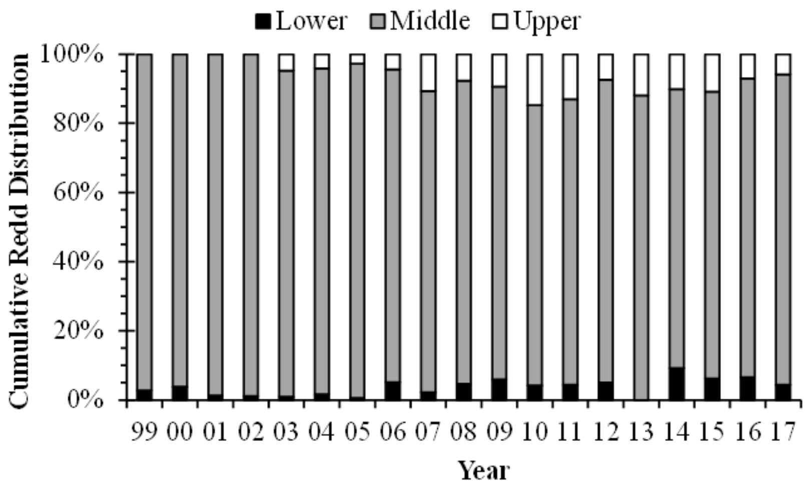

Figure 2. Distribution of Chinook spawning in the Cedar River from natural origin and hatchery origin recruits that voluntarily spawn in the river. The lower is a stretch from RM 0.0 to RM 5.0, the middle river section is from RM 5.0 to Landsburg Dam (RM 21.8) which includes spawning in Rock and Taylor creeks, and the upper river section is from Landsburg Dam to Cedar Falls (RM 34.5).

Sammamish River

The Sammamish River flows from Lake Sammamish into Lake Washington. In the Sammamish River, Chinook primarily spawn in Bear Creek with intermittent spawning in Little Bear Creek (Figure 1). Approximately 10.0 of the 12.4 miles of Bear Creek are accessible to Chinook, but most spawning occurs between RM 4.3 and 8.8. Spawning also occurs in the lower 3.5 miles of Cottage Lake Creek, a tributary to Bear Creek. In Little Bear Creek, there is 3.8 miles of spawning habitat. No Chinook spawning occurs in the Sammamish River mainstem due to a lack of suitable habitat in the low-gradient, heavily silted channel.

Additional spawning occurs in Issaquah Creek, which flows directly into Lake Sammamish (Figure 1). Spawning in Issaquah Creek occurs predominately in the reach between RM 1.0 and the Issaquah Hatchery at RM 3.2. Surplus adults are passed above the Issaquah Creek Hatchery weir to access additional spawning habitat (approximately 4-12 river miles, depending on flow), but are not part of the spawning escapement calculations in Issaquah Creek. Limited spawning occurs in the first 1.0 miles of the East Fork Issaquah Creek.

Life History

Adult salmonid counts are conducted at the Hiram M. Chittenden Locks from June 12 – October 2, and adult Chinook have been observed throughout this period. After a variable migration through the lakes, Chinook begin entering spawning tributaries from mid-August through early November and most spawning is complete by mid-November. The average age composition of adult natural-origin returns between 2003 and 2016 was 36% age-3, 60% age-4, and 4% age-5. The age composition is a composite between the Cedar River and Sammamish River returns due to the limited number of natural origin recruits collected in Sammamish River (average 19 per year) versus the Cedar River (average 163 per year).

Juvenile Chinook trapping occurs in both the Cedar River and Bear Creek (Kiyohara 2015). From 1998-2013, the proportion of juveniles emigrating as fry averaged 79% in the Cedar River but ranged from 34-98%. Conversely, fry emigration in Bear Creek averaged 19% and ranged from 4-56%. The remainder of emigrants were parr in both systems as no yearlings were encountered. The early emigrating fry rear in lacustrine habitat, with an unknown survival rate to smolt. Smolt emigration through the locks is protracted, beginning in May and continuing up to September when environmental (e.g. temperature and flow) conditions allow.

Historically, juvenile Chinook from the Cedar River population would have emigrated through the Black River and into the Duwamish River Estuary. Juvenile salmonids initially rear in lacustrine habitat in Lake Washington. Out of 55 natural origin adults examined in the Cedar River, no adults were found to have emigrated to marine waters in Puget Sound at < 60 mm (Campbell and Claiborne 2017). The median length at emigration to marine waters for successfully recruiting adults was approximately 90 mm and is the largest size at emigration in Puget Sound. The smallest successful emigrant was ~75 mm which is larger than the median size at emigration for North Puget Sound (i.e. Nooksack, Skagit) populations. In addition, Lake Washington contains a robust introduced piscivorous fish community (MIT 2017). After salmonid smolt releases from Issaquah Creek Hatchery, over 60% of smallmouth bass (*Micropterus dolomieu*) stomachs sampled (n=398) contained juvenile salmonids (coho and Chinook). Rearing habitat in Lake Washington can produce large bodied Chinook smolts, but at the cost of much greater predation risk.

Hatchery Production

The first recorded plants of juvenile Chinook into the Lake Washington basin occurred in 1901, and intermittent plants continued for decades. Chinook were first released into Issaquah Creek from the Issaquah Creek Hatchery in 1936 and Portage Bay from the University of Washington (UW) Hatchery in 1950. Beginning in 1952 when standardized record keeping began, Chinook have been periodically released into many of the tributaries in the basin, primarily from Issaquah Creek and Green River hatchery production. Hatchery stocks at both Issaquah Creek Hatchery and the UW Hatchery were principally derived from the Green River hatchery stock.

The only current hatchery production of Chinook in the Lake Washington basin occurs at Issaquah Creek Hatchery. The University of Washington Hatchery program was discontinued after release of the 2009 brood year (Figure 3A). Issaquah Creek Hatchery production averaged

2.6 million sub-yearling smolts for brood year 2016-2020, while the current production objective is 3.0 million sub-yearling smolts and will increase consistent with approval of the Lake Washington Hatchery and Genetic Management Plan. Terminal return rates for the University of Washington hatchery program were highly variable, but almost always greater than return rates from the Issaquah Creek hatchery program (Figure 3B). Both programs generally increased throughout the 1990s and early 2000s then dropping sharply between 2005 and 2008.

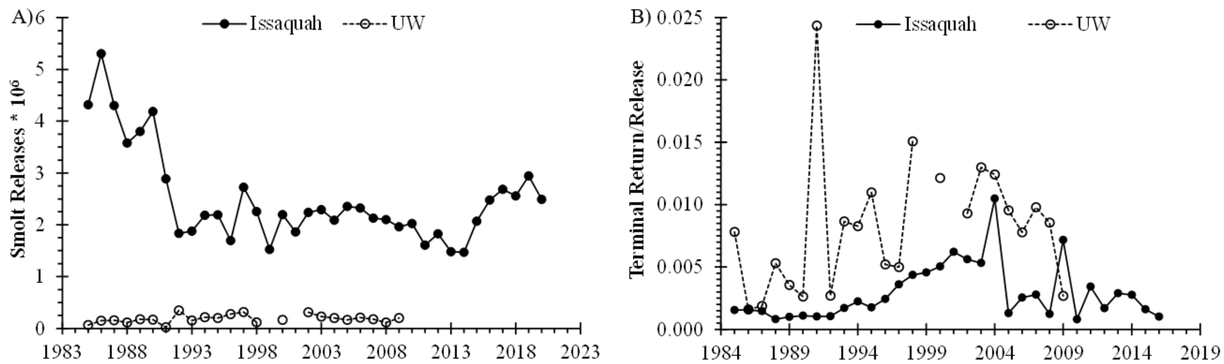

Figure 3. A) Smolt releases from Issaquah Creek Hatchery and the University of Washington Hatchery from brood year 1985-2020and B) smolt to adult (age 3-5) terminal return of completed broods for 1985-2016 at both Issaquah Creek Hatchery and University of Washington Hatchery.

The co-managers are continuing to evaluate options for increasing salmon productivity in Lake Washington, consistent with the joint urban watershed management strategy currently being developed by the Muckleshoot Indian Tribe and the Washington Department of Fish and Wildlife and the agreed to Hatchery and Genetic Management Plans (HGMP) for the basin. Lake Washington (and other Puget Sound) Chinook are well below the planning ranges for recovery escapement, as well as below spawner recruit levels identified as consistent with recovery. Until habitat function is restored, hatchery production will be essential to harvest opportunity in highly urbanized watersheds like Lake Washington.

Genetic Information

A comprehensive review of the available genetic data from naturally-spawning and hatchery produced Chinook in the Lake Washington basin found no evidence to support a conclusion that the naturally-spawning aggregations of Chinook in the Lake Washington basin are anything other than a single genetic population nor are different than other Green River derived populations (Warheit and Bettles 2005; Ruckelshaus et al. 2006).

Status

The Cedar River Chinook population is managed for total natural spawners by an escapement goal that is assumed to provide protection for the Sammamish River population. Spawners have ranged from 135 to 2,247 on the Cedar River (Figure 4A) and from 182 to 2,303 in the Sammamish River (Figure 4B) basin from 1988-2016 (Table 1). Total spawners on the Cedar and Sammamish River declined throughout the 1990s but began a rapid increase to levels seen today. The NOR component of the Cedar River population is moderately productive compared to other Puget Sound populations. Total spawners in both systems have been higher and more variable since the early 2000s. Since 2001, the average NOR return to the Cedar River has been 938. There have been 12 complete broods produced during this time (2001-2012), 6 have observed productivities >1 and 6 have observed productivities <1. The average productivity was 1.33 recruits/spawner, but was not significantly different than 1, indicating the population is stable. This suggests that the Cedar River NOR population is at the current capacity of the habitat. NORs made up about 80% of the spawning population on the Cedar River across the time series while making up less than 20% of adults on the spawning grounds in the Sammamish River population (Figure 4C). Due to the long history of hatchery production and habitat degradation in the basin, hatchery produced Chinook are an important component of natural spawning escapement. Protecting and ensuring hatchery production meets program goals are vital in urban systems (Figure 4D).

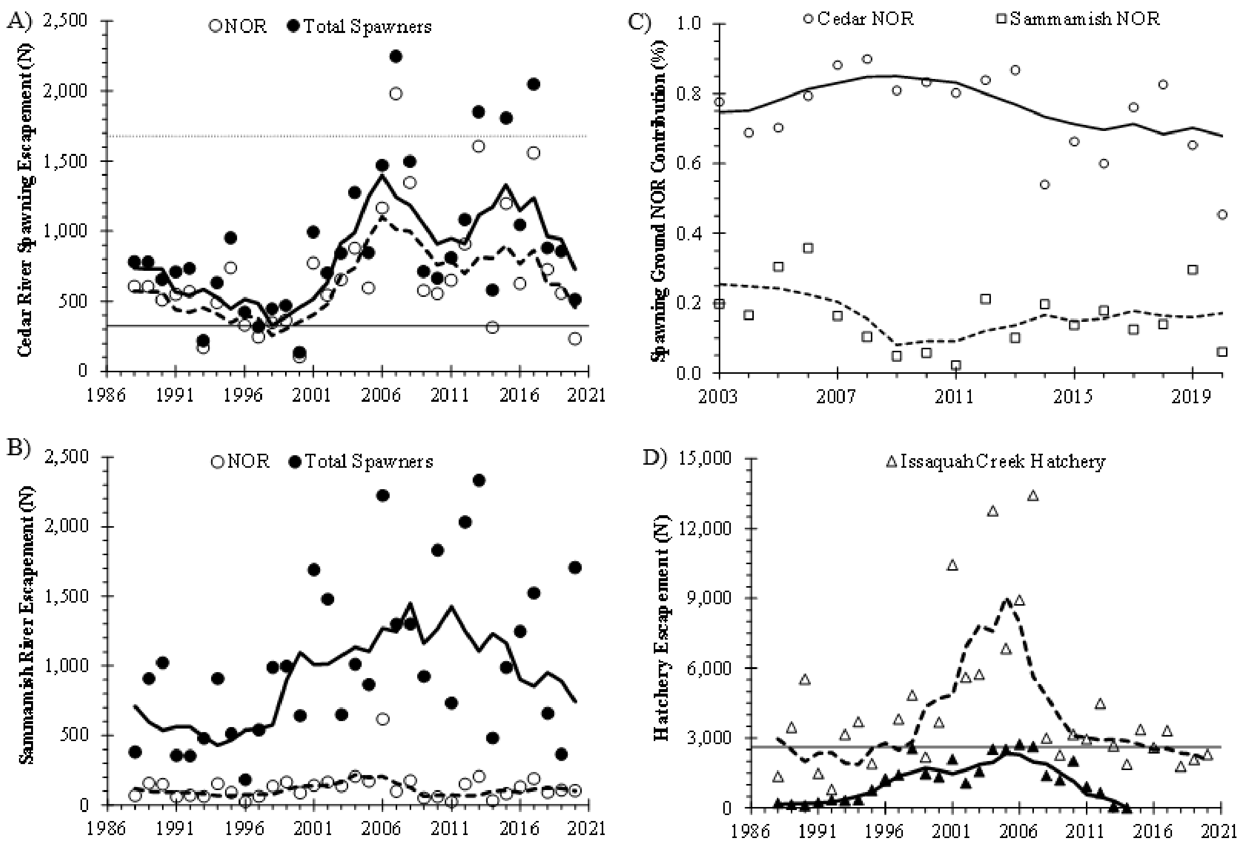

Figure 4. Observed NOR (open circle) and total (filled circle) escapement on the Cedar River (A) and Sammamish River (B) from 1988-2020. A 5-year running geometric mean for total escapement (solid line) and NOR escapement (dashed line) is fit to each data series. The Cedar River interim escapement goal of 1,680 spawners (lite dashed line) is contrasted with the MSY of 324 natural spawners (lite solid line) which is based on current habitat conditions. There is no historic or MSY based escapement goal on the Sammamish River population. Observed NOR Chinook contribution (C) to the Cedar River (open circle) and Sammamish River (open square) spawning grounds from 2003-2020 with a 5-year running geometric mean. Observed hatchery escapement (D) at Issaquah Creek Hatchery (open triangle) from 1988-2020 and University of Washington Hatchery (closed triangle) from 1988-2014 is shown with a 5-year running geometric mean. The hatchery escapement goal of 2,600 adult Chinook needed to make current program goals at Issaquah Creek Hatchery is shown (lite solid line).

Table 1. Natural origin recruits from the Cedar River and Sammamish River populations and hatchery origin recruits from Issaquah Creek hatchery (ICH) and University of Washington hatchery (UWH) that escaped pre-terminal and terminal fisheries. Recruits/Spawner (R/S) includes all adult NORs caught in pre-terminal and terminal fisheries or counted on the spawning grounds in the Cedar or Sammamish rivers. Pre-terminal mortalities from the 1988-2014 brood years are based on FRAM 7.1.1.

	Cedar		Sammamish		Hatchery Return	
Return Year	NOR	R/S[a]	NOR	R/S[a]	Issaquah	UW
1988	781	4.09	381	1.00	1,359	207
1989	780	2.63	909	0.63	3,473	148
1990	655	1.90	1,023	0.60	5,541	106
1991	710	2.35	356	1.01	1,489	223
1992	734	1.55	353	0.54	796	346
1993	218	2.78	479	0.56	3,159	321
1994	632	0.96	909	0.44	3,703	360
1995	952	0.71	513	0.65	1,907	767
1996	423	1.09	182	1.18	1,246	1,167
1997	317	3.31	540	0.37	3,815	1,417
1998	447	2.71	988	0.21	4,855	2,560
1999	470	2.29	998	0.11	2,189	1,461
2000	135	9.79	642	0.10	3,676	1,326
2001	995	1.20	1,690	0.02	10,451	2,094
2002	702	2.39	1,478	0.31	5,620	1,067
2003	842	2.38	650	0.28	5,742	1,563
2004	1,277	2.73	1,012	0.20	12,771	2,520
2005	847	1.16	866	0.03	6,852	2,513
2006	1,120	0.48	1,068	0.03	8,934	2,738
2007	1,849	0.51	685	0.19	13,431	2,637
2008	1,327	0.20	388	0.13	3,007	1,386
2009	544	4.46	80	0.04	2,280	1,187
2010	508	0.52	107	0.05	3,156	2,014
2011	576	2.21	130	0.13	2,954	906
2012	807	0.59	136	0.09	4,492	651
2013	1,477	0.99	78	0.05	2,670	46
2014	308	2.31	60	0.11	1,872	0
2015	1,140	--	175	--	3,373	NA
2016	570	--	165	--	2,596	NA
2017	1,464	--	157	--	3,321	NA
2018	629	--	105	--	1,786	NA
2019	558	--	103	--	2,076	NA
2020	233	--	59	--	2,303	NA

[a] The 1988 R/S estimate does not include Age-3 pre-terminal or terminal freshwater sport mortalities.

An interim escapement goal (i.e. Upper Management Threshold) for the Cedar River was set in 1993 at 1,200 Chinook for the river downstream of Landsburg Dam based on average escapements observed from 1965-1969. This value was updated to 1,680 based on a conversion associated with changing the escapement methodology from area-under-the-curve to a redd based methodology. In 2003, a new fish ladder allowed Chinook to pass above Landsburg Dam, increasing the complexity in determining an appropriate escapement goal for the entire sub-basin. Chinook passed above the dam have counted toward the interim escapement goal and this is reflected in the lower productivity associated with current habitat conditions based on an MSY approach. Update of the Fishery Regulation Assessment Model (FRAM) base period to include brood years 2005-2008 necessitated updating natural and hatchery escapements back to 1988 for calibration. These data were used to fit a Beverton-Holt stock recruit curve (Beverton and Holt

1957) to brood years 1988-2014 (Figure 5). For this model, a=0.0756 and b=0.0006145 which resulted in a spawning stock size at equilibrium of 1,504 and a theoretical maximum recruitment of 1,627. The spawning stock size MSY is 324 (241-398 95%CI) which is expected to result in 1,180 (1,110-1,226 95%CI) recruits. Due to uncertainty in stock dynamics at population sizes near MSY and the potential for negative genetic impacts, an escapement goal of 500 spawning adults is, on average, expected to produce 1,306 recruits.

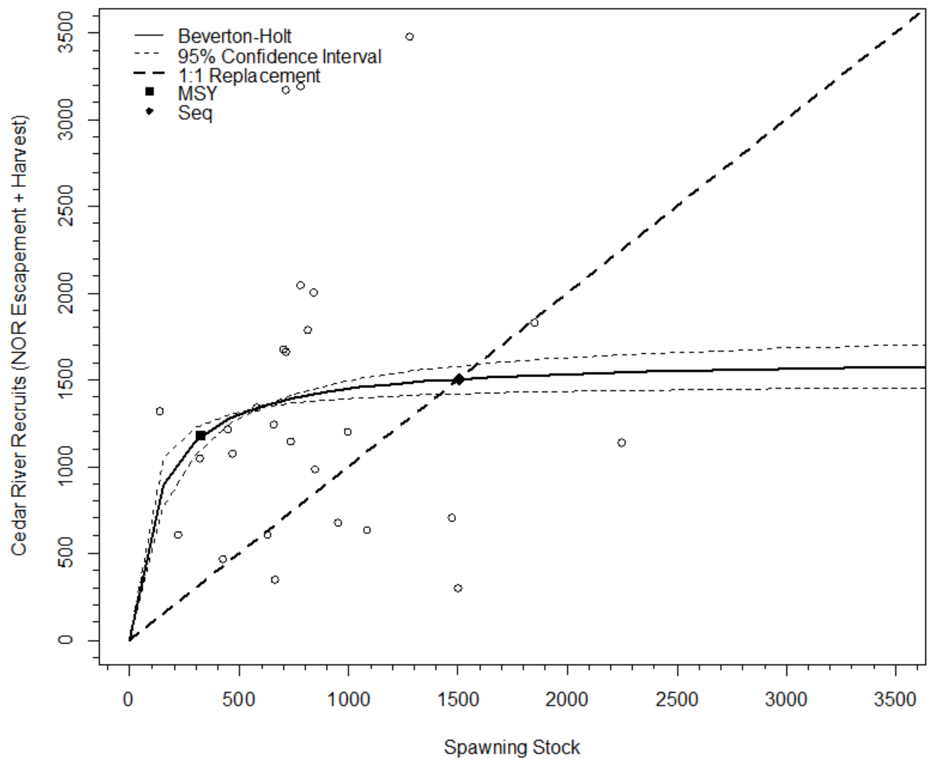

Figure 5. Beverton-Holt stock-recruit curve for Cedar River Chinook based on brood years 1988-2014. The spawning stock size at MSY is 324 (241-398 95%CI) which results in 1,180 (1,110-1,226 95%CI) recruits. The spawning stock size at equilibrium is 1,504 (1,417-1,592 95%CI) Chinook.

Uncertainty exists about the historical presence of a Chinook population in the Sammamish River sub-basin. The Technical Recovery Team concluded that one did exist (Ruckelshaus et al. 2006), although there is uncertainty about this conclusion due to a lack of documentation that Chinook were consistently produced in the Sammamish River sub-basin prior to the establishment of hatchery programs (RITT 2008).

No biologically-based escapement goal has been or can be established for the Sammamish River Chinook population. Protection of the Cedar River population was assumed to provide sufficient protection for the Sammamish River population. As previously alluded to, update of the FRAM base period necessitated reconstruction of the data necessary to fit a Beverton-Holt stock recruit curve (Beverton and Holt 1957) to brood years 1988-2014 (Figure 6). For this model, a=6.6410 and b=0.0000897 which did not result in an equilibrium stock size or spawning stock size at MSY. Recruits to the Sammamish River population exceeded replacement only for the 1996 brood return and reached replacement for the 1988 brood return. Based on current habitat conditions, the Sammamish River population is not viable and should not be included in the 22 extant independent populations of the Puget Sound Chinook evolutionary significant unit. Because the Sammamish River population is dominated by Issaquah Creek hatchery returns (87% across most recent 5-years), protection of the hatchery stock will maintain the Sammamish River stock at sufficient abundances to prevent deleterious genetic effects.

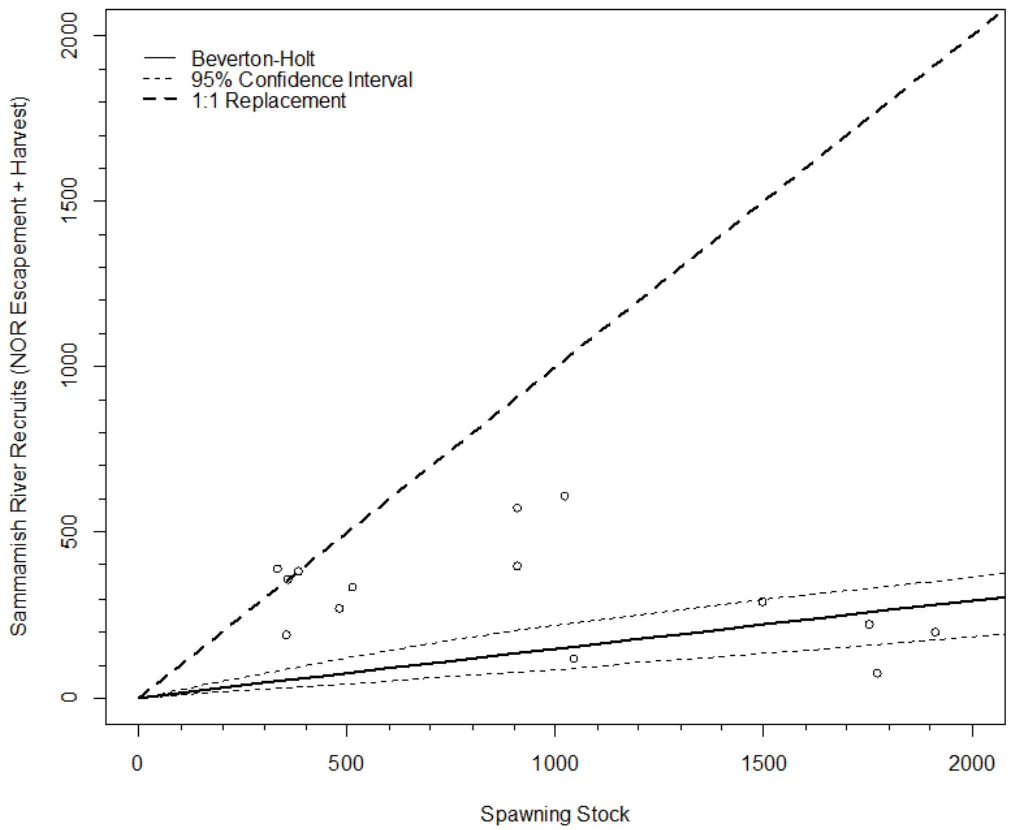

Figure 6. Beverton-Holt stock-recruit curve for Sammamish River Chinook based on brood years 1988-2014. There is no MSY for this population because only 1 brood year (1996) produced more recruits than spawners.

Recruits per spawner have been highly variable in the Cedar River population while the Sammamish River population has been consistent and poor (Figure 7). The 2000 brood year was the most productive brood with 9.8 recruits per spawner produced in the Cedar River. Only two brood years met (1988) or exceeded (1996) replacement in the Sammamish River and both occurred prior to mass marking where confidence in natural origin status determination is low. The 2006-2008 brood years were the longest set of years where recruits per spawner fell below 1.0 in the Cedar River. Escapement during these years averaged 1,738, which is well above the 906 average in the Cedar River across the available years. The equilibrium stock size is 1,504 based on modeling results (Figure 4) and is supported by observed productivities (Table 1). Spawning escapement averages 654 when productivities are >1.0 and averages 1,299 when productivities are <1.0. Delivering more than 906 adult spawners (long-term average) to the Cedar River results in poor stock productivity for this population and should be avoided to maximize natural recruitment. There is no correlation between Cedar River and Green River (r = 0.16) Chinook productivity or between Cedar River and Sammamish River (r = 0.02) natural origin populations. The average productivity for Cedar River Chinook across all brood years is 2.2 recruits per spawner whereas 3.0 recruits per spawner is the current productivity at MSY.

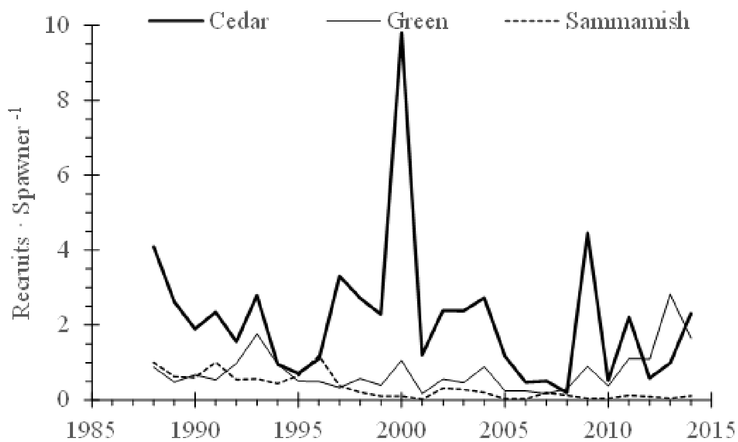

Figure 7. Trend in recruits per spawner for Cedar River (bold line), Sammamish River (dashed line), and Green River (solid line) Management unit natural origin recruits from completed brood years (1988-2014).

Harvest Distribution and Exploitation Rate Trends

Lake Washington Chinook are part of the Mid-South Puget Sound Fall fingerling FRAM stock aggregate. The FRAM base period for this stock aggregate is based upon coded wire tagged indicator groups from Issaquah Creek, Soos Creek, Voights Creek, and Grovers Creek hatcheries from the 2005-2008 brood years. The Cedar River population is the managed natural component of Lake Washington Chinook, which is modeled through terminal fisheries within the Terminal Area Management Module (TAMM).

As estimated by post-season FRAM/TAMM for Cedar River Chinook, Northern (British Columbia and Alaska) fisheries had a combined 13% average exploitation rate, the pre-terminal southern US (PT SUS) exploitation rate averaged 9% and the terminal exploitation rate averaged 5% from 2010-2014. Exploitation rates generally declined through the 1990s (Figure 8). Beginning in the early 2000s northern exploitation rates began to increase to levels near where they were in the early 1990s. Terminal exploitation rates have remained low because of no directed terminal harvest. TAMM is not configured to estimate exploitation rates for the Sammamish River population.

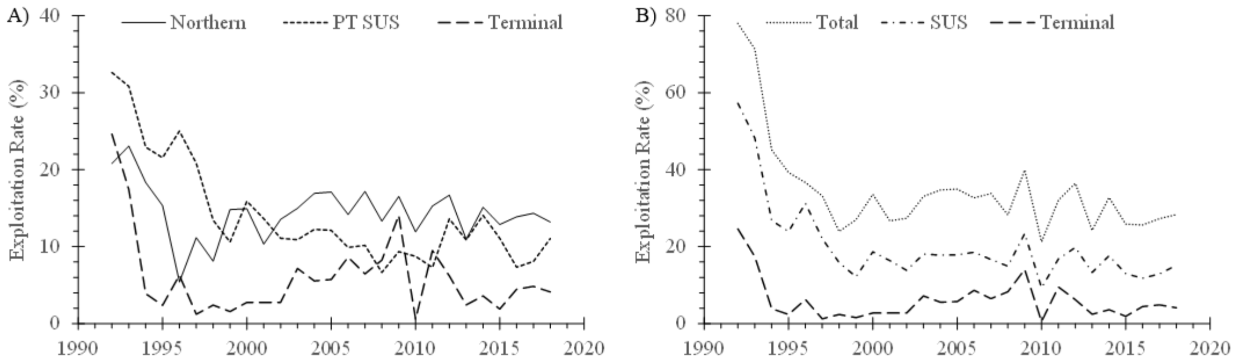

Figure 8. Trend in the A) northern (solid line), pre-terminal southern US (short dashed line), and terminal (long dashed line) exploitation rates and B) Total (dotted line), Southern US (dashed and dotted line), and terminal (long dashed line) exploitation rates on Cedar River natural origin Chinook from 1992-2018 based on FRAM version 7.1.1.

Management Objectives

Lake Washington Chinook stocks will continue to be managed for total natural escapement that includes both natural and hatchery origin adults on the Cedar River spawning grounds; as well as hatchery rack escapement at Issaquah Creek Hatchery needed to achieve program goals[1]. Cedar River escapement goals will be consistent with escapement according to MSY under current habitat conditions. The Upper Management Threshold (UMT) will be set at a conservative trigger of 500, which is above the calculated MSY, to prevent potential demographic instability as described earlier. Southern U.S. fisheries will be planned in the pre-season according to a tiered management regime that accounts for uncertainties in the pre-season forecast. Terminal directed fisheries will be planned in the pre-season when terminal run size meets the threshold abundance but will only go forward when in-season run size estimates project that natural and hatchery escapement goals will be met. The Low Abundance Threshold (LAT) is set at 40% of the escapement goal or no lower than 200 spawners to maintain genetic health. The co-managers have chosen this threshold for the LAT as a conservative measure designed to constrain pre-terminal SUS fisheries and incidental impacts in terminal fisheries which will promote rebuilding of the natural stock in as few generations as possible, and will keep the population from falling to a lower abundance that could cause demographic risk to the population.

MSY associated with current habitat condition is 324 (241-398%CI) naturally spawning adult Chinook, less than 25% of the 1,680 that were managed for under previous plans. The UMT for Cedar River spawning escapement is 500 adults. This trigger will allow a pre-terminal exploitation rate of up to 14%. If both the Puyallup River MU and the Lake Washington MU have met their respective UMTs and the Green River MU meets its upper trigger for a 15% pre-terminal ER, then all Mid-Puget Sound aggregate MUs will be managed for a 15% pre-terminal SUS ER (Table 2).

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[1] However, among pre-terminal entities, the State has agreed to take responsibility for meeting hatchery escapement objectives.

Table 2. Natural spawning escapement goals, management thresholds, and corresponding exploitation rate ceilings for stock components of the Mid-South Puget Sound FRAM stock aggregate. The moderate management threshold (MMT) is triggered when natural spawning escapement is forecasted between the low abundance threshold (LAT) and the upper management threshold (UMT). In pre-terminal fisheries the stock aggregate is managed for its weakest component MU.

Management Unit	Escapement Goal	LAT (SUS)	MMT (SUS)	UMT 1 (PT SUS)	UMT 2 (PT SUS)[2]
Lake Washington[1]	500	200[3] (12%)	18%	500[4] (14%)	500[4] (15%)
Green River	2,744	1,098 (12%)	18%	4,500 (14%)	6,700 (15%)
Puyallup River	1,170	468 (15%)	30%	1,538 (14%)	1,895 (15%)

[1] The Cedar River is the natural managed component of the Lake Washington MU
[2] If the Lake Washington MU meets its UMT and both the Green River and Puyallup River MU meet their respective upper triggers for a 15% pre-terminal ER, then all Mid-Puget Sound aggregate MUs will be managed for a 15% pre-terminal SUS ER.
[3] The LAT will increase to 300 if spawning escapement falls below 200.
[4] The UMT will increase to 570 if spawning escapement falls below 200 or below 324 in two consecutive years.

Hatchery escapement will be managed for an approximate 2,600 adult escapement goal or as modified by agreement of the co-managers (Figure 4D); this may be a constraining factor for planning Puget Sound (sport and terminal) fisheries. Annual variations in abundance of hatchery and natural Chinook may require additional in-season terminal fishery management to ensure both the hatchery and Cedar River escapement goals are met. The LAT, based on a calculation of 40% of the natural spawning escapement goal is 200 adult Chinook which also serves to maintain genetic health of the stock (McElhaney et al. 2000). The lowest observed natural spawning escapement on the Cedar River was 135 in 2000, which produced over 1,300 recruits from that cohort.

Consistent with Cedar River Chinook exceeding the UMT, the PT SUS fisheries will be planned not to exceed a 14% (15% if criteria in the Green River and Puyallup River UMT 2 are met; Table 2) exploitation rate, and directed Chinook fisheries will be planned in the terminal area (10F/Lake Washington Ship Canal, 10G/North Lake Washington, 10C/South Lake Washington, and 10D/Lake Sammamish). Combined terminal fisheries will be designed to achieve spawning and hatchery escapement at or above management objectives. Unlike other mid-Puget Sound management units, the Cedar River population will be managed to meet its UMT threshold (500 adult spawners) and not the MSY abundance (324 adult spawners). The co-managers do not believe terminal fisheries are likely during the life of this plan due to insufficient hatchery surplus. Since 2001, an average of 1,133 adults has spawned in the Cedar River with over 70% of these being natural origin. This will allow the population to test habitat recovery projects and their impacts to survival in this basin while allowing the co-managers time to fully evaluate the productivity of the population since passage was restored at Landsburg Dam.

If FRAM/TAMM pre-season model output of natural spawning escapement falls between the UMT and LAT, the SUS fisheries will implement the moderate management threshold (MMT) where SUS fisheries will not exceed 18% (pre-terminal + terminal) ER. With this approach, terminal fisheries planned in the pre-season at the MMT will have only incidental impacts to Chinook as fisheries will be directed at other salmonids. Under previous plans, pre-terminal fisheries were managed up to an allowable rate when abundances were above the LAT and terminal fisheries were constrained to incidental impacts when forecasted abundances were below the UMT. When forecasted abundances fall within the newly defined MMT, the intent is to manage this stock conservatively and at a lower SUS ER than under previous plans. While these fisheries are modeled and planned in the pre-season North of Falcon process, terminal fisheries will continue to be managed according to an in-season update (ISU) model (described below) that will serve to open fisheries that were not modeled in the pre-season or further constrain fisheries that were modeled in the pre-season depending on observed abundances.

If FRAM/TAMM pre-season model output of natural spawning escapement falls below the LAT, a critical exploitation rate ceiling of 12% will be implemented for SUS fisheries (pre-terminal + terminal). Under this approach, terminal fisheries planned in the pre-season at the LAT will have only incidental impacts to Chinook as fisheries will be directed at other salmonids. Under previous plans, management when the forecast was below the LAT included a 10% pre-terminal ER and a terminal minimal fisheries regime. This plan is for a 12% SUS ER which is more constraining. The 12% SUS ER will be allocated between terminal and pre-terminal fisheries during the annual North of Falcon process. Due to the use of in-season monitoring and management in the terminal area, a Chinook abundance may be observed that is sufficiently greater than UMT such that limited directed terminal fisheries could be prosecuted which would result in higher exploitation rates in the terminal area than modeled in the pre-season, but would still allow both natural spawning and hatchery escapement goals to be met. The lowest SUS ER observed was 8.9% in 2010 and is the only time since 1992 the SUS ER has been below 12% according to post-season validation runs.

During the annual North of Falcon process, Puget Sound (sport and terminal) fisheries will be planned to meet the broodstock needs at Issaquah Creek Hatchery. Even when expected abundance of Chinook returning to the Cedar River to spawn naturally is above the UMT, it is possible that additional fishery actions may be necessary to ensure broodstock needs at the hatchery are met. Broodstock needs at Issaquah Creek Hatchery will be calculated based on pre-spawn mortality in the adult holding ponds, fecundity, male-to-female ratio and egg-to-smolt survival rates, each of which the co-managers will discuss and agree upon during the pre-season planning process. Further in-season actions consistent with the agreed to HGMP will guide actions that may be required to meet natural spawning and hatchery escapement goals as additional information becomes available.

While directed terminal fisheries are planned when the FRAM/TAMM model output of terminal run size exceeds the spawning and hatchery objectives, terminal fisheries will only proceed when in-season information corroborates pre-season expectations. In the Lake Washington basin, in-season information from adult salmonid counts made at the Hiram M. Chittenden Locks is used. This methodology will be used to project harvestable surplus in-season to allow terminal fisheries when terminal run sizes are projected to exceed escapement objectives for the Cedar River spawning grounds and Issaquah Creek Hatchery, or to constrain those fisheries when escapements do not meet management objectives. Regardless of pre-season forecasts, in-season updates will be used to manage terminal area fisheries which may serve to open or close terminal fisheries. In the case where no directed terminal fisheries were modeled in the pre-season (i.e. management at the MMT or LAT), Chinook directed fisheries may be implemented in terminal areas by agreement of the terminal area co-managers (Muckleshoot Indian Tribe, Suquamish Indian Tribe, and Washington Department of Fish and Wildlife) when data indicate a harvestable surplus of both Cedar River natural spawners and Issaquah Creek Hatchery broodstock. In those instances, the total SUS ER may increase over pre-season expectations; but natural spawning and hatchery escapement goals will be met (2,600 hatchery escapement and 500 spawners on the Cedar River). The in-season update method and terminal area fisheries that are based on this update will be agreed to by the terminal area co-managers prior to implementation. As noted previously, hatchery escapement needs will be reviewed, updated, and agreed to annually by the co-managers and available during the pre-season planning process.

In-season Update and Other Terminal Fishery Management Measures

The Lake Washington in-season update is based on counts from salmon entering Lake Washington through the fish ladder and lock chambers at the Hiram M. Chittenden Locks and projects the total run size entering Lake Washington. Salmon are counted (by species and mark status) daily from June 12 through October 2. Chinook counts are aggregated (marked and unmarked) into weekly bins and used to project the run size entering Lake Washington. Up to 12 weekly bins are available but performance of the models begins to asymptote at about week 7 (early August when approximately 15% of the run has entered Lake Washington). Data are evaluated weekly during the Chinook migration period to continually assess the status of the run and plan terminal fisheries. This model is updated annually and its performance will be reviewed prior to any in-season fisheries decisions.

Overall performance of this model is similar to models from dam counts in the Columbia River which makes for one of the strongest ISUs in Puget Sound (Figure 9). Average error is 7.4% and mean absolute error is 26.0%. Over the most recent 10 years (2012-2021), there has been a 1,565 Chinook difference between model projections and post season terminal run size with most projections lower than observations.

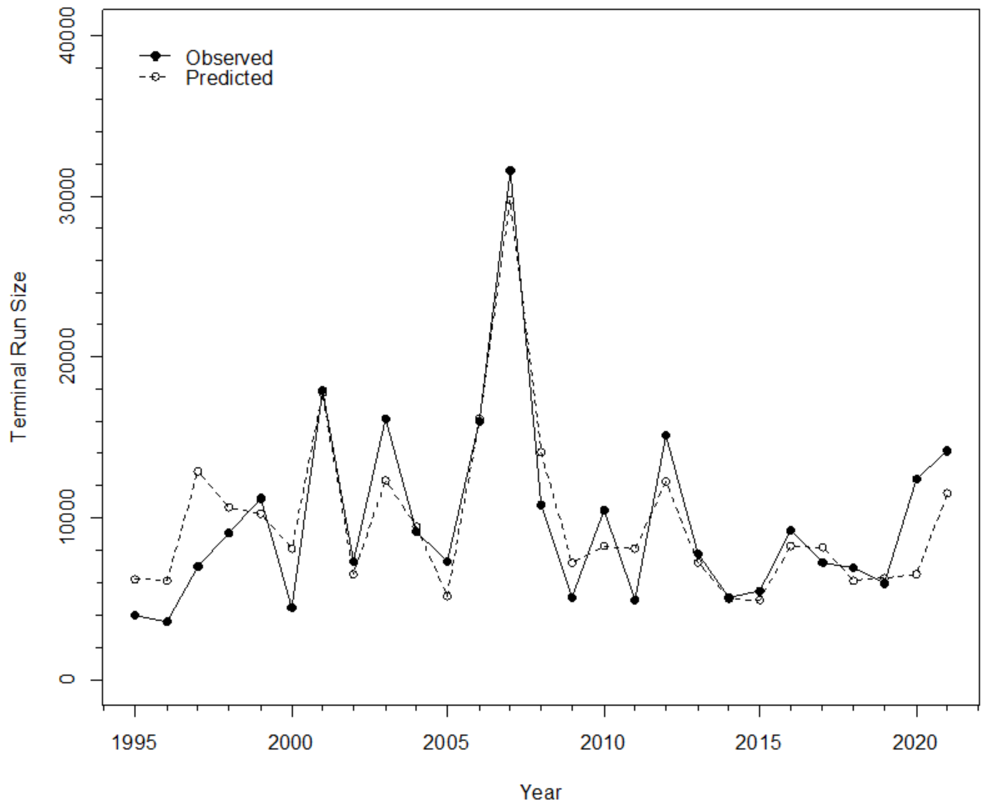

Figure 9. Observed terminal run size (solid line) based on post season run reconstructions and projected terminal run size based on locks counts in Lake Washington.

While there is some uncertainty in annual ERs from northern fisheries (British Columbia and Alaska) on Lake Washington Chinook (Figure 8A), the recently negotiated 2019 Pacific Salmon Treaty was intended to continue reducing these impacts. The management for Cedar River Chinook salmon relies on a scientific assessment of stock productivity that is linked to a fishery management control system that includes pre-season forecasts, FRAM modelling, in-season updates, as well as in-season schedule and management adjustments. There are uncertainties in each of these management tools and therefore they will be continuously evaluated and refined as potential improvements are identified. To ensure the efficacy of the fishery management control system in meeting goals, the following adaptive management scenarios and modifications will be pursued:

> Scenario 1: The in-season estimate predicted a terminal run that exceeded 500 Chinook salmon, terminal fisheries were implemented, but the spawning escapement was less than 200 adult spawners.
> Adaptive Management Action: In the following year, the UMT will be increased to a terminal run of 570 adults and the LAT spawner level to 300 adults.
>
> Scenario 2: On two occasions over a five-year period, the in-season estimate predicted a terminal run that exceeded 500 adults, terminal fisheries were implemented, but the spawning escapement was less than the MSY spawner level of 324 adults.
> Adaptive Management Action: In the year following the second occurrence, the UMT will be increased to a terminal run of 570 adults and the LAT spawner level to 300 adults.

Data Gaps and Information Needs

Table 3. Data gaps in Lake Washington Chinook stock assessment and harvest management, and research required to address those data needs.

Data gap	Research needed
Estimates of return per spawner and egg to emigrant productivity	Juvenile emigrant trapping in Issaquah Creek.
Updated escapement estimates for Sammamish population	Stream life estimates for AUC validation in Bear/Cottage Creek, and assessment of fall-back rate from fish passed above the Issaquah Hatchery weir.
Uncertainty in run size estimates at the Chittenden Locks relative to spawning ground surveys	Evaluation of counting methods and data expansions for the large locks chamber and fish ladder.
Juvenile emigrant survival by stock	Estimate mortality associated with juvenile passage at the Chittenden Locks, mortality in the lakes and residualism.
Invasive piscivores	The diet composition of invasive piscivores has been characterized many times but the impact cannot be modeled until population sizes of piscivores are known.
Pre-terminal in-season update models	In partnership with terminal and pre-terminal Tribes and State, examine relevant fishery dependent or independent data to develop an in-season update model for pre-terminal SUS fisheries.
Stock specific exploitation rates	The Lake Washington stock is a component of the Mid-South Puget Sound Fall fingerling release group in FRAM. Each of the component stocks should be managed separately to assess population level impacts.

The data gaps described above assume that the current annual monitoring in place will continue. This includes spawner surveys in the Cedar River, Bear and Issaquah creeks, including carcass sampling, outmigration estimation in the Cedar River and Bear Creek, hatchery sampling and Locks count estimation.

Green River Management Unit Status Profile

Component Populations

Green River Fall Chinook

Geographic Distribution

The landscape within the Duwamish-Green River Basin is dominated by urban, commercial, industrial, residential, forestry, and agricultural land uses. About 98% of the historic estuary has been lost to development, and the current estuarine habitat is contaminated by industrial waste, stormwater effluent, oil and chemical spills, and runoff from impervious surfaces. Intertidal and marine shorelines are lined with artificial structures, while levees and revetments confine the lower 31 miles of the Green River where floodplain rearing habitat capacity is virtually absent. The lower 5.5 miles are routinely dredged for commercial shipping access. Water temperatures far exceed state water quality standards and at times exceed lethal levels for salmonids as a result of inadequate riparian vegetation and reduced groundwater inflows (MIT 2017, 2018). Habitat complexity is low in the Green River due to adjacent land use and restrictions on instream wood for the purpose of river recreation safety. Estimates of instream wood meeting NMFS' size and frequency criteria are 89 to 95% below levels identified as providing properly functioning conditions.

The Duwamish River basin was dramatically and permanently altered by the diversion of the White River into the Puyallup River Basin in 1906, and the Cedar River into Lake Washington in 1916 with the completion of the Lake Washington Ship Canal and Hiram M. Chittenden Locks. These two actions reduced the watershed to approximately 30% of its historic size. Additionally, access to the upper Green River watershed was limited by construction of the Tacoma Diversion Dam in 1911 and Howard Hanson Dam in 1961.

Development and human population growth is projected to continue to impact fish habitat in the Green River basin into the future. Restoration opportunities in the Green River Basin are challenged by high land costs, conflicting land uses, river recreation safety requirements, and low land availability. The individual and cumulative scale of proposed projects, such as those in the WRIA 9 Salmon Habitat Plan, are generally small, with high priority projects such as lower river off-channel rearing habitat and estuary or transition zone habitat restoration totaling less than 100 acres over the next 50 years. Levee construction and maintenance that preserves eligibility for federal levee rehabilitation funds will likely remain a high priority for King County's river and floodplain management between approximately RM 12.0 to RM 31.0. Establishing even modest levee setbacks to add riparian shade will continue to be a serious challenge. To date, the goal of restoring substantial floodplain habitat and rearing capacity in this reach has had little support given the prime commercial and industrial real estate values involved.

Fall Chinook spawn in the mainstem Green River and in two major tributaries, Soos Creek and Newaukum Creek (Figure 1). Spawning in the mainstem Green River occurs from RM 25.4 to RM 61.0. An adult trap and haul facility was constructed in 2005 at the Tacoma Diversion Dam

(RM 61.0), however, spawning access is currently restricted to downstream areas because no juvenile fish passage facilities exist at Howard Hanson Dam (RM 64.5). Spawning occurs in the lower 4.5 miles of Newaukum Creek and the lower 5.0 miles of Soos Creek. Spawning in Soos Creek occurs below the Soos Creek Hatchery at RM 0.7 and adults surplus to hatchery program needs are passed upstream to spawn. Neither group of spawners in Soos Creek are a part of the escapement goals for the Green River basin.

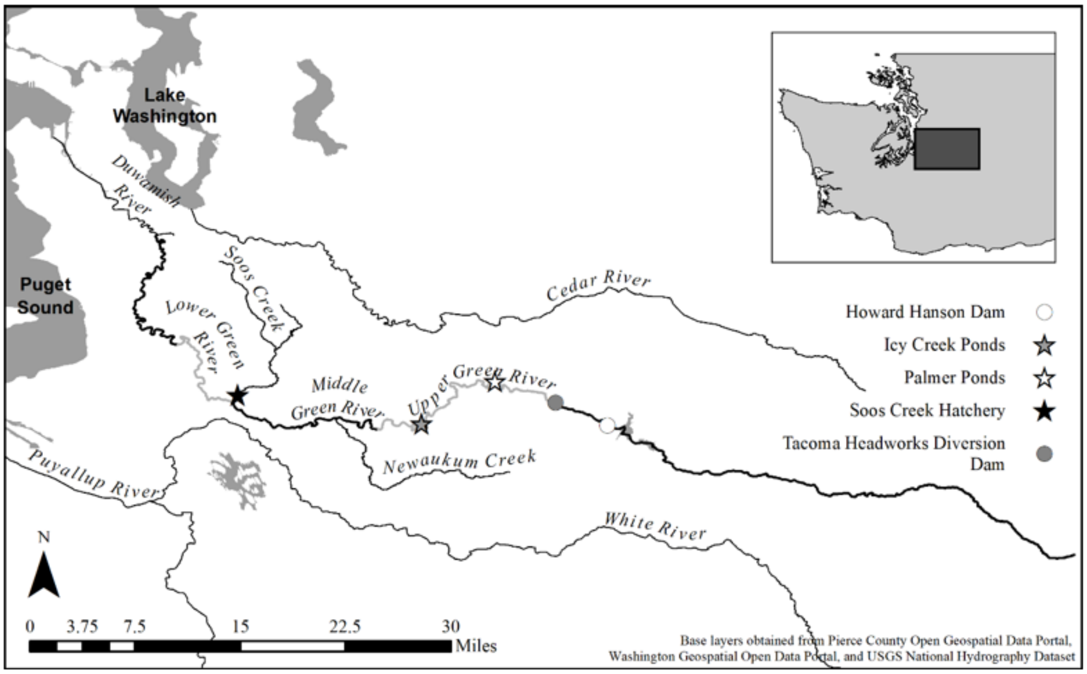

Figure 1. Location of the Green River watershed and associated prominent features discussed throughout this Management Unit Profile.

The magnitude and distribution of Chinook spawning has changed dramatically since 1999 (Figure 2). These changes prompted the co-managers to implement several programs to bolster natural recruitment and take advantage of a gravel supplementation project in the Green River below the Tacoma Headworks Diversion Dam (RM 61.0). Beginning in 2010, adult Chinook that were surplus to Soos Creek Hatchery program needs were transferred to the spawning grounds and allowed to spawn naturally in the Green River. In 2011 (brood year 2010), a rebuilding program that acclimates and releases juveniles in the upper river (RM 56.1) was initiated.

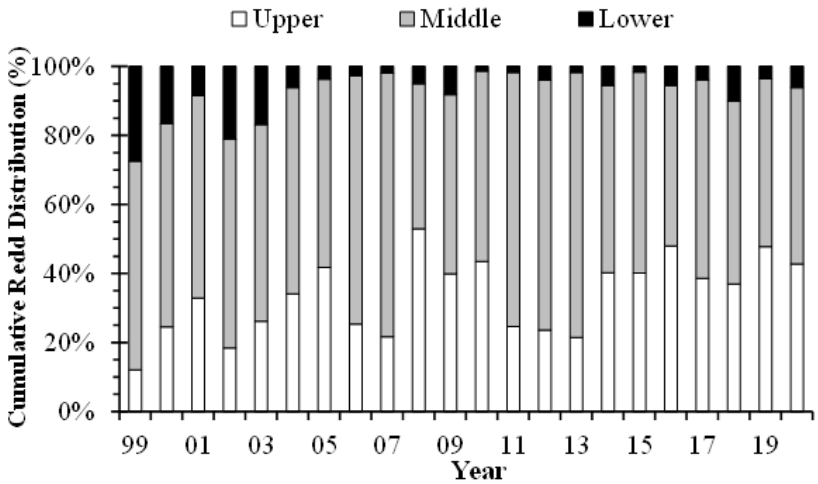

Figure 2. Distribution of Chinook spawning in the Green River from natural origin recruits, hatchery origin recruits that voluntarily spawn in the river, and hatchery surplus adults (Outplant) that are moved to the spawning grounds to supplement the natural spawning population and maintain spawners at the escapement goal. The lower river section is from RM 25.4 to Highway 18 (RM 33.8), the middle river section is from Highway 18 (RM 33.8) to Christy Creek (RM 44.3) which includes spawning in Newaukum Creek, and the upper river section is from Cristy Creek (RM 44.3) to the Headworks Diversion Dam (RM 61.0).

Life History Traits

Fall Chinook begin entering the Duwamish River in July, and spawn from mid-September through early November. The average age composition of adult natural-origin returns between 2003 and 2016 was 27% age-3, 66% age-4 fish, and 7% age-5. Ninety-nine percent of juveniles emigrate from freshwater in their first year with emigration as fry as the dominant strategy (Topping and Anderson 2015). From 1999-2019, fry emigration averaged 64% of the sub-yearling component but was as low as 10% and as high as 97%. Fry begin emigrating during January and peak during February or March. The peak in parr/smolt occurs during May.

Hatchery Production

Shortly after 1900, the first hatchery in the basin was constructed on Soos Creek. Current hatchery production consists of three programs: production of 4.2 million sub-yearlings released on-station from the Soos Creek Hatchery, 2.0 million sub-yearlings which are acclimated and released from Palmer Ponds, and 0.3 million yearlings released from the Icy Creek Hatchery (Figure 3A). The Palmer Pond release program began with brood year 2010 and was designed to provide increased adult returns to the upper anadromous accessible reach of the Green River. The yearling program at Icy Creek was initiated in 1983. Broodstock for both the Icy Creek and Palmer Pond programs is collected at Soos Creek Hatchery. Terminal return rates for the sub-yearling and yearling programs have been highly variable (Figure 3B) across time, though the sub-yearling program returns have trended slightly better over recent years. The co-managers are currently analyzing data that will separate the return rates for on-station Soos Creek releases and

Palmer Ponds releases. Returns from the historic releases above Howard Hanson Dam are unknown due to minimal coded wire releases.

Chinook hatchery operations in the Green River Basin are explained in detail in the co-manager's Hatchery and Genetic Management Plan (HGMP) for the Soos Creek Fall Chinook Hatchery Program, and reflect the joint urban salmon management strategy currently being developed by the Muckleshoot Indian Tribe and the Washington Department of Fish and Wildlife for this and other highly urbanized watersheds. The HGMP acknowledges that Green River (and other Puget Sound) Chinook are well below the planning ranges for recovery escapement, as well as below spawner-recruit levels identified as consistent with recovery. Until habitat function is restored, hatchery production will be essential for harvest opportunities and to maintain abundances of naturally-spawning Chinook in this highly urbanized watershed.

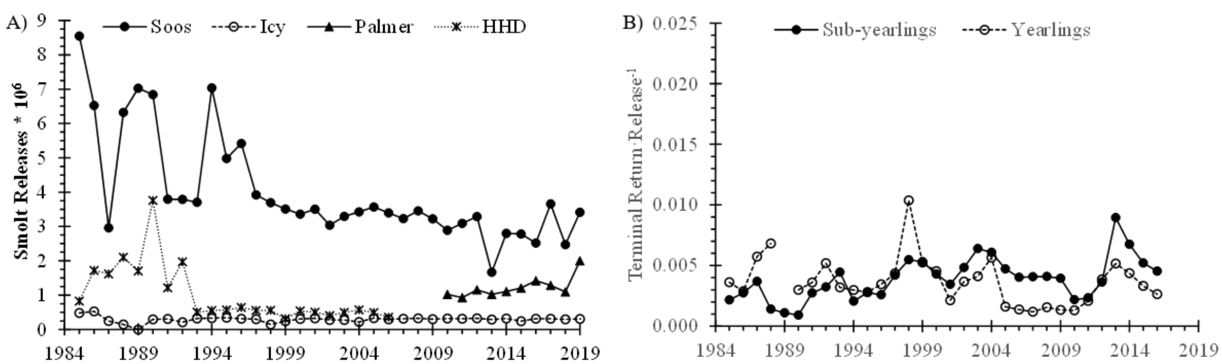

Figure 3. Smolt releases (A) from the sub-yearling (Soos Creek, Palmer Ponds, and above HHD) and yearling (Icy Creek) programs in the Green River basin for brood years 1985-2020 and the resulting terminal return rate from the combined fingerling programs and the yearling program.

Genetic Information

Genetic analyses have shown no significant difference between mainstem and Newaukum Creek natural spawners, and Soos Creek Hatchery Chinook (Marshall et al.1995; Ruckelshaus et al. 2006). The hatchery broodstock program is operated as an integrated program with the natural origin Green River Chinook population and there is significant genetic interchange between natural- and hatchery-origin Chinook on the spawning grounds (WDFW et al. 2002).

Status

The Green River Fall Chinook population is managed for total natural spawners on the spawning grounds, which has varied from 688 to 11,512 since 1988 (Figure 4A; Table 1). Through the early 2000s, spawning escapement was relatively stable with a 5-year geometric mean that remained close to the historic escapement goal of 5,800. From 2009-2015 total spawning escapements were consistently below the historic escapement goal, but escapement has rebounded during recent years. NOR spawners declined from 1988-2015 but increased during the recent 5 years. From 1988-2016, the average NOR contribution to the spawning grounds was

41% but the recent trend has been increasing (Figure 4B). The recently established supplementation releases from the Palmer Ponds program have had a positive effect on the relative contribution of NORs and HORs to natural spawning in the upper watershed below Howard Hanson Dam. This program is designed to provide highly integrated adult spawners to the upper Green River that will take advantage of a gravel supplementation project and corresponding improved spawning habitat. Due in part to the long history of hatchery production and habitat degradation in the basin, hatchery produced Chinook are an important component of natural spawning escapement. Protecting and ensuring hatchery production levels meet program goals are vital in urban systems (Figure 4C).

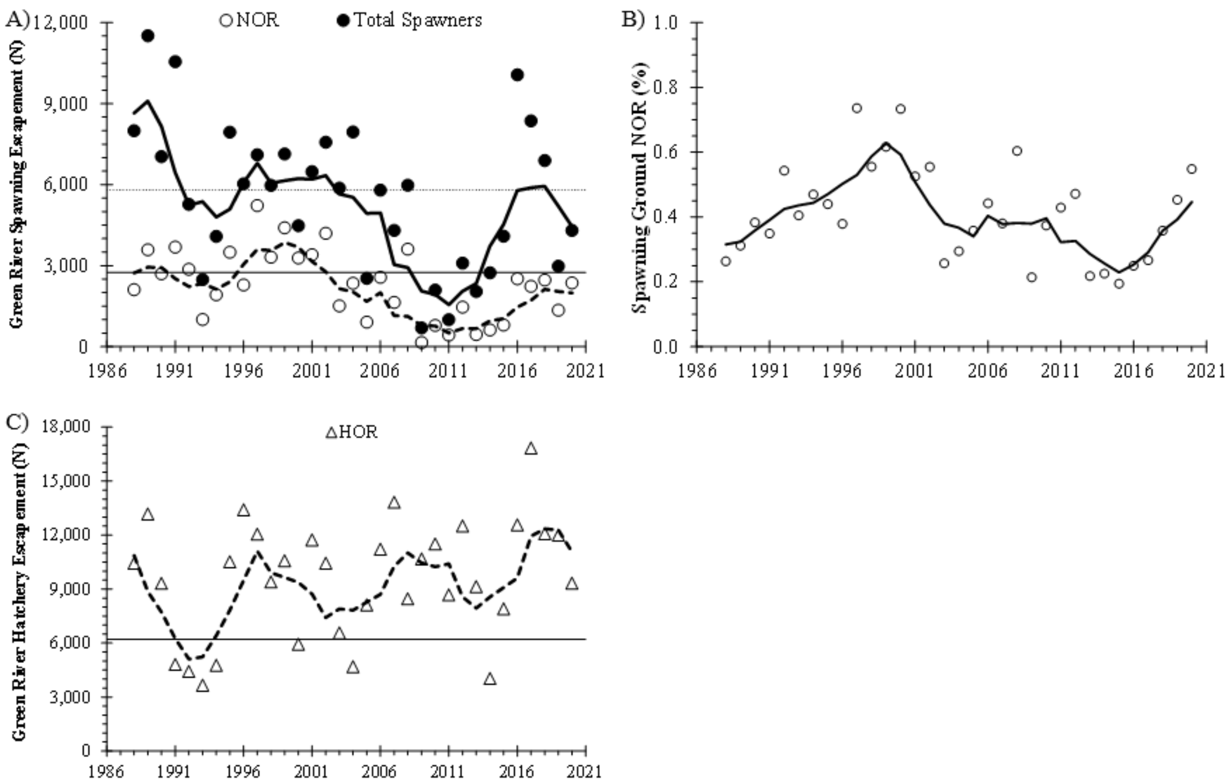

Figure 4. Observed NOR (open circle) and total (filled circle) spawning escapement on the Green River (A) from 1988-2020. A 5-year running geometric mean for total escapement (solid line) and NOR escapement (dashed line) is fit to each data series. The historic escapement goal of 5,800 natural spawners (lite dashed line) and current escapement goal of 2,744 natural spawners (lite solid line) is shown. Observed NOR Chinook contribution to the Green River spawning grounds (B) from 1988-2020 (open circles) with a 5-year running geometric mean (solid line). Observed hatchery rack escapement (open triangle) at Soos Creek Hatchery (C) from 1988-2020 is shown with a 5-year running geometric mean. The hatchery rack escapement goal is 6,200 adult Chinook needed to make current program goals is shown (lite solid line).

Table 1. Natural origin recruits (NOR) and hatchery origin recruits (from the fingerling and yearling programs) that escaped pre-terminal and terminal fisheries. Recruits/Spawner (R/S) includes all adult NORs caught in pre-terminal and terminal fisheries or escaped from fisheries. Pre-terminal mortalities from the 1988-2014 brood years are based on FRAM 7.1.1.

Return Year	NOR	Fingerling	Yearling	Spawners	R/S[a]
1988	2,906	14,472	1,053	7,994	0.88
1989	4,143	19,059	1,488	11,512	0.47
1990	2,498	12,931	929	7,035	0.67
1991	3,720	10,389	1,252	10,548	0.54
1992	1,892	7,147	656	5,267	0.97
1993	896	4,904	333	2,476	1.76
1994	1,456	6,858	528	4,078	0.95
1995	2,811	14,598	1,048	7,939	0.50
1996	2,133	16,428	879	6,026	0.50
1997	2,521	15,655	978	7,101	0.33
1998	2,126	12,424	810	5,963	0.57
1999	2,548	14,204	959	7,135	0.39
2000	1,593	8,219	591	4,473	1.05
2001	2,286	15,013	903	6,473	0.17
2002	2,110	14,895	1,005	7,564	0.56
2003	1,854	9,679	900	5,864	0.47
2004	2,755	7,369	2,517	7,947	0.89
2005	1,431	8,610	602	2,523	0.25
2006	2,978	13,257	771	5,790	0.24
2007	1,790	15,880	456	4,301	0.17
2008	3,657	10,573	207	5,971	0.30
2009	463	9,995	908	688	0.90
2010	1,116	9,214	2,761	2,092	0.38
2011	489	9,074	107	993	1.10
2012	1,771	13,705	124	3,090	1.09
2013	733	8,474	1,968	2,041	2.82
2014	774	5,397	628	2,730	1.65
2015	1,236	10,279	479	4,087	--
2016	3,481	18,016	1,138	10,063	--
2017	2,754	22,171	278	8,357	--
2018	3,286	15,253	443	6,891	--
2019	1,970	12,625	387	2,976	--
2020	2,516	10,976	143	4,300	--

[a] The 1988 R/S estimate does not include Age-3 pre-terminal or terminal freshwater sport mortalities and the 2014 R/S estimate does not include recruits from the Age-5 portion of the cohort.

The historic escapement goal (i.e. Upper Management Threshold, UMT) was established in 1977 (Ames and Phinney 1977) as the average of estimated natural spawning escapements from 1965-1974. This goal does not reflect the reduced productivity associated with current habitat conditions. An update of the Fishery Regulation Assessment Model (FRAM) base period to brood years 2005-2008 necessitated updating natural and hatchery escapements back to 1988 for calibration. These data were used to fit a Beverton-Holt stock recruit curve (Beverton and Holt 1957) to brood years 1988-2014 (Figure 5). For this model, a=0.3774 and b=0.0001697 which resulted in a spawning stock size at equilibrium of 3,668 and a theoretical maximum recruitment of 5,891. The spawning stock size MSY is 1,396 which is expected to result in 2,272 recruits. As outlined in this document, the co-managers have agreed to manage for 2,744 adult Chinook on the spawning grounds. At a spawning escapement of 2,744, the Green River population is expected to produce 3,254 recruits.

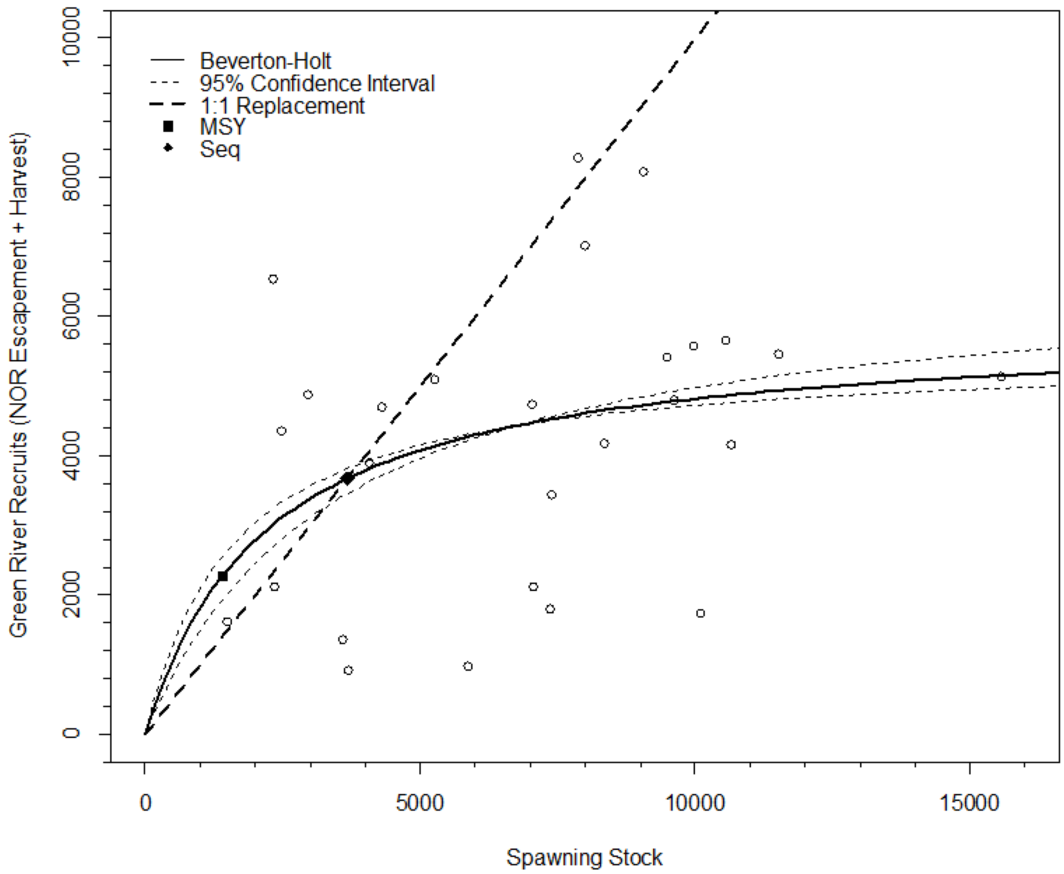

Figure 5. Beverton-Holt stock-recruit curve for Green River Chinook based on brood years 1988-2014. The spawning stock size at MSY is 1,396 (1,281-1,448 95%CI) which results in 2,272 (1,840-2,581 95%CI) recruits. The spawning stock size at equilibrium is 3,668 (3,252-3,877 95%CI) Chinook.

An independent assessment of optimal spawning escapement based on smolt production was recently completed (Anderson and Topping, 2018; Figure 5). That assessment showed that smolt production was affected by both spawner abundance and environmental conditions (river flow), and spawner escapements greater than 3,000 “typically yield few additional parr due to density dependence.” Although increased fry emigrants may result from higher escapement, emigrating fry are presumed to survive and contribute to future adult abundance at a very reduced rate relative to parr, due to degraded habitat conditions in the lower Duwamish River and Elliot Bay. Out of 124 natural origin adults examined, one was found to have emigrated to the Duwamish River estuary at less than 60 mm (Campbell and Claiborne 2017). The median length at emigration to the estuary for successfully recruiting adults was approximately 80 mm which was significantly greater than in the Skagit (65 mm) or Nooksack (70 mm) estuaries where successful rearing does occur.

