Comprehensive Management Plan for Puget Sound Chinook:

Harvest Management Component

PUGET SOUND INDIAN TRIBES

AND

THE WASHINGTON DEPARTMENT OF FISH AND WILDLIFE

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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 2019-2020 through 2028-2029. 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 that does not exceed the ER ceilings for each 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 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 whose abundance exceeds their critical threshold, and that populations with critically low abundance should be guarded against further declines, such that harvest will not significantly reduce the likelihood of survival and recovery of the ESU.

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.

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 2019 -2020 through 2028 - 2029. 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-, 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 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. It includes explicit measures to conserve and rebuild abundance and productivity, and preserve spatial structure and diversity among all the populations that make up 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, 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. 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

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 of salmon fisheries in Washington, Oregon, British Columbia, and Alaska, and the incidental impacts of tribal and recreational 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. Constraints on fishing are primarily focused on Treaty Indian and non-Indian commercial, tribal ceremonial and subsistence, and recreational salmon, steelhead, and trout/char fisheries that occur in the 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.

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).

Salmon fisheries in Alaska, Oregon, and British Columbia are also accounted to assess, as completely as possible, total fishing mortality on Puget Sound Chinook Salmon. 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.

Trout/char, spiny-ray, and hatchery steelhead-directed fisheries in Puget Sound, including tribal and recreational fisheries in marine and freshwater areas, may involve incidental mortality of 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 become an increasing portion of the fishery-related mortality should Puget Sound Chinook Salmon populations continue to decline. These impacts will be accounted as accurately as possible, and included 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, abundance, spatial structure, and diversity of the populations that make up the Puget Sound Chinook Salmon 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 Sockeye, Pink, Coho, and Chum Salmon, and hatchery steelhead, and other anadromous/resident trout/char, as well as harvestable Sockeye, Pink, and Chum Salmon originating in British Columbia pursuant to the Pacific Salmon Treaty.

- Account for all sources of landed and non-landed fishery-related mortality, in all fisheries, when assessing total exploitation rates, 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 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 assumed that the principles of the original abundance-based Chinook management framework, as described under the Chinook Chapter to Annex IV of the PST in 1999, will remain in effect, and a procedure for determining compliance with PST defined obligations will be followed during pre-season planning as described in this Plan.

Most of the harvest-related Puget Sound Chinook Salmon mortality in fisheries governed by this Plan will occur in fisheries directed at harvestable hatchery production, Sockeye and Pink Salmon (including stocks originating in the Fraser River), and Coho Salmon. 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, hatchery escapement and/or natural escapement thresholds as defined in the MUPs. Exploitation rate ceilings are expressed either as rates on all fisheries, southern U.S. fisheries, or pre-terminal southern U.S. fisheries. For some populations, terminal fishery management measures are specified that will achieve stated natural escapement goals. Exploitation rate ceilings for management units comprised of more than one population are defined with the intent of rebuilding 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 rebuilding 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. But 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. 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 increase escapements for those populations that are projected to be at or near critical abundance. For a small number of populations in critical 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.

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 coastal waters of Washington and 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 2015, total landed catch ranged from 244,230 to 499,300 (Table 2-1). The SEAK fishery is managed to achieve the annual all gear PSC allowable catch through plans established by the Alaska Board of Fisheries.

Table 2-1. Chinook salmon catch in southeast Alaska fisheries, 1999-2015 (CTC 2017)

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	69,537	426,534
2003	330,692	39,374	69,370	439,436
2004	354,658	64,038	80,572	499,268
2005	338,451	68,091	86,575	493,117
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	48,465	69,565	293,674
2010	195,614	30,582	58,503	284,699
2011	242,193	48,220	66,575	356,988
2012	209,036	39,491	46,495	295,022
2013	149,541	51,319	56,392	257,252
2014	355,570	49,990	86,942	492,502
2015	269,862	53,718	79,759	403,339

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 46,495 to 86,942 from 1999-2015, 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, 48% of the fishery-related mortality of Hoko, 7% of Stillaguamish, and 23% of Skagit summer Chinook occurred in Alaska (CTC 2017).

2.2 British Columbia

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 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 - 2015 (CTC 2017)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
AABM Fisheries																	
NBC Area 1-5 Troll	54,097	9,948	12,934	102,731	140,497	167,508	174,806	151,485	83,235	52,147	75,470	90,213	74,660	80,257	69,264	172,001	106,703
WCVI Troll	7,434	64,547	79,668	126,383	146,736	176,166	148,798	108,978	94,291	95,170	58,191	84,123	129,023	69,054	49,526	133,499	68,552
WCVI Sport	31,106	24,070	40,636	31,503	26,825	39,086	50,681	36,507	46,323	50,556	66,426	54,924	75,209	65,414	64,072	54,875	48,215
ISBM Fisheries																	
CBC Troll	2,073	0	482	0	0	0	0	0	0	9	0	0	0	0	0	0	0
Johnstone S Troll	273	85	453	129	719	316	2	0	0	0	0	2	0	0	0	0	0
Georgia S Troll	219	609	311	459	279	389	0	0	0	0	0	5	0	0	0	0	0
NBC Area 3-5 Sport	11,700	8,600	11,000	8,000	8,000	8,000	8,000	8,000	8,000	11,970	9,177	7,570	14,677	7,017	10,259	11,973	12,760
CBC Tidal Sport	10,300	7,400	7,650	7,330	8,385	10,677	9,017	9,400	6,130	2,909	3,239	4,043	7,701	5,861	4,457	7,800	10,597
WCVI Tidal Sport	47,163	5,443	6,354	36,073	51,186	61,218	43,577	44,025	39,368	24,855	31,921	24,687	52,131	25,890	22,272	28,679	34,668
JDF, GS, JS Sport	67,381	49,683	58,872	80,759	56,462	70,483	58,528	49,150	50,992	35,535	54,972	40,570	54,660	52,485	65,659	75,880	112,683

2.3 Washington Ocean

Treaty Indian and non-treaty 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], 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. Treaty 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-Indian 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 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. These fisheries primarily target Columbia River Chinook (CTC 2002). 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 fishery has 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 Treaty Indian and non-Treaty 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 – Areas 4B). In the last five years, troll catch has ranged from 60,181 to 166,836 (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

[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.

abundant coho stocks. Since 1999, recreational Chinook catch in Areas 1 – 4 has ranged from 8,500 to 57,800 (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 areas along the coast. The exploitation rate of most individual Chinook salmon management units in these coastal fisheries is, in most years, less than one percent. 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 - 2016 (PFMC 2017)

	Troll			
Year	Non-treaty	Treaty	Recreational	Total
1999	17,456	27,704	9,887	55,047
2000	10,269	7,789	8,478	26,536
2001	21,229	30,480	22,974	74,683
2002	53,819	40,301	57,821	151,941
2003	56,202	35,418	34,183	125,803
2004	35,372	65,903	24,907	126,182
2005	35,066	46,909	36,369	118,344
2006	16,769	31,241	10,667	58,677
2007	14,268	26,683	8,944	49,895
2008	8,636	21.990	14,635	46,261
2009	13,028	12,254	13,331	38,613
2010	56,219	32,376	38,686	127,281
2011	29,738	31,824	30,822	72,384
2012	45,299	54,789	35,433	135,521
2013	42,035	49,881	30,836	122,752
2014	54,889	61,547	42,331	158,767
2015	66,156	58,492	42,188	166,836
2016	19,402	22,832	17,947	60,181

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 Chinook 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, both in pre-terminal and 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. Catches taken by treaty Indians for ceremonial and subsistence purposes are counted against the applicable treaty allocation. 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

Commercial salmon fisheries in Puget Sound, including the U.S. waters of the Strait of Juan de Fuca, Rosario Strait, Georgia Strait, embayments of Puget Sound, and Hood Canal, are managed by the tribes and WDFW under the Puget Sound Salmon Management Plan. Several tribes conduct commercial troll fisheries directed at Chinook salmon in the Strait of Juan de Fuca. These fisheries include 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 ocean fishery in neighboring areas from May through October. Annual harvest over the past 5 years has ranged from 400 to over 3,700 in the winter fishery, and from 958 to 8,402 in the Area 4B spring/summer fishery.

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-treaty fleets) and by individual tribes (treaty 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 also occurs in net fisheries directed at Sockeye, Pink, and Coho 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 and on the coast immediately south of Cape Flattery. 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 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 102,500 since 2000.

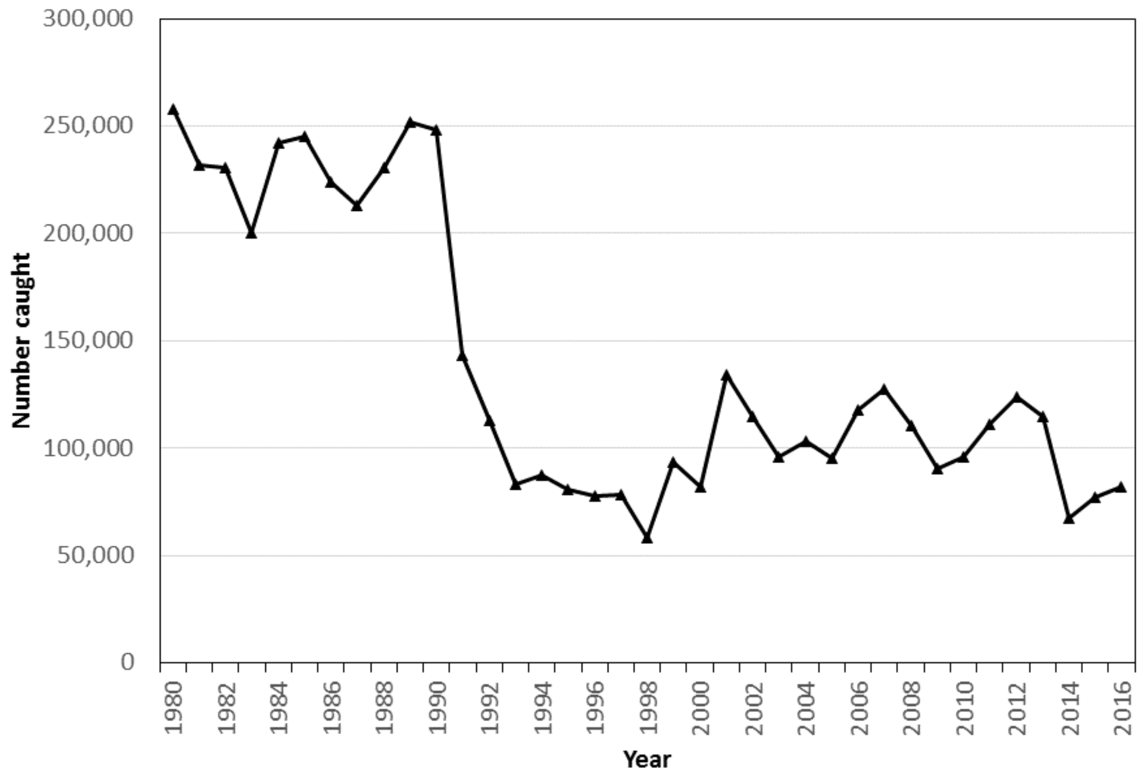


Figure 2-1. Commercial net and troll catch of Chinook in Puget Sound fisheries, 1980 – 2016 (WDFW WaFT database).

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 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 358,817 between 2008 and 2016, ranging from 1,521 to 1,969,066 (Table 2-4). Fraser Pink salmon return in odd years, with odd-year catches averaging 3,049,126 over the same period. Recent Pink salmon harvest has increased substantial over the 2001-07 average, but remains constrained due to concerns for co-migrating late run Sockeye salmon (PSIT and WDFW 2010). 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, 2008-2016

	Species	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Strait of Juan de Fuca	Chinook	4,570	99	2,246	345	1,563	620	1,300	820	258
	Pink	632	1,145	1,141	22,622	21	10,537	45	2,118	17
	Sockeye	34,365	664	138,692	21,628	15,298	4,510	4,012	1,040	1,453
Rosario and Georgia Straits	Chinook	55	1,049	6,758	5,714	437	3,913	6,839	4,781	19
	Pink	49	3,756,274	886	3,640,371	1,744	4,069,935	638	693,502	4
	Sockeye	24,460	6,734	1,830,374	257,501	103,989	22,884	710,030	51,653	68

Commercial fisheries directed at Cedar River Sockeye salmon stocks may occur in Shilshole Bay, the Ship Canal, and Lake Washington. Smaller scale commercial fisheries targeting Baker River Sockeye salmon occur in the Skagit River. The Cedar River stock does not achieve harvestable abundance consistently and has not had a significant fishery since 2006. These fisheries generally involved low incidental Chinook salmon mortality.

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, and 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 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. 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, 2007-2015.

Terminal Area	2007	2009	2011	2013	2015
Bellingham Bay/Nooksack	677	3,052	6,238	87,039	66,509
Skagit Bay/River	5,856	306,294	314,248	537,312	59,721
Stillaguamish/Snohomish	20,463	489,403	440,297	1,006,657	107,072
South Puget Sound	14,132	186,022	110,296	189,478	48,116

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 2011-2016, total landed Coho salmon catches have been relatively stable between 200,000 and 400,000, with a lower catch of 51,551 occurring in 2015 (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, 2011-2016. Regional totals include freshwater catch.

	2011	2012	2013	2014	2015	2016
Strait of Juan de Fuca	3,549	3,938	4,348	3,285	1,014	6,332
Georgia & Rosario Strait	16,335	15,743	21,708	22,873	4,249	8,095
Nooksack-Sammish	71,640	60,651	93,348	29,430	15,193	51,820
Skagit	21,796	19,590	26,899	14,286	3,015	5,537
Stillaguamish-Snohomish	21,561	57,125	54,074	46,939	8,205	77,202
South Puget Sound	42,755	133,209	85,428	56,008	11,207	77,434
Hood Canal	75,089	93,765	44,460	32,462	8,668	53,935
Total	252,725	384,021	330,265	205,283	51,551	280,355

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 (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, 2011 - 2016. Regional totals include freshwater catch.

Region	2011	2012	2013	2014	2015	2016
Strait of Juan de Fuca	1,986	672	1,292	5,286	7,389	26,707
Georgia & Rosario Strait	70,359	73,236	80,472	147,022	126,521	118,263
Nooksack-Samish	49,977	17,462	19,195	32,649	39,918	46,041
Skagit	1,133	4,637	1,344	1,434	1,584	477
Stillaguamish-Snohomish	32,101	4,025	7,761	11,386	5,133	1,525
Area 9	366	5,472	2,740	8,166	13,362	24,202
Hood Canal	508,078	592,301	1,191,216	572,839	648,861	564,928
South Puget Sound	401,495	445,677	422,956	391,863	337,365	214,044
Total	1,065,495	1,143,482	1,726,976	1,170,645	1,180,133	996,187

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 32,200 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 80,000 since 2002.

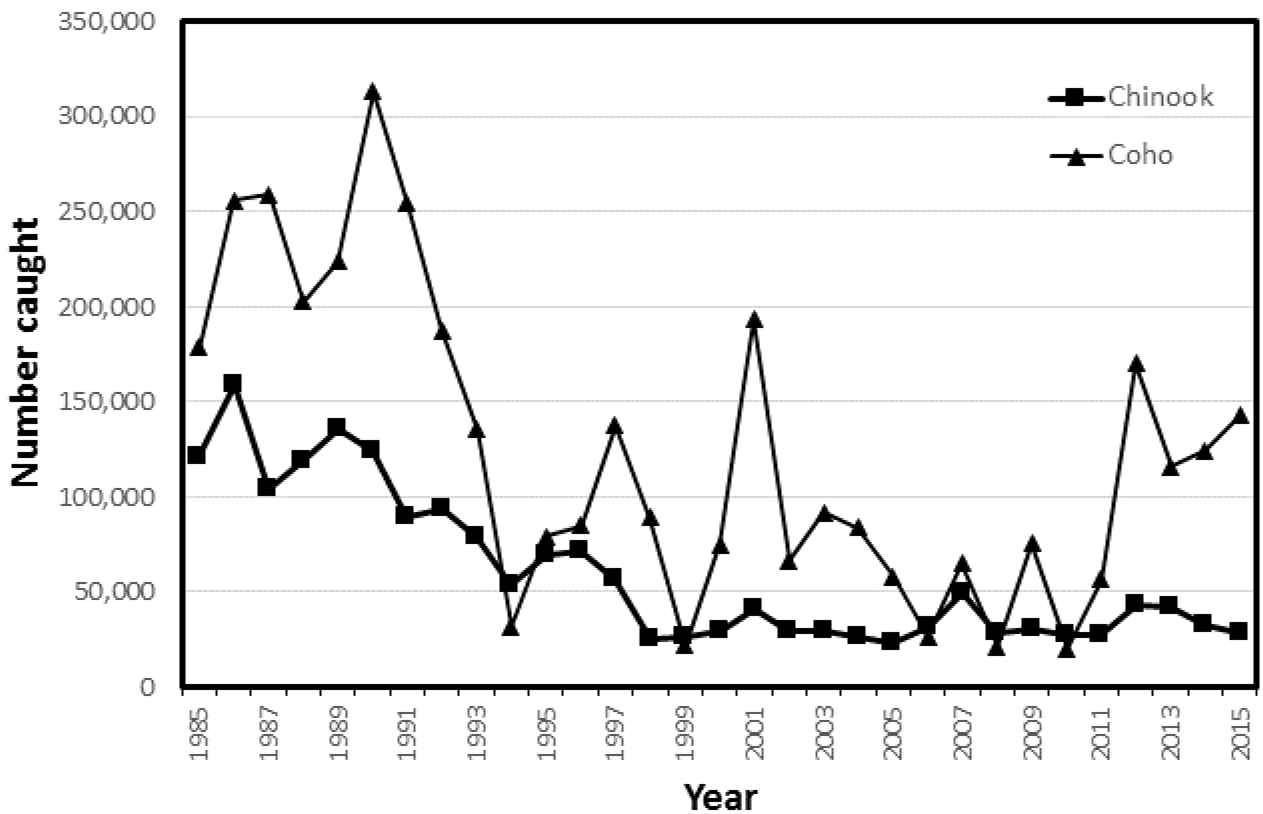


Figure 2-2. Recreational salmon catch in Puget Sound marine areas, 1985 - 2015 (WDFW CRC estimates, 2007 data are preliminary)

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.

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-treaty fisheries to the recreational sector.

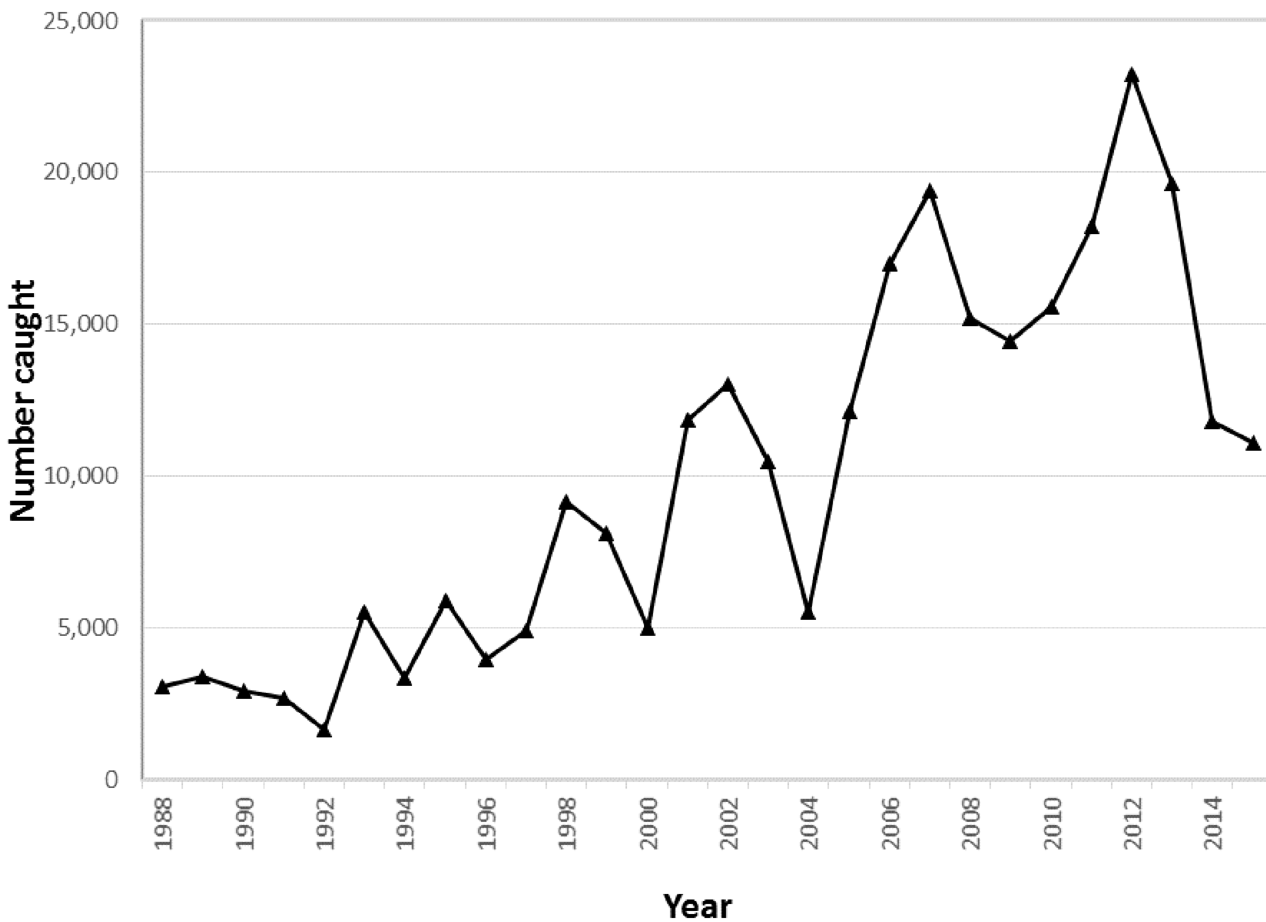


Figure 2-3. Recreational Chinook harvest in Puget Sound freshwater areas, 1988 - 2015(WDFW Catch Record Card estimates).

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. In 2017, the base period used for the FRAM model was updated to use CWT from recent years, 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.	2.0%
Freshwater Recreational	Retention Non-Retention MSF		n.a. 10.0% [b] 10.0% [b]	5.0% 5.0% [b] 5.0% [b]

[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”. Purse seine release mortality is 33 % or 45 % depending on season and maturity. 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 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 significantly 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), 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

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 exploitation rate guidelines or quotas for fisheries subject to the PST based on the forecast abundance of key Chinook salmon stocks. This regime was in effect for the 1999 through 2008 period. Fisheries are classified 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).

Three fishery complexes were designated for management as AABM fisheries: 1) the SEAK sport, net and troll fisheries; 2) the Northern British Columbia troll (statistical areas 1-5) and the Queen Charlotte Islands sport (statistical areas 1 - 2); and 3) the WCVI troll (statistical areas 21,23-27, and 121-127) and sport, for specified areas and time periods. The estimated abundance index each year is computed by a formula specified in the agreement for each AABM fishery. Table 1 of the Chinook salmon chapter of the new Annex IV specified the target catch levels for each AABM fishery as a function of that estimated abundance index.

All Chinook salmon fisheries subject to the Treaty that are not AABM fisheries are classified as ISBM fisheries, including freshwater Chinook salmon fisheries. As provided in the 2008 agreement, “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.” For these fisheries, the agreement specifies that Canada and the U.S. shall reduce the total adult equivalent mortality rate by 36.5% and 40% respectively, relative to the 1979-1982 base period, for a specified list of indicator stocks. In Puget Sound these include Nooksack early, Skagit summer/fall and spring, Stillaguamish, Snohomish, Lake Washington, and Green stocks.

If such reductions do not result in the biologically based escapement objectives for a specified list of natural-origin stocks, ISBM fishery managers must implement further reductions across their fisheries as necessary to meet those objectives or as necessary to equal, at least, the average of those reductions that occurred during 1991-1996. Although the specified ISBM objectives must be achieved to comply with the agreement, the affected managers may choose to apply more constraints to their respective fisheries than are specifically mandated by the agreement. The annual distribution of allowable impacts is left to each country’s domestic management processes.

In 2008, the Pacific Salmon Commission recommended, and the governments endorsed, a new bilateral agreement for the conservation and sharing of harvest sharing of the salmon resource to the governments of the United States and Canada. The new agreement took effect in 2009. The biggest change in that agreement was a reduction to the catch rate limits in the 1999 agreement, resulting in reductions of 15% for Southeast Alaska AABM fisheries, and 30% for West Coast Vancouver Island AABM fisheries. The expectation was that this would result in exploitation rates for most Puget Sound stocks to decline 2 – 3% in these fisheries. However, while this magnitude of a reduction was realized for Puget Sound spring stocks, such impact reductions did not occur for most of Puget Sound fall stocks (CTC 2016). A new agreement scheduled to be completed in 2018 and implemented in 2019 is currently under negotiation. A large focus of the 2018 Chinook salmon agreement negotiations is directed at addressing the conservation needs of Puget Sound Chinook salmon.

Distribution of Fishing Mortality

A significant portion of the fishing mortality on many Puget Sound Chinook salmon stocks occurs 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. 2009-2014 average distribution of fishery mortality, based on coded-wire tag recoveries, for Puget Sound Chinook salmon indicator stocks (CTC 2017).

Indicator stock	Alaska%	Canada	US troll %	US net%	US sport %
Nooksack spring fingerling	8.7%	69.4%	4.0%	5.6%	11.7%
Samish fall fingerling	0.3%	24.2%	8.0%	51.7%	15.7%
Skagit spring fingerling	1.8%	33.7%	0.8%	4.8%	14.4%
Skagit spring yearling	1.4%	32.8%	1.7%	36.2%	28.7%
Skagit summer/fall fingerling	21.1%	39.7%	1.3%	29.6%	8.5%
Stillaguamish fall fingerling	14.6%	52.0%	2.3%	4.7%	26.5%
South Puget Sound fall fingerling	0.9%	39.0%	10.2%	24.7%	25.2%
Nisqually fall fingerling	0.2%	16.2%	7.3%	%	33.5%
Skokomish fall fingerling	0.5%	24.1%	6.7%	32.1%	36.6%
Hoko fall fingerling	41.0%	44.8%	3.4%	0.0%	11.6%

Trends in Exploitation Rates

Post-season FRAM ('validation') runs, which incorporate catch and stock abundance from post-season assessments, are available for management years 1992-2014, 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).