An analysis of the Rebuilding Exploitation Rates (RER) was recently completed (NWFSC 2017) using data from the abundance and productivity tables maintained by NOAA, which covered brood years 1987-2011, a slightly wider timeframe than the stock-recruit analysis considered here. The RER analysis based on a Ricker stock-recruit model indicated an MSY spawning escapement of 2,527 while a Beverton-Holt stock-recruit model indicated an MSY spawning escapement of 1,813 adult Chinook. The RERs associated with these spawning escapements were 20% and 31% for the Ricker and Beverton-Holt models, respectively. Assuming both spawner-recruit functions were equally plausible, the results were averaged for a 26% (19-31% CI) RER with a target spawning escapement of 2,200 adults. These conclusions are consistent with analyses in this document, and provide an independent assessment of escapement based on smolt production.

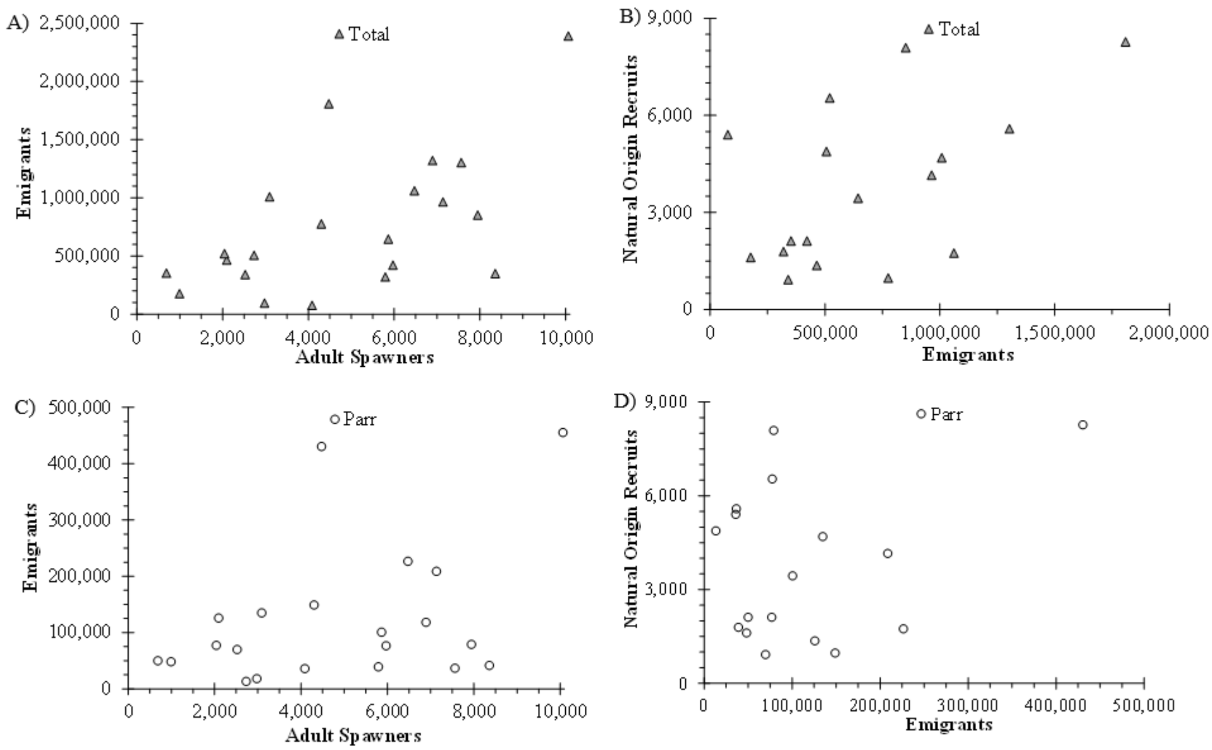

Figure 6. Relationships between adult spawning abundance (A, C), juvenile production (A, B, C, D), and natural origin adult returns (B, D) in the Green River basin from 1999-2019. Juvenile emigration estimates are developed from a rotary screw trap (RM 34.5) and expanded for redd production in the river below the trap (RM 26.7-34.5). Juvenile production from Soos Creek (RM 33.8) is estimated with similar methods and added to the expanded Green River production estimate. Emigrating Chinook smolts are classified as fry or parr. In the Green River parr are the primary life history strategy that contributes to adult recruitment due to poor habitat conditions in the Duwamish River Estuary and nearshore marine waters.

Recruits per spawner have been moderately variable and typically less than 1.0 in the Green River population (Figure 7). The 2013 brood year was the most productive brood with 2.8 recruits per spawner produced. The 2011-2014 broods have all produced >1.0 recruit per spawner. Five of the six broods from 2005-2010 produced fewer than 0.4 recruits per spawner brood were which resulted in the strong observed decline in natural productivity during that period. There is no correlation between Green River and Puyallup River (r = 0.08) or Cedar River (r = 0.16) Chinook productivity. The average productivity across all brood years is 0.8

recruits per spawner whereas current productivity at MSY is 1.3 recruits per spawner. The most recent complete brood returns have shown the strongest productivity observed in Green River and is consistent with the observed relationship between juvenile production and resulting NOR adult production (Figure 6). Current freshwater habitat capacity for parr is severely constrained in the basin.

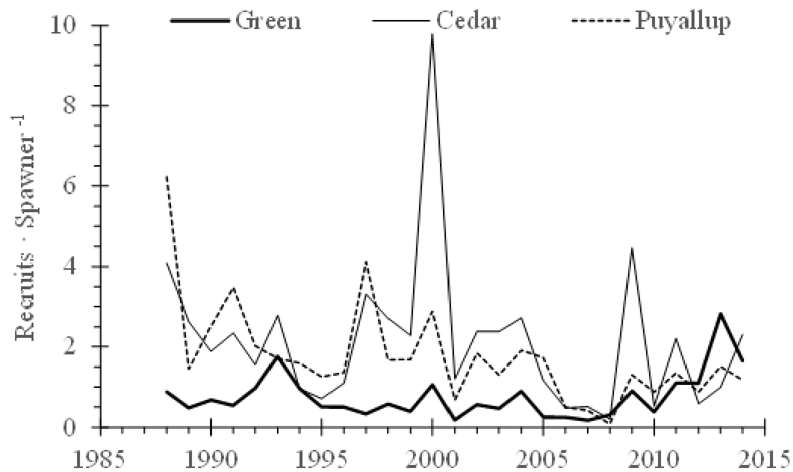

Figure 7. Trend in recruits per spawner for Green River (bold line) and adjacent management unit natural origin recruits from completed brood years (1988-2014).

Harvest Distribution and Exploitation Rate Trends

Green River Chinook are part of the Mid-South Puget Sound Fall fingerling FRAM stock aggregate. The FRAM base period for this stock aggregate is based upon coded wire tagged indicator groups from Issaquah Creek, Soos Creek, Voights Creek, and Grovers Creek hatcheries from the 2005-2008 brood years. Natural spawners in the mainstem Green River and Newaukum Creek are the managed natural components of the Green River Chinook population, which is modeled through terminal fisheries within the Terminal Area Management Module (TAMM).

As estimated by post-season FRAM/TAMM for Green River Chinook, northern (British Columbia and Alaska) fisheries had a combined 13% average exploitation rate, the pre-terminal southern US (PT SUS) exploitation rate averaged 9% and the terminal exploitation rate averaged 8% from 2010-2014. Exploitation rates generally declined through the 1990s (Figure 8). Beginning in the early 2000s northern exploitation rates began to increase to levels near those of the early 1990s. Terminal exploitation rates are highly variable as they are dependent upon whether there is a directed terminal fishery.

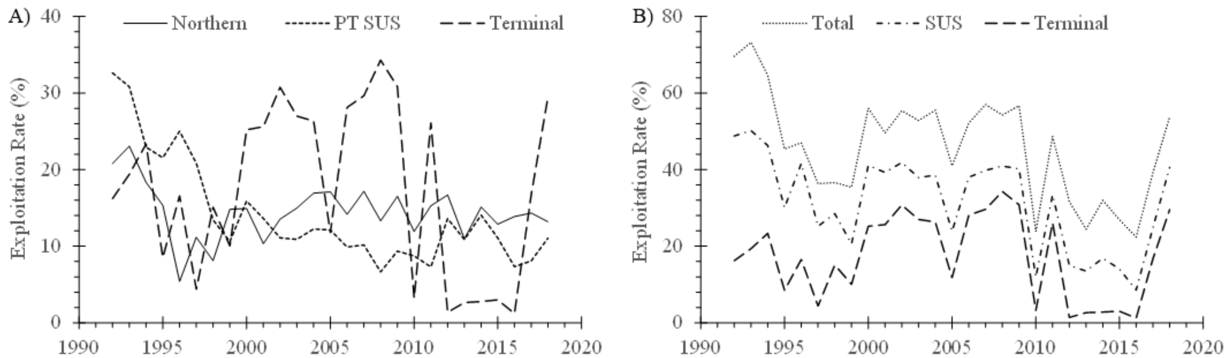

Figure 8. Trend in the A) northern (solid line), pre-terminal southern US (short dashed line), and terminal (long dashed line) exploitation rates and B) Total (dotted line), Southern US (dashed and dotted line), and terminal (long dashed line) exploitation rates on Green River natural origin Chinook from 1992-2018 based on FRAM version 7.1.1.

Management Objectives

The Green River Chinook stock will continue to be managed for total natural escapement that includes both natural and hatchery origin adults on the Green River spawning grounds; as well as hatchery rack escapement at Soos Creek hatchery sufficient to achieve program goals[24]. In practice, managing for both a natural spawning and hatchery rack escapement goal will limit the total exploitation rate on the natural origin component of the Green River Chinook population. Green River escapement goals will be consistent with escapement according to MSY under current habitat conditions. The co-managers intend to review escapement goals on a 5-year cycle similar to NOAA status reviews, and to propose changes to goals if warranted by the review. The Upper Management Threshold (UMT) will be set at the escapement goal with a set of triggers that allow progressively higher pre-terminal exploitation rates during the pre-season planning process, contingent on meeting management objectives in the Lake Washington and Puyallup River management units (MUs). These triggers are designed to account for uncertainties in the pre-season forecast and pre-terminal fisheries, and to increase the likelihood of attaining sufficient terminal abundance to allow terminal area Chinook-directed fisheries to proceed. Southern U.S. fisheries will be planned in the pre-season according to a tiered management regime that accounts for uncertainties in the pre-season forecast. Terminal directed fisheries will be planned in the pre-season when terminal run size meets a threshold abundance that can be reasonably assumed to meet the natural spawning and hatchery escapement objectives, but will only go forward when in-season run size estimates project that natural and hatchery escapement goals will be met.

MSY associated with current habitat conditions is 1,396 (1,281-1,448 95%CI) naturally spawning adult Chinook, less than 25% of the 5,800 that were managed for under previous plans. However, the co-managers will conservatively manage for 2,744 adult Chinook on the Green River spawning grounds. The first UMT trigger will allow a pre-terminal exploitation rate of up to 14% and will be triggered when 4,500 adult Chinook in the terminal area are destined for the spawning grounds. This represents the conservative escapement goal of 2,744, plus a buffer that

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[24]However, among pre-terminal entities, the State has agreed to take responsibility for meeting hatchery escapement objectives.

accounts for forecast uncertainty and a limited Chinook-directed terminal fishery. The second UMT trigger will allow a pre-terminal exploitation rate of up to 15% and will be triggered when 6,700 adult Chinook in the terminal area are destined for the spawning grounds. Similar to the first trigger, the second trigger represents the natural spawning escapement goal of 2,744, plus a buffer that accounts for forecast uncertainty and for a Chinook-directed terminal fishery. The second trigger can only be met if both the Lake Washington and Puyallup River MUs meet or exceed their respective UMT thresholds (Table 2). The Low Abundance Threshold (LAT) will be set at 40% of the escapement goal, or 1,098 natural spawning Chinook. The co-managers have chosen this threshold for the LAT as a conservative measure designed to constrain incidental impacts in SUS fisheries (pre-terminal and terminal), which will promote rebuilding of the natural stock in as few generations as possible, and keep the population from falling to a lower abundance that could cause demographic risk to the population. The lowest observed natural spawning escapement on the Green River was 688 in 2009, which produced 984 recruits from this cohort.

Table 2. Natural spawning escapement goals, management thresholds, and corresponding exploitation rate ceilings for stock components of the Mid-South Puget Sound FRAM stock aggregate. The moderate management threshold (MMT) is triggered when natural spawning escapement is forecasted between the low abundance threshold (LAT) and the upper management threshold (UMT). In pre-terminal fisheries the stock aggregate is managed for its weakest component MU.

Management Unit	Escapement Goal	LAT (SUS)	MMT (SUS)	UMT 1 (PT SUS)	UMT 2 (PT SUS)[2]
Lake Washington[1]	500	200[3] (12%)	18%	500[4] (14%)	500[4] (15%)
Green River	2,744	1,098 (12%)	18%	4,500 (14%)	6,700 (15%)
Puyallup River	1,170	468 (15%)	30%	1,538 (14%)	1,895 (15%)

[1] The Cedar River is the natural managed component of the Lake Washington MU
[2] If the Lake Washington MU meets its UMT and both the Green River and Puyallup River MU meet their respective upper triggers for a 15% pre-terminal ER, then all Mid-Puget Sound aggregate MUs will be managed for a 15% pre-terminal SUS ER.
[3] The LAT will increase to 300 if spawning escapement falls below 200.
[4] The UMT will increase to 570 if spawning escapement falls below 200 or below 324 in two consecutive years.

The hatchery escapement goal has consistently been met under the previous natural spawner escapement goal even when natural abundances have fallen below management objectives (Figure 4C). Hatchery escapement will be managed for approximately 6,200 adult Chinook needed to meet hatchery program objectives. Annual variations in abundance levels of hatchery and natural Chinook may require in-season terminal fishery management to insure the hatchery and natural escapement objectives are met.

Consistent with the goals of achieving the natural spawning and hatchery escapement goals as well as ensuring that terminal directed fisheries will occur, at abundances above the UMT triggers of 4,500 and 6,700 adults in the terminal area destined for the spawning grounds, PT SUS fisheries will be planned not to exceed a 14% or 15% exploitation rate, depending on which triggers have been met. In the terminal area (Area 10A / Inner Elliott Bay and 80B), directed Chinook fisheries will be designed to achieve natural spawning and hatchery escapement at or above management objectives that will allow the population to test habitat recovery projects and their impacts to survival in this basin. This approach reflects the primary goal of meeting the natural spawning escapement that fully seeds the available spawning habitat, as well as the importance of achieving sufficient abundance in the terminal area to allow directed Chinook fisheries.

If the FRAM/TAMM pre-season model output of terminal run size falls between the UMT and LAT, the SUS fisheries will implement the moderate management threshold (MMT) where total Southern United States (SUS) fisheries will not exceed 18% (pre-terminal + terminal) ER. With this approach, terminal fisheries planned in the pre-season at the MMT will only have incidental impacts to Chinook as fisheries will be directed at other salmonids. Under previous plans, pre-terminal fisheries were managed up to an allowable rate when abundances were above the LAT. Conversely, terminal fisheries were constrained to incidental impacts when forecasted abundances were below the UMT. When forecasted abundances fall within the newly defined MMT, the co-manager intent is to manage this stock conservatively and at a lower SUS ER than under previous plans. While these fisheries are modeled and planned in the pre-season North of Falcon process, terminal fisheries will continue to be managed according to an in-season update (ISU) model (described below). Using this approach, terminal fisheries that were not modeled in the pre-season may occur if in-season abundance is large enough to meet escapement targets after fisheries, or fisheries that were modeled in the pre-season may be further constrained if abundance is less than expected.

If the FRAM/TAMM pre-season model output of spawning escapement falls below the LAT, a critical exploitation rate ceiling of 12% will be implemented for SUS fisheries (pre-terminal + terminal). Under this approach, terminal fisheries planned in the pre-season at the LAT will only have incidental impacts to Chinook as fisheries will be directed at other salmonids. Under previous plans, management when the forecast was below the LAT included a 15% pre-terminal ER ceiling and a terminal minimal fisheries regime. This plan is for a 12% SUS ER ceiling which is far more constraining. The 12% SUS ER ceiling will be allocated between terminal and pre-terminal fisheries during the annual North of Falcon process. Due to the use of in-season monitoring and management in the terminal area, abundance may be observed that is sufficiently greater than MSY such that a limited directed terminal fishery could be prosecuted. This would result in higher exploitation rates in the terminal area than modeled in the pre-season, but would still meet both natural spawning and hatchery escapement goals. The lowest SUS ERs observed were 11.9% in 2010 and 8.5% in 2016. These are the only times since 1992 when the SUS ER has been below 12% according to post-season validation runs. If natural spawning escapement falls below the LAT, hatchery rack escapement is likely to further constrain fisheries due to the tight relationship between them.

During the pre-season process, Puget Sound (sport and terminal) fisheries will be planned to meet the broodstock needs at Soos Creek Hatchery. Even when expected abundance of Chinook returning to the Green River to spawn naturally is above the management objectives, it is possible that additional fishery actions may be necessary to ensure broodstock needs at the hatchery are met. Broodstock needs at Soos Creek Hatchery will be calculated based on pre-spawn mortality in the adult holding ponds, fecundity, male-to-female ratio and egg-to-smolt survival that the co-managers will discuss and agree upon during the pre-season planning process. Further in-season actions consistent with the agreed to HGMP will guide actions that may be required to meet natural spawning and hatchery goals as additional information becomes available.

While there is some uncertainty in the annual ERs from northern fisheries (British Columbia and Alaska) on Green River Chinook (Figure 8A), the recently negotiated 2019 Pacific Salmon Treaty was intended to continue reducing these impacts. SUS fisheries will be constrained to the levels described above when natural spawning abundance is expected to be below the management objectives. Those constraints, coupled with the agreed to hatchery objectives with the WDFW, will ensure that fisheries do not reduce the likelihood of recovery of Green River Chinook, while allowing limited fisheries to continue in years when natural spawning abundance falls below the UMT.

In-season Update and Other Terminal Fishery Management Measures

While directed terminal fisheries are planned when the FRAM/TAMM model output of terminal run size exceeds the spawning and hatchery objectives, terminal fisheries will only proceed when ISU model corroborates pre-season expectations. For the Green River stock, this is accomplished with a test fishery in Elliott Bay. This test fishery occurs at 5 sites on 3 nights, once per week typically during management weeks 29-31.

Test fishery catch from each week is aggregated and used to project terminal run size, spawning escapement, and hatchery escapement. If the results of this modeling exercise match the pre-season expectations and/or the co-managers believe that based on terminal run size and expected terminal catch, spawning and hatchery escapement objectives will be met or exceeded after fishing, then directed fisheries will proceed. Conversely, if pre-season expectations and/or projections of spawning and hatchery escapements will not meet objectives, then directed fisheries will not proceed.

If based on the first ISU, the co-managers decide to conduct a first opening; directed treaty and non-treaty terminal fisheries in 10A and 80B are scheduled in week 32. The in-river sport fishery typically does not begin until around September 1. After the first night of a directed terminal net fishery in Elliott Bay (10A) and the Duwamish River (80B), the results of a second ISU are examined and the co-managers will evaluate the projected run size with respect to the escapement objectives.

The first ISU for the Green River occurs after completion of the 10A test fishery. From this model, the terminal run size has a mean absolute error of 25.7% (Figure 9A). This approach can be used to update the in river spawning escapement and hatchery escapement. Before looking at spawning escapements or hatchery escapements, it is important to note that high water during the peak weeks of both 2009 and 2011 prevented a full complement of spawning surveys and resulted in much lower escapement estimates than would have occurred otherwise. These high water events did not impact hatchery escapements. The mean absolute error from the 10A ISU for updating expected spawning escapement on the Green River, when 2009 and 2011 are excluded, is 35.7% (Figure 9B). Similarly, the mean absolute error (including 2009 and 2011) for updating hatchery escapement is 36.9% (Figure 9C).

The second ISU for the Green River occurs after completion of the first night of directed Chinook net fisheries in Elliott Bay and the Duwamish River. There were no terminal net fisheries in the Duwamish River during 1989 or 2010 and therefore no second update. From this ISU model, the terminal run size has a mean absolute error of 16.3% (Figure 9D). The mean absolute error from the Terminal Net ISU for updating expected spawning escapement on the Green River is 27.7% (Figure 9E). Similarly, the mean absolute error (including 2009 and 2011) for updating hatchery escapement is 32.9% (Figure 9F).

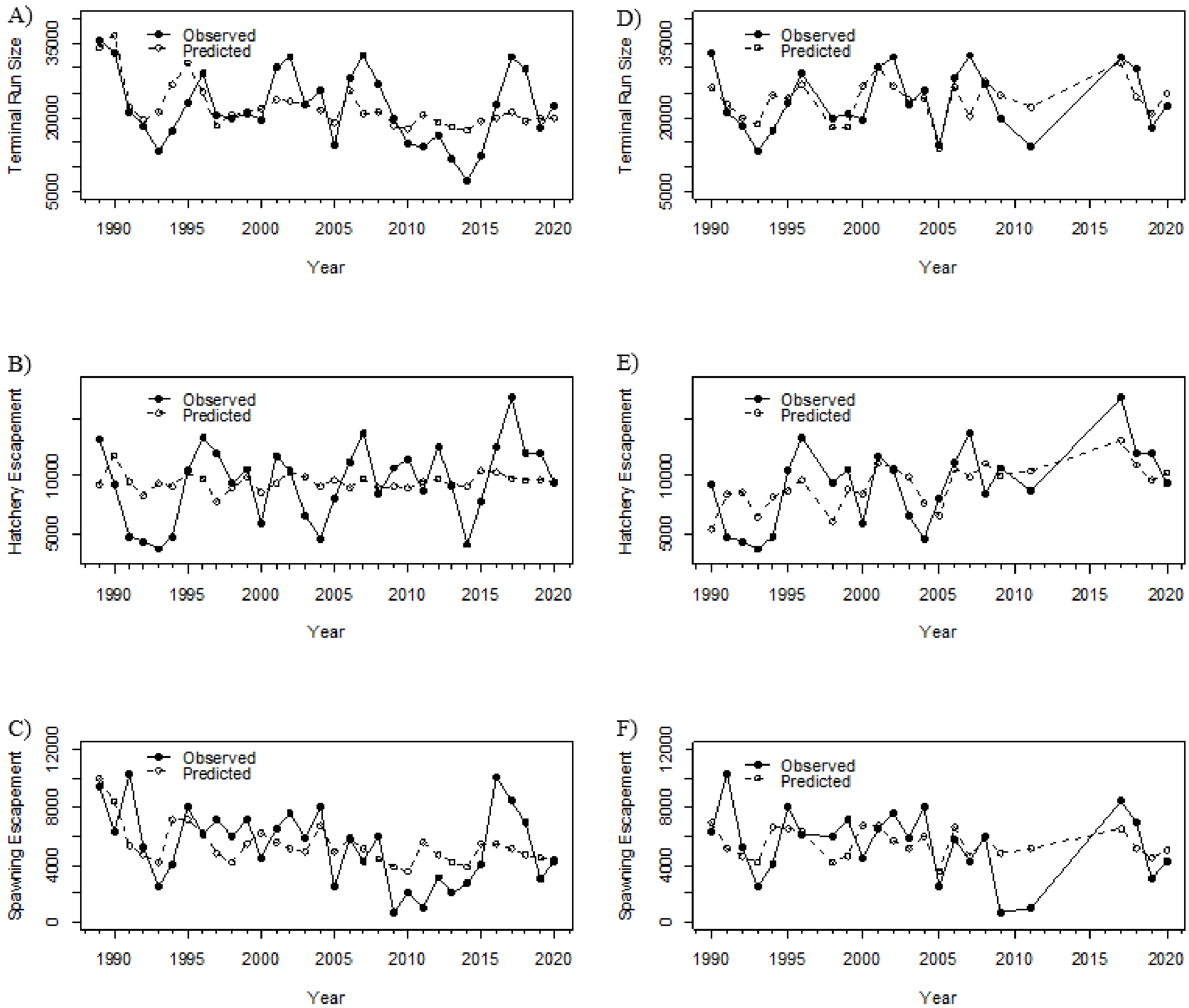

Figure 9. Observed and predicted terminal run size (A), hatchery escapement (B), and spawning escapement (C) in the Green River based on the 10A test fishery ISU and observed and predicted terminal run size (D), hatchery escapement (E), and spawning escapement (F) in the Green river based on the combined test fishery and first night of directed net fishery.

If the ISU model projects a harvestable surplus above management objectives, the planned terminal fisheries will proceed. Regardless of pre-season forecasts, in-season updates will be used to manage terminal area fisheries. The in-season updates may serve to open or close terminal fisheries. In the case where no directed terminal fisheries were modeled in the pre-season (i.e. management at the MMT or LAT), Chinook directed fisheries may be implemented in terminal areas by agreement of the terminal area co-managers (Muckleshoot Indian Tribe, Suquamish Indian Tribe, and Washington Department of Fish and Wildlife) when data indicate a harvestable surplus of both Green River natural spawners and Soos Creek Hatchery broodstock. In those instances, the total SUS ER may increase over pre-season expectations; but MSY and hatchery escapement goals will be met. The in-season update method and terminal area fisheries that are based on this update will be agreed to by the terminal area co-managers prior to implementation. Any directed Chinook fisheries in the terminal area will be designed to result in spawning escapements that meet or exceed the Green River Chinook and Soos Creek Hatchery escapement objectives, 2,744 and approximately 6,200 respectively. Hatchery escapement needs will be reviewed, updated, and agreed to annually by the co-managers and available during the pre-season planning process.

Data Gaps and Information Needs

Table 2. Data gaps in Green River Chinook stock assessment and harvest management, and research required to address those data needs.

Data gap	Related research needed
Evaluation of escapement estimation methodology	Use Soos Creek outplants for a mark/recapture estimate of the spawning escapement.
Investigate potential causes of poor egg to migrant productivity	Perform scour studies on the Green River and Newaukum Creek and investigate the impact of Nanophyetus on productivity of spawners in Soos Creek.
Pre-terminal in-season update models	In partnership with terminal and pre-terminal Tribes and State, examine relevant fishery dependent or independent data to develop an in-season update model for pre-terminal SUS fisheries.
Stock specific exploitation rates	The Green River stock is a component of the Mid-South Puget Sound Fall fingerling release group in FRAM. Each of the component stocks should be managed separately to better assess population level impacts.

The data gaps described above assume that the current annual monitoring in place will continue. This includes spawner surveys in the mainstem Green and Newaukum Creek, including carcass sampling, outmigration estimation in the mainstem Green and Soos Creek, and hatchery sampling.

White River Management Unit Status Profile

Component Populations

White River Spring Chinook

Watershed History

The White River is a glacially influenced river which historically flowed into the Green-Duwamish River drainage near the city of Auburn, Washington. In 1906, a large flood and log jam diverted flow into the Stuck River, a tributary to the Puyallup River. Within a decade, a concrete structure was built to permanently re-route the White River into the Puyallup River. In 1911, Mud Mountain Dam Fish Passage Facilities (MMDFPF; historically White River Diversion Dam) was constructed at river mile (RM) 24.3 near the town of Buckley for hydropower generation (Figure 1). Up to 2,000 cfs was diverted into Lake Tapps and through a power station before returning flow to the White River 20 miles downstream. Streamflow as low as 30 cfs within the bypass reach[25] commonly occurred in summer and early fall until 1986, when a settlement agreement between the Muckleshoot Indian Tribe and Puget Sound Energy raised the minimum instream flow requirement to 130 cfs. Hydropower production ceased in 2004 and the associated facilities and water rights were acquired by the Cascade Water Alliance (CWA) for a future regional water supply project. A 2007 agreement between CWA and the Muckleshoot and Puyallup tribes further raised the minimum instream flow requirement to 500-875 cfs, and placed restrictions on the amount of water that can be diverted to fill Lake Tapps. Fish screening at the diversion dam was inadequate or absent until 1995.

In 1948, the U.S. Army Corps of Engineers (USACE) constructed the Mud Mountain Dam at RM 29.6 for flood control, permanently blocking anadromous fish access to the upper White River watershed. Due to construction of Mud Mountain Dam, approximately 5.5 miles of riverine habitat between the two dams was lost. To address the migration blockage to the upper watershed, the USACE operates the MMDFPF which includes a trap and haul facility to collect Chinook and other anadromous species for transport above Mud Mountain Dam.

Poor passage conditions at the existing MMDFPF have resulted in injury, migration delay, and pre-spawn mortality of Chinook and other species. Downstream passage survival through the 9-foot diameter discharge tunnel at Mud Mountain Dam was also found to be poor (R2 Resources 2013). In the 2014 Biological Opinion for Mud Mountain Dam operations and maintenance, the National Marine Fisheries Service (NMFS) determined that these structures jeopardize the persistence of Puget Sound Chinook and other listed species (NMFS 2014). As a result, the USACE is currently replacing and modernizing its trap and haul facilities and the diversion dam, and relining the 9-foot tunnel to improve downstream survival through Mud Mountain Dam. Construction of the MMDFPF is scheduled for completion by December 2020. The Reasonable and Prudent Alternative (RPA) measures included in the Biological Opinion require a substantial improvement in passage survival for migrating adults and juveniles, with performance criteria of 95% smolt passage survival (currently estimated at 18% through the 9-foot tunnel and 100%

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[25] The Muckleshoot Indian Reservation is located along the bypass reach where hydropower diversion depleted streamflow, devastating fishery resources for 75 years. Decades-long litigation resulted in the 1986 settlement agreement with PSE, the principal elements of which included flow measures and construction of the White River Hatchery. Currently, the Muckleshoot Indian Tribe funds the operations of the White River Hatchery.

through the 23-foot tunnel) and 98% survival of adults through the trapping facility (currently estimated at 70% to 80%) (NFMS 2014). The 2021 adult return and subsequent brood are anticipated to be the first spring Chinook to pass through the new facilities provided that the project is completed on schedule. The existing fish trap will be retained to serve as a back-up facility during the first full year of operations of the new MMDFPF.

Habitat Description and Limiting Factors

The White River originates from the Emmons Glacier on Mt. Rainer and flows for 75 miles

before joining the Puyallup River at RM 10.4 and entering Puget Sound at Tacoma, Washington (Figure 1). Major tributaries upstream of Mud Mountain Dam include the Clearwater River, Greenwater River, Huckleberry Creek, and West Fork White River. Downstream of the dam, Boise Creek is the only tributary large enough to support Chinook spawning, with a mean discharge of 9 cfs in September and 16 cfs in October (USGS Gage No. 12099600). Channel and streambed conditions in the White River and West Fork White River are naturally unstable with heavy bedload and sediment transport due to steep glacial origins and its course through volcanic mudflow deposits. The White and West Fork White Rivers experience seasonally heavy glacial silt and turbidity.

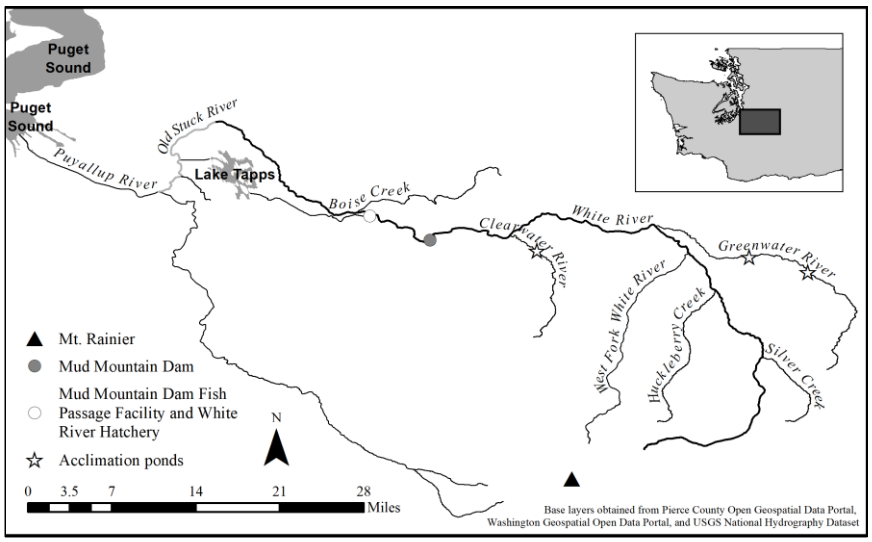

Figure 1. Location of the White River watershed and associated prominent features discussed throughout this Management Unit Profile.

Land use in the White River watershed upstream of Mud Mountain Dam consists of privately-owned timber and National Forest, with Mt. Rainier National Park and wilderness at the headwaters. Most of the upper watershed has been managed for timber production over much of the last century, leading to slope stability problems and increased sediment loads in nonglacial tributaries (Judge 2011). Additional factors limiting salmon habitat in the upper watershed include floodplain connectivity, large woody debris, riparian cover, bank stability, pool habitat, and water quality (Kerwin 1999). Land use downstream of the dam transitions from timber harvest and rural residences to heavily urbanized and industrial areas. The quality and quantity of freshwater and estuarine rearing habitat available to Chinook for fry colonization and juvenile rearing is severely limited in the lower portion of the watershed (Judge 2011**)**. The White River from RM 11 to its confluence with the lower Puyallup River and the entire lower Puyallup River to Commencement Bay has been channelized and is severed from its floodplain by flood control infrastructure, resulting in degraded riparian zones.

Commencement Bay is a highly industrialized estuary, with a near total loss of its estuarine wetlands and significant chemical contamination from point and nonpoint sources (Olson et al. 2008). Out of over 6,000 acres of former intertidal mudflat and emergent marsh, only about 125 acres of wetland habitat remain (WDFW et al. 1996). Elevated levels of toxic chemicals have been found in juvenile Chinook migrating through the Hylebos Waterway inlet to Commencement Bay; these levels were high enough to cause adverse effects and were likely to affect marine survival (O'Neill et al. 2015). One study, based on 37 years of data, found smolt to adult survival was 45% lower for juvenile hatchery Chinook migrating through Puget Sound's contaminated estuaries than for Chinook moving through its uncontaminated estuaries and these impacts are likely exacerbated among the natural origin component (Meador 2014).

The co-managers are actively involved in habitat protection and restoration efforts, in part through the Water Resource Inventory Area (WRIA) 10 salmon recovery process (e.g., PCWSRLE 2018). Top project priorities in the basin include restoring floodplain processes and off-channel habitat in the Puyallup and White rivers; preserving and restoring highly productive tributaries; and restoring the Puyallup River estuary and marine nearshore. Along with land use conflicts and constraints, the scarcity of funding sources and limited project sponsor capacity have slowed implementation of salmon habitat recovery plans in the basin. The scope and scale of the actions necessary to recover Puget Sound Chinook in such a vast, diverse, and largely altered or urbanized area are tremendous (Judge 2011).

Stock History

White River spring Chinook counts at the MMDFPF declined from more than 5,000 in the early 1940s to approximately 50 adults in 1977 (Figure 2). As a result, an emergency egg bank was begun out of basin at the Minter Creek-Hupp Springs hatchery complex near upper Carr Inlet using 17 natural origin White River returns and captive broodstock from the NMFS Manchester Research Station south of Bainbridge Island. This program released variable numbers of yearlings and sub-yearlings into the White River basin to stabilize the population, and by 1985 returns to the Buckley trap exceeded 100 fish. As noted by NMFS (2014), artificial production saved the stock from extirpation. In 1989, the Muckleshoot Indian Tribe began operating the White River Hatchery at RM 24.3 adjacent to the MMDFPF. Beginning in 1992, additional Chinook (acclimation pond program (APP)) were reared at acclimation ponds in the upper watershed to promote spatial distribution of spawning activity and to more fully seed available habitat above Mud Mountain Dam. The location of acclimation ponds in the upper White River watershed has been variable since program initiation, current production is located in the Greenwater and Clearwater rivers (Figure 1). Starting in 1995 the trap collected the first return of the APP adult fish. The majority of these APP adults are transported above Mud Mountain Dam by the USACE where they are released, however some are integrated into the White River Hatchery broodstock depending on program objectives. In its listing of Chinook as threatened in 1999, NMFS specifically recognized that the White River hatchery population is "essential for recovery" (64 Fed. Reg. 14,319). In the years immediately after the initiation of the White River Hatchery program through 1996, the White River Chinook stock had a gradual increase in population size with average returns above Mud Mountain Dam exceeding 200 fish (range: 194-628; Figure 3A). By the 2000 return year, co-manager hatchery actions to improve population abundance resulted in meeting the interim escapement goal of 1,000 Chinook (Natural Origin Recruits (NOR) + APP fish) returning to the MMDFPF. Over the next 18 years, returns were highly variable and in four years (2002, 2009, 2010, and 2014) less than 1,000 Chinook that returned to the MMDFPF were passed above Mud Mountain Dam (Figure 3A;

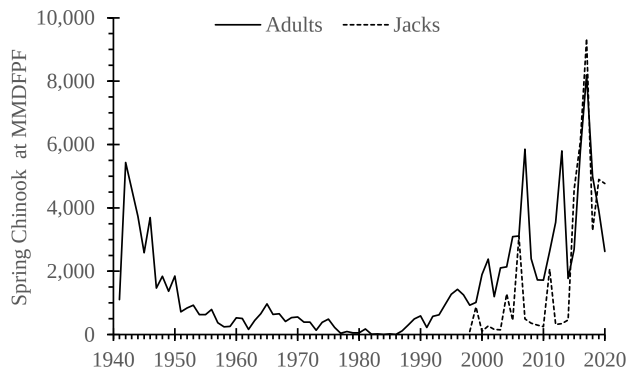

Figure 2. Total adult (solid line) and jack (dashed line) spring Chinook trapped at the Mud Mountain Dam Fish Passage Facilities since the U.S. Army Corps of Engineers began keeping records in 1941. Jack records were not kept or are not reliable before 1998.

Table 5). The interim escapement goal of 1,000 was identified in the White River Spring Chinook Recovery Plan (WDFW et al. 1996). The escapement goal is intended to be met after a full complement of tribal and non-tribal fisheries have occurred, which has yet to have been realized.

The White River and Minter Creek-Hupp Springs hatchery programs reflect the co-manager policies and measures stated in the December 10, 1987 Memorandum of Understanding (MOU) entitled "Production Recommendations White River Spring Chinook" signed by five south sound tribes and the Washington Department of Fisheries. This MOU established the restoration of the native population in the White River watershed as the primary goal of these programs, identified initial production targets, and outlined enhancement and reintroduction strategies including the construction of rearing and acclimation facilities in the White River watershed. The programs generally follow guidance from the White River Spring Chinook Recovery Plan (WDFW et al. 1996). The long-term objective stated in the Recovery Plan is "to restore the native population of White River spring Chinook stock in the White River watershed to a healthy, productive condition. The escapement goal should reflect the watershed carrying capacity and should be met with a full complement of directed and incidental harvest".

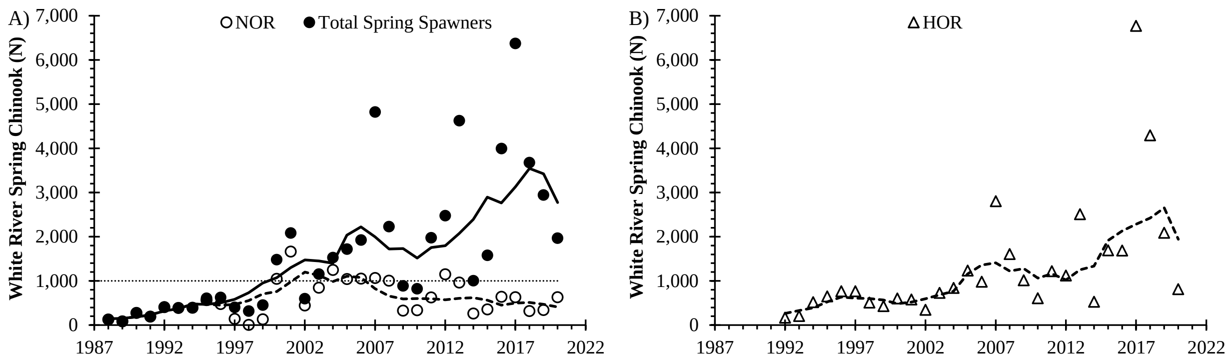

Figure 3. Observed NOR (open circle) and total spring (filled circle) escapement that was hauled above MMDFPF (A) with 5-year running geometric mean for total escapement (solid line) and NOR escapement (dashed line). The interim escapement goal of 1,000 spawning adults is shown as a dotted line. Observed hatchery (sub-yearling + yearling + acclimation pond) recruits (HOR) returning to the White River (B) with a 5-year running geometric mean.

Table 5. Natural origin recruits (NOR), hatchery origin recruits (HOR; including both sub-yearling and yearling program adults), and acclimation pond program (APP) recruits that returned to the MMDFPF or White River Hatchery. Escapement includes NORs not used for broodstock integration, APP recruits, and HORs that are surplus to hatchery program goals or not removed at the MMDFPF. Recruits/Escapement (R/E) includes all adult NORs caught in pre-terminal and terminal fisheries, integrated into White River Hatchery broodstock, and NORs passed above Mud Mountain Dam. Pre-terminal mortalities from the 1988-2014 brood years are based on FRAM 7.1.1.

Return Year	NOR	HOR	APP	Escapement	R/E[a]
1988	127	--	--	127	7.17
1989	83	--	--	83	5.97
1990	275	--	--	275	1.41
1991	194	--	--	194	7.60
1992	406	170	--	406	1.68
1993	391	207	--	391	1.27
1994	392	519	--	392	0.16
1995	568	652	40	608	0.21
1996	476	766	152	628	0.57
1997	139	766	263	402	3.85
1998	19	508	228	245	1.83
1999	93	432	362	444	1.77
2000	872	755	389	1,157	1.09
2001	1,455	883	244	1,547	0.55
2002	452	667	137	534	2.96
2003	910	1,043	274	1,093	0.76
2004	1,009	995	251	1,160	1.12
2005	845	1,676	568	1,488	0.51
2006	778	1,624	710	1,617	0.21
2007	855	2,285	2,732	4,548	0.11
2008	634	1,161	638	1,797	0.36
2009	288	1,161	277	828	1.84
2010	269	1,086	362	734	0.62
2011	487	1,161	983	1,806	0.21
2012	853	1,565	1,119	2,149	0.24
2013	846	2,276	2,734	4,410	0.19
2014	236	896	637	963	0.86
2015	386	1,588	736	1,568	--
2016	739	2,204	2,851	4,009	--
2017	700	4,738	2,749	6,388	--
2018	366	2,773	1,837	3,683	--
2019	399	1,501	2,013	2,945	--
2020	720	693	1,213	1,929	--

[a] The 1988 R/E estimate does not include Age-3 pre-terminal mortalities.

Through 2003, the acclimation pond component (APP) had only modest returns based on small juvenile cohort releases (Figure 4A). Beginning in 2005, APP returns began making up a much larger fraction of the total upstream passage at Buckley Trap, due to recruitment from consistently high APP smolt releases (Figure 4A). In addition, 2005 marked the beginning of consistently exceeding 1,500 total Chinook (NOR + APP fish) passed at Buckley Trap. In 2009, the NOR component had its first major decline since the late 1990s and has persisted at an average of about 550 at the MMDFPF. In contrast, APP recruits have exhibited periodic increases in abundance reaching approximately 3,000 individuals at the MMDFPF.

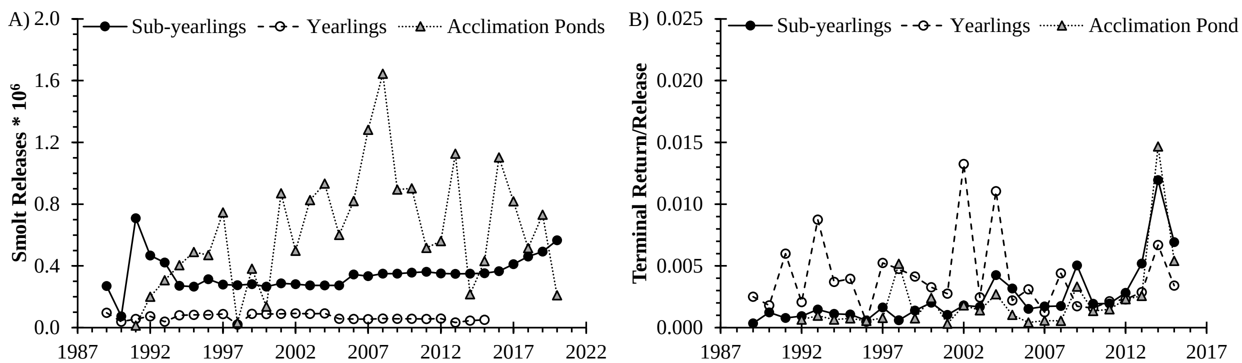

Figure 4. Smolt releases (A) from the sub-yearling, yearling, and acclimation pond program in the White River basin for brood years 1989-2020 and the resulting terminal return rate (age 3-5 adults) from the three components of the two programs release strategies (B).

Adult returns from the White River Hatchery component increased steadily from the initial return of 170 age-3 adults in 1992 to an average of 1,750 beginning in 2005 (Figure 3B). Beginning with the 2000 brood, terminal return rates increased noticeably (Figure 3B). Total returns have fluctuated around 1,750 with an occasional exceptionally productive year in which more than 3,000 adult returns are observed. The majority of adult HOR spring Chinook are held at the hatchery for spawning, but some are intentionally passed above Mud Mountain Dam when program needs are met, or when the MMDFPF becomes inundated with other salmonids and sorting is terminated by the USACE.

Spring Chinook released from each one of the three White River hatchery program components (Minter Creek-Hupp Springs, White River, and APP) are listed components of the Puget Sound Chinook Salmon ESU as they are considered representative of the evolutionary legacy of the ESU and are not reproductively isolated from one another (50 CFR 37160; June 28, 2005). With respect to the White River Hatchery fish in particular, NMFS has recognized that they, combined with NORs, constitute one distinct stock (NMFS 2004). Additionally, the fact that these two components (HOR and APP) of the stock “share identical life history characteristics for the majority of the Chinook salmon life cycle” has also been recognized by NMFS, as has the fact that “the conservation-directed program provides a substantial benefit to Viable Salmonid Population parameters for the White River spring Chinook salmon population” (NMFS 2004). The White River Hatchery program was designed to recover the White River spring Chinook population to sustainable levels (NMFS 2004, 2006).

The APP fish further benefit the abundance, productivity, and spatial structure of the White River spring-run Chinook salmon by creating natural progeny in the upper White River (NMFS

2004), contributing to the overall viability of the population. Given the stock history, all NORs currently in the population are progeny of hatchery production.

White River spring Chinook have been managed with an interim escapement goal of 1,000 spawning adults which is assumed to be met whenever 1,000 adults (NOR + APP fish) are collected at the MMDFPF and passed above Mud Mountain Dam (WDFW et al. 1996). However, the pre-spawn mortality rate of Chinook that are hauled upstream has not been quantified[26], and spawning ground surveys have been unable to account for the majority of Chinook passed above Mud Mountain Dam.

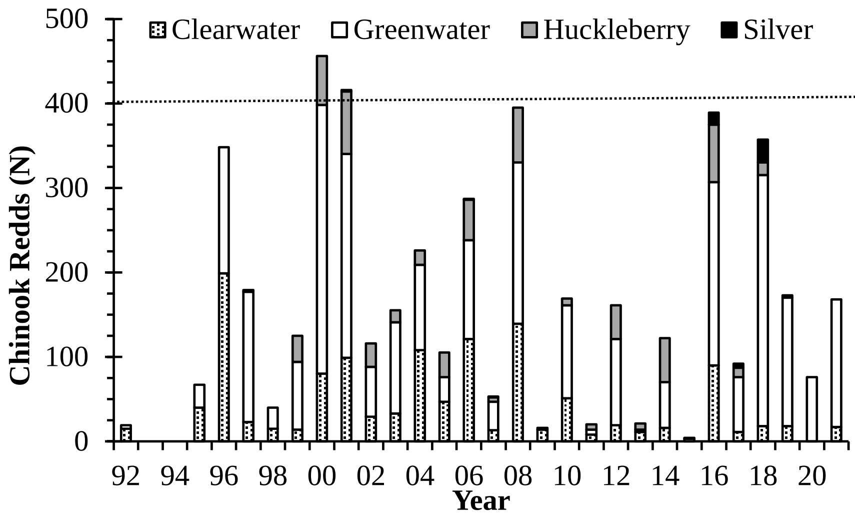

Figure 5. Total White River spring Chinook redds observed above Mud Mountain Dam in Clearwater River, Greenwater River, Huckleberry Creek, and Silver Creek.

Since 1992, an average of only 34% of adult Chinook passed upstream have been accounted for on the spawning grounds, and only 17% have been accounted for over the last 10 years (2009 to 2018). The co-managers use redd surveys to estimate the number of spawners on the spawning grounds, assuming 2.5 spawners per redd. Thus, a count of 400 redds would produce a spawning escapement estimate of 1,000. The 2000 and 2001 return years were the only years in which redd counts have reached 400 (Figure 5). In addition, the assumption of 2.5 spawners per redd has not been validated and may not apply to White River Chinook given the uncertainty around post-transport mortality and the potential for such mortality to be female-biased. Female spring Chinook in a Willamette River trap and haul program experienced higher mortality rates than males (Keefer et al. 2010) and this pattern may hold on the White River. In addition, high levels of carcass predation have impeded determination of spawner sex ratios in spawning ground carcass surveys. The inability to account for a large proportion of Chinook passed above Mud

[26] Pre-spawn mortality has been observed although no studies have been conducted. In 2013, the Puyallup Tribe reported pre-spawn mortality in 7 of 17 female Chinook carcasses collected in Huckleberry Creek. Up to 20% of spring Chinook captured at the Buckley Trap and transported to the White River Hatchery for broodstock have had head lesions or other wounds potentially caused by derelict conditions at the diversion dam and Buckley Trap; these fish died during their holding period.

Mountain Dam may also be influenced by the frequency and spatial coverage of the redd surveys conducted.

Current Stock Status

White River spring Chinook are harvested across a wide range of fisheries. As estimated using the Fishery Regulation Assessment Model (FRAM) and Terminal Area Management Module (TAMM), from 2012 to 2016, fisheries in British Columbia and Alaska (Northern) had a combined 6.3% average exploitation rate, the pre-terminal southern US (PT SUS) exploitation rate averaged 5.6%, and the terminal exploitation rate averaged 7.5%. Pre-terminal SUS exploitation rates have declined since the mid-1990s (Figure 6). Beginning in the late 1990s, northern exploitation rates rapidly increased to near 15% but have gradually declined since. Terminal exploitation rates have increased across this time series as ceremonial and subsistence fisheries have been implemented by both the Muckleshoot and Puyallup tribes. White River Chinook exploitation rates are calculated based on marked sub-yearling release groups at the White River Hatchery from 1991 to 1996, modeled through terminal fisheries within the TAMM. This time period is out of base with most other stocks in FRAM because current production is not marked.

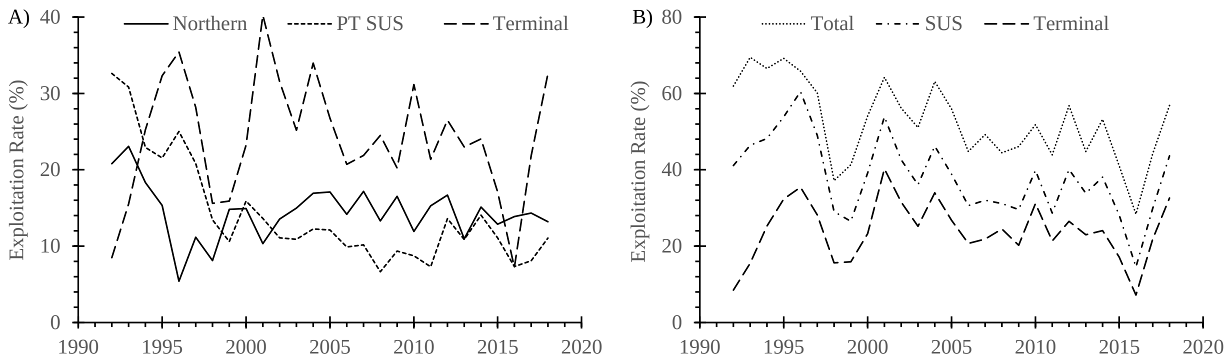

Figure 7. Trend in the A) northern (solid line), pre-terminal southern US (short dashed line), and terminal (long dashed line) exploitation rates and B) Total (dotted line), Southern US (dashed and dotted line), and terminal (long dashed line) exploitation rates on Putallup River natural origin Chinook from 1992-2018 based on FRAM version 7.1.1.

In contrast to other spring stocks in Puget Sound, White River Chinook smolts emigrate primarily as sub-yearlings. Based on adult scale samples taken at the MMDFPF, 92% of maturing Chinook sampled migrated as sub-yearlings. Smolt data from a rotary screw trap operated near the confluence with the Puyallup River (RM 1.0) during 2016 and 2017 shows that juvenile emigration from the White River is > 99% sub-yearlings (Puyallup Tribe, unpublished data). Similar to emigration timing in the Cedar, Green, and Puyallup Rivers, emigration of White River juveniles follows a bi-modal pattern with a fry peak in February/March and a smolt peak in June.

The inbreeding effective size of the White River spring Chinook population has remained stable (~235 using methods in Spidle et al. 2004) as the proportion of APP fish at the MMDFPF has increased over the years from 1995 to 2018. The proportion of NORs intercepted at the MMDFPF and screened for stock origin to integrate the White River fish hatchery program has increased from less than 75% spring (25% fall) to over 90% spring (10% fall) across the period

2004 through 2021 (Figure 7) as the proportion of acclimation pond fish has increased over that time period.

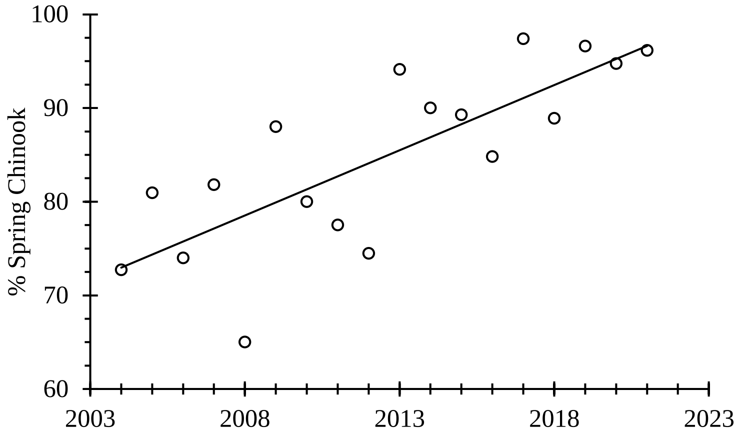

Figure 7. Percent of NOR adults sampled at MMDFPF from 2004-2021 and taken to White River Hatchery for incorporation into the broodstock that were genetically identified as White River spring Chinook.

Adult spring Chinook enter the Puyallup River from May through mid-September and spawn from mid-September through October. Spawning above Mud Mountain Dam occurs in the mainstem White River and several tributaries including the West Fork White River, Clearwater River, Greenwater River, Huckleberry Creek, and Silver Creek. Spring Chinook also spawn below the diversion dam in the mainstem White River, Boise Creek, and Salmon Creek. Spawning ground surveys are conducted in the Clearwater River, Greenwater River, Huckleberry Creek, and Silver Creek, the White River below the diversion dam, Boise Creek, and Salmon Creek. Historically, escapement estimation has been indexed at the MMDFPF because all Chinook are counted. Spawning below MMDFPF (e.g. Boise and Salmon creeks) has not been part of the escapement estimation. Glacial turbidity in the mainstem White River impairs surveys in most years.

The average age composition of adult natural origin returns between 2009 and 2018 was 41% age 3, 53% age 4, and 6% age 5 based on scale analyses. Based on coded wire tag returns, the average age of hatchery returns from both the sub-yearling and yearling programs has been highly variable among broods (Figure 8). Jacks (age-2 males) have been particularly variable, occasionally making up over 50% of the annual return. However, jacks have not accounted for over 50% of the lifetime contribution of any cohort produced by the sub-yearling program. The composition of adult returns from the sub-yearling program (not including APP fish) across the last 10 years of available data (2008 to 2017) was 52% age 3, 46% age 4, and 2% age 5. Similarly, adult returns from the yearling program was 50% age 3, 46% age 4, and 4% age 5.

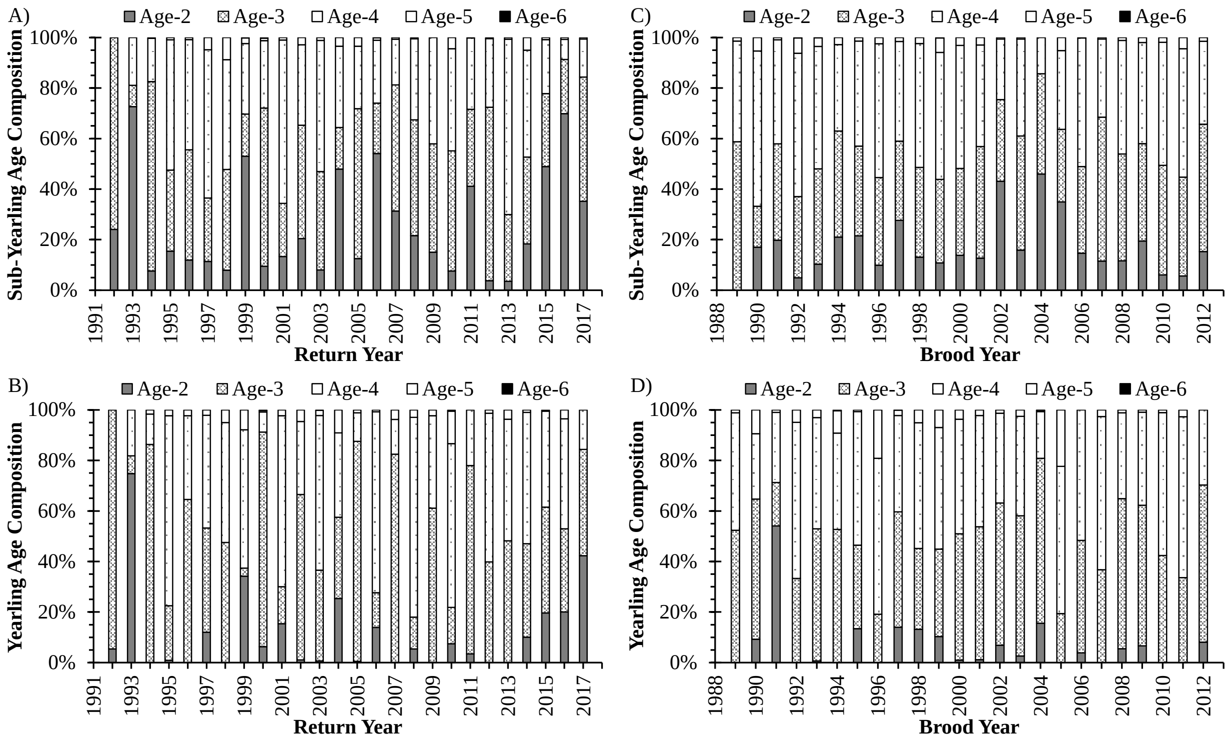

Figure 8. Coded wire tag based age composition of all White River hatchery returns from the sub-yearling (A,B) and yearling (C,D) programs by return year (A,C) and brood year (B,D) since the programs were initiated in 1989.

White River spring Chinook returns have historically been indexed by counts at MMDFPF which results in only those Chinook voluntarily entering the facility counting toward escapement objectives. This differs from spawning ground survey-based estimates in most other Puget Sound management units. White River spring Chinook brood years (1988-2013) were reconstructed from the 1984 to 2017 escapement to the Buckley Trap, by age and origin (Table 1). A Ricker and Beverton-Holt stock recruit function was fit to NOR spring Chinook escapements and their subsequent broods from the 1988 to 2013 brood years (Figure 9). The Ricker model resulted in a stock size of 488 adult Chinook hauled above Buckley Trap at maximum sustainable yield (MSY). To evaluate the variation around MSY, a jackknife procedure was used to estimate a 95% confidence interval (CI). The 95% CI ranged from 455-533 adults at MSY. This implies that 805-1,054 (929 at MSY) recruits would be produced from this range of escapement. The exploitation rate (ER) at MSY would be 47.5% (43.5-49.4% 95% CI). The expected maximum number of recruits from this population is 1,165 (1,140-1,223 95% CI) under current habitat conditions. The Beverton-Holt model resulted in a stock size of 45 (41-56 95% CI) at MSY which is expected to produce 712 (688-772 95% CI) recruits from this range of escapement. The exploitation rate (ER) at MSY would be 78.2% (76.2-79.7% 95% CI). The maximum number of recruits expected from this population is 901-988 recruits. Regardless of the assumed form of the stock recruit function, productivity and capacity is expected to increase, but needs to be corroborated, with the new USACE fish passage facilities which are anticipated to provide more favorable conditions for adult passage and juvenile emigration at Mud Mountain Dam which if conformed should diminish issues with uncertainty in the data.

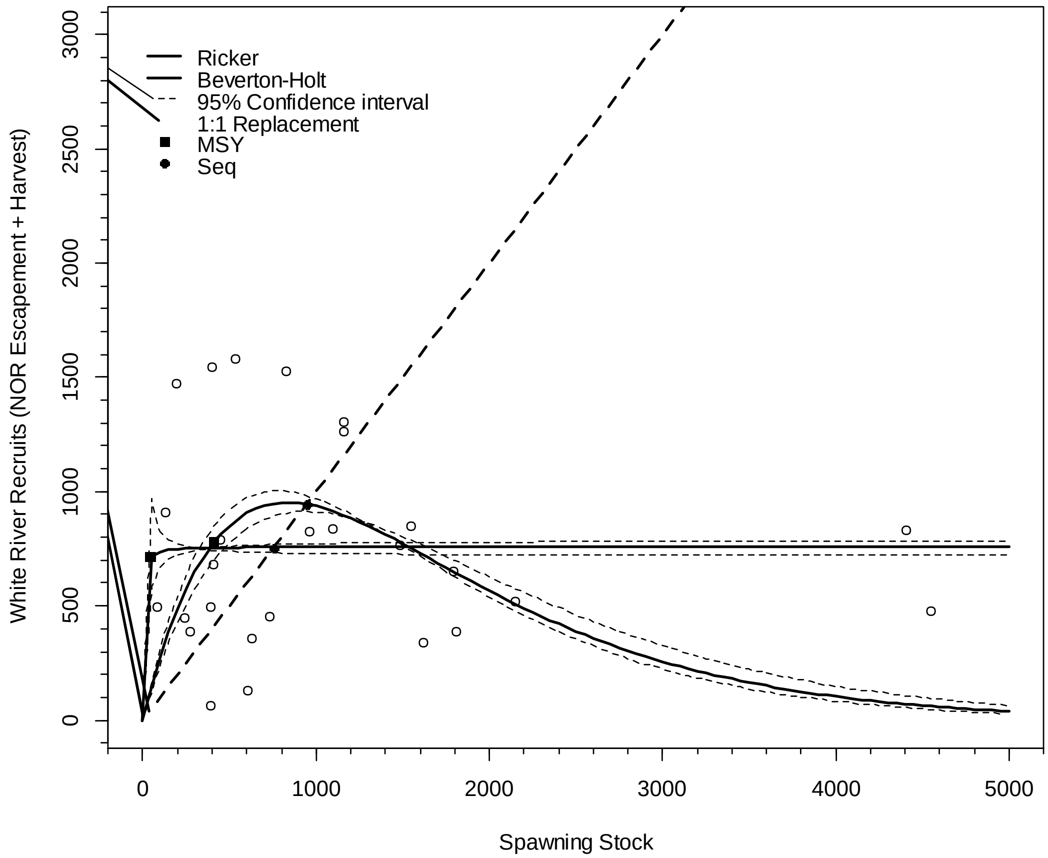

Figure 9. Ricker and Beverton-Holt stock-recruit models were fit to NOR White River spring Chinook returns from brood years 1988-2013 to estimate population size at maximum sustainable yield (MSY). The Ricker MSY is calculated from Scheuerell (2016) and results in an optimal stock size of 410 (372-419 95% CI) Chinook. The maximum number of recruits is 950 (913-1,003 95% CI). The Beverton-Holt MSY is 45 (41-56 95% CI) which is expected to produce 712 (688-772 95% CI) recruits with the maximum number expected recruits of 760 (720-786 95% CI).

Management Objectives

The scheduled improvements to the MMDFPF and downstream passage through Mud Mountain Dam can be viewed as a large-scale restoration action once the stipulated RPA performance criteria are confirmed. Improved survival of both adults and juveniles, as well as improved trap attraction, are anticipated to result in shifts in the capacity and productivity metrics for the population. Although the new facilities are scheduled to be operational by December 2020 (NMFS 2014), until the expected improvements in survival are confirmed through USACE monitoring and assessment, uncertainty will remain around impacts from the MMDFPF operations. Several generations of return data will be required to assess changes in the capacity and productivity of NOR spring Chinook transported to the upper watershed. Maintaining sufficient returns of NOR and APP (which support abundance, productivity, and spatial structure of the population [NMFS 2004]) spring Chinook to the MMDFPF should ensure sustained natural production to offset ongoing mortality impacts associated with Mud Mountain Dam operations, and the extensive constraints on juvenile rearing and survival in the lower Puyallup-White River basin and Commencement Bay. As such, the White River will continue to be managed for an interim Upper Management Threshold of 1,000 adult spring Chinook (NOR + APP fish) escaping to the MMDFPF. In some years, the complement of adult fish (NOR +APP fish) passed above the Mud Mountain Dam will exceed this threshold to test the habitat capacity and productivity of the upper watershed, particularly in response to the expected habitat improvements. Across the life of this plan, the exploitation rate management ceiling will be a 22% Southern US ER, with an assumed northern ER of 6.3% (recent 5-year average) or 8.2% (recent 10-year average) (Figure 6).

The Low Abundance Threshold (LAT) will remain at 40% of the interim escapement goal or 400 adults (NOR + APP fish) escaping to the MMDFPF. The co-managers have chosen this threshold for the LAT as a conservative measure designed to constrain pre-terminal SUS fisheries and incidental impacts in terminal fisheries and promote rebuilding of the natural stock in as few generations as possible. If escapement to the MMDFPF is forecasted to fall below the LAT, a critical exploitation rate ceiling of 15% will be implemented for the total Southern US fisheries, and terminal fisheries directed at other species will be further shaped to reduce their impacts on White River spring Chinook.

Co-manager evaluations of monitoring and assessment data collected in spawning ground survey, smolt trap, and genetic sampling activities (Table 2) together with USACE fish passage performance data will be used to inform any changes in the hatchery programs and/or harvest management through an adaptive management approach. Assuming that NMFS RPA performance criteria are immediately realized at the start of operation of the Mud Mountain Dam Fish Passage Project, by the end of this harvest plan, the co-managers would have data from approximately five complete broods that passed through the new facility to evaluate improvements in productivity and capacity associated with this restoration action.

Data Gaps and Information Needs

Table 6. Key data gaps in White River Chinook stock assessment and harvest management, and research required to address those data needs.

Data Gap	Research Needed
Uncertainty in the number of adult Chinook spawning throughout the White River system	Increased spawning ground surveys are vital to enumerate spawners and to document the spawning success of spring Chinook hauled above MMD. Assessing spawning activity in the mainstem above and below the Buckley Diversion Dam, including in the 5.3-miles between the diversion dam and MMD where little or no spawning data has been collected is needed to fully understand spawner success and distribution.
Uncertainty in stock origin/composition of spawners above and below Mud Mountain Dam	During large pink and coho salmon runs, mark status and size are not sampled at the Buckley Trap resulting in an unknown number of fall Chinook transported above MMD. Increased genetic sampling of umarked/untagged Chinook on the lower White River spawning grounds is necessary to identify the contribution of spring Chinook to the Chinook spawning population below the Buckley Trap.
Estimation of natural smolt production	Quantify total and tributary-specific smolt production above MMD. Puyallup Indian Tribe has operated a smolt trap on the lower White River since brood year 2015 which indexes all Chinook smolt emigration in the basin but does not allow identification of tributary specific spawning success. Muckleshoot Indian Tribe operated a smolt trap on the Greenwater River for brood year 2018.
Resolve differences between trap counts and spawner estimates above the dam	Estimate pre-spawn mortality rate of adults transported above Mud Mountain Dam, recycle rate, and mainstem/tributary spawning abundance.
Uncertainty in factors governing the distribution of Chinook spawning in the White River	Comprehensive spawning ground surveys are needed to identify potential interactions between Chinook salmon and other salmonids with respect to the low productivity of the natural stock.

Addressing the data gaps described above assumes that the annual monitoring that is routinely conducted by the co-managers is continued. This includes sampling and enumeration at the Buckley Trap when possible, at the White River Hatchery, juvenile emigrant trapping in the lower White, and spawning ground surveys in tributaries upstream of Mud Mountain Dam including carcass sampling.

Puyallup River Fall Chinook Management Unit Profile

Component Populations

Puyallup River Fall Chinook

Geographic Distribution

The Puyallup River basin is fed by three major rivers, the Puyallup River, White River, and Carbon River. All three originate from glaciers on Mount Rainier and carry a high sediment load. Similar to other rivers in urban areas, the Puyallup River has been extensively modified. The Electron diversion dam was constructed on the Puyallup River at RM 41.7 in 1904, blocking anadromous access to approximately 26 miles of habitat. Connectivity was reestablished in 2000 with the construction of a fish ladder. Prior to 1906, the White River primarily flowed into the Green/Duwamish River basin. However, a flood blocked the channel in Auburn, Washington diverting nearly the entire flow through the Stuck River channel into the Puyallup River at RM 10.4. In 1915, this diversion was made permanent with the installation of a concrete structure and more than doubled the size of the Puyallup River drainage basin (Figure 1).

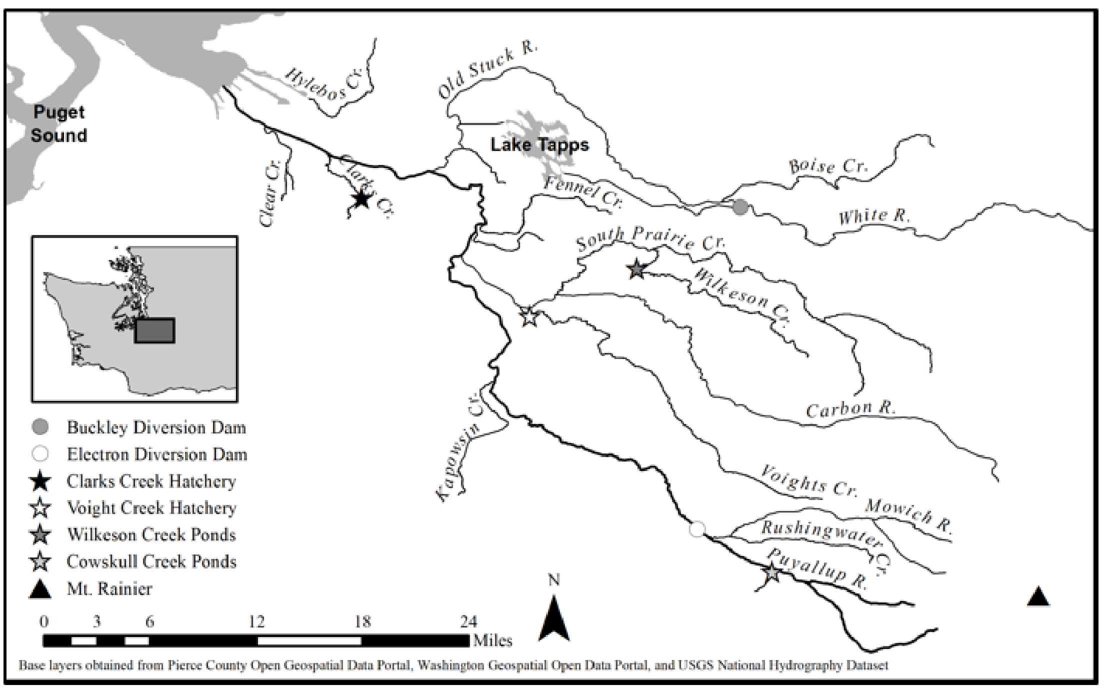

Figure 1. Location of the Puyallup River and associated prominent features discussed throughout this Management Unit Profile.

Fall Chinook spawn in South Prairie Creek (a tributary of the Carbon River) up to RM 12.6; the Puyallup mainstem up to and above (to an unknown extent) Electron Dam at RM 41.7; the Carbon River up to RM 8.5; Wilkeson, Voight, Fennel, Canyon Falls, Clarks, Clear, Kapowsin, Salmon, and Boise creeks; and the lower White River. The recent 10-year average (2008-2017) indicates that South Prairie Creek is the largest contributor to Puyallup River escapement at 33%.

The Puyallup River (20%), the lower White River (15%), and Boise Creek (12%) are the other main contributors to total escapement. All other tributaries combined contribute less than 20% of the spawning escapement. Recent genetic data indicates that natural origin Fall Chinook and Spring/Fall Chinook hybrids are trapped at the Buckley diversion dam and passed above Mud Mountain Dam on the White River.

Life History Traits

Fall Chinook begin entering the Puyallup River in June, and spawning occurs from mid-September through mid-November. Over 99% of juveniles emigrate from freshwater in their first year with parr emigration as the dominant strategy (Berger et al. 2016). Recent smolt trap data indicate parr averaged 58% of the catch. The average age composition of adult natural origin returns between 2009 and 2018 was 24% age-3, 67% age-4, and 10% age-5 (Figure 2). The age composition of hatchery origin returns was similar to that of natural origin returns with the exception that age-2 males are more likely to be recovered at the hatchery rack than they are on the spawning grounds due to their smaller size.

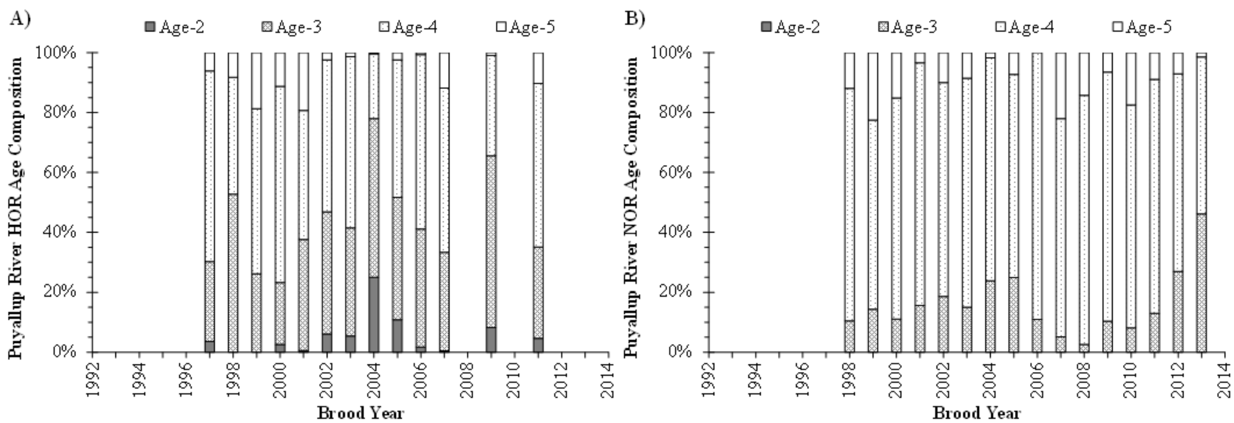

Figure 2. Brood year fall Chinook hatchery origin (HOR) age composition (A) based on CWT recoveries and natural origin (NOR) age composition (B) based on scale recoveries in the Puyallup River. All brood years were not implanted with coded wire tags in the Puyallup River hatchery programs and scale collections were not initiated until 2001 for natural origin returns in the Puyallup River.

Hatchery Production

The first hatchery in the Puyallup River basin was constructed on Voights Creek in 1914. Current hatchery production of Fall Chinook occurs at Voight Creek Hatchery (WDFW), which enters the Carbon River at RM 4; and Clarks Creek Hatchery (Puyallup Tribe), which enters the lower Puyallup mainstem at RM 6. The current production objective at Voights Creek is 1.6 million sub-yearlings released on-station. The production objectives for the Clarks Creek facility are 1.0 million sub-yearlings released on-station, 0.2 million acclimated and released (into Rushingwater Creek, Cowskull Creek, and Mowich River) above Electron Dam, and 20,000 released directly into Hylebos Creek. Releases from Voights Creek and Clarks Creek hatcheries are 100% adipose clipped and a portion are coded-wire tagged.

Voights Creek Hatchery went through an extensive renovation and modernization project that temporarily reduced releases (Figure 3A). In addition to on-station releases from the two hatchery programs, Chinook have been sporadically released into the Puyallup River or its tributaries from acclimation ponds above Electron Dam since the late 1990s. More recently, there have been releases directly into Hylebos Creek which are expected to return to this tributary in Commencement Bay (Figure 1). Terminal return rates have generally increased from the 1983 brood to present (Figure 3B). The 1989 and 2008 broods were exceptions as they exhibited particularly poor survival, while the 2004 brood and 2013-2016 brood survived exceptionally well. The co-managers are currently analyzing data that will better inform terminal return rates of both on-station hatchery programs as well as off-station releases.

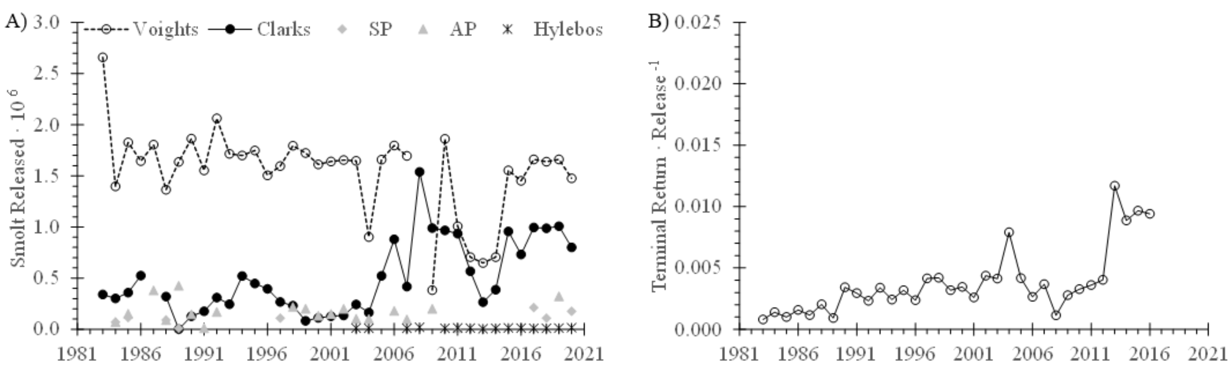

Figure 3. A) Smolt releases from Voights Creek Hatchery, Clarks Creek Hatchery, plants into the Puyallup River above (AP) or below (SP) Electron Dam, and plants into Hylebos Creek from brood year 1983-2020 and B) smolt to adult (age 3-5) terminal return of the aggregated hatchery production released into the Puyallup River basin from complete broods released in 1983-2016. Note that Hylebos Creek is not a part of the Puyallup River basin and brood year 2016 does not contain 5-year old recoveries.

The co-managers are continuing to evaluate options for increasing salmon productivity in Puyallup River basin consistent with a watershed management strategy currently being developed by co-managers and the agreed to Hatchery and Genetic Management Plans (HGMP) for the basin. Puyallup River Chinook are well below the planning ranges for recovery escapement (Figure 4A), as well as below spawner recruit levels identified as consistent with recovery (NMFS 2006). In the Puyallup River, recovery planning ranges for escapement are 17,000 - 33,000 natural origin (NOR) Fall Chinook with productivities ranging from 1.0 - 2.3 recruits/spawner (NMFS 2006). The recent 10-year average spawning abundance for NOR Fall Chinook is 813 with a productivity of 0.9 recruits/spawner. Until habitat function is restored, hatchery production will be essential to harvest opportunity in highly urbanized watersheds like Puyallup River.

Genetic Information

Puyallup River Fall Chinook are genetically indistinguishable from Green River Chinook, reflecting extensive use of this stock to initiate local hatchery programs (Ruckelshaus et al. 2006). There is no genetic evidence of an extant, native Fall stock in the basin. However, Fall

Chinook returning to the Puyallup and White rivers are genetically distinct from the White River Spring Chinook population.

Status

The Puyallup River Chinook population has historically been managed for total natural spawners on the spawning grounds which has varied from 663 to 3,438 since 1988 (Figure 4A). The escapement methodology in the Puyallup and Carbon Rivers is consistent with other watersheds in Puget Sound and carries uncertainties associated with water clarity in glacial systems and interactions with other species (i.e. pink salmon). Despite these limitations, the co-managers are confident that current escapement estimates provide an accurate estimate of the number of spawners in the Puyallup and Carbon Rivers. Additionally, over 50% of spawning activity takes place within the non-glacial tributaries and the co-managers believe these estimates are as good as any spawning escapement estimates in Puget Sound.

Due to its glacial influence and turbid waters, a threshold of 500 adult Chinook in the Puyallup River basin has been used for the low abundance threshold (LAT) and a threshold of 500 adult Chinook in South Prairie Creek was used for the upper management threshold (UMT). The general trend in escapement has been negative across the available data, but the last three returns have been moderate to large. Since the low in 2013, total spawning escapement has increased to an average over 2,000 across the last three years (Table 1). Spawning abundance has never fallen below the LAT, however, spawning abundance has fallen below the escapement objective in two out of the last ten years. NOR spawners have followed a pattern similar to total spawners. Since mass marking of hatchery Chinook began in 2000, confidence in estimated NOR/HOR contributions has increased, and NOR contributions to the spawning grounds have decreased from near 60% in 2005, the first year where all returning hatchery broods were marked, to less than 40% in 2017 (Figure 4B). Without the 2008 return included, there would be no trend in the NOR or HOR stock composition on the spawning grounds after all broods were mass marked. Due in part to the long history of hatchery production and habitat degradation in the basin, hatchery produced Chinook are an important component of natural spawning escapement (Figure 4C).

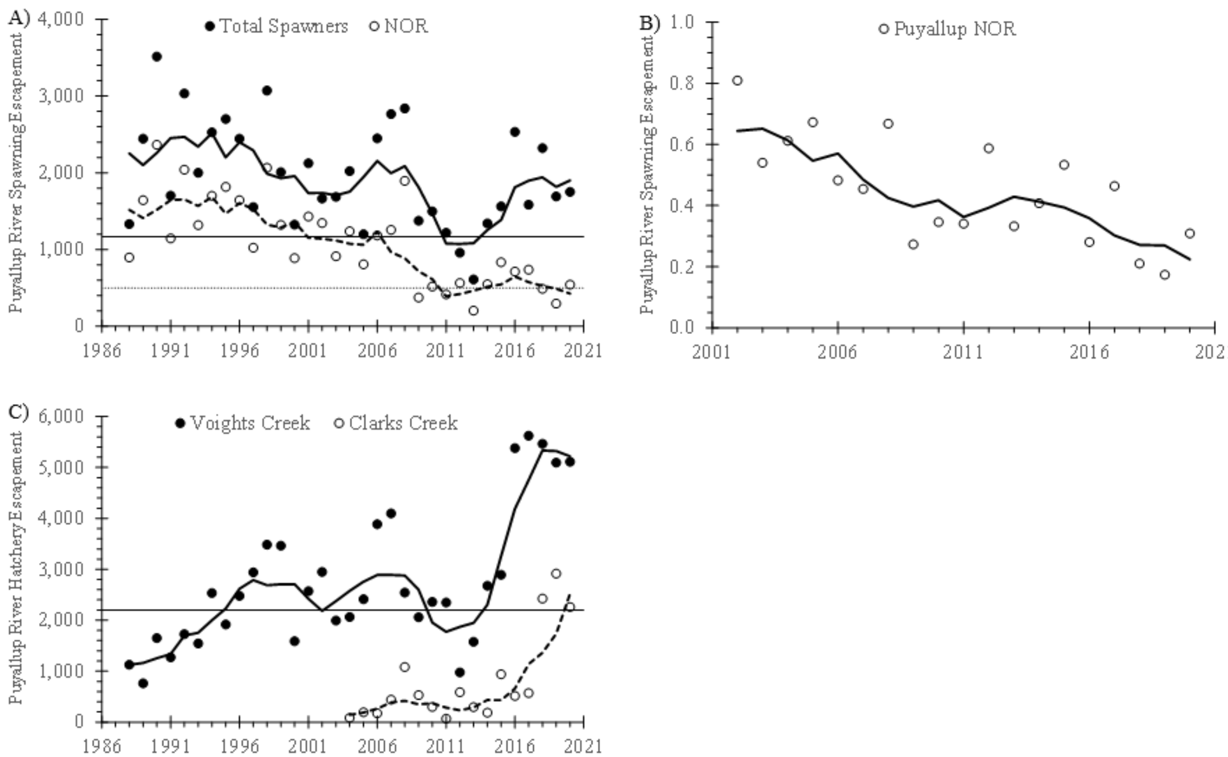

Figure 4. Total (filled circle) and NOR (open circle) spawning escapement on the Puyallup River Chinook spawning grounds (A) from 1988-2020. A 5-year running geometric mean for total (solid line) and NOR (dashed line) escapement is fit to each data series. The historic escapement goal of 500 natural spawners in South Prairie Creek (lite dashed line) and current escapement goal (1,170) of natural spawners (lite solid line) in the Puyallup River based on current habitat conditions are shown. Observed NOR Chinook contribution to the Puyallup River spawning grounds (B) from 2002-2020 (open circles) with a 5-year running geometric mean (dashed line). Hatchery rack escapement (C) at Voights Creek Hatchery (filled circle) from 1988-2020 and Clarks Creek Hatchery (closed circle) from 2004-2020 are shown with a 5-year running geometric mean. The combined hatchery rack escapement goal of approximately 2,200 (the current goal is not necessarily reflective of historic goals) adult Chinook needed to make program goals is shown (lite solid line).

The historic escapement goal of 500 in the Puyallup River basin (i.e. LAT) or South Prairie Creek (i.e. UMT) was not based on a biological objective and does not reflect the productivity of current habitat conditions. Update of the FRAM base period to brood years 2005-2008 necessitated updating natural and hatchery escapements back to 1988 for calibration. These data were used to fit a Beverton-Holt stock recruit model with additive error structure and with multiplicative error structure (Beverton and Holt 1957) to brood years 1988-2014 (Figure 5). For the additive error structure model, a=0.2468 and b= 0.000174 which resulted in a spawning stock size at equilibrium of 4,317 and a theoretical maximum recruitment of 5,732. The spawning stock size at MSY is 1,433 which is expected to result in 2,885 recruits. The exploitation rate (ER) at MSY would be 50.3% (38.0-58.2% 95% CI). For the multiplicative error structure model, a=0.3003 and b=0.000234 which resulted in a spawning stock size at equilibrium of 2,993 and a theoretical maximum recruitment of 4,278. The spawning stock size at MSY is 1,060 which is expected to produce 1,934 recruits. The ER at MSY would be 45.2% (37.0-51.1% 95%CI).

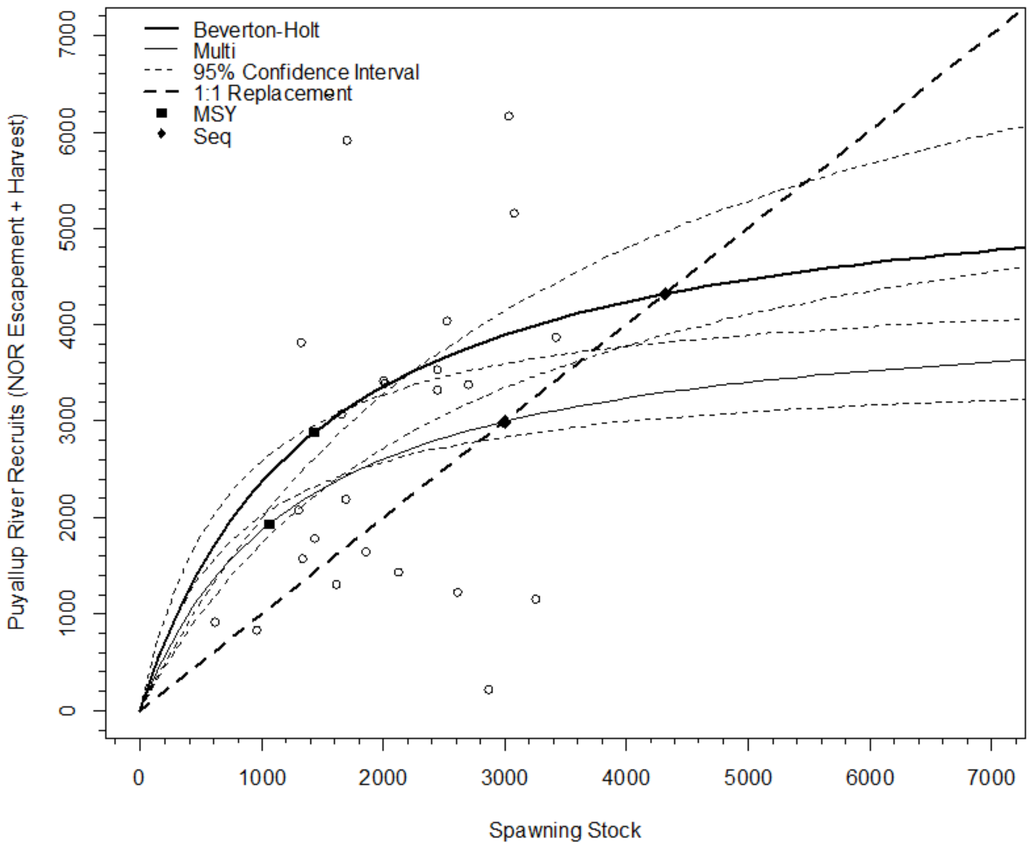

Figure 5. Beverton-Holt stock-recruit model with additive error structure (bold solid line) and multiplicative error structure (lite solid line) for Puyallup River Chinook based on brood years 1988-2014. The spawning stock size at MSY is 1,433 (1,102-2,090 95%CI) which results in 2,884 (2,635-3,373 95%CI) recruits for the additive error structure model and MSY is 1,060 (886-1,485 95%CI) which results in 1,934 (1,811-2,359 95%CI) recruits for the multiplicative error structure model. The spawning stock size at equilibrium is 4,317 (3,763-5,471 95%CI) Chinook for the additive error structure model and 2,993 (2,734-3,845 95%CI) for the multiplicative error structure model.

Table 1. Natural origin recruits (NOR; including Fall spawners in the Puyallup and White rivers) and hatchery origin recruits (HOR; including both Voights Creek and Clarks Creek hatcheries) that escaped pre-terminal and terminal fisheries. Recruits/Spawner (R/S) includes all adult NORs caught in pre-terminal and terminal fisheries and counted on the spawning grounds in the Puyallup or White rivers. Pre-terminal mortalities from the 1988-2014 brood years are based FRAM 7.1.1.

Return Year	NOR	HOR	Spawners	R/S[a]
1988	956	1,504	1,332	6.22
1989	1,753	1,451	2,442	1.45
1990	2,525	2,641	3,515	2.52
1991	1,222	1,753	1,702	3.48
1992	2,228	2,532	3,034	2.03
1993	1,436	2,109	1,999	1.71
1994	1,774	3,285	2,526	1.60
1995	1,854	2,766	2,701	1.25
1996	1,637	3,287	2,444	1.36
1997	1,016	3,477	1,554	4.12
1998	1,959	4,596	3,071	1.68
1999	1,248	4,224	2,009	1.69
2000	834	2,133	1,322	2.89
2001	1,297	3,475	2,123	0.68
2002	1,090	3,760	1,663	1.85
2003	998	2,789	1,687	1.30
2004	1,209	3,070	2,020	1.91
2005	866	3,005	1,200	1.73
2006	1,234	5,331	2,449	0.50
2007	1,392	6,269	2,766	0.42
2008	2,132	4,572	2,837	0.08
2009	538	3,620	1,375	1.30
2010	550	3,737	1,497	0.87
2011	487	3,509	1,218	1.35
2012	654	1,984	958	0.87
2013	252	2,468	610	1.51
2014	544	3,789	1,339	1.17
2015	984	4,971	1,561	--
2016	737	7,854	2,533	--
2017	735	7,043	1,584	--
2018	487	9,722	2,321	--
2019	294	9,407	1,691	--
2020	541	8,579	1,750	--

[a] The 1988 R/S estimate does not include Age-3 pre-terminal or terminal freshwater sport mortalities.

Recruits per spawner have been moderately variable in the Puyallup River population (Figure 6). The 1988 brood year was the most productive brood with 6.2 recruits per spawner. The least productive brood years were 2006-2008 which produced fewer than 0.5 recruits per spawner. Escapement during these three low productivity years averaged 2,684, which is larger than average recruitment in the Puyallup basin but does not explain the low productivity. The anomalously low 2008 brood year recruit-per-spawner (0.08) was the result of January flood event. This flood peaked on January 7th at 212.7 $m^3 \cdot s^{-1}$ and likely scoured Chinook eggs and fry that were incubating, resulting in the lowest productivity examined across the available data. This event in South Prairie Creek the largest observed monthly average discharge (24.3 $m^3 \cdot s^{-1}$) in the 58-year record in South Prairie Creek and was 2.7 standard deviations greater than the 11.1$m^3 \cdot s^{-1}$ average January discharge. There is no correlation between Green River and Puyallup

River Chinook productivity (r = 0.08). Within the Puyallup basin, Puyallup River Fall and White River Spring Chinook productivity is moderately correlated (r = 0.74). The average productivity across all brood years is 1.8 recruits per spawner whereas 1.8-2.0 (depending on the model) recruits per spawner is the current productivity at MSY.

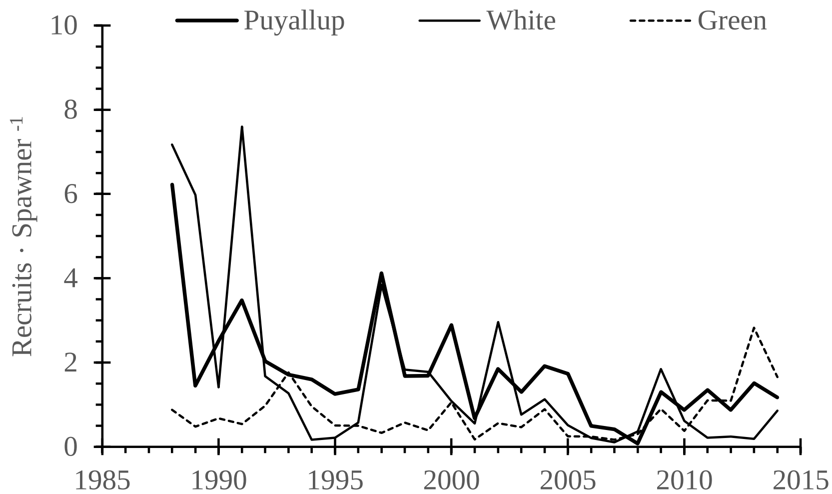

Figure 6. Trend in recruits per spawner for Puyallup River (bold line) and adjacent management unit natural origin recruits from completed brood years (1989-2014).

Harvest Distribution and Exploitation Rate Trends

Puyallup River Chinook are part of the Mid-South Puget Sound Fall fingerling FRAM stock aggregate. The FRAM base period for this stock aggregate is based upon coded wire tagged indicator groups from Issaquah Creek, Soos Creek, Voights Creek, and Grovers Creek hatcheries from the 2005-2008 brood years. Natural spawners in the Puyallup River basin including the lower White River are the managed natural components of the Puyallup River Chinook population, which is modeled through terminal fisheries within the Terminal Area Management Module (TAMM).

As estimated by post-season FRAM/TAMM for Puyallup River Chinook, from 2010 to 2014 fisheries in British Columbia and Alaska had a combined 13% average exploitation rate, the pre-terminal southern US (PT SUS) exploitation rate averaged 10% and the terminal exploitation rate averaged 32%. Pre-terminal exploitation rates generally declined through the 1990s (Figure 7). Beginning in the early 2000s, northern exploitation rates began to increase to levels similar to those of the early 1990s. Terminal exploitation rates have been consistent across the time series at about 30% with only a few years falling below 20%.

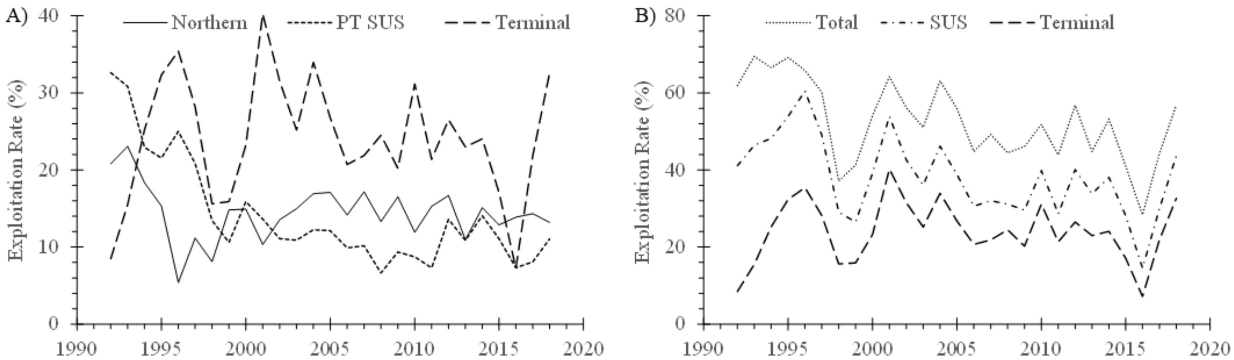

Figure 7. Trend in the A) northern (solid line), pre-terminal southern US (short dashed line), and terminal (long dashed line) exploitation rates and B) Total (dotted line), Southern US (dashed and dotted line), and terminal (long dashed line) exploitation rates on Puyallup River natural origin Chinook from 1992-2018 based on FRAM version 7.1.1.

Management Objectives

The harvest management strategy for Puyallup River Chinook assumes the indigenous Fall population has been extirpated. Management in the Puyallup River for the Green River derived stock will continue based on total natural escapement that includes both natural and hatchery origin adults on the spawning grounds; as well as hatchery rack escapement at Voights Creek Hatchery and Clarks Creek Hatchery[27]. Puyallup River escapement goals will be consistent with escapement according to MSY under current habitat conditions. The co-managers intend to review escapement goals on a 5-year cycle similar to NOAA status reviews. The Upper Management Threshold (UMT) will be set at MSY escapement with a trigger that allows progressively higher pre-terminal exploitation rates during the pre-season planning process contingent on meeting management objectives in the Lake Washington and Green River management units (MUs). This trigger is designed to account for uncertainties in the pre-season forecast and pre-terminal fisheries, and to increase the likelihood of attaining sufficient terminal abundance to allow terminal area Chinook-directed fisheries to proceed. Southern U.S. fisheries will be planned in the pre-season according to a tiered management regime that accounts for uncertainties in the pre-season forecast. Terminal directed fisheries will be planned in the pre-season when terminal run size meets a threshold abundance that can reasonably be assumed to meet the natural spawning and hatchery escapement objectives. The Low Abundance Threshold (LAT) will be set at 40% of the escapement goal. The co-managers have chosen this threshold for the LAT as a conservative measure designed to constrain pre-terminal SUS fisheries and incidental impacts in terminal fisheries which will promote rebuilding of the natural stock in as few generations as possible and will keep the population from falling to a lower abundance that could cause demographic risk.

The co-managers developed two spawner-recruit functions for the Puyallup River Fall Chinook management unit. These spawner-recruit functions estimated an MSY escapement goal of 1,060

[27] However, among pre-terminal entities, the State has agreed to take responsibility for meeting hatchery escapement objectives.

- 1,433 with both estimates receiving similar support from the data. A spawning escapement goal of 1,170 was ultimately chosen.
To manage terminal fisheries so that an 1,170 spawning escapement goal can be met while equitably sharing harvest and minimizing the risk that mixed stock fisheries pose when operating on pre-season projected abundances, triggers similar to those developed for the Green River Fall Chinook management unit are needed. These are tier-based triggers that allow for progressively higher pre-terminal southern US exploitation rates as terminal abundance increases.

To develop these triggers, terminal harvests (sport, directed net, and incidental net) were examined to estimate the impacts these fisheries had on terminal abundances. For the first upper management threshold (UMT 1), at least one directed net fishery opening, a full complement of incidental (i.e. coho and chum directed) fisheries, and 50% of the typical sport catch was calculated and related to the estimated number of spawners entering the terminal area (81B). For the second upper management threshold (UMT 2), the recent average fishery impacts from all net and sport fisheries was calculated and related to the estimated number of spawners entering the terminal area. Hatchery escapements were able to be met for all observed terminal runs and did not provide any additional constraints. For UMT 1, a projected spawning escapement (hatchery + natural) of 1,538 entering the terminal area would provide one directed Chinook net fishery, average incidental impacts during coho and chum fisheries, and 50% of the average sport catch. For UMT 2, a projected spawning escapement (hatchery + natural) of 1,895 entering the terminal area would provide for average fisheries in recent years. UMT 1 does not become constraining at any observed abundance. UMT 2 would have been constraining only during 2012 and 2013 which were years impacted by the hatchery rebuild at Voights Creek and likely not representative of typical hatchery returns or straying to the spawning grounds.

The new UMT 1 for Puyallup River is 1,538 adults in the terminal area destined for the spawning grounds prior to terminal area fisheries. The newly established UMT 2 for the Puyallup River is 1,895 adults in the terminal area destined for the spawning grounds. Consistent with the goals of achieving the natural and hatchery spawning escapement goals and ensuring that terminal directed fisheries will occur, at abundances above the UMT 1 of 1,538 adults in the terminal area destined for the spawning grounds and sufficient projected escapement to Voights Creek and Clarks Creek Hatcheries, PT SUS fisheries will be planned not to exceed a 14% ER if criteria in the Lake Washington and Green River MU are also met (Table 2). If abundance is projected above the UMT 2 of 1,895 adults in the terminal area destined for the spawning grounds, UMT 1 is projected to be met for Lake Washington, and UMT 2 to be met for Green River, then the Mid-Puget Sound aggregate will be managed for up to a 15% PTSUS ER. In the terminal area (81B), directed Chinook fisheries will be designed to achieve spawning and hatchery escapement at or above management objectives that will allow the population to test habitat recovery projects and their impacts to survival in this basin. This approach reflects the primary goal of meeting the conservation objective of achieving MSY escapement, as well as the importance of achieving a sufficient abundance in the terminal area to allow fisheries directed at Chinook.

Table 2. Natural spawning escapement goals, management thresholds, and corresponding exploitation rate ceilings for stock components of the Mid-South Puget Sound FRAM stock aggregate. The moderate management threshold (MMT) is triggered when natural spawning escapement is forecasted between the low abundance threshold (LAT) and the upper management threshold (UMT). In pre-terminal fisheries the stock aggregate is managed for its weakest component MU.

Management Unit	Escapement Goal	LAT (SUS)	MMT (SUS)	UMT 1 (PT SUS)	UMT 2 (PT SUS)[2]
Lake Washington[1]	500	200[3] (12%)	18%	500[4] (14%)	500[4] (15%)
Green River	2,744	1,098 (12%)	18%	4,500 (14%)	6,700 (15%)
Puyallup River	1,170	468 (15%)	30%	1,538 (14%)	1,895 (15%)

[1] The Cedar River is the natural managed component of the Lake Washington MU
[2] If the Lake Washington MU meets its UMT and both the Green River and Puyallup River MU meet their respective upper triggers for a 15% pre-terminal ER, then all Mid-Puget Sound aggregate MUs will be managed for a 15% pre-terminal SUS ER.
[3] The LAT will increase to 300 if spawning escapement falls below 200.
[4] The UMT will increase to 570 if spawning escapement falls below 200 or below 324 in two consecutive years.

The LAT will be 468 naturally spawning adult Chinook. Observed natural spawning escapements have not fallen below this level: the lowest observed natural spawning escapement on the Puyallup River was 993 in 2012, which produced 541 recruits, and the five most recent cohorts have produced an average of 1,255 recruits.

If the FRAM/TAMM pre-season model output of natural spawning escapement entering the terminal area falls between the UMT and LAT, the SUS fisheries will implement the moderate management threshold (MMT) where SUS fisheries will not exceed a 30% (pre-terminal + terminal) ER. Under this approach, terminal fisheries planned in the pre-season at the MMT or LAT will only have incidental impacts to Chinook as fisheries will be directed at other salmonids. The MMT threshold for the Puyallup River management unit differs from the other component populations in the mid-South Puget Sound aggregate due to the structure of fisheries. Puyallup River Fall Chinook overlap much more extensively with coho returns to the basin than in the Green River or Lake Washington management units.

If the FRAM/TAMM pre-season model output of natural spawning escapement entering the terminal area falls below the LAT, a critical exploitation rate ceiling of 15% will be implemented for SUS fisheries (pre-terminal + terminal). Under this approach, terminal fisheries planned in the pre-season will only have incidental impacts to Chinook fisheries and will be directed at other salmonids. When Chinook abundance is forecast below the LAT, coho fisheries will be delayed until week 37 which will eliminate Chinook encounters during the traditional first week (36) of coho fisheries. However, directed fisheries may occur at the MMT or LAT and result in a higher exploitation rate if a terminal area co-manager (Puyallup Indian Tribe, Muckleshoot Indian Tribe, and Washington Department of Fish and Wildlife) agreed-to terminal in-season update (ISU) model is developed that predicts a terminal run-size above the UMT and is sufficient for limited terminal Chinook directed fisheries. If natural spawning escapement falls below the LAT, hatchery rack escapement is likely to further constrain fisheries due to their relationship.

During the pre-season process, Puget Sound (sport and terminal) fisheries will be planned to meet the broodstock needs at Voights Creek Hatchery and Clarks Creek Hatchery. Even when expected abundance of Chinook returning to the Puyallup River to spawn naturally is above the management objectives, it is possible that additional fishery actions may be necessary to ensure broodstock needs at the hatchery are met. Broodstock needs at Voights/Clarks Creek Hatcheries will be calculated based on pre-spawn mortality in the adult holding ponds, fecundity, male-to-female ratio and egg-to-smolt survival that the terminal area co-managers will discuss and agree to during the pre-season planning process. Further in-season actions consistent with the agreed to HGMP may be required to meet natural spawning and hatchery goals as additional information becomes available.

There is some uncertainty in rates of impact of northern fisheries (British Columbia and Alaska) on Puyallup River Chinook (Figure 7A), therefore the co-managers are assuming northern fisheries impacts follow a recent year average. SUS fisheries will be constrained to the levels described above when natural spawning abundance is expected to be below the management objectives. Those constraints, coupled with the agreed-to hatchery objectives, will ensure that fisheries do not reduce the likelihood of recovery of Puyallup River Chinook, while allowing limited fisheries to continue in years when natural spawning abundance falls below the UMT.

In-season Update and Other Terminal Fishery Management Measures

Unlike the Lake Washington or Green River MUs, there is no current in-season update methodology in place to guide terminal fisheries prior to fisheries initiation. However, historic terminal net catch is available that has been used to construct an ISU after directed Chinook openings. This results in a model similar to the second ISU in the Green River MU. For the proposed Puyallup River ISU, Chinook catch from the first commercial opening and the week that catch occurred is used to project the aggregate Puyallup River Fall Chinook terminal run size. This new Puyallup ISU performed well for having only one night of directed net fisheries (Figure 8). This model has an average percent error of 16.6% or 1,458 adults across all years and has predicted the recent large terminal run sizes extremely well. Assuming the co-managers determine sufficient surplus remains to open a second directed net fishery, an additional ISU is available to evaluate the terminal abundance after this fishery. While there have been fewer years where a second terminal net fishery has occurred, this model has an average percent error of 11.1% or 1,107 adults across all years. Like the first ISU, the second ISU has responded well to the recently observed adult returns.

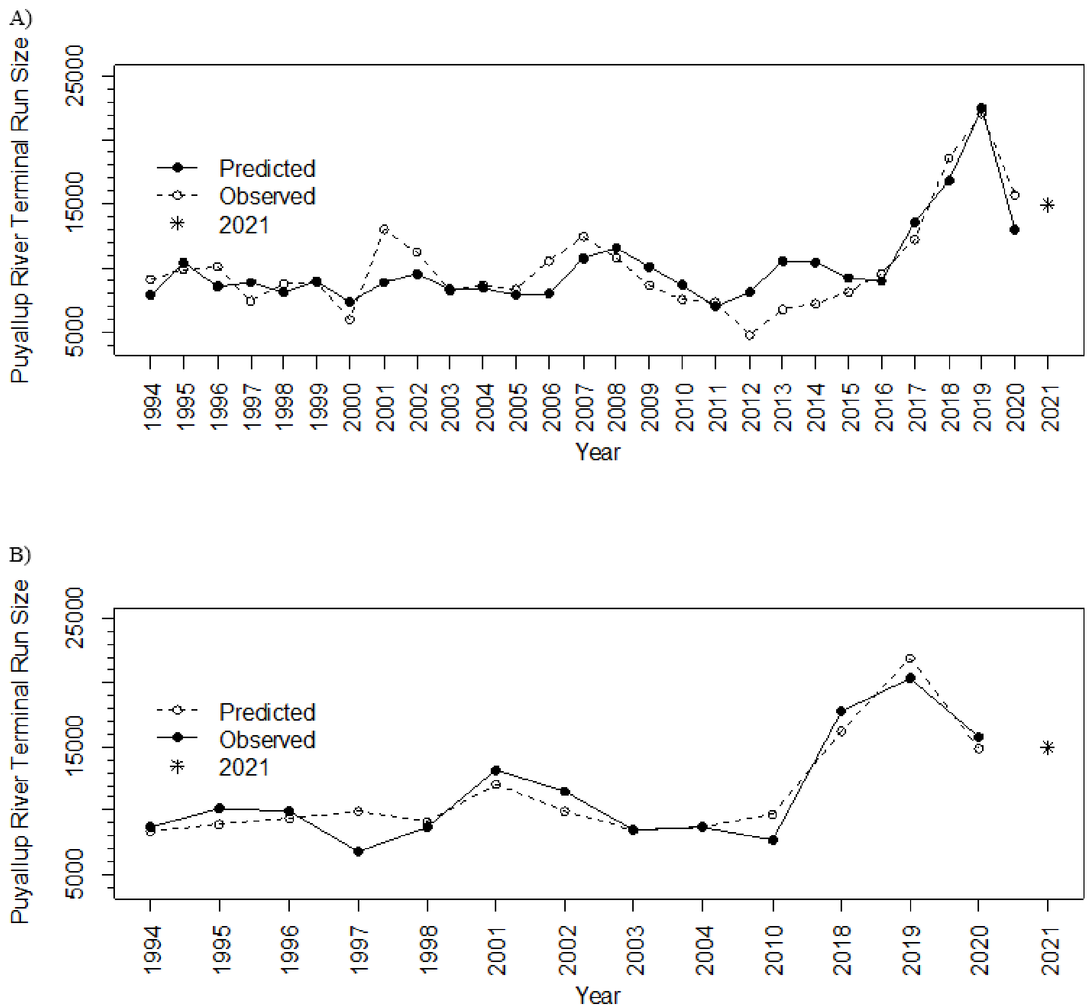

Figure 8. Observed and predicted terminal run sizes for the Puyallup River fall Chinook MU based on the first (A) or first and second (B) directed net fisheries.

Terminal and pre-terminal fisheries will be planned during the pre-season process to meet the outlined conservation goals. In-season, terminal net and sport fisheries will be initiated as planned during the pre-season. After the first directed net fishery opening is conducted, natural spawning and hatchery escapement objectives will be re-evaluated. If projected escapements conform to or exceed pre-season expectations, terminal fisheries will continue as planned. However, should projected escapements fall short of pre-season expectations such that escapements may not be achieved, fisheries (both net and sport) will be reduced so that escapements are more likely to be achieved. These ISUs will be used to inform both directed and incidental fisheries that impact Chinook in the Puyallup River MU and can serve to increase or decrease fisheries in response to in-season information.

The co-managers recognize the importance of maintaining strong monitoring and enforcement programs to ensure that fishery impacts are accurately assessed and that fisheries remain in compliance with planned seasons and regulations. Therefore, the co-managers agree to develop and implement a coordinated Annual Monitoring and Enforcement Plan annually during the term of the RMP. WDFW is committed to continuing and improving fishery enforcement and compliance on the Puyallup and Carbon rivers, particularly during times of Chinook, coho, and pink salmon returns in August and September. Communication between WDFW and tribal enforcement on issues arising on the river should continue, and opportunities for enhanced coordination between state and tribal enforcement staff should be considered through development of the annual plan to maximize the effectiveness and efficiency of co-manager enforcement activity.

In 2021, WDFW implemented a creel sampling study to provide estimates of salmon catch, releases of unmarked fish, and angler effort, with the intent of using the data and estimates to evaluate and improve management of the freshwater recreational salmon fishery in the Puyallup and Carbon rivers. Creel surveys were previously conducted on this fishery from 2004-2010, and updated creel sampling was undertaken to ensure that the fishery is being properly represented in pre-season modeling and post-season assessment. WDFW will continue to implement creel surveys in the Puyallup and Carbon annually from 2022 through 2027. The creel survey design will be developed by a co-manager technical team, and beginning in 2023 reporting of catch and encounter estimates will occur on a weekly basis.

As a conservative approach to management of the freshwater sport fishery while additional creel data is collected, the recreational salmon fishery in the Puyallup and Carbon will be limited to a maximum of 4 open days per week from 2022 through 2027 during times of Chinook presence (August-September). Open and closed days within each week will continue to be determined during the North of Falcon process to minimize potential gear conflicts between tribal and non-tribal fisheries, but the entire recreational salmon fishery will open and close on the same days for the Carbon and Puyallup so that effort shifts between areas are not created. Beginning in 2028 the Puyallup Tribe, Muckleshoot Tribe and WDFW will annually review fisheries, creel survey results, and the abundance of Puyallup Chinook and will agree on the recreational fishing schedule during the North of Falcon process.

If the co-managers are unable to reach agreement on Puyallup Chinook topics related to implementation of the RMP, the co-managers agree to seek assistance from the Federal Mediation and Conciliation Service or other mutually agreed dispute resolution service.

Data Gaps and Information Needs

Table 2. Data gaps in Puyallup River Chinook stock assessment and harvest management, and research required to address those data needs.

Data gap	Related research needed
Evaluation of escapement estimation methodology	Use Voights/Clarks Creek outplants for a mark/recapture estimate of the total spawning escapement.
Spawning escapement in the lower/upper White River	Increased genetic sampling to evaluate the extent of Fall Chinook spawning in the White River basin.
Estimate Chinook mortality during mark selective fisheries	Encounter rate study, freshwater hooking mortality study, compliance study.
Pre-terminal in-season update models	In partnership with terminal and pre-terminal Tribes and State, examine relevant fishery dependent or

	independent data to develop an in-season update model for pre-terminal SUS fisheries.
Stock specific exploitation rates	The Puyallup River stock is a component of the Mid-South Puget Sound Fall fingerling release group in FRAM. Each of the component stocks should be managed separately to better assess population level impacts.

The data gaps described above assume that the current annual monitoring in place will continue. This includes spawner surveys and carcass sampling, outmigration estimation in the mainstem Puyallup River, and hatchery rack sampling.

Nisqually River Management Unit Status Profile

The State of Washington through its Department of Fish and Wildlife (WDFW) and the Nisqually Indian Tribe (Tribe or NIT) (collectively herein, "Local Co-managers") prepared this Management Unit Profile (MUP) for the Nisqually River fall-run Chinook.

Component Populations

Nisqually River fall-run Chinook

Recovery Plan

This MUP is informed by and relies upon the Fishery Regulation Assessment Model (FRAM) version 7.1.1 and the *Stock Management Plan for Nisqually Fall Chinook Recovery – December 2017 Final (Nisqually SMP)*. The *Nisqually SMP* describes the latest set of actions and the monitoring plan for the Nisqually River fall-run Chinook, as developed by the Local Co-managers and the National Oceanic and Atmospheric Administration (NOAA) (NCWG 2017). It is attached to the *Puget Sound Resource Management Plan* (*RMP*) as an appendix, and the Local Co-managers refer readers to that document for specific details on the population, recovery objectives for it, and actions for evaluating the reintroduction of a self-sustaining Chinook population in the Nisqually River.

Geographic Description

Adult Chinook ascend the mainstem of the Nisqually River to river mile (RM) 42.5, where migration is blocked by the La Grande and Alder Hydroelectric Complex, which was constructed by the City of Tacoma's public utility in 1945. Below La Grande, the river flows to the northwest across a broad and flat valley floor characterized by mixed coniferous and deciduous forest and cleared agricultural land. Between river miles 5.5 and 11, the river runs through the Nisqually Indian Reservation, and between river miles 11 and 19, through the largely undeveloped Fort Lewis military reservation. At river mile 26, flow is diverted into the Yelm Power Canal, which carries the water downstream to the Centralia Powerhouse, where the flow returns to the mainstem at river mile 12. A fish ladder provides passage over the diversion. The Federal Energy Regulatory Commission licenses issued to Tacoma and Centralia require maintenance of minimum flows in the mainstem Nisqually.

Chinook spawn in the mainstem above river mile 3, in numerous side channels, in the lower reaches of the Mashel River, and in several tributaries, if flow allows.

Life History Traits

Run Timing

Table 1. Run timing distribution for various life stages of Nisqually River fall-run Chinook salmon.

Nisqually Chinook	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
River entry (fishery)												
Spawn timing												
Emergence timing												
FW Outmigration												

Table 2. Nisqually Chinook Age Composition.

Hatchery Origin				Natural Origin			
Return Year	Age 3	Age 4	Age 5	Return Year	Age 3	Age 4	Age 5
2004	31%	66%	3%				
2005	64%	29%	7%				
2006	56%	43%	1%				
2007	73%	26%	1%				
2008	40%	60%	0%				
2009	47%	53%	0%				
2010	82%	18%	0%	2010	79%	21%	0%
2011	20%	79%	1%	2011	24%	76%	1%
2012	69%	29%	2%	2012	59%	40%	2%
2013	43%	56%	0%	2013	38%	62%	0%
2014	44%	55%	1%	2014	54%	42%	4%
2015	34%	64%	3%	2015	51%	48%	1%
2016	65%	31%	5%	2016	67%	29%	4%
2017	90%	10%	0%	2017	75%	23%	1%
2018	63%	37%	0%	2018	51%	48%	1%
2019	63%	36%	1%	2019	77%	23%	0%
2020	60%	38%	2%	2020	41%	57%	1%
Average	55%	43%	2%		56%	43%	1%

Nisqually River Chinook juveniles primarily migrate downstream as sub-yearlings in two distinct modes: an early fry component and a later parr component (Klungle et al. in prep). The fry component rears in the Nisqually Delta for over a month before migrating offshore in late June (Ellings and Hodgson 2007). Nisqually Chinook parr outmigrate in June through July and move quickly through the river and estuary.

Population Status

In determining the status of the Nisqually fall Chinook population, several parameters are considered: productivity, abundance, spatial diversity, and life-history diversity. Collectively, these parameters describe attributes of viable salmonid populations (VSP).

The average number of natural-origin adult returns (adults returning to the Nisqually River) has been approximately 1,000 Chinook in recent years, following two strong returns in 2007 and 2008 and excepting 2017 (Figure 1). Natural-origin natural spawning escapement has been relatively stable despite declining natural-origin adult runs to the river (Figure 2). The number of hatchery-origin Chinook escaping to natural spawning areas declined beginning in 2013, likely in response to changes in operation of the fish ladders to the hatcheries and poor survival of hatchery Chinook in some of the years. Beginning in 2013, the fish ladders were kept open at the Kalama and Clear Creek hatcheries for the entire adult migration period. Prior to 2013, the ladders were closed during the first part of the adult migration and then only opened for short periods during the season to meet hatchery broodstock collection needs. Starting in 2021, hatchery gates remained closed through August to promote strays to support total escapement on spawning grounds at or above 3,500.

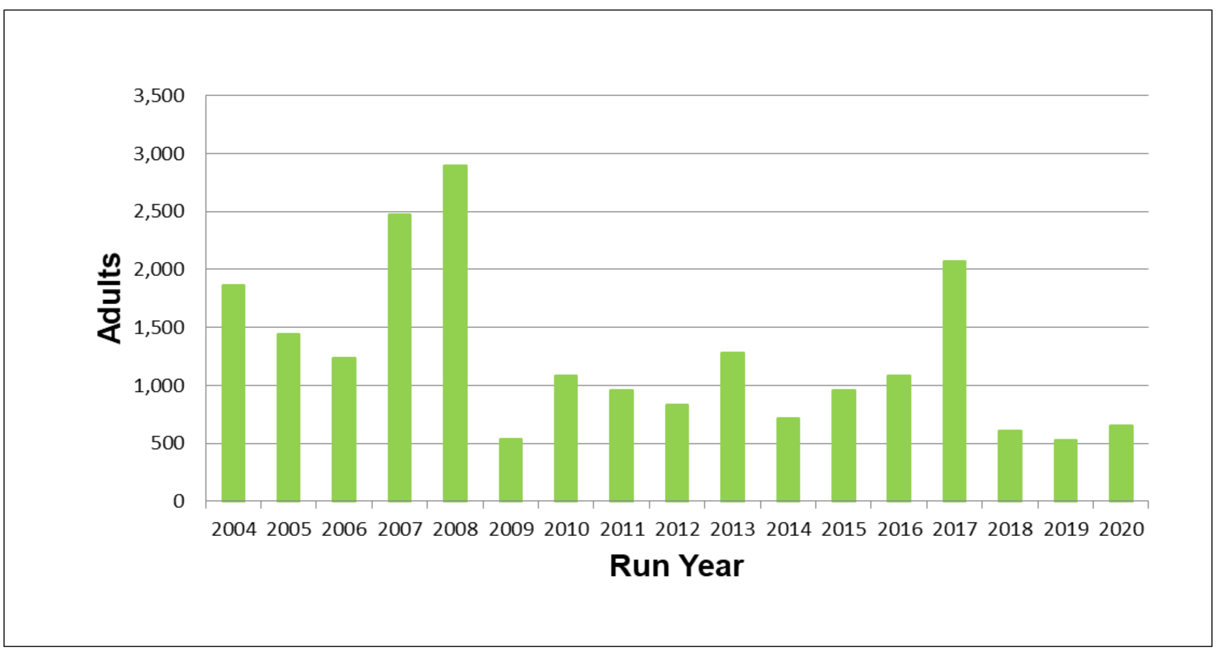

Figure 1. Natural-Origin Adult Returns to Nisqually River. Source: Nisqually Chinook run reconstruction ISIT file (September 2021).

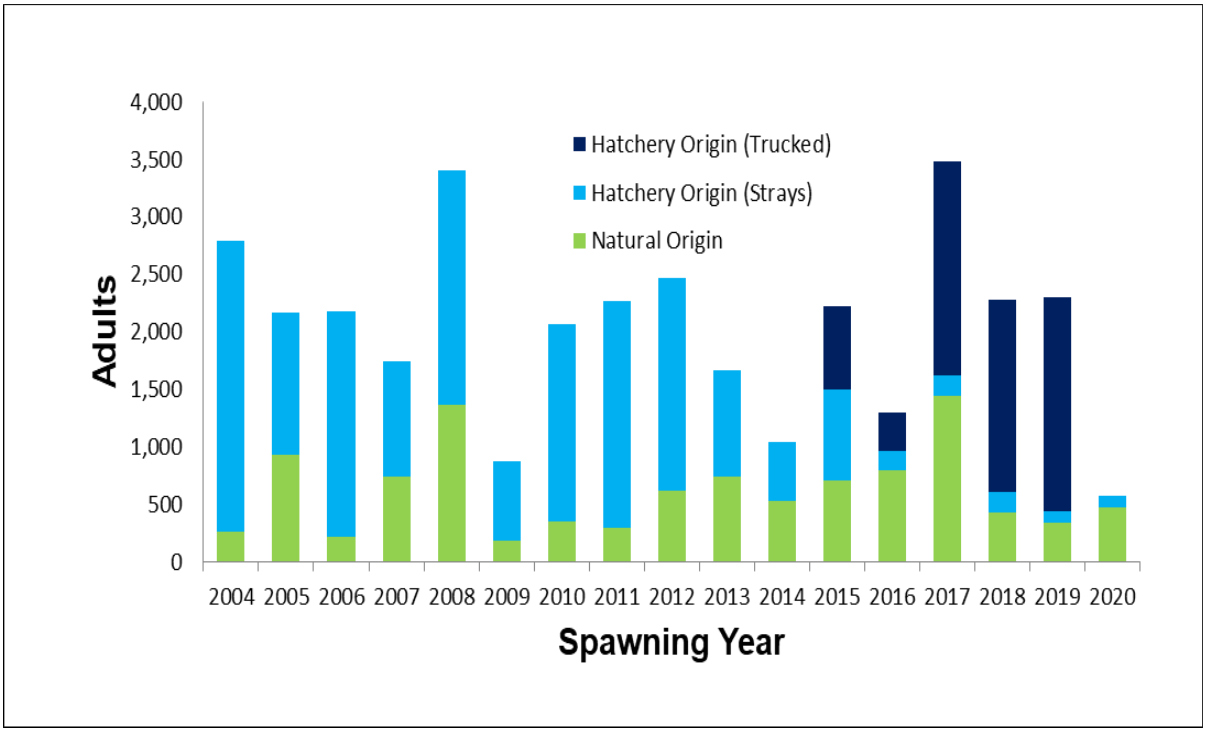

Figure 2. Natural Spawning Escapement of Natural-Origin and Hatchery-Origin Chinook (includes fish trucked in 2015–2019). Source: Nisqually Chinook run reconstruction ISIT file (September 2021).

The estimated annual natural production of juvenile Chinook (subyearling and yearling), estimated by WDFW since 2009 in terms of outmigrant juveniles at RM 12.8, has varied from less than 3,000 fish in 2016 to over 400,000 fish in 2009 (Figure 3). The high estimated abundance in 2009 of subyearlings followed the highest estimated natural spawning escapement of nearly 3,500 Chinook in the fall of 2008 (Figure 2).

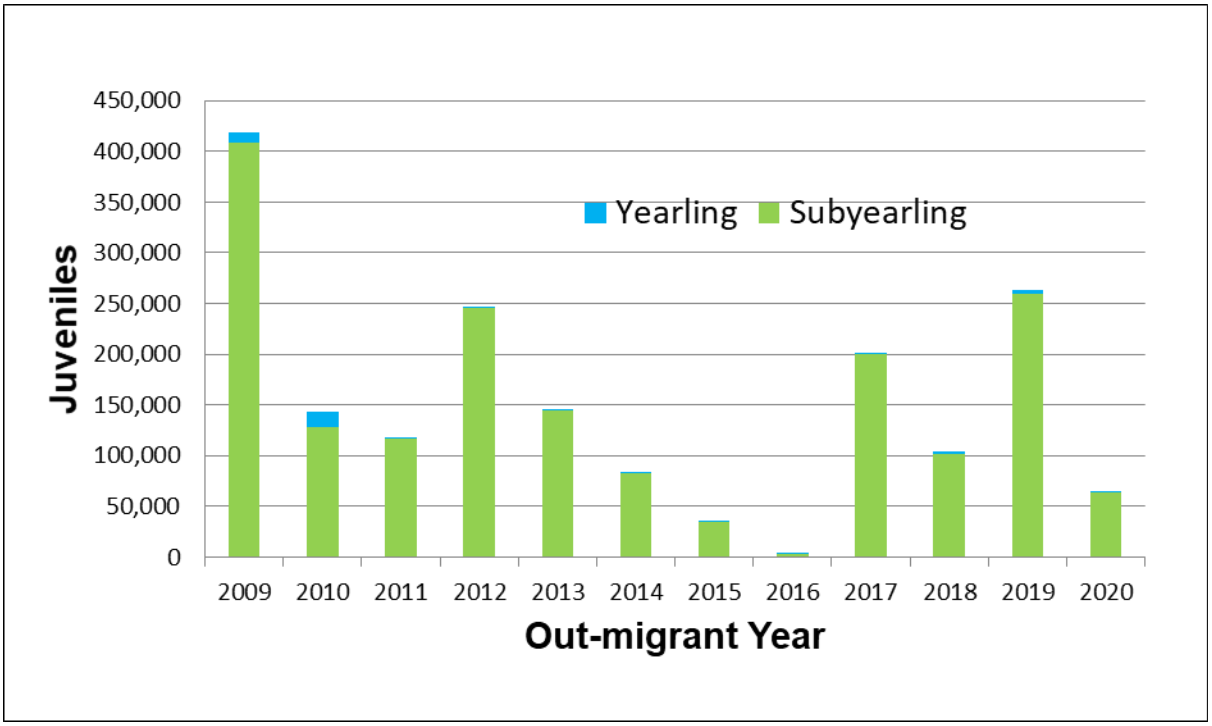

Figure 3. Estimated Annual Juvenile (Subyearling and Yearling) Chinook Abundance at RM 12.8. Source: WDFW.

Juvenile recruits per spawner, as estimated by the number of sub-yearling and yearling juveniles divided by the number of naturally spawning Chinook (hatchery- and natural-origin), has varied from a low of 1.3 recruits per spawner from the 2015 brood year to 155.5 recruits per spawner from the 2016 brood year (Figure 4). Compared to the Skagit River, a watershed with an abundant Chinook population and long-time series where the range of outmigrants per female spawners varied from 270 to 1,230 outmigrants per female (Zimmerman et al. 2015), the Nisqually River Chinook productivity is much lower. Assuming a 1:1 sex ratio for Nisqually River Chinook, the number of juvenile recruits per female spawner ranged 3 to 311, with a geometric mean freshwater productivity of 105. The extremely low juvenile abundance in 2016 was the likely result of poor in-river environmental conditions during adult migration and spawning in the parent year (fall of 2015). In the fall of 2015, Nisqually River water temperatures exceeded 20˚C during the first half of the adult migration. A thermal barrier in the Centralia Diversion Dam reach just upstream of the WDFW outmigrant trap location affected upstream movement of migrating Chinook.

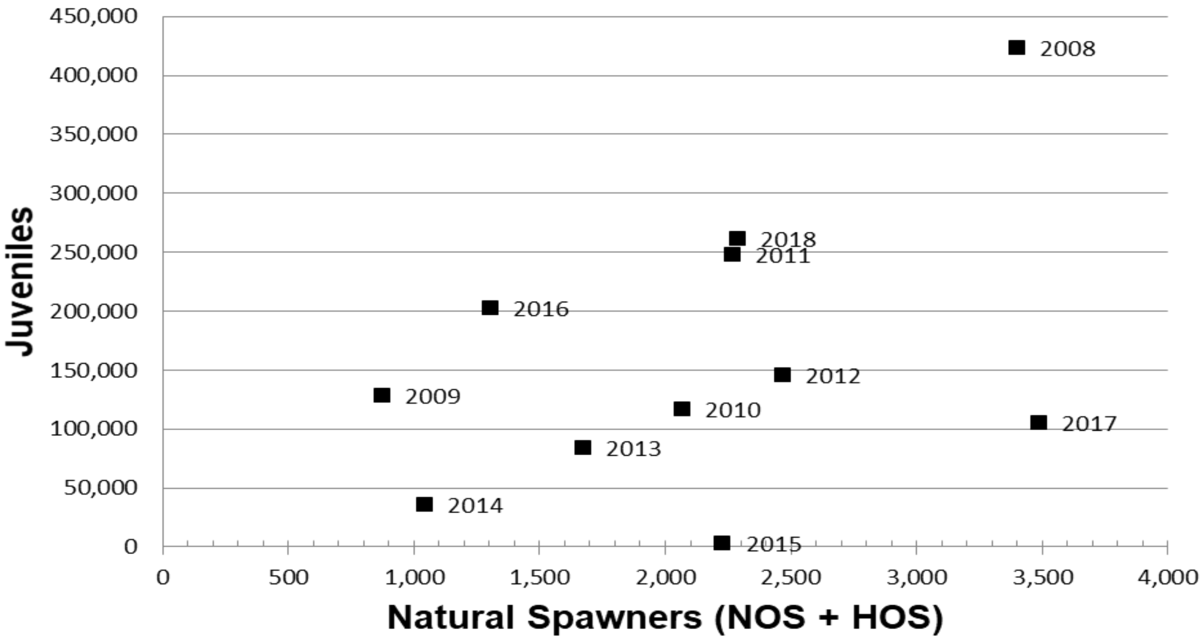

Figure 4. Juvenile Recruits per Spawner (brood years shown). Source: NIT and WDFW data in Nisqually Chinook run reconstruction ISIT file (September 2021).

The number of adult recruits per natural spawner has varied from 0.2 to 1.8 from 2004 to 2017. Adult recruitment exceeded replacement (recruits per spawner greater than 1.0) in just three brood years (2004, 2009 and 2014) over the thirteen-year period (Figure 5). An assessment of habitat potential using the Ecosystem Diagnosis and Treatment (EDT) model suggests observed population performance is much less than habitat potential for the watershed.

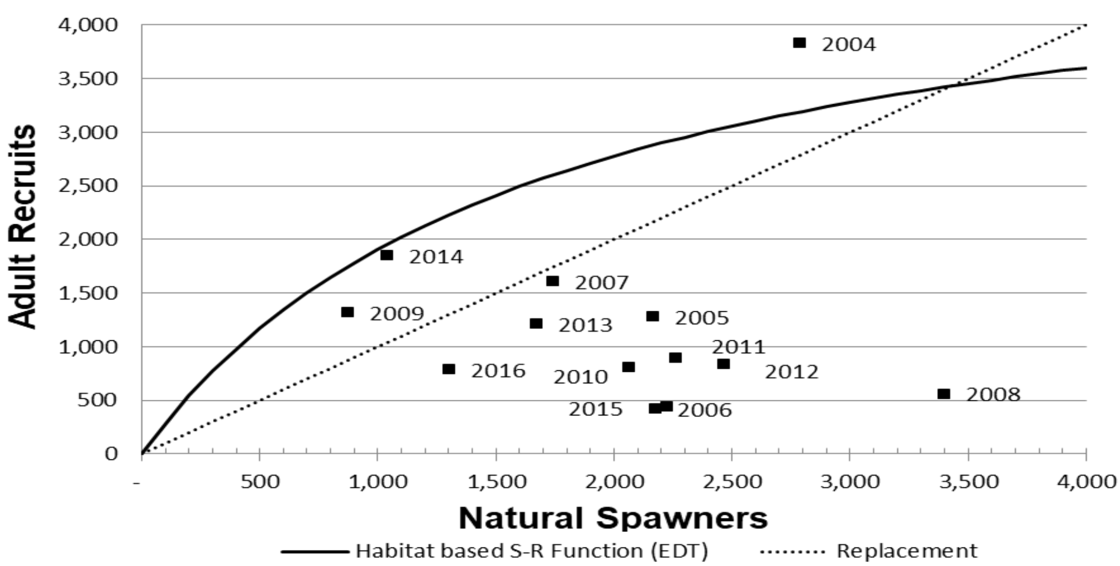

Figure 5. Natural-Origin Adult Recruits per Spawner (brood years shown). Source: NIT and WDFW data in Nisqually Chinook run reconstruction ISIT file (September 2021).

Taking these various aspects of VSP parameters into consideration, the Nisqually Technical Work Group agreed that, based on the Hatchery Scientific Review Group (HSRG) Recovery Phase framework, (1) the population status is in the Colonization Phase, and (2) management priorities should focus on substantially increasing natural-origin fish (NCWG 2017).

Hatchery Programs

The Nisqually River watershed, like most of southern Puget Sound, has a long history of hatchery enhancement. Hatchery production is currently necessary for sustaining harvest that natural production cannot support due to habitat degradation and reduced population productivity. The Tribe initiated hatchery production in 1979 at Kalama Creek Hatchery and in 1990 at Clear Creek Hatchery with the sole purpose of supporting harvest. The 2017 *Nisqually SMP* identifies hatchery program objectives for the current population status (NCWG 2017). Under that Plan, release strategies will include 3.0 million sub-yearling releases from Kalama Creek Hatchery and Clear Creek Hatchery combined, as well as 1.0 million off-station releases at McAllister Creek (NCWG 2017). Changes to the hatchery program are envisioned, dependent on evaluation of population status, as captured in the *Nisqually SMP* (NCWG 2017) and our *Hatchery Genetic Management Plan for the Nisqually River Fall Chinook Salmon Hatchery Program (HGMP)* (NIT and WDFW 2021).

Habitat Limiting Factors

Since the implementation of the original *Nisqually Chinook Recovery Plan* (NCRT 2001), major habitat restoration initiatives have been accomplished in core areas while efforts have continued to protect existing habitat and to evaluate restoration activities. Habitat monitoring and evaluation efforts have generated new insights into the status of core habitat-forming processes in the watershed and led to the development of large-scale restoration and protection initiatives. However, Nisqually Chinook have the longest migration through Puget Sound of all the core populations in the ESU, making their successful recovery dependent on habitat recovery throughout the region.