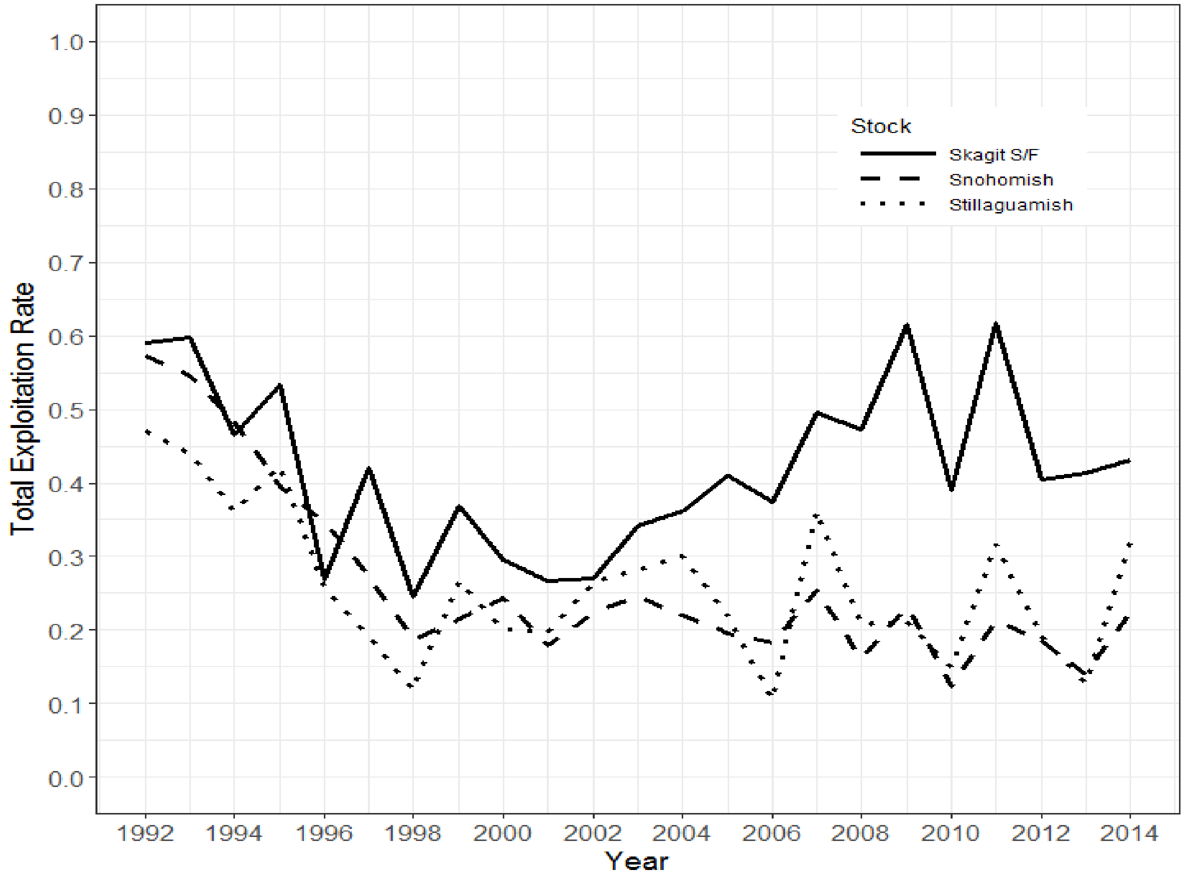


Figure 2-4. Total exploitation rate for Skagit, Stillaguamish, and Snohomish summer/fall Chinook salmon management units, 1992-2014 (based on 2017 FRAM validation run).

Figure 2-5. Total exploitation rate for Nooksack, Skagit, and White spring Chinook salmon management units, 1992-2014 (based on 2017 FRAM validation run).

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 are aggregated 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 genetic and ecological diversity of populations throughout 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. These stocks generally occur in watersheds where independent populations existed historically. To assist their delineation of historical population structure, the Puget Sound Technical Recovery Team's (TRT) (Ruckelshaus et al. 2006) examined juvenile freshwater life history, age of maturation, spawn timing, and physiographic characteristics of watersheds. Therefore, the spatial structure of the stocks in this Plan conforms to the TRT population delineation (Ruckelshaus et al. 2006) that was developed as part of recovery planning, although many of the historical, distinct populations are now extinct.

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 native to, or produced naturally, 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

[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.

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.

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 comprise one population.
[2] The Hoko River is not part of the listed Puget Sound ESU.

Puget Sound Chinook salmon populations primarily exhibit a subyearling ('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 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).

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').

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. 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 population aggregates – Strait of Juan de Fuca, Nooksack River early, Skagit, Stillaguamish River summer and fall[4] and Snohomish rivers, central and southern Puget Sound and Hood Canal late, and 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, Stillaguamish, Snohomish, Lake Washington, Green/Duwamish, Puyallup, Nisqually, Skokomish, Mid-Hood Canal and Elwha systems (Table 6 in Ruckelshaus et al. 2006). Genetic analyses of extant returns to these systems do not detect continued distinct, native 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

This Plan aggregates populations that exhibit similar run timing into management units, for the purpose of managing harvest (Table 3-1). This is due largely to the spatial and temporal commingling of these populations throughout their harvest distribution. For these management units, a technical means for planning or implementing differential harvest of single populations does not exist.

[4] Analysis of subsequent data gathered since this initial work indicates geographic distinction for these populations is not warranted. Genetic analysis of this data indicates that these populations overlap within the basin. The comanagers now view this as a summer/fall management unit.

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 requirement, 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 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 of which (Mid-Hood Canal) is comprised of spawning aggregations within three distinct rivers. This Plan includes management measures intended to conserve the genetic and run-timing characteristics of each population until habitat is restored to levels that can support viable populations and sustainable harvest (see Chapter 6, and the management unit profiles for Skagit, Stillaguamish, Snohomish, and Lake Washington[5] in Appendix A). Management units are not the smallest units considered in management of Puget Sound fisheries; however, that does not mean that separate populations must be managed for the same objective as the management units (i.e., MSH escapement). It means that each separate population is managed to avoid or reduce its risk of extinction.

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.

[5] See Chapter footnote 1

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 population is functionally extinct. Habitat conditions may not currently support self-sustaining natural production.

- 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 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, especially the Green River stock which was used to initiate and perpetuate many hatchery programs in many of these 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 fish 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 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, and where current habitat conditions may prevent recovery, generally have higher levels of harvest than Category 1 populations under this Plan. 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

Escapement to each MU is projected during pre-season fishery planning, after accounting for fishing mortality in all fisheries. 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. 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 population status, either pre-season or post-season.

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. UMTs for the Skagit summer/fall, Skagit spring, Stillaguamish, 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. 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. 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]			16% SUS ER		10.5% SUS ER, 13.5% SUS ER[1]	
North/Middle Fork		2,000		800		
South Fork		1,000		400		
Skagit Summer/Fall		14,500	47%	6,500 [3]	15% SUS even-years/17% SUS odd-years	1,677
Upper Skagit summer-run				2,200 [3]		
Sauk summer-run				400 [3]		
Lower Skagit fall-run				900 [3]		
Skagit spring-run		2,000	38%	690 [3]	18% SUS	215
Upper Sauk				130 [3]		
Upper Cascade				170 [3]		
Suiattle				170 [3]		
Stillaguamish River [2]		1,500	24%[3]	1,200	see MUP [3]	900
Snohomish River		4,900	21%	3,375 [3]	15% SUS	
Skykomish summer-run		3,600		2,092 [3]		1,745
Snoqualmie fall-run		1,300		1,066 [3]		700
Lake Washington – Cedar River fall-run [4]	12%-13% PT SUS[5]	500	18% SUS	200	12% SUS	
Green River fall-run [4]	12%-13% PT SUS[5]	3,800	18% SUS	805	12% SUS	
White River spring-run		1,000	22% SUS	400	15% SUS	
Puyallup fall-run [4]	12%-13% PT SUS[5]	1,300	30% SUS	319	15% SUS	
Nisqually			47%	7,000 [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		750	15% PT SUS	400	12% PT SUS	
Dungeness		925	10% SUS	500	6% 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
Elwha		2,900	10% SUS	1,500	6% SUS	1,000
Western Strait of Juan de Fuca – Hoko River		1,050	10% SUS	500	6% SUS	

[1] SUS ER will not exceed 10.5% in 4 out of 5 years
[2] See Stillagumaish MUP for description of sliding ER implementation at various abundance thresholds, including SUS ceilings on hatchery-origin spawners.
[3] Natural-origin spawners.
[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 13% PT SUS for Lake Washington, Green River, and Puyallup River is triggered if all three Management Units meet the additional upper management thresholds (UMT #2) stipulated in each MUP (see Appendix A), otherwise the Upper Management ER ceiling is 12% PT SUS.
[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. The ER ceiling of 50% applies exclusively to the late-timed component of fall-run stock. Harvest impacts on the earlier-timed George Adams component is expected to be higher (see Skokomish MUP for greater description).
[8] See Skokomish Recovery Plan for Skokomish River spring-run Chinook harvest 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 and associated uncertainty about population dynamics.

For the Skagit River spring-run Chinook and summer/fall-run MUs, the LATs were established based on consideration of the 95% confidence interval range around the modeled 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.

The LAT for the Stillaguamish MU, is based on MSY capacity estimate and rounded up to 1,200 natural spawners, almost double NOAA's rebuilding escapement threshold (RET=650 spawners) to inform their RER analysis.

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, referring to published literature, the LAT was set 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 has defined 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. 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 quantified as 5% of the estimated spawning equilibrium abundance derived from stock-recruit relationships with additional considerations for model uncertainty and trends in habitat conditions (see respective MUP's for further detail). The Stillaguamish stock POI was determined by estimating lowest spawners with positive recruitment in recent years.

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 verified 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, 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, Stillaguamish, and Snohomish management units were derived from risk analysis based on quantified productivity from population dynamics modeling reflected 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 managed to achieve natural spawning escapements at, or above, the MSY estimates in addition to meeting hatchery escapement goals.

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 critical Chinook management units 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 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 result in minimal additional demographic and genetic risk to critical stocks while providing some opportunity on healthy, harvestable stocks and species. An important outcome of this Plan's approach to defining fishing limits on stocks in critical 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 status response, including complete closure of all fisheries, is unlikely to improve the status of any critical MU. 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 total SUS ceiling exploitation rates for most management units. For the Skokomish and Mid Hood Canal MUs, the CER ceilings apply only to pre-terminal fisheries. For these units, additional terminal fishery conservation measures are detailed in their respective MU profiles (Appendix A).

Derivation of Exploitation Rate Ceilings

ER ceilings applying to all fisheries are established for the Skagit summer / fall, Skagit spring, Stillaguamish, 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:

1. 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,
2. 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 Stillaguamish MU were based on Chinook Technical Committee (CTC) modeled exploitation rate estimates, while the Skagit River MUs harvest related mortality parameters are based on FRAM modeled exploitation rates. The Snohomish MU ER celing 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 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.

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 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 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 that 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 escapement 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 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 natural and/or hatchery 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 proposed to protect escapements of hatchery populations. 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.

- 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 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 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 meet or exceed the respective management unit's management objectives above the upper management threshold, and confirmed by in-season modeling and 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 stocks, except Stillaguamish and Snohomish MUs, 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 2018 Pacific Salmon Treaty Chinook Agreement, such that the SUS ISBM Fishery impacts will not exceed the Treaty-mandated obligation (see Section IV, Pacific Salmon Treaty). The SUS ISBM Fishery comprises the aggregate of Washington/Oregon coastal and Puget Sound 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 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 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 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, 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 status.

As described in Chapter 1.3, restriction of harvest will not, by itself, enable recovery of populations that have suffered severe decline in abundance, resulting from loss and degradation of properly functioning habitat conditions. 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 total SUS ceiling exploitation rates for the Nooksack, Skagit Summer/Fall, Skagit Spring, Snohomish, Lake Washington, Green, White, Puyallup, Dungeness, Elwha, and Hoko Chinook Salmon MUs. For the Mid Hood Canal and Skokomish Chinook Salmon MUs, the ceiling rates apply only to pre-terminal fisheries. For these units, additional terminal fishery conservation measures are detailed in the unit profiles (Appendix A). For the Nisqually River MU, the CERC will be up to a maximum 50% reduction in SUS ER impacts (including elimination of the freshwater gear evaluation fishery) after accounting for Alaskan and Canadian fisheries to a FRAM estimated total escapement of 7,000 fish to the hatcheries and spawning ground. The SUS ER reduction for Nisqually will be made equal and commensurate to both marked and unmarked Nisqually Chinook.

During pre-season planning the co-managers may, by agreement, set the management objective for any critical MU below the specified CER ceiling. Fishing patterns and regulations vary between years and the impacts on critical units in individual fisheries will also vary. To ensure that SUS ERs for critical MUs do not exceed the CER ceiling, fisheries that incur projected impacts on critical 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[6].

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 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 (PSC 2006). 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 2018 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 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 status is unlikely over the duration of this plan. In the past, the

[6] 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*.

Snohomish and Stillaguamish MUs, which both have total ER cielings, have at times been managed under this status. However, the co-managers intent for these MUs under this plan, is to ensure that fisheries impacts will not exceed the total ER ceilings regardless of level of impacts from northern fisheries (see respective MUPs for details). While this measure may imposes a further conservation burden on Washington fisheries, pursuant to the underlying rationale for the MFR, it maintains access to the harvestable surplus of non-listed 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 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 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- 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 2018 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.

In 2018, the parties to the Pacific Salmon Treaty agreed to a revised 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[7]. The summer/fall indicator stocks include the Hoko, Skagit, Stillaguamish, Snohomish, Lake Washington, and Green 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.

[7] Escapement goals for the Puget Sound indicator stocks, equivalent to the upper management thresholds stated in this plan, have been proposed to the Joint Chinook Technical Committee of the Pacific Salmon Commission for incorporation into the Chinook Agreement.

The US ISBM Fishery obligation is defined in the 2018 Chinook Agreement (PSC 2018). The PST defers to any more restrictive limit mandated by the Puget Sound Chinook Harvest Management Plan, or otherwise implemented by the co-managers.

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

5.7 In-season Management

Fisheries 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 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-treaty 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 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-four[8] associated component populations of Chinook salmon throughout the 5 biogeographical regions that comprise the Puget Sound 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 ESU. Harvest constraint will play a role by providing adequate escapement to optimize natural production under existing habitat conditions, and maintaining the existing diversity of populations that make up the 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.

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 will increase escapement for populations at critical or near-critical abundance. Hatchery recovery programs are in place for some of the

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

populations at high risk of extinction to ensure their persistence. 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.

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). The 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 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 used to derive escapement thresholds and exploitation rate ceilings for the Skagit summer / fall, Skagit spring, Stillaguamish, 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 abundance is currently above the critical threshold, rebuilding to their viable threshold must not be impeded. The long-term goal for recovery of the ESU envisions restored functionality of habitat, and much higher than current productivity, with proportionately higher harvest potential, and higher escapement suited to restored habitat function. Viable abundance 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 in the context of current habitat capacity. Such viable thresholds reflect levels of abundance that fulfill the requirement to not impede recovery but are much lower than would be possible under the future restored habitat condition.

The abundance of most Puget Sound populations exceeds their critical low abundance thresholds. For some MUs (Skagit summer/fall, Skagit spring, Stillaguamish summer/fall, and Snohomish) ER ceilings were derived with the intention of having a high probability of achieving their viable abundance thresholds. 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[9]. 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 all these MUs. Hatchery supplementation is

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

essential to maintaining the viability of the Stillaguamish populations and are considered as part of the abundance thresholds. 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 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 is based on assessment of available spawning habitat area and spawner density. The UMT for the Skokomish MU is 3,650, including 1,650 natural spawners and 2,000 returns to the George Adams Hatchery.

Under this Plan, harvest limitations are not specifically designed to produce escapements that 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, 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.

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. Hatchery programs have been operating for decades in these systems. 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, and Skokomish systems. Recovery potential is uncertain because these populations will depend on the adaptability of introduced stocks. Available estimates indicate that current natural productivity of the populations in these systems is low and there is strong evidence that freshwater and marine habitat conditions are a significant cause. The additive risk of hatchery-related fitness loss is uncertain, but we assume that productivity will not recover significantly until the freshwater and marine habitat constraints are addressed. Reliable assessments of the effectiveness of habitat restoration and protection efforts which are ongoing in most watersheds will not be available for decades.

With these circumstances in mind, the strategy of this Plan is to maintain current abundance for all populations and, for more healthy and productive MUs, to increase escapements up to or above the optimum levels defined by productivity associated with current habitat condition. The

Plan provides more restrictive fishery impact limits when the abundance of populations is forecast to be below their threshold defining critical, or Low Abundance Threshold, status. Absent immediate and effective measure to address habitat constraints, 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. 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 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 synch more appropriately with the local hydrograph. As a result of this strategy, a higher harvest rate is envisioned for the earlier component (July-August entry timing) of the fall-run stock and a total ER ceiling of 50% on the later component of this fall run (Appendix A, Skokomish MUP).

Management Units in Critical Status

Annual pre-season fisheries planning will respond to the status (i.e., projected spawning escapement) of individual populations at or near critical status, 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 (CER). 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 MUs or populations, management efforts made by the co-managers with fisheries under their jurisdiction to address critical status are limited and may even be compromised by lack of response in those northern fisheries.

Critical or near-critical 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 hatchery recovery programs to ensure their persistence. Chinook-directed fisheries in the terminal areas for these populations have been closed, except for tribal C&S harvest in the Nooksack River and Stillaguamish River. Pre-terminal SUS fishery impacts from 2010 to 2014 have been held to low levels: 5 – 8% for the Nooksack, 5 – 12% for the Stillaguamish, 8 – 13% for Mid Hood Canal, and 4 – 6% for the Dungeness and Elwha MUs based on New Base period 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 listing, the co-managers implemented harvest conservation measures in response to declining returns of certain stocks. Total or SUS ER ceilings were implemented with previous versions (2001, 2004 and 2010) of this Plan. Since 2008, SUS ERs for 10 of the 14 MUs have been reduced relative to the late 1990s (Table 6-1)**Error! Reference source not found.**.

Table 6-1. Average Southern U.S. fishery exploitation rates for Puget Sound Chinook Salmon management units based on FRAM validation runs.

Management Unit	1994-98 Avg	2001-08 Avg	2009-14 Avg
Nooksack Spring	14.2%	5.6%	8.8%
Skagit Summer/Fall	13.9%	10.2%	21.4%
Skagit Sprring	8.4%	5.7%	10.9%
Stillaguamish	15.6%	7.8%	7.5%
Snohomish	21.3%	8.0%	6.9%
Lake Washington	21.5%	15.5%	16.5%
Green	31.8%	35.4%	21.1%
White River Spring	24.1%	15.4%	15.4%
Puyallup	47.7%	42.0%	40.4%
Nisqually	67.5%	61.7%	46.4%
Skokomish	24.7%	46.7%	44.8%
Mid-Hood Canal	20.9%	12.1%	10.9%
Dungeness	4.9%	2.6%	5.0%
Elwha	5.6%	2.3%	4.2%

Analysis of escapement trends for Puget Sound Chinook demonstrates changes in population status during the period 2001-2015 using the Geiger 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 status. Based on this method, four populations exhibit biologically significant declining trends. Negative slopes are evident in 12 other populations, but are not considered biologically significant. Five populations exhibit biologically significant increasing trends, with positive slopes evident in two 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 (NWIFC 2013, 2016 and NMFS 2011) indicate the habitat conditions continue to worsen, despite ongoing efforts to restore and protect habitats.

Table 6-2. Fifteen-year (2001-2015) trends in natural spawning escapement for Puget Sound Chinook populations.

MU	Population	15-year series slope	slope/y_0
Nooksack	North / Middle Fk	-83.80	0.036
	NF/MF NORs	-12.40	0.041
	So Fork NORs	-4.70	0.057
Skagit spring	Suiattle	-3.50	0.008
	Upper Sauk	46.30	0.134
	Cascade	-11.50	0.028
Skagit S/F	Lower Sauk	-50.40	0.052
	Upper Skagit	-507.70	0.035
	Lower Skagit	-133.80	0.042
Stillaguamish [1]	Summer and Falls	-38.41	0.022
Snohomish	Skykomish	-129.30	0.030
	Snoqualmie	-205.80	0.059
Lake Washington	Sammamish	-5.10	0.005
	Cedar River	25.50	0.028
Green		-374.33	0.050
White		167.90	0.116
Puyallup		-36.30	0.017
	South Prairie Cr.	-32.70	0.034
Nisqually		46.80	0.031
Skokomish		-59.20	0.031
Mid Hood Canal		16.00	2.417
Dungeness		-23.30	0.035
Elwha		180.70	0.161
Hoko		55.80	0.100

[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 assure stable or increasing escapement for those management units. By setting the fishery exploitation rate ceilings conservatively and all else remaining constant, the Plan anticipates an increase in the probability that escapement will trend upward over time. 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 for each management unit. These equilibrium rates are represented by the curve that forms the border between the shaded and white regions in Figure 6-1. Note that, due to declining productivity, the equilibrium ER decreases as escapement increases. In the region below this 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.

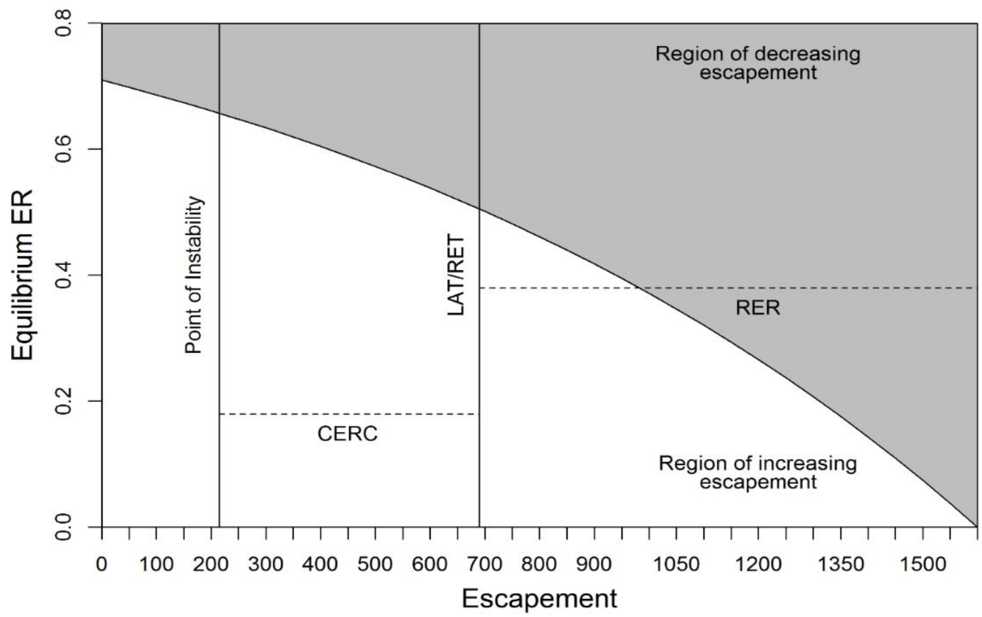


Figure 6-1. The equilibrium exploitation rate, at each escapement level, for Skagit spring Chinook.

For Skagit spring Chinook, the NMFS Limit 6 “viable threshold” is equivalent to the “rebuilding escapement threshold” (RET) used in the ER ceiling analyses and is the MSY escapement level of about 850 derived from the Ricker spawner-recruit parameters (Figure 6-1). The NMFS Limit 6 “critical threshold”, however, is NOT equivalent to the “critical 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 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 threshold for Skagit spring Chinook in this Plan is 690 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).

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 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 status. In fact, even ER's significantly above the ER ceiling satisfy this criterion.

For escapements greater than the viable 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 threshold. Thus, the plan also satisfies the criterion that, for escapements above the viable threshold, abundance will, on average, be maintained in that region.

For escapements below the 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 point of instability. Rebuilding above this level could only be accomplished through fortuitous returns or increased productivity. This plan addresses risks associated with abundances below the 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 regime occurs at a threshold of 690, which is over 3 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 point of instability, and then was followed by a fortuitous recruitment that exceeded that level, the 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 2 times higher than the calculated point of instability – escapements have exceeded 1,000 during 5 of the last 5 years, which is higher than the viable 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.

	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. 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 conditions limit the potential for recovery for most populations.

With the exceptions noted above, these population recovery goals are not of immediate relevance to current harvest management objectives. Because these recovery goals are high enough to support substantial harvest, they may exceed the abundance levels required to delist the ESU. ESU recovery may be possible under more than one combination of recovered 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. 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) that mitigate adverse conditions.

For several Puget Sound populations, mass marking of hatchery production has enabled 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 to spawn, whereas returns of natural-origin Chinook salmon, though stable, have not increased. Abundance (escapement) data for the North Fork Nooksack, Skokomish, Skykomish, and Dungeness rivers shows NOR returns have remained at very low levels, while total natural escapement has either increased or held stable where hatchery supplementation programs exist. 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.