The *Nisqually Chinook Recovery Plan* (NCRT 2001) contained an action plan that outlined specific restoration and protection priorities. The action plan, which was guided by EDT model results, identified the following general priority areas: the Nisqually delta, portions of the Nisqually mainstem, Ohop Creek, and the Mashel River. We continue to work on actions listed in the 2001 Plan and to refine the habitat priorities through research, assessments, monitoring, and evaluation. Juvenile Chinook sampling since 2001 has indicated that the nearshore areas adjacent to the Nisqually Delta are important for Chinook rearing and migration. Additionally, several nearshore assessments have been completed, including the Nisqually to Point Defiance Nearshore Habitat Assessment. South Sound Nearshore habitat protection and restoration is now a high priority. The continued evaluation of key physical processes in the watershed have resulted in the identification of critical large-scale initiatives that need to occur for recovery of essential salmon habitat.

Extensive post-restoration research by the Tribe, U.S. Geological Survey (USGS), and others of 900 acres of restored Nisqually Delta identified that altered physical processes (river flow control, reduced sediment inputs) and the 100-year history of subsidence (since initial diking)

threaten to undermine the Delta's recovery trajectory (Curran et al. 2016). When viewed in the light of climate change and sea level rise, this threat is even greater. In order to alleviate the sediment deficit, the routing of sediment needs to be improved through Interstate-5, and more sediment needs to make it through Alder and LaGrande Reservoirs. These projects will likely cost more than $1 billion but are critical for the long-term recovery of Chinook.
The Mashel River, identified by both the *Nisqually Chinook Recovery Plan* (NCRT 2001) and the *Draft Nisqually Winter Steelhead Recovery Plan* (NSRT 2014), is the most important tributary for Chinook and steelhead recovery in the "tributary poor" Nisqually watershed. The Mashel watershed has been decimated by commercial forestry operations for over a century. To date, recovery actions in the Mashel have consisted of constructing engineered log jams and land acquisition in the lower Mashel. This large-scale, multimillion-dollar effort has been extremely successful at increasing instream habitat diversity, restoring riparian zones, and reducing channel confinement. However, continued and future degradation of watershed processes in the upper watershed threatens to negate the progress already made and makes recovery of Nisqually salmon improbable. In response, the Nisqually Land Trust, Nisqually Indian Tribe, Nisqually River Council, and others have launched the Nisqually Community Forest Initiative. The goal of the initiative is to purchase much of the privately held timberlands in the upper Mashel and to manage them for long-term ecosystem services recovery and sustainable local economies. This initiative will cost nearly $200 million and will take decades to come to fruition.

The location of the Nisqually River in South Puget Sound makes the Nisqually fall Chinook stock arguably the most dependent on the Puget Sound ecosystem out of all the 27 stocks listed in the Puget Sound Chinook ESU. Juvenile Nisqually Chinook need functional nearshore habitat as well as offshore-based prey resources to feed, grow, and survive during their lengthy migration to the Pacific. Additionally, returning adults must have forage fish throughout Puget Sound to put on growth essential for the arduous river migration and spawning stages of their life history. The cumulative effect of marine mammal predation on juveniles and adult Nisqually Chinook is yet another impact magnified by their lengthy traverse through the Sound.

The effort to protect and restore salmon habitat in the Nisqually River has been incredibly successful in the face of persistent human population pressure, insufficient funding, and wavering political will. While the current condition of the Nisqually watershed is more conducive to salmon recovery than it was just 20 years ago, the need for massive investments in watershed process–based recovery still remains. EDT modeling indicates that the improvements made since implementation of the 2001 Plan have resulted in increases of 31%, 58%, and 82% in productivity, capacity, and abundance, respectively (Figure 6). Even larger jumps in Nisqually Chinook population performance can be expected from successful implementation of large-scale habitat initiatives, including the recovery of sediment delivery and channel migration in the Delta and changing management of the forestland in the Mashel watershed to focus on ecosystem services and watershed processes. The long road to a viable, self-sustaining, and productive Nisqually Chinook population starts at the watershed but will ultimately depend on sustained and aggressive actions to recover the Puget Sound ecosystem.

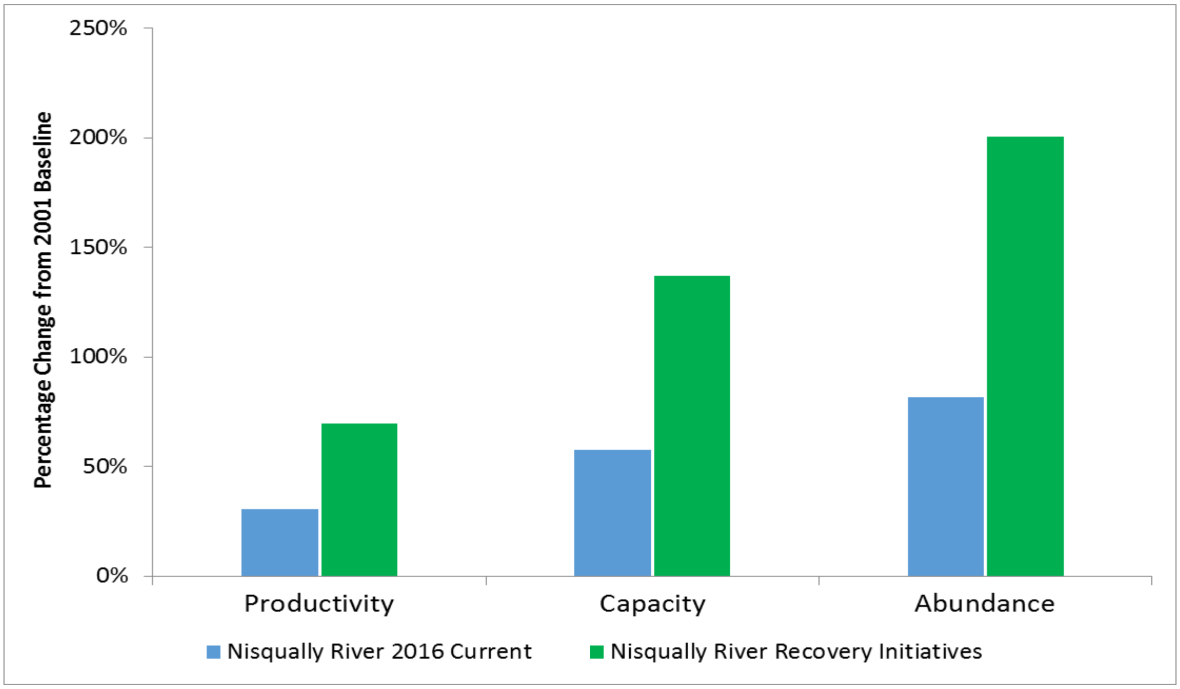

Figure 6. Modeled Improvements in Nisqually Chinook Population Performance. Source: Ecosystem Diagnosis and Treatment model run September 20, 2017.

Harvest distribution and Exploitation rate trends

Terminal harvest of unmarked Chinook has decreased since 2009 consistent with terminal harvest objectives described in the *Puget Sound Chinook Comprehensive Management Plan* (PSIT and WDFW 2010). FRAM version 7.1-based reporting of total exploitation rates shows a decrease from an average of 67% in 2008–2010 to an average of 48% in 2011–2018 (Figure 7). This decrease has been primarily from reductions in the terminal treaty fishery; recent year (2011–2018) terminal exploitation rates have averaged 26% compared to an average terminal exploitation rate of 47% from years 2008–2010. The impact of pre-terminal Southern U.S. (SUS) fisheries has increased slightly from an average of 10% to an average of 12% while the impact from Northern fisheries has dropped an average of 1% in the same years (Figure 8). Extreme terminal harvest rates on natural-origin Chinook in the treaty fishery have averaged 26% since 2012. The extreme terminal sport fishery harvest rate on natural-origin Chinook has been relatively stable since 2008, at an average of 4% (Figure 9).

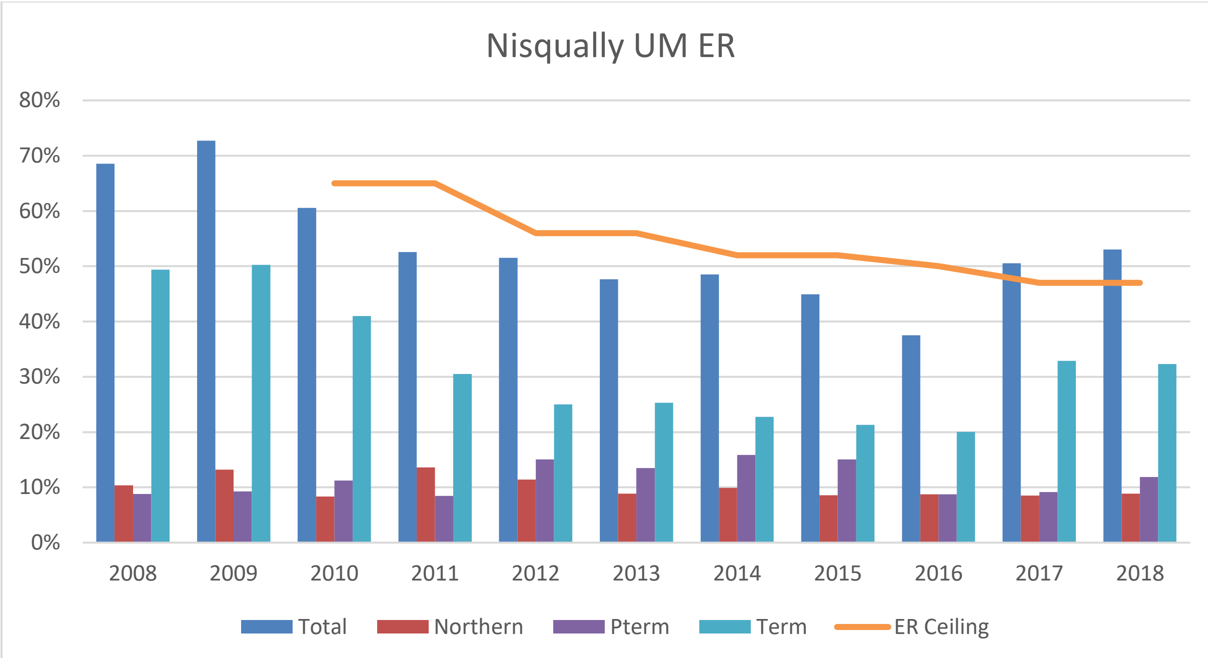

Figure 7. Exploitation Rates on Unmarked Nisqually Chinook. Source: FRAM 7.1.

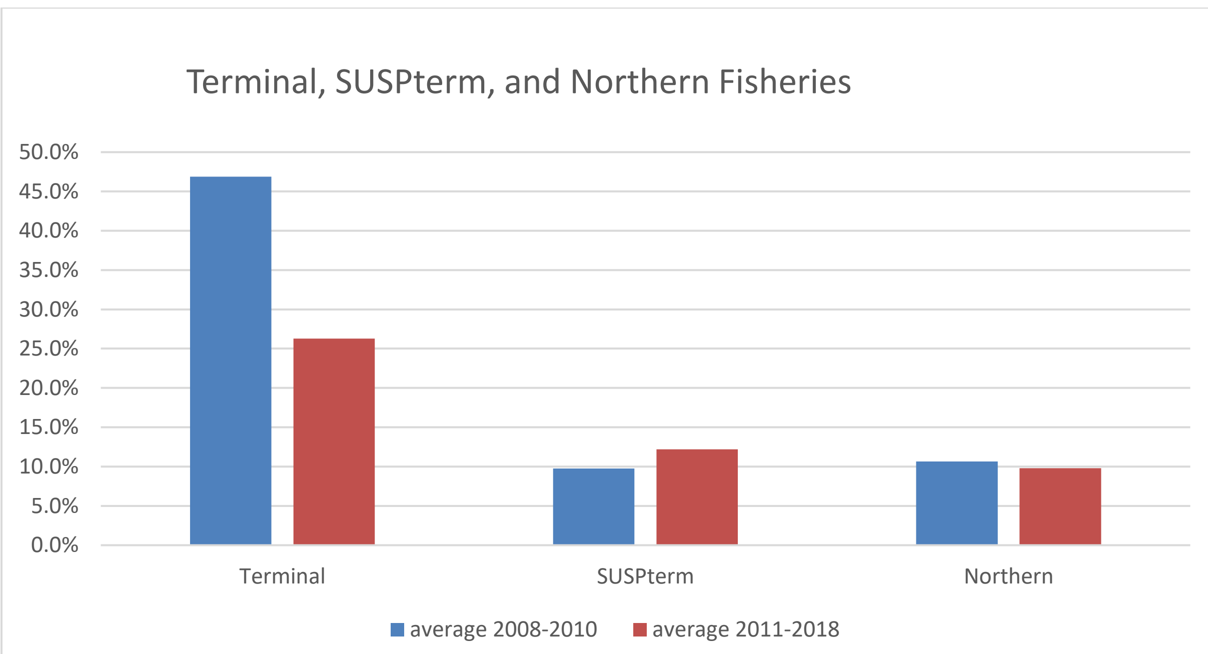

Figure 8. Average Terminal, SUSPterm, and Northern exploitation rates over time on Nisqually Unmarked Chinook. Source: FRAM 7.1.

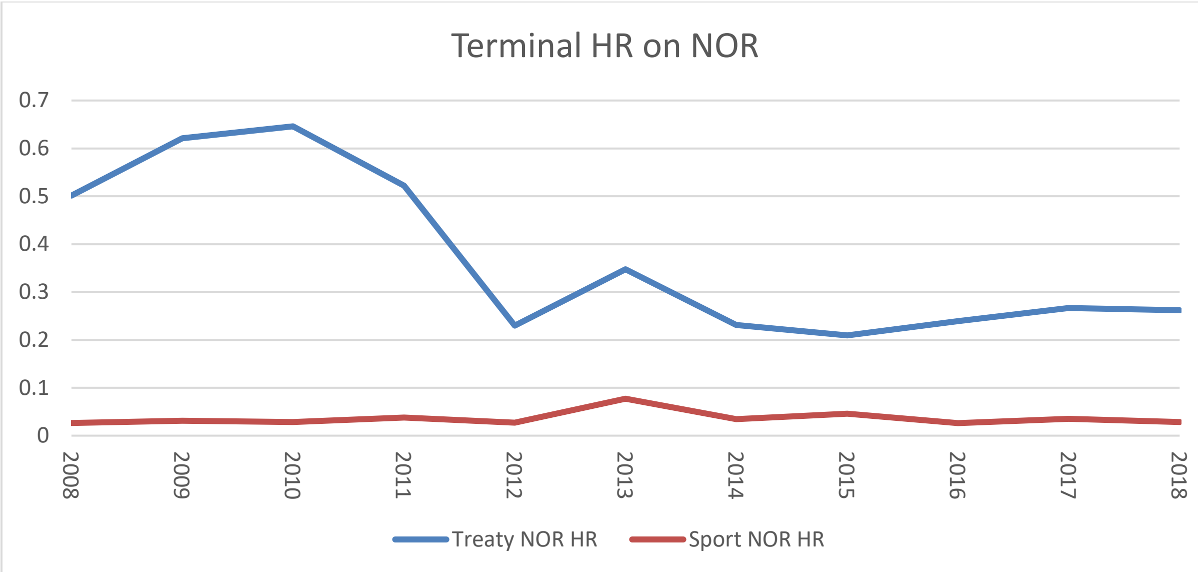

Figure 9. Nisqually Terminal Harvest Rates on Natural Origin Chinook. Source: Nisqually Chinook run reconstruction ISIT file (September 2021).

Management Objectives

The Local Co-managers of this MUP are implementing a grand experiment to promote adaptation of non-native, introduced stock in the Nisqually River with the goal of it becoming a self-sustaining productive population that will support treaty and non-treaty fisheries and that will contribute to the recovery of the Puget Sound Fall Chinook ESU. We are unaware of another effort on this scale that has resulted in a self-sustaining population of Chinook salmon and successfully managed the influence of the hatchery population on the recovering population.

Because this effort presents significant uncertainty, it requires the Local Co-managers to collaboratively exercise adaptive management as informed by data collection and analysis using best-available science. Data collection and analysis will inform the Local Co-managers' establishment of key aspects of this MUP, including escapement goals, exploitation rate ceilings, extreme terminal area harvest rates and techniques, and evaluative tools for recovery. The Local Co-managers' *HGMP* is incorporated herein by reference (NIT and WDFW 2021).

The Local Co-managers anticipate that as updated monitoring or evaluation data become available, their management actions and strategies could require adjustment, and several potential paths for accomplishing this experiment could be identified. The adaptive management framework described in the *Nisqually Stock Management Plan* (attached as an appendix and incorporated herein) appropriately provides a structure and guidance for future decision-making (NCWG 2017). The *Nisqually SMP*, together with data collection and analysis, will inform the Local Co-managers' ranking and selection of any potential paths.

The *Nisqually SMP* describes in detail the specific management objectives and the scientific rationale that will guide future decision-making for this MUP (NCWG 2017). The *Nisqually SMP* follows HSRG guidance. The HSRG (2014) defines four biologically based phases for "restoration and rebuilding" of salmon populations: 1) preservation, 2) re-colonization, 3) local adaptation, and 4) full restoration. The *Nisqually SMP* starts with the re-colonization phase (renamed “Colonization” Phase) and continues through full restoration (renamed “Viable Population” Phase) (NCWG 2017). These three phases, the ecological conditions characterizing each phase, and the primary objective during each phase, as defined by HSRG and revised slightly to better reflect the Nisqually population, are described in Table 3-1 in the *Nisqually SMP* as appendix 1 (NCWG 2017). These phases represent milestones toward recovery and mark a shift in population status as well as priorities and policy direction (*i.e.*, harvest, conservation, and maintenance of progress).

Specifically, during the Colonization Phase, management actions are to increase adult natural spawning regardless of composition (hatchery vs. naturally produced) with the objectives to increase juvenile outmigrant abundances and corresponding adult returns. Mean natural-origin adult escapement abundances are low for the last decade. In addition, we anticipate low forecasts for the next several years based on the estimated number of juvenile outmigrants in recent years (Figure 2). During Colonization, natural spawning will be supplemented with hatchery-origin adults. The Nisqually Technical Work Group hypothesized this action will result in higher annual juvenile abundances and higher annual natural-origin returns to the Nisqually River. Productivity, as measured by juvenile outmigrants per spawner, will be evaluated for the presence of an asymptote in outmigrants per spawner (an indication of freshwater capacity constraints). Results from these monitoring activities will be used to refine escapement objectives during local adaptation. Adult monitoring for natural spawning abundance and distribution, as measured by number of adults spawning downstream and upstream of the Centralia Diversion Dam, in tributaries, and composition (hatchery-origin/natural-origin), will be evaluated to determine effectiveness of adult supplementation actions and habitat potential.

During the Local Adaptation Phase, annual management decisions will consider the 4-year running average of PNI with the objective to continually improve the PNI running average. That means small deviations in PNI from year-to-year are acceptable as long as the running average is continuing to improve. In practice, the 4-year running average PNI will be calculated each spring during the annual project review based on previous year data. The next-year forecast PNI will be calculated and added to the 4-year running average. If the forecast running average is declining then additional management actions will be developed to increase the next year PNI to produce an upward trend in the running average. Additional actions may include reducing the hatchery program size and implementing additional selective fisheries to remove more hatchery origin returns. The Local Co-managers currently intend for the population to move into the Local Adaptation Phase of recovery beginning in 2025; however, we will review the data collected and analyses performed to confirm the population has met the criteria for moving into the Local Adaptation Phase before making that determination or pursuing another path.

Low Abundance Threshold

The Low Abundance Threshold (LAT) for Nisqually River Chinook during Colonization is designed to ensure that total escapement of Chinook spawning naturally remains near the goal identified in the *Nisqually SMP*, even in years of low projected returns (NCWG 2017). Recent adult returns (2015–2019) would suggest that, on average, 747 NORs and an additional 1,834 hatchery Chinook will stray for a total of 2,581 to escape all fisheries and swim freely to the spawning grounds (hatchery stray rate ~15%). In addition, our expectation, based again on recent year observations and a 15% stray applied to hatchery return, is that an additional 10,393 adults will return to the hatcheries. With a total brood need of approximately 2,800, we would see 7,593 fish in excess of our broodstock needs. These excess hatchery fish serve as an opportunity to supplement the free-swimming adult fish in order to achieve our total natural spawning escapement objective during colonization.

During Colonization, the goal is to explore the upper bounds of productivity consistent with the *Nisqually SMP*, which is likely to include a substantial component of trucked fish from the hatchery (NCWG 2017). We have determined over the most recent three years that trucking 3,500 Chinook is challenging due to a truncated hatchery timing and the difficulty of physically moving fish within the very small timing curve of hatchery return. Our current ability to truck Chinook for supplementation is about 2,000. Using hatchery gate management, we will promote straying (15%), as seen in years when the gate was closed through August. Applying a 15% stray rate to the pre- and post-season hatchery runs in 2013–2018 plus unmarked escapement in combination with trucking up to 2,000 Chinook has been shown to achieve the 3,500 goal for all years (Figure 9). As stated above, we would expect to see an average of 2,581 Chinook freely swimming to the spawning grounds. In addition to supplementing natural spawners with hatchery-origin fish via trucking, we are establishing a LAT to further ensure that we fulfill our management objectives for the Colonization Phase of recovery and to safeguard in the case of an unexpectedly low preseason forecast. As a result, the LAT will consist of hatchery broodstock needs plus sufficient adults available for straying and trucking/release on the spawning grounds to reach the escapement goal described in the *Nisqually SMP* of 3500 total natural spawners (NCWG 2017). In order to assure enough Chinook to escape, stray, truck, and fulfill production needs, a total system escapement of 6,300 in needed. Escapement of 833 hatchery strays [(6300-747)*0.15=833], 2000 trucked, and 747 NORs allows a spawning objective of 3,500 to be met (3,580). The average hatchery escapement for the recent 5 years (average includes 2020) has been 11,342, slightly more than twice the need for the hatchery LAT component of 5,526 (6,300-747=5,526). When pre-season escapement estimates are projected to exceed the LAT, an exploitation rate ceiling of 47% will be implemented for Nisqually unmarked Chinook, with co-manager goals for freshwater fisheries that include maintaining a minimum 20% harvest rate on unmarked untagged Chinook in tribal fisheries and a full recreational salmon season including mark-selective fishing for Chinook beginning July 1.

The trucking and upstream release of surplus hatchery adults is secondary to meeting the production goals of the hatchery program so that hatchery fish continue to return and, ultimately, the opportunity for trucking to promote colonization continues. If pre-season abundance is predicted to be low, planned fisheries will be reduced until the Critical Exploitation Rate Ceiling (CERC) is not exceeded or the LAT is projected to be exceeded. If the LAT is projected to be exceeded, then the preseason expectation is that escapement will be sufficient to meet goals for broodstock, trucking, and natural escapement. If the CERC is implemented and the LAT is not projected to be met pre-season despite reductions to planned fisheries, then the Local Co-managers will plan to use rack returns to meet hatchery broodstock needs prior to any upstream trucking of adults. Upstream trucking would be contingent on in-season abundance exceeding expectations and hatchery broodstock needs being likely to be met.

If it appears in-season that unexpected poor adult Chinook returns will challenge meeting Nisqually's rack needs, trucking of adult salmon may be postponed until in-season information indicates a positive change in run size, or halted entirely if it is clear program goals will be threatened if broodstock are transplanted. Total number of Chinook escaping to the hatchery rack does not become clear until well after the normal treaty Chinook fishery and so cannot be used to affect savings in this fishery. There may be an opportunity, however, to modify recreational fisheries or coho-directed net fisheries to maximize rack escapement to support broodstock collection and the trucking program at times of low returns. If applicable, the Local Co-managers will consider the in-season information and opportunities to modify fisheries to support the colonization goal using adult supplementation.

The Local Co-managers' original intent was for the population to move into the Local Adaptation Phase of recovery beginning in 2025; however, we will review the data collected and analyses performed to confirm the population has met the criteria for moving into the Adaptation Phase before making that determination or pursuing another path. Adaptive management actions resulting in a change to current colonization efforts will be consistent with the stage of recovery described in the *Nisqually SMP*, which establishes escapement objectives and the resulting harvest management response based on natural Nisqually Chinook population performance indicated by monitoring VSP parameters.

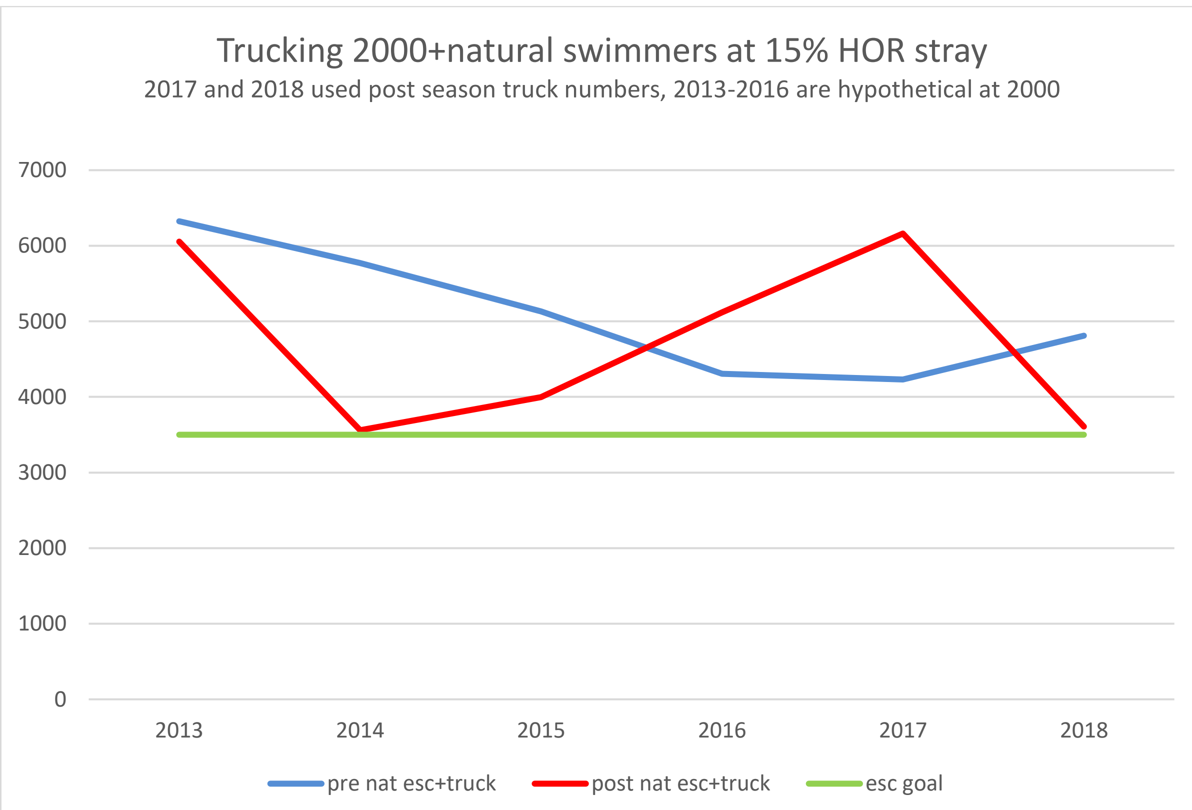

Figure 10. Trucking 2000+natural swimmers at 15% stray preseason vs postseason and colonization goal. Source: FRAM 7.1.

The LAT amount of 6,300 adults has been achieved in each of the past 6 years while managed for much higher ER ceilings (Figure 11).

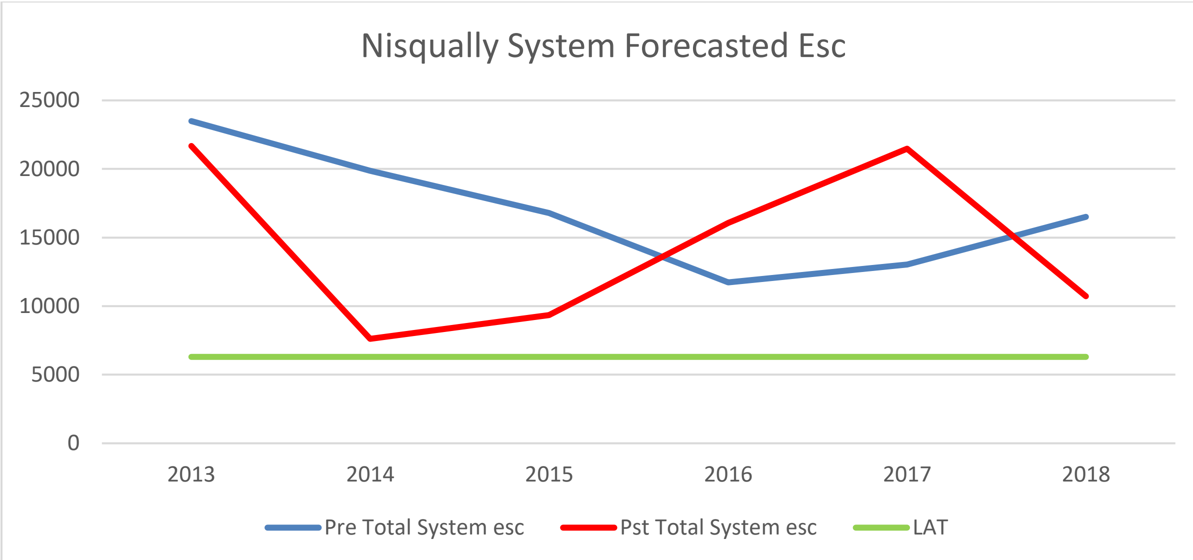

Figure 11. Nisqually LAT if applied to historical data. Source: FRAM 7.1.

It is extremely unlikely that the LAT will be triggered during the Colonization Phase. However, if the pre-season projected escapement does not exceed the LAT escapement during Colonization, then the CERC will be triggered. For Nisqually Chinook, the critical response will take the form of targeted fishery reductions until the LAT of 6,300 is projected to be met or until the SUS ER on unmarked Nisqually Chinook does not exceed the CERC. The maximum allowable SUS ERC for unmarked Nisqually Chinook for preseason planning when escapement is projected above the LAT is equal to 47% minus the projected rate in Northern fisheries. The CERC for SUS fisheries is equal to one half of the allowable ER for SUS fisheries at abundances above the LAT. As an example, if northern fisheries are projected to have an ER of 10%, then an SUS ER of up to 37% would be allowed if escapement was projected above the LAT. If escapement is projected below the LAT, then the allowable SUS ER would be reduced by one half to 18.5%. Should escapement be projected below the LAT during preseason planning and a critical response is triggered, planned SUS fisheries will be reduced until the LAT is projected to be met or until the planned SUS fisheries do not exceed the CERC, through the typical North of Falcon (NOF) process of negotiations. The LAT and CERC will be evaluated through adaptive management.

Table 3. Management objectives for Nisqually Chinook.

LAT	ERC	CERC
6,300 total system escapement including hatchery rack and fish swimming to spawning grounds	47% ER on Unmarked when above LAT and a minimum extreme terminal treaty harvest rate on unmarked untagged of 20%.*	Preseason escapement is less than LAT Management actions: Up to 50% SUS ER reductions of M and UM to achieve LAT.

*2022 is the last year of the experiment.

In order to fulfill the objective of the *Nisqually SMP* to provide meaningful harvest for treaty and non-treaty fisheries in the Nisqually River and to restore a viable, self-sustaining, and locally-adapted population of fall Chinook salmon that adds to the spatial diversity, abundance, and recovery of the Puget Sound Chinook ESU, the Tribe has been investigating selective fishing techniques (NCWG 2017). These techniques are being considered for use in the Tribe's traditional in-river commercial and ceremonial and subsistence (C&S) fisheries. The Tribe will cap total ER to no greater than 2% above 47% on natural Chinook during this experimental fishery. Gear types investigated, until determined, will be modeled as a total encounter with 100% mortality.

After three years of experimenting with different gear types used for selective fishing, drift gill net (GN) has been chosen as the gear type to determine release mortality with the intent to implement a commercial mark selective fishery in 2024 or sooner. In 2022, we will continue to determine short-term mortality estimates of adult Chinook salmon from 6" drift GN in the freshwater portions of the Nisqually River consistent with 2021 framework presented and agreed to by NOAA Fisheries (NOAAF) prior to the 2021 season. A Study Plan for this effort was agreed to by WDFW, the Tribe, and NOAAF prior to the 2021 pre-season planning process with estimates of mortality associated with this critical activity. This Study Plan will inform the pre-season planning process. All *Nisqually SMP* goals will be met with the additional 2% ER on unmarked adult Chinook for the entire Colonization Phase (NCWG 2017).[28] Elements of the experimental fishing plan include the following:

- Identify feasible gears (tangle net, beach seines, circular seines, mesh sizes, etc.)
- Implementation details
- Methodology to estimate short term mortality associated with tested gear types
- Final report - Strategy to establish harvest plan in fishery for selected gear type(s)

The investigation will occur utilizing up to an additional 2% ER on adult unmarked Chinook during 2022. Unless otherwise agreed to by the Local Co-managers and NOAAF, the experimental phase of this selective gear development will sunset after the 2023 season.

This gear experiment will not be implemented in the case that the LAT is triggered and CERC measures are taken. Furthermore, implementation of the ER cap of 2% on natural Chinook will be modified as to not trigger a LAT response. Specifically, the 2% ER on natural Chinook and the associated fisheries impact on both natural and hatchery Chinook may be reduced in years when the LAT may be reached as a result of this gear experiment.

Based on the results of this effort and discussions with NOAAF and WDFW, the Tribe will determine which gear type(s) to incorporate into our commercial fishery in 2024 consistent with the recovery objectives for that season.

Success for the Local Co-managers will include the Tribe having the ability to selectively harvest hatchery Chinook in its commercial fishery with gear that is accepted by its community and its

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[28] Specific implementation language being developed and will not impact any fisheries management actions outside of the Nisqually River.

fishers. The Tribe desires to identify and implement selective opportunities that are accepted by the Nisqually community and to have an agreed estimate of release mortality by the time the Local Adaption Phase is reached to adequately support the need to manage escapement composition.

The Local Co-managers have also agreed to move up to 1.0 million fall Chinook fingerling production from the Clear Creek Hatchery to an acclimation site on McAllister Creek. Adult fish returning to McAllister Creek are excess to escapement needs and will be fully harvested by treaty and non-treaty fishers. These releases are fully marked and representatively tagged and will be monitored in all sampling activities from juvenile to returning adult.

In the spirit of co-management principles, the local co-managers will share information on the data and methodology used for an update to their MUP, resulting ER estimates, escapement goal levels, and new management objectives with all co-managers in a timely manner and will provide an opportunity for technical and policy discussion prior to its submission of the new MUP to NOAA. No co-manager waives any rights by agreeing to participate in these discussions.

Data gaps

The following table describes the core and additional monitoring activities by monitoring variable for each of the five programs: adult catch and escapement monitoring, juvenile freshwater monitoring, juvenile Nisqually River delta monitoring, hatchery monitoring, habitat monitoring, and stock-recruitment analysis.

Monitoring Programs

Monitoring Program	Monitoring Variables	Core Monitoring	Additional Monitoring
Adult Catch and Escapement Monitoring	Nisqually River Catch in Treaty and Sport fisheries	Sampling of the treaty net fishery (sampling min 20%, typical 45%) for marks, CWT, age, and size and sex. Sampling estimates contribution of natural-origin fish to catch In the absence of creel samples Catch Record Cards reporting of the sport catch of harvest marked and harvested unmarked Chinook and estimates impact of landed and incidental mortality of natural-origin Total encounters estimated from years of CRC and creel study years	Creel sampling of sport fishery and methods to estimate impact of landed and incidental mortality of natural-origin Mark-selective fishery study commercial selective fishery and sport nonlanded mortality Study net dropout rate in freshwater commercial fishery
	Nisqually Watershed-Wide Adult Escapement and Composition	Escapement estimated from change-in-ratio method (Seber 1982) Watershed-wide composition and distribution (hatchery- and natural-origin) based on: Carcass sampling priority index reaches in the Mashel (RM 3.2 to RM 0) and Nisqually River (RM 26.2 to RM 21.9); these will be surveyed weekly Supplemental nonindex reaches (Nisqually River RM 32.9 to RM 26.2 and RM 15.7 to RM 10.1); these will be surveyed biweekly.	Historical escapement estimated from live and dead counts and expansion formula (Tweit 1986) and will be calculated to better understand bias in the historical abundance estimates. Additional surveys may be conducted in the Mashel and Nisqually River as resources allow
	Adult Escapement and Composition Upstream of the Centralia Diversion Dam	Abundance and composition from adult passed or excluded at the Centralia Diversion Dam adult trap (Colonization will include hatchery origin) Composition estimated from carcass recoveries from priority index reach (surveyed weekly) in the Mashel (RM 3.2 to RM 0); supplemented with nonindex reach (Nisqually River RM 32.9 to RM 26.2) surveyed biweekly	Radio tagging and tracking of adults (hatchery- and natural-origin) captured in lower river/delta to evaluate migration and spawning behavior through lower river and above Centralia Diversion Dam
	Adult Escapement and Composition Downstream of the Centralia Diversion Dam	Abundance based on subtraction of CDDFL counts Composition estimated from carcass recoveries from priority index reach (surveyed weekly) in the Nisqually River (RM 26.2 to 21.9); supplemented with	Radio tagging and tracking of adults (hatchery- and natural-origin) captured in lower river/delta to evaluate migration and spawning behavior through

		nonindex reach (Nisqually River RM 15.7 to RM 10.1) surveyed biweekly	lower river and above Centralia Diversion Dam Additional surveys could be conducted to supplement carcass data below CDDFL
Juvenile Freshwater Monitoring	Freshwater Productivity, Capacity, and Juvenile Life History	Operation outmigrant trap at RM 12.8 to estimate abundance, timing, life stage, and size of juvenile migrants Productivity: # outmigrants per natural spawner Capacity: # outmigrants by life stage Life history: relative abundance of outmigrants by life stage	
Juvenile Nisqually River Delta Monitoring	Juvenile Life History Diversity (temporal and spatial), Delta Productivity and Capacity,	Beach seining sites in all habitat zones (matching sites that have been monitored regularly in previous years), allows for understanding of spatial and temporal diversity, relative abundance, and long-term comparisons Randomly selected beach seine sites in each habitat zone for density and capacity analyses	Lampara net sampling of mudflats Fyke net sampling of channels Benthic, fallout and neuston sampling for prey availability monitoring Bioenergetics, habitat connectivity, accessibility, and fish density across a wide range of natural and hatchery juvenile abundances Monitoring habitat use, movement, and residence time of juveniles using passive integrated transponder (PIT) tags; Otolith analyses for growth, residence time, and life history types surviving to adult return.
Hatchery Monitoring	Hatchery broodstock, in-hatchery survival, release, and post-release survival	Number of adults and jack counts to hatcheries and McAllister Springs/Creek plus outlet creeks and McAllister Creek	

		Number of hatchery-origin adults used for broodstock Number of natural-origin adults and jacks collected for broodstock Survival rates (surviving to spawn) of natural-origin adults used for broodstock Fecundity of hatchery- and natural-origin adults used for broodstock Age composition (hatchery- and natural-origin) Survival rates green egg to eyed egg Survival rates eyed egg to ponding Survival rates ponding to release Number released, dates, size of fish, and number marked	
Habitat Monitoring	Habitat Project Implementation and Habitat Condition	Track implementation of Chinook habitat action plan Percentage of mainstem and primary tributaries protected Acres of floodplain and estuary restored Miles of tributary restored (e.g., engineered logjams, channel reconnection)	Habitat status and trends monitoring to track impervious surface, riparian condition, temperature, flows, in-stream habitat diversity, sediment, etc.
Stock Recruitment Analysis	Natural-Origin Adult Abundance to River	Terminal adult natural origin run calculated as the sum of the following: In-river catch and nonlanded mortality (released fish) (sport based on catch record card, treaty based on fishery samples) Natural-origin adults removed for broodstock (Local Adaptation) Watershed-wide natural spawning escapement of natural-origin adults	Sport catch may be estimated from creel survey data

	Survival rates from juvenile outmigrant to adult	Survival rates based on outmigrant estimates and estimate of natural-origin adult recruits to river Requires age data from unmarked (natural-origin) for recruit analysis; check this data	Otolith microchemistry and microstructure for growth, residence time, and life history types surviving to adult return
	Spawner to adult brood year recruitment rates	Recruitment rates calculated from the following: Parent natural spawning abundance by origin Terminal natural-origin run allocated to brood year; data from treaty fishery sampling used to estimate total age of adults in annual run (catch plus escapement) Estimation of age 2 recruits/spawner	
Nisqually Chinook Genetics Assessment	Genetic Mark Recapture	Estimate adult abundance using trans-generational genetic mark recapture (tGMR) Estimate effective breeders by origin Estimate relative contribution to juvenile production for the three adult types in the escapement (natural origin, hatchery origin volunteers, and hatchery origin truck and hauled) Conduct a genetic based brood year reconstruction to evaluate relative contribution of natural and hatchery origin to adult recruits	

Skokomish River Management Unit Status Profile

Component Populations

North Fork Spring Chinook Salmon
George Adams Summer/Fall Chinook Salmon
George Adams late-timed Fall Chinook Salmon

Geographic description and Life History Traits

Two hydroelectric dams block passage to the upper North Fork Skokomish River watershed. The reservoirs inundate 18 miles of river habitat that was formerly suitable to Chinook salmon production. Under the terms of the Cushman settlement, Tacoma Power was responsible to design, construct, and implement methods of providing effective fish passage—both upstream and downstream—at the Cushman Dams. Both upstream and downstream passage facilities are now in place and operational.
The historic spawning distribution of Chinook salmon in the basin extended to the upper reaches of both the North and South forks, major tributaries to both forks, and the entirety of the mainstem downstream of the forks (Elmendorf and Kroeber 1992; Smoker et al. 1952; Deschamps 1954; WDF 1957). The spatial separation between the spring and fall populations was generally regarded to be in the vicinity of Little or Big Falls[29] in the North Fork and the vicinity of the gorge in the South Fork. As noted by the TRT, however, some spring run fish may have spawned as far downstream as Vance Creek in the South Fork. The historic Skokomish River spring Chinook salmon were produced in the upper North and South Fork reaches of the Skokomish River.

Historically, Skokomish River Chinook salmon exhibited a diverse set of life histories, having, among other traits, a wide range of river entry timing patterns. Both spring-run and fall-run racial groups were supported by the river. Besides differences in river entry timing, these groups differed markedly in their spatial use of the watershed with spring Chinook salmon utilizing the upper reaches of the North and South forks and fall Chinook salmon utilizing the lower reaches of the forks and mainstem. Both indigenous racial groups are now extinct in the river basin and what remains is a highly domesticated hatchery population derived from Green River falls, which has been propagated at the George Adams Hatchery since the early 1960’s (Ruckelshaus et al. 2006; SIT and WDFW 2017). This fact presents particular challenges for recovery since well-adapted genetic stock sources have not recently existed in the river system.

Chinook (Spring, Summer/Fall and Late-Timed) salmon currently spawn throughout the Mainstem Skokomish River up to the confluence of the South and North Forks. In the South Fork spawning primarily occurs below River Mile (RM) 5.0 including Vance Creek. In the North Fork spawning occurs upstream to Cushman Dam at RM 17.0. However, the current distribution of naturally spawning Chinook salmon is less than 1/3 of what it was historically in the river basin. There are presently only about 16 miles of stream habitat are being used by natural spawners, which occur mostly in the lower North Fork and in the mainstem downstream of the confluence of the North and South Forks. Only approximately 2.5 miles of the 16 miles

[29] / The two falls are also often referred to as Upper Falls (Big Falls) or Lower Falls (Little Falls), as discussed in James (1980).

are located in the lower South Fork—a number that has shrunk because of ineffective passage that migratory Chinook salmon have had in accessing the lower South Fork due to aggradation and dewatering of the channel.

The aggraded channel of the lower South Fork Skokomish River has resulted in seasonal subsurface flows preventing adult Chinook salmon migration to access about five miles of spawning habitat in the river. In 2008 the Skokomish Tribe (SIT) began monitoring the presence, location, and timing of these low flow events in which the channel of the South Fork becomes dewatered. Seven out of the fourteen years (2009, 2010, 2012, 2015, 2016, 2020, 2021) a completely dry streambed was observed on the South Fork downstream of the old confluence (confluence up to 2007) to the new confluence of the North Fork (one river mile below old confluence) although this section of the river did not dewater during 2014, 2018 and 2019, it was extremely low possibly preventing/limiting passage. This section of river is described in the WRIA 16 catalog as the mainstem RM 8.0-9.0. Significant changes in the river in the 2012-2013 river split the South Fork channel just below the old mainstem confluence (RM 9.0 or 0.0) into two channels. One channel carries more than half of the water into the North Fork channel at this location. This channel completely bypasses the section of South Fork that has been going dry in the recent past. In 2013 and 2017 this channel section remained wetted and allowed Chinook salmon unimpeded migration into the South Fork spawning habitat throughout the entire season.

Under the terms of the recent Cushman settlement agreement, flow in the North Fork below the lower dam will be regulated to track the natural hydrologic regime. Increased volume flow will be provided in the winter and early spring to restore channel function in the North Fork and Mainstem. These measures are expected to improve conditions for migration passage and rearing in the North Fork[30]. Under the new restoration strategy, spring Chinook salmon will be introduced into the lake and upper watershed with upstream and downstream passage provided through the two dams.

The observations and conclusions about life history for the historic Skokomish populations are compared to patterns seen for other wild Chinook salmon populations in Western Washington in Figure 1. The figure reflects common patterns among freshwater life stages among populations with little or no hatchery influence. The figure is displayed as a periodicity table. Five non-Skokomish populations are shown, three in the Skagit River system and two in the Queets River (SIT and WDFW 2017).

[30] / Component 3 flows of the Cushman Settlement, intended as flushing flows for the mainstem Skokomish River, have been suspended until channel capacity has been increased in the mainstem river (see RPSRCS 2017).

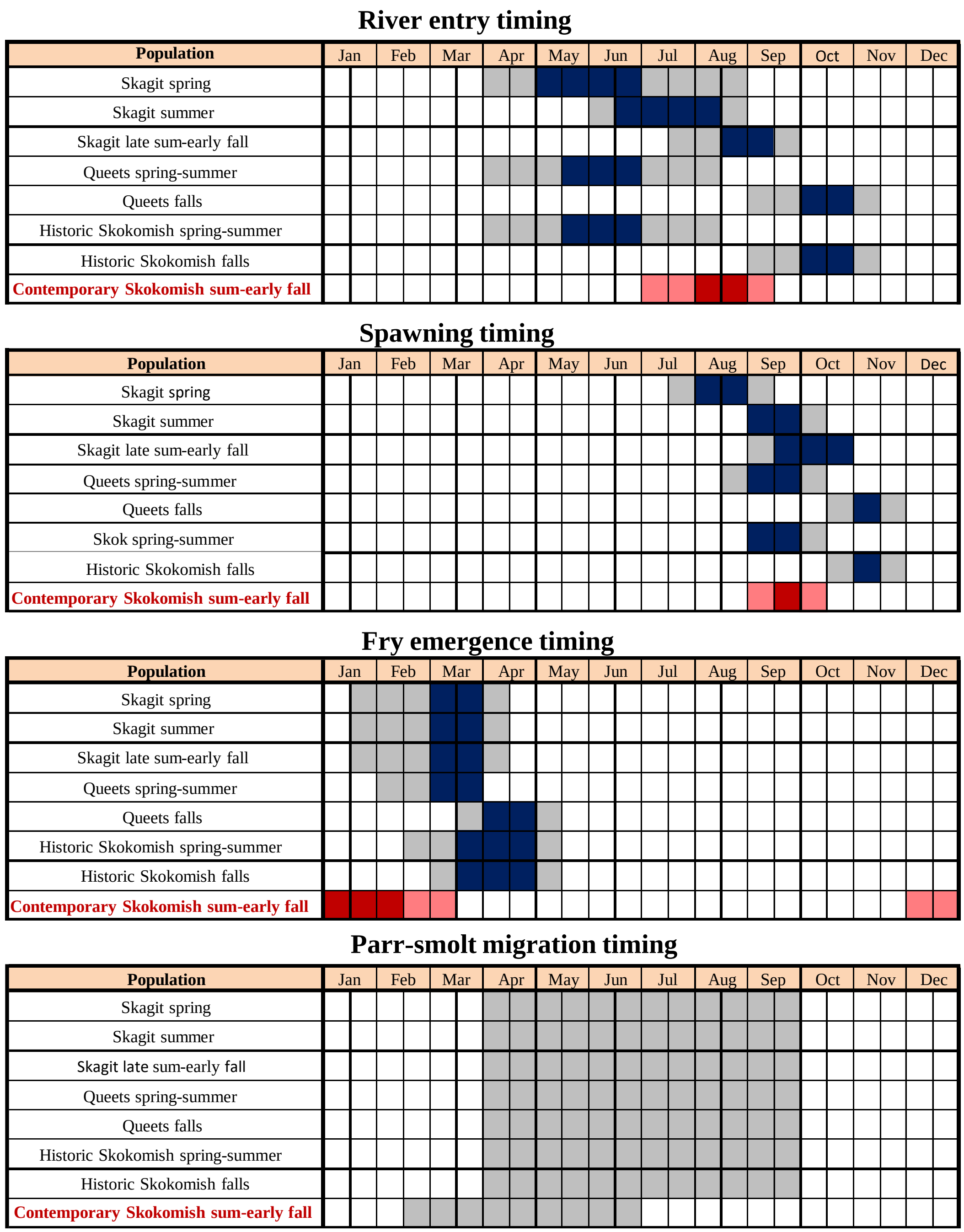

Figure 5. Periodicity table showing timing of freshwater life stages for seven wild populations of Chinook, compared to the timing patterns for the contemporary Skokomish Chinook salmon population. Weekly time intervals are highlighted gray for the range of timing seen; dark blue highlighting shows peak migration periods. Cells are highlighted red for the contemporary Skokomish population (SIT and WDFW 2017).

The extant population in the Skokomish River is a highly domesticated hatchery stock (George Adams) derived from Green River Hatchery fish. The life history characteristics of the stock as it now exists differ dramatically from both the original source fall-run wild population in Green River and from the indigenous fall-run Skokomish population, with river entry for these fish beginning as early as June and peaking in August. Unlike wild fall populations such as the lower Skagit in Puget Sound, fish enter the river in early summer (June through August) and hold for extended periods of time prior to spawning in mid-September. Available evidence shows that reproductive success of George Adams Hatchery fish spawning naturally in the Skokomish River is extremely poor. The evidence shows that egg to emergent fry survival is poor and that the number of natural-origin recruits (NORs) is less than the number of original spawners (see Abundance Status section). Because it originated from a fall stock, has been historically referred to as a fall stock, but exhibits run timing and spawning characteristics of a summer-run population, presumably due to years of domestication at the George Adams Hatchery, we refer to it as the George Adams Summer/Fall.

The 2010 Skokomish Chinook Salmon Recovery Plan focused on recovery of a spring Chinook salmon population. In brief, the co-manager Recovery Plan concluded that recovery of a true fall-run population presented more uncertainties and that it would require a longer period of time to make significant progress than for the re-establishment of a spring-run population. The primary basis for this conclusion is the level of habitat degradation in the lower watershed where fall Chinook would be recovered and the time horizon for restoring properly functioning conditions in the lower watershed. The development of the 2010 Recovery Plan coincided with the Settlement Agreement with Tacoma Power, which included a Spring Chinook salmon Program to be implemented at the North Fork Hatchery (Table 1).

Table 7. Summary of egg transfers and releases to date for the Spring Chinook salmon program at North Fork Hatchery (NFH) (Ollenburg, Tacoma Power, pers comm., 2021)

Brood Year	Marblemount				Comments
	Eyed Eggs	Release			
2014	149,000	131,026			Incubated, hatched, and reared at Lilliwaup
2015	357,059	339,632			Incubated and hatched at Lilliwaup, reared at the NFH
2016	411,450	375,755			Brought in to NFH
2017	423,862	398,384			Brought in to NFH
	North Fork Hatchery		Marblemount		
	Eyed Eggs	Release	Eyed Eggs	Release	
2018	89,071	81,857	385,186	349,341	
2019	266,719	235,775	198,597	180,427	
2020	47,709	34,137	392,528	301,503	Yearlings have not been released yet

The donor stock, Skagit River spring Chinook salmon from Marblemount Hatchery exhibits a river entry pattern and other life history traits similar to the aboriginal Skokomish spring-run population. Program targets for the spring Chinook salmon program call for the release of 300,000 fingerlings and 75,000 yearlings, all of which are unclipped and coded-wire-tagged (CWT). The 2017 Skokomish Recovery Plan update continues to maintain a strong emphasis on recovering a spring Chinook salmon population. Implementation of this program is underway with the first transfer of eggs occurring in 2014 with the first release occurring in 2015 such that Age-4 fish began to return with eggs collected at the North Fork Hatchery from 2018 -2020 (2021 data NA). We refer to this component population as the North Fork Spring Chinook salmon. Although this stock is likely to eventually recolonize or be introduced into the upper South Fork as well, there is little likelihood this will occur within the timeframe of this management plan. Based upon life history characteristics exhibited in their watershed of origin, we expect this component to return to the river from May through June, and spawn in early to mid-August.

The premise on which the Skokomish Chinook Salmon Recovery Plan update is built is that population recovery requires restoring life histories that are adapted to the environmental conditions that either still exist in the watershed or that are being restored. For fall Chinook salmon, the prospect that a late-timed true fall Chinook salmon life history could re-emerge from the extant stock seems plausible given the fall Chinook salmon stock origin. Domestication effects appear to have been so significant that the potential of this occurring carries uncertainties. Part of the experimental aspect of this program will be testing to what degree run timing and spawn timing are heritable traits. Should efforts to reestablish these traits prove successful, the resulting component population will also require exhibition of other traits such as outmigration timing and ocean survival to complete a successful life history. However, the extant stock has demonstrated some degree of adaptation with regards to ocean migration and survival and an affinity for returning through the Hood Canal environment to the Skokomish River. For this reason, we are currently testing whether a later timed component of the extant stock could be redeveloped, i.e., one that enters the river in September and early October and spawns in synchrony with the fall flow regime, that it would be more effective at producing natural-origin fish compared to the effectiveness of the stock as it currently exists. As the river conditions are improved through restoration, reproductive success should be further improved.

The success of this “Late-Timed” George Adams Chinook salmon program will depend on 1) whether we have sufficient later returning and maturing George Adams late-timed Fall Chinook salmon to take eggs, 2) whether these timing characteristics have a high degree of heritability, and 3) whether those characteristics lead to the production of natural origin returns above replacement on the spawning grounds. Over the last seven years eggs have successfully been obtained for this program, which calls for the release of 200,000 from the hatchery, and 100,000 in off-station releases, all unmarked and 100% CWT (Table 2). Our preliminary success in answering whether we have sufficient later returning and maturing George Adams late-timed Fall Chinook salmon from which to take eggs, will be followed by assessing the return rates both at the hatchery and on the spawning grounds through CWT analysis. We refer to this component population as the George Adams late-timed Fall Chinook salmon.   Based on life history characteristics of other wild “true fall” populations in Puget Sound, particularly the lower Skagit falls, we expect the return timing to the river to be in September with spawning occurring in October and November.

Table 8. Summary of egg transfers and releases to date for the late-time fall Chinook salmon program at George Adams (Mark Downen, WDFW, FishBooks database, 2021)

Brood year	Date	Females	Males	Eggs	Date	Release Number	size	mark/tag	Release site
2014	6-Oct	36	36	162,214	5/15/2015	186,287	72	CWT Only	GA Hatchery
	13-Oct	12	9	54,732					
Total				216,946					
2015	6-Oct	29	30	109,579	5/17/2016	202,225	72	CWT Only	GA Hatchery
	13-Oct	9	11	36,268					
/b	12-Oct			75,150					
Total				220,997					
2016	6-Oct	90	87	333,850	4/26/2017	35,354	82	CWT Only	Vance Cr
					4/26/2017	37,138	80	CWT Only	NF Skok
					5/17/2017	197,385	73	CWT Only	GA Hatchery
Total				333,850		269,877			
2017	10-Oct	108	108	435,997	5/16/2018	194,981	79.9	CWT Only	GA Hatchery
	17-Oct	13	13	44,722	5/4/2018	53,338	139	CWT Only	Vance Cr
	24-Oct	36	33	117,100	5/4/2018	52,361	139	CWT Only	NF Skok
Total				480,719					
2018	2-Oct	96	96	359,136	5/17/2019	180,177	75	CWT Only	GA Hatchery
	15-Oct	34	34	110,360	4/12/2019	50,235	79	CWT Only	Vance Cr
					4/12/2019	50,347	79	CWT Only	NF Skok
Total				469,496					
2019	7-Oct	110	110	413,100	5/8/2020	199,226	69	CWT Only	GA Hatchery
	15-Oct	7	7	22,500	4/16/2020	54,453	76	CWT Only	Vance Cr
					4/16/2020	55,327	76	CWT Only	NF Skok
Total				435,600					
	28-Sep	75	75	247,300	5/21/2021	73,373	68.6	CWT Only	GA Hatchery
						53,716	69	CWT Only	Vance Cr
2020						53,912	70	CWT Only	NF Skok
	6-Oct	35	36	127,500	5/21/2021	124,450	68.6	CWT Only	GA Hatchery
	13-Oct	4	4	15,700	5/21/2021				
Total				390,500					

/b These eggs were received from Hoodsport Hatchery in order to make program

Abundance Status

Historically, the Skokomish River supported the largest natural Chinook salmon production of any stream in Hood Canal, but the construction and operation of the Cushman hydroelectric project coupled with severe habitat degradation, has reduced the productive capacity of the basin. As previously noted, the North Fork has been blocked by two hydroelectric dams.

Hatchery Chinook salmon production has been developed at the George Adams Hatchery to augment harvest opportunities and to provide partial mitigation for the loss of production due to destruction of Chinook salmon habitat in the North Fork caused by construction and operation of the Cushman hydroelectric project.

Chinook salmon escapements to George Adams Hatchery remained stable during the 1980s reached record lows in the 1990s and have increased from the early 2000s ranging from about 6,000 to 35,000 fish from 2008-2019 (Table 3). There is significant uncertainty in estimates of natural escapement for return years prior to 2010. Reliable estimates of the proportions of hatchery-origin and natural-origin fish among natural spawners are not possible for return years prior to 2010 due to low mark and sampling rates, few recoveries of CWT or marked Chinook salmon, and uncertainty about expanding marked recoveries to fully account the hatchery proportion. Estimates of hatchery-origin fish in the natural escapement averaged approximately 85% from 2012-2015 and has averaged approximately 88% from 2016-2019 (Table 3).

Table 3. Chinook salmon spawning escapement-Skokomish River watershed (SIT and WDFW 2021).

Year	Non-selective FW catch	Mark-selective FW catch	GAH escapement	Spawning escapement (HOR +NOR)	NOR escapement	pHOS	HOR ETRS	NOR ETRS	ETRS
1988	9,237	-	4,439	2,666					16,342
1989	9,938	-	2,523	1,204					13,665
1990	5,977	-	2,186	642					8,805
1991	6,458	-	3,068	1,719					11,245
1992	549	-	294	825					1,668
1993	521	-	612	960					2,093
1994	275	-	495	657					1,427
1995	-	-	5,447	1,398					6,845
1996	-	-	3,100	995					4,095
1997	4	-	1,885	452					2,341
1998	13	-	5,584	1,177					6,774
1999	2,340	-	8,235	1,692					12,267
2000	1,081	-	4,032	926					6,039
2001	6,549	-	8,816	1,913					17,278
2002	5,674	-	9,395	1,479					16,548
2003	7,315	-	10,034	1,125					18,474
2004	6,811	-	12,278	2,398					21,487
2005	12,259	-	16,018	2,032					30,309
2006	13,493	-	12,356	1,209					27,058
2007	15,364	-	13,270	429					29,063
2008	13,267	-	13,695	1,134					28,096
2009	12,041	-	13,220	1,066					26,327
2010	9,654	6,336	12,891	1,214	174	87%	29,821	274	30,095
2011	11,761	5,784	24,581	1,321	55	96%	43,368	79	43,447
2012	15,434	12,261	22,874	1,533	142	91%	51,870	231	52,102
2013	8,894	5,458	21,444	1,722	171	90%	37,282	236	37,518
2014	3,680	2,167	6,227	849	109	87%	12,758	165	12,923
2015	6,286	3,297	6,033	432	117	73%	15,817	231	16,048
2016	10,314	-	22,076	1,342	177	87%	33,474	255	33,732
2017	16,515	-	35,129	8,058	875	89%	58,492	1,210	59,702
2018*	9,985	-	23,796	2,459	288	88%	35,843	397	36,240
2019*	9,608	-	12,182	2,265	310	86%	23,538	517	24,055
*Preliminary									
4 year Means:									
2012-2015	8,574	5,796	17,603	1,134	134	85%	29,432	216	29,648
2016-2019	11,606	-	23,296	3,531	413	88%	37,837	595	38,432
% increase	35%	-100%	32%	211%	207%	3%	29%	176%	30%

In order to clarify ongoing updates to estimates of natural origin fish some background on past methodologies is in order. The first rigorous analysis of the contributions of hatchery fish to the spawning grounds and returns of natural origin fish was conducted as part of the Skokomish Rebuilding Exploitation Rate derivation analysis. This analysis produced estimates for years 1987 through 2006 and was continued afterward (Figure 2). The pHOS estimate was generated by CWT and adipose-clip return rate divided by the tag/mark rate, divided by the sample rate on the spawning grounds for each return year (NMFS 2009). This old method of estimating pHOS is essentially the same as the current method, where the adipose clip rate of Chinook salmon carcasses from spawning ground surveys are divided by the adipose clip rate at George Adams Hatchery (adipose clip rate for different brood years contributing to return is weighted by the return year age comp). The one difference in methodology is to use only the adipose clip rates (not including CWT rates) to avoid error due to CWT retention and detection. However, the accuracy and precision of a carcass mark rate expanded by a hatchery mark rate is dependent on a high proportion of the hatchery releases being marked.

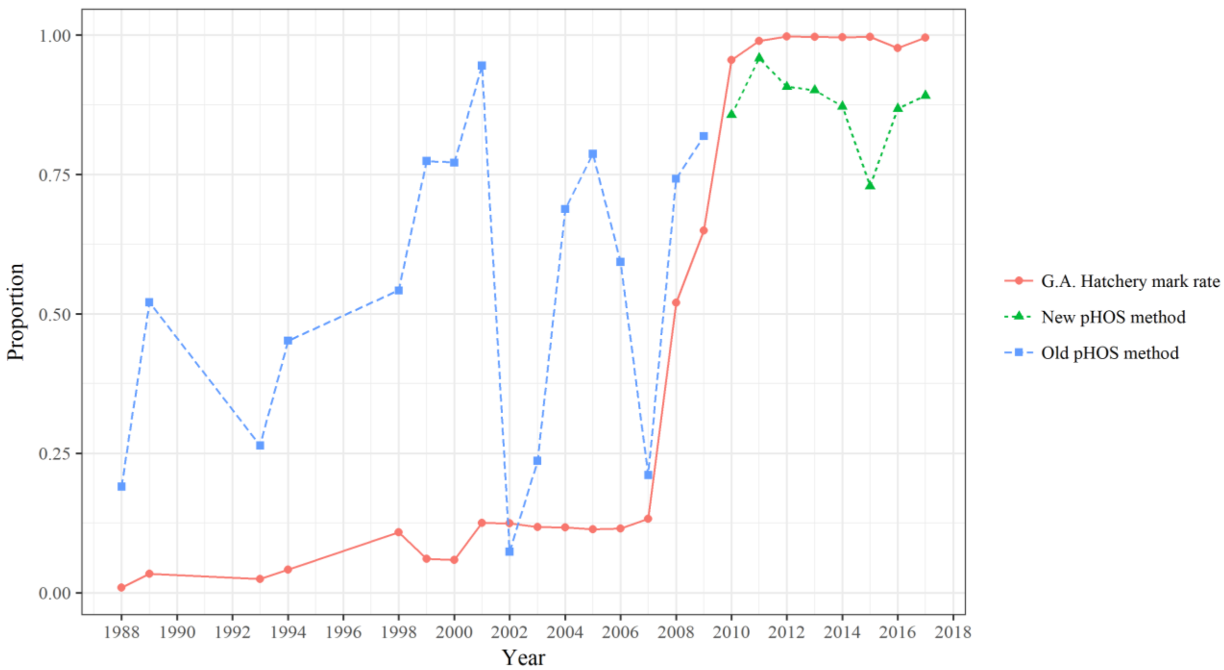

Figure 2. The old pHOS estimation method was not viable because of very low George Adams Hatchery (GAH) mark rates (including CWTs and adipose fin clips). After return year 2010, the mark rate at GAH has been above 95%, and the pHOS estimates have stabilized.

In the old pHOS methodology, including the adipose-clipped fish was necessary due to the extremely low sample sized of tag recoveries. However, only a small proportion of each hatchery release was marked and/or tagged prior to brood year 2006. Not all hatchery facilities which contributed Chinook salmon strays to the Skokomish spawning grounds had quantified mark rates at release. Not all cohorts were tagged and small random samples from the spawning grounds coupled with tag detection error, tag loss, and variable survival and straying of hatchery fish likely resulted in underestimates of hatchery fish and a poor signal to noise ratio. Highly variable estimates and dramatic swings in the proportions of hatchery fish on the spawning grounds from year to year (Figure 2) are not reasonable in the context of the Skokomish River watershed. Total hatchery releases have been very consistent since 1995 (Figure 3), with a mean of 3,848,320 Chinook salmon, and a coefficient of variation of only 5.6%. With a hatchery program of this size with very consistent total releases that supports a small population of NORs in the hundreds of fish every year, it is not reasonable to believe the pHOS would drop from 95% to 7% in one year as indicated in the old pHOS estimates (2001-2002). The large standard deviation and wide 95% confidence estimates in the old pHOS estimates (Table 4) further calls into question their accuracy and precision given more recent estimates which show a much more consistent pattern, it seems unlikely that the last 20 years of restoration work in the river, implementation of mark selective fisheries, increased flows in the north fork, and adoption of lower exploitation rates in 2010 would coincide with declining returns of natural origin spawners to the Skokomish.

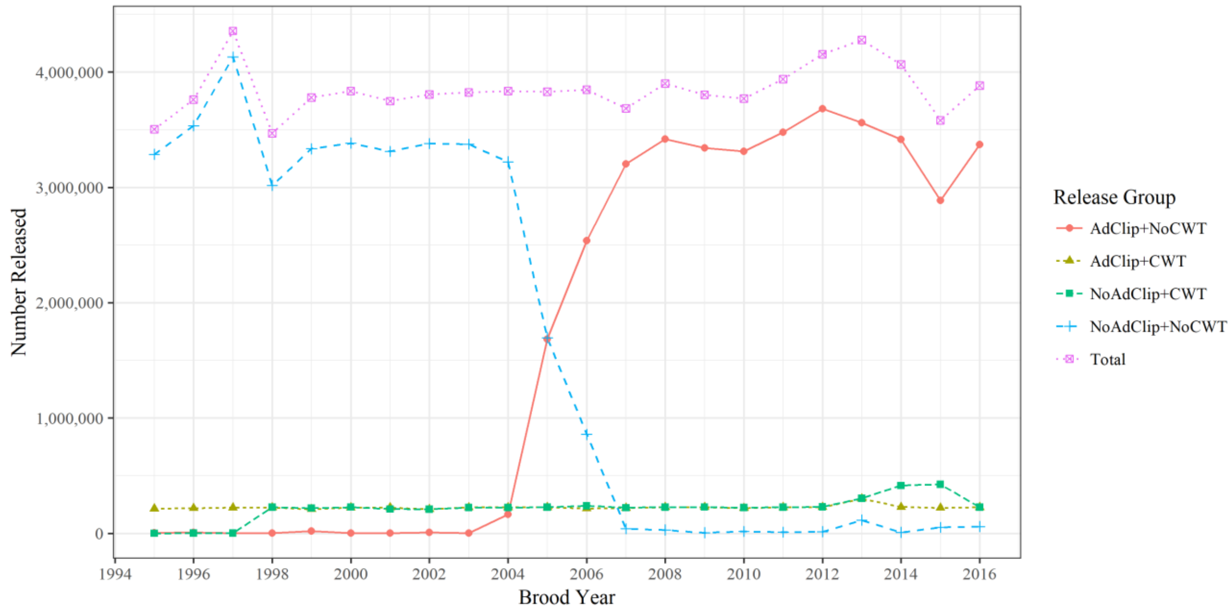

Figure 3. Total fingerling releases from George Adams Hatchery have been very consistent from Brood Year 1995 to the present, although mass marking has increased dramatically after Brood Year 2006.

Table 4. The old pHOS estimates are not consistent with the new estimates from after the onset of mass marking.

pHOS method	Mean	SD	N	95% CI
old	54%	27%	16	39-68%
new	87%	7%	8	82-93%

By 2008, higher mark rates for returning brood years were being phased in. In 2008, 50% of Age 3s and 5% of Age 4s were marked, in 2009 75% of Age 3s and 50% of Age 4s were marked, and by 2012 the first return of 100% (minus Double Index Tag (DIT) groups and clip error) of all broods were marked. From 2008 through 2013, the co-managers expanded clip rates of each brood year to estimate the marked fish on the spawning grounds, then added expanded CWT detections to estimate the total hatchery contribution to escapement. As clip rates for the non-DIT production reached 100% this method continued to be implemented up through 2016.

However, an alternative approach was taken in 2017 with the idea of validating the ad-clip rate plus CWT methodology. The new pHOS methodology used only ad clip rates, including the DIT group and expanded returns by brood year ad-clip rate using CWT age composition. The result was a higher estimate of the proportion of hatchery fish on the spawning grounds. The explanation for this is likely error associated with tag detections in the field, either due to equipment error, sampler error, or tag migration or shedding. This hypothesis is strongly supported by data collected in the assessment of the Hamma Hamma Chinook salmon supplementation program in which all supplementation fish were 100% CWT and otolith marked. Yet over a five-year period, the number of Chinook salmon carcasses recovered in the Hamma Hamma which were otolith marked but returned no CWT either in the field or in the lab averaged about 28%. Both the adipose clip + CWT expansion method and the adipose only expansion method yielded consistent, somewhat stable, estimates as compared with the old RER analysis, but the adipose only method reduced the uncertainty associated with CWT detections and was thus deemed the cleanest method to use going forward by the co-managers. In addition, fish of unknown ad clip status had been erroneously included in the unmarked group. Upon detection of this error only fish with known ad clip status were included in the new pHOS calculations.

After the new pHOS methodology was finalized by the co-managers in February of 2018, multiple tests were done to compare the old pHOS methodology to the new pHOS methodology. There is convincing evidence (Welch Two Sample t-test, t=-4.7, P = 0.000184) that the mean pHOS estimates are different (Figure 4). The 95% confidence interval on difference in means is 18-49% lower in the old pHOS methodology despite major habitat restoration efforts in the floodplain, riparian zone, and active channel (SIT and WDFW 2017), including an increased flow regime below the North Fork Dams. The combination of these habitat actions has more than doubled the available spawning habitat for summer-fall Chinook salmon after 2010, and if anything should have had a positive effect on natural spawning production that would lead to a lower pHOS.

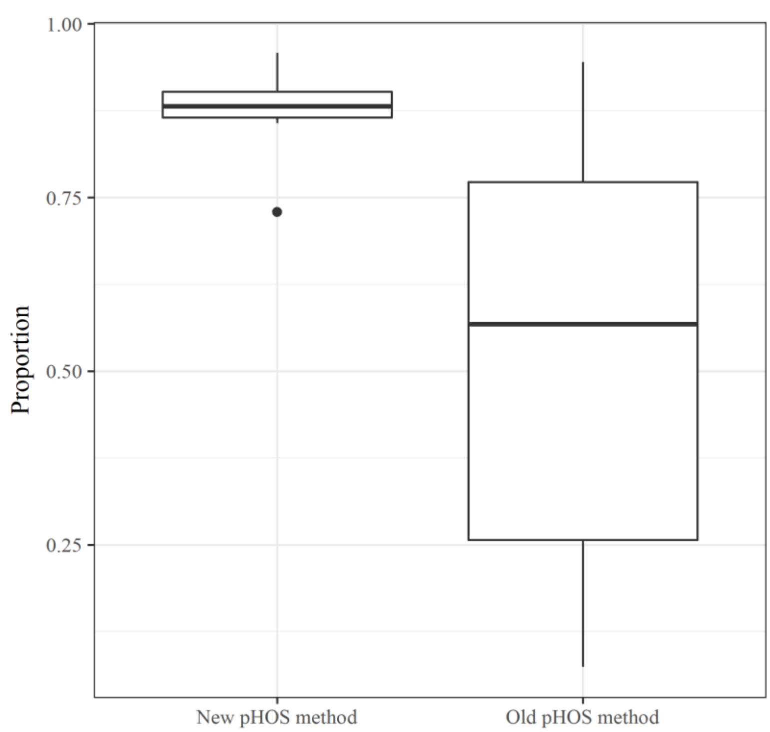

Figure 4. Estimates of pHOS using the new versus old methodology and available data.

Furthermore, there is convincing evidence that the pHOS estimates from the old and new methods/data are not from the same population distribution, shown in Figure 5 (Two-sample Kolmogorov-Smirnov test, D = 0.8125, two-side P = 0.000732). Considering the above evidence, the tight distribution of the new pHOS estimates, and the consistent releases of fingerling Chinook salmon at GAH (Figure 3), the co-managers have determined the best available pHOS determination for years prior to 2010 is the mean pHOS from 2010-2017.

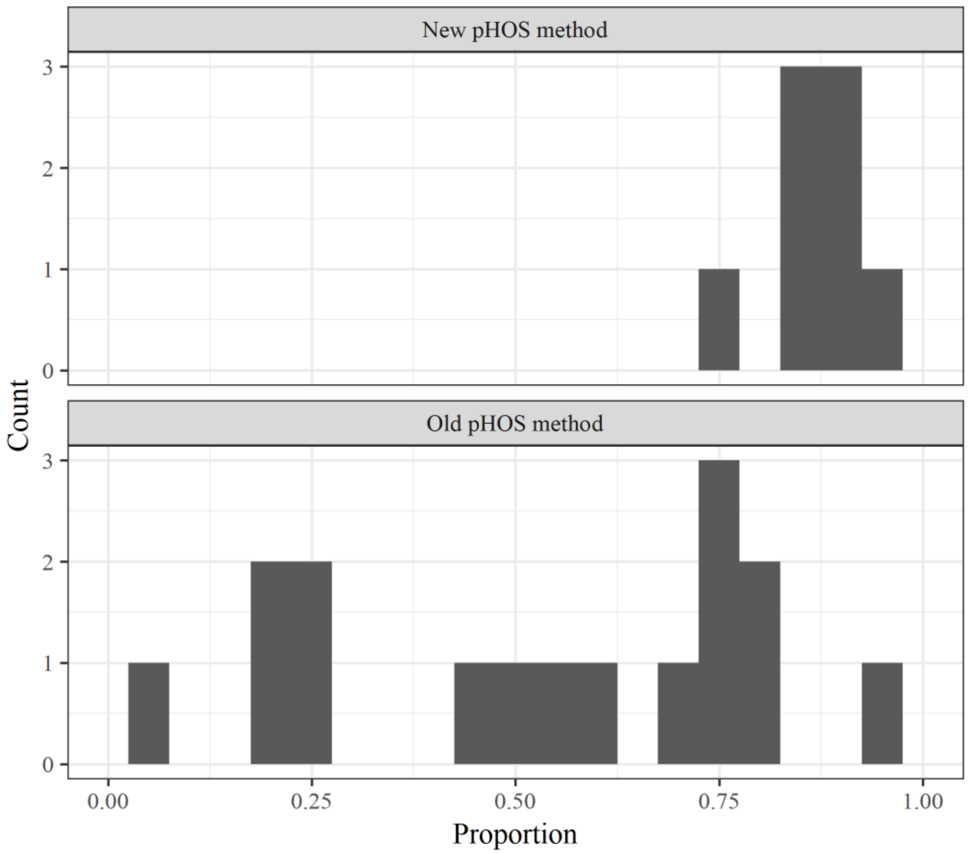

Figure 5. Frequency distributions of pHOS generated from prior to 2010 using the old method and low hatchery mark rates are not consistent with those from 2010 and after using the new method and high hatchery mark rates.

Harvest distribution and exploitation rate trends

The harvest distribution of Skokomish River Chinook salmon is described by CWT recoveries of fingerlings released from George Adams Hatchery. Since harvest estimates presented in 2010 PSCHMP and Skokomish MUP/Recovery Plan were based on this methodology, updated estimates using this approach are provided here as well. The standard analysis conducted by the PSC Chinook Technical Committee (CTC) involves expansion of estimated recoveries from fisheries to account for non-landed mortality. Analysis of the 2007-2014 CWT recoveries indicate that 75% percent of harvest occurred in Washington fisheries and 24% in Canadian (BC) fisheries, with less than 1% occurring in Alaskan (AK) fisheries. Recent analysis by the CTC indicate that 80% of harvest occurred in Washington fisheries and 18% in Canadian (BC) fisheries, with Alaskan (AK) fisheries again comprising less than 1% (Table 5). Distribution of fishing mortality between Alaska, Canada and the southern U.S. was shifted slightly south by a reduction in impacts in fisheries north of the U.S. and Canada border, but proportion of escapement has remained relatively unchanged.

Table 5. Harvest distribution of George Adams Hatchery fingerling Chinook salmon, from analysis of CWT recoveries (TCCHINOOK 21-05). Note, WA-Net, -Sport and -Troll include a small number of southern U.S. recoveries outside of WA.

	AK	BC	WA-Net	WA-Sport	WA-Troll
2007 to 2014	0.6%	24.4%	30.4%	38.0%	6.5%
2015 to 2018	0.1%	18.8%	46.4%	27.0%	7.3%

The total annual (i.e., management year) exploitation rate as computed by post-season FRAM runs has exceeded 50% through 2015, but recent years has maintained 50% or lower after terminal fisheries were restructured beginning in 2016 (Table 6). This exceedance through 2015 can be attributed to the higher than expected terminal harvest rates on lower than forecasted abundances (i.e. possible forecasting error; climate change; the Warm Ocean Blob etc.).

Table 6. Total fishery-related adult equivalent exploitation rates of Skokomish River natural Fall Chinook for management years 2001- 2018 as estimated by post-season FRAM validation runs using the Base-Period 6.2. with Base-Period 7.1 and BP 7.1.1 shown for comparison only as was not applied during 2001-2021 with future use dependent on co-manager agreement (25OCT2021).

Year	North			PT SUS			Terminal			Total		
	6.2	7.1	7.1.1	6.2	7.1	7.1.1	6.2	7.1	7.1.1	6.2	7.1	7.1.1
2001	9%	9%	9%	16%	17%	17%	32%	30%	30%	56%	56%	56%
2002	13%	14%	14%	14%	14%	14%	26%	25%	25%	52%	53%	53%
2003	13%	14%	14%	13%	13%	13%	31%	30%	30%	57%	57%	57%
2004	13%	14%	14%	16%	17%	17%	24%	24%	24%	54%	55%	55%
2005	12%	14%	14%	16%	19%	19%	30%	28%	28%	58%	62%	62%
2006	11%	12%	12%	14%	14%	14%	39%	39%	39%	64%	64%	64%
2007	16%	17%	17%	13%	14%	14%	39%	38%	38%	68%	69%	69%
2008	14%	14%	14%	13%	13%	13%	39%	38%	38%	65%	65%	65%
2009	15%	16%	16%	10%	10%	10%	39%	38%	38%	63%	64%	64%
2010	11%	13%	13%	10%	10%	10%	34%	33%	33%	55%	56%	56%
2011	15%	16%	16%	9%	9%	9%	29%	29%	29%	53%	54%	54%
2012	12%	15%	15%	15%	15%	15%	36%	30%	30%	63%	60%	60%
2013	9%	11%	11%	12%	13%	13%	29%	28%	28%	50%	52%	52%
2014	11%	12%	12%	14%	15%	15%	33%	32%	32%	59%	59%	59%
2015	10%	12%	12%	13%	14%	14%	40%	38%	38%	63%	64%	64%
2016	11%	13%	13%	9%	9%	9%	29%	28%	28%	49%	51%	51%
2017	NA	13%	13%	NA	10%	10%	NA	27%	27%	NA	50%	50%
2018	NA	12%	12%	NA	12%	12%	NA	25%	25%	NA	49%	49%

Harvest Management Objectives

Salmon fisheries along the entire west coast of North America are today constrained by a variety of catch limits, harvest rates, time-area closures and restrictions, or species and size retention limits that are designed to achieve conservation objectives for wild salmon stocks (PFMC Framework Plan or Amendment, PSIT and WDFW 2010).

State and tribal co-managers developed the Puget Sound Salmon Management Plan (PSSMP) in 1985 and the Hood Canal Salmon Management Plan (HCSMP) in 1986, establishing management units and escapement goals to guide annual management of fisheries. Hood Canal Hatchery Chinook salmon stocks were designated as the "primary" management units by the HCSMP, so commercial Chinook salmon fisheries in Hood Canal during the 1980s were managed to achieve sufficient escapement to perpetuate production at the George Adams and Hoodsport Hatcheries. Natural Chinook salmon stocks were designated as "secondary" management units in the HCSMP, so fisheries were not managed to achieve a specific number of natural spawners.

After Puget Sound Chinook salmon ESU was listed as threatened, associated management objectives (i.e. ER Ceilings) were set for all natural Chinook salmon populations. The specific objectives for the Skokomish River Summer/Fall population have evolved over the several versions of the Puget Sound Chinook Salmon Harvest Management Plan. In the 2010 plan the Skokomish River objective was set at a total ER of 50%.

Harvest management objectives reflect a new strategy for recovering Chinook salmon suited to environmental conditions in the Skokomish River watershed restored to normative conditions.[31] The extant population in the river is a highly domesticated hatchery stock (George Adams) derived from Green River Hatchery fish with dramatically altered life history characteristics differing from both the original source fall-run wild population in Green River and from the indigenous fall-run Skokomish River population. Available evidence shows that reproductive success of George Adams Hatchery fish spawning naturally in the Skokomish River is extremely poor (SIT and WDFW 2017). The evidence shows that egg to emergent fry survival is poor and that the number of natural-origin recruits (NORs) is less than the number of spawners that produced them (Table 7). It is also noteworthy that broods 2016 and 2017 in Table 7 are incomplete, and these are the minimum productivity estimates for those years that will increase as the older age classes' return. It is noted that the extant population in the river currently is neither a spring-timed run nor a true fall-timed run. Both river entry and spawning timing have been advanced significantly over decades of hatchery propagation such that the run now is best described as a summer-early fall run.

Table 7. Simulated brood table for Chinook salmon spawning in the Skokomish River. Since NOR age composition is unknown for any year, an average age comp from 207 sample fish between 2009 and 2020 was used for all years. Prior to return year 2010 (corresponding to the 2007 brood) NOR-HOR breakouts were estimated using the average PHOS from 2010-2020, denoted in red text.

[31] / The normative condition concept simply means that restoration will not return the river to its state prior to the way it was before the rapid human-caused alterations over the past 150 years. Restoration aims to return the river to a more productive state for wild salmon than currently exists, a state that can sustain productive salmon runs that meets the needs for recovery and delivers ecological services that achieve broad sense goals. Normative refers to the norms of ecological functions and processes characteristic of salmon-bearing streams and other natural aquatic habitats.

	Parent Spawners		NOR Recruits by age				Total Spawner Productivity
Brood Year	NOR	Total	3	4	5	total	(NOR recruits / total spawners)
1992	106	825	100	116	4	220	27%
1993	123	960	67	66	44	177	18%
1994	84	657	6	84	7	96	15%
1995	179	1398	78	106	3	188	13%
1996	128	995	251	181	14	446	45%
1997	58	452	19	141	5	166	37%
1998	151	1177	399	282	13	693	59%
1999	217	1692	115	235	21	371	22%
2000	119	926	92	411	34	537	58%
2001	246	1913	248	299	10	557	29%
2002	190	1479	345	263	5	612	41%
2003	144	1125	162	130	9	301	27%
2004	308	2398	41	119	4	164	7%
2005	261	2032	294	266	7	567	28%
2006	155	1209	111	131	1	243	20%
2007	55	429	254	97	10	361	84%
2008	146	1134	21	102	4	127	11%
2009	137	1066	243	230	7	479	45%
2010	174	1214	122	174	9	305	25%
2011	55	1321	87	186	8	281	21%
2012	142	1533	129	116	30	275	18%
2013	171	1722	236	488	8	733	43%
2014	109	849	1231	235	5	1471	173%
2015	117	432	319	167	1	488	113%
2016	177	1342	138	22		161	12%
2017	875	8058	13			13	
2018	288	2459					
2019	310	2265					
2020	37	2061					
means:							
1992-2008							32%
2009-2016							56%

To meet this challenging Chinook salmon recovery issue, the SIT and Washington Department of Fish and Wildlife have embarked on an aggressive and innovative plan to restore naturally produced Chinook salmon to the river (SIT and WDFW 2010 and 2017). The plan calls for addressing both of the original spring and fall components of the population. Updated harvest management strategies constitute a key part of the plan.

The recent settlement agreement between the SIT, the City of Tacoma, State and Federal Resource agencies regarding operation of the Cushman hydroelectric project and associated mitigation supports restoration of spring Chinook salmon, initially in the North Fork, and then subsequently in the South Fork. Details of this strategy have been developed as part of the Recovery Plan for Skokomish River Chinook Salmon (RPSRCS developed by SIT and WDFW 2010 and 2017), to achieve the Co-managers' objective of recovering a self-sustaining, naturally-produced Chinook salmon population in the Skokomish River watershed.

This updated plan (specifically Chapters 1 & 5 of the SIT and WDFW 2017) also incorporates meaningful steps to make significant progress in improving the potential for recovery of a late-timed Chinook salmon population other than just habitat-related actions. These steps include both hatchery and harvest-related actions. The efforts aim to improve the potential for a successful natural life history of later timed fish that complements the habitat restoration strategy. This new strategy is to first stop, and then reverse to some extent the advanced timing of the George Adams stock and also promote an even later timed segment of the run. The purpose for doing this is twofold: first, to create a distinct timing separation between the returning spring Chinook salmon (as the re-introduction effort advances) and returning George Adams Chinook salmon; and second, to experimentally determine the success of re-creating later timed George Adams fish and subsequently to assess their reproductive performance (over the entire life cycle) when spawning naturally in the river. Actions to accomplish these steps are to occur while progress continues toward restoring properly functioning habitat in the lower river valleys.

The purpose of the harvest-related strategies presented in this plan is to ensure that fishery-related mortality will not impede recovery of spring Chinook salmon in the watershed and maximize the potential for recovering a late-timed (fall) population component. Further, fisheries will be adaptively managed to not impede recovery of Spring Chinook salmon or the "late-timed" George Adams fish. This will be accomplished by managing the genetic diversity and composition of the extant summer/early fall George Adams Hatchery population to achieve three sub-objectives: (1) minimize impacts on the reintroduced spring Chinook salmon by reducing or eliminating the earliest segment of the summer/fall hatchery population; (2) support treaty Indian and non-treaty fisheries by stabilizing the core mode of this run with an August river entry timing; and (3) closing treaty fisheries in 12C (September) and the Skokomish River (September – 2nd week of October) to facilitate an extension of the latest segment of river entry, which increases access to spawning grounds in the absence of any salmon-directed fisheries (September-October) and should facilitate a shift in spawn timing to improve the potential for recovering a late/fall George Adams Chinook salmon population. As the plan goes forward, the success of recovery efforts will be re-evaluated based on progress of efforts aimed at recovering a spring population and progress toward establishing a later-timed Chinook salmon stock component (see Chapter 1 of the Recovery Plan for Skokomish River Chinook-SIT and WDFW 2017). Based on that evaluation, the approach may be revised as per the adaptive management provisions of the Recovery Plan (SIT and WDFW 2017) and the Addendum to 2014 Plan for Management of Fall Chinook in the Skokomish River (SIT and WDFW 2014).

Fisheries will be planned and implemented to achieve the following objectives related to spring and summer/fall Skokomish River Chinook salmon:

1. Protect and conserve the abundance and life history diversity of a locally adapted, self-sustaining, spring population during and after its recovery.
2. Maintain stable abundance and genetic diversity of naturally spawning summer/fall George Adams Chinook salmon, with emphasis on the late/fall George Adams Chinook salmon component.
3. Maximize the opportunity to harvest surplus production from other species and populations, including those produced in hatcheries (e.g., George Adams and Hoodsport hatchery-origin Chinook salmon, re-introduced sockeye, hatchery-origin and wild coho, and fall chum).

4. Emphasize the importance of ceremonial and subsistence (C&S) tribal fisheries, prioritize C&S fisheries over any other fisheries targeting the Skokomish River spring Chinook salmon during all stages of recovery.
5. Adhere to the principles of the Puget Sound Salmon Management Plan and the Hood Canal Salmon Management Plan, and other legal mandates pursuant to *U.S. v. Washington* to ensure equitable sharing of harvest opportunity, and among treaty and non-treaty fishers.
6. Monitor abundance, productivity, and spawning distribution of spring and summer/fall Chinook salmon, which will include estimating catch distribution, age composition, and hatchery- and natural-origin total mortality in all fisheries.

Harvest Management Strategies

Harvest management strategies embody specific actions designed to achieve the objectives stated above. Consequently, this section describes in more detail the terminal area fisheries directed at the fish arriving earlier (the July and August sub-components) of the George Adams summer/fall Chinook salmon, protective actions for the 'late-fall' Chinook stock, and fisheries for sockeye, coho, and fall chum that involve indirect impacts on either Chinook salmon stocks.

Spring Chinook Salmon

Management of the fisheries for early timed Chinook salmon in the initial phase of the re-introduction program will apply data for the pre-terminal catch distribution for Skagit (Marblemount Hatchery) spring Chinook salmon, which is the donor stock being used for the Skokomish River re-introduction effort. A program will be implemented to collect stock-specific information on the run timing, distribution, and fishery-specific harvest mortality of the Skokomish River early population, to better inform future harvest management. Terminal harvest will be more certain, due to the unique run timing of spring Chinook salmon and the ability to identify hatchery-origin returns.

In the interim, management objectives for terminal harvest will be implemented and monitored. Early fisheries for George Adams Summer/Falls will include real time (CWT) reading should unmarked, tagged fish be encountered. Ultimately, harvest objectives will be revised to reflect the productivity and abundance of spring Chinook salmon as they colonize and adapt to habitat in the North Fork, and later, the South Fork. This Plan for a period of twenty years starting in 2018, lays out a transition in harvest management as the spring population achieves a sequence of phases of recovery, triggered primarily by achieving specific thresholds of increasing abundance and survival (Chapters 3 & 5, Section 5.4. SIT and WDFW 2017).

Planning targets for population performance have been identified: using the Ecosystem Diagnosis and Treatment (EDT) model (Blair et al. 2009) and the All-H Analyzer (AHA) model (HSRG 2009) to quantify planning targets, the recovery target for Skokomish spring Chinook Salmon has been identified to be a naturally spawning population with an average annual return of approximately 1,000 natural-origin adults to the mouth of the Skokomish River and a recruit per spawner ratio (population growth rate or productivity) of 2.0 from 400 spawners. The target presented here may differ from delisting criteria that NMFS might apply to the Puget Sound ESU (SIT and WDFW 2017). The pace of progressing through the phases will be determined by the response of the population to each phase. No explicit timeline for recovery can be projected given the levels of uncertainty that exist for how fast the watershed can be restored, about future impacts of climate change, and how quickly the reintroduced population will respond. The co-managers expect that recovery will not be achieved by the end of the current license for the Cushman Project, which spans the next 30 years.

PSIT and WDFW (2017) concluded that the local adaptation phase for at least some Chinook salmon recovery efforts within the Puget Sound ESU may require a particularly long period (>100 years). For populations currently consisting of a mix of hatchery-origin and natural-origin fish, a considerable time period is expected to be required to gain the fitness level needed to transition to the fully restored phase (Chapters 3-5 SIT and WDFW 2017). Also note that restoration of the South Fork and lower mainstem Skokomish River are likely to be slow in their progression to Properly Functioning Conditions (PFC).

In order to maximize spawning escapement for a period of at least two brood cycles seven years starting in 2018, except for limited ceremonial and subsistence harvest, terminal fisheries targeting spring Chinook salmon will not be implemented. As abundance increases, opportunities for expanding terminal fishing will be evaluated and implemented as determined to be consistent with program management objectives (i.e. 50%ER on the George Adams Summer-/Fall Chinook salmon and the George Adams late-timed Fall Chinook salmon) and to not impede recovery of any salmonid species in the Skokomish River. Additional commercial fishing opportunities will occur once the population is recovered (Chapter 6 SIT and WDFW 2017).

During the re-introduction recovery phase, limited C&S fisheries (hook & line only) will occur in the lower mainstem. The initial fisheries will be scheduled based on expected entry and migration timing with reference to the behavior of the donor stock, from early May through mid-June (Figure 6). To generate information on local run timing a beach seine test fishery may operate, also in the lower river. C&S removals could occur from the test fishery, all other catch will be released. Harvest will not increase beyond minimal C&S harvest until survival and run timing is described, when the 8-year running average return of spring Chinook salmon adults to the North Fork trap exceeds 600 fish. This would indicate that the abundance and productivity of the hatchery population likely exceeds the biological targets.

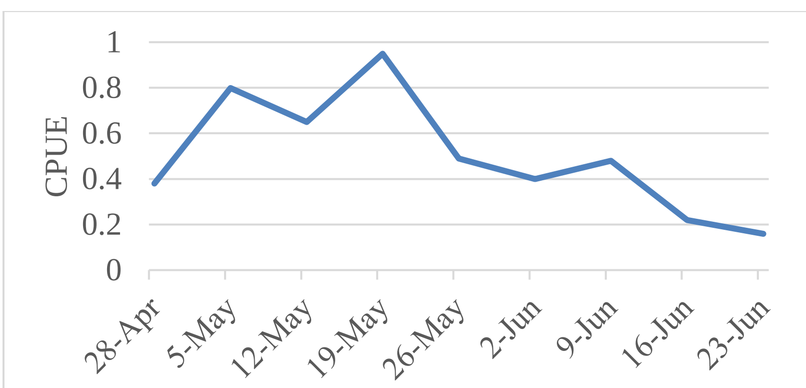

Figure 6. River entry timing for Skagit spring Chinook salmon (SIT and WDFW 2017).

Pre-terminal fisheries will involve incidental mortality of spring Chinook salmon returning to the Skokomish River. Sport Chinook salmon blackmouth fisheries in Salmon Management Areas 5, 6, 7, 9, and 12 may also involve indirect mortality via releases of these unmarked fish in mark selective fisheries. But overall, it is expected that recent constraints on pre-terminal fisheries in Washington, which have been driven by concern for weak Puget Sound Chinook salmon stocks, will be sufficient to meet the conservation and protection objectives of this Plan for Skokomish River spring Chinook salmon.

The re-introduction of spring Chinook salmon to the Skokomish River Basin began with release into the North Fork of BY 2014 smolts in the spring of 2015, from which the first Age-3 adults were expected to return to the North Fork Hatchery in 2017, however the first adults were not collected until 2018 (Table 8). The current data available on adult returns is insufficient to estimate the level or distribution of fishing mortality. However, The Recovery Plan for Skokomish River Chinook salmon specifies the elements of the monitoring and evaluation program necessary to estimate catch distribution and fishing mortality, and develop harvest objectives and conservation measures for each phase of recovery when data permits (Chapter 3 SIT and WDFW 2017).

Table 8. 2018 - 2021 Spring Chinook Salmon Adult Collector Summary Data at North Fork Hatchery (NFH) (Ollenburg, Tacoma Power, pers comm., 2021).

Year	Spawned	Green	Male Surplus	Mortality	Total Caught	Comments
2018	63	3	20	27*	113	*Primarily holding fungus in males
2019	146	4	4	12	166	
2020	56	3	39	29*	127	*Primarily holding fungus in males
2021	100	5	41	67*	213	*Primarily otter Predation and holding fungus in males

When sufficient information has been collected to characterize fisheries mortality and distribution, the Skokomish River Chinook spring population will be added to the FRAM, for pre-season planning and post-season assessment. Specific management objectives (e.g. harvest rate or exploitation rate ceilings, and thresholds) will be developed for pre-terminal and terminal fisheries. A threshold of abundance returning to the North Fork Hatchery of 600 adults has been set to mark the transition from the Phase 1 (Establish Founder Stock) to Phase 1 (Recolonization) of recovery. The threshold is based on modeling and expected broodstock needs at the hatchery to transition to Phase 2 (Chapter 6 SIT and WDFW 2017). The threshold is based in EDT models of productivity and capacity in the context of current habitat conditions in the North Fork.

Skokomish River Summer/Fall Chinook Salmon (2010-2017)

The management objectives for the extant summer/fall population (George Adams Hatchery related fish) have been to achieve escapement sufficient to meet hatchery broodstock requirements and to maintain stable abundance of natural spawners in the Skokomish River.

Harvest measures to achieve this objective have included:

- Managing southern U.S. (i.e. Washington) fisheries, and considering projected fisheries mortality in B.C`. fisheries, so that the total exploitation rate does not exceed 50% on the of the summer/fall population.

- For the purposes of pre-season harvest planning, the Upper Management Threshold will be 3,650 (the aggregate of 1,650 natural spawners and 2,000 escapement to the hatchery), and the Low Abundance Threshold will be 1,300 (the aggregate of 800 natural spawners and 500 escapement to the hatchery).
- If abundance falls due to reduced survival, and pre-season projections of natural escapement are 800 or less, and/or hatchery escapement falls below 500, pre-terminal fisheries will be further constrained so as not to exceed an ER of 12%, and the terminal fisheries will be shaped to increase escapement by reducing recreational and net fishing opportunity in southern Hood Canal and the Skokomish River.

If abundance remains within the recently observed range, we expected that natural escapement will exceed 1,200 in most years.

Summer/Fall George Adams Hatchery Chinook Salmon (2018 and forward)

Consistent with the objectives of the 2017 Skokomish Chinook Recovery Plan (SIT and WDFW 2017) of 1) reintroduction of spring Chinook salmon, 2) stabilization of the extant George Adams summer/fall population, and 3) development of a true fall Chinook salmon population from the extant hatchery stock, the co-managers have already begun implementation of changes to fisheries. Specifically, changes related to the latter of the objectives were made under the Addendum to 2014 Plan for Management of Fall Chinook salmon in the Skokomish River (SIT and WDFW, 2015).

Terminal-area fisheries for summer/fall Chinook salmon target a mixture of Hoodsport Hatchery and George Adams Hatchery production in Marine Area 12C, and George Adams production in the Skokomish River. This terminal fishing regime was developed to maximize harvest opportunity, while achieving conservation objectives for the natural component, as specified in the Puget Sound Chinook Salmon Harvest Plan. However, extensive monitoring of this approach has called into question the long-term prospect for success in recovering the extant population in the wild. In spite of ample numbers of Chinook salmon on the spawning grounds, natural-origin returns (NOR) are consistently low and likely below numbers required for a minimum viable population (Figure 7).

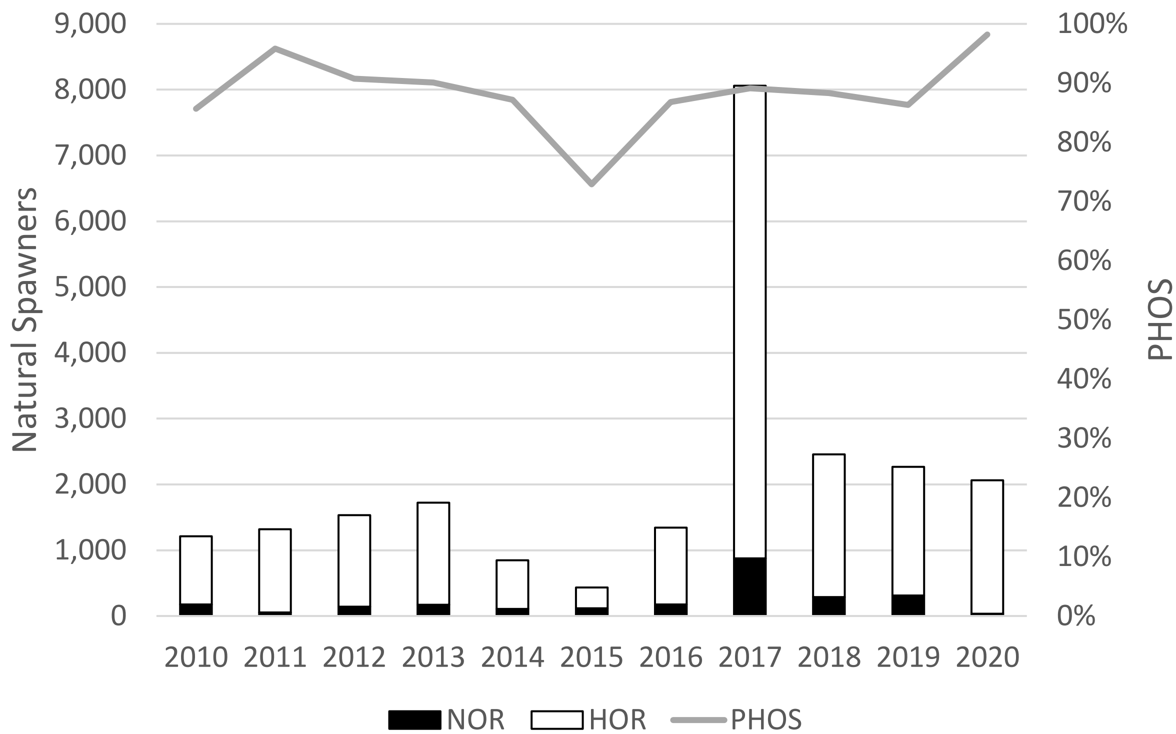

Figure 7. Skokomish River Chinook salmon natural-origin escapement (2017 Chinook Recovery Plan updated October 2021).

The George Adams stock appears poorly adapted to conditions in the Skokomish River, likely due to hatchery influences and impaired habitat. Constructing an accurate brood table, and estimating productivity of Chinook salmon broods in the Skokomish River is limited by the available spawning ground data. Prior to return year 2010, accurate PHOS estimates of the natural spawners are not possible because hatchery fish were not marked. Therefore, estimates of the number of NOR-HOR natural spawners is extremely uncertain prior to 2010 (see previous discussion). That uncertainty carries through to productivity estimates based on this earlier information (total spawners divided by NOR recruits). Furthermore, sample sizes of un-marked (and presumably mostly natural-origin) Chinook salmon carcasses used for scale-based age determinations were too low to produce a reliable age composition on an annual basis (Table 9). However, age compositions based on all Chinook salmon sampled from 2009-2020 suggest that the NORs have an older age structure than HORs. Trying to quantify the NOR age structure and incorporating it into management models and plans is ongoing. Due to the unknown NOR age structure for any given year, there is no way to reliably determine which brood a NOR recruit belongs to and here we have attempted to work around the above data limitations by using the average PHOS from 2010-2017 for years prior to determine the NOR-HOR breakout of parents and recruits. In addition, we have applied the average age comp from unmarked fish recovered in 2009-2020 to all years (Table 9). Therefore, these results should be interpreted cautiously—the productivity or NOR replacement for any given brood year may not be accurate, but the mean productivity of broods 2007-2015 should be reliable and the mean productivity prior to brood year 2007 should provide a useable baseline.

Table 9. Scale-based age composition of Skokomish River Chinook salmon carcasses sampled from 2009 through 2020. Fish without an adipose clip or CWT were labeled unmarked and presumed to be mostly NORs. Age denotation is total-age, freshwater emigration age (0 indicates a subyearling).

	Age composition of unmarked (mostly NOR) Chinook					Age composition of known HOR Chinook				
Ruturn Year	2,0	3,0	4,0	5,0	Total	2,0	3,0	4,0	5,0	Total
2009	0	4	30	0	34	22	15	54	1	92
2010	0	6	8	1	15	3	42	17	0	62
2011	0	1	5	0	6	14	7	28	0	49
2012	1	11	1	0	13	14	101	18	1	134
2013	0	6	13	0	19	13	104	88	1	206
2014	0	2	6	1	9	3	16	18	0	37
2015	0	4	6	0	10	4	11	17	1	33
2016	3	14	1	0	18	26	32	15	1	74
2017	1	27	24	1	53	31	282	85	5	403
2018	1	3	5	0	9	21	67	42	1	131
2019	0	10	8	1	19	5	141	112	1	259
2020	0	1	1	0	2	14	60	67	2	143
Total	6	89	108	4	207	170	878	561	14	1623
Total %	3%	43%	52%	2%	100%	10%	54%	35%	1%	100%

The 2014 and 2017 plans both envision extending the run timing for the George Adams stock to include true fall river entry and spawn timing, which involve changes in terminal harvest strategy. To a great extent these changes have already been implemented under those plans.

In recent years George Adams Chinook salmon have exhibited earlier return timing, such that returns to the hatchery have been observed as early as June. To minimize overlap in timing with the introduced spring population, hatchery broodstock collection protocols and targeted harvest will be implemented to substantially reduce or eliminate early returns in June and July, such that river entry timing of George Adams returns begins in late July and peaks in late August.

For a period of at least two brood cycles (seven years starting in 2018) fishing pressure may perhaps be increased in the Skokomish River (as per the SCSCI) and Area 12C during the month of July to remove early George Adams returns. Fisheries directed at the earliest returning summer/fall Chinook salmon will occur in Area 12C and the Skokomish River (as per the SCSCI) through the fourth week of August. Skokomish River fisheries will include openings in the mainstem below SR 106, between SR 106 and US 101(as per the SCSCI), and in Purdy Creek. Skokomish River fisheries will commence the last week of July and end the last week of August, with regulations for use of hook & line, dip-net, gillnet, and beach seine gear as per the SCSCI. Fisheries in Purdy Creek will begin in July and the purpose of these fisheries is to remove as many of these fish as possible, i.e. prevent them from spawning naturally or use as broodstock.

Mark selective sport fisheries will be implemented in Area 12 and commercial non-treaty beach seine fisheries in the Hoodsport Hatchery Zone 12C-12H which target hatchery Chinook salmon while meeting management thresholds for wild Chinook salmon stocks. Similar fisheries may occur in-river below the Highway 101 bridge where the co-managers agree they are compatible with tribal fisheries and recovery goals.
Commercial fisheries will be closed in Area 12C during the month of September and the Skokomish River the month of September opening the second week of October. These closures will enable the latest segment of the George Adams Chinook salmon population to pass through Area 12C and enter the Skokomish River in the absence of any salmon-directed fisheries

(September-October). This action will increase access to spawning grounds in the Skokomish River and facilitate a shift in spawn timing to improve the potential for recovering a late/fall George Adams Chinook salmon population. Coho salmon directed fisheries will then begin October 1 in Area 12C and the second week of October in the Skokomish River, when 0.0%-.00046% impacts will occur to the late/fall George Adams Chinook salmon population (Hood Canal Region Chinook TAMM Development Tool 2015).

As the later run-timing of the George Adams stock emerges, we expect that opportunity targeting the peak of the run will continue to provide significant harvest benefits in late July and August. This will be followed by the complete closure of the in-river commercial fisheries during September, except ceremonial and subsistence. This closure will increase the escapement of later-timed hatchery recruits (i.e. those entering the river in September and October, which are expected to have higher natural production potential, particularly as habitat constraints can be alleviated). Although the terminal harvest rate on this later-timed component will be managed consistent with the total ER summer/fall ceiling of 50%, it is expected that the total ER on the late-timed component of the George Adams Hatchery-related fish will be substantially less since terminal harvest contributions to the total ER will be greatly reduced.

Should co-manager efforts to rebuild a late timed life history prove successful, this subpopulation may also be added to the FRAM, for pre-season planning and post-season assessment. The co-managers plan to estimate escapement for the late-timed Chinook salmon by combining to two strategies. The first by using live fish counts and hatchery rack returns from after September 20, and then the second by redds constructed and carcasses sampled in the river after October 1. These dates will be adaptively managed as new data becomes available over the duration of this plan. CWT recoveries will be used to estimate terminal area harvest rates. However, since these fish are unmarked, the co-managers will need to rely on preterminal harvest rates of early-timed George Adams Chinook salmon to develop an exploitation rate for late timed Chinook salmon. Specific management objectives (e.g. harvest rate or exploitation rate ceilings, and thresholds) will be developed for pre-terminal and terminal fisheries.

Based on the return timing of Marblemount spring Chinook salmon to the Skagit River (characterized by long-term test fisheries data) we expect the North Fork spring return to extend from early May until mid-June. So we expect that incidental harvest of spring Chinook salmon will be very low in summer/fall George Adams Chinook salmon fisheries in July and August. However, the timing and migration behavior of spring Chinook salmon returning to the Skokomish River will be monitored, with supplemental data from CWT recoveries in fisheries, to determine the extent of run timing overlap, and locations where spring Chinook salmon hold in the lower river, that might expose them to harvest. Should timing characteristics of the late-timed program broodstock prove heritable, a reduction in harvest rates is likely to occur for this subpopulation as well, which we expect will be confirmed or refuted with CWT recovery data collected over the next couple of brood cycles.

Sockeye

The recently initiated sockeye hatchery program in lower Hood Canal is intended to restore a naturally produced sockeye population in the upper North Fork, and to provide harvest opportunity in the terminal area. The program began with egg transfers from the Baker River Hatchery in brood year 2016, so the initial returns are expected to begin with 3+ returns in the summer of 2019 juvenile sockeye produced at the Hood Canal Hatchery are released into Cushman Reservoir.

Sockeye fisheries, beyond minimal C&S opportunity, will not be initiated until returns exceed hatchery broodstock requirements (broodstock requirement as per the pending TPU HGMP). Once that threshold is reached (i.e. returns exceed broodstock requirements), fisheries will be planned and implemented in Area 12C and the lower mainstem of the Skokomish River, however unlikely throughout the duration of this plan. No foreseeable impacts to spring or fall Chinook salmon are expected throughout the duration of this plan.

In recent years, the peak of arrival of Baker River sockeye at the Baker trap was July 9; with timing extending from early June through early August (Figure 8). Ruff et al (2015) estimated that migration timing in the Skagit River, from Skagit Bay to the Baker River trap, was 14.5. Based on these Baker River data, that river entry of sockeye will begin in late May and continue through the end of July, and that migration toward the North Fork will take about a week, considering the shorter path in the Skokomish River system, incidental harvest of sockeye salmon will be very low in summer/fall Chinook salmon fisheries in July and August.

If the Hood Canal Hatchery sockeye stock and the North Fork spring Chinook salmon stock exhibit behavior similar to the Skagit donor stocks, we would expect some overlap in the latter part of spring Chinook salmon entry with sockeye. But incidental harvest of spring Chinook salmon will be kept low during sockeye fisheries, primarily through harvest regulations that specify use of smaller mesh (5 3/4") gillnets that target sockeye. A gill-net test fishery will be implemented in the lower Skokomish River to determine the entry and migration timing of sockeye. Incidental Chinook salmon catch in the sockeye test fishery will be carefully monitored. Ceremonial and subsistence removals of spring Chinook salmon could be taken by the test fishery.

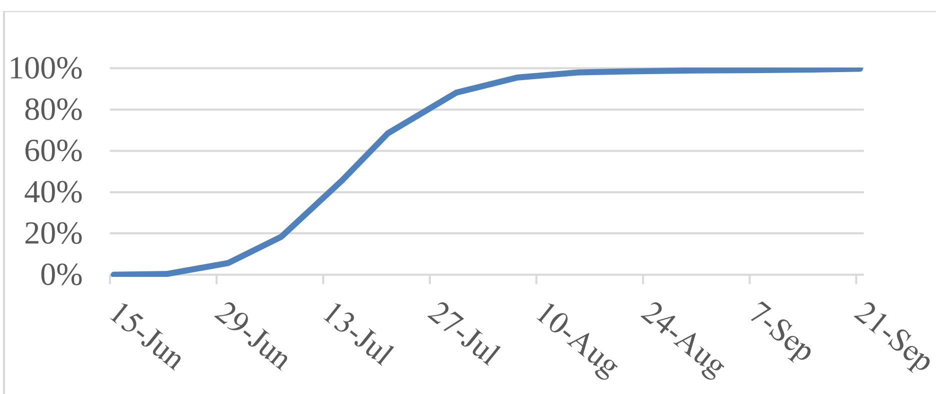

Figure 8. The timing of arrival of sockeye salmon at the Baker River trap (SIT and WDFW 2017).

Sport fisheries for sockeye in Area 12 are also planned once escapement goals are met and harvestable surpluses are identified by the co-managers. However, limited opportunity is likely to emerge in marine areas of Hood Canal given historical catch rates in Area 8 outside the Skagit River basin.

Summer Chum

Hood Canal summer chum were listed as threatened under the ESA in 1999. The ESU comprises two populations: one in the eastern Strait of Juan de Fuca, and one in Hood Canal. The Hood Canal population comprises extant sub-populations in the Big and Little Quilcene River, Hamma Hamma River, Duckabush River, Dosewallips River, Union River, and Lilliwaup Creek. Very small numbers of fish also persist in several other streams but these are not considered to be extant subpopulations. The abundance of the Hood Canal population has rebounded strongly (Figure 9) since the listing (Lestelle et al. draft 2017).

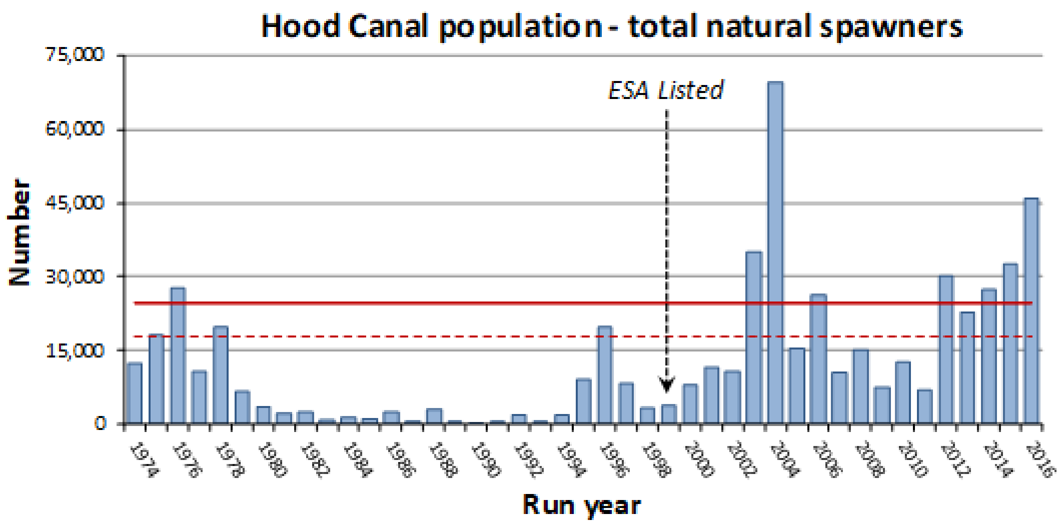

Figure 9. Estimated numbers of naturally spawning summer chum in the Hood Canal population from 1974 to 2016. The upper (solid red line) and lower (dashed red line) ends of the minimum spawning thresholds needed for recovery as shown in Table 2 are displayed; those ranges are based on analyses in Sands et al. (2009) (Lestelle et al, 2017 Figure re-printed by permission of author).

The threshold for determining low risk of extinction for the Hood Canal summer chum population is being exceeded by a substantial margin.

An abbreviated summary of results from the VRAP analysis in Sands et al. (2009) is given in Table 10 and Table 11. These results utilize population data for brood years 1974-2001. The results are given as a range in capacity (incorporating a reasonable range of productivities) and a range in expected spawning escapement associated with a specific pair of capacity and productivity values.

Table 10. Minimum abundance viability thresholds (5% risk of extinction over 100 years) for the SJDF and Hood Canal populations of summer chum as given in Sands et al. (2009) derived with VRAP modeling. The results are shown as a range, based on different values for productivity (P) that bracket a reasonable range of values for each population. The results are shown with two exploitation rates (ER): 0% and 10%. Data for brood years 1974-2001 were used in the modeling.

Population	ER	Range of average escapements		Capacity range	
		Low	High	Low	High
		P=6	P=3	P=6	P=3
SJDF	0%	4,700	5,100	3,300	4,300
	10%	4,600	5,400	3,700	5,300
		P=9	P=5	P=9	P=5
Hood Canal	0%	17,900	20,600	13,000	17,000
	10%	18,600	21,500	15,500	20,500

Table 11. Minimum abundance viability thresholds for the Hood Canal population of summer chum as given in Sands et al. (2009) derived using the VRAP model and as updated in the current analysis (2017 update). ER is exploitation rate and P is intrinsic productivity. Escapement values are arithmetic means[32] as in Sands et al. (2009) (Lestelle et al, 2017).

Population	ER	Assessment	Range of average escapements		Capacity range	
			Low	High	Low	High
			P=8	P=6	P=8	P=6
Hood Canal	0%	Sands et al. 2009	18,300	19,100	13,500	15,000
		Lestelle et al. 2014	8,700	9,100	7,000	7,800
		2017 update	4,800	4,900	3,600	3,900
	10%	Sands et al. 2009	18,300	20,400	15,500	18,500
		Lestelle et al. 2014	8,700	9,600	8,000	9,300
		2017 update	5,000	5,100	4,200	4,500

Summer chum have also rebounded substantially in the Skokomish River and this subpopulation is now considered to be robust (Figure 10). However, no special recovery efforts are warranted to be directed specifically at this subpopulation. It is recognized that the large restoration effort called the Skokomish River Basin Ecosystem Restoration Project, led by the U.S. Army Corps of

32/ The arithmetic mean is skewed high (by approximately 35 to 40%) due to the lognormal distribution of observed escapements compared to the geometric mean, which is equivalent to what this report refers to as equilibrium abundance.

Engineers and authorized for federal funding, will provide significant habitat benefits to the summer chum subpopulation (USACE 2015; SIT and WDFW 2017). (Lestelle et al. draft 2017). The summer/fall Chinook salmon fishing regime outlined above, consistent with the summer chum Base Conservation Regime (BCR), including the hiatus in fishing from late August through September, will minimize incidental impacts on summer chum.

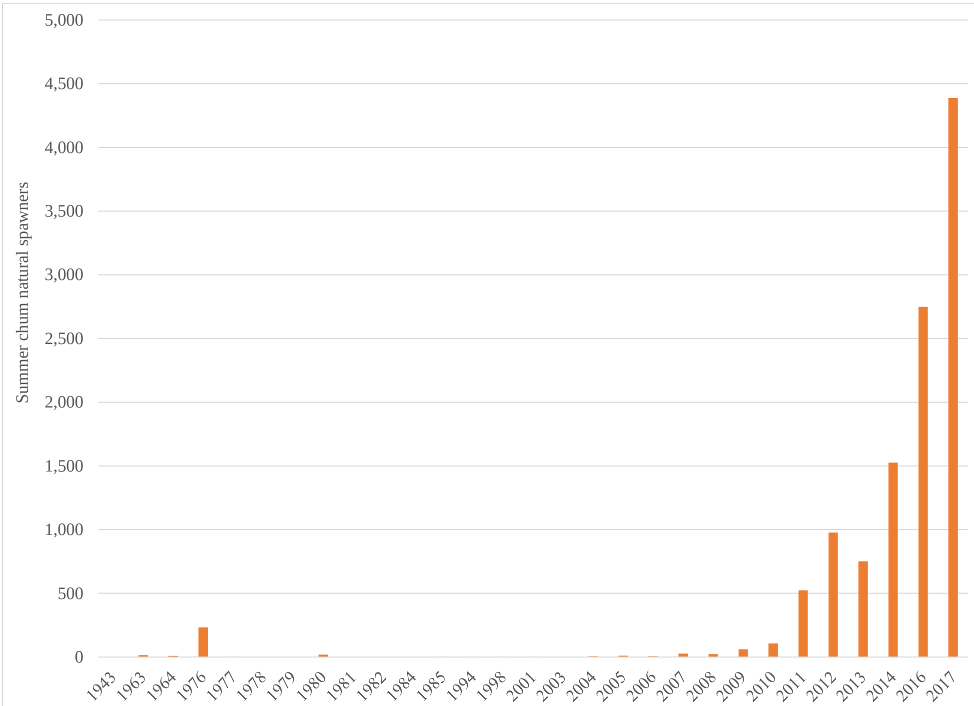

Figure 10. Live counts of summer chum in the Skokomish River, 1943 - 2017. (WDFW SaSI 2017; Larry Lestelle and Mark Downen pers comm June 6, 2017).

Coho

Fisheries directed at coho salmon in Puget Sound have been managed in accordance with the Comprehensive Coho Salmon Plan developed by the co-managers in the 1990s (though this plan was not formally agreed by all parties). Harvest of wild coho salmon originating in Hood Canal (the many stocks comprise a single, primary management unit) are restricted by a stepped exploitation rate ceiling which is set relative to forecast abundance. The ceiling rates developed for Hood Canal are in the following Status steps: Critical - 10% in all SUS fisheries; Poor - 45% in all fisheries; Moderate - 65% in all fisheries; Abundant - 65% in all fisheries, plus 90% of any recruitment over 78,000.

Though hatchery produced coho intermingle with wild coho in the terminal area, harvest is constrained to conserve wild coho and summer chum. Commercial net fisheries occur in the mainstem of Hood Canal (Areas 12, 12B, 12C, and 12D), in Quilcene and Port Gamble Bays (12A and 9A, respectively) and the Skokomish River (82G). Also, limited dip-net coho fisheries occur in the Quilcene River (82F). A sport fishery for coho also occurs in Area 12 and historically in the Skokomish River as well. Any future in-river coho sport fishery will be contingent upon co-manager agreement.

Most relevant to this Plan, commercial net fisheries for coho in Area 12C begin in late September and run through mid-October. Fisheries in the Skokomish River now occur in October to increase escapement to the spawning grounds. We hypothesize that a successfully developed true late-timed fall Chinook population will exhibit similar run timing patterns as other wild, Puget Sound fall populations, such as the lower Skagit falls. Lower Skagit falls enter the river in mid to late September, then await the first rains in October to spawn. However, CWT analysis will inform adaptive management of fisheries. In previous years the coho fishery in the river began earlier, e.g. in mid-September. Recent year catch data indicate that incidental catch of summer – fall Chinook salmon are very low by the opening of coho directed fisheries in 12C and the river, as the peak of the hatchery return to George Adams has past. Wild coho continue to return at relatively lower abundance from October to January, but fishery encounters on Chinook salmon have been consistently very low (annually ranging from 7 – 80 Chinook salmon landed) through the coho and fall chum management period.

Fall Chum

There is substantial production of fall chum salmon at Hoodsport Hatchery and GAH/McKernan Hatchery, with smaller programs at the Enetai Hatchery (SIT-South of Potlatch) and Little Boston Hatchery (Port Gamble Bay). These programs support large scale commercial fisheries, and appreciable sport fishing at Hoodsport Hatchery and in the Skokomish River. These fisheries are managed to achieve escapement of sufficient broodstock to perpetuate the hatchery programs. Natural escapements to the Skokomish River and numerous other river systems throughout the Canal have been stable.

Fall chum fisheries in the mainstem of Hood Canal (Areas 12, 12B, and 12C) start in mid-October and continue through the end of November. They incur very low incidental mortality on summer-fall Chinook salmon.

Winter Steelhead

Fisheries for winter steelhead have been highly constrained in recent decades because the wild populations have been depressed. Hatchery production was terminated, but limited experimental production operated by the NMFS / co-managers continues in the South Fork Skokomish River, Dewatto River, and Duckabush River. Very limited tribal C&S fisheries operate in the Skokomish River in December through early March; recreational fisheries have been closed. Steelhead fisheries do not incur incidental mortality of Chinook salmon.

Pink

Odd-year pink salmon, once abundant in several Hood Canal rivers, have been depressed from the 1990s through 2010, so there are no directed fisheries. Returns to the Skokomish River, however, have increased since 2013. Spawning surveys have documented pink salmon presence from late August through September. An upsurge in pink returns was observed somewhat earlier in many of the large river systems in southern Puget Sound, with terminal run abundance reaching approximately one million in some years. Their river entry and spawn timing in the Skokomish River overlaps that of summer-fall Chinook salmon in September, which can further complicate estimation of Chinook salmon escapement. No terminal fisheries targeting pink salmon returns to the Skokomish River are envisioned, but incidental harvest of pinks is expected in Chinook salmon fisheries in August.

Harvest objectives and guidelines for Skokomish River spring Chinook salmon will be incorporated in subsequent revisions of the Puget Sound Chinook Harvest Management Plan. The co-managers will continue to monitor natural escapement, age composition, and spawning distribution of fall Chinook salmon, about which recent information is summarized below, to inform subsequent recovery planning decisions.

Monitoring and Adaptive Management

- Continue spawning survey regime and assess the current methodology used to estimate natural spawning escapement (i.e. current survey reaches, survey frequency, assumptions about stream live of live fish, redd life and sex ratios).
- Continue sampling terminal catch and spawning grounds to determine age composition and hatchery/natural-origin.
- Expand the geographic and temporal coverage of surveys to encompass spring Chinook reintroduction and late-timed fall Chinook program development.
- Continue to operate the smolt trap in the North Fork to estimate production (especially after early-stock reintroduction).
- Monitor and re-evaluate assess of the “Late-Timed” Chinook salmon Program using tag recoveries to identify timing, distribution, and interceptions in fisheries.
- Strategically submit CWT recoveries for real time reading where questions of spring or late-timed fall Chinook presence at hatchery facilities or interceptions in fisheries could lead to in-season management adjustments.
- Analyze differences in tag recoveries for spring Chinook, late-timed, Chinook and George Adams Chinook Double Index Tag groups to assess survival, and exploitation rates.
- Re-evaluate as additional brood years become available the terminal cohort reconstruction in order to monitor recruitment and productivity.
- Develop methodologies for applying VSP parameters of abundance, geographic distribution, productivity, and diversity to spring Chinook and late-timed true fall Chinook.
- Monitor the effects of normative flows, and resulting channel changes in the North Fork on spawning distribution.
- Continue to monitor the effects of normative flows, and resulting channel changes in the South Fork on spawning distribution
- Evaluate the feasibility and design a project in the South Fork to remove car body levies in order to reduce stream aggradation and de-watering.
- Annually, harvest management objectives (CERC, RER, ER etc.) will be determined through implementation of the co-manager agreed-to Chinook Fishery Regulation Assessment Model (FRAM) and associated Base Period.

Mid-Hood Canal Management Unit Status Profile

Population

Mid-Hood Canal

Geographic Description

There are three rivers in the Mid-Hood Canal region that may have supported native Mid-Hood Canal Chinook salmon; they are the Hamma Hamma River, Dosewallips River, and Duckabush River. These rivers are individual watersheds with their adjacent river mouths separated by 6 km to 14 km of marine water. The drainage area of each river alone is much smaller than the smallest watershed in Puget Sound identified as supporting an independent Chinook population (the Cedar River).

The Mid-Hood Canal rivers originate high in the Olympic Mountains. They have steep gradient headwaters and several barriers to migration, which make their upper reaches and tributaries inaccessible to salmon. Consequently, the lower mainstems of these rivers provide nearly all the production potential for Mid-Hood Canal Chinook salmon. Chinook salmon can travel up the Hamma Hamma River mainstem to RM 2.5, where a barrier falls blocks anadromous fish migration. Chinook salmon occasionally enter a tributary of the Hamma Hamma River (John Creek) when flows permit access. The Duckabush River is blocked by a series of falls starting at river mile seven, particularly during seasonal low flows. The Duckabush River has a canyon section between RM three and four that contains several cascades, which can partially block migration (Williams et al. 1975). The Dosewallips River is the largest drainage entering northern and central Hood Canal, but salmon access beyond RM 14 is blocked by a large waterfall. Chinook salmon also may enter a tributary of the Dosewallips River (Rocky Brook Creek) at river mile 3.6.

The flow regimes of the Mid-Hood Canal rivers have been classified as *transitional* between rainfall dominated and snowmelt dominated (Beechie et al. 2006). These rivers have their lowest flows from mid-August to mid-October. Peak flows occur from May through early July, with the Duckabush and Hamma Hamma rivers having a second peak from late October through January.

Population Structure

Mid-Hood Canal Chinook are currently recognized as one of 22 historical populations of Chinook salmon within the Puget Sound Chinook Salmon ESU (Ruckelshaus et al. 2006) and are identified in the Puget Sound Recovery Plan (SSDC 2017) as an essential component to the recovery of the Puget Sound Chinook ESU. When the Puget Sound Technical Recovery Team (TRT) deduced the historical population structure of Chinook salmon in Mid-Hood Canal, it decided that the three Mid-Hood Canal watersheds (Dosewallips, Duckabush, and Hamma Hamma) collectively may have supported a single independent Chinook population based on the similarity of freshwater and estuarine habitats and the proximity of these rivers to each other. Although the Mid-Hood Canal rivers are independent drainages separated by marine water, the TRT decided that their combined drainage areas could collectively support a single independent population of Chinook, because their combined drainage area is larger than some Puget Sound watersheds that have been identified as supporting an independent Chinook population (Ruckelshaus et al. 2006). However, the TRT acknowledged that the amount of demographic interconnectivity among the Mid-Hood Canal spawning aggregations was unknown. Currently there remains no evidence to conclude that there would be enough demographic connectivity among the three Mid-Hood Canal rivers to support a single independent population of Chinook.

Since the Mid-Hood Canal rivers are close to the Skokomish River, the TRT acknowledged the possibility of genetic exchange between Chinook originating in the Mid-Hood Canal rivers and Chinook originating in the Skokomish River. Accordingly, the TRT recognized the possibility of alternative historical population scenarios for Chinook salmon in Hood Canal, including that there may have been one or more self-sustaining Chinook populations in the Skokomish River that largely supported a Mid-Hood Canal sub-population.

The TRT concluded that the "historical characteristics of Hood Canal Chinook salmon are largely unknown" and that the "largest uncertainty is the degree to which Chinook salmon spawning aggregations are demographically linked in the Dosewallips, Hamma Hamma, and Duckabush rivers." TRT observations included the following:

1) The "overall size of each watershed and the area accessible to anadromous fish are small relative to other independent populations" of Chinook salmon in the Puget Sound ESU (Ruckelshaus et al. 2006, page 56).

2) "Only a few historical reports document Chinook salmon spawning in the Mid-Hood Canal streams, which might suggest that they were not abundant in any one stream before hatchery supplementation began in the early 1900s" (Ruckelshaus et al. 2006, page 56).

3) Some historical records indicate the presence of a spring run or a late fall run. If those runs existed historically, they have now been extirpated (Ruckelshaus et al. 2006, page 31).

4) Genetic data were not informative and the lack of difference in allele frequencies between Skokomish River and Hamma Hamma River Chinook salmon probably reflects "the use of Green River-origin broodstock for hatchery programs in Hood Canal" (Ruckelshaus et al 2006, page 55).

If there was an indigenous self-sustaining population of Chinook salmon in Mid-Hood Canal, it died out sometime in the past (Ruckelshaus et al. 2006), possibly from a combination of factors such as habitat degradation, historic use of splash dams, hatchery influence, historic harvest practices, and other anthropogenic disturbances (LLK 2010). Although habitat conditions and harvest management practices have improved substantially since the loss of the indigenous Chinook, productivity remains too poor to support a self-sustaining population (see additional discussion in section on Hatchery Supplementation).

There has been a long history of Green River-origin Chinook salmon being released from hatcheries in the Hood Canal region. That practice eventually led to the strain of Chinook currently used in Hood Canal for hatchery production. The recent Chinook population in Mid-Hood Canal was derived from this hatchery lineage and is not genetically distinct from George Adams and Hoodsport hatchery broodstock or existing Skokomish River Chinook (Marshall 2000; Jones 2006; NMFS 2016).

For decades (1995 – 2015) Mid-Hood Canal Chinook were sustained by a hatchery supplementation program. However, with the supplementation program ended, Chinook salmon no longer exists at reproductively viable numbers in Mid-Hood Canal. A few Chinook have been found in the Mid-Hood Canal rivers following the final returns of the supplementation program, but many of those are thought to be strays from Chinook production in the Skokomish River region.

Life History

Adult Hood Canal summer/fall Chinook, including the Mid-Hood Canal population, have river entry timing from mid-August to late September. Spawning takes place from late September to mid-October. Juveniles migrate from freshwater as sub-yearlings, with the majority of smolt outmigration occurring early April through late May. The smolts that emigrated from the Mid-Hood Canal rivers appeared to remain in the estuary from June through mid-July, after which most have migrated into the marine environment. They appeared to remain in Hood Canal for an extended period, many up to 100 days before moving out of Hood Canal (Chamberlin, et al. 2011). When Hood Canal summer/fall Chinook leave Hood Canal they typically migrate through the Strait of Juan de Fuca to ocean waters off the west coast of Vancouver Island, as indicated by coded wire tag (CWT) recovery data.

Population Status

Spawning escapement estimates for Mid-Hood Canal Chinook show persistently low escapements from 1990 to 2020 (Table 1), even with a hatchery supplementation program operating from 1995 to 2015. The time series shown in Table-1 may not consistently represent total escapement to the index reaches, because both survey effort and survey area have increased since 2007. Surveys done in the lower reaches may include some “dip-ins” that ultimately spawned elsewhere in Hood Canal.

The higher spawner abundances observed between 1998 and 2001 coincided with initial returns from the supplementation program, however the higher returns may have been related to concurrent changes in marine net pen Chinook hatchery production in the area (WDFW 2010), therefore the increase in abundance in those years may not be indicative of any changes in natural productivity or status of Mid-Hood Canal Chinook at that time. A similar increase in abundance occurred from 2012 to 2013, which coincided with very high proportions of supplementation origin recruits (94% – 99%) returning to the Hamma Hamma River. Other factors could also have influenced these larger returns, such as unusually high freshwater, estuarine, or ocean survival.

Table 1. Natural spawning escapement of Mid-Hood Canal Chinook (1990 - 2020).

Year	Hamma Hamma	Duckabush	Dosewallips	Total
1990	35	10	1	46
1991	30	14	42	86
1992	52	3	41	96
1993	28	17	67	112
1994	78	9	297	384
1995	25	2	76	103
1996	11	13	No Surveys	24
1997	5	No Estimate	No Estimate	5
1998	172	57	58	287
1999	557	151	165	873
2000	380	28	29	437
2001	248	29	45	322
2002	32	20	43	95
2003	95	12	87	194
2004	49	0	80	129
2005	33	2	10	45
2006	20	1	13	34
2007	60	4	9	73
2008	255	0	18	273
2009	98	9	23	130
2010	91	0	15	106
2011	294	5	11	310
2012	425	6	7	438
2013	707	7	4	718
2014	117	13	11	141
2015	236	20	3	259
2016	268	15	8	291
2017	365	2	7	374
2018	58	4	1	63
2019	18	3	0	21
2020	3	2	0	5
2021	3	2	3	8

Note: Survey effort and survey area have increased since 2007.

Since the hatchery supplementation program ended, mid-Hood Canal Chinook escapements have declined to extremely low numbers.

Hatchery Supplementation

A hatchery supplementation program was initiated in 1995 on the Hamma Hamma River with the goal of restoring a viable, self-sustaining, natural-origin Chinook population to the Mid-Hood Canal river systems. The program was intended to help restore and maintain a sustainable, locally adapted, natural-origin Chinook population by using supplementation hatchery fish to increase the number of naturally spawning adults on the spawning grounds. Beginning in 2005, the supplementation program attempted to collect 100% of its broodstock from the Hamma Hamma River to help promote local adaptation. However, too few Chinook salmon returned to the Hamma Hamma River to meet the supplementation program's broodstock collection goal. Consequently, the program continued to rely on the George Adams Hatchery as a source of broodstock.

The supplementation program was ended after 20-years, with its final release in 2015, primarily because it was unsuccessful at achieving its goal of restoring a self-sustaining Chinook population in the Hamma Hamma River and more broadly a Chinook population in the Mid-Hood Canal rivers (LLK 2014). It became clear during the program that putting more supplementation origin spawners on the spawning grounds did not result in a sustained increase in the number of natural-origin recruits. Natural production remained extremely low even when large numbers of supplementation-origin fish were passed through to the spawning grounds.

The George Adams Hatchery stock used for the supplementation program could not sufficiently reproduce itself naturally in the Mid-Hood Canal rivers, even when the supplementation program was augmenting the number of natural spawners. Following the end of the supplementation program, Mid-Hood Canal Chinook escapement dropped to 63 fish in 2018 (4- and 5-year-old return from hatchery conservation program), to 21 fish in 2019 (only 5-year-old return from hatchery conservation program), and to only 5 fish in 2020 (Table 2). Also the Dosewallips and Duckabush rivers, where juvenile Chinook salmon from the hatchery supplementation program were not released, both had low numbers of Chinook spawners.

Table 2. Number of Chinook salmon spawners in Mid-Hood Canal rivers.

Spawn Year	Dosewallips River	Duckabush River	Hamma Hamma River	HOS Age Classes Potentially Present
2015	3	20	236	2 - 5
2016	8	15	268	2 - 5
2017	7	2	365	3 - 5
2018	1	4	58	4 - 5
2019	0	3	18	5
2020	0	2	3	-

After observing these results, the co-managers recognized that questions remained regarding the capacity of the Mid-Hood Canal rivers to support a sustainable, locally adapted Chinook salmon run under current conditions. For example, perhaps the hatchery supplementation program would have been successful with an alternative source of broodstock.