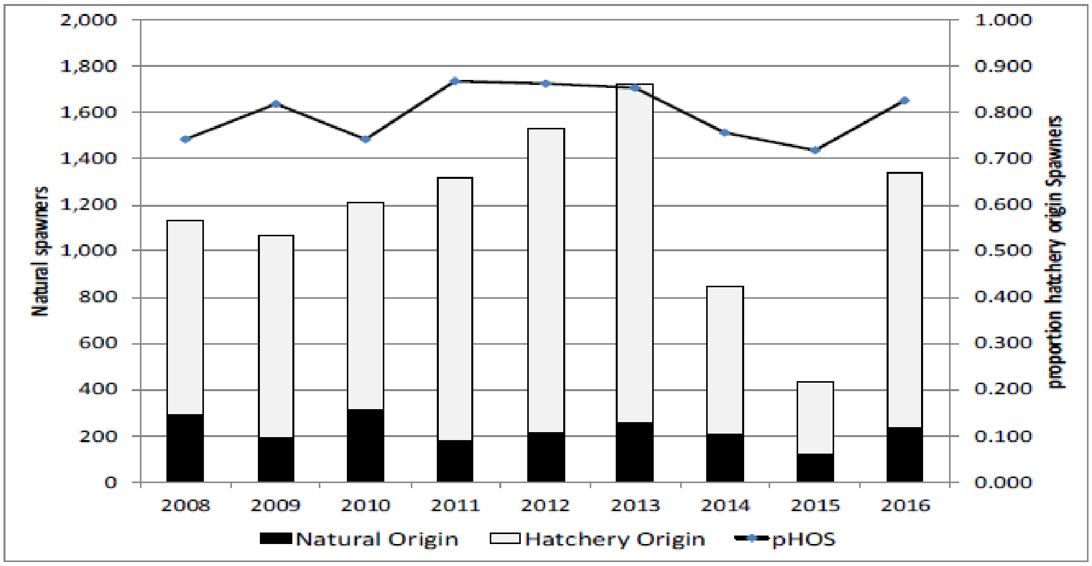


Figure 6-2. Natural and hatchery origin spawner abundance on the Skokomish River for 2008 – 2016.

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 poputlation 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.

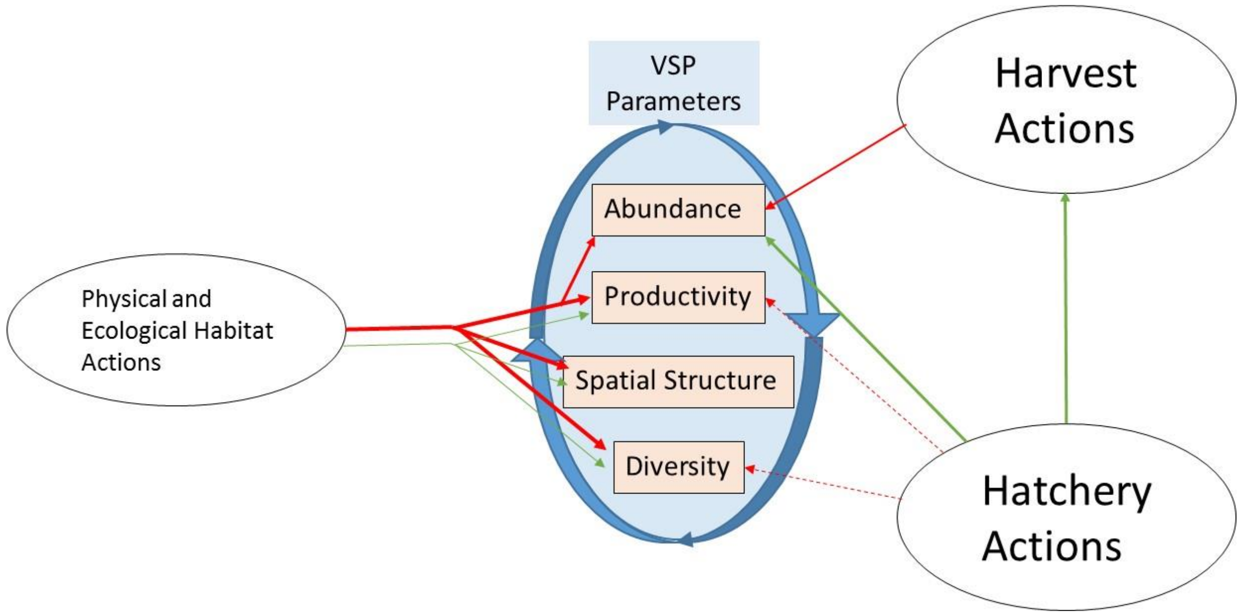


Figure 6-3. Effects of habitat, harvest, and hatchery management sectors on viable salmonid population (VSP) attributes.

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 2006)
- Different factors interact to affect overall risk to the listed populations (NMFS 2007)
- Interactions and tradeoffs between risks 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 2006, 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. 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.[10]

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:

1) the opportunity for habitat recovery (i.e., the adequacy of habitat protection);
2) the current status of the habitat; and
3) 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 treaty and non-treaty 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. Conservation

[10] *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").

by all sectors that affect salmon population viability is necessary to protect and recover salmon. Ignoring the population viability 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, habitat 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 2014a, b; 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 2006). Although NMFS has not yet assessed salmon habitat based on the qualities they identified (Beechie et al. 2016), 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 (NMFS 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).

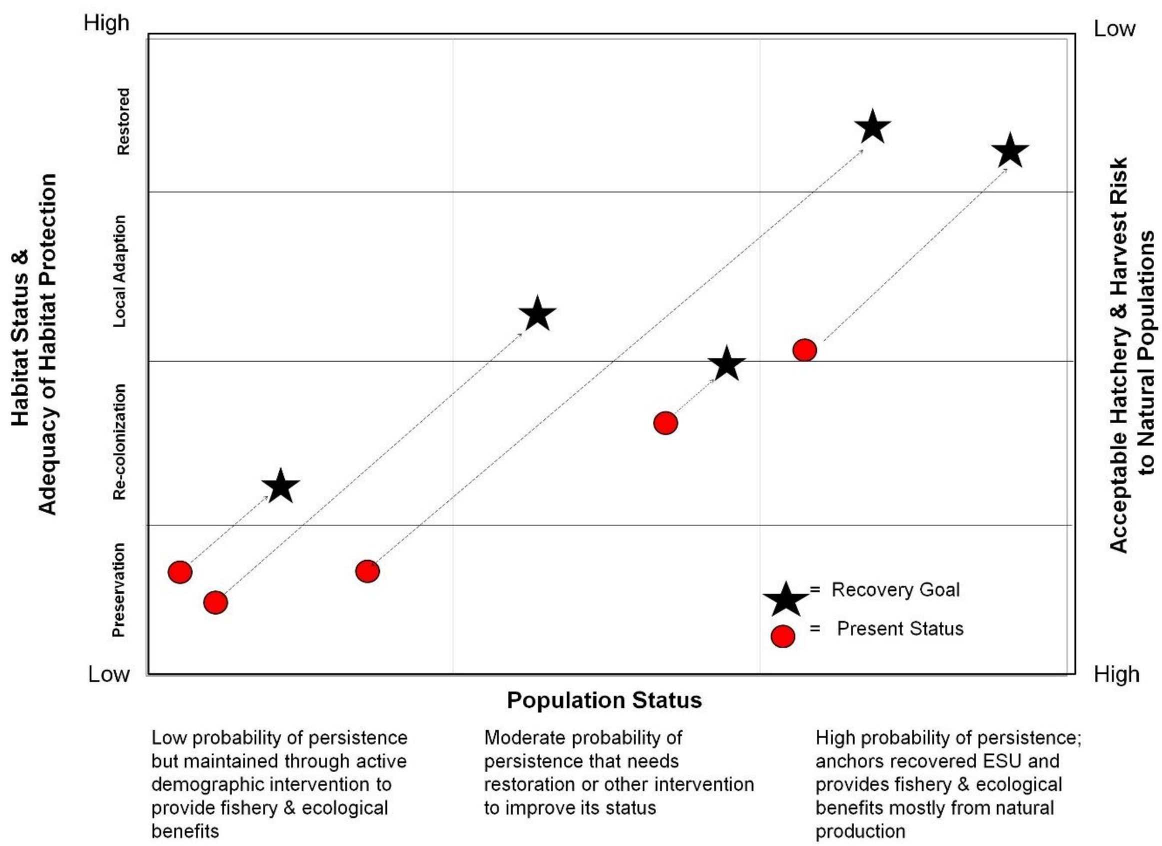


Figure 6-4. Pathways for changing harvest and hatchery management based on habitat status and the adequacy of regulatory protection for habitat. Circles indicate current status; stars

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 2006, 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 change. 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 primary 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 2006), 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 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 successful life-history types versus protection and

Biological Phases	Ecosystem Conditions	Objectives	Conflicting Objectives and Trade-Offs
Re-colonization (cont.)			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 adaptive management	• Long-term cost, pace, and certainty of protecting habitat for natural production of salmon versus using the same habitat to support human population

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 be play 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 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 of populations in Puget Sound by enabling some populations to reach their viable thresholds, hold others at stable abundance levels, well above their critical 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, Stillaguamish summer/fall, and Snohomish populations reflect low risk of decline to critical 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. 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 some areas may 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 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. Hatchery recovery programs are operating in these systems to ensure persistence. Rebuilding the naturally-produced abundance of these populations requires alleviating 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

1. 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.

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

3. 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.

4. 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.

5. Total exploitation rate ceilings are set for six MUs. Except for Stillaguamish and Snohomish MUs, if interceptions in Canadian or Alaskan fisheries cause exceedance of those ceilings, the lower SUS ER ceilings, otherwise implemented due to critical status,

will be implemented to increase escapements. For Stillaguamish and Snohomish MUs, ER ceilings will not be exceeded, regardless of northern fishery impact levels.

6. If escapement is projected to be below the low abundance threshold, SUS fisheries will be managed to not exceed a lower exploitation rate ceiling. The low abundance thresholds are intentionally set at levels substantially higher than the critical threshold (i.e. 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 the critical threshold.

7. Under all 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 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, unless the work pertains to ongoing monitoring and research already authorized by NOAA under previous Harvest Plans (i.e. PSC Chum GSI work in the Strait of Juan de Fuca and salmonid predator research in Lake Washington by WDFW and Muckleshoot Indian Tribe, respectively).

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[11]. 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 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 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

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

data produces preliminary estimates of management year (May – April) catch by July of the following year.

For some recreational fisheries managed under catch quotas, catch and effort is monitored by creel surveys. In-season catch estimates are produced for coastal areas 1 – 4, some 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.

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. 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'[12], 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 similar information collected from carcasses to characterize the origin, age, and size composition of local populations.

[12] 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 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 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 have the same genetic and life history characteristics as the wild 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 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 catch and escapement to detect coded-wire tags.

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. 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 the preceding management year.

Non-landed mortality

The annual report will include estimates of encounter rates and non-landed mortality, and associated analyses for monitored recreational and commercial troll fisheries. 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. Performance assessments will be completed every six years with the next report covering fishing years 2011-2016. This assessment is scheduled for completion by the end of 2019, assuming that post season FRAM ‘validation’ runs for 2015 and 2016 will be completed no later than 2018. Although post-season FRAM ‘validation’ runs are compiled every three 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 may be supplemented with CWT analysis based on PSC Chinook Salmon Technical Committee work or other independent analysis, where available and warranted. 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.

There is no 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). 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 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).

10. Literature Cited

Ames, J., and D.E. Phinney. 1977. 1977 Puget Sound Summer-Fall Chinook Methodology: Escapement Estimates and Goals, Run Size Forecasts, and In-season Run Size Updates. Technical Report Number 29, Washington Department of Fisheries. Olympia, Washington. 71p.

Ashbrook, C.E., K.W. Yi and J. Arterburn. 2005. Tangle nets and gill nets as a live capture selective method to collect fall Chinook Salmon broodstock in the Okanogan River: 2004. Washington Department of Fish and Wildlife. Olympia, WA. May 2005. 20 p.

Azmi, K., R. Davis, Q. Hanich, and A. Vrahnos. 2016. Defining a disproportionate burden in transboundary fisheries. Lessons from International Law. Marine Policy 70:164-173.

Barclay, M. 1980. 1980 Radio-tagging study of Nooksack spring Chinook. Nooksack and Lummi Tribal Fisheries Departments. Deming, WA. 35pp.

Barclay, M. 1981. Second year radio-tagging study and first year mark and recapture study of Nooksack spring Chinook. Nooksack and Lummi Tribal Fisheries Departments. Deming, WA. 29pp.

Barr, John, G. Blair, G. Kautz, L. Lestelle, J. Miniken, L. Mobrand, E. Salminen, J. Strong, D. Troutt, G. Walter, and T. Willson. 1999. Nisqually Basin Fall Chinook Recovery Plan – DRAFT. Nisqually EDT Work Group.

Barrowman, N. J. and R. A. Myers (2000). "Still more spawner-recruitment curves: the hockey stick and its generalizations." Canadian Journal of Fisheries and Aquatic Sciences 57: 665-676.

Bartz, K.K., M.J. Ford, T.J. Beechie, K.L. Fresh, G.R. Pess, R.E. Kennedy. 2015. Trends in developed land cover adjacent to habitat for threatened salmon in Puget Sound, Washington, U.S.A. PLoS ONE 10(4):e0124415.

Beamer, E., R. Bernard, B. Hayman, B. Hebner, S. Hinton, G. Hood, C. Kraemer, A. McBride, J. Musslewhite, D. Smith, L. Wasserman, and K. Wyman. 2005. Skagit Chinook recovery plan 2005. in Puget Sound salmon recovery plan, Vol. II, Local watershed chapters, Skagit chapter. Available at: http://www.sharedsalmonstrategy.org/plan/wpas/skagit.zip

Beechie, T. J., O. Stefankiv, B. L. Timpane-Padgham, J. E. Hall, G. R. Pess, M. Rowse, C. M. Liermann, K. L. Fresh, and M. D. Ford. 2017. Monitoring salmon habitat status and trends in Puget Sound : development of sample designs, monitoring metrics, and sampling protocols for large river, floodplain, delta, and nearshore environments. NOAA technical memorandum NMFS-NWFSC 137.

Bernhardt, E.S., M.A. Palmer, J.D. Allan, G. Alexander, K. Barnas, S. Brooks, J. Carr, S. Clayton, C. Dahm, J. Follstad-Shah, and D. Galat, D. 2005. Synthesizing US river restoration efforts. Science 308:636-637.

Bernhardt, E.S., E.B. Sudduth, M.A. Palmer, J.D. Allan, J. L. Meyer, G. Alexander, J. Follastad-Shah, B. Hassett, R. Jenkinson, R. Lave, and J. Rumps. 2007. Restoring rivers one reach at a time: results from a survey of US river restoration practitioners. Restoration Ecology 15:482-493.

Busack, C.A. 2012. First declaration of Craig A. Busack in support of federal defendants' opposition to plaintiffs' motion for partial summary judgment. Wild Fish Conservancy, et al. v. National Park Service, et al. No. 3:12-CV-05109-BHS.

Campbell, B., and Q. Hanich. 2015. Principles and practice for the equitable governance of transboundary natural resources: cross-cutting lessons for marine fisheries management. Maritime Studies 14:8-28.

Candy, J.R., E.W. Carter, T.P. Quinn and B.E. Riddell. 1996. Adult Chinook salmon behavior and survival after catch and release from purse-seine vessels in Johnstone Strait, British Columbia. North American Journal of Fisheries Management. 16:521-529.

Chasco, B., I.C. Kaplan, A. Thomas, A. Acevedo-Gutiérrez, D. Noren, M.J. Ford, M.B. Hanson, J. Scordino, S. Jeffries, S. Pearson, K.N. Marshall, and E.J. Ward. 2017. Estimates of Chinook salmon consumption in Washington State inland waters by four marine mammal predators from 1970 to 2015. Canadian Journal of Aquatic and Fisheries Science. 74:1173-1194.

Chinook Technical Committee (CTC). 1996. Joint Chinook Technical Committee 1994 Annual Report, TCCHINOOK (96)-1. Pacific Salmon Commission. Vancouver, British Columbia. 67 pages + appendices.

Chinook Technical Committee (CTC). 1999. Joint Chinook Technical Committee Report 1995 and 1996 Annual Report. Report TCCHINOOK (99)-2. Pacific Salmon Commission. Vancouver, British Columbia. 111p + appendices.

Chinook Technical Committee (CTC). 2002. Catch and Escapement of Chinook Salmon Under Pacific Salmon Commission Jurisdiction, 2001. Pacific Salmon Commission Report TCCHINOOK (02)-1.

Chinook Technical Committee (CTC). 2003. Annual Exploitation Rate Analysis and Model Calibration. Pacific Salmon Commission Report TCCHINOOK (03)-2. Vancouver, British Columbia.

Chinook Technical Committee (CTC). 2006. Report of the Joint Chinook Technical Committee Workgroup on the October 19, 2005 Assignment Given to the Chinook Technical Committee by the Pacific Salmon Commission Regarding the Conduct of Canadian AABM Fisheries. Pacific Salmon Commission Report TCCHINOOK (06)-1. Vancouver, British Columbia.

Chinook Technical Committee (CTC). 2008. 2008 Annual report of catches and escapements, exploitation rate analysis and model calibration. Pacific Salmon Commission Report TCCHINOOK (08)- 2. Vancouver, British Columbia. 271 pages.

Chinook Technical Committee (CTC). 2009. 2009 Annual Report of Catches and Escapements. Pacific Salmon Commission Report TCCHINOOK (09)-1. Vancouver, British Columbia.

Chinook Technical Committee (CTC). 2016.

Chinook Technical Committee (CTC). 2017a. Pacific Salmon Commission, Joint Chinook Technical Committee Annual Report 2016 exploitation rate analysis and model calibration supplement data notebook. TCCHINOOK (17)-01. February 16, 2017. 97 p.

Chinook Technical Committee (CTC). 2017b. Pacific Salmon Commission, Joint Chinook Technical Committee Annual Report of Catch and Escapement for 2016. TCCHINOOK (17)-2. May 19, 2017. 225 p.

Christie, M. R., M.J. Ford, and M.S. Blouin. 2014. On the reproductive success of early-generation hatchery fish in the wild. Evolutionary applications 7:883-896.

Coe, T. and T. Cline. 2009. Nooksack River Watershed Water Temperature Monitoring Program: 2007 and 2008 Data. Nooksack Indian Tribe Natural Resources Department. Deming, WA.

Cuo, L., T.K. Beyene, N. Voisin, F. Su, D.P. Lettenmaier, M. Alberti, and J.E. Richey. 2011. Effects of mid-twenty-first century climate and land cover change on the hydrology of the Puget Sound basin, Washington. Hydrological Processes 25:1729-1753.

Fiegberg, J. 2014. Role of parameter uncertainty in assessing harvest strategies. North American Journal of Fisheries Management. 24:459-474.

Ford, M.J. 2002. Selection in captivity during supportive breeding may reduce fitness in the wild. Conservation Biology 16:815-825.

Ford, M. J. (ed.), Cooney T, McElhany P, Sands N, Weitkamp L, Hard J, McClure M, Kope R, Myers J, Albaugh A, Barnas K, Teel D, Moran P, Cowen J. 2010. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. Draft U.S. Department of Commerce, NOAA Technical Memorandum NOAA-NWFSC-113.

Franklin, I.R. 1980. Evolutionary change in small populations. In M.E. Soule and B.A. Wilcox (eds), Conservation Biology: an evolutionary – ecological perspective. P. 135 – 149. Sinauer Associates, Sunderland, MA.

Geiger, H.J., and X. Zhang. 2002. A Simple Procedure to Evaluate Salmon Escapement Trends that Emphasizes Biological Meaning over Statistical Significance. Alaska Fishery Research Bulletin 9(2): 128-134.

Gregory, S.V., and P.A. Bisson. Degradation and loss of anadromous salmonid habitat in the Pacific Northwest. 1997. Pages 277-314 in Stauder et al (editors), Pacific Salmon & Their Ecosystems. Springer.

Gresh, T., J. Lichatowich, and P. Schoonmaker. 2000. An estimation of historic and current levels of salmon production in the northeast Pacific ecosystem: Evidence of a nutrient deficit in the freshwater systems of the Pacific Northwest. Fisheries. 25:15-21.

Good, T.P., R.S. Waples, and P. Adams (editors). 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-66.

Good, T.P., T. J. Beechie, P. McElhany, M.M. McClure, M.H. Ruckelshaus. 2007. Recovery planning for Endangered Species Act-listed Pacific salmon: using science to inform goals and strategies. Fisheries, 32:426-440.

Hanich, Q., B. Campbell, M. Bailey, and E. Molenaar. 2015. Research into fisheries equity and fairness—addressing conservation burden concerns in transboundary fisheries. Marine Policy 51:302-304.

Harrington-Tweit, B., and K. Newman. 1986. Estimating Chinook Salmon Escapements in the Nisqually River system for the Years 1979-1985. Nisqually Indian Tribe Technical Report No. 14. 11 pages.

Hatchery Scientific Review Group (HSRG). 2012. Review of the Elwha River Fish Restoration Plan and accompanying HGMPs. Prepared for the Lower Elwha Klallam Tribe and Washington Department of Fish and Wildlife (www.hatcheryreform.us).

Hatchery Scientific Review Group (HSRG). 2014. On the Ssience of hatcheries: an updated perspective on the role of hatcheries in salmon and steelhead management in the Pacific Northwest. (http://hatcheryreform.us/wp-content/uploads/2016/05/On-the-Science-of-Hatcheries_HSRG_Revised-Oct-2014.pdf).

Hayman, R., E. Beamer, and R. McClure. 1996. FY 1995 Skagit River Chinook research. Skagit System Cooperative Chinook restoration research progress report #1, NWIFC Contract #3311 for FY95. Skagit System Cooperative, La Conner, WA.

Hayman, B. 1999. Calculating the exploitation rate target and floor escapement (for Skagit Chinook). Technical memorandum to the co-managers' Chinook technical workgroup. November 24, 1999. 13 p.

Hayman, B. 2000. Skagit spring Chinook exploitation rate target and escapement floor. Technical memorandum to the co-managers' Chinook technical workgroup, January 19, 2000. Skagit River System Cooperative, La Conner, WA. 98257. 12 p.

Healey, M.C. 1991. Life history of Chinook salmon (Oncorhynchus tshawytscha). Pages 313-393 in C. Groot and L. Margolis, ed. Pacific salmon life histories. University of British Columbia Press, Vancouver, British Columbia.

Henderson, R, and R.A. Hayman. 2002. Fiscal year 2002 Skagit summer Chinook indicator stock study. Final project performance report to the Northwest Indian Fisheries Commission, Contract 3901. 16p.

Hirshi and M. Reed. 1998. Salmon and Trout Life History Study in the Dungeness River. Report to the Jamestown S'Klallam Tribe, Sequim, Washington.

Judge, M. 2011. 2011 Implementation Status Assessment Final Report: A qualitative assessment of implementation of the Puget Sound Chinook Salmon Recovery Plan. Lighthouse Natural Resource Consulting, Inc. Everett, WA. 45 p.

Krembs, C., S. Albertson, J. Bos, C. Maloy, M. Keyzers, B. Sackmann, L. Hermanson, and M. Dutch. 2014. Can long term-nitrogen increases affect pelagic food web processes and the vertical structure of biogeochemical processes in Puget Sound? Salish Sea Ecosystem Conference, Western Washington University CEDAR.

Lackey R.T. 2003. Adding nutrients to enhance salmon runs: developing a coherent public policy. Fisheries 28(8):34-35.

Lande, R. 1995. Mutation and conservation. Conservation Biology 9(4):782-791.

Marshall, A.R. , C. Smith, R. Brix, W. Dammers, J. Hymer, and L. LaVoy. 1995. Genetic diversity units and major ancestral lineages for Chinook salmon in Washington. In Busack, C., and J.B. Shaklee (eds). 1995. Genetic Diversity Units and Major Ancestral Lineages of Salmonid Fishes in Washington. p.111-173. Washington Department of Fish and Wildlife Technical Report RAD 95-02.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionary significant units. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-42, 158p.

Mobrand Biometrics, Inc. 2003. Development of salmonid recovery plans for the White, Puyallup, Chambers-Clover, and Hylebos watersheds - Strategic priorities for salmon conservation and recovery actions in WRIAs 10 and 12. Vashon, Washington: Mobrand Biometrics, Inc.

Musslewhite, J., and P. Kairis. 2009. FY 2008 Skagit summer Chinook indicator stock study. Skagit System Cooperative Chinook indicator stock prog. rept. No. 22. Final progress performance report to the Northwest Indian Fisheries Commission, Contract # 3901 for FY 2008. 27 p.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-35, 443p.Naish, K. A., J. E. Taylor III, P. S. Levin, T. P. Quinn, J. R. Winton, D. Huppert, and R. Hilborn. 2007. An evaluation of the effects of conservation and fishery enhancement hatcheries on wild populations of salmon. Advances in Marine Biology 53:61-194.

National Marine Fisheries Service (NMFS). 1999. Endangered and Threatened Species:Threatened Status for three Chinook Salmon Evolutionarily Significant Units in Washington and Oregon, and Endangered Status of one Chinook Salmon ESU in Washington; Final Rule. Federal Register, Vol. 64. No.56, 1999. Pp – 14308-14322.

National Marine Fisheries Service (NMFS). 2000. Endangered Species Act – Reinitiated Section 7 Consultation. Biological Opinion. Effects of Pacific Coast Ocean and Puget Sound Salmon Fisheries During the 2000-2001 Annual Regulatory Cycle. National Marine Fisheries Service, Protected Resources Division. p. 96.

National Marine Fisheries Service (NMFS). 2004. Puget Sound Chinook Resource Management Plan – Final Environmental Impact Statement. NOAA-NMFS Northwest Region. Seattle, WA.

National Marine Fisheries Service (NMFS). 2005a. Endangered and Threatened Species: Final listing determination for 16 ESUs of West Coast salmon, and final 4(d) protective regulations for threatened ESUs. 50 CFR Parts 223 and 224. FRN 70(123):37160 - 37204 (June 28, 2005).

National Marine Fisheries Service (NMFS). 2005b. Policy on the Consideration of Hatchery-Origin Fish in Endangered Species Act Listing Determinations for Pacific Salmon and Steelhead. 50 CFR Parts 223 and 224. FRN 70(123):37204-37216 (June 28, 2005).

National Marine Fisheries Service. 2006. Recovery Plan for the Puget Sound Chinook Salmon (Oncorhynchus tshawytscha). National Marine Fisheries Service, Northwest Region. Seattle, WA.

National Marine Fisheries Service (NMFS). 2007. Adaptive management for ESA-listed salmon and steelhead recovery: decision framework and monitoring guidance. National Marine Fisheries Service, Northwest Region. Seattle,WA.