To address these questions, the co-managers initiated a project in 2020 - 2021 that assessed:

1) the current Chinook habitat in the Mid-Hood Canal rivers (Meridian 2020);

2) the likelihood that the Mid-Hood Canal rivers, based upon that habitat survey, would have sufficient capacity and productivity to sustain a Chinook salmon population (Meridian 2021a); and

3) the likelihood that an alternative brood stock source would be more successful in reintroducing Chinook salmon to the Mid-Hood Canal rivers than the recently completed 20-year hatchery supplementation program (Meridian 2021b).

Field surveys were initiated on September 21, 2020 and were completed by October 7, 2020 (Meridian 2020). Each of the three rivers, and tributaries believed to potentially support Chinook salmon, were surveyed from the mouth to near the upstream terminus of potential usage by anadromous salmonids. The stream habitat surveys followed the Oregon Department of Fish and Wildlife Aquatic Inventory Protocol (Moore et al. 2019), and this represents the first detailed, consistent, field-based assessment of Chinook habitat in the Mid-Hood Canal rivers.

The habitat survey data were used to estimate the juvenile Chinook parr rearing capacity, spawner capacity, and the sustainability of Chinook salmon (Meridian 2021a). Under average conditions for parr rearing capacity, egg-to-migrant survival, and smolt-to-adult return (SAR), total adult Chinook returns to the Dosewallips, Duckabush, and Hamma Hamma watersheds are estimated to be 213, 144, and 59 (respectively). However, model results suggest that adult replacement of the 2nd generation (assuming these adult returns) would not be achieved under average conditions (i.e., only 159, 108 and 44 adult returns would be produced in each watershed). These simulation results are consistent with empirical observations for the Mid-Hood Canal rivers. The co-managers also evaluated the potential success of reintroducing Chinook salmon to the Mid-Hood Canal rivers using alternative sources of broodstock. Five scenarios were evaluated:

1) Scenario 1 – Mid-Hood Canal rivers with previous conservation hatchery program (through 2015)
2) Scenario 2 – Mid-Hood Canal rivers with no hatchery
3) Scenario 3 – Mid-Hood Canal rivers with new conservation hatchery program using Dungeness Hatchery spring Chinook as broodstock
4) Scenario 4 – Mid-Hood Canal rivers with new conservation hatchery program using Marblemount Hatchery spring Chinook as broodstock
5) Scenario 5 – Mid-Hood Canal rivers with new conservation hatchery program using Hoko Falls Hatchery fall Chinook as broodstock

Meridian (2021b) provided the following assessment of these scenarios using the All-H

Analyzer (Model) (HSRG 2020). The Model analysis of the previous hatchery conservation program using George Adams Hatchery broodstock projected that the program would not be successful in establishing a self-sustaining Chinook population. That projection is consistent with the observed decline in Chinook salmon spawners in the Mid-Hood Canal rivers subsequent to the termination of the program. The modeling also suggests that creating a self-sustaining population is unlikely if Chinook salmon are reintroduced from one of the three donor stocks evaluated. While re-initiating a conservation hatchery program in the Mid-Hood Canal assessment area would increase the magnitude of adult returns, establishing a self-sustaining population will depend on increased natural productivity through an increase in the SAR for natural-origin returns or egg-to-migrant survival (EMS).

Model sensitivity analyses suggest that it is unlikely that EMS could be increased enough to support a naturally self-sustaining Chinook population in the Mid-Hood Canal area by using a more well adapted donor stock. The EMS for the Dungeness River has averaged 4.8%, higher than the 3.5% estimated for the Duckabush River, but slightly less than the value of 5% used in the AHA analyses. Since the Dungeness Hatchery program uses the local Dungeness stock, and previous analyses indicated that the EMS productivity of the Dungeness River exceeds the Mid-Hood Canal rivers, we would not expect a higher EMS if the Dungeness stock was introduced into the Mid-Hood Canal rivers. More generally, this modeling exercise estimates that adult productivity (calculated from red/adult female, eggs/spawner, EMS, and SAR data) would need to at least double (from 0.75 to 1.5) to support a small, self-sustaining natural spawning population if all other parameters remain the same (total exploitation rate, out-of-basin hatchery stray rate, etc.).

Based upon genetic analyses, experimental testing, and simulation analyses, the co-managers conclude the following (Meridian, in prep.):

1) The genetic analysis indicate that any unique genetic evolutionary legacy of Mid-Hood Canal Chinook has been lost. Genetic analyses of juvenile and adult Chinook salmon sampled from Mid-Hood Canal rivers have repeatedly confirmed a Green River-George Adams Hatchery lineage for adult salmon spawning in Mid-Hood Canal rivers.

2) The TRT combined the three Mid-Hood Canal watersheds into a presumed integrated watershed system that could possibly support a Chinook salmon population, because each river system individually is not sufficiently large enough to support a Chinook salmon population on its own. There remains no evidence to conclude that there is enough demographic connectivity among the three Mid-Hood Canal rivers to support a single independent population of Chinook.

3) A 20-year hatchery supplementation program to reintroduce Chinook salmon into the Mid-Hood Canal rivers failed to establish a sustainable population. Fewer than 50 Chinook salmon have returned to spawn in the Mid-Hood Canal rivers for the last two years.

4) Simulation analysis, driven by the first detailed, field-based, consistent assessment of habitat in the three Mid-Hood Canal rivers, projected that under average EMS and SAR

parameter estimates a sustainable Chinook salmon population could not be established in any of the Mid-Hood Canal rivers. These simulation results are consistent with our empirical observations for the Mid-Hood Canal rivers.

5) Model analyses indicate that a Chinook salmon reintroduction program would be unlikely to establish a self-sustaining Chinook population in Mid-Hood Canal, using one of the three evaluated alternative donor stocks (Marblemount spring Chinook, Dungeness spring Chinook, and Hoko fall Chinook) evaluated. Modeling also indicates that productivity would need to at least double (from 0.75 to 1.5) to support a small, self-sustaining natural spawning population if all other parameters remain the same (total exploitation rate, etc.).

Considering this habitat assessment data, and other information gathered over the past 20 years, the co-managers now think that the Mid-Hood Canal rivers do not have the necessary quality and quantity of habitat, capacity, and connectivity to support an independent self-sustaining Chinook population. Given this information, it is likely that within the timeframe of this RMP the National Marine Fisheries Service (NMFS) may reconsider the role that Mid-Hood Canal Chinook has in the recovery of the Puget Sound Chinook ESU.

Harvest Distribution and Exploitation

The Fishery Regulation Assessment Model (FRAM) provides preseason and postseason estimates of adult equivalent (AEQ) exploitation rates for Puget Sound Chinook, including the Mid-Hood Canal Chinook management unit. FRAM relies on CWT recoveries from George Adams Hatchery, Hoodsport Hatchery, and Rick’s Pond fall fingerling Chinook as surrogates for the Mid-Hood Canal Chinook management unit, except tag recoveries from fisheries south of Ayock Point are excluded to reflect the different migration paths of Chinook salmon returning to the Mid-Hood Canal rivers and those migrating to destinations further south in Hood Canal. Given the indistinguishable genetic make-up and life history among these fish, it is reasonable to assume that tagged fingerling Chinook released from the George Adams Hatchery on the Skokomish River would follow a similar migratory pathway and experience mortality in a similar set of pre-terminal fisheries in Washington, British Columbia, and Alaska.

Postseason FRAM estimates of total AEQ exploitation rates on Mid-Hood Canal Chinook show there was a noticeable decrease in total exploitation rates from 1992 to 1998, dropping from 50.2% to 26.0% (Figure 1). Following that decline, annual total exploitation rates on Mid-Hood Canal Chinook have remained relatively steady from 1999 to 2018, at an average total exploitation rate of 25.4%.

Southern U.S. (SUS) fisheries and northern fisheries (Alaska and Canada) have not followed similar historical exploitation rate patterns or trends, particularly in relation to 1999 when Puget Sound Chinook were ESA-listed (Table 3). For example, prior to the ESA listing of Puget Sound Chinook, southern U.S. fisheries showed a rapid decrease in exploitation rates, declining from 37.9% in 1992 down to 17.8% in 1998 (Figure 2). Since the ESA listing, annual exploitation rates in southern U.S. fisheries have remained relatively stable at an average exploitation rate of 12.2%. In contrast, the exploitation rates of northern fisheries initially increased following ESA listing of Puget Sound Chinook (Figure 3). Based on preseason FRAM runs using base period 7.1, there appears to be a decreasing trend in the annual exploitation rates of northern fisheries from an average of 13.4% (2009 – 2018) to an average of 10.6% (2019 – 2021), which may be due to the recently renegotiated 2019–2028 Chinook Annex of the Pacific Salmon Treaty (PST). However, those preseason results will need to be verified with FRAM validation runs. Terminal fishery exploitation rates have remained low throughout the entire time series.

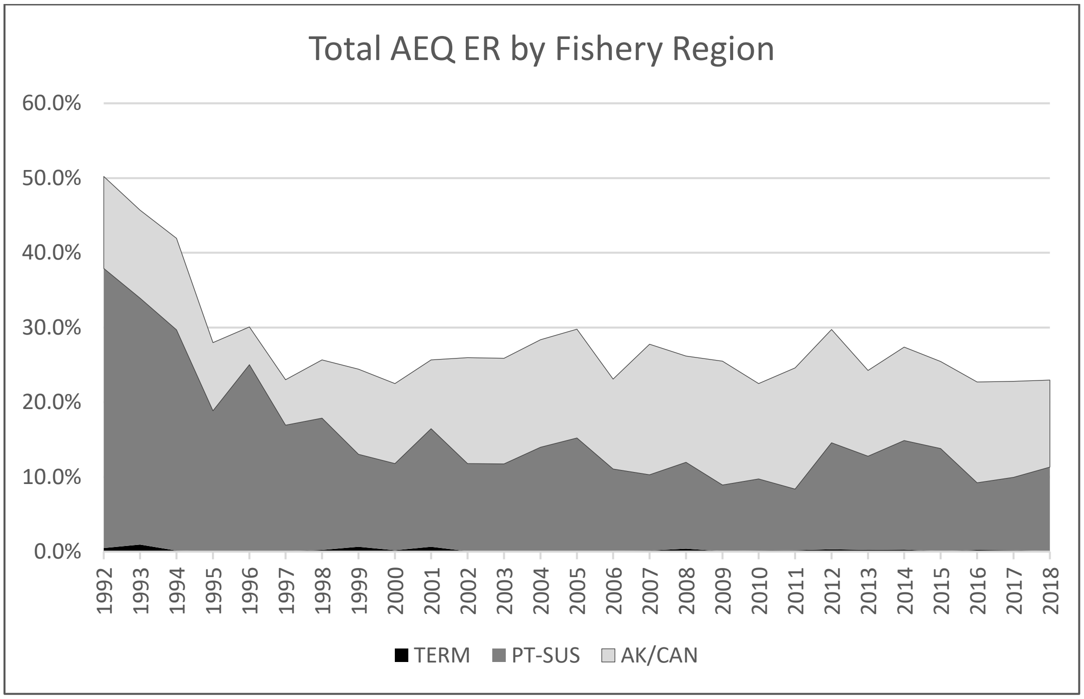

Figure 1. Total annual adult equivalent fisheries exploitation rate of Mid-Hood Canal Chinook from 1992 – 2018, as estimated by FRAM validation runs using base period 7.1. Shaded by fishery region (Term, terminal; PT SUS pre-terminal southern U.S.; Northern, Alaska and Canada).

Table 3. Average AEQ exploitation rates on Mid-HC Chinook by fishery region for: 1992–1998 (prior to ESA listing); 1999–2008 (10 years following ESA listing); 2009–2018 (10 years most recent FRAM validation runs). FRAM validation runs used base period 7.1.

		Southern U.S.			
Years	Northern	PT-SUS	Terminal	SUS Total	Total
1992 - 1998	9.2%	25.5%	0.3%	25.7%	34.9%
1999 - 2008	13.2%	12.5%	0.2%	12.7%	26.0%
2009 - 2018	13.4%	11.2%	0.2%	11.4%	24.8%

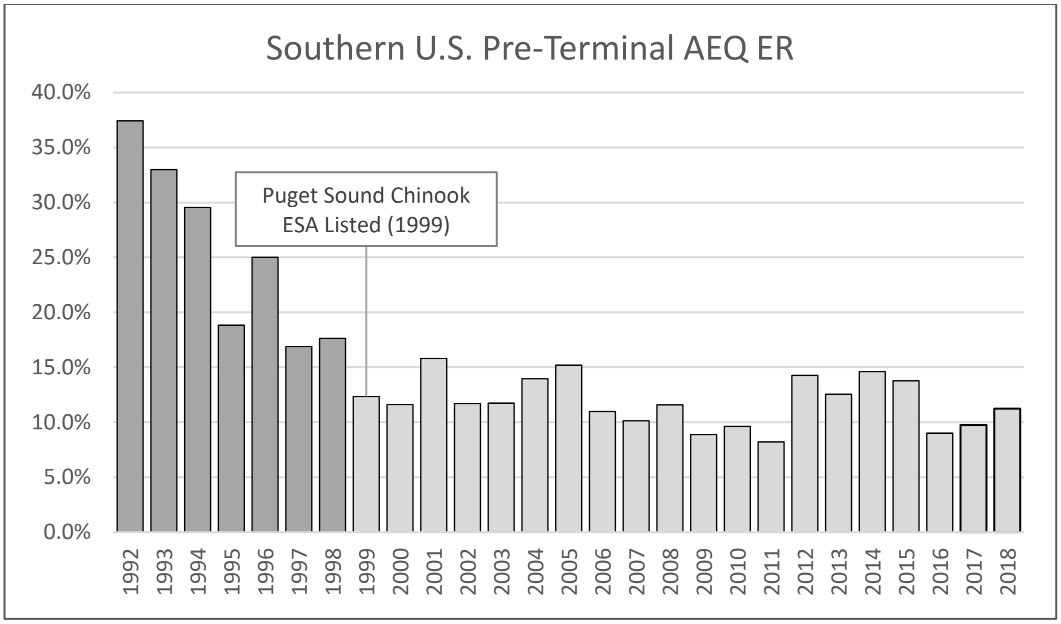

Figure 2. Southern U.S. annual adult equivalent fisheries exploitation rate of Mid-Hood Canal Chinook from 1992 – 2016, as estimated by FRAM validation runs using base period 7.1.

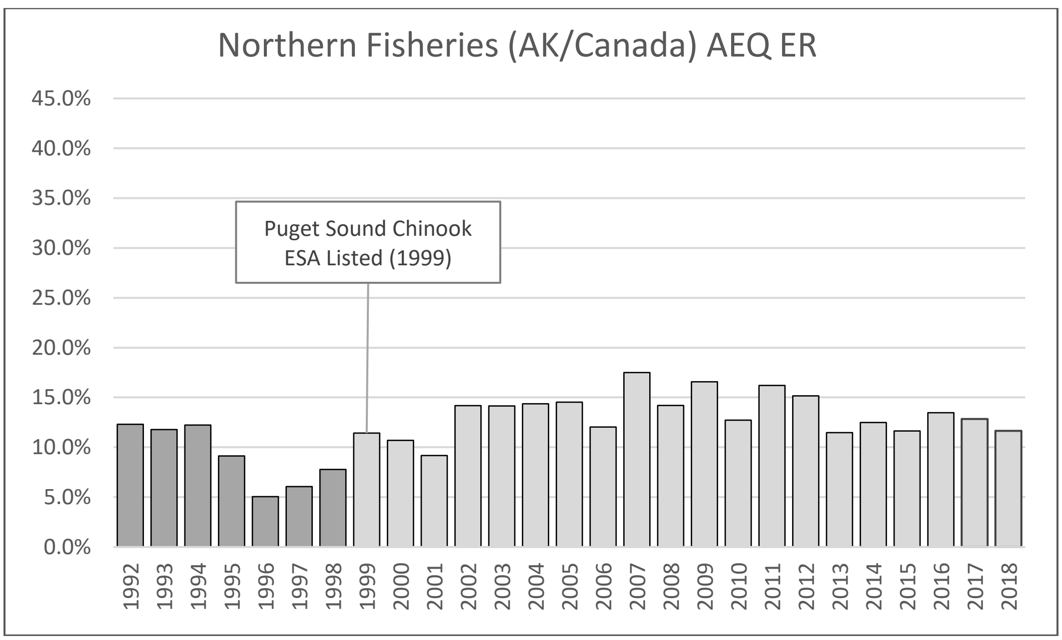

Figure 3. Northern fisheries (Alaska and Canada) adult equivalent fisheries exploitation rate of Mid-Hood Canal Chinook from 1992 – 2016, as estimated by FRAM validation runs using base period 7.1.

Management Objectives

The management objectives for mid-Hood Canal Chinook will be addressed in relation to the relevant ESA criteria in 50 CFR 223.203(b)(4), focusing on the 4(d) rule regarding harvest activities affecting threatened anadromous fish. These interim management objectives will be in place for the life of the RMP or until NMFS completes the review discussed at the end of this MUP and determines that fishery management constraints on MHC are no longer necessary for inclusion in the RMP.

Criterion B. "Utilize the concepts of 'viable' and 'critical' salmonid population thresholds, consistent with the concepts contained in the technical document entitled 'Viable Salmonid Populations {VSP} (McElhany et al. 2000).'…Harvest actions impacting populations that are functioning at or below critical threshold must not be allowed to appreciably increase genetic and demographic risks facing the population and must be designed to permit the population's achievement of viable function, unless the plan demonstrates that the likelihood of survival and recovery of the entire ESU in the wild would not be appreciably reduced by greater risks to that individual population."

Although the co-managers do not believe there is an independent, distinct, or viable population in mid-Hood Canal, we realize that the small numbers of Chinook salmon entering the mid-Hood Canal river systems are identified in the Puget Sound Recovery Plan (SSDC 2017) as an essential component to the recovery of the Puget Sound Chinook ESU. Considering that classification under ESA, a Low Abundance Threshold (LAT) and Upper Management Threshold (UMT) will continue to be included in this MUP.

However, based on what is now known about the population's natural productivity and potential abundance, the previously used LAT of 400 spawners and UMT of 750 spawners are no longer meaningful metrics for the population. In the most recent biological opinion for Puget Sound salmon fisheries (NMFS 2021) NOAA identified a critical threshold of 200 spawners and a rebuilding threshold of 1,250 spawners. For the purposes of this MUP, the co-managers will use those thresholds to represent the mid-Hood Canal Chinook LAT and UMT respectively.

Considering the origin, productivity, and extremely low abundance of Mid Hood Canal Chinook, fishery actions cannot appreciably increase the genetic or demographic risks to the population. Fishery impacts to Mid-Hood Canal Chinook will therefore not affect the likelihood of survival or the recovery of the entire Puget Sound Chinook ESU. Nevertheless, Criteria C and D below will describe how the actions outlined in this RMP will result in fisheries that would not appreciably increase genetic and demographic risks to a mid-Hood Canal population and would not impede the recovery of a Mid-Hood Canal Chinook salmon population, if such a population were present.

Criterion C. "Set escapement objectives or maximum exploitation rates for each management unit or population based on its status and on a harvest program that assures that those rates or objectives are not exceeded. Maximum exploitation rates must not appreciably reduce the likelihood of survival and recovery of the ESU. Management of fisheries where artificially propagated fish predominate must not compromise the management objectives for commingled naturally spawned populations."

This RMP identifies escapement objectives or maximum exploitation rates for 14 management units and numerous Chinook salmon populations within those management units. Within the marine areas of Puget Sound where Mid-Hood Canal Chinook salmon are present, an average of 9 other Chinook management units are also present. Therefore, managing Puget Sound marine salmon fisheries to meet the exploitation rate limits of all other Puget Sound Chinook management units will concurrently reduce marine impacts on Mid-Hood Canal Chinook salmon.

The exploitation rate in Puget Sound marine fisheries for Mid-Hood Canal Chinook salmon will be the exploitation rate associated with achieving the management objectives for the 14 other management units. In addition, to ensure protection in the Mid-Hood Canal marine and freshwater areas where other management units have little or no presence, fisheries in Hood Canal north of Ayock Point will not be expanded or increased, i.e. the relative dates and duration of recent recreational salmon fishing seasons[33], time and area closures, tribal Chinook catch limit of 1500 in 12/12B, and other conservation measures for mid-Hood Canal Chinook will continue in Hood Canal north of Ayock Point for the life of the RMP or until NOAA Fisheries determines that fishery management constraints on MHC are no longer necessary for inclusion in the RMP.

To further strengthen the management objectives, the co-managers propose a check of the effect of Puget Sound fisheries on the projected number of spawners in Mid-Hood Canal rivers. During the preseason planning process, the projected number of spawners associated with the proposed suite of fisheries will be compared with the projected number of spawners associated with the closure of all Puget Sound fisheries. The reduction in spawners associated with Puget Sound fisheries must not change the status of the Mid-Hood Canal population relative to its critical and rebuilding thresholds and must have a negligible effect (less than 7 spawner reduction) on the survival or recovery of the spawning aggregations within the Mid-Hood Canal population.

Criterion D. "Display a biologically based rationale demonstrating that the harvest management strategy will not appreciably reduce the likelihood of survival and recovery of the ESU in the wild, over the entire period of time the proposed harvest management strategy affects the population, including effects reasonably certain to occur after the proposed actions cease."

The Mid-Hood Canal rivers currently lack an independent or sustainable Chinook population, and current evidence suggests these rivers are unlikely to support a reintroduced population; therefore, Mid-Hood Canal Chinook are unable to meaningfully contribute to the recovery of the Puget Sound Chinook ESU at this time. The management objectives defined under Criterion C would nonetheless limit Puget Sound exploitation rates on the Mid-Hood Canal Chinook salmon, primarily through the management of Puget Sound marine fisheries to meet the management

[33] The 2020 and 2021 recreational fishery seasons during the summer and fall months in Area 12 North of Ayock Point were as follows:

2020

August 1 – August 31:	No min. size. Daily limit 4 coho only. Only open north of a true east line from the mouth of Turner Creek to the Toandos Peninsula.
Sept. 1 – Sept. 30:	No min. size. Daily limit 4. Release Chinook and chum.
Oct. 1 – Nov. 30:	No min. size. Daily limit 4. Release Chinook. Oct. 1-Oct. 15: release chum.

2021

July 11 – Sept. 30:	No min. size. Daily limit 4. Release Chinook and chum.
Oct. 1 – Nov. 30:	No min. size. Daily limit 4. Release Chinook. Oct. 1-Oct. 15: release chum.

objectives of the other Puget Sound Chinook management units, which co-mingle with Mid-Hood Canal Chinook in the marine areas. This management strategy will not appreciably reduce the likelihood of survival and recovery of the ESU, because all other Puget Sound Chinook management units will be protected by their individual management objectives outlined in this RMP.

The exploitation rates for Mid-Hood Canal Chinook that would result from implementing the management objectives defined under Criterion C will both provide a level of protection to Mid-Hood Canal Chinook and ensure that Puget Sound fisheries do not appreciably reduce the likelihood of survival and recovery of the Puget Sound Chinook ESU. The impact of Puget Sound marine fisheries on the Mid-Hood Canal management unit will continue to be constrained through the implementation of the management objectives in this RMP for the other management units in this plan. Exploitation rates in Puget Sound fisheries are low relative to the total exploitation rate of fisheries outside Puget Sound. The average fishery exploitation rate from 2012 through 2018 in Puget Sound marine and river fisheries was 5.2% versus 20.0% in all other fisheries (Table 4).

Table 4. Total annual adult equivalent fisheries exploitation rate of Mid-Hood Canal Chinook from 2012 – 2018 in Puget Sound and other fisheries as estimated by FRAM V7.1 validation runs.

Year	Puget Sound	Other
2012	4.3%	24.2%
2013	4.0%	18.4%
2014	5.5%	21.1%
2015	5.8%	18.9%
2016	6.2%	18.3%
2017	6.5%	18.9%
2018	4.4%	17.1%
Average	5.2%	20.0%

Potential Reevaluation of Mid-Hood Canal Chinook's Role in the Recovery of the ESU

The native Hood Canal Chinook population that once spawned in mid-Hood Canal disappeared long ago, and whatever remains of its genetic lineage has been replaced or substantially altered through decades of extensive hatchery production and the release of nonnative hatchery fish into the Hood Canal region, including historical hatchery releases into the mid-Hood Canal rivers. The Chinook salmon returning to Mid-Hood Canal in more recent years are genetically identical to both George Adams Hatchery Chinook and Skokomish River Chinook. A 20-year hatchery supplementation program to re-introduce Chinook salmon to Mid-Hood Canal failed to establish a naturally reproducing population. Since the hatchery supplementation program ended, the mid-Hood Canal Chinook population has collapsed to extremely low numbers. All current data and analyses indicate that the George Adams Hatchery lineage stock is not viable through natural production in the mid-Hood Canal rivers. Additionally, the recent comprehensive habitat assessment of the mid-Hood Canal rivers suggests that attempting another reintroduction program with an alternative Chinook stock (e.g. a spring or late-fall stock) would have low likelihood of success. In the current absence of either an independent or viable Chinook salmon population in Mid-Hood Canal, fisheries cannot appreciably reduce the likelihood of the survival and recovery of the Puget Sound Chinook ESU by impacting the remnants of a hatchery-lineage population in Mid-Hood Canal.

For these reasons the co-managers would like the NMFS to reevaluate the current Mid-Hood Canal population's role in recovery of the Puget Sound Chinook salmon ESU. That process will undoubtedly take time; therefore, this MUP includes how the criteria for an RMP (50 CFR 223.203(b)(4)) will be addressed in the interim, with a focus on sections of the 4(d) rule that are directly applicable to management objectives.

Information on Mid-Hood Canal Chinook is widely dispersed in data files, unpublished reports, and publications. To assist in re-evaluating the role of Mid-Hood Canal in the recovery of the Puget Sound Chinook salmon ESU, the co-managers will be collecting and summarizing this information in a report to NMFS.

Dungeness Management Unit Status Profile

Component Populations

Dungeness River Chinook

Distribution and Life History Characteristics

Originating in the Olympic Mountains of Washington State, the Dungeness River and its main tributary, the Gray Wolf, drain a 270-square-mile watershed of steep mountains, deep forested canyons, and a broad open valley. With headwaters at 6,400 feet in Olympic National Park, the steep, 32-mile course of the Dungeness flows almost due north before emptying into the Strait of Juan de Fuca at sea level. The lower ten miles flow through a broad alluvial valley, which is characterized by a mixed use of small forested parcels, agriculture, and increasingly, a mix of rural/urban residential development in proximity to the City of Sequim (Jamestown S'Klallam Tribe, 2007).

Glacially colored water and chronically low returns of adults tend to obscure the entry timing of Dungeness Chinook, but they generally enter the river from May through September, peaking in July. Adult weir operations indicate that most of the adult Chinook return has entered the river by early August. Spawning occurs from early August through early October (WDFW, unpublished data). At the current low level of abundance, no distinct spring or summer populations are distinguishable in the return. Chinook typically spawn first in the upstream reaches and as the spawning season progresses, further downstream in the lower mainstem reaches (WDFW et al.1993).

Freshwater entry timing has been inferred from several sources of information, among them, broodstock trapping/netting observations in the lower river (RM 2.3), spawning surveys beginning in early August and intermittent steelhead surveys in the spring as water conditions allow. A lack of visibility and high water precludes direct observations of entry timing in late spring and early summer, however we know from the sources mentioned above that entry usually takes place sometime in May. The Dungeness and Elwha River Chinook are similar in spawn timing and appear to share similar river entry timing. Entry timing and runsizes have been estimated since 2009 (except 2011) on the Elwha River using SONAR (Denton et al. 2016, 2020).

Elwha Chinook river entry timing has been documented as early as May 20 and as late as September 21 based on in-river netting to determine species composition during SONAR operation. Mid-June is the typical timing for first Chinook. The 50% passage rate for Elwha Chinook has occurred between July 20th and August 1st. WDFW recently purchased a SONAR unit which will be used in the Dungeness River to detect river entry timing and run size.

Chinook spawn in the Dungeness River up to RM 18.9, where falls just above the mouth of Gold Creek block further access. Spawning distribution in recent years has been weighted toward the lower half of the accessible reach, with approximately seventy-five percent of redds located downstream of RM 10.8, which is near the Dungeness Hatchery (Table 1 and Figure 1).

Chinook also spawn in the Gray Wolf River (confluence with Dungeness at RM 15.8) up to RM 6.1.

Table 1. Range and average Chinook redd counts, proportions, and redd density by section in the Dungeness and Gray Wolf rivers 1998 through 2020.

Stream and section	Reach	SURVEY REACHES (miles)			Minimum	Maximum	Average	Average	Average
Lower Dungeness River (RM 0.5-RM 10.8)	Number	Lower RM	Upper RM	Total length (mi)	Redd count	Redd count	Redd count	Proportion	redds/mi
Mouth to Woodcock Bridge	1	0.5	3.3	2.80	2	127	33.2	0.170	11.85
Woodcock Bridge to Hwy 101	2	3.3	6.4	3.10	1	128	43.8	0.224	14.12
Hwy 101 to Taylor Cut-Off - May	3	6.4	9.2	2.80	5	88	37.7	0.193	13.45
Taylor Cut-Off - May to Canyon Ck.	4	9.2	10.8	1.60	4	75	28.0	0.144	17.53
Total				**10.30**			**142.7**	**0.731**	**13.85**
Upper Dungeness River (RM 10.8-RM 18.7)									
Canyon Creek to Clink Bridge	5	10.8	13.8	3.00	0	79	18.7	0.096	6.25
Clink Bridge to Forks Campground	6	13.8	15.8	2.00	0	59	11.6	0.059	5.78
Forks Campground to East Crossing	7	15.8	17.5	1.70	0	42	9.3	0.048	5.50
East Crossing to Gold Creek	8	17.5	18.7	1.20	0	13	2.1	0.011	1.78
Total				**7.90**	**3**	**193**	**41.8**	**0.214**	**5.29**
Gray Wolf River (RM 0.0-RM 6.1)									
Mouth to RM 1.0 Bridge	9	0.0	1.0	1.00	0	26	5.5	0.028	5.52
RM 1.0 Bridge to Above 2 Mile Camp	10	1.0	2.5	1.50	0	38	4.6	0.023	3.04
Above 2 Mile Camp to Cliff Camp	11	2.5	4.0	1.50	0	5	0.4	0.002	0.27
Cliff Camp to Slab Camp -Suppl. Surveys	12	4.0	5.1	1.10	0	3	0.2	0.001	0.21
Slab Camp and upstream 1 mile -Suppl. Surveys	13	5.1	6.1	1.00	0	0	0.0	0.000	0.00
Total				**6.10**			**10.7**	**0.055**	**1.75**
Dungeness Basin Grand Total				**24.30**					

Note: Confluence of Gray Wolf River and Dungeness River at Dungeness Forks Campground at RM 15.8.
Natural Barrier at RM 18.9 Dungeness River

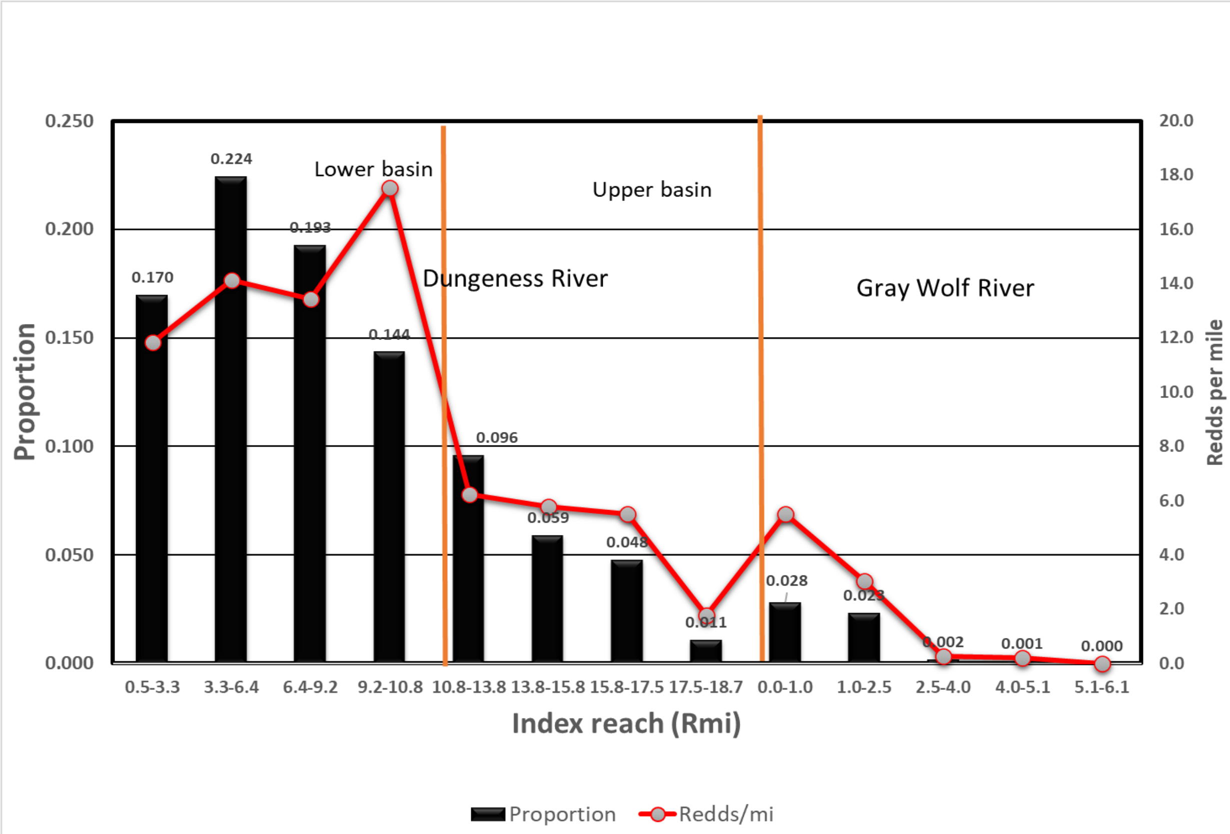

Figure 1. Average Chinook redd proportion and density in Dungeness and Gray Wolf rivers from 1998-2020.

Juvenile Chinook from the Dungeness River exhibit primarily an ocean-type life history, with age-0 emigrants (sub-yearling) comprising 95 to 98 percent of the total (WDF et al.1993, Smith and Sele 1994, and WDFW 1995 cited in Myers et al.1998). Adults mature primarily at age four (60%), with age 3 and age 5 adults comprising 22% and 18%, of the annual returns, respectively (WDFW, unpublished data) (Table 2).

Stock Status

The SASSI report (WDF et al.1993) classified the Dungeness spring/summer as critical due to chronically low spawning escapements to levels such that the viability of the stock was in doubt and the risk of extinction was considered to be high. Dungeness Chinook continue to be classified as critical in the SASSI report (WDFW 2003) because of continuing chronically low spawning escapements.

Dungeness Escapement 1986-2020

The calculated escapement goal for the Dungeness River is 925 spawners, natural and supplementation origin, based on historical escapements observed in the 1970's and estimated production capacity re-assessed in the 1990's (Smith and Sele 1994). Although there have been small improvements in habitat since the 1994 survey, the escapement goal of 925 is still considered applicable due to relative similar habitat conditions. There are some major habitat restoration projects (e.g. dike setback) in the planning and implementation phases which may increase capacity. Upon completion of these projects production capacity may be assessed again. From 1988 through 2000, the average total escapement was only 162. Escapements increased from 2000 through 2006, averaging 797. However, this increase is largely attributable to the captive brood supplementation program. Estimates of natural-origin fish have remained low, averaging only 164 from 2006 through 2020. The captive brood program, by design came to a conclusion after the 2003 brood (see below for description of hatchery actions) and returns from the program peaked in 2006. Subsequent escapements have again declined to lower levels. From 2007 through 2016, the average escapement was 400, natural and supplementation origin, and ranged from 204 to 665. However, escapements have been on the rise since 2016 with an average escapement, natural and supplementation origin, of 843 between 2017 and 2020 (Table 2, Table 3).

Dungeness Chinook escapement is considered the Terminal Run Size (TRS) due to no directed terminal harvest and minimal incidental terminal harvest. Incidental terminal catch in Dungeness Bay (Catch Area 6D) has averaged less than 1 fish per year over the last 10 years and these are not included in the TRS data included in this analysis. There are no records of incidental catch in the river itself over the last 10 years as fisheries are planned to begin after spawning is complete. See Table 2 below for TRS by year and Table 3 for Natural Origin (NOR) and Hatchery Origin (HOR) breakdown.

Table 2. Dungeness River Chinook adult ages (HOR and NOR combined) for Return Years 1988-2020.

Return year	Total Age-3	Total Age-4	Total Age-5+	TRS
1988	0	306	66	372
1989	51	15	29	95
1990	0	361	0	361
1991	28	143	28	199
1992	1	115	38	154
1993	8	5	41	54
1994	12	49	4	65
1995	18	104	41	163
1996	5	112	66	183
1997	8	13	31	52
1998	3	92	15	110
1999	16	13	46	75
2000	65	140	13	218
2001	22	412	19	453
2002	114	104	415	633
2003	32	427	181	640
2004	181	627	206	1,014
2005	200	600	281	1,081
2006	19	1,025	499	1,543
2007	108	95	200	403
2008	77	146	6	229
2009	49	152	19	220
2010	231	207	19	457
2011	315	304	46	665
2012	157	413	44	614
2013	26	220	32	278
2014	87	95	22	204
2015	101	278	28	407
2016	121	303	90	514
2017	451	235	19	705
2018	374	521	10	905
2019	266	637	27	930
2020	173	607	53	833
No. Years	33	33	33	33
Mean	101	269	80	450
Proportion	0.2244	0.5978	0.1778	1.0000
STD	115	232.1	115.9	353.4
95% CI	39.242	79.196	39.543	120.564
Lower CI	61	190	40	329
Upper CI	140	348	119	571

For return years 2006-2020, the NOR portion of the Chinook returns ranged from 43 to 339 and the number of HOR returns ranged from 90 to 1,204. The fifteen-year average percentages of NORs and HORs are 31.00% and 69.00%, respectively (Table 3).

Table 3.

Total number of NOR and HOR Chinook natural spawners and broodstock collected in the mainstem Dungeness River from RY 2006-2020.

Return year	Natural spawners 1/ NOR	Natural spawners 1/ HOR	Natural spawners 1/ NOR+HOR	Broodstock collection 2/ NOR	Broodstock collection 2/ HOR	Broodstock collection 2/ NOR+HOR	Natural Spawners + Broodstock NOR	Percentage NOR Spawners + Broodstock	Natural Spawners + Broodstock HOR	Percentage HOR Spawners + Broodstock	Total returns NOR+HOR
2006	293	1,112	1,405	46	92	138	339	21.97%	1,204	78.03%	1,543
2007	146	159	305	47	51	98	193	47.89%	210	52.11%	403
2008	86	54	140	53	36	89	139	60.70%	90	39.30%	229
2009	71	57	128	42	50	92	113	51.36%	107	48.64%	220
2010	76	269	345	18	94	112	94	20.57%	363	79.43%	457
2011	83	452	535	21	109	130	104	15.64%	561	84.36%	665
2012	212	296	508	38	68	106	250	40.72%	364	59.28%	614
2013	46	122	168	31	79	110	77	27.70%	201	72.30%	278
2014	21	87	108	22	74	96	43	21.08%	161	78.92%	204
2015	65	200	265	37	105	142	102	25.06%	305	74.94%	407
2016	135	273	408	30	77	107	165	32.04%	350	67.96%	515 4/
2017	149	456	605	26	74	100	175	24.82%	530	75.18%	705
2018	127	661	788	20	97	117	147	16.24%	758	83.76%	905
2019	173	665	838	19	73	92	192	20.65%	738	79.35%	930
2020	294	439	733	27	70 + 3unk	100	321	38.54%	512	61.46%	833
Mean	131.8	353.5	485.3	31.8	76.8	108.6	163.6	31.00%	430.3	69.00%	599.5

1/ Natural spawners: Chinook that spawned naturally in the river. Natural spawner estimate based on redd surveys.

2/ Broodstock collection: Chinook that were collected in the river or returned to the hatchery and used for broodstock. Total includes pre-spawn mortalities.

3/ NORs and HORs determined by CWT detection, otolith marks, scales, or visible marks (adipose clips) from broodstock and river carcasses sampled.

4/ Excludes 8 jacks

Dungeness Juvenile Salmonid Outmigrant Monitoring 2005-2020

WDFW has operated a floating five-foot diameter screw trap in the lower Dungeness each year since 2005, to estimate the number of juvenile salmon produced in the basin. This trap is operated continuously between February to late July or mid-August. High water events, debris, and mechanical failures may shut down trapping operations temporarily. Although the hatchery released Chinook are unmarked, they are 100% Coded Wire Tagged (CWT). Hatchery produced juvenile Chinook migrants can be distinguished from natural juveniles caught in the screw trap by scanning with a CWT detector.

Due to the low abundance of NOR yearling Chinook in the Dungeness, production estimates for them have not been calculated. Since 2005, the number of naturally produced sub-yearling Chinook in the Dungeness River ranged from a low of 3,870 in 2015 to a high of 164,815 in 2013. In that time period an average of 58,760 sub-yearlings has been naturally produced in the Dungeness River. The two lowest years for Chinook sub-yearling production have been recent with 3,870 in 2015 and 5,556 in 2016 (Table 4) (Data are available in WDFW juvenile monitoring annual report series, including Topping et al. (2008). Juvenile Chinook outmigration in the Dungeness typically peaks around late May and is 99% complete by the beginning of August.

Table 4. Dungeness River juvenile salmonid production for trap years 2005-2020.

TRAP DATE		Sub-yearling Chinook		Natural Smolt Production			
Beginning	**Ending**	**Natural**	**Hatchery**	**Coho 1+**	**Pink 0+**	**Chum 0+**	**Steelhead 1+**
3/8/2005	8/5/2005	81,865		57,095	0		9,192
2/2/2006	8/17/2006	136,724		43,888	696,642	194,721	6,125
2/21/2007	8/19/2007	110,021	65,016	22,134	0	381,781	11,445
2/13/2008	8/12/2008	11,612	74,038	21,293	472,334	98,483	10,344
2/19/2009	8/12/2009	20,443	11,374	30,780	43,161	630,358	10,101
2/8/2010	7/28/2010	10,604	36,547	38,210	197,963	41,326	17,486
2/9/2011	8/31/2011	10,250	63,608	26,280	33,209	202,658	19,600
2/14/2012	8/28/2012	71,810	72,868	31,794	3,687,547	38,968	5,521
2/6/2013	8/8/2013	164,815	74,038	52,336	11,043	338,568	7,812
1/16/2014	8/13/2014	26,513	86,954	35,839	29,547,068	92,275	13,167
2/4/2015	7/28/2015	3,870	101,696	6,040	0	155,645	5,972
2/3/2016	7/25/2016	5,556	73,279	20,493	89,802	23,927	4,354
2/2/2017	8/10/2017	27,881	33,780	12,991	0	214,914	11,897
2/6/2018	8/14/2018	45,595	56,904	58,173	237,410	27,051	10,387
1/31/2019	8/10/2019	76,474	26,626	48,462	0	63,934	10,618
1/30/2020	8/11/2020	136,130	37,203	34,434	1,331,613	54,697	12,281
Average production:	**183 days trapped**	**58,760**	**58,138**	**33,765**	**2,271,737**	**170,620**	**10,394**

Notes:

- Natural origin Chinook production estimates are extrapolated to and starting date of 1/15 and an ending date of 8/31
- Production estimates for Chinook, chum and Pink are generated using maiden captured fish that are marked after capture and released above the trap. Individual efficiency tests are pooled using a G-test to inform efficiency strata that are applied to the estimated maiden catch for each efficiency strata.
- Production estimates for Coho and steelhead are generated by utilizing a two trap design, Coho and steelhead captured in a weir trap on Matriotti Creek located upstream of the screw trap are marked, released, and recaptured downstream in the screw trap. (Source: Pete Topping, WDFW).

Estimated egg-to-smolt survival has averaged 4.96% since trapping began (Table 5). There is concern among the co-managers about flow related mortality associated with egg-to-smolt survival. When looking at peak annual flows, there is a relationship between flow and egg-to-smolt survival in the Dungeness River. In the years with higher peak flows, egg to smolt survival is down compared to years with lower peak flows. Years 2015 and 2016 had some of the highest flows in the 15-year dataset. Consequently, those two years have had the lowest egg-to-smolt survival since 2005 (Table 5 and Figure 2). For comparison, similar data collected in the Skagit River, a healthier Chinook system, produce egg-to-smolt survival estimates of around 8% for the same period, and over 10% since 1990. The low egg-to-smolt survival rate estimates for Dungeness Chinook are indicative of the habitat degradation mentioned in this report, along with flow related issues and of the general low productivity of the population.

Table 5. NOR sub-yearling production and egg-to-migrant survival related to peak flow (cfs) 2005-2020.

Trap Year	Maximum cfs 10/16 thru 1/15	Number Redds	Deposition at 5,300 eggs	Estimated Subyearling production	Migrants Per Redd	Egg to migrant Survival
2005	2130	381	2,019,300	81,865	215	4.05%
2006	2440	382	2,024,600	136,724	358	6.75%
2007	1820	562	2,978,600	110,021	196	3.69%
2008	3180	122	646,600	11,612	95	1.80%
2009	1640	56	296,800	20,443	365	6.89%
2010	3100	51	270,300	10,604	208	3.92%
2011	3890	138	731,400	10,250	74	1.40%
2012	1500	214	1,134,200	71,810	336	6.33%
2013	1450	203	1,075,900	164,815	812	15.32%
2014	817	67	355,100	26,513	396	7.47%
2015	3680	43	227,900	3,870	90	1.70%
2016	3420	106	561,800	5,556	52	0.99%
2017	1470	163	863,900	27,881	171	3.23%
2018	2,980	242	1,282,600	45,595	188	3.55%
2019	1,870	315	1,669,500	76,474	243	4.58%
2020	846	335	1,775,500	136,130	406	7.67%
Average	**2,265**	**211**	**1,119,625**	**58,760**	**263**	**4.96%**

Source: Pete Topping, WDFW

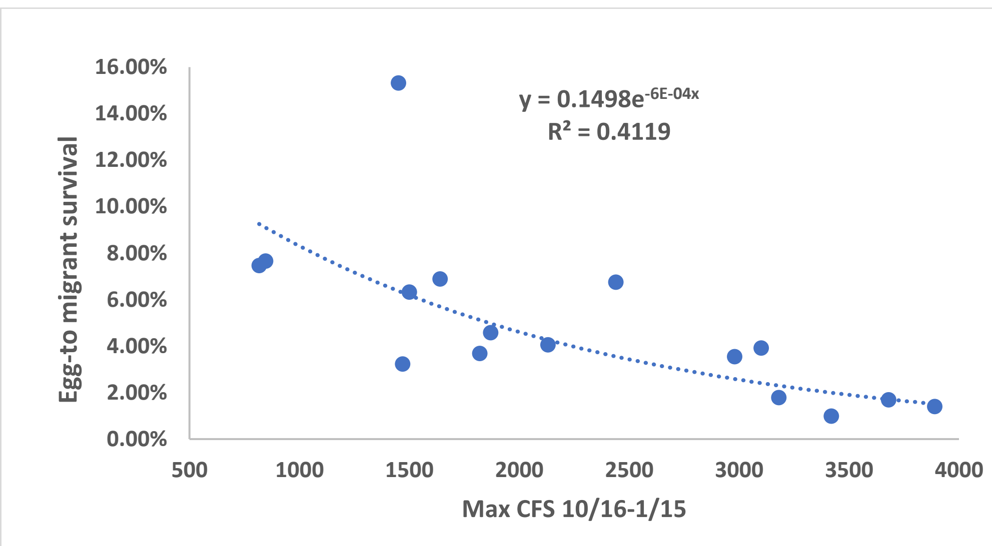

Figure 2. Natural-origin 0+ Chinook egg-to-migrant survival and annual peak incubation flow for brood years 2004 through 2020 in the Dungeness River. (Assumes 5,300 eggs per female based on average fecundity of brood stock).

Another concern for co-managers is the low in-river survival rate associated with hatchery Chinook. Since the 2007 trap year, the average survival rate for hatchery Chinook from release site to the trap site was 45.14% and has gone as low as 11.52% in 2009 (Table 6 and Figure 3).

While we cannot directly measure predation on NOR Chinook, the mortality rate associated with HOR Chinook is high enough to raise significant concerns about NOR mortality in the river. Aside from flow related mortality, predation from native species such as Bull Trout and various shore birds is the main concern for in-river survival. In recent years, some measures have been taken to try and reduce predation on hatchery Chinook. This has involved trucking one or two CWT release groups from its rearing location to river mile 0.5 to be released. Upon return, we will be able to assess survival between release groups and if the measures were successful in helping to prevent in-river mortality by comparing them to the other release groups.

Table. 6. Sub-yearling (SY) hatchery Chinook release survival estimates, Dungeness 2007-2020.

Brood year	Trap year	No. Hatchery SY Released	Estimated No. SY Migrants	% SY Survival
2006	2007	102,540	65,016	63.41%
2007	2008	153,650	74,038	48.19%
2008	2009	98,726	11,374	11.52%
2009	2010	100,600	36,547	36.33%
2010	2011	76,918	63,608	82.70%
2011	2012	169,099	72,868	43.09%
2012	2013	153,650	74,038	48.19%
2013	2014	170,404	86,954	51.03%
2014	2015	128,217	101,696	79.32%
2015	2016	158,289	73,279	46.29%
2016	2017	154,584	33,780	21.85%
2017	2018	157,263	56,904	36.18%
2018	2019	96,900	26,626	27.48%
2019	2020	102,100	37,203	36.44%
Average		**130,210**	**58,138**	**45.14%**

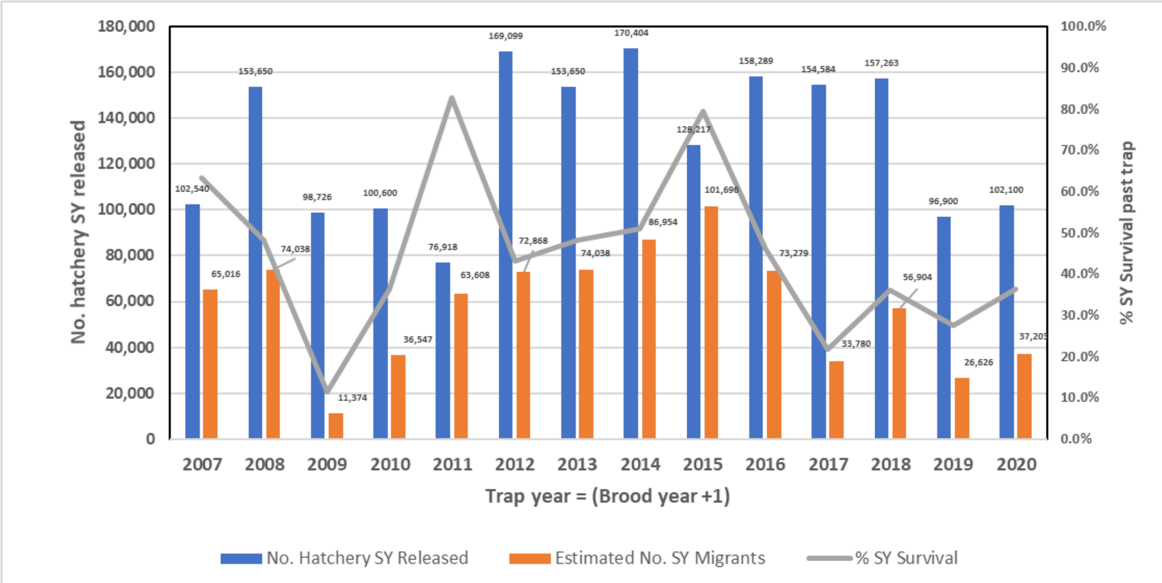

Figure 3. Number of hatchery Dungeness Chinook sub-yearlings released in the Dungeness basin and the estimated number Chinook sub-yearlings migrating past trap based on capture efficiency tests for trap years 2007 to 2020.

The Dungeness River drains into Dungeness Bay, which includes the 1.2 sq. mi Dungeness Wildlife Refuge (DWR). The 5.5-mile-long natural sand spit (Dungeness Spit), Graveyard Spit, and portions of Dungeness Bay and Harbor are within the refuge. This area provides habitat for nesting colonies of seabirds and haul-out areas for marine mammals. Known predators of juvenile salmon and steelhead, such as Caspian terns, Glaucous winged/Western gulls, and harbor seals are present in Dungeness Bay (Pearson et.al. 2015). The extent of predation on outmigrant salmon and steelhead by these predators in this estuary is currently unknown.

<u>Dungeness Marine Survival and Productivity</u>

The Smolt-to-Adult Rate (SAR) survival for Dungeness Chinook is relatively low, with an average of 1.08% from 2004 through 2015. NOR smolt-to-adult return rates were estimated by dividing the number of NOR adults by the number of natural-origin smolts. NOR return rates, based on age 2 to age 5 returns, ranged from .0763% to 4.9871% (Table 7).

Recruits per Spawner (R/S) or Adult (HOR+NOR natural spawners) to Adult (NOR) production were measured for brood years 2004 to 2015 and ranged from 0.0598 to 1.7848 and averaging 0.5789 for the 12-year period (Table 8).

Table 7. NOR smolt-to-adult return rates for Dungeness River Chinook for trap years 2005-2016 (brood years 2004-2015). Natural spawners include both NOR and HOR.

Smolt Trap Year	Juvenile Chinook Abundance	NOR						
		Age-2	Age-3	Age-4	Age-5	Age-6	Total	SAR
2005	81,865	0	75	98	17	0	190	0.2321%
2006	136,724	0	38	96	12	0	146	0.1068%
2007	110,021	0	4	57	23	0	84	0.0763%
2008	11,621	0	25	44	19	0	88	0.7573%
2009	20,443	0	37	175	16	0	228	1.1153%
2010	10,604	0	56	57	10	0	123	1.1599%
2011	10,250	0	2	21	11	0	34	0.3317%
2012	71,810	0	13	74	26	0	113	0.1574%
2013	164,815	0	14	120	14	0	148	0.0897%
2014	26,513	0	18	62	5	0	85	0.3220%
2015	3,870	4	99	75	19	0	197	4.9871%
2016	5,556	0	66	108	28	0	202	3.6357%
2017	27,881	0	65	235				
2018	45,595	0	49					
2019	76,474	0						
2020	136,100	0						

Table 8. Recruits per spawner, by age class, from naturally spawning HOR and NOR Chinook in the Dungeness River for brood years 2004 to 2015.

Brood year	Natural spawners HOS	Natural spawners NOS	Natural spawners HOS+NOS	Age 3 NOR	Age 4 NOR	Age 5 NOR	Age 6 NOR	Total NOR	Spawner per spawner
2004			953	75	98	17	0	190	0.1994
2005			955	38	96	12	0	146	0.1529
2006			1,405	4	57	23	0	84	0.0598
2007	159	146	305	25	44	19	0	88	0.2885
2008	54	86	140	37	175	16	0	228	1.6286
2009	57	71	128	56	57	10	0	123	0.9609
2010	269	76	345	2	21	11	0	34	0.0986
2011	452	83	535	13	74	26	0	113	0.2112
2012	296	212	508	14	120	14	0	148	0.2913
2013	122	46	168	18	62	5	0	85	0.5060
2014	87	21	108	99	75	19	0	193	1.7870
2015	200	65	265	66	108	28	TBD	202	0.7623
2016	273	135	408	65	235				
2017	456	149	605	49					
2018	661	127	788						
2019	665	173	838						
2020	439	294	733						

It should be noted that smolt-to-adult survival in the natural spawning population is higher than that of the hatchery component on average. Hatchery SAR's typically fall below 0.4% and average around 0.1% (Table 9 and Figure 4.). Natural-origin survivals are from the river mouth (smolt trap location) to adult return (Table 9 and Figure 5), whereas hatchery survivals are from release to adult return. In comparison to the natural survival, hatchery estimates therefore include the additional mortality suffered in the river prior to ocean entry. We do not know in-river mortality for natural smolts because the trap is near the mouth. Natural SAR rates are likely less when considering in-river mortality. Estimates are total return to the river, and do not account for fishing mortality.

Table 9. Smolt to adult return rate of natural origin produced and hatchery released Chinook salmon in the Dungeness River for Ocean Entry Years (OEY) 2005 to 2016.

Ocean entry year	Natural SAR	SUB-YEARLINGS Age 0+			
		Gray Wolf (GW)	Upper Dungeness (UPDG)	Dungeness Hatchery (DH)	Hurd Creek (HC)
2005	0.2321%				
2006	0.1068%	0.0587%			
2007	0.0763%	0.1209%			
2008	0.7579%	0.3966%			
2009	1,1153%	0.3958%			
2010	1.1599%	0.2823%		0.2234%	
2011	0.3317%	0.1495%		0.0876%	
2012	0.1574%	0.1355%	0.18795%	0.2070%	
2013	0.0897%	0.1705%	0.1350%	0.2182%	
2014	0.3220%	0.1303%	0.1605%	0.1640%	0.3647%
2015	4.9881%	0.5048%	0.7329%		
2016	3.6357%	0.3463%	0.2677%	0.4884%	0.3664%

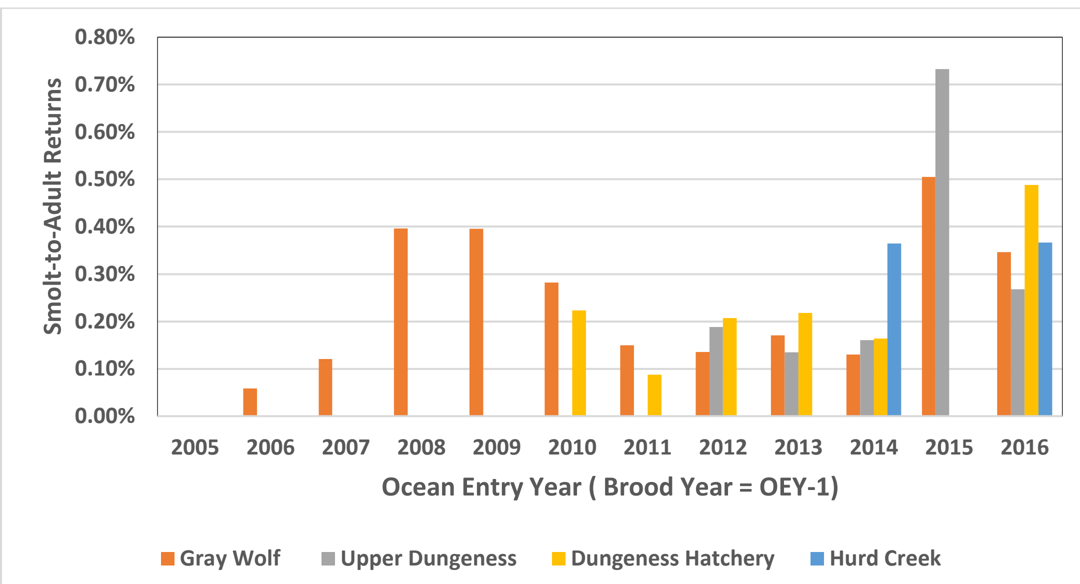

Figure 4. Percent smolt-to-adult returns for hatchery Dungeness Chinook released from Gray Wolf Acclimation Pond, Upper Dungeness Acclimation site, Dungeness Hatchery, and Hurd Creek Hatchery for Ocean Entry Years 2005-2016 (Brood Year equals OEY-1).

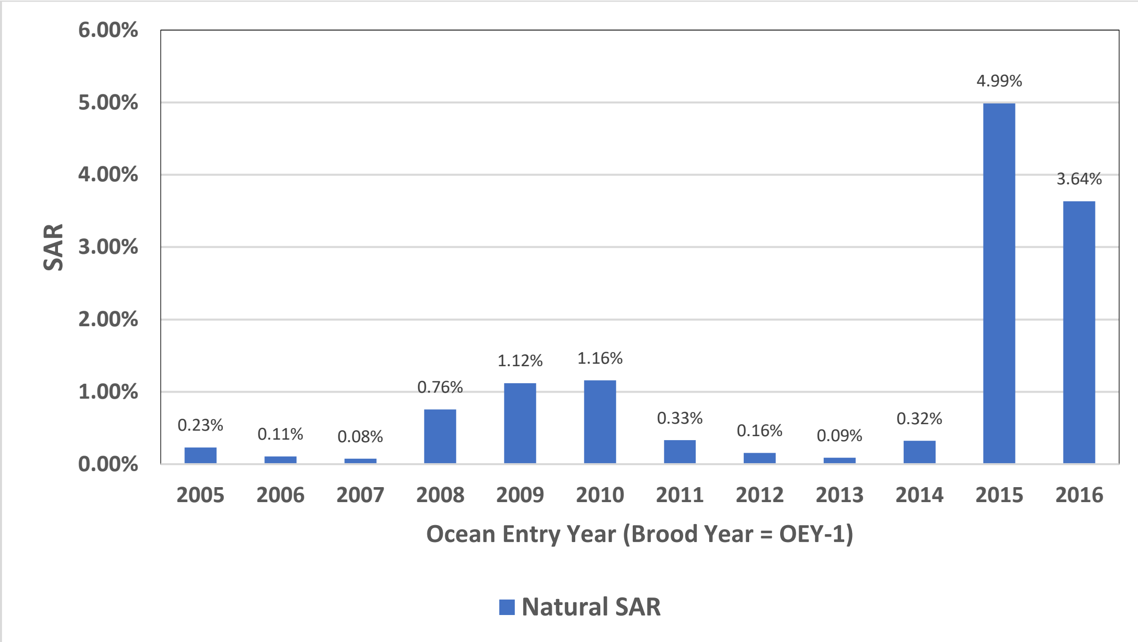

Figure 5. Percent smolt-to-adult returns for natural-origin Dungeness Chinook for Ocean Entry Years 2005-2016 (Brood Year equals OEY-1).

<u>Hatchery and Habitat Practices/Projects</u>

Chinook production in the Dungeness River is constrained primarily by degraded spawning and rearing habitat in the lower half of the basin. Significant channel modification has contributed to substrate instability in spawning areas and has reduced and isolated side channel rearing areas. Water withdrawals for irrigation during the migration and spawning season have also limited access to suitable spawning areas and decreased habitat availability.

The co-managers, in cooperation with federal agencies and private-sector conservation groups, implemented a captive brood stock program in December 1991 to rehabilitate Chinook runs in the Dungeness River. The primary goal of this program was to increase the number of fish spawning naturally in the river, while maintaining the genetic characteristics of the existing stock. The last significant egg-take from the captive brood program occurred in 2003. Beginning in 2004, returning adults were collected and spawned, with the goal of releasing 100,000 accelerated zeros (sub-yearlings) and 100,000 yearlings each year. Subsequent escapement data demonstrated that the accelerated zero releases outperformed the yearling releases.

Consequently, the release strategy was adjusted to 200,000 accelerated zero aged Chinook annually. There are 4 separate rearing and release sites for Dungeness Chinook. Chinook are reared at Hurd Creek Hatchery and Dungeness Hatchery. CWT groups are released from these hatcheries along with two upper river acclimation sites in the Grey Wolf River and Upper Dungeness. Each release group has a distinctive CWT ID and all releases are unmarked.

The co-managers are currently working with NOAA to update the Dungeness Chinook Hatchery Genetic Management Plan (HGMP) to reinitiate the captive broodstock program. Due to the continued low proportion of NOR adult returns the co-managers have decided to start captive broodstocking adult Dungeness Chinook again. The new release goal is being determined with NOAA. With the new lower river habitat restoration projects currently taking place the co-managers are hopeful that this reintroduction of the captive broodstock program will help to saturate the spawning grounds and help to bring back more NOR returns in the future.

In 2013, the Washington Department of Ecology adopted the Dungeness Water Management Rule. "The intention of the Water Rule is to guide planning and decision making for new water users, as well as set policies to help protect the availability of water for current and future needs of people and the environment" (Dungeness Water Exchange, website). The Rule sets instream flow levels for the mainstem Dungeness as well as several of its tributaries. These established instream flow levels are used to determine how much water is withdrawn from the river during the low flow season. As the flow and water levels drop, the amount of water that is withdrawn from the river is reduced in correlation.

In addition to the captive broodstock program and Water Rule implementation, the local watershed council (Dungeness River Management Team) and the local lead entity for salmon (North Olympic Lead Entity for Salmon) along with a group of state, tribal, county and non-profit organizations are working on several habitat restoration efforts. Following the recommendations of the various recovery, restoration, and conservation plans, restoration practitioners have installed 20 engineered log jams, lengthened and made salmon-friendly the pedestrian bridge at Railroad Bridge Park, installed many miles of water conserving irrigation piping, and permanently conserved over 200 acres of floodplain properties. Two projects have restored Dungeness Estuary habitats. Other projects including larger scale riparian land acquisition, dike setback and bridge lengthening are in the planning, analysis and proposal phases. The Middle- Corps dike setback is expected to begin construction in 2021.

Management Objectives

The management objectives for Dungeness Chinook are to stabilize escapement and recruitment, with the ultimate objective of restoring the natural-origin population through adaptive hatchery supplementation, habitat improvements, and fishery restrictions.

The Upper Management Threshold (UMT) for the Dungeness MU is a TRS of 925 naturally spawning adults, corresponding to the calculated escapement goal described above. The Low Abundance Threshold (LAT) is a TRS of 500 adult returns (HOR + NOR). This threshold represents a reasonable balance between demographic and genetic risks facing this small population. Based on the recent-year average of NORs in the population (31%; Table 3), the 500 LAT would correspond to an average of 155 NORs and 345 HORs. These abundances would provide enough brood stock to sustain the small hatchery program, which is an important demographic safety net for the population, while allowing NORs to spawn naturally. Historically, however, abundance of NORs has ranged between 43 and 339 (2006 through 2020) with the population above the LAT, for HOR and NOR combined, in seven of the last 10 years, and experience has shown that when TRS is less than 500 additional management actions should be considered to protect the population. Genetically, the LAT of 500 would also minimize potential inbreeding depression and maintain the evolutionary potential of the population. This can be seen in the context of the 50/500 rule, where a genetic effective size (N_e) of greater than 50 minimizes the loss of fitness from inbreeding and N_e of 500 or more maintains the balance between genetic diversity lost to genetic drift and the new genetic diversity from mutation and gene flow (Franklin 1980, Frankel and Soule 1981), which preserves the adaptive potential of the population. For the Dungeness population with an LAT of 500, inbreeding N_e would be 384 after accounting for Ryman-Laikre effects from the hatchery (Ryman and Laikre 1991), assuming future variability for the proportions of hatchery fish spawning in the wild, brood stock sizes, and abundance of the natural spawning aggregation are similar to what occurred between 2007-2016. Therefore, the appropriate criterion to compare 384 to is 50 in the 50/500 rule**.** Conversely, to evaluate the capacity of an LAT to maintain the evolutionary potential of the population, it is necessary to consider the loss of genetic diversity from genetic drift and new diversity from gene flow. This involves calculating a global genetic effective size based on metapopulation structure (Jamieson and Allendorf 2012). Based on analysis of gene flow among 35 Puget Sound Chinook Salmon populations at 13 microsatellite loci, Dungeness Chinook are part of a larger metapopulation consisting of Skykomish and Snoqualmie Chinook Salmon. (Note: The Elwha Chinook population, which based on empirical observations that straying is more common as geographical proximity increases, may also be part of this metapopulation but no data were available to analyze its contribution). The available data show that Skykomish and Snoqualmie populations contributed an average of 8-9 genetically effective migrants per generation to the Dungeness. This leads to a global genetic effective size of approximately 5520. The appropriate criterion to compare 5520 to is 500 in the 50/500 rule. All of this indicates that an LAT of 500 maintains the evolutionary potential of the population.

The above analysis is based on data from Dungeness Chinook using genetic markers to estimate straying. While data is lacking for actual NOR stray rate we do observe some straying in the HOR component. Since 2002, nineteen sampled HOR Chinook in the Dungeness River have come from various other hatcheries. Of those 19 Chinook, fifteen of them were from the Elwha River hatchery, while the other 4 came from George Adams, Glenwood Springs and Nooksack hatcheries. This is based on CWT's recovered on the spawning grounds or for the supplementation program. The observed straying in the HOR component is likely to be replicated in the NOR component, although we cannot estimate how much straying or from what populations it will occur.