National Marine Fisheries Service (NMFS). 2007. Endangered and Threatened Species; Recovery Plans. 72 FR 2493 (January 19,2007) . Available online at: http://www.nwr.noaa.gov/Publications/FR-notices/2007/upload/72FR2493.pdf

National Marine Fisheries Service (NMFS). 2008. Endangered Species Act Section 7(a)(2) Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation, Consultation on the Approval of Revised Regimes under the Pacific Salmon Treaty and the Deferral of Management to Alaska of Certain Fisheries Included in those Regimes. NMFS, Northwest Region. December 22, 2008. 372p. + appendices.

National Marine Fisheries Service (NMFS). 2014b. Endangered Species Act biological opinion and Magnuson-Stevens Act essential fish habitat consultation: 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 Number: F/WCR-2014-578 (May 1, 2014)

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: stocks at risk from California, Oregon, Idaho and Washington. Fisheries 16:4-21.

Nisqually Chinook Recovery Team (NCRT). 2001. Nisqually Chinook Recovery Plan. 63 pages + appendices.

Northwest Indian Fisheries Commission (NWIFC). 2011. Treaty Rights at Risk: Ongoing habitat loss, the decline of the Salmon resource, and recommendations for change. July 14, 2011. 35 p.

Northwest Indian Fisheries Commission (NWIFC). 2012. State or our watersheds report. Northwest Indian Fisheries Commission, Olympia, WA.

Northwest Indian Fisheries Commission (NWIFC). 2016. State of our watersheds report. Northwest Indian Fisheries Commission, Olympia, WA.

O'Neill, S.M., A.J. Carey, J.A. Lanksbury, L.A. Niewolny, G.Ylitalo, L.Johnson, and J.E. West. 2015. Toxic contaminants in juvenile Chinook salmon (Oncorhynchus tshawytscha) migrating through estuary, nearshore and offshore habitats of Puget Sound. Washington Department of Fish and Wildlife Report FBT 16-02. Olympia.

Orrell, R. 1976. Skagit Chinook Race Differentiation Study. Proj. Comp. Report to National Marine Fisheries Service, NOAA-NMFS Grant in Aid Program Project No. 1098-R, Wash. Dept. Fisheries, Olympia, WA. 53 p.

Pacific Fishery Management Council (PFMC). 1997. Puget Sound Salmon Stock Review Group Report 1997: An Assessment of Puget Sound Chinook and Strait of Juan de Fuca Coho Stocks as required under the Salmon Fishery Management Plan. Pacific Fishery Mangement council, Portland, Oregon. 85 pages.

Pacific Fishery Management Council (PFMC). 2009. Review of 2008 Ocean Salmon Fisheries. (Document prepared for the Council and its advisory entities.) Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Pacific Fishery Management Council (PFMC). 2017. Review of 2016 Ocean Salmon Fisheries: Stock assessment and fishery evaluation document for the Pacific Coast Salmon Fishery Management Plan. Portland, OR. February 2017. 353 p.

Pacific Salmon Commission (PSC). 2001. 1999/2000 Fifteenth Annual Report. Pacific Salmon Comission, Vancouver, CA. 178 pages.

Pacific Salmon Commission (PSC). 2006

Parken, C.K., R.E. McNicol and J.R. Irvine. 2004. Habitat-based methods to estimate escapement goals for data limited Chinook salmon stocks in British Columbia. Department of Fisheries and Oceans, Canada. Nanaimo, B.C.

Peterman, R.M. 1977. A simple mechanism that causes collapsing stability regions in exploited salmonid populations. J. Fish. Res. Board Can. 34:1130-1142.

Pierce County. 2008. Salmon Habitat Protection and Restoration Strategy, WRIA-10 Puyallup Watershed, WRIA-12 Chambers/Clover Watershed. Pierce County Lead Entity, Tacoma, WA. 52 pages.

Puget Sound Indian Tribes and Washington Department of Fish and Wildlife (PSIT and WDFW). 2001. Puget Sound Comprehensive Chinook Management Plan: Harvest Management Component. Northwest Indian Fisheries Commission , Olympia, WA. 129 pages.

Puget Sound Indian Tribes and Washington Dept. Fish and Wildlife (PSIT and WDFW). 2003. Puget Sound Comprehensive Chinook Management Plan: Harvest Management Component. Northwest Indian Fisheries Commission, Olympia, WA. 239 pages.

Puget Sound Indian Tribes and Washington Department of Fish & Wildlife (PSIT and WDFW). 2004. Comprehensive Management Plan for Puget Sound Chinook: Harvest Management Component. Northwest Indian Fisheries Commission, Olympia, WA. 247 pages.

Puget Sound Indian Tribes and WDFW. 2013.

Puget Sound Recovery Implementation Technical Team (RITT). 2008. Addressing uncertainty in the identification of salmon independent populations in the Puget Sound Chinook ESU. Draft report, Seattle, WA.

Puget Sound Salmon Management Plan. 1985. United States vs. Washington (1606 F.Supp. 1405)

Puget Sound Technical Recovery Team (PSTRT). 2003. Abundance and productivity data tables summarizing key biological and life history data for the North/Middle Fork Nooksack early Chinook population and the South Fork Nooksack early Chinook population. Excel workbook. Nov. 11, 2003. NOAA Fisheries, Northwest Region, Seattle, WA.

Rawson, K. 2000. Stillaguamish Summer Chinook: Productivity Estimates from Coded-Wire Tag Recoveries and A simple Model for Setting Interim Exploitation Rate Objectives – January 26, 2000. Tulalip Fisheries. Marysville, Washington. 15p.

Rawson, K., C. Kraemer, and E. Volk. Estimating the Abundance and Distribution of Locally Hatchery Produced Chinook Salmon Throughout a Large River System Using Thermal Mass-Marking of Otoliths. North Pacific Anadromous Fish Commission. Technical Report No. 3, 2001, pages 31-34.

Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. Ottawa, Fisheries and Marine Service.

Roni, P. 1992. Life history and spawning habitat in four stocks of large-bodied Chinook salmon. M.S. Thesis, University of Washington, Seattle. WA. 96p.

Ruckelshaus, M. H., P. Levin, J. B. Johnson, and P. M. Kareiva. 2002. The Pacific salmon wars: what science brings to the challenge of recovering species. Annual Review of Ecology and Systematics 33: 665-706.

Ruckelshaus, B., B. Ack, K. Berg, B. Cairns, D. Davidson, B. Kelly, R. Kinley, J. Koenings, P. Kremen, S. Lewis, B. Lohn, J. Manning, C. Mosher, B. Nichols, J. Ryan, R. Sims, M. Shelby, D. Troutt, and T. Williams. 2005. Puget Sound salmon recovery plan. Submitted by the Shared Strategy Development Committee, plan adopted by NMFS Jan. 19, 2007. Available online at: http://www.sharedsalmonstrategy.org/plan/index.htm

Ruckelshaus, M., K. P. Currens, R. Fuerstenberg, W. Graeber, K. Rawson, N. J. Sands, and J. B. Scott. 2006. Independent populations of Chinook salmon in Puget Sound. National Oceanographic and Atmospheric Administration (NOAA) Technical Memorandum NMFS-NWFSC 78, 125 pages.

Quinn, T.P., 2011. The behavior and ecology of Pacific salmon and trout. UBC press. 378p.

Salmon Technical Team (STT). 2000.

Sanderson, B.L., K.A. Barnas, and , A.M.W Rub. 2009. Nonindigenous species of the Pacific Northwest: an overlooked risk to endangered salmon? BioScience 59:245-256.

Scheuerell, M.D., R. Hillborn, M.H. Ruckelshaus, K.K. Bartz, K.M. Lagueus, A.D. Haas, and K. Rawson. The Shiraz model: a tool for incorporating anthropogenic effects and fish-habitat relationships in conservation planning. Canadian Journal of Fisheries and Aquatic Science 63: 1596-1607.

Seiler, D., L. Kishimoto, and S. Neuhauser. 2000. Annual Report: 1999 Skagit River wild 0+ Chinook production evaluation. Washington Department of Fish and Wildlife, Olympia, WA. 75 p.

Shaklee, J. B., and S. F. Young. 2003. Microsatellite DNA analysis and run timing of Chinook salmon in the White River, Puyallup basin. Washington Dept. Fish and Wildlife Tech. Rep. #FPT 03-5. Washington Dept. Fish and Wildlife, Olympia.

Smith, C. and P. Castle. 1994. Puget Sound Chinook Salmon (*Oncorhynchus tshawytscha*) escapement estimates and methods – 1991. Northwest Fishery Resrouce Bulletin, Project Report Series No. 1. Olympia, WA. 62 p.

Smith, C. and B. Sele. 1994. Evaluation of Chinook spawning capacity for the Dungeness River. Technical Memorandum to Bruce Crawford (WDFW), from P. Crain (Lower Elwha S'Klallam Tribe), B. Williams (Port Gamble S'Klallam Tribe), and N.Lampsakis (Point No Point Treaty Council).

Snohomish Basin Salmonid Recovery Technical Committee (SBSRTC). 1999. Initial Snohomish basin Chinook salmon conservation/recovery technical work plan.

Snover, A. K, G. S. Mauger, L. C. Whitely Binder, M. Krosby, and I. Tohver. 2013. Climate Change Impacts and Adaptation in Washington State: Technical Summaries for Decision Makers. State of Knowledge Report prepared for the Washington State Department of Ecology.

Climate Impacts Group, University of Washington, Seattle.

Sustainable Fisheries Act. 1996. U.S. Statutes at Large, 110:3559.

Tribal Hatchery Policy. 2013

Topping, P., M. Zimmerman, and L. Kishimoto. 2008. Juvenile Salmonid Production Evaluation Report: Green River and Dungeness River Chinook Monitoring Evaluations in 2007. Washington Department of Fish and Wildlife, Olympia, WA. 97 pages.

Vander Haegen, G.E., Ashbrook, C.E., Yi, K.W. and Dixon, J.F. 2004. Survival of spring Chinook salmon captured and released in a selective commercial fishery using gill nets and tangle nets. Fisheries Research 68:123-133.

Waples, R. 1990. Conservation genetics of Pacific salmon. II. Effective population size and rate of loss of genetic variability. J. Heredity 81: 267-276.

Ward, L., P. Crain, B. Freymond, M. McHenry, D. Morrill, G. Pess, R. Peters, J.A. Shaffer, B. Winter, and B. Wunderlich. 2008. Elwha River Fish Restoration Plan–Developed pursuant to the Elwha River Ecosystem and Fisheries Restoration Act, Public Law 102-495. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-90, 168 p.

Warheit, K. I. and C.M. Bettles, 2005. Genetic Characterization of Chinook Salmon (Ocorhynchus tshawytscha) Populations within Watershed Resource Inventory Area 8 (WRIA 8), Washington State. Draft Report. Washington Department of Fish and Wildlife, Olympia. 31 p.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty Indian Tribes (WDF et al.1993). 1993. 1992 Washington State salmon and steelhead stock inventory (SASSI). Wash. Dep. Fish Wildlife, Olympia 212 p. + 5 volumes.

Washington Dept. of Fish and Wildlife, and Western Washington Treaty Indian Tribes. 1994. 1992 Washington State Salmon and Steelhead Stock Inventory: Appendix One Puget Sound Stocks, North Puget Sound Volume. Washington Dept. of Fish and Wildlife, Northwest Indian Fisheries Commission, Olympia, WA.

Washington Department of Fish and Wildlife, Puyallup Indian Tribe, Muckleshoot Indian Tribe (WDFW et al). 1996. Recovery Plan for White River Spring Chinook Salmon. Washington Department of Fish and Wildlife. Olympia, Washington.

Washington Department of Fish and Wildlife. 2002. Salmonid Stock Inventory (SASI). Washington Department of Fish and Wildlife, Olympia, WA. Available online at: http://wdfw.wa.gov/fish/sasi/index.htm

Washington Department of Fish and Wildlife and Puget Sound Treaty Tribes (WDFW and PSTT). 2003. Resource Management Plan, Puget Sound Chinook Salmon Hatcheries, a component of the Comprehensive Chinook Salmon Management Plan. WDFW, Olympia, WA.

Washington Department of Fish and Wildlife and Puget Sound Indian Tribes (WDFW and PSIT). 2008. Annual Report Covering the 2007-2008 Fishing Season. WDFW, Olympia, WA.

Washington Department of Fish and Wildlife and Puget Sound Indian Tribes (WDFW and PSIT). 2009. Annual Report Covering the 2008-2009 Fishing Season. WDFW, Olympia, WA.

Water Resource Inventory Area 1 Salmon Recovery Board (WRIA 1 SRB). 2005. WRIA 1 Salmonid Recovery Plan. Whatcom County Public Works, Bellingham, WA. 287 pages + appendices.

Williams, R. W., R. M. Laramie, and J. J. Ames. 1975. A catalog of Washington streams and salmon utilization, Vol. 1, Puget Sound region. Wash. Dep. Fish., Olympia, WA. 926 p.

Literature Cited – Appendix A – MUPs

Nooksack MUP

Barclay, M. 1980. 1980 Radio-Tagging Study of Nooksack Spring Chinook. Nooksack andLummi Tribal Fisheries Departments. Deming, WA. 35 pp.

Barclay, M. 1981. Second Year Radio-tagging study and first year mark and recovery study ofNooksack spring chinook. Nooksack Tribal Fisheries. 25 pp plus appendix.

Beamer, E., C. Greene, E. Brown, K. Wolf, C. Rice, and R. Henderson. 2016. An assessment of juvenile Chinook salmon population structure and dynamics in the Nooksack estuary and Bellingham Bay shoreline, 2003-2015. Report to City of Bellingham under 2013 Interlocal Agreement (Contract# 2014 – 0102). Skagit River System Cooperative, La Conner, WA.

Blake, S., and B. Peterson. 2005. Water Resource Inventory Area 1 (WRIA 1) Watershed Management Plan – Phase 1. March 25, 2005. Submitted to WRIA 1 Watershed Management Project Participants. Bellingham, WA.

Brown, M., M. Maudlin, and J. Hansen. 2005. Nooksack River Estuary Habitat Assessment. Report for Salmon Recovery Funding Board, IAC #01-1340N. Lummi Nation, Natural Resources Department. Bellingham, WA.

Brown, M. and M. Maudlin. 2007. Upper South Fork Nooksack River habitat assessment. Prepared by the Lummi Indian Business Council, Department of Natural Resources, Restoration Division for the Salmon Recovery Funding Board, Bureau of Indian Affairs, and U.S. Fish and Wildlife Service through Interagency Agreement Contract 04-1487N; Bellingham, WA.

Butcher, J., M. Faizullabhoy, H. Nicholas, P. Cada, and J. Kennedy. 2016. Quantitative Assessment of Temperature Sensitivity of the South Fork Nooksack River Nooksack River under Future Climates using QUAL2Kw. EPA/600/R-14/233. Western Ecology Division, National Health and Environmental Effects Research Laboratory. Corvallis, OR.

Coe, T. 2015. Nooksack Chinook monitoring and adaptive management Phase 1b Final Report. Report to Puget Sound Partnership under Interagency Agreement 2015-43; March 31, 2015; Nooksack Indian Tribe, Natural Resources Department. Deming, WA.

Currence, N. 2000. Middle Fork Nooksack Anadromous Salmonid Potential Upstream of the Diversion Dam. Nooksack Indian Tribe, Natural Resources Department. Deming, WA.

Dickerson-Lange, S., and R. Mitchell. 2013. Modeling the Effects of Climate Change Projections on Stream flow in the Nooksack River basin, Northwest Washington. Hydrological Processes. DOI: 10.1002/hyp.10012.

Environmental Protection Agency (EPA). 2016. Qualitative Assessment: Evaluating the Impacts of Climate Change on Endangered Species Act Recovery Actions for the South Fork Nooksack River, WA. EPA/600/R-16/153. Western Ecology Division, National Health and Environmental Effects Research Laboratory. Corvallis, OR.

Hyatt, T., and A. Rabang. 2003. Nooksack Chinook Spawning and Incubation Assessment. Nooksack Indian Tribe, Natural Resources Department. Deming, WA.14 p.

Hyatt, T. 2007. Lower North Fork Nooksack River: Reach Assessment and Restoration Recommendations. June 29, 2007. Nooksack Indian Tribe, Natural Resources Department. Deming, WA.

Kuhlman, K., J. Freimund, and G. Gabrisch. 2016. Lummi Nation climate change and mitigation and adaption plan: 2016-2026. Prepared for the Lummi Indian Business Council by the

Lummi Natural Resources Water Resources Division under U.S Environmental Protection Agency Assistance Agreement No. BG-97042602-4; February 16, 2016. Bellingham, WA.

Liermann, M.C., R. Sharma and C.K. Parken. 2010. Using accessible watershed size to predict management parameters for Chinook salmon, Oncorhynchus tshawyscha, populations with little or no spawner-recruit data: a Bayesian hierarchical modeling approach. Fisheries Management and Ecology 17:40-51

Maudlin, M., T. Coe, N. Currence, and J. Hansen. 2002. South Fork Nooksack River Acme-Saxon Reach Restoration Planning: Analysis of Existing Information and Preliminary Recommendations. Lummi Nation Natural Resources Department. Bellingham, WA.

Murphy, R. 2015. Modeling the effects of forecasted climate change and glacier recession on late summer stream flow in the upper Nooksack River basin. M.S. Thesis, Western Washington University, Department of Geology. Bellingham, WA.

NMFS. 2003. Derivation of the Rebuilding Exploitation Rates (RER) for the Nooksack Chinook Populations. National Marine Fisheries Service, Sustainable Fisheries Division, Northwest Region. 13 p.

NMFS. 2017. Derivation of the Rebuilding Exploitation Rates (RER) for the Nooksack Chinook Populations. National Marine Fisheries Service, Sustainable Fisheries Division, Northwest Region. 36 p.

NMFS. 2017. Endangered Species Act Biological Opinion and Magnuson-Stevens Act Essential Fish Habitat (EFH) Consultation – 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 2017. NMFS, West Coast Region. F/WCR-2017-6766. May 3, 2017. 202 p.

Northwest Fisheries Science Center. 2015. Status review update for Pacific Salmon and Steelhead listed under the endangered species act: Pacific Northwest. Seattle, WA.

Northwest Fisheries Science Center. 2017. Abundance and Productivity (A&P) Tables, MS Excel spreadsheets. NWFSC, Seattle, WA.

Parken, C.K., R.E. McNicol and J.R. Irvine. 2006. Habitat based methods to estimateescapement goals for Chinook salmon stocks in British Columbia, 2004. Research Document 2006/083. Canadian Science Advisory Secretariat, Ottawa, Ontario. 15 p.

PSP. 2014. Nooksack Watershed Chinook monitoring and adaptive management Phase I Summary Report: preliminary monitoring and adaptive management framework. Prepared by the Recovery Implementation Technical Team (RITT) and coordinating partners for the Puget Sound Partnership WRIA1 Salmon Recovery Board; May 31, 2014. Olympia, WA.

PSTRT (Puget Sound Technical Recovery Team) 2003. Abundance and productivity data tables summarizing key biological and life history data for the North Fork Nooksack early chinook population and the South Fork early chinook population. Excel workbook. Nov. 11, 2003. NOAA Fisheries. Northwest Region, Seattle WA.

Soicher, A., T. Coe, and N. Currence. 2006. South Fork Nooksack River Acme-Confluence Reach Restoration Planning: Analysis of Existing Information and Preliminary Restoration Strategies. IAC #02-1500N Final Report. Nooksack Indian Tribe, Natural Resources Department. Deming, WA.

SSDC (Shared Strategy Development Committee). 2007. Puget Sound salmon recovery plan: Volumes I and II. Plan adopted by National Marine Fisheries Service, 19 January 2007. Shared Strategy for Puget Sound, Seattle, WA. Online at: http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/puget_sound/puget_sound_chinook_recovery _plan.html[accessed31 August 2015].

SSMSP. 2016. Salish Sea Marine Survival Project, United States-Canada Science Retreat Report 2016; December 1-2, Bellingham WA. Work is contracts through a joint US-Can cooperative research plan administrated by the Long Live the Kings Organization in the US and the Pacific Salmon Foundation in Canada.

U.S. Geological Survey. 2017. Estuaries and large river deltas in the Pacific Northwest. URL: https://walrus.wr.usgs.gov/climate-change/lowNRG.html

WDFW and PSIT. 2016. Puget Sound Chinook Comprehensive Harvest Management Plan: Annual Report 2015-2016 Fishing Season. Olympia, WA.

WRIA 1 Salmon Recovery Board (WRIA 1 SRB). 2005. WRIA 1 Salmonid Recovery Plan. In Shared Strategy Development Committee, Puget Sound Salmon Recovery Plan, Volume 2: Watershed Recovery Plans. Plan adopted by the National Marine Fisheries Service, January 19, 2007. Shared Strategy for Puget Sound. Seattle, WA. http://www.westcoast.fisheries.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/puget_sound/puget_sound_chinook_recovery _plan.html [accessed 26 September 2017].

Skagit MUP

Beamer, E. M., J. C. Sartori, and K. A. Larsen. 2000. Skagit Chinook life history study: progress report number 3. Federal Energy Regulatory Commission, Project 553, Washington, D.C. Available: www.skagitcoop.org/index.php/documents/. (August 2017).

Beamer, EM, A McBride, C Greene, R Henderson, et al. 2005. Delta and nearshore restoration for the recovery of wild Skagit River Chinook salmon: Linking estuary restoration to wild Chinook salmon populations. www.skagitcoop.org/index.php/documents/. (August 2017).

Beechie, T., Buhle, E., Ruckelshaus, M., Fullerton, A. and Holsinger, L., 2006. Hydrologic regime and the conservation of salmon life history diversity. Biological Conservation, 130(4), pp.560-572.

Bond, N. A., M. F. Cronin, H. Freeland, and N. Mantua (2015), Causes and impacts of the 2014 warm anomaly in the NE Pacific. Geophys. Res. Lett., 42, 3414–3420. doi: 10.1002/2015GL063306

Dale, K.E., Daly, E.A. and Brodeur, R.D., 2017. Interannual variability in the feeding and condition of subyearling Chinook salmon off Oregon and Washington in relation to fluctuating ocean conditions. Fisheries Oceanography, 26(1), pp.1-16.

Daly, E.A., Brodeur, R.D. and Auth, T.D., 2017. Anomalous ocean conditions in 2015: impacts on spring Chinook salmon and their prey field. Marine Ecology Progress Series, 566, pp.169-182.

Du, X., Peterson, W. and O'Higgins, L., 2015. Interannual variations in phytoplankton community structure in the northern California Current during the upwelling seasons of 2001-2010. Marine Ecology Progress Series, 519, pp.75-87.

Greene, C, E Beamer, J Anderson. 2016. Skagit River estuary intensively monitored watershed annual report. www.skagitcoop.org/index.php/documents/. (August 2017).

Hayman, R. A., E. M. Beamer, and R. E. McClure. 1996. Fiscal year 1995 Skagit River Chinook restoration research. Skagit River Systems Cooperative, Final Project Performance Report for Northwest Indian Fisheries Commission Contract 3311, La Conner, Washington.

Lee, S.Y., Hamlet, A.F. and Grossman, E.E., 2016. Impacts of climate change on regulated streamflow, hydrologic extremes, hydropower production, and sediment discharge in the Skagit river basin. Northwest Science, 90(1), pp.23-43.

Magnusson, A. and Hilborn, R., 2003. Estuarine influence on survival rates of coho (Oncorhynchus kisutch) and Chinook salmon (Oncorhynchus tshawytscha) released from hatcheries on the US Pacific coast. Estuaries and Coasts, 26(4), pp.1094-1103.

Mote, P. W., D. E. Rupp, S. Li, D. J. Sharp, F. Otto, P. F. Uhe, M. Xiao, D. P. Lettenmaier, H. Cullen, and M. R. Allen (2016), Perspectives on the causes of exceptionally low 2015 snowpack in the western United States, Geophys. Res. Lett., 43, 10,980–10,988, doi:10.1002/2016GL069965

NWIFC (Northwest Indian Fisheries Commission) 2016. The 2016 State of our watershed: Salmon habitat in decline. https://nwifc.org/publications/state-of-our-watersheds/. (August 2017).

Peterman, R. 1977. A simple mechanism that causes collapsing stability regions in exploited salmonid populations. J. Fish Res. Board Can. 34:1130-1142.

PSIT (Puget Sound Indian Tribes) and WDFW (Washington State Department of Fish and Wildlife). 2010. Comprehensive Management Plan for Puget Sound Chinook: Harvest Management Component. http://wdfw.wa.gov/publications/00854/wdfw00854.pdf (July 2017).

Ruff C.P., Anderson J.H., Kemp I.M., et al. Salish Sea Chinook salmon exhibit weaker coherence in early marine survival trends than coastal populations. Fish Oceanogr. 2017;00:1–13.

SRSC (Skagit River Systems Cooperative) and WDFW (Washington Department of Fish and Wildlife). 2005. Skagit Chinook recovery plan. SRSC and WDFW. Available: www.skagitcoop.org. (August 2017)

Thayer, J.A., Field, J.C. and Sydeman, W.J., 2014. Changes in California Chinook salmon diet over the past 50 years: relevance to the recent population crash. Marine Ecology Progress Series, 498, pp. 249-261.

Zimmerman, M.S., Kinsel, C., Beamer, E., Connor, E.J. and Pflug, D.E., 2015. Abundance, survival, and life history strategies of juvenile Chinook salmon in the Skagit River, Washington. Transactions of the American Fisheries Society, 144(3), pp. 627-641.

Snohomish MUP

Beamer, E.M., W.T. Zackey, D. Marks, D. Teel, D. Kuligowski, and R. Henderson. 2013. Juvenile Chinook salmon rearing in small non-natal coastal streams draining into the Whidbey basin. Skagit River System Cooperative, Tulalip Tribes, and NOAA Fisheries unpublished report. 74p.

Healey, M.C. 1991. Life history of Chinook salmon (Oncorhynchus tshawytscha). In: Groot, C.; Margolis, L., eds. Pacific salmon life histories. Vancouver, British Columbia, Canada: University of British Columbia Press: 313–393.

Kubo, J.S. K. Finley, and K. Nelson. In Prep. 2000-2012 Skykomish and Snoqualmie Rivers Chinook and Coho Salmon Out-migration Study. Tulalip tribes Natural Resources Department, Tulalip WA.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-42,156 p.

PSC Joint Chinook Technical Committee; 2012 Exploitation Rate Analysis and Model Calibration. Report TCCHINOOK (12)-4. PSC Vancouver, B.C. 262 pages.