The Fisheries Regulation Assessment Model (FRAM) is the tool used for the following management metrics. When projected escapement to the Dungeness River exceeds the LAT of 500, Southern U.S. (SUS) fisheries will be managed to not exceed a 10.0% Exploitation Rate (ER) ceiling. If escapement is projected to be below the LAT, SUS fisheries will be managed to further reduce fishery mortality to AEQ (adult equivalent mortality) impacts of less than 6.0%. Projected escapement refers to the FRAM accounting for the combined hatchery and natural origin recruits or adults. Fishery mortality in terminal and extreme terminal fisheries (Dungeness Bay and River) is expected to be very low for the duration of this plan. This is because Chinook-directed commercial and recreational fisheries are not expected to occur, and coho and pink fisheries will be regulated to limit incidental Chinook mortality. In general, SUS harvest is minimal, especially when compared to harvest in Canadian and Alaska fisheries (Table 7).

Using projections of the FRAM new base period post-season runs (as of round 7.1 of the QAQC process, September 2021), the pre-terminal SUS ER has averaged 5% over the last 10 years and the terminal ER has averaged 0.5% over the same time period. In contrast, harvest in Canadian and Alaska fisheries have averaged 21% ER over the last 10 years with 2 years reaching as high as 25% and 28%. In years 2011 and 2012, when the forecast exceeds the LAT and preseason fisheries were managed to 10%, projected SUS harvest (based on new base period post-season FRAM) stayed at 6% or below (Table 10). NOAA currently recommends a 5% Recovery Exploitation Rate (RER) for Dungeness Chinook based on surrogate data used from the Nooksack River. However, the co-managers feel that may unnecessarily constrain SUS fisheries while providing little in return to the Dungeness River. A 6% difference in ER amounts to 30 total Chinook using a forecast of 500 adult returns. Applying the 34% NOR rate results in only 10 more NOR Chinook returning to the river, which is insignificant regarding recovery of the stock. The pre and post- season mortality estimates for each SUS fishery are very minimal (Table 11). To return an additional 30 Chinook to the Dungeness River, entire fisheries in mixed stock areas would need to be closed. Therefore a 10% ER ceiling when the forecast is above the LAT and a 6% ER ceiling when the forecast is below the LAT are expected to have a minimal impact on Dungeness Chinook and may provide fishing opportunities for other salmon stocks in mixed stock areas.

Table 10. New Base Period post season FRAM Round 7.1 exploitation rates for Dungeness Chinook 2009-2018.

Year	Total ER	Northern ER	PT-SUS ER	Terminal ER
2009	38.0%	27.6%	6.8%	3.6%
2010	22.7%	17.9%	4.8%	0.0%
2011	29.1%	23.0%	6.1%	0.0%
2012	29.0%	24.7%	4.3%	0.0%
2013	25.4%	18.7%	6.7%	0.0%
2014	28.9%	21.0%	7.6%	0.4%
2015	26.0%	20.8%	5.2%	0.0%
2016	23.7%	19.8%	3.4%	0.4%
2017	20.4%	18.0%	2.4%	0.0%
2018	20.1%	15.9%	3.9%	0.3%
10 Yr Avg	**26.3%**	**20.7%**	**5.1%**	**0.5%**

The co-managers have not identified a point of instability, or lower bound, below the Low Abundance Threshold for Dungeness Chinook. The LAT of 500 returning adults is likely close to the point of instability and will be treated as such. Should preseason forecasts slip much below the LAT, the co-managers will consider what additional fishery actions may be appropriate to provide further protection for Dungeness Chinook. Past fishery actions have included closure of terminal fisheries during times of spring Chinook presence, and closure of summer marine area recreational Chinook fisheries in the vicinity of the Dungeness River (eastern portion of Catch Area 6). The east part of Area 6 is a rather large area in the Eastern Strait of Juan de Fuca and as such a mixed stock area. It has been closed to protect Dungeness Chinook for several years now. This is currently the only complete closure of a mixed stock area to protect a listed species. In 2017, the winter Chinook fisheries in the Strait of Juan de Fuca (catch areas 5 and 6) were also shortened in duration to help protect Dungeness Chinook. These actions are likely to continue in the future, and other actions such as additional closures or restrictions may be considered if there is not an improvement in the status of this stock.

Dungeness Chinook CWT release groups were not adipose fin clipped during the updated base period years used to calibrate the FRAM. The FRAM is used by the co-managers during preseason fisheries planning and postseason exploitation rate evaluation, and an adipose fin clip is essential for CWT detection in many FRAM fisheries. Therefore, for the new Base Period FRAM calibration, a surrogate procedure was used to simulate the Elwha and Dungeness River Chinook (ELDU) CWT recoveries. After an analysis of Salish Sea Chinook populations, it was determined that the Stillaguamish Chinook population was the best proxy for ELDU exploitation in fisheries outside of the Salish Sea (McHugh, unpublished). For pre-terminal fisheries outside the Salish Sea, ELDU CWT recoveries were simulated using a one-to-one ratio with Stillaguamish CWT recoveries from the new Base Period. For fisheries inside the Salish Sea, ELDU CWT recoveries were based on Stillaguamish CWT recoveries from the new Base Period, and the historic relationship of CWT recoveries between ELDU and Stillaguamish in years when both management groups were released with CWTs and adipose fin clips (Gordon Rose, NWIFC, personal communication). The accuracy of FRAM's projections of Dungeness Chinook exploitation may be limited by the small stock size and surrogate procedure. However, the co- managers will continue to develop and adopt conservation measures that protect critical management units, while realizing the constraints on quantifying their effects in the simulation model. Beginning with the release of 2012 brood, a portion of the annual releases from the Elwha Chinook hatchery program have been marked with an adipose fin clip and otolith mark, and tagged with a CWT. There were data issues with the 2013 brood releases, and few CWTs (n=2) were recovered associated with tag codes from that brood year. However, recovery data are now available for brood years 2012, 2014, 2015 (age 2, 3, and 4 only), and 2016 (age 2 and 3 only). The co-managers currently believe that there should be sufficient years of Elwha CWT recovery data to use an out-of-base procedure to represent Elwha and Dungeness Chinook in FRAM during the life of this Resource Management Plan, likely by 2023 or 2024. This approach should be a significant improvement to modeling these units over the surrogate method currently used. Once FRAM is updated with CWT data from Elwha Chinook, the co-managers will review the resulting ER estimates for both Dungeness and Elwha Chinook. It is up to the local co-managers to achieve a consensus on updates to the Elwha/Dungeness FRAM stock and possible modifications to management objectives, and these can be based on any number of considerations.

Contribution to Fisheries

No harvest is presently directed on wild or hatchery Chinook produced in the Dungeness River. Treaty and non-Treaty fisheries directed at species other than Chinook are managed to minimize incidental effects to Dungeness Chinook salmon. While there is currently no directed harvest on Dungeness spring Chinook salmon in the terminal area, there is a commercial fishery directed at hatchery coho, that takes place in Dungeness Bay (Catch area 6D). The start date for this fishery is intentionally delayed until late September to avoid incidental harvest on Dungeness Chinook. Furthermore, any Chinook that may be caught during the early part of the fishery is required to be released unharmed. The fishery is heavily monitored to ensure incidental Chinook are not harvested as well as to record mark rates for coho. Incidental Chinook impacts in the Dungeness Bay coho commercial fishery have averaged less than one fish per year over the last 10 years.

There is also a sport fishery for coho in Dungeness Bay and River as well as a handheld treaty subsistence fishery in the river, all of which are restricted to the time period after Chinook spawning is considered 100% complete. There are also commercial opportunities and mark selective sport fisheries in mixed-stock areas that have minimal incidental impacts to Dungeness Chinook (Table 11). Since 2004, hatchery produced Dungeness Chinook have been CWT'd but not clipped to avoid direct harvest in mixed stock selective fisheries. There are no plans to adipose clip hatchery Chinook released from the Dungeness. Harvest opportunity is the long- range objective, both direct and indirect, when recovery goals are attained.

Table 11 below was provided by the WDFW Fish Management Ocean Management group and contains information on the contributions to fisheries for Dungeness Chinook salmon. These data reflect mortalities, rather than "landed catch" or escapements for unmarked hatchery- and natural-origin Dungeness Chinook salmon. Looking at the table, SUS AEQ mortality is very minimal, averaging 23 AEQ mortalities annually from 2008 through 2014, while fisheries to the North (particularly Canada) have averaged 77 AEQ mortalities annually during the same time period. Most SUS impacts to Dungeness Chinook occur in the winter/spring-time period since the Chinook start to return to the river in May. Currently, the main SUS fisheries impacting Dungeness Chinook are the Area 5 and 6 sport fisheries during the winter- time period (spring blackmouth fishery) and the Strait of Juan de Fuca treaty troll during the winter-time period with some smaller impacts associated with the same fisheries in the summer- time period. Tables 12 and 13 below represent recent CWT Recovery estimates from all North Pacific fisheries, although Dungeness Chinook CWT's are only detected in fisheries that electronically sample catch because Dungeness hatchery releases are not adipose clipped.

Table 11. Impacts on Dungeness Chinook by fishery expressed as adult equivalent (AEQ) mortalities.

FISHERY	2021	2020	2019	2018	2017	2016	2015	2014	2013	2012
Canada	111	146	177	162	149	120	106	53	63	200
Alaska	10	17	15	11	8	13	8	5	5	14
South of Falcon	0	0	0	0	0	0	0	0	0	0
North of Falcon Troll (NT)	0	0	0	1	0	0	0	0	0	1
North of Falcon Troll (TR)	9	9	10	7	2	4	5	3	4	9
North of Falcon Sport	2	2	3	1	2	1	1	1	1	2
PS Treaty Troll	4	7	10	3	1	3	1	3	5	5
Area 5 Sport	7	5	9	3	3	4	5	2	2	5
Area 6 Sport	3	4	9	10	5	5	2	7	6	5
Area 7 Sport	1	1	2	4	4	2	3	2	2	3
Area 8-13 Sport	5	4	6	8	4	3	9	2	2	4
PS Net (NT)	0	3	1	0	0	0	0	0	0	0
PS Net (TR)	4	2	2	9	0	4	3	2	2	3
Freshwater Sport	0	0	0	0	0	0	0	0	0	0
Freshwater Net	0	0	0	0	0	0	0	0	0	0
Escapement	673	766	911	869	696	511	407	198	271	614

* 2019 through 2021 represent pre-season runs with base period Round 7.1
* 2012 through 2018 represent post-season runs with base period Round 7.1.1

Table 12. Dungeness River Hatchery Spring Chinook Fishery Contributions.

Brood Years: 2009 to 2015 Fishing Years: 2011 to 2020		
Release Strategy	**Sub-Yearlings**	**Yearlings**
Average SAR	0.31%	0.04%
Fishery	**% Adults Recovered**	
Coastal Gillnet	0.5%	0.0%
Fish Trap (FW)	0.5%	5.1%
Hatchery Escapement	5.1%	0.0%
Northern	2.7%	3.9%
NT Ocean Troll	0.3%	0.0%
PS Net/Seine	0.0%	14.5%
Puget Sound Spt, May to Sep	1.1%	0.0%
Spawning Ground	88.4%	76.5%
Sport (Charter)	0.1%	0.0%
TR Ocean Troll	1.4%	0.0%

Table 13. Gray Wolf River Hatchery Spring Chinook Fishery Contributions.

Brood Years: 2009 to 2015 Fishing Years: 2011 to 2020	
Release Strategy	**Sub-Yearlings**
Average SAR	0.29%
Fishery	**% Adults Recovered**
Coastal Gillnet	0.4%
Fish Trap (FW)	0.6%
Hatchery Escapement	1.0%
Northern	3.3%
NT Ocean Troll	0.1%
PS Net/Seine	0.2%
Puget Sound Spt, May to Sep	0.2%
Spawning Ground	93.7%
Sport (Charter)	0.1%
TR Ocean Troll	0.3%

Data Gaps and Work to Continue

- Describe river entry timing
- Assess predation impacts on juvenile chinook in the river and bay
- Continue annual estimates of smolt production, and corresponding estimates of freshwater survival
- Continue to collect scale or otolith samples to describe the age composition of the terminal run

Elwha River Management Unit Status Profile (2022 PS RMP)

Component Populations

Elwha River Chinook

Background

The 45-mile (72 km) Elwha River drains 321 mi^2 (83 km^2) of the north slope of the Olympic Mountains into the Strait of Juan de Fuca. More than 80% of the watershed is located within Olympic National Park. Chinook (*Oncorhynchus tshawytscha*), steelhead/ rainbow trout (*Oncorhynchus mykiss*), coho (*Oncorhynchus kisutch*), chum (*Oncorhynchus keta*), pink (*Oncorhynchus gorbuscha*), sockeye (*Oncorhynchus nerka*), and bull trout (*Salvelinus confluentus*) are native to this system. The Lower Elwha Indian Reservation, home to the Lower Elwha Klallam Tribe, encompasses the lowest 2.17 miles (3.5 kms) of the River, where it empties into the Strait of Juan de Fuca. The Tribe's usual and accustomed fishing rights area, reserved in the 1855 Treaty of Point No Point, includes not only the Elwha River but also other surface streams that drain into the Strait of Juan de Fuca, as well as a large expanse of marine water.

The Elwha River is the site of the most significant fish passage barrier removal and ecosystem restoration project in United States history. For over a century prior to removal of the Elwha and Glines Canyon Dams, utilization by Chinook salmon and other salmonids, was confined to the lower 4.9 miles (7.9 kms) of the river below the Elwha Dam. A legacy of channel manipulation that altered the habitat-forming processes of alluvial sediment and large woody debris transport and deposition restricted most of the available spawning habitat to the river channel below the City of Port Angeles water diversion structure at RM 3.4 (Rkm 5.5). The Elwha River Ecosystem and Fisheries Restoration Act of 1992 authorized the Secretary of the Interior to pursue an agency process that has led to the removal of the two dams.

Dam deconstruction began in September 2011; demolition of the Elwha Dam was completed in March 2012, and the Glines Canyon Dam removal was completed in late August 2014. Additional demolition was completed in October 2015 and September 2016 to remove subsequent rockfall immediately downstream of the Glines Canyon dam, which had appeared to create a barrier to salmon migration. Removal of these dams restored access to approximately 71.5 miles (115 kms) of potential Chinook spawning and rearing habitat, allowing Chinook and the other species of Pacific salmon, as well as sea-run cutthroat and bull trout, to begin recolonizing a major watershed that had been blocked since 1913 (Hosey and Associates 1988).

Removal of the Elwha and Glines Canyon Dams has released a large proportion of the estimated 21 million m^3 (± 3 million m^3) of sediment stored behind the two dams. Approximately 7.1 million m^3 of this sediment was released during the first two years following dam removal (2011 and 2012), much of which has been transported and stored in river channels, floodplains, delta, and nearshore. Nearly 50% of the estimated sediment release is classified as fine (silt and clay) material, which could have adverse effects on downstream salmonid spawning habitats in the near term (Peters *et al.* 2017).

Status

Puget Sound Chinook Salmon and Puget Sound steelhead are both listed as threatened under the Endangered Species Act (ESA); an adaptive management framework has been adopted and federally approved to guide restoration and recovery of these species on the Elwha River. In 2012, the National Marine Fisheries Service (NMFS) issued a Biological Opinion (2012 BiOp) regarding the Hatchery and Genetic Management Plans (HGMPs) for five Elwha River hatchery programs operated by the Lower Elwha Klallam Tribe (four programs, including ESA-listed steelhead) and the Washington Department of Fish and Wildlife (WDFW) (one program, ESA-listed Chinook). Each HGMP provides detailed descriptions of the proposed operations for each salmonid species, including provisions for monitoring and evaluation activities.[34] In 2014-15, NMFS issued a supplemental Environmental Assessment (EA) and Biological Opinion (2014 BiOp), together with new decision documents, to confirm and fine-tune the 2012 BiOp. Together, these documents are the legal instruments that guide the recovery of ESA-listed salmonids in the Elwha River.

In 2014, an inter-agency group of fisheries scientists published the "Guidelines for Monitoring and Adaptively Managing Restoration of Chinook Salmon (*Oncorhynchus tshawytscha*) and Steelhead (*O. mykiss*) on the Elwha River" (Elwha Monitoring and Adaptive Management Plan or EMAM) (Peters *et al*. 2014). This EMAM describes a long-term recovery monitoring process requiring Federal, State, and Lower Elwha Klallam tribal scientists to work together to monitor and document changes in the abundance, spatial structure, genetic composition, and life history diversity of these populations during and after dam removal. Although some differences exist between the BiOp and the EMAM in defining recovery metrics and triggers that will guide transitioning through the four phases of recovery (Preservation, Re-colonization, Local Adaptation, and Viable Natural Population), congruity among the earlier recovery metrics is sufficient to help define the abundance thresholds identified in this MUP.

Viable Salmon Population (VSP) metrics – including abundance, productivity, spatial distribution, and diversity (McElhany *et al*. 2000) – are used to monitor and adaptively manage the salmon recovery process, functioning as trigger values for moving the Elwha Chinook salmon recovery process through the four distinct biologically based restoration phases of Preservation, Recolonization, Local Adaptation, and Viable Natural Population, as defined in the 2014 EMAM. Several of these VSP metrics rely on data describing adult abundance, productivity, the proportion of natural and hatchery fish, and the number of out-migrating smolts.

Abundance: SONAR enumeration

Prior to dam removal, adult enumeration was conducted using foot and boat surveys as well as rack returns to the hatchery to estimate the returning numbers of Chinook salmon. Dam removal was expected to make visual techniques even more limiting as sediment levels increased during

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[34] The Lower Elwha Tribal hatchery is authorized to propagate steelhead, coho, chum, and pink salmon. However, with limited broodstock available, chum have been propagated only opportunistically, while pink salmon have not yet been propagated due to poor returns. WDFW collects Elwha Chinook broodstock to support hatchery incubation at its Dungeness and Sol Duc hatcheries; yearlings and zero aged juveniles are returned to the Elwha for release from the WDFW Rearing Channel.

and immediately following project implementation. Facing the prospect of not being able to accurately enumerate any species of salmon following dam removal, National Oceanic and Atmospheric Administration (NOAA) awarded a grant to the Lower Elwha Klallam Tribe to assess the feasibility of counting returning salmon with a SONAR camera (Didson Corporation) (Lower Elwha Klallam Tribe 2016).

Initial efforts to evaluate the Didson camera were made in 2010 and 2011 and focused solely on returning Chinook salmon. A camera power and mounting system was developed and the unit was deployed into the lower mainstem during the Chinook migration period (June to early October). The timeframe was expanded in 2012 to estimate wild winter steelhead returning to the Elwha River from late winter through early summer. In 2013, a second SONAR system (Didson multi-beam) was added in the Hunt Road Channel (HRC) complex at RM 0.5 (Rkm 0.8). The SONAR equipment cannot monitor during periods of high flow and turbidity events, so passage during these periods is estimated by averaging passage from four days before and after each data gap. Due to technical malfunctions, the first SONAR estimates of Chinook returns to the Elwha River were in 2012 (Table 1). Prior to 2012, Chinook escapement was measured as the sum of hatchery broodstock and returns, and naturally spawning Chinook.

The 2020 Chinook escapement estimate of 3,250 is smaller than the average of the projection (~4,000) going back to 2009 (Table 1). This year's return is roughly equal to the average Chinook run going back to 1986 (Figure 1). Most Elwha Chinook salmon out-migrate as age 0+ fingerlings and spend three to five years at sea before returning to spawn. The vast majority of Elwha Chinook are age three or four when they return as adults. Therefore, a majority of the 2020 returning adults were spawned, incubated, and subsequently out-migrated during the fall, winter, and spring of 2017 and 2018 which saw several high flow events. While most of the sediment in the reservoirs has stabilized (Ritchie *et al*. 2018), it is unclear how much sediment impacts may be influencing Chinook egg incubation and survival in the mainstem at this point. These impacts have resulted in very few naturally produced juvenile out-migrants between 2014 and 2018 (McHenry *et al*. 2020). However, in 2019 and 2020 approximately 571,000 and 950,000 natural 0+ out-migrants were estimated to have been produced in the river (McHenry *et al*. 2021). Some portion of the out-migrants in 2019 would return to the river as 2-year-old jacks in 2020 which could explain the increased proportion of jacks in our net sampling that year (Denton *et al*. 2020).

Table 1: Annual estimates of adult Chinook returning to the Elwha River. The return was broken into percent Hatchery Origin (pHOR) using carcass sampling for coded-wire tags (CWTs), otolith marks, and scale patterns. Age determinations were made with scale analysis. There were four ceremonial fish harvested each year that are included in the SONAR estimate. Fish that entered the hatchery and were returned to the river are counted as natural spawners. (Weinheimer *et al.* 2021). Not included in Table 1 are four Chinook salmon harvested per year allocated to ceremonial purposes. The first SONAR estimates for Chinook were made in 2009 but co-managers opted to use the historic method (sum of hatchery returns plus naturally spawning Chinook based on redd surveys). The first SONAR estimate of Chinook returns to the Elwha River used for management purposes was in 2012 (as shown in table below).

Return Year	Sonar estimate	Hatchery Broodstock	Natural Spawners	pHOR Samples	pHOR	Age Samples	Age-2	Age-3	Age-4	Age-5	Age-6
2007	NA	760	380	NA	NA	557	3%	13%	79%	5%	1%
2008	NA	667	470	NA	NA	216	0%	69%	25%	6%	0%
2009	NA	1514	678	298	98%	283	0%	5%	94%	1%	0%
2010	NA	709	569	275	94%	401	15%	28%	18%	40%	0%
2011	NA	1010	852	992	97%	407	11%	56%	33%	0%	0%
2012	2,638	979	1655	103	90%	157	5%	64%	29%	3%	0%
2013	4,243	1813	2426	934	95%	413	2%	23%	72%	3%	0%
2014	4,360	1847	2509	783	96%	738	1%	23%	57%	19%	0%
2015	4,112	1556	2552	848	94%	728	1%	20%	65%	14%	1%
2016	2,628	605	2019	546	96%	449	6%	9%	62%	23%	0%
2017	3,083	1053	2026	1079	96%	898	5%	60%	30%	5%	0%
2018	7,107	1837	5266	742	98%	658	0%	50%	49%	1%	0%
2019	7,600	1289	6307	609	97%	460	1%	10%	85%	4%	0%
2020	3,250	624	2626	402	93%	348	2%	38%	41%	19%	0%

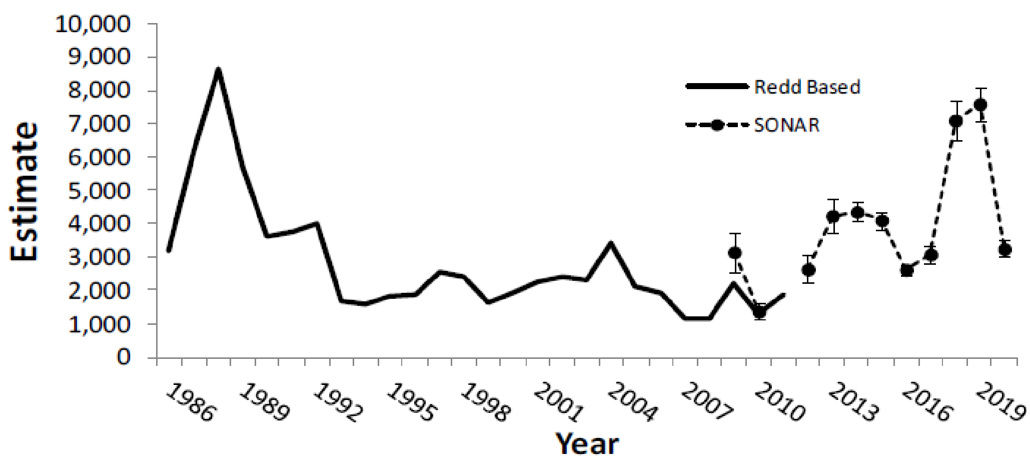


Figure 1: Trend in Elwha Chinook escapement 1986-2020. Chinook escapement was measured by SONAR from 2012 to present. Prior to 2012, Chinook escapement was the sum of hatchery broodstock/returns and field estimates of naturally spawning Chinook (Denton *et al.* 2020).

To estimate the abundance of natural-origin salmon, the proportion of the total return that was produced in hatcheries was subtracted from the overall abundance. WDFW carcass surveys conducted between 2009 and 2020 have found that the overall proportion of hatchery-origin Chinook among all Chinook returning to spawn was 95.4% (Figure 2) (data source Weinheimer *et al*. 2021).

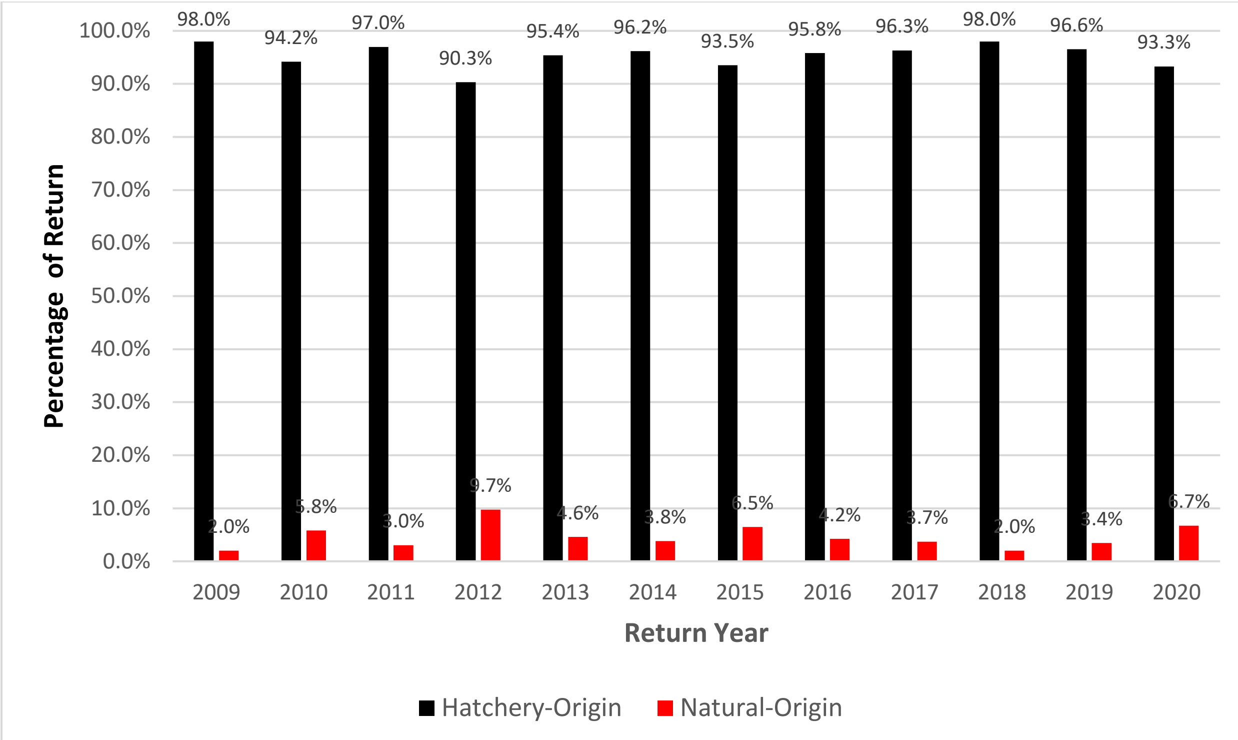


Figure 2: Percent composition of hatchery- vs. natural-origin spawning Chinook detected in the Elwha River between 2009 and 2020 (Data source Weinheimer *et al*. 2021).

Productivity:

Hatchery marks – such as coded-wire tags (CWT) or adipose and otolith marks – in combination with SONAR counts and age data from scale collections (Table 1) provided the adult return estimates needed to evaluate spawner-to-spawner productivity for Chinook spawning naturally in the river (of hatchery- and natural- origin).

Spawner-to-spawner ratios for natural spawners and natural-plus-hatchery spawners are available for complete brood years 2004 through 2015, and returns through age-4 are available for brood year 2016. Across the entire time series, natural spawner productivity averaged 0.16, or roughly one returning adult for every six natural spawners, well below the replacement value of 1.0 (Table 2a). Hatchery plus natural spawners had a combined average of 1.5 returning adults per spawner for complete brood years 2004-2015, and each of the four consecutive brood cycles from 2008 - 2011 exceeded the replacement value of 1.0 (Table 2b). Both natural (Table 2a) and hatchery-plus-natural spawners (Table 2b) showed decreases in productivity coinciding with dam removal activities in 2012. Brood year 2015 yielded the highest hatchery-plus-natural spawner-to-spawner ratio observed in the time series (2.64, Table 2b) (Weinheimer *et al*. 2021).

Table 2a: Spawner per spawner ratio for naturally spawning Chinook (HOR and NOR) salmon in the Elwha River, brood years 2004-2017. (Weinheimer *et al*. 2021, Table 13).

Brood Year	Natural Spawners	Natural-origin returning adults						Recruits per natural spawner
		Age-2	Age-3	Age-4	Age-5	Age-6	Total	
2004	2075	NA	16.4	47.5	0.5	0	64.4	0.03
2005	835	2.1	10.6	41.4	29.6	0	83.6	0.10
2006	693	0.0	2.3	13.2	0.1	0	15.7	0.02
2007	380	0.0	20.6	18.6	6.5	0	45.8	0.12
2008	470	11.2	31.3	73.4	5.7	0	121.6	0.26
2009	678	6.4	163.1	140.0	32.4	1.8	341.9	0.50
2010	569	13.1	45.4	95.1	37.4	0.2	190.9	0.34
2011	852	4.3	38.4	172.6	25.1	0.0	240.3	0.28
2012	1655	1.2	52.8	68.1	5.9	0.0	127.9	0.08
2013	2426	2.2	10.3	33.7	1.1	0.6	47.3	0.02
2014	2509	6.6	68.6	70.1	10.3	0.0	155.6	0.06
2015	2552	6.1	72.3	222.8	42.0		343.2	0.13
2016	2019	0.2	26.8	89.1			116.1[A]	0.06[A]
2017	2026	1.7	82.8					

[A] Incomplete cohort, age-5 offspring will return in 2021.

Table 2b: Spawner per spawner ratio for all spawners in the hatchery and in the river (natural + hatchery origin) Chinook in the Elwha River, brood years 2004-2017. (Weinheimer *et al*. 2021, Table 14).

Brood Year	Hatchery + Natural Spawners	Returning adults (NOR+HOR)						Recruits per spawner
		Age-2	Age-3	Age-4	Age-5	Age-6	Total	
2004	3,439	NA	143	279	23	0	446	0.13
2005	2,231	29	787	2,056	508	0	3,380	1.52
2006	1,920	0	116	227	5	0	348	0.18
2007	1,140	0	355	614	67	0	1,036	0.91
2008	1,137	192	1,036	756	123	0	2,107	1.85
2009	2,192	211	1,680	3,041	846	28	5,806	2.65
2010	1,278	134	986	2,481	576	6	4,183	3.27
2011	1,862	92	1,003	2,660	596	0	4,351	2.34
2012	2,634	31	813	1,618	158	0	2,620	0.99
2013	4,239	34	245	910	54	17	1,259	0.30
2014	4,356	158	1,850	3,467	297	0	5,772	1.33
2015	4,108	165	3,575	6,460	626		10,825	2.64
2016	2,624	11	777	1,326			2,113[A]	0.81[A]
2017	3,079	50	1,233					

[A] Incomplete cohort, age-5 offspring will return in 2021.

By combining the carcass samples with the SONAR data (Table 1), it was estimated that 209 (6.7%) of the non-jack adults returning in 2020 were of natural-origin. The 2020 return was dominated by age-3 hatchery-origin Chinook salmon that were spawned in 2017 and released during spring of 2018 as sub-yearlings as well as by age-4 hatchery-origin Chinook that were spawned in 2016 and released as sub-yearlings in the spring of 2017.

Diversity: juvenile and adult life histories of Chinook returning to the Elwha River

Currently, the vast majority of natural-origin Elwha Chinook exhibit the ocean-type juvenile life history strategy (migrate seaward as sub-yearlings) (McHenry *et al*. 2015). It is hypothesized that access to the upper watershed might allow for a stream-type, early returning life history trait (seaward migration as yearlings) (Pess *et al.* 2008, McHenry *et al.* 2016). Adult Chinook return timing is currently from June into September, peaking in July. The July peak timing is similar to summer Chinook populations in North Coast rivers and in the Dungeness River to the east along the Strait of Juan de Fuca. Return timing may broaden as the population transitions to natural origin and increases in numbers. Elwha Chinook spawning occurs from late August to mid-October, similar to the North Coast and Dungeness summer Chinook populations. North Coast populations (Queets, Hoh, and Quillayute systems) also host fall Chinook that return in larger numbers and peak in mid-October. It remains to be seen if this life history pattern will develop in the Elwha.

Spatial distribution:

While Chinook redds have been observed as far upstream as Godkin Creek (RM 34.2, ~Rkm 55), the number of spawners accessing upstream habitats above Rica Canyon (RM 14.5, Rkm 23.4) has been disappointing thus far (see Appendix A for the 2012-2020 time-series of Chinook redd spatial distribution). McHenry *et al*. 2021, at page 11, have noted as follows:

> In 2020, the number of Chinook redds observed was the third lowest since inception of the project. A total of 625 Chinook redds were counted with the majority (52.6%) in the middle Elwha, followed by the Lower Elwha (30.4%) and upper Elwha (16.9%). We observed three discrete areas of high Chinook redd density including the reach from the Highway 112 Bridge downstream to the Elwha River Road Bridge, Indian Creek, and the former Mills Reservoir surface. Although the total number of redds was low, the percentage that spawned above the former Glines Canyon site was the highest to date. Those Chinook that ascended above Glines Canyon spawned only on the former Mills Reservoir surface as well as Cat and Boulder Creeks. No adult Chinook or redds were observed upstream of Rica Canyon in 2020. In previous years, Chinook and sockeye adults have been documented above Rica Canyon. Coho juveniles have been observed in Geyser Valley since 2019, but no coho redds were encountered in that reach during surveys in 2020.

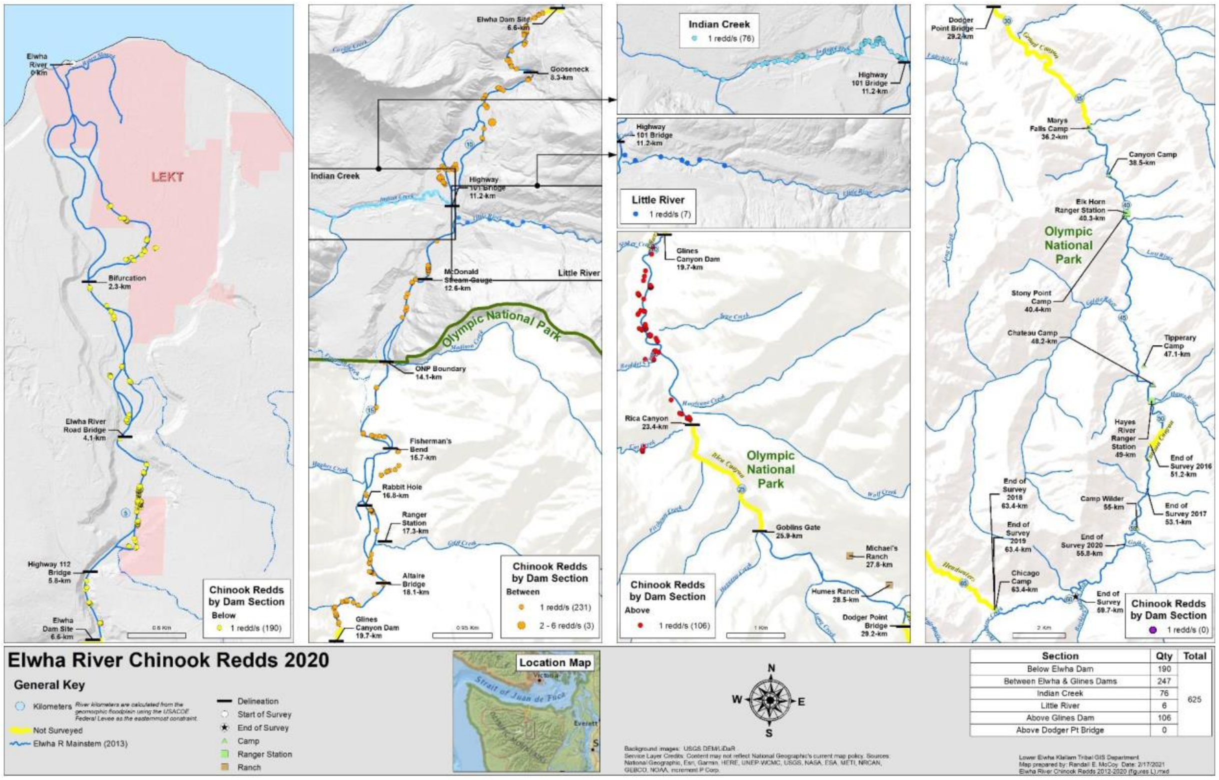


Figure 3: Distribution of Chinook salmon redds in the Elwha River in 2020 (McHenry *et al.* 2021, Figure 2). A longer time-series of Chinook redd spatial distribution from 2012-2020 is in Appendix A.

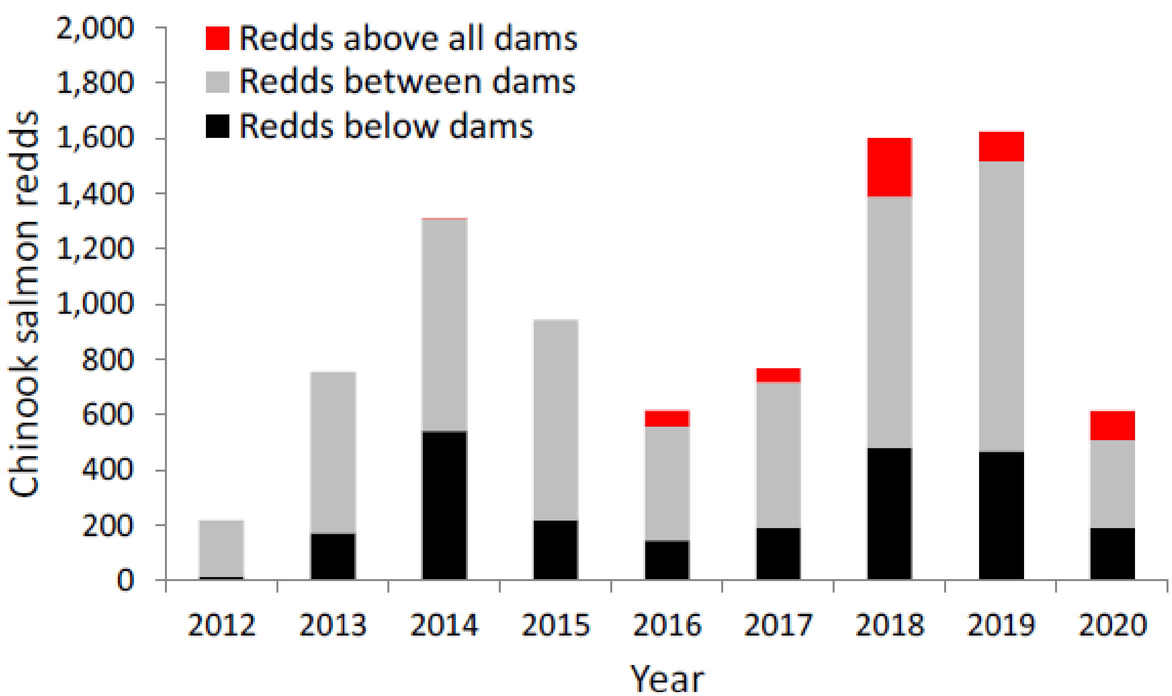


Figure 4: Utilization of the Elwha River by Chinook salmon since dam removal. Black bars indicate the number of Chinook redds below former Elwha dam. Grey bars indicate the number of Chinook redds between former Elwha

dam and former Glines Canyon dam, and red bars indicate the number of redds above former Glines Canyon dam (McHenry *et al.* 2021).

Harvest Distribution and Exploitation Rate Trends

FRAM (the Fisheries Regulation Assessment Model) is used by the Treaty Tribes and State of Washington (WDFW) co-managers during pre-season fisheries planning and post-season evaluations to estimate rates of exploitation for pre-terminal fisheries (Table 4). FRAM uses fishery data that includes catches, size limits, encounters, growth functions, mark rates, and abundances to calculate CWT-derived exploitation rates by stock, age, fishery, and time period.

Table 3: Total Adult-Equivalency Exploitation Rates (AEQ ERs) of Elwha River Chinook (FRAM Validation Runs V7.1). 2019 to 2021 ERs are based on pre-season run estimates using the FRAM v7.1 base period (post-season validation not yet available).

Year	Total ER	Northern ER	SUS ER	PT-SUS ER	Terminal ER
1992	80.1%	53.1%	27.1%	24.8%	2.3%
1993	49.7%	31.0%	18.6%	14.7%	3.9%
1994	51.7%	28.4%	23.3%	21.9%	1.4%
1995	40.1%	23.9%	16.2%	16.1%	0.1%
1996	21.7%	11.0%	10.7%	10.6%	0.1%
1997	10.2%	6.7%	3.5%	3.0%	0.5%
1998	23.4%	17.5%	6.0%	5.9%	0.1%
1999	22.1%	17.6%	4.5%	3.5%	1.0%
2000	32.0%	23.7%	8.3%	8.3%	0.0%
2001	20.2%	15.2%	5.0%	5.0%	0.0%
2002	23.9%	19.4%	4.5%	4.5%	0.0%
2003	27.6%	22.3%	5.3%	5.3%	0.0%
2004	29.6%	21.8%	7.8%	7.8%	0.0%
2005	25.6%	20.6%	5.0%	4.8%	0.1%
2006	23.8%	18.7%	5.1%	5.0%	0.2%
2007	26.9%	22.8%	4.1%	3.8%	0.3%
2008	23.0%	18.5%	4.6%	4.3%	0.3%
2009	32.5%	26.0%	6.5%	6.5%	0.0%
2010	22.4%	17.3%	5.1%	4.6%	0.4%
2011	29.6%	23.2%	6.3%	6.1%	0.2%
2012	30.3%	25.7%	4.6%	4.4%	0.1%
2013	26.4%	19.5%	6.9%	6.9%	0.0%
2014	30.8%	22.6%	8.3%	8.2%	0.1%
2015	26.5%	21.1%	5.4%	5.4%	0.1%
2016	23.8%	20.0%	3.8%	3.8%	0.0%
2017	20.3%	17.8%	2.5%	2.5%	0.0%
2018	19.5%	15.4%	4.1%	4.1%	0.0%
2019	20.8%	16.1%	4.7%	4.7%	0.0%
2020	20.8%	16.1%	4.7%	4.7%	0.0%
2021	20.8%	16.1%	4.7%	4.7%	0.0%

Elwha and Dungeness Chinook CWT release groups were not adipose fin clipped during the updated base period years used to calibrate the FRAM. The FRAM is used by the co-managers during preseason fisheries planning and postseason exploitation rate evaluation, and an adipose fin clip is essential for CWT detection in many FRAM fisheries. For example, many Northern fisheries do not electronically sample unmarked fish and CWTs would only be recovered from marked fish in mark-selective fisheries. Therefore, for the new Base Period FRAM calibration, a surrogate procedure was used to simulate the Elwha and Dungeness River Chinook (ELDU) CWT recoveries. After an analysis of Salish Sea Chinook populations, it was determined that the

Stillaguamish Chinook population was the best proxy for ELDU exploitation in fisheries outside of the Salish Sea (McHugh, unpublished). For pre-terminal fisheries outside the Salish Sea, ELDU CWT recoveries were simulated using a one-to-one ratio with Stillaguamish CWT recoveries from the new Base Period. For fisheries inside the Salish Sea, ELDU CWT recoveries were based on Stillaguamish CWT recoveries from the new Base Period, and the historic relationship of CWT recoveries between ELDU and Stillaguamish in years when both management groups were released with CWTs and adipose fin clips (Gordon Rose, NWIFC, personal communication). The accuracy of FRAM's projections of Elwha Chinook exploitation may be limited by the small stock size and surrogate procedure. However, while sufficient sample sizes of adipose- clipped, coded wire tagged Elwha Chinook are not available to use in FRAM, the co-managers will continue to develop and adopt conservation measures that protect Elwha Chinook, while realizing the constraints on quantifying their effects in the simulation model. Beginning with the release of 2012 brood, a portion of the annual releases from the Elwha Chinook hatchery program have been marked with an adipose fin clip and otolith mark, and tagged with a CWT. There were data issues with the 2013 brood releases, and few CWTs (n=2) were recovered associated with tag codes from that brood year. However, recovery data are now available for brood years 2012, 2014, 2015 (age 2, 3, and 4 only), and 2016 (age 2 and 3 only). The co-managers currently believe that there should be sufficient years of Elwha CWT recovery data to use an out-of-base procedure to represent Elwha Chinook in FRAM during the life of this Resource Management Plan, likely by 2023 or 2024. This approach should be a significant improvement to modeling these units over the surrogate method currently used. Once FRAM is updated with CWT data from Elwha Chinook, the co-managers will review the resulting ER estimates for Elwha Chinook. It is up to the local co-managers to achieve a consensus on updates to FRAM and modifications to management objectives, and these can be based on any number of considerations.

Management Considerations

Recovery of Elwha Chinook salmon populations will require significant habitat, harvest, and hatchery management actions, and the integration of these actions with one another. Because the outcome of salmon recovery efforts depends on this combined and cumulative effort, the effectiveness of actions in one of these areas is best evaluated when informed by the status of actions in the other areas. Harvest management plans typically acknowledge that productivity is dependent on the state of fresh- and salt-water habitats, and assume a constant habitat condition. Habitat restoration plans typically state that their effectiveness is predicated on continued control of harvest levels. Hatchery plans assume stable harvest rates and habitat conditions.

For example, the effectiveness of harvest management planning depends critically on habitat conditions. If habitat is functioning properly in all areas affecting all life history stages of a salmon stock, then the failure of the stock to respond to a harvest rate reduction might mean that the harvest rate reduction was not sufficient to allow recovery. On the other hand, if the habitat supporting a stock is significantly degraded or lost, then the failure of that stock to respond to a harvest rate reduction most likely cannot be addressed through further harvest rate reductions alone. Lost habitat must be restored and degraded habitat must be upgraded for harvest management to be effective. The same is true for hatchery management actions. The dam removals on the Elwha River have provided an opportunity for the Lower Elwha Klallam Tribe and the State of Washington to implement and integrate all three areas of harvest, hatchery, and habitat management.

Brief Description of Current Management Approaches

Adaptive Management and Recovery

The harvest strategy for Elwha Chinook salmon during the early stages of recovery is to limit overall fishery-related mortality to a level that will allow the Elwha Chinook population to increase (Ward *et al.* 2008). Recovery of Elwha Chinook as the population expands into the upper watershed depends on the transition from primarily hatchery origin to natural origin recruits. To encourage this process and maximize the number of spawners in the Elwha, the Lower Elwha Tribe, WDFW, and Olympic National Park have, since spring of 2012, jointly implemented a fishing moratorium in the Elwha River that precludes all in-river fishing of all species. The moratorium will remain in effect through spring of 2022, at which time it will be re-assessed on a species-by-species basis to determine if resumption of one or more fisheries may be appropriate. No in-river fishery, other than ceremonial and subsistence (C&S) fishing, will be directed on Chinook in the Elwha River during the 10-year planning period, and incidental bycatch impacts to Chinook by other in-river fisheries that may take place during the term of the Resource Management Plan of which this MUP is a part will be subject to the Southern U.S. (SUS) exploitation rates agreed to by the co-managers. Other non-Chinook directed fisheries may exist in the future that may place impacts on bull trout and steelhead, but impacts to other species will be addressed outside of the context of this MUP.

WDFW and the Lower Elwha Tribe remain concerned about the impact to Elwha Chinook from the current levels of Canadian and Alaskan harvest of this stock (Table 3). These harvest rates, with more than 75% of the fishery mortality exerted by Alaska and Canada fisheries, result in reduced terminal area returns, a disproportionate burden of conservation, and heavy constraints on Washington fisheries, which are managed to meet specific objectives for Puget Sound ESA-listed Chinook salmon.

Fishing regulations affecting Chinook salmon in the area from Southeast Alaska to south of the Columbia River are determined annually through the regional North of Falcon process and the international Pacific Salmon Commission in a manner that makes cumulative harvest impacts on salmon originating from the Elwha River basin predictable. Fisheries in U.S. waters other than Alaska that affect ESA-listed Elwha Chinook salmon are developed according to the co-managers' harvest management plan.

The 2012 Biological Opinion (NMFS 2012) acknowledges that Elwha River Chinook salmon propagated by the WDFW hatchery program will be a key component of watershed restoration during early stock preservation and subsequent phases of recovery following dam removal. To promote the goal of restoring Chinook salmon to the Elwha River during the Preservation and Recolonization phases of recovery, hatchery supplementation is required to achieve desired adult return levels and to maintain the genetic characteristics of the extant population (WDFW Elwha River Summer/Fall Chinook HGMP 2012; HSRG 2012). *See also* National Marine Fisheries Service, 2011, Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation. NMFS Consultation Number: F/NWR/2010/06051 at page 135 (NMFS 2011) (2011 BiOp). Various field monitoring activities are also required under the BiOp to estimate productivity of Chinook salmon and steelhead (redd counts, outmigrating smolts, etc.). There is no precedent for estimating the effects that removal of two large dams will have on the spawning and rearing habitat of five critically depressed populations of anadromous salmonids, two of which are listed as threatened under the ESA. The 2012 Biological Opinion recognizes the prudence of a restoration strategy that preserves as many options as possible. The lowest risk option, and the one recommended by the Elwha River Fish Restoration Plan (Ward *et al*. 2008), was to combine hatchery supported propagation with natural passage of adult fish upstream of the former dam sites to spawn naturally. The desire to ensure that useful progress towards fish restoration would occur within a 20- to 30-year timeframe was also a factor in supporting hatchery supplementation to ensure the recovery of natural-origin Chinook in the Elwha River watershed (Ward *et al*. 2008).

It should be noted that the majority of the management period in which this RMP is in effect, Elwha Chinook populations will likely be within the Recolonization phase of recovery (NMFS 2012). With pHOS values consistently hovering near 0.95 since dam removal, a significant upward shift in the proportion of natural spawners will be required prior to any transitioning to Local Adaptation, the next phase of recovery. The management goal of the Preservation phase was focused on protecting the species from extinction during the post-dam removal period when high sediment loads were expected, at times, to be lethal to fish. For a successful and significant pNOS increase to occur, the contribution of hatchery-origin Chinook will continue to be critically important during the tenure of this RMP. The spatial distribution trigger ("portion of population accessing above Elwha Dam") has already been met (McHenry *et al*. 2018), the abundance trigger (natural spawners > 950) has already been met (Denton *et al*. 2017, and prior SONAR reports) and there are no diversity or productivity triggers required to remain in the Recolonization Phase (NMFS 2012).

As Chinook recovery moves from the Recolonization to the Local Adaptation Phase, hatchery influence will be scaled back in response to an expected increase in the proportion of natural-origin Chinook (Figure 2). The currently low abundance of NOR Chinook and the much greater abundance of the HOR component, will necessitate continued hatchery augmentation throughout the Recolonization Phase (NMFS 2012). Consequently, both the natural and hatchery components of the current Elwha Chinook population are essential to recovery and are managed under the same harvest regulations.

Harvest Management

The Lower Elwha Klallam Tribe and WDFW, as co-managers of fisheries resources of the Elwha River system, are responsible for establishing harvest management regulations for all salmonid stocks. A fishing moratorium has been in place for terminal fisheries on the Elwha River since the start of the dam removal process in 2011. The moratorium is intended to promote the recolonization and recovery of all native salmonid populations until self-sustaining populations are established. The fishing moratorium will likely extend well into the RMP management horizon for most species, as Elwha River salmonid populations are still in the early stages of recovery. Apart from ceremonial and subsistence fisheries, Chinook salmon are unlikely to be targeted for terminal sport or commercial fisheries. Management abundance thresholds are being slightly increased to help facilitate ongoing recovery efforts because salmonid recovery in the Elwha River system is still in its early stages.

The Low Abundance Threshold (LAT) escapement level is being adjusted upward in order to better align escapement goals with the VSP restoration strategies for Elwha Chinook (NMFS

2012; Peters *et al*. 2014). This addresses the use of VSP criteria required by NMFS's 4(d) Rule, 50 C.F.R. § 223.203(b)(4)(B), and the need to establish viable Upper Management Threshold (UMT) and critical (LAT) escapement targets. Currens, 2018, has noted:

> Analysis of the demographic data for Elwha River Chinook Salmon from 2004-2015, when natural spawning abundances ranged from 380 to 2,548, indicates that, were similar return patterns to occur in the future, the population would likely maintain an average inbreeding genetic effective size of 1,962 (95% CL: 1,573-2,079). Similarly, analyses based on the worst-case scenario of escapement levels at a Low Abundance Threshold (LAT) of 1,500 spawners indicate that the inbreeding genetic effective size would likely be 1,996 (95% CL: 1,716-2,080). Although the global effective size for Elwha River Chinook was not calculated, genetic data indicate that they are likely part of the same meta-population as Dungeness River Chinook (Ruckelshaus *et al*. 2006), which was previously calculated as a global genetic effective size of approximately 5,520. (K. Currens, personal communication, August 23, 2018).

The previously adopted Low Abundance Threshold (LAT) of 1,500 Chinook included 500 Chinook for annual broodstock collection and 1000 fish for natural spawning. With the spawning habitat made available after dam removal, the co-managers have agreed to increase the critical escapement level at the LAT to 2,000 Chinook, including 500 Chinook for annual broodstock collection and 1500 fish for natural spawning. This better reflects analyses based on the worst-case scenario of escapement levels indicating that the inbreeding genetic effective size of Elwha Chinook would likely be 1,996 to maintain genetic diversity. This addresses the provision of the 4(d) Rule, 50 C.F.R. § 223.203(b)(4)(C) by managing for an escapement goal that surpasses minimum genetic inbreeding effective size that maximum exploitation rates must not appreciably reduce the likelihood of survival and recovery of the ESU. Escapement forecasted to be between 1,500 and 2,000 Chinook will trigger a critical SUS exploitation rate of 6%. It is anticipated that the annual escapement of Elwha Chinook will exceed this LAT threshold during the 10-year scope of the RMP based on escapement data and increased levels of outmigration in recent years. We also expect exploitation rates for the duration of the plan to remain similar to rates seen over the past 10 years.

The new LAT of 2,000 Chinook salmon agreed to by the co-managers is a more appropriate low abundance threshold for the expanded habitat capacity of the recovering Elwha River system. Over the last few years, Elwha Chinook salmon have maintained total escapement levels well above 2,000 Chinook needed to avoid invoking the LAT and the consequent lower SUS harvest rate ceiling. Escapement to natural spawning habitat is currently expanding as a result of improvements in the quantity and quality of spawning and rearing habitat. Historical escapements since 1988 suggest a high degree of confidence that greater than 2,000 spawners will return to natural spawning areas during the RMP management period, even after hatchery broodstock are collected (Figure 1). However, 2020 Chinook escapement (3,250) and early estimates for 2021 escapement (likely <3000) suggest that escapement levels remain volatile in the early years of Elwha River recovery. Monitoring the recovery of Elwha Chinook by the co-managers in the context of marine exploitation rates will be critical as recolonization and recovery continues.

When terminal abundances exceed the LAT, a 10% UMT exploitation rate will be imposed on SUS fisheries to assist recovery by providing sufficient escapement to the river to rebuild the natural spawning potential of the watershed as the population continues expanding into the upper watershed while continuing to provide broodstock for the supplementation program. The co-managers have agreed that this 10% Upper Management Threshold exploitation rate will be implemented at abundances up to and above the target threshold escapement of 5,789 Chinook, including 500 Chinook for annual broodstock collection and 5289 fish for natural spawning. This target escapement level is based on meta-analysis of watershed area and MSY spawning levels conducted by Parken *et al.* (2006). The meta-analysis used data from 25 Chinook salmon stocks from Alaska to the Oregon coast to estimate the relationship between watershed area and S_{MSY}, or between watershed area and the equilibrium spawning level. Stocks had a wide range of watershed areas and included both ocean- and stream type life histories. Versions of the model were developed for life history type and geographic location (north or south of the central coast of British Columbia). The Parken model was used to estimate S_{MSY} for Chinook salmon in the Elwha River. S_{MSY} was estimated using equation 4 from Parken *et al*. (2006):

$$\hat{\gamma} = x^{\hat{b}} e^{(\ln(\hat{\alpha}) + \frac{\hat{\delta}^2}{2})}$$

with a watershed area of 833 km^2 (Pess *et al.* 2008). Estimates of S_{MSY} ranged from 2,253 to 5,789 for the model derived for different life history types and for the South geographic area (Table 5).

Table 4. Estimates of S_{MSY} for Elwha Chinook salmon for three variation of the Parken model. All parameter estimates are from Parken *et al.* (2006).

Parken Model Type	$\ln(\hat{a})$	$\hat{b}$	δ^2	S_{MSY}
Ocean Life History Type	2.20	0.914	0.146	4,535
Stream Life History Type	2.92	0.692	0.293	2,253
South Geographic Region	4.64	0.579	0.260	5,789

The 5,789 S_{MSY} output was chosen as the UMT escapement threshold as it recognizes latitudinal north-south geographic region differences in reference watershed conditions and was considered justifiable given Parken *et al.* use of degraded watersheds in their meta-analysis versus the Elwha River's relatively pristine watershed condition.

The 10% SUS exploitation rate limit and the current lack of any freshwater fisheries in the Elwha River effectively maximize the escapement and subsequent spawning of Chinook in the river and hatchery for each return year. When the Elwha fishing moratorium expires, any in-river fisheries directed at other species will be structured to avoid Chinook impacts by managing fisheries in-river so as not to exceed 6% (LAT) or 10% (UMT) SUS. However, to provide a further layer of protection for Elwha Chinook, a lower bound (LB) escapement threshold of 1,500 Chinook has been established below which co-managers will reach agreement on what, if any, incidental and ceremonial and subsistence fisheries will occur.

Recommended broodstock goals for Elwha Chinook are anticipated to change as the population advances through the four stages of restoration (NMFS 2012). For the duration of this plan, the population will likely remain in the Recolonization phase where the broodstock goals are <1700

(WDFW HGMP 2012). Logistical constraints in collecting adults that return to the hatchery and the river have precluded achieving the broodstock goal in three of the last five years, despite terminal escapements that exceed the goal. From 2012-2020, on average ~30% of the terminal escapement returned to the hatchery or was collected from the river for broodstock. We anticipate the same logistical constraints going forward, leading to similar success reaching broodstock goals observed over the last 5 years.

To predict the likely impact of the harvest thresholds and corresponding exploitation rates defined in this profile, we can rely on data from recent years with the same broodstock goals. From 2012-2020, terminal Chinook abundances averaged 4,336 fish (SONAR estimate, Table 1) with natural origin Chinook making up 5.0% of the total return. Preseason forecasted abundances exceeded the previous LAT of 1,000 Chinook (and the new LAT of 2,000) in all of these years, allowing up to a 10% SUS exploitation rate in SUS fisheries. The average SUS exploitation rate from 2012-18 on Elwha chinook was ~5.1% (TAMM "ER ESC Overview"), which equates to an average of 13 natural fish adult equivalent mortalities (FRAM 2021). We anticipate returning abundances of Elwha chinook and the proportion of natural origin fish to increase over the duration of this plan as returning Chinook continue to expand their use of the newly available spawning habitat as shown in Figure 3.

Hatchery Management

The Elwha River Fish Restoration Plan (Ward *et al.* 2008) identifies two main strategies for Chinook stock restoration in the Elwha River: natural recolonization and hatchery supplementation. Hatchery operations are a necessary component of the preservation and restoration strategies outlined in the fish restoration plan. The use of hatcheries to restore and preserve stocks is supported by the trust responsibilities of the federal government to exercise its authorities to promote a meaningful harvestable surplus of anadromous fish in which Indian tribes have reserved fishing rights under treaties with the United States and the Tribes. In particular, the Lower Elwha Klallam Tribe has reserved fishing rights under the 1855 Treaty of Point No Point, and the Lower Elwha Klallam Reservation is located on the Elwha River, where the Tribe operates a hatchery with funding support from the United States and intends to engage in on-Reservation harvest at the conclusion of the current moratorium. Additional Tribes hold treaty fishing rights in marine waters through which Elwha River Chinook, Steelhead, and other salmonids migrate.

Achieving the various restoration thresholds outlined in the Elwha Fish Restoration Plan relies heavily on increasing natural-origin spawning abundance, (Peters *et al.* 2014). To reach a sustainable recovery of Chinook, Ward *et al.* (2008) stipulates that Elwha Chinook spawners must maintain a proportion of natural influence (PNI - proportion of the spawning stock that is of natural origin) greater than 67%. However, Peters *et al.* (2014) established goals for reducing hatchery influence that far exceed the 67% PNI by designating the transitional trigger value required to move from the Local Adaptation Phase to full recovery as zero percent hatchery-origin fish (i.e., elimination of hatchery production). At this time, however, approximately 95% of Chinook spawning in the Elwha River are of hatchery-origin (Figure 2).

Importance of Hatchery-Harvest Integration

Adjustments to hatchery production may be initiated in the latter portion of this ten-year resource management plan as Elwha Chinook transition from the Colonization to Local Adaptation phase (Table 5). Tribal subsistence fisheries may be considered by the co-managers as a means of managing pHOS in the lower river and increasing the ratio of natural- to hatchery -origin spawners in the river. Other key measures are productivity greater than 1.56 recruits per natural spawner, and Chinook salmon spawning above the former dam sites (NMFS 2012; Peters *et al.* 2014). Until then, hatchery supplementation will continue to play a necessary and significant role in stock rebuilding.

Table 5: Population viability (VSP) triggers defining the four phases of Elwha River Chinook restoration (NMFS 2012). Values in parentheses are numerical components of total escaping adult abundance composed by ocean-type and stream-type origin fish, respectively.

Restoration Phase	Abundance			Productivity			Spatial Structure	Diversity*	
	Hatchery-origin adult escapement (broodstock)	Natural-origin adult spawning escapement	Proportion Natural Influence (PNI)	Juveniles/ females	R/S (spawner to spawner)	R/S (pre-fishing)		Allele Frequency in Selected Loci	Expected Population Heterozygosity
Preservation	1,700	1,028 (707, 321)	No goal set	200	>1.0 (natural + hatchery fish)	>1.56 (natural + hatchery fish)	Some adults spawning above Elwha Dam site	No change	No change
Recolonization	<1,700	4,847 (3,333, 1,314)	No goal set	200	>1.0 (for natural fish only)	>1.56 (for natural fish only)	Adults spawning above Elwha Dam and 33% of intrinsic potential	No change	No change
Local Adaptation	500	9.694 (6,664, 3.029)	Work towards PNI = 1.0	200	>1.0 (for natural fish only)	>1.56 (for natural fish only)	Adults spawning above Glines Canyon Dam and 66% of intrinsic potential	Initial decrease, then stable	Initial decrease, then stable
Self-sustaining Exploitable Population	0	14,688 (10,099. 4.589)	PHOS = 0; PHOB = 0	200	~1.0 (for natural fish only)	≥1.85 (for natural fish only)	100% of intrinsic potential	Stable; less than historical	Stable; less than historical

* There are two additional indicators of diversity that apply only to the Local Adaptation and Self-Sustaining Exploitable Population phases — proportion of stream type Chinook salmon (yearling migrants returning to spawn) and variation in adult entry timing. For the Local Adaptation phase, a positive trend for both indicators will be the trigger values. For the Self-Sustaining Exploitable Population phase, the population will have stabilized with well-defined early and late run timing and a consistent proportion of the returning spawners each year will have resulted from yearling smolt migrants.

Habitat Management

Habitat Restoration and Assessment

Habitat restoration efforts complementary to dam removal were developed and implemented by the Lower Elwha Klallam Tribe, and concentrated on floodplain habitats in the lower river downstream of the former Elwha Dam site. To date, these efforts include the construction of 50 engineered logjams (ELJs) between river miles 1.0-3.5, additions of large wood to four side-channels, removal of four relic push-up flood control dikes, the planting of 60,000 native trees and shrubs in areas disturbed during construction or dike removal, and the control of non-native vegetation. Future restoration is being planned for Little River and Indian Creek, which includes wood additions and culvert barrier corrections; the first of these projects in Little River has been funded by the Salmon Recovery Funding Board and was implemented in 2018-2019.

Additional restoration efforts focusing on the Elwha River estuary and on the dewatered Aldwell reservoir are being considered. The Elwha estuary has been severely degraded over its history by diking and channelization (Duda *et al*. 2011). The former Aldwell reservoir, which was logged prior to inundation, has a scarcity of large wood and may be an excellent candidate for ELJs (Peters *et al*. 2014). The Washington State Department of Transportation (DOT) entered into an agreement with the Lower Elwha Klallam Tribe to install ten ELJs in the former Lake Aldwell reach (approx. RM 8 - 8.5, Rkm 12.9 – 13.7) as mitigation for the Highway 101 bridge replacement project. This will improve salmon habitat conditions along the newly restored river channel through the former reservoir following the removal of the Elwha Dam.

Ecosystem Response

Since dam removal, available habitat has increased as the river has become more dynamically engaged with its floodplain. These floodplain reaches have been serving as fine sediment retention sites, mitigating the potentially negative effects of fine sediment on the mainstem channel substrate. This buffering effect has improved the effectiveness of cobble-strewn mainstem reaches to function as higher quality spawning and rearing habitat for Chinook. In general, these findings demonstrate the ability of river systems like the Elwha to attenuate the impacts of dam removal (Peters *et al.* 2017).

Revegetation

The overall revegetation effort for Elwha restoration is guided by the Elwha Revegetation Plan (Chenoweth *et al*. 2011). The plan's goals, broadly stated, are to establish native vegetation communities and to accelerate natural succession toward older communities. As dam removal neared completion, dewatering of the Mills and Aldwell Reservoirs exposed approximately 800 acres of former hillslope and floodplain habitat along seven miles of newly transformed river channel. Revegetation of the former reservoirs has been critical to habitat restoration processes and was necessary to stabilize sediment that had accumulated on hillslopes and terraces during dam removal.

Revegetation activities are co-managed by Olympic National Park, leading revegetation efforts in the former Lake Mills Reservoir within the Park, and the Lower Elwha Klallam Tribe, leading revegetation efforts in the former Lake Aldwell Reservoir downstream from the Park. Revegetation began in 2004 and the vast majority of the planting of native vegetation has been completed. Control of exotic vegetation continues to be carried out during the summer and fall seasons. (McHenry 2017, *personal communication*). Monitoring plans have been developed to assess the need to modify and refine planting actions (Peters *et al*. 2014).

Suspended Sediment

The estimated 21 million m^3 of sediment that was entrained behind the Elwha River dams presented the single greatest challenge posed by the removal of the restoration project. This necessitated a multi-year, staged removal of the dams using adaptive management protocols. Bureau of Reclamation (BOR), the National Park Service (NPS), and the US Geological Survey (USGS) were responsible for monitoring suspended and bedload sediment transport in real time as part of the sediment monitoring and adaptive management activities of the Elwha dam removal project (Randle *et al*. 2012). Peak sediment transport during dam removal occurred in 2013, when nearly 20 times the river's annual sediment supply was transported downstream from the Glines Canyon dam and, to a lesser extent, Elwha dam (Morley *et al*. 2020). Average daily suspended sediment concentrations (SSC) exceeded 1,000 ppm for most of the year, peaking at 10,000 ppm during the period of greatest sediment transport (Morley *et al*. 2020). Since final debris removal efforts were completed in 2015, conditions have largely returned to near baseline with respect to sediment transport and SSC.

Additionally, changes in reservoir and riverbed elevation as well as water surface elevation are monitored through time, as are sediment erosion from the reservoirs, floodplain deposition, and volumetric changes in the river mouth and adjacent shoreline. Monitoring of particle size distribution of suspended, bedload, and deposition sediment continues. Regular aerial photogrammetry occurs on weekly to monthly intervals depending on hydrology and flight conditions.

Data from these monitoring activities have contributed to a broader effort to test and verify the U.S. Bureau of Reclamation model for predicting vertical and lateral sediment erosion in river and reservoir settings (Bradley and Bountry 2014; Warrick and Bountry 2015; Randle *et al.* 2015).

APPENDIX A:

Figure 5: Distribution of Chinook redds in the Elwha River 2012.