PSC Joint Chinook Technical Committee; 2017. 2016 Exploitation Rate Analysis and Model Calibration Supplement Data Notebook. Report TCCHINOOK (17)-1. PSC Vancouver, B.C. 93 pages.

PSIT and WDFW 2010. Comprehensive Management Plan for Puget Sound Chinook: Harvest Management Component. 230 pages.

PSIT and WDFW. 2013. Puget Sound Chinook Harvest Management Performance Assessment 2003 - 2010. NWIFC and WDFW, Olympia, Washington. 98 pages.

Quinn, T.P. 2005. The behavior and ecology of Pacific salmon and trout. Univ. Press, Seattle. 320p.

Rawson and Crewson, Tulalip Tribes 2017. Productivity Analysis of the Snohomish Chinook salmon populations.

Rawson and Crewson (b), Tulalip Tribes 2017. Harmonizing of regulatory habitat protection with other recovery efforts, a new H-integration framework for Chinook salmon recovery.

Ruckelshaus, M., K. P. Currens, R. Fuerstenberg, W. Graeber, K. Rawson, N. J. Sands, and J. B. Scott. 2004. Independent populations of Chinook salmon in Puget Sound. Draft report. National Oceanographic and Atmospheric Administration (NOAA), Northwest Fisheries Science Center, Seattle, WA,. http://research.nwfsc.noaa.gov/cbd/trt/popid.pdf.

Shared Strategy Development Committee. 2007. Puget Sound Salmon Recovery Plan (adopted by the National Marine Fisheries Service (NMFS). 472 pages. http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/puget_sound/chinook/pugetsoundchinookrecoveryplan.pdf

Snohomish River Basin Salmon Recovery Forum. 2005. Snohomish River Basin Salmon Conservation Plan. Snohomish County Department of Public Works, Surface Water Management Division, Everett, WA.

Stillaguamish MUP

Eldridge, W.H. and K. Killebrew. 2008. Genetic diversity over multiple generations of supplementation: an example from Chinook salmon using microsatellite and demographic data. Conservation Genetics.

Small, M.P., A. Spidle, C. Scofield, J. Griffith, P. Verhey, J. Whitney, M. Kissler, and C. Bowman. 2016. Summary report of genetic analyses of summer and fall-run Chinook salmon in the North and South Fork Stillaguamish River. Report to the Stillaguamish Tribe of Indians. December 2016.

State of Our Watersheds (SOW) Report. 2016. A report by the Treaty Tribes of Washington, Stillaguamish River Basin, pg 252-267.

Lake Washington, Green River, Puyallup River, and White River MUPs

Anderson, J.H. and P.C. Topping. In Press. Juvenile life history diversity and freshwater productivity of Chinook salmon in the Green River, Washington. North American Journal of Fisheries Management.

Berger, A., J. Paul, and J. Close. 2016. Puyallup River Juvenile Salmonid Production Assessment Project 2016. Puyallup Tribal Fisheries Division, Puyallup, WA.

Beverton, R.J.H. and S.J. Holt. 1957. On the dynamics of exploited fish populations. Chapman and Hall, London. Facsimile reprint, 1993.

Kiyohara, K. 2015. Evaluation of juvenile salmon production in 2015 from the Cedar River and Bear Creek. Washington Department of Fish and Wildlife, Olympia, WA.

Marshall, A.R., C. Smith, R. Brix, W. Dammers, J. Hymer, and L. LaVoy. 1995. Genetic diversity units and major ancestral lineages for Chinook salmon in Washington. In C. Busack and J.B. Shaklee (eds.), Genetic diversity units and major ancestral lineages of salmonid fishes in Washington. Washington Department of Fish and Wildlife Technical Report RAD 95-02, Olympia, WA.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42.

Northwest Fisheries Science Center (NWFSC). 2017. Derivation of rebuilding exploitation rates (RER) for Green River Chinook populations. U.S. Department of Commerce, NOAA Fisheries, West Coast Region and Northwest Fisheries Science Center, Seattle, WA.

Ruckelshaus, M.H., K.P. Currens, W.H. Graeber, R.R. Fuerstenberg, K. Rawson, N.J. Sands, and J.B. Scott. 2006. Independent populations of Chinook salmon in Puget Sound. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-78.

Scheuerell, M.D. 2016. An explicit solution for calculating optimum spawning stock size from Ricker's stock recruitment model. PeerJ 4:e1623; DOI 10.7717/peerj.1623.

Topping, P.C. and J.H. Anderson. 2015. Green River juvenile salmonid production evaluation: 2014 annual report. Washington Department of Fish and Wildlife, Olympia, WA.

Warheit, K.I. and C.M. Bettles. 2005. Genetic Characterization of Chinook Salmon (*Oncorhynchus tshawytscha*) populations within Watershed Resource Inventory Area 8 (WRIA 8), Washington State. Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fisheries (WDF). 1977. 1977 Puget Sound summer-fall Chinook methodology: escapement estimates and goals, run size forecasts, and in-season run size updates. Technical Report 29, Olympia, WA.

Washington Department of Fish and Wildlife (WDFW). 2002. Salmonid Stock Inventory. Washington Department of Fish and Wildlife, Olympia, WA.

Nisqually MUP

Curran, C.A., Grossman, E.E., Magirl, C.S., and Foreman, J.R., 2016, Suspended sediment delivery to Puget Sound from the lower Nisqually River, western Washington, July 2010–November 2011: U.S. Geological Survey Scientific Investigations Report 2016-5062, 17 p., http://dx.doi.org/10.3133/sir20165062.

Ellings C. E., S. Hodgson. 2007. Nisqually estuary baseline fish ecology study: 2003-2006. Nisqually National Wildlife Refuge and Nisqually Indian Tribe, Olympia, Washington, U.S.A.

Klungle, M., J. Anderson, and M. Zimmerman. In prep. Nisqually River outmigrant juvenile salmonid report: 2009 - 2016. Washington Department of Fish and Wildlife. Unpublished draft report.

NSIT. 2017.

WIT and WDFW. In DRAFT. Stock Management Plan for Nisqually Fall Chinook Recovery. September 2017 Draft Version.

Nisqually Chinook Recovery Team. 2001. Nisqually Chinook Recovery Plan. August.

Nisqually Steelhead Recovery Team. 2014. Draft Nisqually Winter Steelhead Recovery Plan.

PSIT and WDFW. 2010.

Zimmerman, M. S., C. Kinsel, E. Beamer, E. J. Connor, and D. E. Pflug. 2015. Abundance, survival, and life history strategies of juvenile Chinook salmon in the Skagit River, Washington. Transactions of the American Fisheries Society 144:627-641.

Skokomish MUP

2014 Plan for Management of Fall Chinook in the Skokomish River (SIT and WDFW). Skokomish Indian Tribe and Washington Department of Fish and Wildlife, Oct 2014.

Addendum to the 2014 Plan for Management of Fall Chinook in the Skokomish River (SIT and WDFW). Skokomish Indian Tribe and Washington Department of Fish and Wildlife, Oct 2015.

Deschamps, G. 1955. Puget Sound investigations: September through December 1954. Progress Rep., Skokomish River studies. Washington Dept. Fisheries, Olympia. (Available from Washington State Library, Point Plaza East, 6880 Capitol Blvd., Tumwater, WA. Library code no. WA 639.2 F532pus psisk 1954.)

Elmendorf, W.W. and A.L. Kroeber. 1992. The Structure of Twana Culture, with Comparative Notes on Yurok Culture , Pullman, WA: Washington State University Press [information collected in the 1930's].

Gray, C. and M. Downen. 2017. Personal Communication. Data available upon request C. Gray 360-877-5213, Skokomish Indian Tribe.

Hood Canal Salmon Management Plan. 1986. United States vs. Washington No.9213, Ph. I Proceeding 83-8).

Lestelle, L. 2017 draft. Guidance for updating recovery goals for Hood Canal summer chum populations and subpopulation-specific recovery targets – 2017 update. Draft report submitted to the Hood Canal Coordinating Council. Poulsbo, WA.

Pacific Fishery Management Council (PFMC). Framework amendment for managing the ocean salmon fisheries off the coasts of Washington, Oregon and California commencing in 1985. PFMC, Portland, Oregon. 145 p.

Pacific Salmon Treaty (PST) Treaty Concerning Pacific Salmon, U.S.-Can., Jan. 28, 1985, TIAS 11091, 1469 U.N.T.S. 357. Chinook Annex 2010.

Puget Sound Indian Tribes and Washington Department of Fish and Wildlife (PSIT and WDFW). 2010. Comprehensive management plan for Puget Sound Chinook: Harvest management component. Northwest Indian Fisheries Commission and WDFW, Olympia, WA.

Puget Sound Salmon Management Plan. 1985. United States vs. Washington (1606 F.Supp. 1405).

Recovery Plan for Skokomish River Chinook Salmon 2017 Update(SIT and WDFW 2017). Skokomish Indian Tribe and Washington Department of Fish and Wildlife, June 2017.

Smoker, W.A., H.M. Jensen, D.R. Johnson, and R. Robinson. 1952. The Skokomish River Indian fishery. Washington Department of Fish and Wildlife, Olympia, WA.

TCCHINOOK (17)-01 Pacific Salmon Commission Joint Chinook Technical Committee Report (PSC JTC). 2016 Exploitation rate analysis and model calibration supplement data notebook report. February 16, 2017.

Washington Department of Fisheries (WDF). 1957. Research relating to fisheries problems that will arise in conjunction with current and projected hydroelectric developments in the

Skokomish River. Washington Department of Fisheries, Olympia, WA. (Available from Washington State Library, Point Plaza East, 6880 Capitol Blvd., Tumwater. Inventory code No. A60003 087623).

Mid-Hood Canal MUP

Dungeness MUP

Denton, K, M. McHenry, R. Moses, E. Ward, M. Liermann, O. Stefanik, W. Wells, and G. Pess. 2016. 2016 Elwha River Chinook estimation based on DIDSON/ARIS multi-beam SONAR data. Report to Olympic National Park, Port Angeles, Washington.

Dungeness Water Exchange. http://www.washingtonwatertrust.org/water-exchange

Jamestown S'Klallm Tribe. 2007. Protecting and restoring the waters of Dungeness, CWA 319 Plan. Sequim, WA.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-NWFSC-35, 443 p.

Pearson, S.F., S.J. Jeffries, M.M. Lance and A.C. Thomas. 2015. Identifying potential juvenile predators in the marine water of the Salish Sea. Washington Department of Fish and Wildlife Science Division, Olympia, Washington.

Smith, C. and B. Sele. 1994. Evaluation of Chinook spawning capacity for the Dungeness River. Technical Memorandum to Bruce Crawford (WDFW), from P. Crain (Lower Elwha S'Klallam Tribe, B. Williams (Port Gamble S'Klallam Tribe), and N. Lampsakis (Point No Point Treaty Council).

Topping, P. M. Zimmerman, and L. Kishimoto. 2008. Juvenile Salmonid Production Evaluation Report: Green River and Dungeness River Chinook Monitoring Evaluations in 2007. Washington Department of Fish and Wildlife, Olympia, WA. 97 p.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty Indian Tribes (WDF et al). 1993. 1992 Washington State salmon and steelhead stock inventory (SASSI). Washington Dept. Fish Wilidlife, Olympia 212 p. +5 volumes.

Washington Department of Fish and Wildlife and Puget Sound Treaty Tribes (WDFW and PSTT). 2003. Resource Management Plan, Puget Sound Chinook Salmon Hatcheries: A component of the Comprehensive Chinook Salmon Management Plan. WDFW, Olympia, WA.

Elwha MUP

Bradley, N. and J. Bountry. 2014. Modeling Delta Erosion with a Landscape Evolution model. BOR Technical Report No. SRH-2014-40. 10 pp. https://www.usbr.gov/research/projects/researcher.cfm?id=1571

Chenoweth, J., S. Acker, and M. McHenry. 2011. Revegetation and Restoration Plan for Lake Mills and Lake Aldwell. Olympic National Park and the Lower Elwha Klallam Tribe. Port Angeles, Washington. Available online at https://www.nps.gov/olym/learn/nature/upload/Elwha_Reveg_Plan_2011_FINAL.pdf

Denton, K., M. McHenry, R. Moses, E. Ward, M. Liermann, O. Stefankiv, W. Wells and G. Pess. 2017. 2016 Elwha Chinook escapement based on DIDSON/ARIS multi-beam SONAR data. Olympic National Park and the Lower Elwha Klallam Tribe. Port Angeles, Washington.

Duda, J.J., J.A. Warrick, and C.S. Magirl. 2011a. Coastal and lower Elwha River, Washington, prior to dam removal – history, status, and defining characteristics. Pages 1-26 in J.J. Duda, J.A. Warrick, and C.S. Magirl, editors. Coastal Habitats of the Elwha River: Biological and Physical Patterns and Processes Prior to Dam Removal. U.S. Geological Survey Scientific Investigations Report 2011-5120. http://pubs.usgs.gov/sir/2011/5120/

HSRG (Hatchery Scientific Review Group). 2012. Review of the Elwha River fish restoration plan and accompanying HGMPs. http://hatcheryreform.us/wp-content/uploads/2016/05/Review-of-Elwha-River-Fish-Restoration-Plan-and-HGMPs.pdf

Hosey and Associates. 1988. Response to request additional information of 28 May 1977. Elwha Project (FERC No. 2683) and Glines Project (FERC No. 588) James River II Inc. Vol. 2 of 4. Prepared by Hosey and Associates for Perkins Coie, May 27, 1988., Hosey and Associates Engineering Company, Bellevue, WA.

Lower Elwha Klallam Tribe. 2016. 2016 HGMP Annual Report Narrative. Lower Elwha Klallam Tribe, Port Angeles, WA.

McHenry, M. 2017. Personal communication updating accomplishments on Elwha River habitat restoration activities.

McHenry, M., G. Pess, J. Anderson, and H. Huginin. 2017. Spatial distribution of Chinook salmon (Oncorhynchus tshawytscha) spawning in the Elwha River, Washington State during dam removal and early stages of recolonization (2012-2016). ONP. 28 pp.

McHugh, 2015

Nowlin M. and V. Martinez. 2017. At Elwha River, forests, fish and flowers where there were dams and lakes. The Seattle Times, accessed via web: http://www.seattletimes.com/seattle-news/environment/at-elwha-river-forests-fish-and-flowers-where-there-were-dams-and-lakes/?utm_source=email&utm_medium=email&utm_campaign=article_left_1.1,.

Pess, G. R., M. McHenry, T. J. Beechie, J. R. Davies. 2008. Biological impacts of the Elwha River dams and potential salmonid responses to dam removal. Northwest Science, 82(sp1):72-90.

Peters R., J. Duda, G. Pess, M. Zimmerman, P. Crain, Z. Hughes, A. Wilson, M. Liermann, S. Morley, J. McMillan, K. Denton, D. Morrill, and K. Warheit. 2014. Guidelines for Monitoring and Adaptively Managing Restoration of Chinook Salmon (Oncorhynchus tshawytscha) and Steelhead (O. mykiss) on the Elwha River. USFWS. 101 pp.

Peters, R.J., Liermann, M., McHenry, M.L., Bakke, P. and Pess, G.R., 2017. Changes in Streambed Composition in Salmonid Spawning Habitat of the Elwha River during Dam Removal. JAWRA Journal of the American Water Resources Association, 53(4), pp.871-885.

Puget Sound Indian Tribes and Washington Department of Fish and Wildlife. 2010. Comprehensive Management Plan for Puget Sound Chinook: Harvest Management Component. http://wdfw.wa.gov/publications/00854/wdfw00854.pdf

Randle, T.J., Bountry, J.A., and G. Smillie. 2012. Elwha River Restoration: Sediment Adaptive Management Summary. Department of Interior, Bureau of Reclamation and National Park Service, Reclamation. Report Number: SRH-2012-09. 15pp

Randle T.J., J.A. Bountry, A. Ritchie, and K. Wille. 2015. Large-scale dam removal on the Elwha River, Washington, USA: Erosion of reservoir sediment. Geomorphology 246 (2015) pp. 709-728.

Ruckelshaus, M. H., K. P. Currens, W. H. Graeber, R. R. Fuerstenberg, K. Rawson, N. J. Sands, and J. B. Scott. 2006. Independent populations of Chinook salmon in Puget Sound. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-78.

Schwartz, J. (2013) Dead salmon found along silt-choked Elwha River after hatchery release. Peninsula Daily News; April 12, 2013. http://archive.peninsuladailynews.com/article/20130412/NEWS/304129979/dead-salmon-found-along-silt-choked-elwha-river-after-hatchery-release

Ward, L., P. Crain, B. Freymond, M. McHenry, D. Morrill, G. Pess, R. Peters, J. A. Shaffer, B. Winter, and B. Wunderlich. 2008. Elwha River Fish Restoration Plan - developed pursuant to the Elwha River Ecosystem and Fisheries Restoration Act, Public Law 102-495. U.S. Dept of Commerce NOAA Tech. Memo. NMFS-NWFSC-90.

Warrick J.A., J. A. Bountry, A. E. East, C. S. Magirl, T. J. Randle, G. Gelfenbaum, A. C. Ritchie, G. R. Pess, V. Leung, J. J. Duda. 2015. Large-scale dam removal on the Elwha River, Washington, USA: Source-to-sink sediment budget and synthesis. Geomorphology 246 (2015) 729-750.

Weinheimer J., J. Anderson, R. Cooper, S. Williams, M. McHenry, P. Crain, S. Brenkman, and H. Hugunin. 2017. Age structure and hatchery fraction of Elwha River Chinook Salmon: 2016 Carcass Survey Report. WDFW. Draft report.

Hoko MUP

Ames, J., and D.E. Phinney. 1977. 1977 Puget Sound Summer-Fall Chinook Methodology: Escapement Estimates and Goals, Run Size Forecasts, and In-season Run Size Updates. Technical Report Number 29, Washington Department of Fisheries. Olympia, Washington. 71p.

Martin, D. L. Benda, C. Coho, S. Cooke, D. Vagt, D. Monaghan, N. Currence, and M. McHenry. Hoko River watershed analysis, watershed administrative unit 1903023 resource assessment report and prescriptions. Prepared for: Cavenham Forest Industries and Rayonier Timberlands.

McHenry, M., J. Lichatowich, and R. Kowalksi-Hagaman. 1996. Status of Pacific salmon and their habitats on the Olympic Peninsula, Washington. Report to the Lower Elwha S'Klallam Tribe, Port Angeles, Washington.

McHenry, M., S. Shaw, C. Toal, and J. Gorsline. 1995. Assessment of physical and biological conditions within the Deep Creek watershed, North Olympic Peninsula, Washington, and recommendations for watershed restoration. Report to Washington Department of Natural Rsources, Olympic Region, Forks, Washington.

Myers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-NWFSC-35, 443 p.

Parken, C.K., R.E. McNicol and J.R. Irvine. 2004. Habitat-based methods to estimate escapement goals for data limited Chinook salmon stocks in British Columbia. Department of Fisheries and Oceans, Canada. Nanaimo, B.C.

Phinney, D. and Bucknell. 1975. A catlog of Washington streams and salmon utilization. Vol. 2 Coastal Region. Washington Department of Fisheries, Olympia, Washington.

Smith, C.J. 1999. Salmon and steelhead habitat limiting factors in the western Strait of Juan de Fuca. Washington State Conservation Commission, Lacey, Washington.

Williams, R.W., R.M. Laramie and J.J. Ames. 1975. A catalog of Washington streams and salmon utilization. Volume 1. Puget Sound Region, Washington Department of Fisheries, Olympia, WA.

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 real cause of salmon decline. Additionally, as long as fisheries outside the jurisdiction of this plan continue to account for 80% of the exploitation rate on Nooksack early Chinook populations, restrictions on fisheries in the southern US will have little effect on "recovery".

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.

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, creates a fish passage barrier and cuts off 17 miles of former Chinook habitat.

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 and 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 from the Skookum Creek early Chinook population recovery program in the August terminal area fisheries appear to support the hypothesis that the behavior of the SF population is different than of the NF/MF population. South Fork Chinook river entry timing appears to continue longer than for the NF/MF population.

Spawning
Beginning in the late 1970s, spawning ground survey effort started increasing in the North Fork and South Fork. For the Middle Fork, survey effort did not increase until the mid-1990s, after Chinook were detected there. By the late 1990s, survey effort in all forks, increased 2 to 4 fold over previous decades.

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 through September, with peak spawn timing in 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 early 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 through 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 natural-origin 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 natural-origin spawners show the NF/MF spawning population to consist of 29% yearlings while the SF spawning population consists of 38% yearlings (PSTRT 2003).

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.

Table 1. Estimates of the age composition of returning adult natural origin Nooksack early Chinook by population 1999-2014 (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	1%	11%	74%	14%	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
A population recovery program for the NF/MF Chinook population has operated at the Kendall Creek Hatchery since 1981. 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. A portion of the Kendall Hatchery NF/MF Chinook releases have been coded wire tagged since 1983.

The production strategy for the NF/MF program was adjusted in 2003 to reduce straying into the South Fork. On-station releases, which exhibited the highest stray rate into the South Fork, 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 remains the current on-station release goal. 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. The current total NF/MF program release objective is 800,000 sub-yearlings.

Skookum Creek Hatchery – South Fork Chinook Program
A captive brood South Fork population recovery program was initiated in 2007 using natural-origin juveniles captured from the South Fork and reared at Kendall Creek and Manchester facilities. 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. A key priority for the program is maintaining genetic diversity of the populations. By 2016, approximately half of the program broodstock came from adult returns and half from captive brood reared adults. In the initial phase of recovery, the target release for the Skookum hatchery is 1,000,000 sub-yearling smolts.

All juvenile Chinook released from the Skookum Creek Hatchery have been coded-wire tagged to improve evaluation of the program. The co-managers will likely propose that the coded wire tag program transition to an indicator stock program with a planned release of 200,000 CWT-adipose clipped fish; this is 20% of the current program size. Beginning in 2018, all release groups will be thermally otolith marked annually to allow estimation of returning adults, particularly during 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 (WRIA 1 SRB 2005). For the WRIA 1 Salmonid Recovery Plan, Ecosystem Diagnosis and Treatment (EDT) modeling was used to estimate the capacity and productivity of each Nooksack Chinook population under historic, current, and "properly functioning conditions"; model estimates for current capacity and productivity were an order of magnitude less than under historic conditions (WRIA 1 SRB 2005).

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 (WRIA 1 SRB 2005). 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 (WRIA 1 SRB 2005). 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, blocks at least 10.2 miles of habitat in the Middle Fork and 6.9 miles in its tributaries (Currence 2000).

In the South Fork, Chinook are limited by low habitat diversity and lack of deep holding pools, along with higher water temperatures and lower instream flows (compared to the other forks), due to instream wood loss and removals and degraded riparian conditions coupled with extensive bank hardening and wetland loss through the South Fork valley (Maudlin et al. 2002; Soicher et al. 2006). Pathology analysis of Chinook prespawn mortalities in the South Fork in 2003, 2006, and 2009 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, 23.8, and 22.1, respectively (EPA 2016). The respective fisheries passed these fish through, but they did not survive to reproduce. There have also been 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 (WRIA 1 SRB 2005). 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 near-shore to the south of the delta is urbanized, and legacy industrial uses on the waterfront have contaminated sediments and water quality in Bellingham Bay (WRIA 1 SRB 2005). 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 increase in annual flood peak is projected, such that the magnitude of the historical 10-year flood in the main stem 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 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 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 critical, with significantly degraded habitat contributing to consistently poor returns of natural-origin Chinook and low productivity. Between 1999 and 2015, escapement of NF/MF natural-origin spawners ranged from a low of 85 to a high of 453, with an average of 281. During this time period, two of the highest and two of the lowest natural-origin escapements occurred in the most recent four years, 2012-2015. The escapement of NF/MF hatchery-origin Chinook to the spawning grounds 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 natural-origin returns in the subsequent three to five years. The most recent 5-year average productivity of NF/MF natural spawners is 0.50 (NMFS 2017; NWFSC 2017).

Between 1999 and 2015, SF Chinook natural-origin escapement ranged from a low of 7 to a high of 159, averaging just 60 spawners per year. The estimated 10 natural-origin spawners in 2013 and 7 in 2015 are considered minimum estimates due to a large return of pink salmon spawning concurrently with SF Chinook and the difficulties associated with identifying Chinook redds during these conditions (Figure 1). In recent years, the productivity of the SF population has ranged from 0.35 to 5.99 natural-origin recruits per spawner, and has been below replacement in 2 of the last 5 years (NMFS 2017; NWFSC 2017). This high degree of variability is primarily a result of consistently low abundance. Although the number of SF natural-origin spawners has consistently been below 200, 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.

Overall, the population recovery programs at Kendall Creek and Skookum Creek Hatcheries have contributed to the total number of Nooksack early Chinook spawners in the watershed, however, productivity has not increased and the natural-origin populations have remained very low. In fact, significant and on-going restrictions in Southern US fisheries are not detectable in population trends for Nooksack early Chinook. Fisheries have been constrained so much that further restrictions would not improve productivity nor would they provide sufficient spawners to significantly change stock status (NMFS 2017; NWFSC 2017).

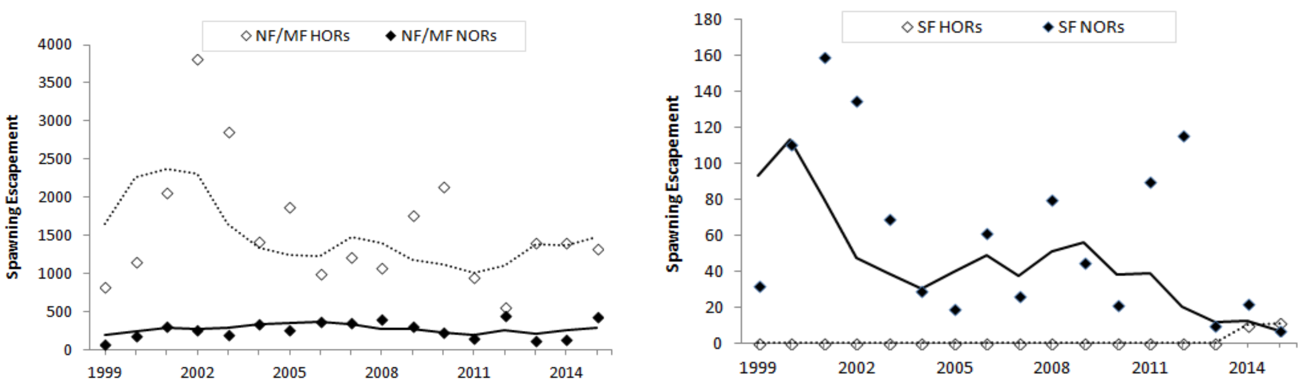


Figure 1. Spawning ground escapement estimates for the NF/MF (left graph) and SF (right graph) Nooksack early Chinook populations (1999-2015). The filled and unfilled diamonds represent point estimates, while the solid and dashed lines represent the four-year geometric means.

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. The methodology assumes all redds are accurately counted in all geographic areas utilized by spawners, that no spawning Chinook after October 1 are early Chinook and that all Chinook that spawn through September 30 die within a week (October 7).

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) with variable flow 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 and frequent surveys, were considered to more accurately reflect total abundance in this area.

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. Posterior assignments over 51% of the primary assignment result in acceptance of that assignment for use of the individual carcasses. 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 Sept. 30, 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 the new FRAM base period.

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 36% from 1992-2014. Pre-terminal and terminal fisheries conducted in the southern US averaged 6.9% and 1.4% ER, respectively, for the same time period (Figure 2). Viewed another way, northern fisheries averaged 81.3% of the total annual exploitation rate between 1992 and

2014, while pre-terminal and terminal fisheries averaged 15.1% and 3.6% of the total annual exploitation rate on Nooksack early Chinook, respectively (Figure 2).

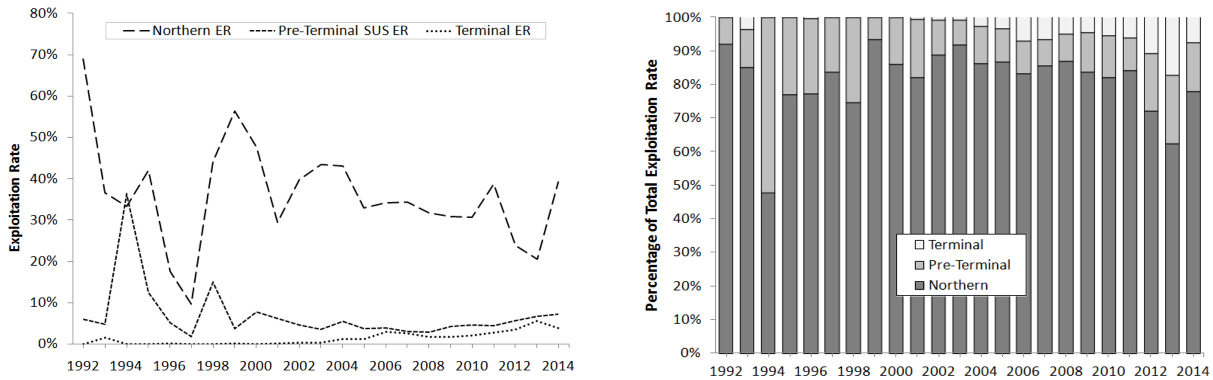


Figure 2. Northern, Pre-Terminal and Terminal exploitation rates on natural-origin Nooksack early Chinook from 1992-2014 (left graph), and the percentage of the total annual exploitation rate attributed to the Northern, Pre-Terminal and Terminal fisheries (right graph). Both graphs are based on post-season model runs using the new FRAM base period.

Management Objectives

The management objectives of this plan are 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.

The Kendall and Skookum hatchery programs are key components in the recovery of native Nooksack Chinook populations and assist in recovery by significantly increasing population abundances, and buffering demographic and genetic risks while improvements to habitat quantity and quality occur. Both the NF/MF and SF Nooksack early Chinook populations will be managed for natural escapement, which consist of natural- and hatchery-origin spawners, and to achieve hatchery rack goals at the Kendall Creek and Skookum Creek hatcheries consistent with the recovery phase of each population.

In recent analyses of Nooksack early Chinook populations' abundance and productivity, a maximum sustainable yield (MSY) escapement level of 500 adult spawners was identified for the combined NF/MF and SF populations (NMFS 2003; NMFS 2017; NWFSC 2017). Because the SF population generally represents less than 5% of total spawners returning to the Nooksack River, 500 adult spawners is a good reference point for establishing a Low Abundance Threshold (LAT) for the NF/MF population. Taking into account uncertainty associated with forecasting and modeling fishing impacts, a LAT of 800 natural spawners was set. The natural spawners will consist of both hatchery-origin and natural-origin fish on the spawning grounds. The Upper Management Threshold (UMT) for the NF/MF population will be set at 2,000 natural spawners, making the LAT 40% of the UMT (Table 2).

For the SF population, chronically low natural-origin abundances and highly uncertain productivity estimates limit 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 the same logic for taking a conservative approach for the NF/MF population, a LAT for the SF population is set at 400 natural spawners, consisting of hatchery-origin and natural-origin fish. The UMT is set at 1,000 natural spawners, making the LAT 40% of the UMT (Table 2). 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 pre-season modeled outputs from FRAM 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 Critical Exploitation Rate Ceiling (CERC). The CERC will be 10.5% SUS ER on the natural-origin components of the combined populations, except that once in five years the SUS ER ceiling may increase to 13.5%. When natural spawning escapements for both populations are projected to exceed their respective LATs, the SUS ER ceiling of 16% defines the maximum level of fishing related mortality allowed (Table 2). These ceilings are not viewed as targets, but rather as ceilings within which tribal C&S fisheries, and fisheries on abundant Nooksack/Samish Fall Chinook and other species will be prosecuted.

The CERC was developed by converting the previous CERC, used through 2016 (7% SUS ER, with 9% SUS ER once every 5 years), into new base-period FRAM terms. For each year from 1995-2014, a conversion factor was calculated by dividing the new-FRAM post season estimates by the old-FRAM post season estimates. The mean conversion factor across years was 1.5, so 7% SUS ER in the old model equates to 10.5% SUS ER in the new model, and 9% SUS ER in the old model equates to 13.5% SUS ER in the new model (Table 2).

Table 2. Upper Management Thresholds (UMT) and Low Abundance Thresholds (LATs) of natural 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	16% SUS ER	2000	800	10.5% SUS ER; 13.5% 1 out of 5 years
SF		1000	400	

Achieving hatchery rack goals for the Kendall and Skookum hatcheries are an essential component of realizing recovery goals for 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. The CERC will not be exceeded unless projected escapements for each population are greater than their respective LATs and hatchery rack goals for the Kendall and Skookum hatcheries are projected to be met.

There have been no directed commercial fisheries on Nooksack spring Chinook in Bellingham Bay and the Nooksack River since the late 1970s. Incidental harvest of Nooksack early Chinook in fisheries directed at fall hatchery-origin 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 to early Chinook spawning areas. Beginning in 2008, fisheries in July were discontinued entirely. Since 2010, there have been very limited C&S fisheries in the Nooksack River from April into June.

The tribal treaty right fishery on Nooksack early Chinook in the Nooksack River is the highest priority in the tribal terminal area fishing regime. Under this plan, this fishery will be conducted from mid-March through July, targeting Kendall and Skookum Creek Hatchery returns, and will occur in the lower river below Slater Road Bridge and in the upriver area of the mainstem located from ¼ mile downstream of the Nugent's Corner Bridge up to no higher than the lowest ¼ mile of the North Fork. The Nooksack Tribe will manage to not exceed the total Chinook number as determined by FRAM. The tribes may utilize selective gear, to enable release of natural-origin Chinook. These fisheries are designed to collect information on the migration characteristics of the NF/MF and SF populations. Otoliths and tissue samples will be collected from natural-origin Chinook and summer run steelhead caught in this fishery and will be used to assess fishery impacts and migration timing. The projected total harvest of early Chinook by in-river tribal fisheries will be determined during preseason planning, with reference to forecasted abundance of natural-origin and hatchery-origin returns.

Under this plan, fisheries in Bellingham Bay and the Nooksack River directed at Nooksack/Samish fall Chinook will not open prior to August 1. Subsequent fishing in the Nooksack River will occur in progressively more upstream zones to enable early Chinook stocks to clear these areas. Thus the area from ¼ mile above Nugent's Corner Bridge (RM 30.9) to a line coinciding with the Nooksack Tribe blue colored Automotive shop, approximately 1.3 miles downstream from the South Fork confluence, opens the fourth week.

The area extending 1.3 miles downstream of the confluence of the North and South Forks will also not open during the early portion of the coho management period, remaining closed prior to statistical week 39. The intent is to protect holding adult South Fork Chinook in the upper mainstem where temperatures are cooler than the South Fork. The area from the confluence downstream to the yellow painted marker upstream of the Deming Bus Barn will also remain closed to recreational fishers, prior to statistical week 39 (Subject to WDFW review and approval).

Data Gaps

- Evaluate and potentially modify escapement estimate methodologies to improve abundance and productivity estimates
- Improve understanding of NF/MF and SF Chinook freshwater entry and migration
- Chinook life history model
  - The Chinook life history model will identify, prioritize and estimate the temporal and spatial aspects of factors limiting recovery. The life history model would also provide survival information for forecasting. There is currently no funding for this work.
- Smolt to Adult Survival
  - Improvements in the outmigrant population estimates from the smolt trap will provide the information to calculate smolt to adult return survival estimates.
  - Combined with the Chinook life history model, the smolt to adult survival will identify freshwater and marine survival factors limiting recovery.
  - Skookum Creek Hatchery early Chinook survival
    - Metrics are being developed to evaluate this new program.

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 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 main-stem Skagit River, 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 (combination of rain-on-snow and snowmelt peak flows; 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 (WDFW and WWIT 1994) identified three summer/fall and three spring timed populations, which was later corroborated 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, Zimmerman et al. 2015, Greene et al. 2016). Diversity of life history strategies appears to be a density dependent response to the availability of freshwater and estuarine habitat (Zimmerman et al. 2015, Greene et al. 2016).

Spawning and incubation potential of juvenile Skagit River Chinook salmon has been limited by instream barriers, sedimentation and hydrograph regimes. In 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 have shown as 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 (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 river-bank; 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 0.082% (Pierce 2011). This change analysis looked more closely at riparian buffers approximately 290 miles of fish-bearing streams and documented permanent development in 67.5 acres and non-permanent development (e.g. forest clearing) in 53 acres.

Annually, a large proportion of juvenile Chinook fry rely on estuarine habitat for rearing (Beamer 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 (Beamer 2005) and 24% of Skagit Bay has been armored.

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 time 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 et al. 2016). 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, which has caused managers to become increasingly concerned.

Skagit River Chinook salmon populations are under threat of contemporary climate change and broad scale anthropogenic development. 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 may 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 populations 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

The Skagit River Chinook salmon are comprised of six identified populations. After extensive examination and analysis, it has been determined that they are best and most effectively managed as two MU's; Skagit spring Chinook salmon MU and Skagit summer/fall Chinook salmon MU. These fish spawn and rear as juveniles throughout the Skagit River basin exhibiting a variety of life-history strategies. Following the estuarine and early marine rearing period, most migrate to the ocean and rear in marine waters off the coasts of Oregon, Washington, British Columbia and Alaska, although some remain within Puget Sound, until maturity. All mature adults return to the Skagit River through the Puget Sound and are subject to harvest throughout their entire migratory path. Over the past 11 years, an average of 12% Skagit River spring Chinook salmon and 28% Skagit River summer/fall Chinook salmon are harvested by Alaska and Canada (i.e.

northern fisheries) before they return to the Southern US (SUS) waters. This plan only includes fisheries in SUS waters after accounting for impacts from northern fisheries including those occurring in Alaska and Canada.

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, but historical spawning in the high-gradient channel above this point is believed to have been very limited.
- 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 summer Chinook salmon stock and lower Sauk River summer Chinook salmon stock spawn from early September through October. 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 river fall stock enters the river and spawns later than the summer stocks; summer Chinook salmon spawning peaks in early- to mid-October. Age of spawning is primarily age-4 years, with significant age-3 and age-5 fish. Most summer/fall Chinook salmon smolts emigrate from the river as sub-yearlings, though 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).

Spring Management Unit

The Skagit River spring Chinook salmon 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 and spawn from late July through early October. Adult spring Chinook salmon returning to the Suiattle River are predominantly age-4 and age-5 (WDF et al. 1993 and WDFW 1995 cited in Myers et al. 1998). Analysis of scales collected from adults on the spawning grounds indicates that the proportion of spawners that outmigrate 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.

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 summer/fall Chinook, but local indicators have since been developed and are believed to provide more relevant information. The Skagit River summer Chinook 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. Summer Chinook fingerlings are acclimated in the County Line Ponds before they are released. 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 research (see Ruff et al. 2016). Information from the PSC indicator program is directly used in this plan. A Skagit Fall Chinook indicator program that provided fishery distribution information specific to Lower Skagit Falls operated from 1999 to 2008, but was terminated due to funding constraints.

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 also incorporates a PSC indicator stock program, essential to management of this 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 Units Status

Natural escapement for all three Skagit River summer/fall Chinook salmon MU has shown to be stable and oscillating trend over the last 26 years (Table 1). The geometric mean escapement for the past 12 years (2005-2016) was 11,761 as compared to the prior 12-year period (1993-2004) of 9,886. Skagit River summer/fall Chinook salmon MU escapement has varied widely over years and leads to uncertainty around rate of change.

Natural escapement of Skagit River spring Chinook salmon MU has increased over recent five years. The geometric mean escapement from for the most recent 12 year period (2005 – 2016) was 1,428 compared to the previous 12 year period (1993 – 2004) spawning escapement of 939.
Table 1. Spawning escapement of Skagit River Chinook salmon, 1992 to 2016 (co-manager unpublished data). 2016 escapement estimates are still preliminary and have not been finalized.

Table 1. Spawning escapement of Skagit River Chinook salmon, 1992 to 2016 (co-manager unpublished data). 2016 escapement estimates are still preliminary and have not been finalized.

Year	Suiattle spring	Upper Sauk spring	Cascade spring	Total spring	Lower Skagit Falls	Lower Sauk summer	Upper Skagit Summer	Total summer /fall
1992	201	580	205	986	1,331	469	5,548	7,348
1993	291	323	168	782	942	205	4,654	5,801
1994	167	130	173	470	884	112	4,565	5,561
1995	440	190	225	855	666	278	5,948	6,892
1996	435	408	208	1,051	1,521	1,103	7,989	10,613
1997	428	305	308	1,041	409	295	4,168	4,872
1998	473	290	323	1,086	2,388	460	11,761	14,609
1999	208	180	83	471	1,043	295	3,586	4,924
2000	360	388	273	1,021	3,262	576	13,092	16,930
2001	688	543	625	1,856	2,606	1,103	10,084	13,793
2002	265	460	340	1,065	4,866	910	13,815	19,591
2003	353	193	298	844	1,161	1,493	7,123	9,777
2004	495	700	380	1,575	3,070	443	20,040	23,553
2005	518	308	420	1,246	3,320	875	16,608	20,803
2006	375	1,043	478	1,896	3,508	1,095	16,165	20,768
2007	108	282	223	613	1,053	383	9,845	11,281
2008	203	983	284	1,470	2,685	538	8,441	11,664
2009	273	367	338	978	1,439	250	5,290	6,979
2010	263	768	330	1,361	1,017	356	6,644	8,017
2011	215	345	265	825	820	210	4,480	5,510
2012	460	1,826	488	2,774	3,295	715	9,808	13,817
2013	620	1,080	310	2,010	1,551	530	8,801	10,882
2014	460	923	225	1,608	1,785	364	8,308	10,480
2015	478	743	188	1,409	2,203	406	10,705	13,076
2016	648	1,502	295	2,445	2,921	1,044	15,423	19,388

Harvest Distribution

Skagit River Chinook salmon are commonly caught in Alaskan, Canadian and Southern US waters. Coded-wire tag recoveries for PSC indicator stocks provide a description of the harvest distribution of Skagit Chinook salmon MU’s, and contrast the differences between summer/fall and spring timed stocks. Hatchery spring Chinook fingerling releases from Marblemount hatchery are intended to describe the distribution of wild Skagit River spring Chinook salmon. Tagged Skagit River summer/fall Chinook salmon indicator stock is being used for these estimates.

Post-season FRAM validation runs associated with the new base period for FRAM suggest decreased fishery related mortality of Skagit River Chinook salmon in Alaskan and Canadian (northern) fisheries (Table 2). Management of these fisheries is beyond the jurisdiction of this plan. For the Skagit River spring Chinook MU, there has been an approximate 50% reduction in fishery related mortality in northern fisheries (2009-2015), yet northern fisheries still account for a large proportion of fishery related mortality. Skagit River summer/fall Chinook MU (2009-2015), on the other hand, has seen little reduction in fishery related mortality in Northern Fisheries. Washington net fisheries and recreational fisheries had increases in fishery related mortality on both MU's. Net fisheries impacts tended to track extraordinary odd-year pink returns, while sport fisheries tended to fluctuate from year to year.

Table 2. Average distribution of fishery mortalities for Skagit River Chinook for 1999-2008 and 2009-2015 expressed as percent of total fishery mortality (PSC Chinook Technical Team 2016).

Indicator Group	Year	Alaska	Canada	SUS Troll	SUS Net	SUS Sport
Spring yearling	1999-2008	1.3%	76.4%	1.9%	6.8%	13.6%
	2009-2015	1.5%	34.1%	0.8%	49.1%	14.5%
Spring fingerling	1999-2008	5.6%	74.6%	2.4%	10.5%	7.0%
	2009-2015	2.1%	40.8%	2.5%	42.3%	12.3%
Summer fingerling	1999-2008	19.5%	45.1%	1.8%	4.4%	29.3%
	2009-2015	17.7%	33.3%	1.4%	26.4%	21.1%

Exploitation Rate Trend

Annual (management year) exploitation rates for Skagit River summer/fall Chinook MU, as estimated by post-season FRAM runs, have fallen drastically, from levels averaging nearly 70% over 1983–1987, to an average of 37% from 2000-2008 (Figure 1). Since the decline, annual exploitation rates have averaged 48% (2008-2014). The challenge to see further reductions in exploitation rates is that northern fisheries maintain an average 27% exploitation rate (2008-2014) on Skagit summer/fall Chinook MU (Total allowable exploitation rate 50%; PSIT and WDFW 2010) and limits SUS fisheries to approximately 23% exploitation rate, which can constrain SUS management to incidental impacts in pursuing harvest opportunity on other salmon stocks (e.g. coho, sockeye, pink and chum).

Over the same period, exploitation rates for Skagit River spring Chinook MU have decreased an even larger amount, from historical levels to an average of 20% since 2000 (Figure 2). Currently, Skagit spring Chinook MU are managed well below the total ERC of 38%.

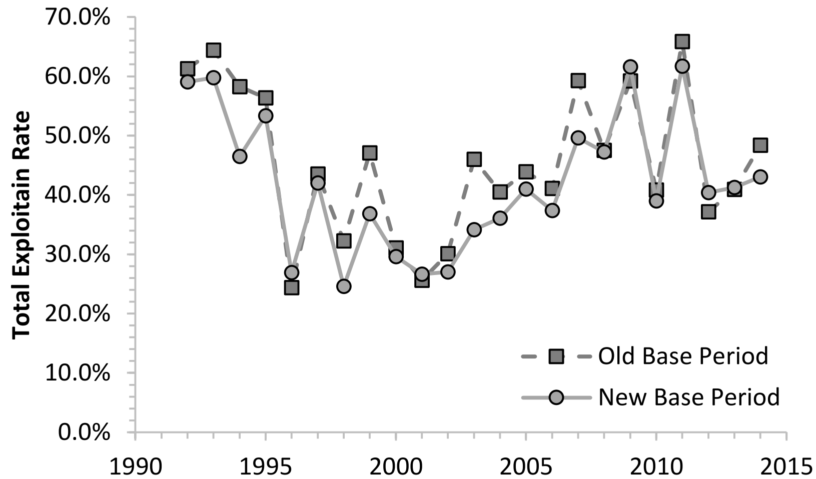


Figure 1. Total fisheries exploitation rate of Skagit summer/fall Chinook MU estimated from post-season FRAM runs for management years 1992-2014 with old and new FRAM base period.

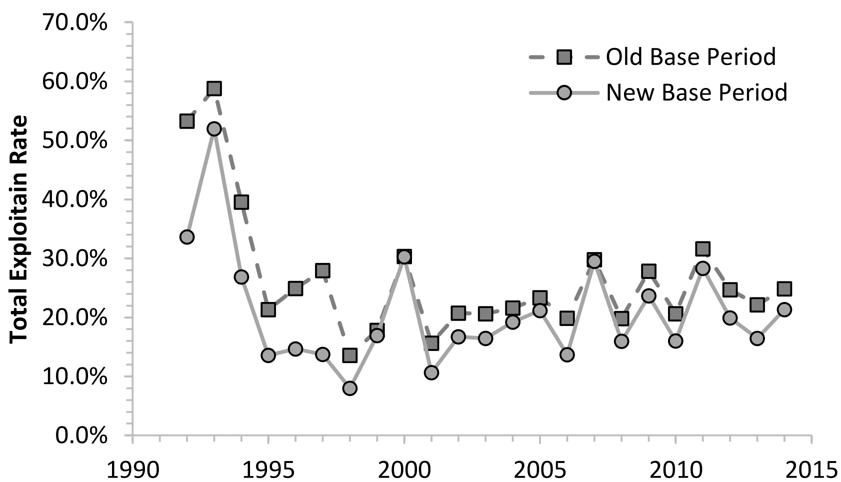


Figure 2. Total fisheries exploitation rate of Skagit spring Chinook MU estimated from post-season FRAM runs for management years 1992-2014 with old and new FRAM base period.

Management Objectives

We utilized results from the updated spawner-recruit and RER analysis 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 3). 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). The spawner-recruit relationship and RER assume an equilibrium state suggesting historical patterns and trends will continue through the scope of this plan. There is strong evidence, however, from freshwater, estuary and ocean environments that broad-scale change is occurring that will likely alter productivity and carrying capacity of Skagit Chinook salmon MU's. In addition, the future northern fisheries exploitation rates are currently being negotiated and thus uncertain. Given the additional risk associated with management of terminal area fisheries targeted at a limited number of MU's versus multiple mixed stock fisheries, terminal area managers have taken a cautious approach setting management objectives for Skagit River Chinook MU's.

Table 3. Harvest management thresholds and objectives for Skagit River Chinook salmon MU's.

Management Unit	PI	CERC	LAT	ERC	UMT
Skagit Spring	**215**	**18%**	**690**	**38%**	**2,000**
Upper Sauk			130		
Upper Cascade			170		
Suiattle			170		
Skagit Summer/Fall	**1,677**	**17%/15%**	**6,500**	**47%**	**14,500**
Upper Skagit			2,200		
Sauk			400		
Lower Skagit			900		

Point of instability (PI)

For the purposes of this plan, the point of instability is defined as spawning abundance below which there is significant genetic or demographic risk to the management unit while accounting for uncertainty. We use the point of instability for each management unit which is 5% of the equilibrium abundance (Peterman 1977); in addition, we account for uncertainties associated with spawner recruit relationships, current trends in habitat quantity and quality and northern fisheries impacts by increasing the PI by 50% for each MU. For Skagit River spring Chinook salmon MU, the point of instability for management purposes is 215 spawners which is equal to 50% above the upper bound of the 95% CI. For Skagit River summer/fall Chinook salmon MU, the point of instability for management purposes is 1,677 which is equal to 50% above the lower bound of the 95% CI. For spring Chinook, due to a combination of higher uncertainty in the spawner recruit relationship coupled with significantly lower abundance relative to summer/fall Chinook, we used the upper 95% credible interval (95% CI) estimate of the spawner recruit parameters to derive the PI. If Spawner abundance for either management unit is forecast below the PI during the pre-season harvest planning process, management shall follow principles put forth in chapters 4 and 5 of this RMP.

Consistent with the principles of Chapter 4 of this RMP, co-managers have defined a Point of Instability (POI) abundance, or lower bound, below the LAT, in order to provide further conservation protections when stock abundance falls to an extremely critical level. When pre-season escapement is expected to fall below the POI for those MUs, SUS exploitation rate impacts would be determined pre-season through co-manager discussions, but would be more constraining than the respective critical exploitation rate ceiling set for that MU. Additionally, triggering of the POI would require Co-managers to develop of a stock management rebuilding plan.

Consistent with the principles of Chapter 5 of this RMP, 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 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 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.

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)

The low abundance threshold (LAT) for each management unit reflects the uncertainty in the spawner-recruit relationship for each management unit and to account for the risk to any individual population within each management unit falling to low levels. Therefore, we utilize the 95% CI range in Smsy derived for each management unit to help inform setting a new LAT. For Skagit River spring Chinook salmon MU, we set the LAT to 690 which is the median estimate of Smsy. We used the median estimate of Smsy in consideration of the amount of uncertainty associated with intrinsic productivity of the Skagit Spring Chinook salmon MU. For Skagit River summer/fall Chinook salmon MU, we set the LAT to 6,577 which is equal to the lower bound of the 95% CI estimate of Smsy. Any modeled escapement below 6,577 would be outside Smsy and would result in critical exploitation rate management. Each of the population specific LAT's remain unchanged from the earlier plan.

Critical exploitation rate ceiling (CERC)

The CERC for each management unit were established under the 2010 Chinook RMP with reference to preseason SUS estimates during years constrained by critical status for some Puget Sound populations. This enabled fisheries to occur on more abundant stocks, provided that the total SUS exploitation rate was below the CERC. For Skagit River spring Chinook salmon MU, the current CERC is set at 18% SUS. For Skagit River summer/fall Chinook salmon MU, the CERC is set at 15% SUS during even years and 17% SUS during odd years. For this plan, we propose no changes to the CERC from the previous plan for either Skagit Chinook management unit.

Exploitation rate ceiling (ERC)

Due to a combination of potential low abundance and uncertainty in the spawner recruit relationship, we will maintain the Skagit River spring Chinook salmon MU exploitation rate ceiling (ERC) at 38% although the median RER for the management unit is 44%. The reason we use the 38% RER addresses terminal area manager concerns for uncertainties and the allowable risk. For Skagit River summer/fall Chinook salmon MU, the results indicate that the ERC should be reduced from 50% to 47%.