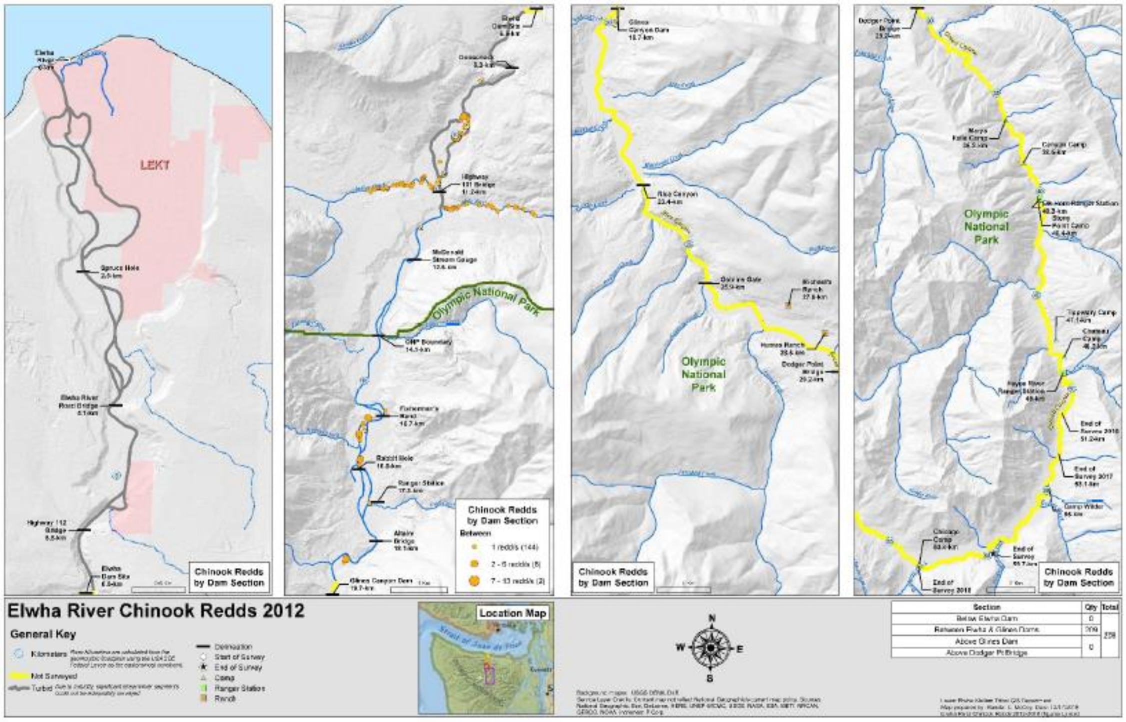


Figure 6: Distribution of Chinook redds in the Elwha River 2013.

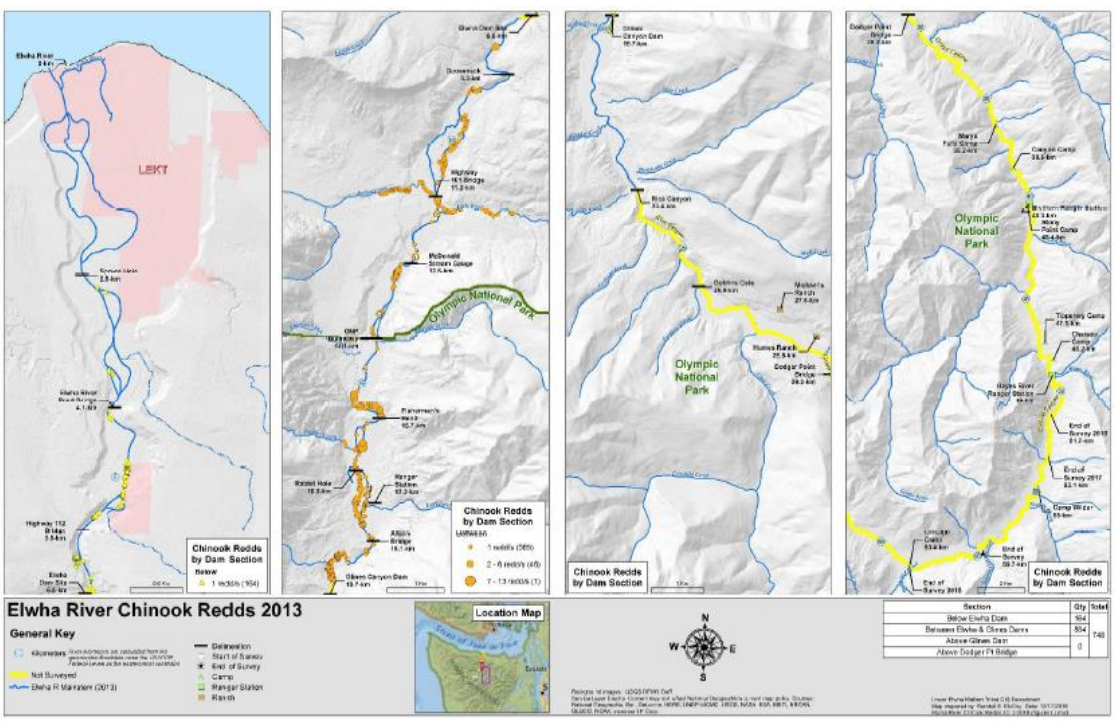


Figure 7: Distribution of Chinook redds in the Elwha River 2014.

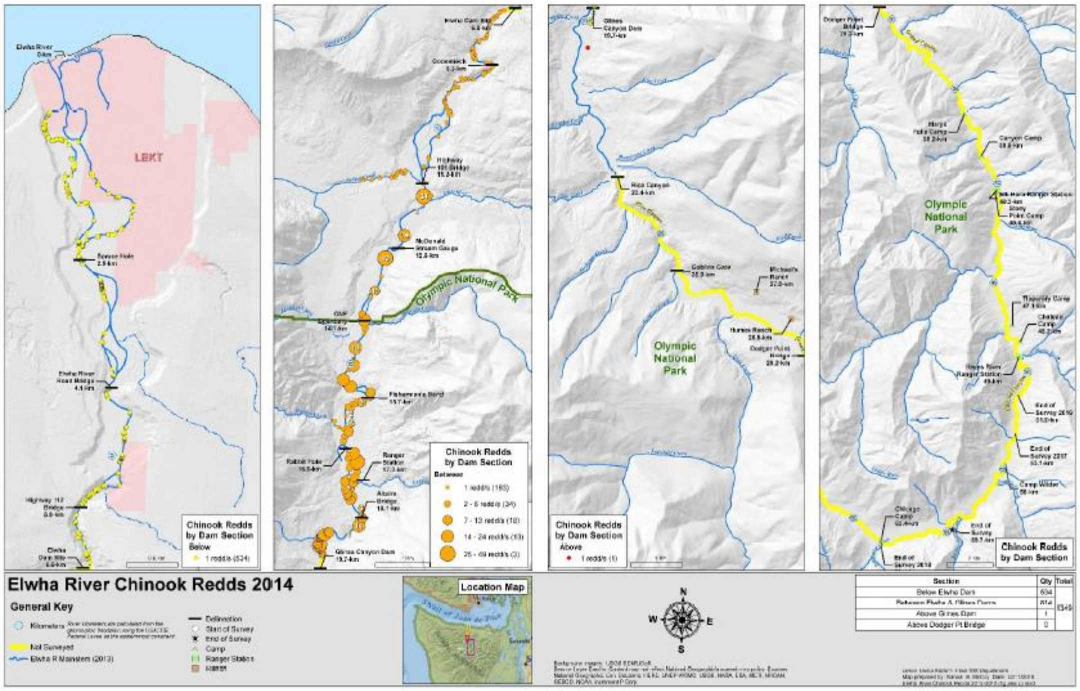


Figure 8: Distribution of Chinook redds in the Elwha River 2015.

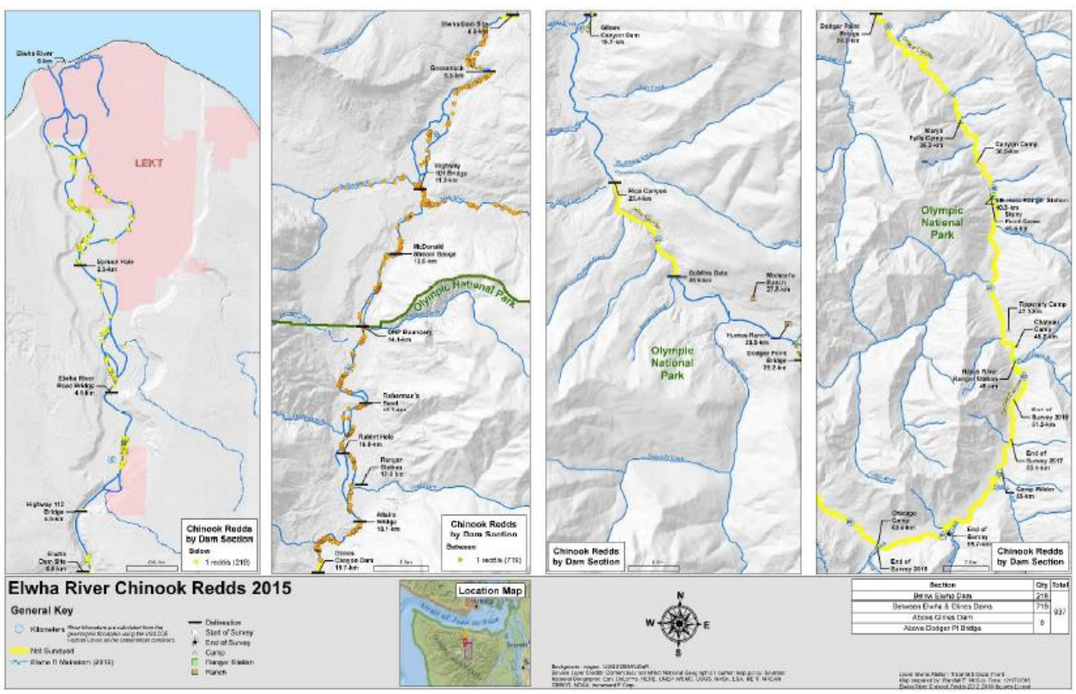


Figure 9: Distribution of Chinook redds in the Elwha River 2016.

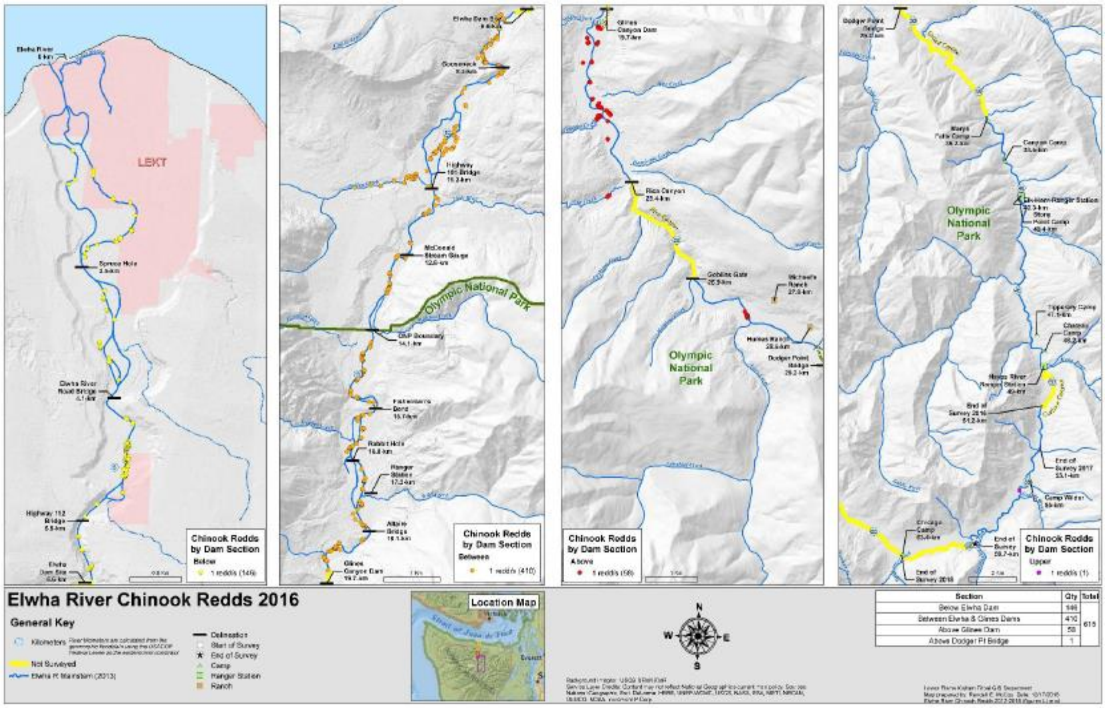


Figure 10: Distribution of Chinook redds in the Elwha River 2017.

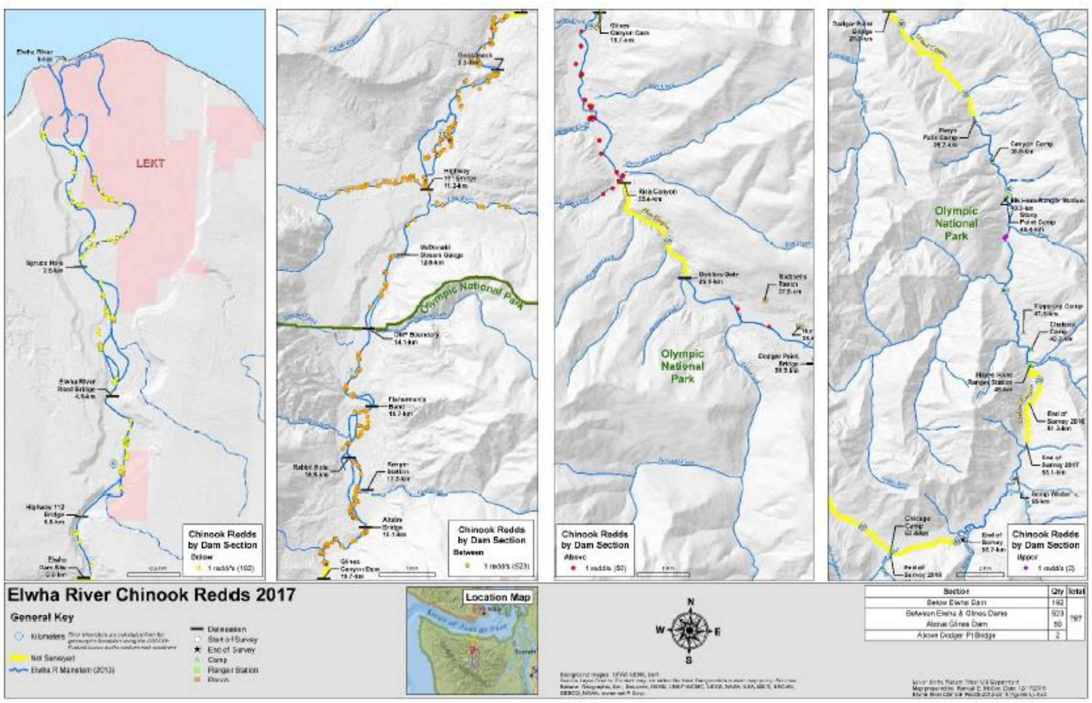


Figure 11: Distribution of Chinook redds in the Elwha River 2018.

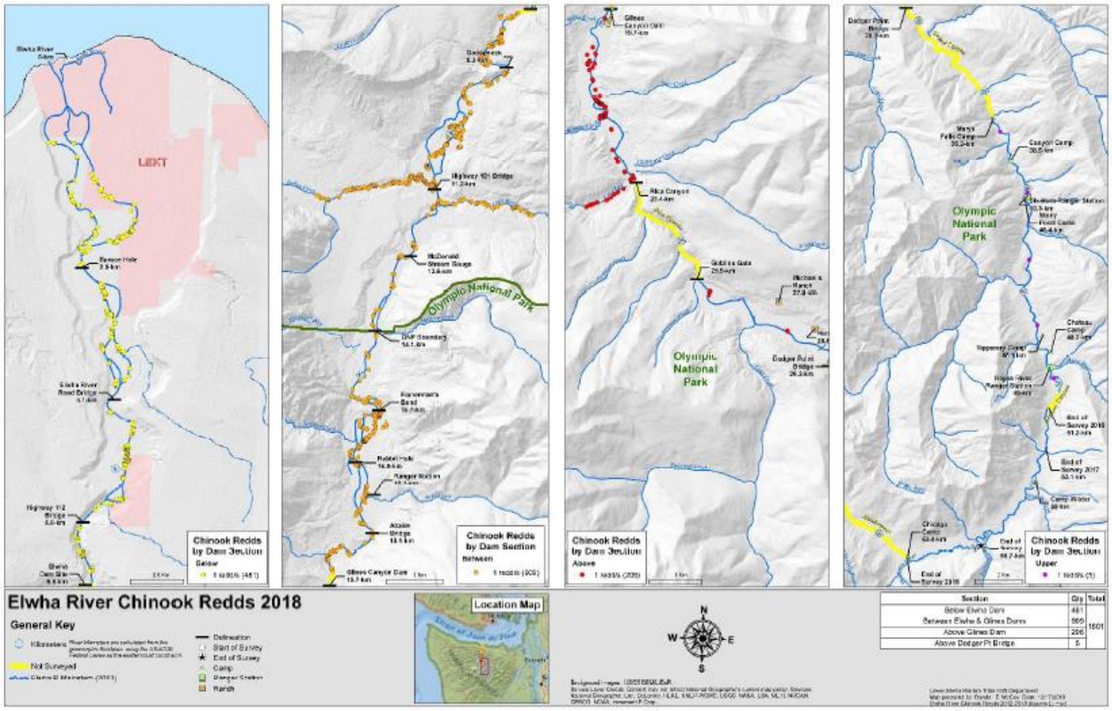


Figure 12: Distribution of Chinook redds in the Elwha River 2019.

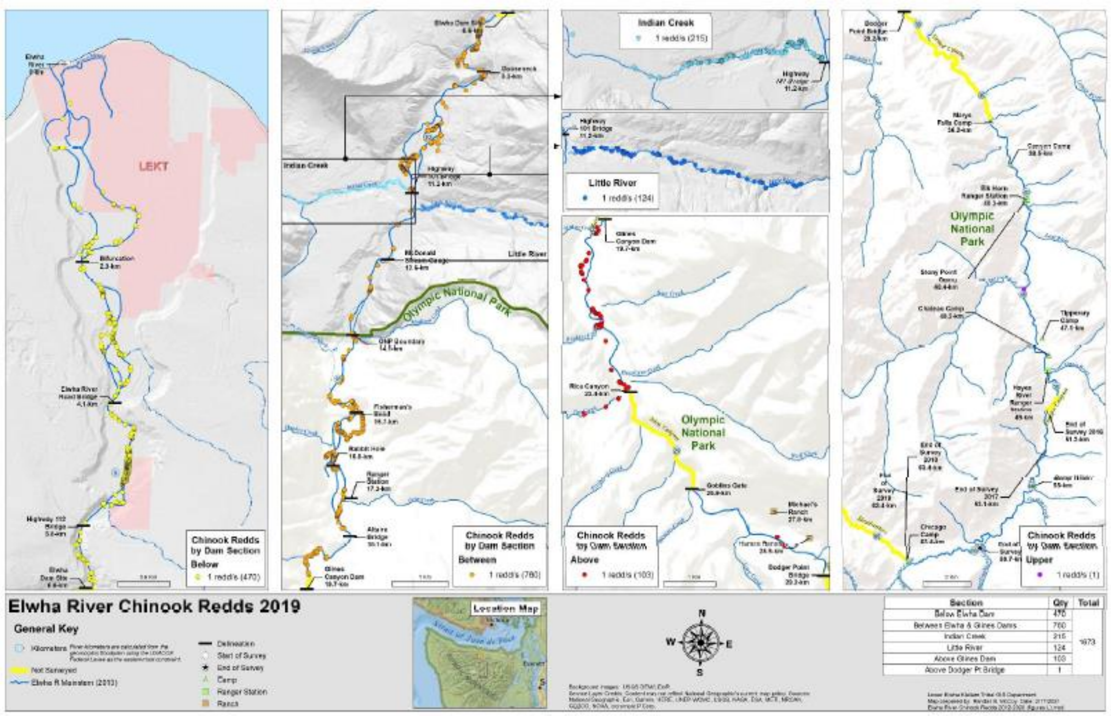
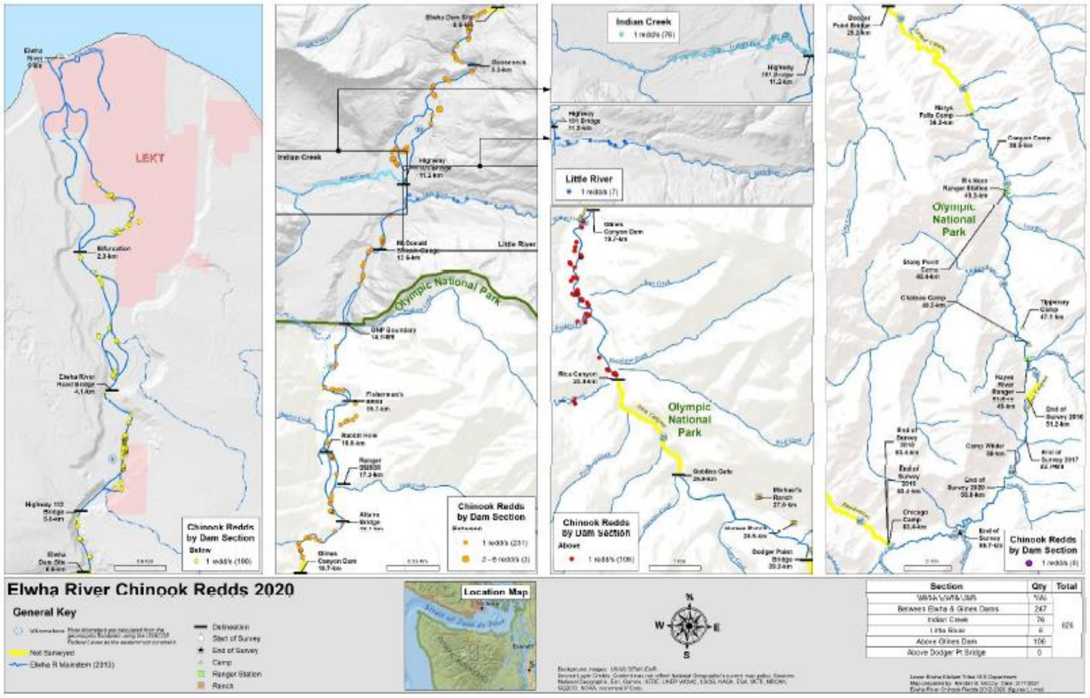


Figure 13: Distribution of Chinook redds in the Elwha River 2020.


Elwha River Chinook Redds 2020
General Key
Location Map
LEKT
Indian Creek
Little River
Olympic National Park
Chinook Redds by Dam Section
Below
Between
Above
Section
Qty
Total
Between Elwha & Glines Dams
247
Indian Creek
76
Little River
6
Above Glines Dam
106
Above Dodger Pt Bridge
0
626

Western Strait of Juan de Fuca Management Unit Status Profile

Component Stocks

Hoko River fall Chinook

Hoko River fall Chinook are not a component of the Puget Sound ESU, so they are not listed as a threatened stock under the Endangered Species Act. The Hoko River, however, is a tributary of the Strait of Juan de Fuca, which is part of Puget Sound in the context of salmon fishery management in Washington.

In 1985, the Pacific Salmon Commission (PSC) designated Hoko fall Chinook as an indicator stock for the Strait of Juan de Fuca. Under this program, the PSC provides funding for spawning ground surveys, coded-wire tagging, coded-wire tag (CWT) data analysis, and other activities required for monitoring Hoko Chinook. As a part of the PSC's indicator stock program, forecast information from the Hoko stock as well as some other Puget Sound indicator stocks, is used to determine quotas for fisheries from Alaska to Washington. Because the performance of Hoko Chinook is considered when setting quotas in the northern fisheries, it can affect the impact those fisheries have on other Puget Sound stocks.

Geographic Description

The Hoko River is the largest watershed in the western end of Water Resource Inventory Area (WRIA) 19, with about 25 lineal miles of mainstem and 80 lineal miles of tributaries (Phinney and Bucknell, 1975). The Hoko originates in the foothills of the Olympic Mountains and is primarily a rain-driven system. The Hoko basin receives between 90 and 120 inches of rain annually. The lower 10 miles of the Hoko have a low gradient and plentiful gravel. The zone of tidal influence extends about 1.5 miles upstream from the mouth.

Most of the Hoko River's approximately 48,000-acre basin is forested, with about 500 acres of agricultural area. Timber harvest in the watershed began in the 1880's. Nearly all of the basin has been logged down to the river bank at least once (Martin *et al.*, 1995). Most of the land in the Hoko basin is owned by private timber companies. In fact, 70% of the Hoko watershed is owned by two timber companies alone: Campbell Global and Rayonier. Of the original old growth in the Hoko watershed, 95% has been logged, and the land converted into active tree farms (McHenry *et al.*, 1996).

In addition to affecting the land in the watershed, timber harvest has had impacts within the river itself. At one time, the lower mainstem of the Hoko was cleared and bulldozed in order to allow floating logs downstream, to more easily transport them to mills.

Fall Chinook spawn primarily in the mainstem of the Hoko River, from above intertidal zone to river mile (RM) 21.5, but primarily between RM 3.5 (the confluence of the Little Hoko River) to the falls at RM 10 (McHenry *et al.*, 1996). Chinook may ascend the falls and spawn in the upper mainstem up to RM 22, and the lower reaches of larger tributaries such as Bear Creek (RM 0 to 1.2) and Cub Creek (RM 0 – 0.8), Ellis Creek (0 – 1.0), the mainstem (RM 0 – 2.5) and North Fork (RM 0 – 0.37), of Herman Creek, and Brown Creek(RM 0 – 0.8). Chinook also spawn in the lower 2.9 miles of the Little Hoko River. Historically, Chinook have also spawned in other

Western Strait streams, including the Pysht, Clallam, and Sekiu rivers. Recent surveys of the Sekiu River have counted small numbers of Chinook; their origin is unknown, but they are assumed to be strays from the Hoko.

Life History Traits
The available data suggest that most Chinook smolts produced in the Hoko system are ocean-type and emigrate as sub-yearlings (Williams *et al*., cited in Myer *et al.*, 1998). The Hoko Falls Hatchery, operated by the Makah Tribe, releases its Chinook as sub-yearlings, usually in June of the year of hatching.

Estimates of age composition based on CWT recoveries from fisheries and on scales collected from natural spawners and broodstock in return years 1989 through 2019 returning Hoko Chinook adults are predominately age 3(27%), age 4 (45%) and age 5 (21%), with the other age groups comprising much smaller proportions of the recruits.

Table 1. Average age composition of Hoko Chinook recruits from return years 1989-2019.

	Age 2	Age 3	Age 4	Age 5	Age 6	Total
Percent of Recruits	6%	27%	45%	21%	1%	100%

Abundance Status

Abundance of Hoko Chinook has been highly variable over the past 20 years, but shows no long-term positive or negative trend. Total abundance of Hoko Chinook, natural- and hatchery-origin combined, has averaged about 1,960 ocean recruits (return years 1988 through 2019) and has ranged from as low as 782 to a high of nearly 4,200 (Figure 1). Since the 1980's, just over one-third (37 percent) of these recruits have been of natural origin (Figure 2). In the past decade, as the number of hatchery-origin recruits has increased, however, the natural-origin proportion of the total run size (and sometimes absolute numbers of fish) has decreased.

The stock's productivity in recent decades presents a problem for recovery. Recruits per natural spawner (calculated from CWT-based cohort reconstruction have averaged 1.65 for complete brood years (1992 through 2013). That average, however, is heavily influenced by one brood year with a very high estimate (B.Y. 2009 with an estimate of nearly 14 recruits per spawner) and masks the data indicating that two-thirds of the brood years had fewer ocean recruits than the number of spawners that produced them. Cohort-reconstruction estimates of recruit abundance shows that for most (17 out of 26) of the completed brood years since 1989, the number of natural-origin recruits has been lower than the number of spawners that produced them. In other words, most of the brood years of natural-origin recruits have not even replaced themselves, and sustaining the stock has relied on hatchery production.

Table 2. Spawners and recruits produced from brood years 1989 through 2015 (the most recent complete brood year).

Brood Year	Spawners	Brood Year Recruits
1989	775	1,162
1990	378	448
1991	894	719
1992	642	291
1993	775	787
1994	332	1,627
1995	750	387
1996	1,227	203
1997	768	760
1998	1,618	569
1999	1,497	583
2000	612	258
2001	768	980
2002	443	406
2003	863	820
2004	866	55
2005	203	378
2006	845	182
2007	462	658
2008	431	196
2009	69	959
2010	319	1,346
2012	663	679
2013	656	320
2014	1,534	272
2015	2,425	576

The observed low recruitment rates is likely related to both freshwater habitat conditions, including flooding and resulting scouring of the gravel during the egg incubation period, and varying ocean conditions encountered during marine residence.

Degradation of the freshwater habitat that supports these Chinook is well-documented. Almost the entire Hoko River watershed (98%) has been clearcut logged at some time, with 60% of the watershed being clearcut within the last 30 years. There are 350 miles of roads, both paved and gravel, in the 72 square mile watershed.

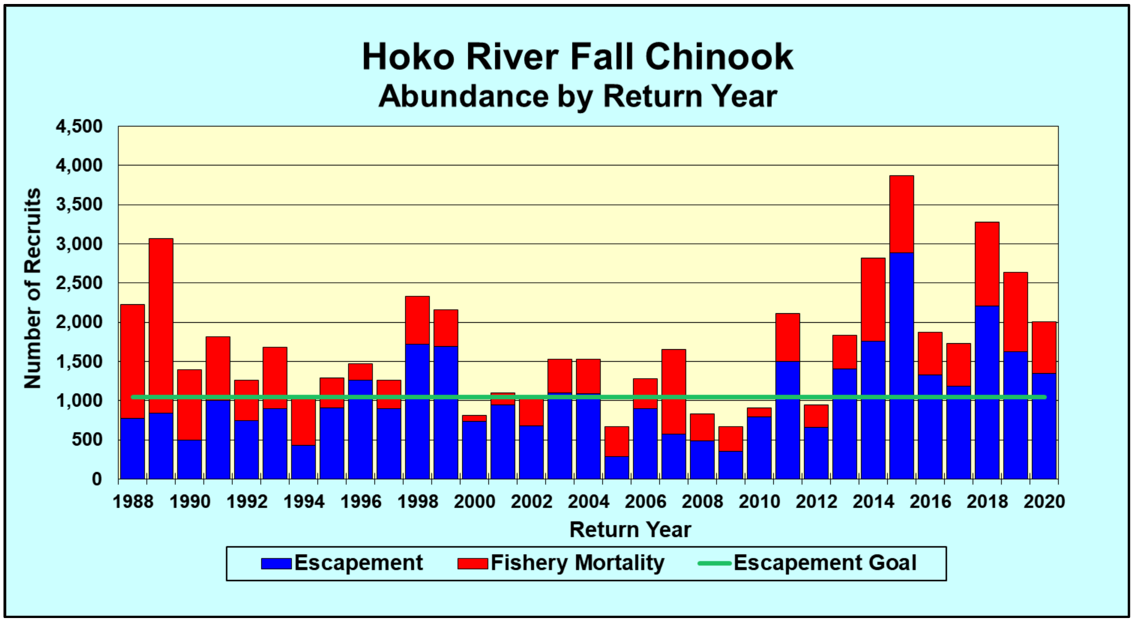


Figure 1. *Hoko Chinook, Abundance by Return Year, showing breakouts of escapement and fishery mortality. Green horizontal line indicates the historic escapement goal of 1,050, for reference. Total exploitation rates on Hoko Chinook, as estimated by CWT data, have declined from an average of 30% in the 1990's, to an average of 24% in the years since the 2009 Pacific Salmon Treaty Chinook agreement.*

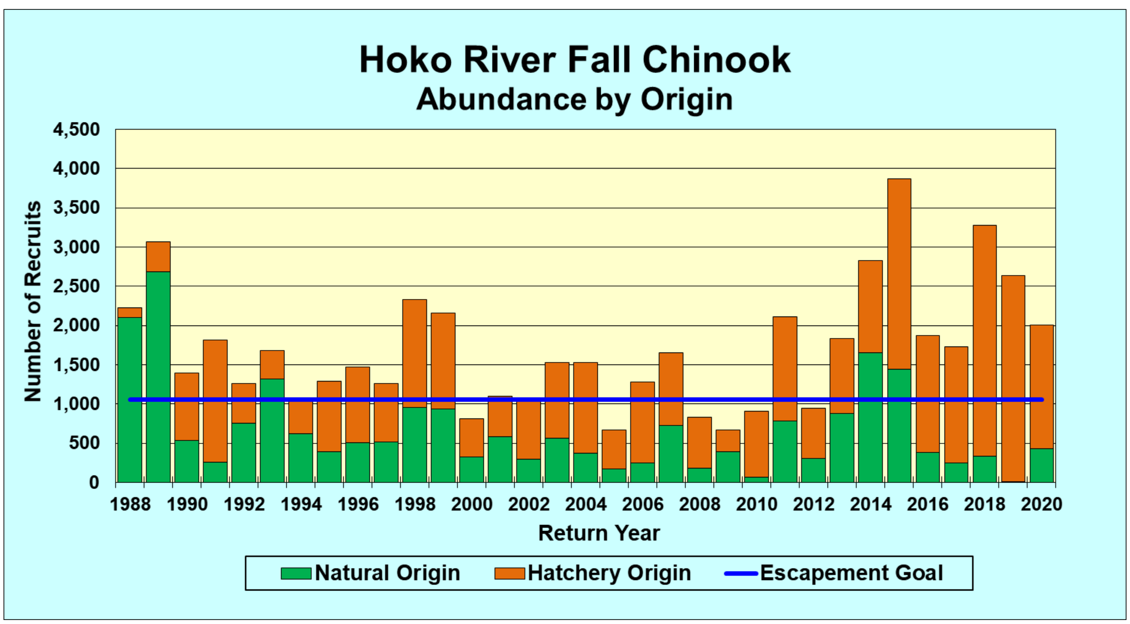


Figure 2. *Hoko Chinook, Abundance and Origin by Return Year.*
Since the late 1980's, nearly two-thirds (63%) of the recruits have been of hatchery origin. Blue horizontal line indicates historical escapement goal of 1,050.

Table 3. Hoko Chinook spawning escapement (numbers of fish) by return year and age.

Year	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Totals
1989	0	117	128	568	29		842
1990	8	64	227	111	83		493
1991	6	23	676	282	18		1,006
1992	10	35	171	390	121	0	727
1993	7	87	277	486	26	1	883
1994	3	88	130	186	17	0	424
1995	25	56	320	462	34	5	901
1996	1	142	316	725	81	0	1,265
1997	3	105	462	315	9	0	894
1998	39	59	931	655	38	0	1,722
1999	33	50	442	1,094	69	0	1,688
2000	68	156	232	245	30	0	731
2001	7	326	488	125	0	0	946
2002	6	70	458	145	1	0	680
2003	18	53	481	537	9	0	1,098
2004	34	153	217	667	15	0	1,086
2005	11	53	145	40	35	0	284
2006	0	240	535	63	57	0	895
2007	1	28	331	207	1	0	568
2008	5	22	62	394	0	0	483
2009	29	125	155	38	4	0	351
2010	20	371	260	141	1	0	793
2011	5	92	1,333	74	0	0	1,504
2012	43	60	197	361	1	0	663
2013	430	413	563	0	0	0	1,406
2014	152	1,053	472	83	0	0	1,760
2015	179	542	2,011	155	0	0	2,886
2016	62	426	573	261	0	0	1,323
2017	477	250	429	32	1	0	1,188
2018	100	1,697	386	20	0	0	2,203
2019	18	679	1,156	2	0	0	1,856
2020	31	293	930	92	0	0	1,347
Averages (1989-2008)	**14**	**96**	**351**	**385**	**34**	**0**	**880**
Averages (2009-2020)	**129**	**500**	**705**	**105**	**1**	**0**	**1,440**

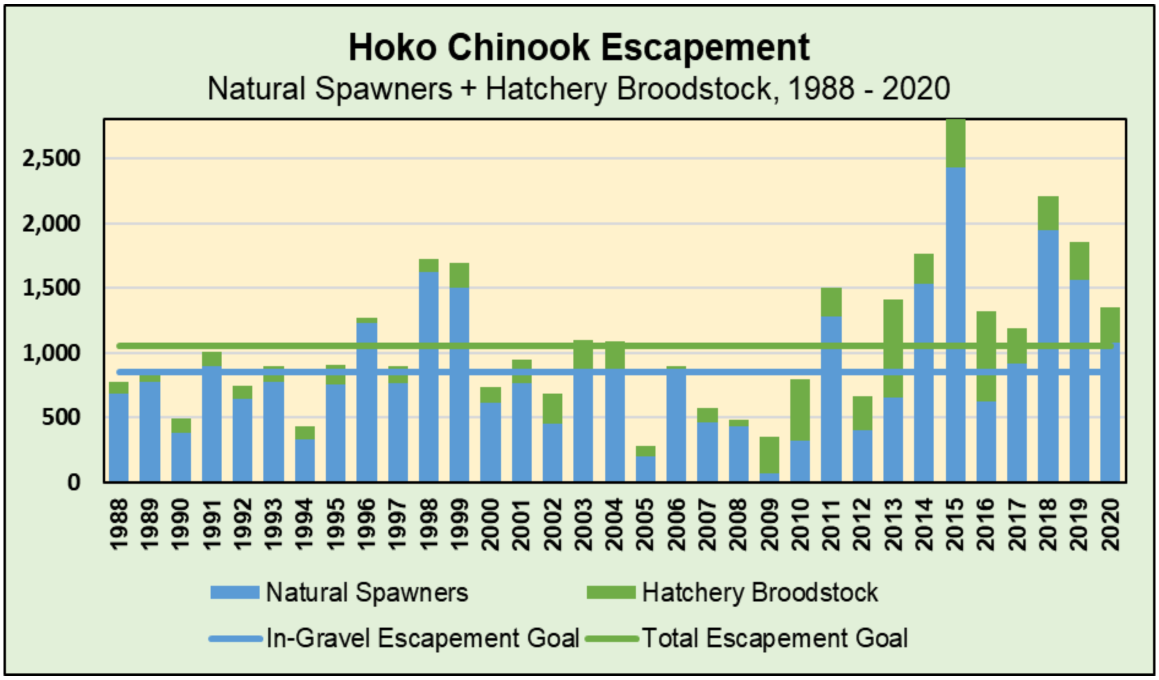


Figure 3. *Hoko Chinook Escapement, showing breakout of natural spawners and hatchery broodstock. Hoko Chinook escapement has achieved the goal for total spawners in fewer than half the years (14 of 33 years) since return year 1988. Nine of those 14 years have been in the 11 years since the 2009 Pacific Salmon Treaty Chinook Agreement went into effect. The blue horizontal line represents the historical escapement goal minus hatchery broodstock goal of 200. The green horizontal line represents the historic total escapement goal (in the gravel and hatchery broodstock combined).*

Additional years of cohort reconstruction may also shed light on the spawner-recruit relationship for Hoko Chinook, which may allow for revision in the escapement goal. Makah Fisheries Management (MFM) has maintained a cohort reconstruction database for Hoko Chinook, among other stocks, covering brood years since 1985. The results of this cohort reconstruction are part of an effort by MFM to improve the accuracy of pre-season forecasts, and to analyze trends in marine survival and exploitation rates.

Hatchery Programs

The low rates of survival and recruitment of natural-origin Chinook underscore the importance of the Hoko Falls Hatchery in maintaining this stock. The Tribe operates the hatchery as an integrated program for Chinook, often taking unmarked spawners from the river as broodstock, so as to not breed a separate stock of hatchery fish.

The Hoko Falls Hatchery is a small facility, producing Chinook since 1985. In addition to Chinook, the hatchery also raises coho and steelhead, and as part of the Lake Ozette sockeye recovery program, it incubates Lake Ozette sockeye at remote sites.

The Hoko Falls Hatchery has varying releases for fall Chinook based on availability of broodstock, but they average about 250,000 sub-yearlings with a high of 514,000 and a low of 68,000. Of those releases, an average of 76% of the Chinook released are coded-wire tagged, with a smaller proportion, 57%, being adipose fin-clipped.

With the hatchery's limited capacity for incubation and rearing, the Tribe has been pursuing other approaches to increase production of adult recruits. In 2011, the Hoko Falls Hatchery began using a salt-enhanced feed for Chinook raised in the hatchery. This change in feed appears to be a successful approach, leading to higher returns to the Hoko River, but further analysis of return rates with more complete brood years is needed.

Numbers of natural Chinook spawners have increased since the inception of the supplementation program in 1982, from counts of fewer than 200, before hatchery supplementation was initiated, to a 2009-2020 average of 1,066 spawners. Since 2007, about one-third of the Hoko Chinook natural spawners can be attributed to the supplementation program. Nevertheless, the historic goal of 850 natural spawners has been achieved in only 14 of the last 33 years (1988 to 2020; Figure 3).

Harvest Distribution and Exploitation Rate Trends

Over the long-term (return year 1988 to 2021) total exploitation rates (ERs) on Hoko Chinook, as estimated by annual (not base period) CWT data, have averaged about 28%, with a range of 8% to 55%. However the stock has experienced a dramatic decline in exploitation rates in the last four decades, from over 50% in the 1980's, to about 30% in the 1990's, and more recently to an average of less than 24% in the years since the 2009 Pacific Salmon Treaty Chinook agreement was implemented (Makah Tribe, unpublished cohort reconstruction data).

The migration pathway and harvest distribution of Hoko Chinook have been described from recoveries of coded-wire tagged fish released from the Hoko Falls Hatchery. The CWT data used in cohort reconstruction indicate that 89 percent of the fishery mortality on Hoko Chinook is in fisheries in Southeast Alaska and British Columbia, *i.e.*, northern fisheries. About 10 percent of the fishery mortality is in Washington, with less than 1 percent in fisheries in Oregon. Nearly all the fishery impacts on Hoko Chinook are in pre-terminal fisheries; there has been no terminal Chinook-directed fishery in the Hoko since the 1980's with only occasional incidental mortality of Chinook during steelhead fisheries in the terminal area.

As with other Chinook stocks, in Washington, fishery-related impacts on Hoko Chinook are analyzed by the state and tribal co-managers using FRAM. Before 2006, the Hoko stock was aggregated with the other Strait of Juan de Fuca Chinook stocks (Elwha and Dungeness) for FRAM modeling purposes. However, the migration timing of this stock is different from that of the other two Strait stocks, with Hoko Chinook showing substantially later timing, entering the river later in the fall, and spawning in October and well into November. For this reason, since 2006, the Hoko stock has been modeled in FRAM separately from the other Strait of Juan de Fuca Chinook stocks.

FRAM-based post-season estimates of exploitation rates specific to Hoko are available for 2006 through 2018 (Table 3). Like the annual CWT data, FRAM validation estimates indicate that

Hoko Chinook are harvested primarily in northern fisheries. Result from the two sources of estimates for return years 1989 through 2019 indicate similar proportions: FRAM estimates using the 2007-2013 base period (Round 7.1.1) show 91 percent of fishing mortality taken in northern fisheries; CWT-based cohort reconstruction generally agrees with the FRAM results, showing 89 percent of the fishing mortality being taken in northern fisheries.

As noted above, Hoko Chinook are not harvested is the Hoko River itself. Because of the low abundance of naturally spawning Hoko Chinook, the Makah Tribe has not had a Chinook-directed terminal fishery in the Hoko River since 1981. Non-tribal sport fisheries in the river are also closed to Chinook fishing. Both treaty and non-treaty steelhead fisheries in the river are timed to open only after Chinook spawning is complete, so as to minimize the potential for incidental impacts to Hoko Chinook. In addition, both treaty and non-treaty fisheries are closed in Hoko Bay, outside the mouth of the river.

Table 4. Distribution of exploitation rates on Hoko Chinook from FRAM validation runs, using base period 7.1.1.

Return Year	Alaska	Canada	SUS Pre-terminal	SUS Terminal	Totals
2006	10%	14%	2.1%	0.0%	26.5%
2007	17%	15%	1.2%	0.0%	33.8%
2008	11%	9%	0.8%	0.0%	20.7%
2009	9%	12%	2.2%	0.0%	23.1%
2010	4%	9%	2.5%	0.0%	16.3%
2011	10%	11%	1.8%	0.0%	23.2%
2012	10%	10%	2.1%	0.0%	22.7%
2013	5%	8%	2.1%	0.0%	14.9%
2014	6%	9%	2.4%	0.0%	17.7%
2015	9%	9%	1.9%	0.0%	18.9%
2016	0%	14%	1.1%	0.0%	23.7%
2017	5%	13%	2.2%	0.0%	20.8%
2018	4%	12%	2.2%	0.0%	18.0%
Averages	**8%**	**11%**	**1.9%**	**0.0%**	**21.6%**
Data Source: post-season FRAM, 2021 validation runs.					

Management Objectives

Since the early 1980's, the Makah Tribe has pursued the goal of rebuilding Hoko Chinook, which had been at a low level of abundance. That goal was the reason the Tribe built and continues to operate the Hoko Falls Hatchery, which has been supplementing this run since 1985. All broodstock for the hatchery has been the local Hoko River stock, with the hatchery collecting spawners returning to the hatchery as well as spawners from the river, in order to not breed a separate stock of hatchery Chinook.

Through 2021, the management objectives for Hoko Chinook (Table 5) have remained unchanged since the first Puget Sound Chinook Resource Management Plan (RMP) was submitted to NOAA Fisheries in 2004. The conditions under which this stock is managed have changed considerably since that time, which led the Makah Tribe to re-evaluate the relevant scientific information and consider revisions of the stock's management objectives to reflect those changes.
Among the changes in Chinook fisheries management since the 2004 plan are:

- Two Chinook agreements have been negotiated under the Pacific Salmon Treaty. Both of these agreements included major reductions in Chinook quotas in Canada and Alaska, where most of the catch of Hoko Chinook is taken. CWT-based exploitation rates on Hoko Chinook have declined by over one-fourth since the 2009 PST Chinook agreement went into effect.

- FRAM, which is the primary tool for the state and tribal co-managers and NOAA to evaluate the impact of Washington salmon fisheries, has been revised several times. When the FRAM base period is changed (which has happened at least five times since the 2004 RMP) the pre-season predictions and post-season estimates of impacts to Chinook stocks also change.

- In addition, much of the stock assessment data for Hoko Chinook has been collected in the years since 2004, so estimates of abundance and productivity have been updated from what was known when the 2004 RMP was prepared.

Management objectives for the western Strait of Juan de Fuca management unit, *i.e.*, the Hoko Chinook stock, include an escapement goal, abundance thresholds for two abundance tiers, and exploitation rate ceilings, as shown in Table 5, below.

Table 5. Previous management objectives for Hoko River Chinook (2004-2021).

Upper Management Tier		Low Abundance Threshold	
Escapement	**ER Ceiling**	**Escapement**	**ER Ceiling**
1,050 Natural Spawners + Hatchery Broodstock	10% SUS	500 Natural Spawners + Hatchery Broodstock	6% SUS

Upper Management Tier		Low Abundance Threshold	
Escapement	**ER Ceiling**	**Escapement**	**ER Ceiling**
916 Natural Spawners + Hatchery Broodstock	10.6% SUS	633 Natural Spawners + Hatchery Broodstock	6.3% SUS

Table 6. Current management objectives for Hoko Chinook (2022 forward)

Escapement Goal, or Upper Management Threshold

The escapement goal in this Management Unit Profile (MUP) has been adjusted from that of previous RMPs using two methodologies. The first is a correction for spawners per redd, a calculation used to develop the escapement estimate for Hoko Chinook. The second is a translation of FRAM-derived escapement from FRAM base period 5 to FRAM base period 7.1. The combination of these adjustments resulted in a reduction of the upper management threshold from 850 to 716 in-river, *i.e.*, natural, spawners. The hatchery broodstock goal of 200 spawners is unchanged and remains additive to the 716 natural spawners. Since Hoko Chinook are managed as an integrated stock, with no distinction between hatchery and natural-origin fish, the revised upper management threshold for the stock as a whole would be 916 spawners. Applying the same analysis, the low abundance threshold was also updated and for 2022 forward is reduced from 500 to 433 in-river spawners plus 200 for hatchery broodstock for an escapement goal of 633 for the stock as a whole.

Other methods to estimate maximum sustainable yield (MSY) escapement have been explored, including a Ricker spawner-recruit model and the Parken habitat-based model (Parken *et al.*, 2004), but the results of these methods were not compelling enough to change the escapement goal.

The Ricker model gave a very low estimate of escapement at MSY, but the model results were likely influenced by fitting it to a data set in which 14 out of 23 brood years produced recruits in such small numbers that they did not even replace the parent-year spawners.

Further, while spawners are of course essential to sustaining the population, results of a regression model predicting recruits per spawner as a function of both spawners and an ocean temperature-related variable (PDO index) suggest that ocean conditions may be a more significant predictor of recruit abundance for Hoko Chinook than parent-year spawners are. So while the Ricker model might be useful in describing the population conditions in the past three decades, using its estimate of MSY to set an escapement goal does not appear to be the best approach to recovery.

The Parken habitat-based model, on the other hand, produced an estimate of MSY escapement that was about 200 spawners higher than the former escapement goal; however, the Parken model is based on habitat from 12 watersheds producing ocean-type Chinook from Alaska to Oregon. The average watershed area used in developing this model is over 2,000 square kilometers (km), while the Hoko watershed, at 174 square km., is smaller than even the smallest watershed used in the Parken data set. Perhaps most importantly, because the Hoko watershed has been severely degraded from over 130 years of logging, the habitat in the Hoko might not support as many spawners per square km as a similarly sized watershed in the other areas included in the Parken data set.

The historic escapement goal of 850 in-river spawners for the Hoko stock was first proposed by Ames and Phinney in 1977 in the Washington Department of Fisheries *Technical Report 29*. At the time, there was very little escapement data on Hoko Chinook; even now, escapement estimates shown in the Puget Sound Run Reconstruction database show a constant number of spawners (520) in the Hoko for every year before 1981, and Ames and Phinney noted, “There is a lack of chinook survey data on streams tributary to the Strait of Juan de Fuca.” For that reason, Ames and Phinney use data from some of the Washington coastal rivers to develop an escapement goal for the Hoko. They used the following estimates in their calculations:

- 23.6 lineal miles of river accessible to Chinook
- 12 redds per lineal mile
- 3 spawners per redd

The resulting goal of 850 in-river spawners was adopted by the co-managers and was used through 2021. For some perspective on its performance, in the 33 return years for which we have detailed spawner survey data for the Hoko (1988 through 2020), that escapement goal has been met or exceeded in only 14 years.

One problem which the updated escapement goal corrects is a mismatch between the number of spawners per redd: Ames and Phinney estimated 3 spawners per redd in developing the escapement goal, while the co-managers use the 2.5 spawners per redd in their annual escapement estimation. To be consistent, either the goal should be reduced by a factor of 2.5/3, to 708 in-river spawners, or the annual calculations to estimate spawning escapement should be increased by a factor of 3/2.5, or 1.20. Rather than revising 33 years of historical escapement estimates, we chose to revise the goal instead.

In addition to the adjustment for spawners per redd, this updated MUP modifies the escapement goal for Hoko Chinook to make it consistent with the changes in the FRAM base period. The pre-season predictions made by FRAM do not remain the same (even within a year) under different FRAM base periods. Chinook modelers from WDFW and the Northwest Indian

Fisheries Commission have re-run the final Pacific Fisheries Management Council (PFMC) pre-season FRAM runs from 2013 through 2021 using the latest base period (round 7.1) . The escapement predictions under the two FRAM base periods are highly correlated (r^2=0.999, P<0.0001; see Figure 4) but are not identical. The different predictions reflect the changes in stock distribution and fishery impacts in the two base periods. The differences in predictions between the two sets of model runs (Table 5) are of only borderline statistical significance (paired t-test, P=0.06, with the predictions under FRAM Round 7.1 averaging about 1% lower). Nevertheless, evaluating impacts on Hoko Chinook during the pre-season PFMC process would be more precise if the upper management threshold is revised to be consistent with the new FRAM base period.

Table 7.
Hoko Chinook Escapement
Pre-Season FRAM Predictions
Comparing Base Periods

Year	PFMC Final	R7.1
2013	1,057	1,034
2014	2,448	2,400
2015	3,038	2,971
2016	2,345	2,280
2017	1,246	1,276
2018	1,295	1,289
2019	2,315	2,307
2020	2,170	2,158
2021	1,054	1,048

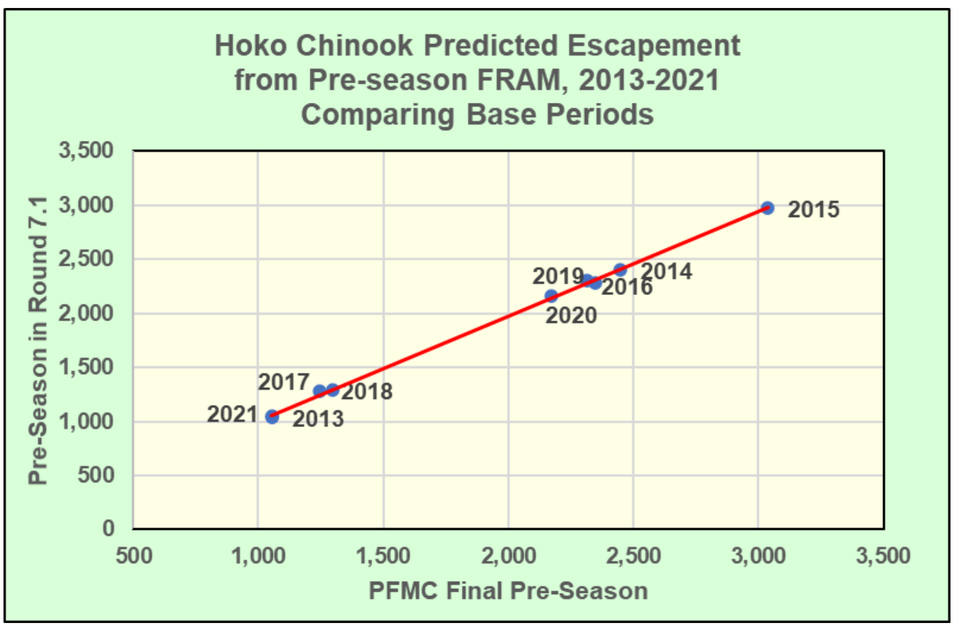


Figure 4 *Translation of FRAM predicted escapement for Hoko Chinook from PFMC Final Pre-season runs using previous versions of FRAM to FRAM BP 7.1.*

At first it might seem concerning to change these abundance thresholds to conform to a new FRAM base period. The carrying capacity of the river does not change when the model changes.

As described above, however, the current management objectives for Hoko Chinook have remained a work-in-progress since they were first adopted. The original goal of 850 natural spawners was not based on a rigorous analysis of habitat carrying capacity in the Hoko, but was adapted from stock assessment data from other rivers. Another important consideration for the Puget Sound Chinook RMP, when we evaluate whether the stock achieves either of those abundance thresholds, either in pre-season planning or in a post-season analysis, we very often use FRAM to make that determination. The same abundances and fishery impacts that would have resulted in a FRAM estimate of 850 natural spawners now give an estimate of 859 natural spawners. The remaining adjustments for spawners per redd change the abundance further, to the estimates shown in Table 6.

Exploitation Rate Ceilings

The exploitation rate ceiling is 10.6% in southern U.S. (SUS) fisheries. This rate, when added to the average exploitation rate of 20% in northern fisheries would allow a total exploitation rate of about 30%. For comparison, since the implementation of the 2009 PST Chinook agreement, the total exploitation rate has averaged 20%, as estimated by post-season FRAM modeling (new base period, Round 7.1.1). SUS fisheries impacts on Hoko Chinook have been limited (and entirely pre-terminal), averaging 1.8% over the same period.

The Low Abundance Threshold (LAT) for Hoko Chinook is 433 natural spawners plus 200 for hatchery broodstock. When natural spawning escapement for this stock is projected to be below this level, the harvest management plan will call for SUS fisheries to be limited to a 6.3% exploitation rate ceiling.

The management objectives include exploitation rate ceilings for two different abundance categories. When the escapement is predicted to be at or above the LAT, the exploitation rate ceiling is 10.6% in SUS fisheries. At predicted escapement levels below the LAT, the stock is considered to be in critical status and the exploitation rate ceiling is 6.3% SUS.

To translate the exploitation rates between different FRAM base periods, we compared Round 5, which was used at the time the 2017 RMP was prepared, and the current Round 7.1. The estimates under Round 5 of the base period and those produced under the current Round 7.1 are also highly correlated (r^2=0.94, $P<0.0001$. See Figure 5.). Translating the exploitation rate ceilings between the relevant FRAM base periods ensures that the management objectives reflect current scientific information regarding harvest impacts on Hoko Chinook.. Using the linear regression relationship depicted in Figure 5, the 10% SUS exploitation rate ceiling translates to 10.6%, and the critical exploitation rate ceiling of 6% SUS translates to 6.3%. The updated ceilings will be included in the management objectives for 2022 and future years.

Several management measures and natural conditions help minimize fishery impacts to Hoko Chinook. As noted above, there has not been a terminal fishery for Hoko Chinook in many years, and incidental mortality is minimized in pre-terminal fisheries in Washington by the timing of the fisheries, which typically close in September, and that of the spawners, which return to the river in October and November. Treaty troll fisheries as well as sport fisheries in the Strait are closed in late September and in October. Both treaty and non-treaty fisheries in the Strait observe the closed area in Hoko Bay to reduce impacts on Hoko Chinook. Tribal steelhead fisheries in the Hoko River are delayed until December, after the last of the Chinook have spawned. Sport fisheries in the river are limited to trout, other game fish, and hatchery-produced steelhead.

Data gaps

- **Develop improved methods for escapement estimation**

Currently, escapement of Hoko Chinook is estimated from redd counts, using the formula of 2.5 spawners per redd. Redd counts might not be the best method to estimate escapement in this river, given the tendency for flooding in October and November, at the time of peak spawning activity. Other methods under consideration, but not yet implemented, include mark-recapture estimates.

In addition, a consistent method is needed to estimate the origin (hatchery *vs*. natural) of the spawners. The current methods, using hatchery mark-rates, sometimes result in unrealistically low estimates of natural-origin spawners. Those estimates, in turn, influence the estimates of the origin of total ocean recruits, and therefore affect the estimated spawner-recruit relationship. This situation could be improved by higher tagging rates, or by otolith marking; however, either of these solutions would impose higher costs.

- **Derive an improved spawner-recruit relationship for Hoko Chinook**

The in-gravel spawner and natural-origin recruit estimates from cohort reconstruction fit a Ricker spawner-recruit model. With so many data points (14 out of 23 brood years) below the replacement line, however, the estimate of MSY escapement derived from this model is very low. It is likely that this model is not appropriate for the Hoko, given the habitat degradation and resulting low productivity of the population discussed above.

- **Estimate abundance of natural outmigrants**

A means of estimating the number of naturally produced Chinook out-migrants each year would help estimate marine survival rates and allocate the annual variability in survival to the freshwater and marine environments.

The Makah Tribe operates a smolt-sampling program for coho from late April to early June in two tributaries of the Hoko (Johnson Creek and the Little Hoko River). However, very few Chinook are taken in the smolt traps, either because of the location in the tributaries, or because the smolt traps are removed in early June, before most of the juvenile Chinook migrate downstream. No smolt traps are used in the mainstem of the river, because spring flooding makes it difficult to maintain the weirs; however, sampling in the mainstem might be possible in June, and could allow for estimation of survival rates for the natural-origin Chinook.

13. APPENDIX B: Tribal Minimum Fishing Regime (MFR)

Strait of Juan De Fuca Troll Fisheries:

- Open June 15 through April 15.

Strait of Juan De Fuca Net Fisheries:

- Setnet fishery for Chinook open June 16 to August 15. 1000-foot closures around river mouths, except that closure around mouth of Elwha River shall be 1/2 mile.Gillnet fisheries for sockeye, pink, and chum managed according to PST Annex.
- Gillnet fisheries for coho from the end of the Fraser Panel management period, to the start of fall chum fisheries (approximately Oct. 10).
- Closed mid-November through mid-June.

Strait of Juan De Fuca Terminal Net Fisheries:

- Hoko, Pysht, and Freshwater Bays closed May 1 – October 15.
- Elwha River closed April 1 through mid-September, except for minimal ceremonial harvests.
- Dungeness Bay (6D) closed March 1 through mid-September; Chinook non-retention mid-September – October 10 during coho fishery
- Dungeness River closed March 1 through September 30. Chinook non retention during coho fishery, except for minimal ceremonial harvest.
- Miscellaneous JDF streams closed March 1 through November 30.

Area 6/7/7A Net Fisheries:

1) Sockeye, pink, and chum fisheries managed according to PST Annexes.
2) Net fisheries closed from mid-November through mid-June.
3) Area 6A Closed.

Nooksack/Samish Terminal Area Fisheries:

- Fisheries may occur in the mainstem from March through July, with catch of natural-origin Chinook limited to 30.
- Bellingham Bay (7B) and Samish Bay (7C) closed to commercial fishing from April 15 through July 31.
- Area 7B/7C hatchery fall Chinook fishery opens August 1.
- Nooksack River commercial fishery for hatchery fall Chinook opens August 1 in the lower river section; and staggered openings in up-river sections will occur over 4 successive weekly periods. (see Appendix A).
- Pink fishery may open August 1, subject to pink forecast.

Skagit Terminal Area Net Fisheries :

- Tribal commercial fisheries may be conducted from May 1 through April 15, provided fisheries are directed at runs with harvestable surplus.
- Treaty Ceremonial and Subsistence fishery access to Chinook of all populations.
- Net fishery impacts incidental to fisheries directed at sockeye, pink, coho, chum, and steelhead.
- Targeted hatchery spring Chinook fishery.
- Conduct test fisheries to collect in-season information including data to update the terminal run abundance.

Area 8A and 8D Net Fisheries:

- Area 8A fishery Chinook impacts incidental to fisheries directed at coho, pink, chum, and steelhead.

- Effort in the pink fishery will be adjusted in-season to maintain Chinook impacts at or below those modeled during the pink management period.
- Area 8D Chinook fisheries limited to C & S beginning in May, (and to 3 days/wk during the Chinook management period) .

Stillaguamish River Net Fisheries:

- Ceremonial fishery may occur from May to mid-July, with catch of natural origin Chinook limited based on annual abundance estimates and agreedto impacts.
- Net fishery impacts incidental to Chinook may occur in fisheries directed at pink, coho, chum, and steelhead, limited to at or below agreedto impacts.

Snohomish River Fisheries:

- Net fisheries closed.

Area 9 Net Fisheries:

- Research & tribal commercial chum, restricted to Admiralty Inlet.

Area 10 Net Fisheries:

- Closed from mid-November through June and August.
- Sockeye net fishery during first three weeks of July when ISU indicates harvestable surplus of Lake Washington stock.
- Net fisheries for coho and chum salmon will be determined based on in-season abundance estimates of those species. Limited test fisheries will begin the 2nd week of September. Commercial fisheries schedules will be based on effort and abundance estimates. Marine waters east of line from West Point to Meadow Point shall remain closed during the month of September for Chinook protection. Chinook live release regulations will be in effect

Lake Washington Terminal Area Fisheries:

- Chinook run size update based on Ballard Lock count, to re-evaluate forecasted status.
- If the ISU has determined the run size is at MMT or below no Chinook directed commercial fishery in the Ship Canal or Lake Washington.
- Limited Chinook test fisheries to acquire data
- C&S fisheries on all species including Chinook
- Net fisheries directed at sockeye and coho salmon will be managed in-season based on abundance assessment at the Ballard Locks, and will incur incidental Chinook mortality. Incidental Chinook impacts minimized by time, area and live Chinook-release restrictions. Sockeye fisheries scheduled as early as possible. Coho fishery delayed until 1st week of September or until 95% of the Chinook run has passed through the locks. Net fisheries directed at sockeye take place in the Ship Canal, Lake Union, and south Lake Washington. Net fisheries directed at coho take place in the Ship Canal, Lake Union, north Lake Washington, and Lake Sammamish.
- Possible Chinook-directed fishery in Lake Sammamish for Issaquah Hatchery surplus.

Area 10A Net Fisheries:

- Chinook gillnet test fishery 12 hours/week, 3 weeks, beginning mid-July to re-evaluate forecasted status.
- If the ISU has determined the run size is at MMT or below no Chinook directed commercial fishery.
- Net fishery impacts incidental to fisheries directed at pink, coho and chum. Pink/coho opening delayed until 1st week of September.
- C&S fisheries on all species including Chinook

Duwamish/Green River Fisheries:

- Possible Chinook test fisheries to acquire additional data
- If the 10A ISU has determined the run size is at MMT or below no Chinook directed commercial fishery.
- C&S fisheries on all species including chinook
- Net fishery impacts incidental to fisheries directed at pink and coho. Pink/coho opening delayed until the 1st week of September and restricted to waters below the 1st Ave Bridge. Pink/coho opening delayed until the 2nd week of September and restricted to waters below the 16th Ave Bridge. Coho opening delayed until the 3rd week and restricted to waters below the Boeing Street Bridge (upstream of the turning basin). Coho opening above the Boeing Street Bridge to the Hwy 99 Bridge delayed until late September
- Chinook incidentals during chum management not likely, but possible.

Area 10E Net Fisheries:

- Closed from mid November until last week of July.
- Chinook net fishery 5 day/wk last week of July through September 15.
- Chinook impacts incidental to net fisheries directed at coho and chum, from mid-September through November

Area 11 Net Fisheries:

- Closed from end of November to beginning of September.
- No Chinook-directed fishery.
- Net fishery Chinook impacts incidental to fisheries directed at coho and chum.

Area 11A Net Fisheries:

- Closed from beginning of December to end of August.
- Net fishery Chinook impacts incidental to fisheries directed at coho and chum.

Puyallup River System Fisheries:

- Possible spring Chinook gillnet test fishery on the White and or Puyallup Rivers to re-evaluate forecasted status.
- Possible Fall Chinook gillnet test fishery on the Puyallup River to re-evaluate forecasted status.
- If the fall Chinook ISU has determined the run size is at MMT or below no Chinook directed commercial fishery.
- C&S fisheries on both the White and Puyallup Rivers on all species including both fall/spring chinook
- Commercial net fisheries on the Puyallup River directed at other species (coho, pink and chum) will incur incidental fall Chinook mortalities. Coho opening may be delayed until 2nd week in September and further closures may be in place above Clarks Creek Bridge. Other incidental fall Chinook impacts minimized by time, area and live Chinook-release restrictions.

Fox Island/Ketron Island (Area 13) Net Fisheries:

- Closed from end of October to August 1.
- Net fishery Chinook impacts incidental to fisheries directed at coho and chum.

Sequalitchew Net Fisheries:

- Net fishery Chinook impacts incidental to fisheries directed at coho.

Carr Inlet (13A) Net Fisheries:

- Closed from beginning of October through August 1.
- Net fishery Chinook impacts incidental to fisheries directed at coho and chum.

Chambers Bay (13C) Net Fisheries:

- Closed from end of mid-October to August 1.
- Net fishery Chinook impacts incidental to fisheries directed at coho and chum.

Case Inlet Area 13D Net Fisheries:

- Closed from mid-September to August 1.
- Net fishery Chinook impacts incidental to fisheries directed at coho and chum.

Henderson Inlet (Area 13E) Net Fisheries:

- Closed year-around.

Budd Inlet Net Fisheries:

- Closed from mid-September to July 15Net fishery Chinook impacts incidental to fisheries directed at coho and chum.

Areas 13G-K Net Fisheries:

- Closed Mid-September to August 1.
- Net fishery Chinook impacts incidental to fisheries directed at coho and chum.

Nisqually River and McAllister Creek Fisheries:

- Chinook fishery July through September managed to minimize mortality of natural origin fish. (up to three days per week dependent on in-season abundance assessment (see Appendix A).
- Coho fishery October through mid-November.
- Late chum fishery late November through January.

Hood Canal (12, 12B, 12C, 12D) Net Fisheries: (also see: Skokomish and Mid-Hood Canal Management Unit profiles in Appendix A):

- Chinook directed fishery limited to Areas 12C and 12H.
- Coho directed fisheries in Areas 12 and 12B delayed to Sept. 24; in Area 12C, to Oct. 1. Beach seines release Chinook through Oct. 15.
- 1,000 foot closures around river mouths, when rivers are closed to fishing.
- Net fisheries closed from mid December to mid July

Area 9A Net Fisheries:

- Closed from end of January to mid-August (dependent upon pink fishery).
- Beach seines release Chinook through Oct. 15.

Area 12A Net Fisheries:

- Closed from mid-December to mid-August.
- During coho and fall chum fisheries, beach seines release Chinook through Oct. 15.

Hood Canal Freshwater Net Fisheries:

- Dosewallips, Duckabush, and Hamma Hamma rivers closed.
- Skokomish River Chinook fishery August 1 – September 30, limited to two to five days per week.
- Skokomish River closed March – July 31(also see: Skokomish MU profile in Appendix A).