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 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 within the bounds of the ERC derived for each management unit. For Skagit River spring Chinook salmon MU, the UMT of 2,000 spawners is outside the upper bound of the 95% CI for Smsy. However, given the risk of underestimating Smsy and due to uncertainty in the spawner recruit relationship, the UMT for Skagit River spring Chinook salmon MU will remain at 2,000 spawners. For Skagit River summer/fall Chinook salmon 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 salmon 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 management units and Skagit River Summer/Fall Chinook management units which are necessary for testing and refining harvest management objectives include:

- Develop 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, estimate annual variability in freshwater productivity for each of the six populations. 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.

- 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 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.

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

Introduction

We reassessed the spawner recruit relationship for Skagit River spring Chinook management unit and Skagit River summer/fall Chinook management unit to help inform updates to abundance thresholds and harvest management reference points for each management unit. We utilized recent estimates of fisheries mortality provided by the fishery regulation and assessment model (FRAM) validation runs (2014 and 2017) to conduct a cohort reconstruction and estimates of spawners and estimates of recruits for brood years 1986 – 2012 for Skagit River spring Chinook salmon, and 1983 – 2012 for Skagit River summer/fall Chinook salmon. Annual estimates of the spawners, age composition, and harvest for each management unit were used to update the spawner-recruit relationship and derive appropriate abundance based management reference points including the point of instability (PI), low abundance threshold (LAT), and the upper management threshold (UMT) and to evaluate a range in exploitation rate ceilings that would that would minimize long term risk to each management unit.

Methods

Spawner recruit model

We used a Bayesian state-space model to estimate the population dynamics for each aggregate Skagit River Chinook management unit including Skagit Spring Chinook and Skagit River Summer/Fall Chinook. State-space models have been used to evaluate general monitoring schemes for estimating extinction risk (e.g., Dennis et al. 2010, 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 abundance 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 1983 – 2014 for Summer/Fall Chinook and 1986 – 2014 for Spring Chinook. We considered using a constrained data set that encompassed only 1992 – 2014, since post-season FRAM runs using the new base period are not available for years prior to 1992. Results were similar whether the shorter or longer time series was used.

We begin with our process model where the number of offspring born in year *t* that survive to adulthood (R_t) equals the product of a nonlinear function of the number of spawning adults (S_t) and a time-varying stochastic error ε_t:

$$R_t = f(S_t|\boldsymbol{\theta})\, e^{\varepsilon_t}. \tag{1}$$

Here we consider two different forms for *f*: the Ricker model (Ricker 1954) and the Beverton-Holt model (Beverton and Holt 1957); see Table 1 for model forms and descriptions of their parameters and associated abundance based reference points.

Table 1. Two different forms of the process model in Equation (1) used in the analyses, and their associated reference points. The constant *e* is Euler's number and *W*(·) is the Lambert function (see Scheuerell 2016). MSY = maximum sustainable yield. The point of instability (PI) was estimated following Peterman (1977).

	Ricker	Beverton-Holt
R_t	$\frac{\alpha S_t}{e^{\beta S_t}}$	$\frac{\alpha S_t}{1+\beta S_t}$
R/S as $S \to 0$	α	α
Carrying capacity	$\frac{\log(\alpha)}{\beta}$	$\frac{\alpha - 1}{\beta}$
Spawners at MSY	$\frac{1 - W\left(\frac{e}{\alpha}\right)}{\beta}$	$\frac{\sqrt{\alpha} - 1}{\beta}$
Spawners at PI	$.05 \times \frac{\log(\alpha)}{\beta}$	$.05 \times \frac{\alpha - 1}{\beta}$

The ε_t are often assumed to be independent draws from a Gaussian distribution with a mean zero and an unknown variance. However, the stochastic environmental drivers that the ε_t are meant to represent typically show relatively strong autocorrelation over time. Thus, we evaluated an additional form for ε_t, with non-zero, autocorrelated means. Here, we assumed that

$$\varepsilon_t \sim \text{Normal}(\phi\varepsilon_{t-1}, \sigma_\varepsilon) \tag{2a}$$
$$\varepsilon_0 \sim \text{Normal}\left(0, \frac{\sigma_\varepsilon}{1-\phi^2}\right) \tag{2b}$$

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

$$N_{a,t} = R_{t-a}\, \pi_{a,t-a}. \tag{3}$$

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):

$$\ln(E_t) \sim \text{Normal}(\ln(S_t), \sigma_S). \tag{4}$$

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 difference between the estimated total run size (N_t) and harvest (H_t)

$$S_t = N_t * (1 - H_t), \tag{5}$$

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 a combination of the 2014 and 2016 FRAM post-season model runs. Because the most recent set of post-season model runs utilizing the new base period (2005 – 2008) were only completed for years 1992 – 2014, we utilized fishing year exploitation rates for years 1983 – 1991 estimated from the 2014 validation runs which utilized the old base period (1974 – 1979).

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

$$\mathbf{O}_t \sim \text{Multinomial}(Y_t, \mathbf{d}_t). \tag{6}$$

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

$$Y_t = \sum_{a=2}^{6} O_{t,a} \,. \tag{7}$$

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

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

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 $2{\times}10^5$ iterations. Following a burn-in period of $1{\times}10^5$ 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 used all uninformative priors for the Bayesian analysis. We assessed convergence and diagnostic statistics via the CODA package in **R** (Plummer et al. 2006). We visually inspected 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. Each model was evaluated by calculating Watanabe's Akaike Information Criterion (WAIC), which is based on point-wise log-likelihood of the model estimates of escapement and age composition.

Results

For each Skagit River Chinook management unit, the Ricker spawner recruit model is the most supported model as indicated by the lowest WAIC (Table 3). For Skagit River spring Chinook salmon, a normally distributed error structure with a mean of 0 received the highest data support whereas for Skagit River summer/fall Chinook salmon there was no discernable difference in data support for either error structure (ΔWAIC < 2). For consistency between Skagit River Chinook management units, we selected the Ricker spawner recruit model.

Table 3. Model selection results for the suite of spawner recruit models evaluated for each management unit.

Management unit	Errors	Model	WAIC	ΔWAIC	WAIC weight
Spring	no AR1	Ricker	423.2	0	0.616
	no AR1	B-H	424.8	1.6	0.277
	AR1	B-H	426.7	3.5	0.107
	AR1	Ricker	846.3	423.1	0
Summer/Fall	AR1	Ricker	677	0	0.409
	no AR1	Ricker	677.7	0.7	0.288
	no AR1	B-H	678.8	1.8	0.166
	AR1	B-H	679.2	2.2	0.136

We estimated considerable uncertainty in the spawner recruit relationship for both Skagit River Chinook management units (Figures 1-2; Table 4). For the Skagit River spring Chinook management unit, the median of the intrinsic productivity was 3.13 offspring per spawner (95% credible interval = 1.62 – 6.94) and the median of the carrying capacity was 1,683 (95% credible interval = 1,335 – 2,866). For Skagit River summer/fall Chinook management unit, the median of the intrinsic productivity was 3.29 offspring per spawner (95% credible interval = 2.20 – 5.19) and the median of the carrying capacity was 22,366 (95% credible interval = 16,860 – 41,480).

Except for a few years, model estimates of escapement for each management unit appeared to track annual variability in observations well (Figures 3 – 4). Neither management unit exhibited a discernable long-term trend in productivity for the period included in the study; however, Skagit River spring Chinook management unit tended to be lower than Skagit River summer/fall Chinook management unit (Figures 5 – 6).

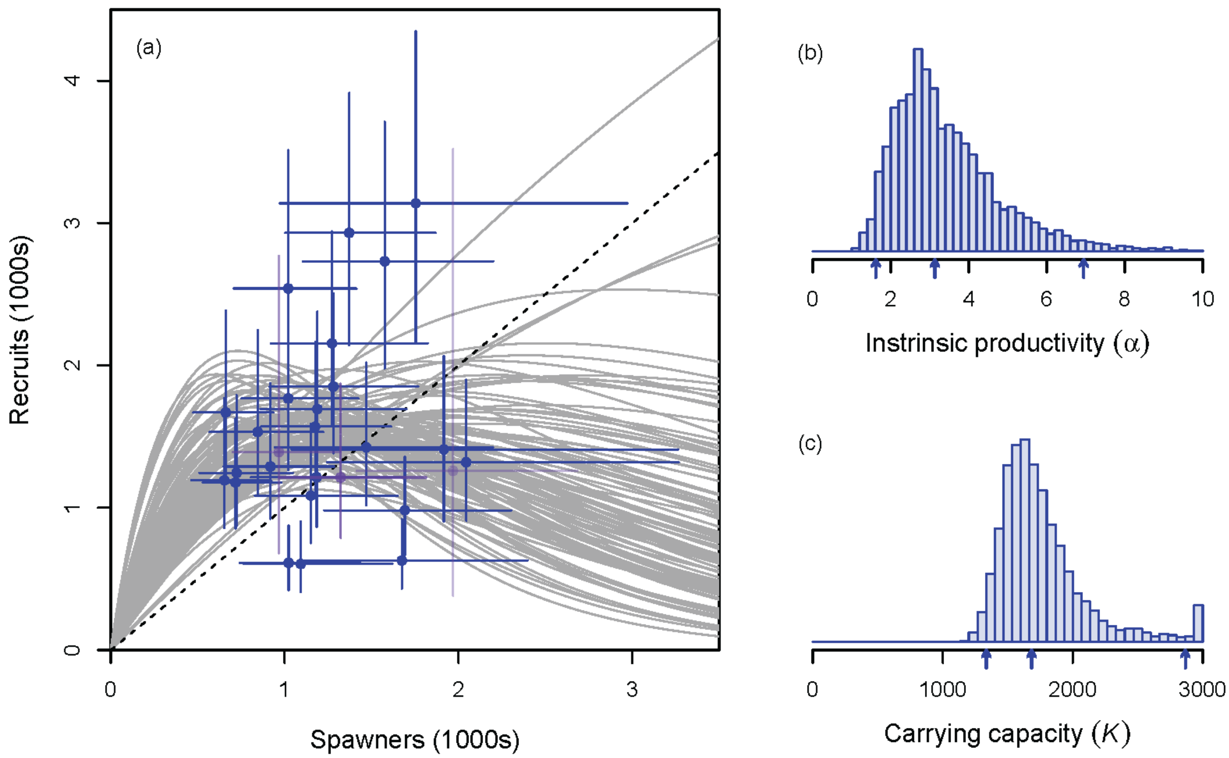


Figure 1. Skagit Spring Chinook spawner recruit relationship. Relationship between the number of spawning adults and their subsequent surviving offspring (recruits) (a). Points are medians of the posterior estimates; error bars indicate the 95% credible intervals. Blue points are for estimates with complete 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.

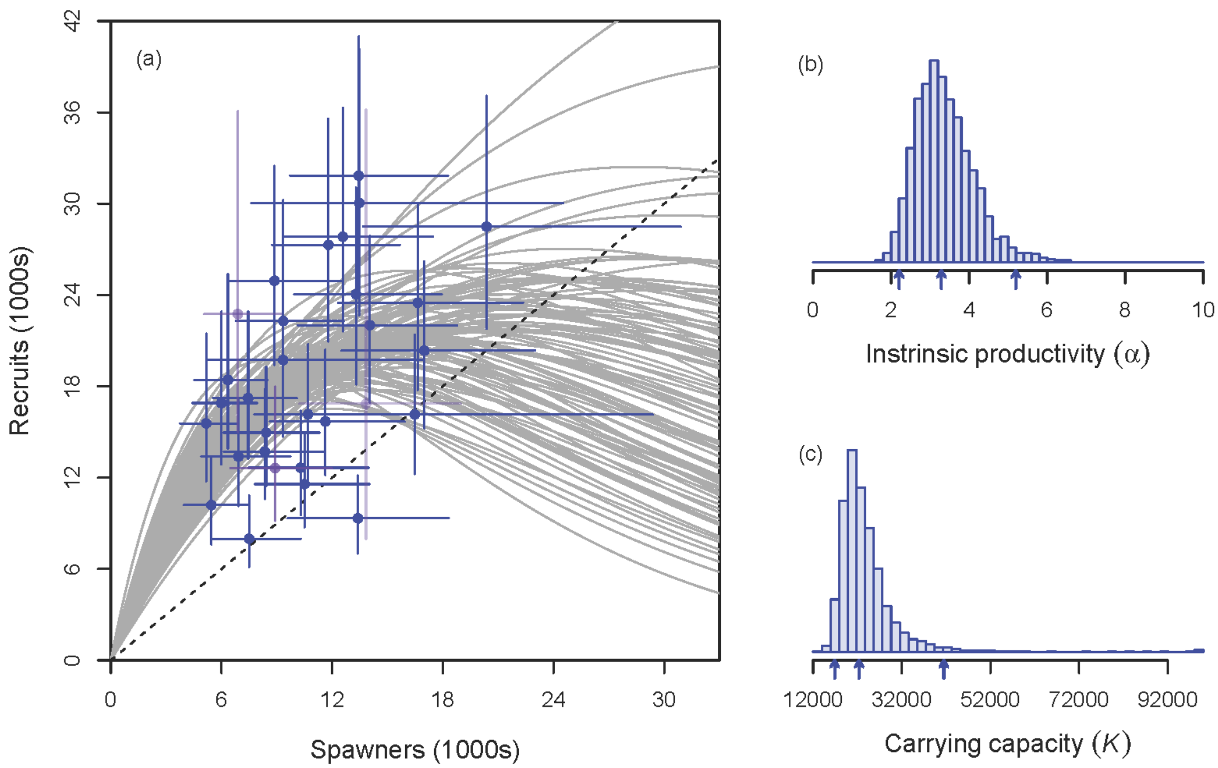


Figure 2. Skagit Summer/Fall Chinook spawner recruit relationship. Relationship between the number of spawning adults and their subsequent surviving offspring (recruits) (a). Points are medians of the posterior estimates; error bars indicate the 95% credible intervals. Blue points are for estimates with 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 4. 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)	3.13 (1.376 - 6.945)	3.29 (2.20 - 5.194)
Carrying capacity (K)	1,683 (1,335 - 2,866)	22,366 (16,860 - 41,480)
Spawners at MSY (Smsy)	690 (513 - 1,291)	9,202 (6,577 - 17,875)
Spawners at PI (Spi)	84 (67 - 143)	1,118 (843 - 2,074)

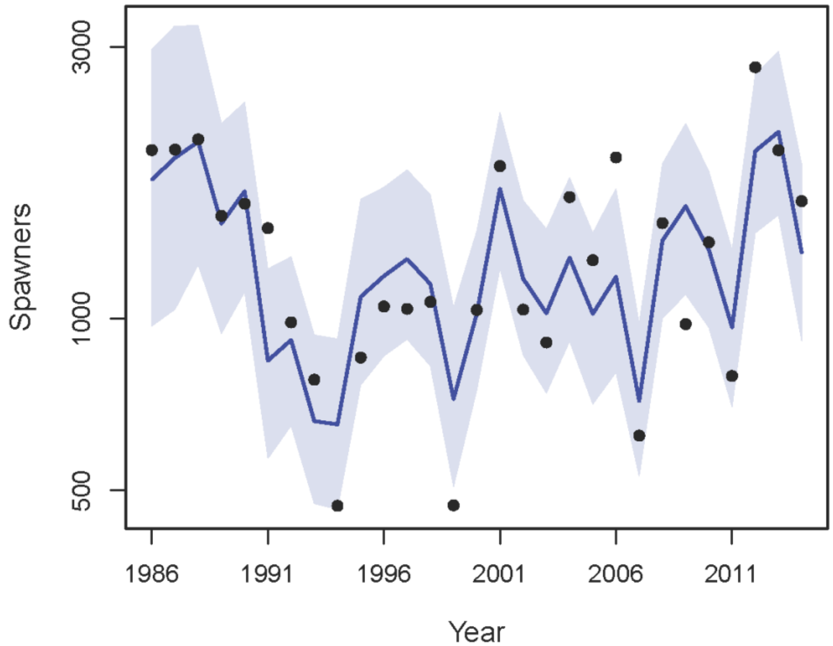


Figure 3. Time series of the estimated escapement for Skagit Spring Chinook. The observed data are the points; the solid line is the median estimate and the shaded region represents the 95% credible interval.

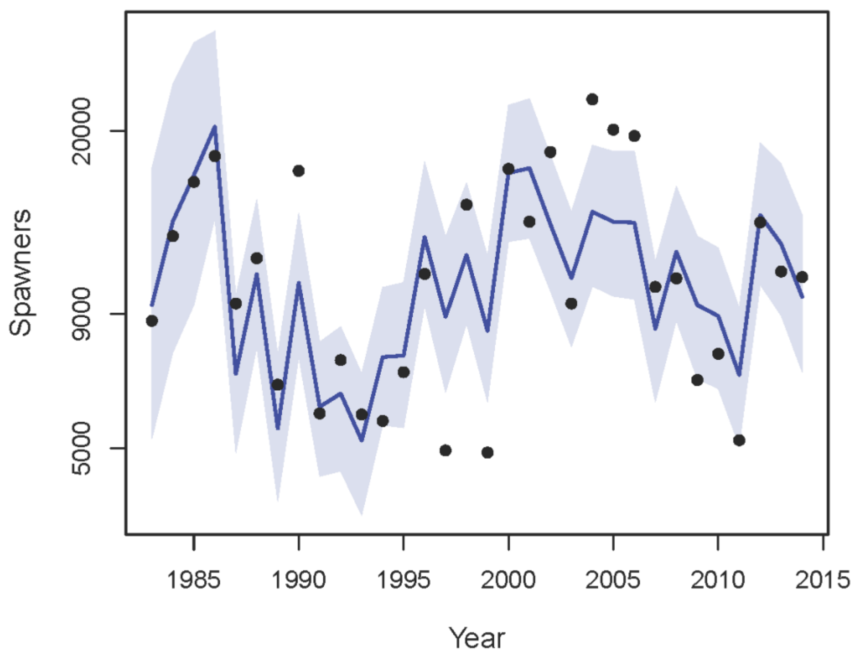


Figure 4. Time series of the estimated escapement for Skagit Summer/Fall Chinook. The observed data are the points; the solid line is the median estimate and the shaded region represents the 95% credible interval.

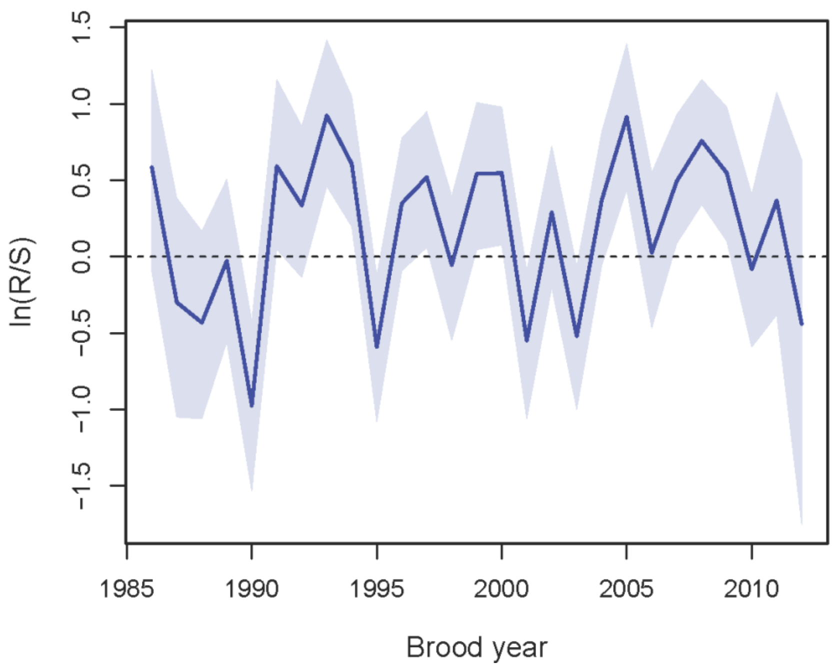


Figure 5. Time series of the estimated productivity for Skagit Spring Chinook for the period 1986 - 2012. The solid line is the median estimate and the shaded region represents the 95% credible interval.

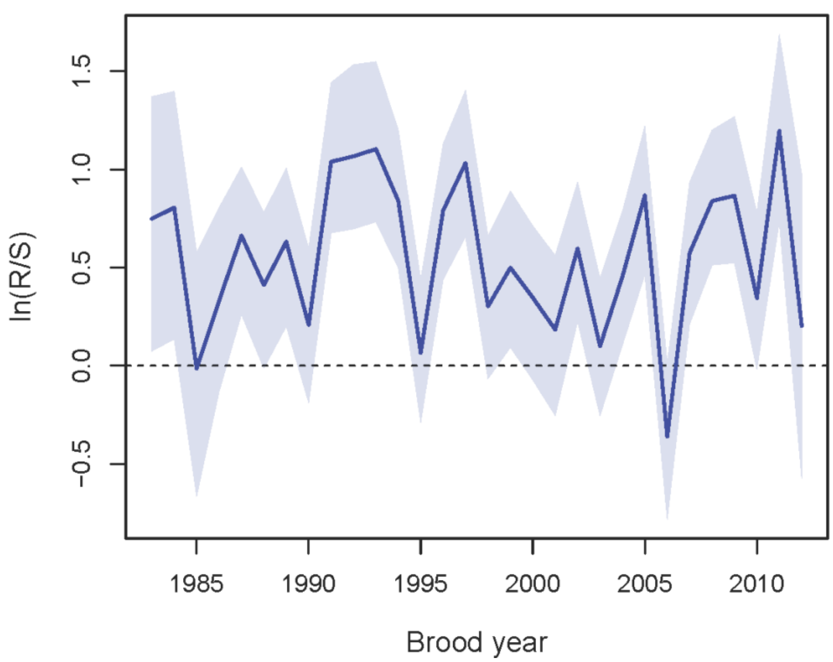


Figure 6. Time series of the estimated productivity for Skagit Summer/Fall Chinook for the period 1983 - 2012. The solid line is the median estimate and the shaded region represents the 95% credible interval.

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 as the median of the posterior distribution of the point of instability and the upper threshold as the median of the posterior distribution of MSY escapement (Table 4). For Skagit River spring Chinook salmon, we set the lower escapement threshold at 84, and the upper threshold at 690. For Skagit summer/fall Chinook salmon, we set the lower escapement threshold at 1,118 and the upper threshold at 9,202.

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 is 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 44% with a credible interval of 28% - 57% (Figures 7-8). For Skagit Summer/Fall Chinook, the posterior median RER was 47% with a credible interval of 35% - 53% (Figures 9-10).

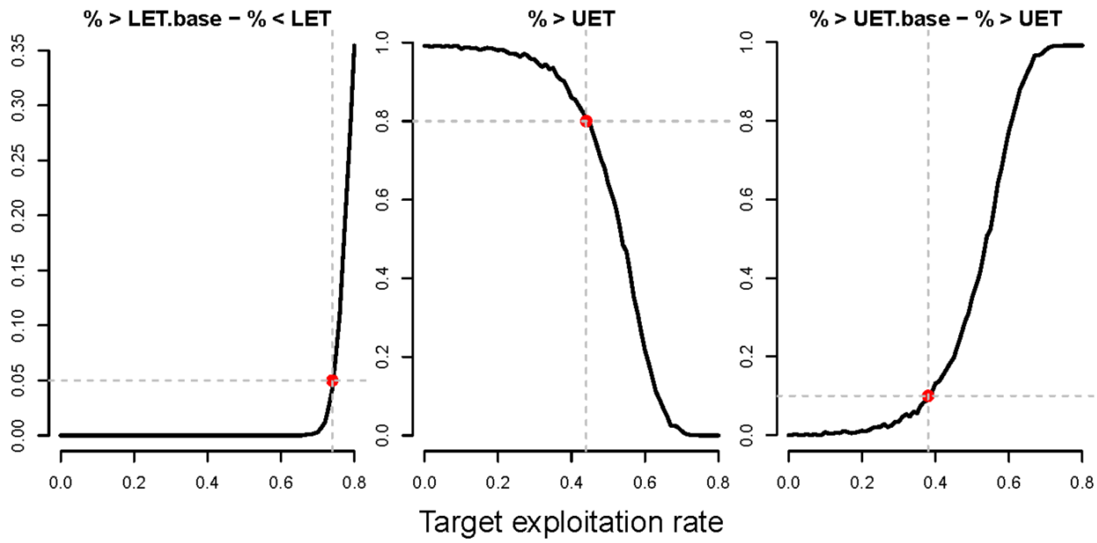


Figure 7. The probability of each of the three RER criteria being met across a range in target exploitation rates for Skagit River Spring Chinook.

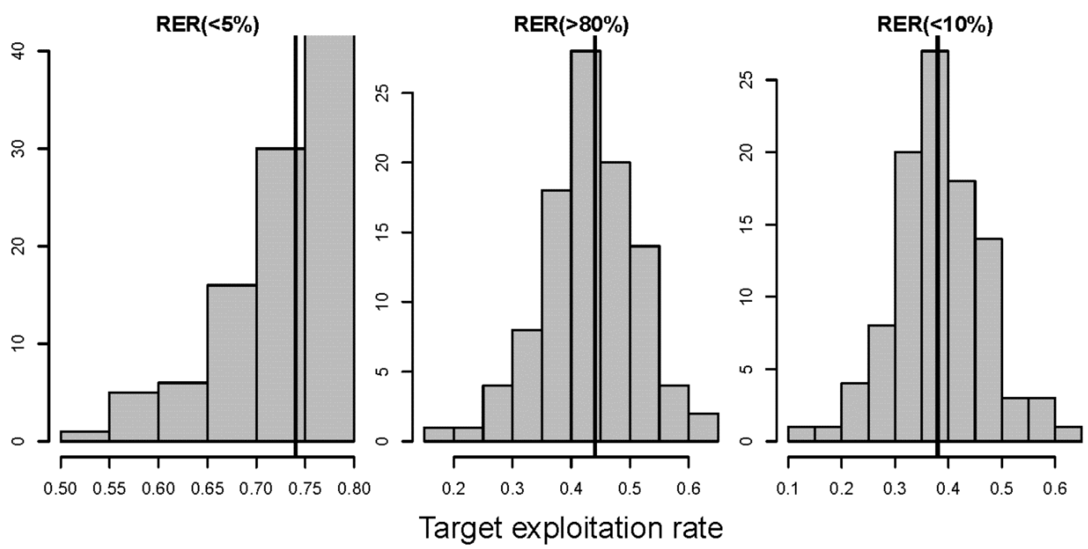


Figure 8. RER range for Skagit Spring Chinook. Histograms show the frequency in which each of the three RER criterion were met for each target exploitation rate. The thick black line shows the median exploitation rate that satisfies each RER criteria.

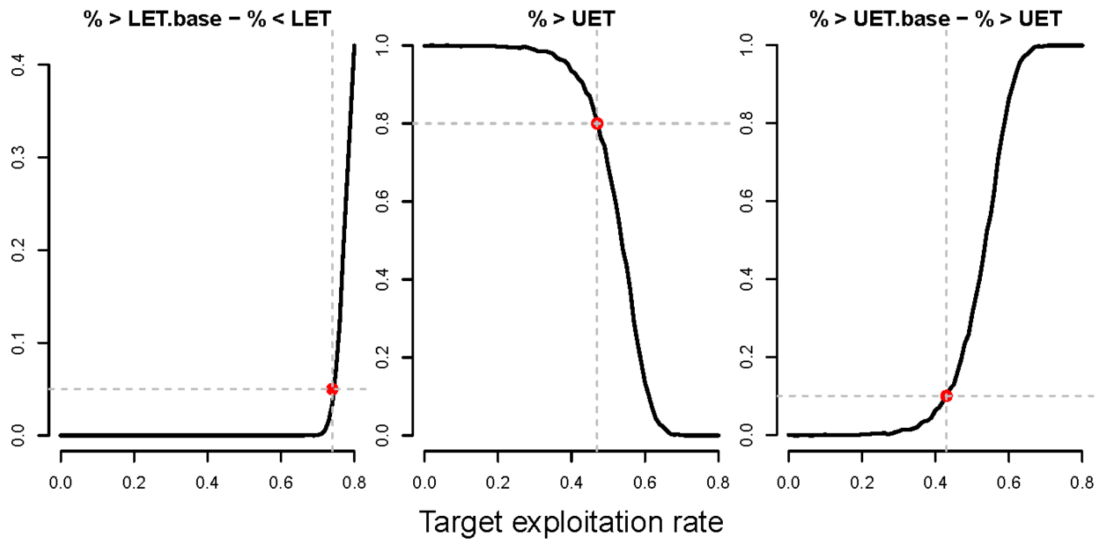


Figure 9. The probability of each of the three RER criteria being met across a range in target exploitation rates for Skagit River Summer/Fall Chinook

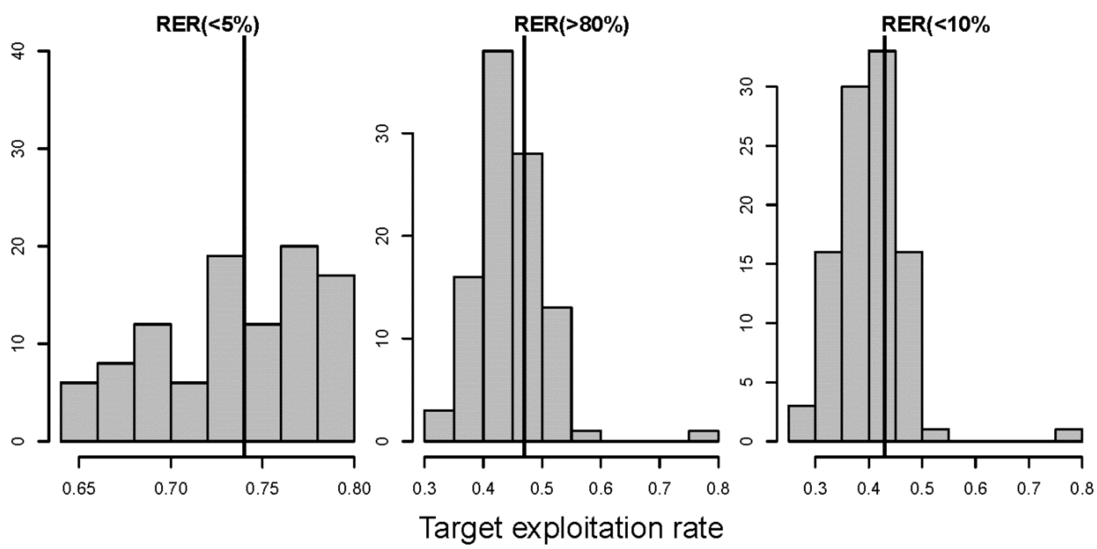


Figure 10. RER range for Skagit Summer/Fall Chinook. Histograms show the frequency in which each of the three RER criterion were met for each target exploitation rate. The thick black line shows the median exploitation rate that satisfies each RER criteria.

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.

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 spawns 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 MU escapement.

Table 1. **Age Structure Estimates for Stillaguamish MU* from Stillaguamish Chinook scales collected during spawning ground surveys and broodstocking activities in the North Fork (NF) between 2002-2013.**

Age Structure Estimates for Stillaguamish MU*	
AGE	**Avg. %**
2	7.1%
3	33.1%
4	53.5%
5	6.1%
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

An integrated summer-timed Chinook recovery program has operated since 1986, with small number releases using native broodstock collected since the 1981-1983 period. 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 PSC indicator stock to monitor harvest distribution and mortality. During 2011-2015, broodstock spawning ranged from 105 to 115 summer adults, averaging around a 1:1 ratio of natural origin (NOR 48%) to hatchery origin (HOR 51%) 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 are genotyped to verify their stock assignment. Juveniles assigned fall are retained for the recovery program, with summer assigned being 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 at 35,000 on average. 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. Stillaguamish MU NOR escapement estimates (EE) show a decline since 1988, a negative trend is also observed in the total natural spawner escapement, but starting later in the 1990s. Overall productivity (lambda) for NOR averages 0.96 for years 1974-2015, with more recent years averaging 0.75 (NOAA Stillaguamish RER Analysis 2016, A&P table).

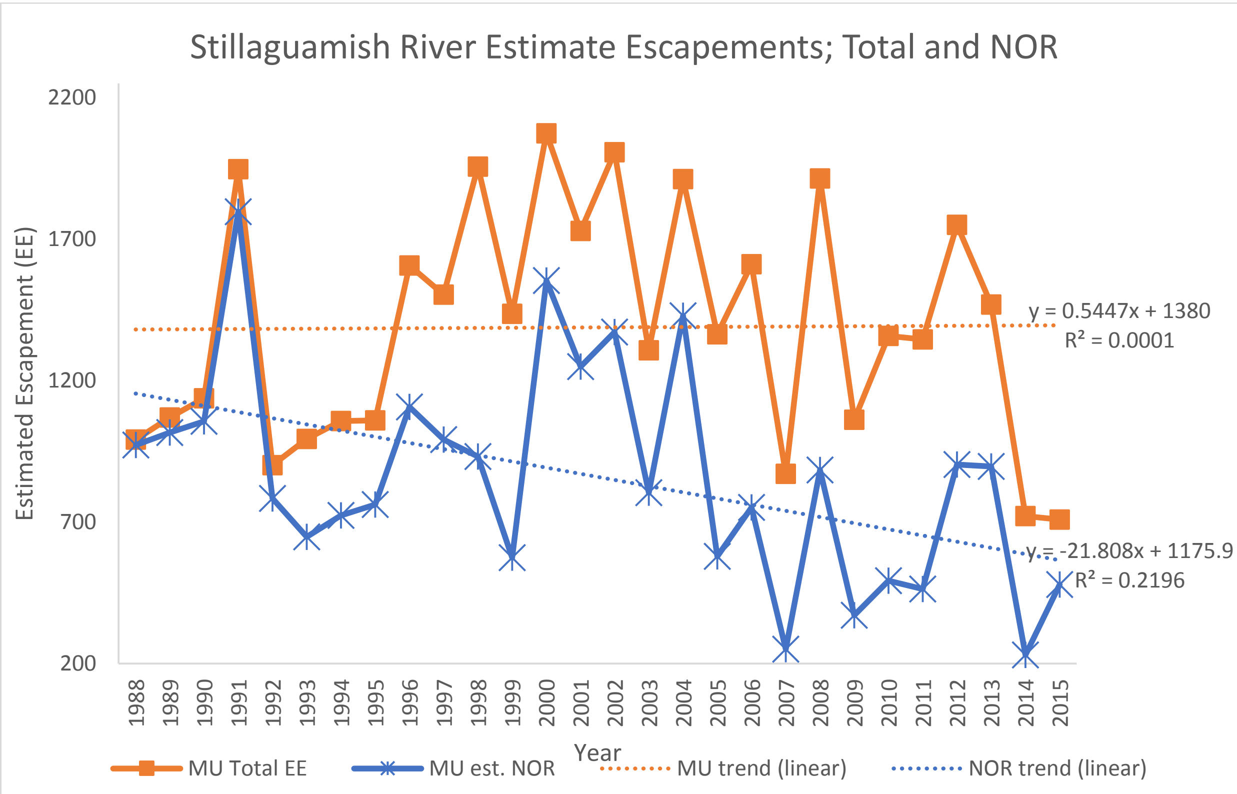


Figure 1. Stillaguamish Management Unit annual GMR adjusted estimated escapements for years 1988 through 2015.

Escapement estimates were derived from a combination of foot and aerial spawning ground redd surveys, expanded by a factor of 2.5 fish per redds. 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 (2006 – 2015), the number of total adult spawners, in watershed has ranged from 838 to 2043 (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 287 to 1029 NORs and HOR spawners ranged from 298 to 1100.

Table 2. GMR adjusted spawning escapement estimates (EE) of Stillaguamish summer and fall-timed Chinook, 1988-2015. Stillaguamish Chinook 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.

YEAR	TOTAL EE	SGS EE	BROOD STOCK	TOTAL EST NOR	TOTAL EST HOR
1988	1008	992	16	987	21
1989	1097	1070	27	1035	62
1990	1204	1138	66	1094	110
1991	2043	1947	96	1845	198
1992	1054	901	153	854	200
1993	1163	994	169	708	455
1994	1238	1057	181	798	440
1995	1149	1060	89	803	346
1996	1751	1606	145	1178	574
1997	1661	1504	157	1025	636
1998	2100	1956	144	975	1125
1999	1567	1436	131	601	966
2000	2197	2074	123	1597	600
2001	1856	1729	127	1338	518
2002	2146	2007	139	1446	700
2003	1429	1307	122	870	560
2004	2049	1912	137	1505	544
2005	1503	1363	140	658	846
2006	1745	1612	133	809	936
2007	1036	870	166	327	709
2008	2043	1914	129	943	1100
2009	1210	1061	149	423	787
2010	1498	1358	140	551	947
2011	1518	1345	173	509	1009
2012	1929	1750	179	1029	900
2013	1601	1469	132	977	624
2014	865	721	144	287	578
2015	838	709	129	479	298

Source: WDFW & Stillaguamish Tribe Fisheries Data (Verhey, Whitney, Konoski)

Habitat Limiting Factors

Current Phase of Recovery: Preservation
Current Habitat Condition: Low

Escapement to the Stillaguamish River has varied widely since the mid-1990s, appearing apparently stable due to hatchery supplementation beginning in 1986. 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. Peak winter flows caused by long-term increases in rainfall (but proportionally less snowfall) scour redds, and bed material needed during future spawning events, leading to significant 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.

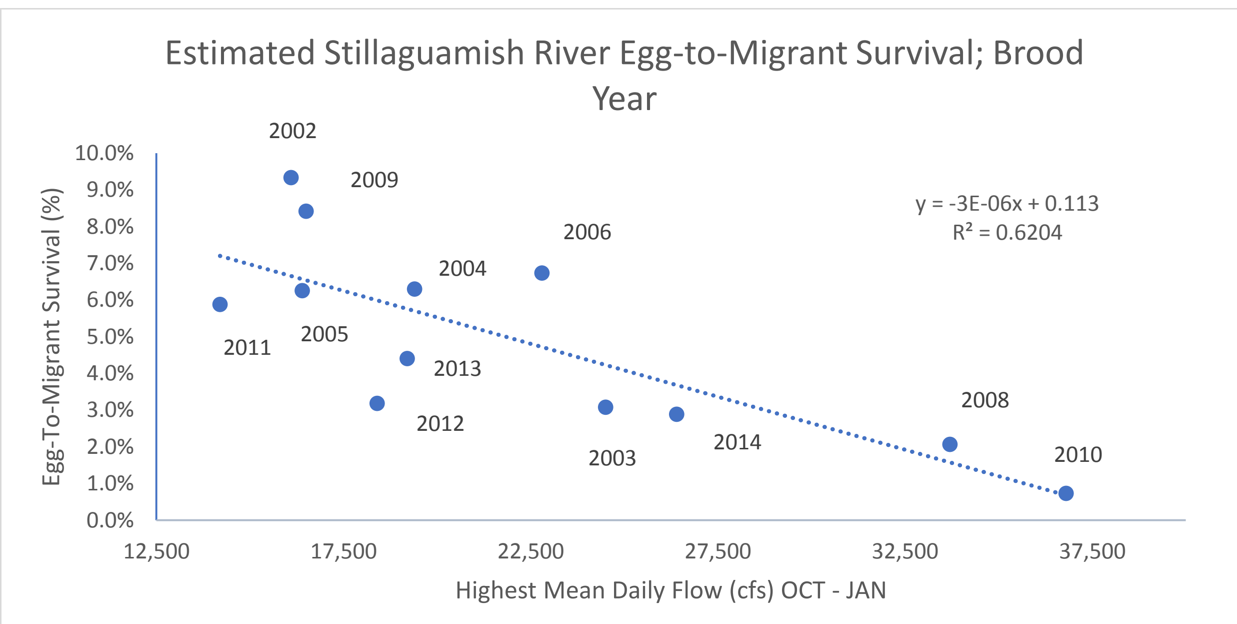


Figure 3. Stillaguamish Natural Origin (NOR) Egg-to-Migrant survival vs Stillaguamish River Peak Flows. Egg-to-Migrant survival calculated by dividing estimated Chinook smolt outmigration by number of females that spawned naturally in the given brood year and their associated fecundity.

Harvest distribution

Recoveries of coded-wire tagged Stillaguamish summer Chinook are utilized to infer harvest distribution in fisheries. Since 2005, Northern fisheries in Alaska (AK) and British Columbia (BC) accounted for 62.3% of total marked and 71.1% of total unmarked harvest mortalities. Southern United States(SUS) Troll and Net combined accounted for 10.9% of marked and 11.9% of unmarked, and SUS Sport accounting for 26.9% of marked and 17.0% of unmarked mortalities (Table 4).

Table 4. Average distribution of total fishery-related mortality Stillaguamish River Chinook, 2005-2014 (FRAM_Rnd4 post-season Reports).

Fishery related mortalities - Distribution by Mark					
	AK	BC	SUS Troll	SUS Net	SUS Sport
MARKED	6.5%	55.8%	7.4%	3.5%	26.9%
UNMARKED	7.5%	63.6%	7.0%	4.9%	17.0%

Table 5. Annual exploitation rates of Stillaguamish Chinook, 2005-2014 (FRAM_Rnd4 post-season Reports).

FRAM Post Season ERs on Stillaguamish Chinook, by Fishery & Mark										
MARKED	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	AVG ER
AK	4.0%	2.5%	3.2%	2.1%	1.4%	2.4%	1.7%	1.5%	1.3%	2.6%	**2.3%**
BC	29.9%	22.5%	30.7%	22.8%	13.2%	16.4%	17.5%	13.2%	10.1%	19.6%	**19.6%**
SUS Troll	4.9%	3.8%	3.1%	0.9%	0.9%	2.6%	1.2%	1.3%	3.7%	3.6%	**2.6%**
SUS Net	1.2%	0.7%	0.6%	1.1%	0.4%	0.8%	3.5%	1.0%	1.6%	1.2%	**1.2%**
SUS Sport	7.0%	9.4%	13.1%	6.9%	5.7%	7.6%	7.2%	6.9%	13.0%	17.7%	**9.4%**
TOTAL ER	46.9%	38.9%	50.7%	33.9%	21.6%	29.9%	31.0%	23.9%	29.7%	44.7%	**35.1%**
SUS ER	13.0%	13.9%	16.8%	9.0%	7.0%	11.0%	11.8%	9.2%	18.3%	22.5%	**13.3%**
UNMARKED	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	AVG ER
AK	2.4%	0.9%	2.9%	1.6%	1.8%	1.6%	2.2%	1.6%	0.9%	2.5%	**1.8%**
BC	16.4%	7.6%	28.2%	17.0%	15.7%	10.5%	22.1%	13.7%	7.0%	19.2%	**15.7%**
SUS Troll	1.8%	0.7%	2.5%	0.8%	0.7%	2.3%	2.1%	1.3%	1.6%	3.5%	**1.7%**
SUS Net	1.1%	0.7%	0.6%	1.0%	0.5%	0.8%	3.3%	1.0%	1.8%	1.4%	**1.2%**
SUS Sport	2.5%	1.9%	7.5%	2.7%	3.2%	2.8%	6.7%	3.3%	3.5%	7.9%	**4.2%**
TOTAL ER	24.1%	11.8%	41.8%	23.1%	21.9%	18.0%	36.4%	20.9%	14.8%	34.5%	**24.7%**
SUS ER	5.3%	3.3%	10.7%	4.5%	4.4%	5.9%	12.1%	5.7%	6.9%	12.8%	**7.1%**

Exploitation rate trends

Post-season FRAM validation ER estimates during 2005 – 2014 ranged from 21.6% to 50.7% on marked, 11.8% to 41.9% on unmarked; SUS ERs ranged from 7.0% to 22.5% on marked and 3.3% to 12.8% on unmarked (Table 6). In most recent years, harvest in SUS fisheries has been managed under the 2010 RMP critical ER ceiling (15%) for NOR (unmarked) Stillaguamish adults and were below that level in all years. HOR (marked) Stillaguamish adults did not have defined management objectives.

Table 6. Total MU and SUS exploitation rates (ER) for Stillaguamish Chinook (FRAM post-season Reports).

	MARKED		UNMARKED	
YEAR	MU ER	SUS ER	MU ER	SUS ER
2005	46.9%	13.0%	24.1%	5.3%
2006	38.9%	13.9%	11.8%	3.3%
2007	50.7%	16.8%	41.9%	10.7%
2008	33.9%	9.0%	23.1%	4.5%
2009	21.6%	7.0%	22.0%	4.4%
2010	29.9%	11.0%	18.0%	5.9%
2011	31.0%	11.8%	36.4%	12.1%
2012	23.9%	9.2%	20.9%	5.7%
2013	29.7%	18.3%	14.8%	6.9%
2014	44.7%	22.5%	34.5%	12.8%
AVG:	35.1%	13.3%	24.7%	7.1%

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 limited to no introgression has occurred during the length of the integrated recovery program. Migration timing and CWT data have also shown that HOR spawners may be considered representative of the NOR cycle. When genetic-based population escapement estimates become available, management thresholds and objective will be reviewed accordingly.

Forecasted terminal run size (regardless of origin) 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 whether changes to the EMPAR, specifically to its terminal run size (TRS) forecast methodology, are appropriate prior to completion of pre-season forecasts in 2018 and if necessary, for the duration of the plan. Changes to fishery impact rates expected to begin in 2018 may affect the ability of the model to forecast TRS, as it relies on recent year fishing patterns to predict the number of fish escaping to the terminal area.

The management thresholds for Stillaguamish Chinook will change from those established by the 2010 Harvest Plan to include total natural spawners, with a lower bound threshold (LBT) established below the low abundance threshold (LAT) to trigger further management review and discussions at very low escapement levels.

NOAA reviewed the productivity and risk analyses supporting the thresholds and ER ceilings during recent RER analysis. The analysis identified the highest allowable exploitation rate that meets specific criteria for minimizing the risk that escapement will fall below a critical escapement level, and ensuring that escapement will reach a rebuilding escapement threshold. NOAA's analysis identified an RER of 39% as an acceptable risk for the Stillaguamish MU, which equated to a FRAM ER of 26%. Subsequent FRAM validation runs have changed the FRAM estimated ERs on Stillaguamish Chinook in past years, and will change the CWT-FRAM rate conversion. Preliminary analysis suggests that 24% is the FRAM equivalent to 39% using the latest validation runs.

Fisheries will be planned to not exceed a total ER ceiling of 24% for natural-origin Stillaguamish Chinook. An additional SUS ER ceiling will be implemented for HOR Stillaguamish Chinook at some abundances. The HOR ceiling will vary with total escapement projected for the MU. Should subsequent revised validation runs substantially change the CWT to FRAM rate conversion of NOAA's 39% RER, the comanagers will review whether an update to the FRAM rate of 24% is appropriate.

Lower Bound Threshold

NOAA defines the critical escapement threshold (CET) as the lowest spawner abundance resulting in positive recruit, determining 400 natural spawners for the Stillaguamish Unit. 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. Because this estimate pre-dates the time series of GMR adjusted estimates, it is not comparable to recent escapement estimates. Using GMR adjusted EE, an estimated natural spawning escapement (combined NOR and HOR) of 901 is the lowest escapement with positive recruitment (Table 7). Based on this, a LBT of 900 total spawners will be implemented for the MU. If forecasted TRS is at or below the LBT, total impacts to NORs will not exceed 24% ER in all fisheries, and the co-managers commit to developing guidelines of appropriate management actions to implement, if any, SUS fisheries.

Should the forecasted TRS fall below the LBT, additional measures will be taken to attempt to prevent further declines in abundance. The comanagers 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 comanagers 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.

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

YEAR	TOTAL RECRUITS	TOTAL SPAWNERS	R/S
1990	1159	1138	1.02
1991	707	1947	0.36
1992	915	901	1.02
1993	887	994	0.89
1994	1124	1057	1.06
1995	387	1060	0.37
1996	1597	1606	0.99
1997	1099	1504	0.73
1998	1022	1956	0.52
1999	935	1436	0.65
2000	1259	2074	0.61
2001	837	1729	0.48
2002	1186	2007	0.59
2003	309	1307	0.24
2004	868	1912	0.45
2005	1295	1363	0.95
2006	486	1612	0.30
2007	652	870	0.75
2008	973	1914	0.51
2009	1302	1061	1.23

Source: Derek Dapp, DFW

Low Abundance Threshold

NOAA analysis estimated MSY capacities of 650 and 1,180 natural spawners using two different spawner recruit models. Recognizing NOAA determined the rebuilding escapement threshold to be 650 for the total MU, a LAT of 1,200 natural spawners will be implemented, representing the higher of the two capacity estimates. If forecasted TRS is at or below the LAT, total impacts to NORs will not exceed 24% ER in all fisheries, with SUS fisheries constrained to a ceiling of 8% if northern fisheries do not exceed 16%. 8% represents the average post-season estimate of SUS ER on Stillaguamish NORs for the most recent 6 years with validation data available (2009-2014), and represents a conservative approach for SUS fisheries given concerns over low abundances of Stillaguamish Chinook. If northern fisheries exceed 16%, SUS impacts will be lowered to maintain NOR impacts to not exceed 24% ER.

Upper Management Threshold

An upper management threshold (UMT) of 1500 natural spawners will be implemented, with the objective to exceed the threshold annually for the duration of the plan. The UMT was calculated as the recent 10-year average of escapement from 2005-2014 (1495). If the forecasted TRS is at or below UMT, total impacts to NORs will not exceed 24% ER in all fisheries, with SUS fisheries constrained to a ceiling of 10-13%, adjusted based on forecasted TRS. With consideration to northern fisheries, if total impacts exceed 24%, SUS impacts will be lowered. See table 8 for adjustment to ERs based on forecasted TRS.

If forecasted TRS is above UMT, total impacts to NORs will not exceed 24% ER in all fisheries, with SUS fisheries constrained to a ceiling of 13% if northern fisheries do not exceed 11%. If northern fisheries exceed 11%, SUS impacts will be lowered to maintain NOR impacts to not exceed 24% ER.

HOR management

Impacts to HOR (marked) Stillaguamish Chinook in SUS fisheries will be limited to no greater than a difference of 4-6% above NOR impacts (i.e. [NOR ER %] + [4 to 6%] = [SUS HOR ER]) when forecasted TRS is between the LAT and UMT threshold levels. If the SUS ER ceiling on NORs is reduced due to northern fisheries impacts, the difference of 4-6% will be maintained from the determined NOR allowable impact. See table 8 for adjustment to ERs based on forecasted TRS.

If forecasted TRS is above UMT, HOR impacts will not be constrained.

Table 8. Management Thresholds and applicable actions. SUS NOR ER adjusts from 10-13% between LAT and UMT thresholds. SUS HOR ER difference adjust from 4-6% between LBT and UMT thresholds. Total NOR impacts are not to exceed 24% at all threshold levels.

THRESHOLD LEVEL	FORECASTED TRS	SUS NOR ER CEILING	HOR % diff	SUS HOR ER CEILING	TOTAL NOR ER*
BELOW LBT	< 900	LBT GUIDELINES IMPLEMENTED			24.0%
LBT	900	8.0%	4.0%	12.0%	24.0%
	1000	8.0%	4.2%	12.2%	24.0%
	1100	8.0%	4.4%	12.4%	24.0%
LAT	1200	10.0%	4.8%	14.8%	24.0%
	1300	11.0%	5.2%	16.2%	24.0%
	1400	12.0%	5.6%	17.6%	24.0%
UMT	1500	13.0%	6.0%	19.0%	24.0%
ABOVE UMT	1500+	13.0%	no constraint		24.0%

* Total NOR ER not to be exceeded w/ consideration of Northern Fisheries, which may cause SUS impacts to be lowered from defined ceiling rates.

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, 2, 15, 64, and 19%, respectively (years 2005-2015; Rawson and Crewson, Tulalip Tribes 2017, see Appendix 3).

Analysis of scales and otoliths collected from natural-origin adult returns (Rawson and Crewson, *Ibid*) indicates that on average, 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. 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). Escapements from 2012 through 2016 increased moderately, but still remained low.

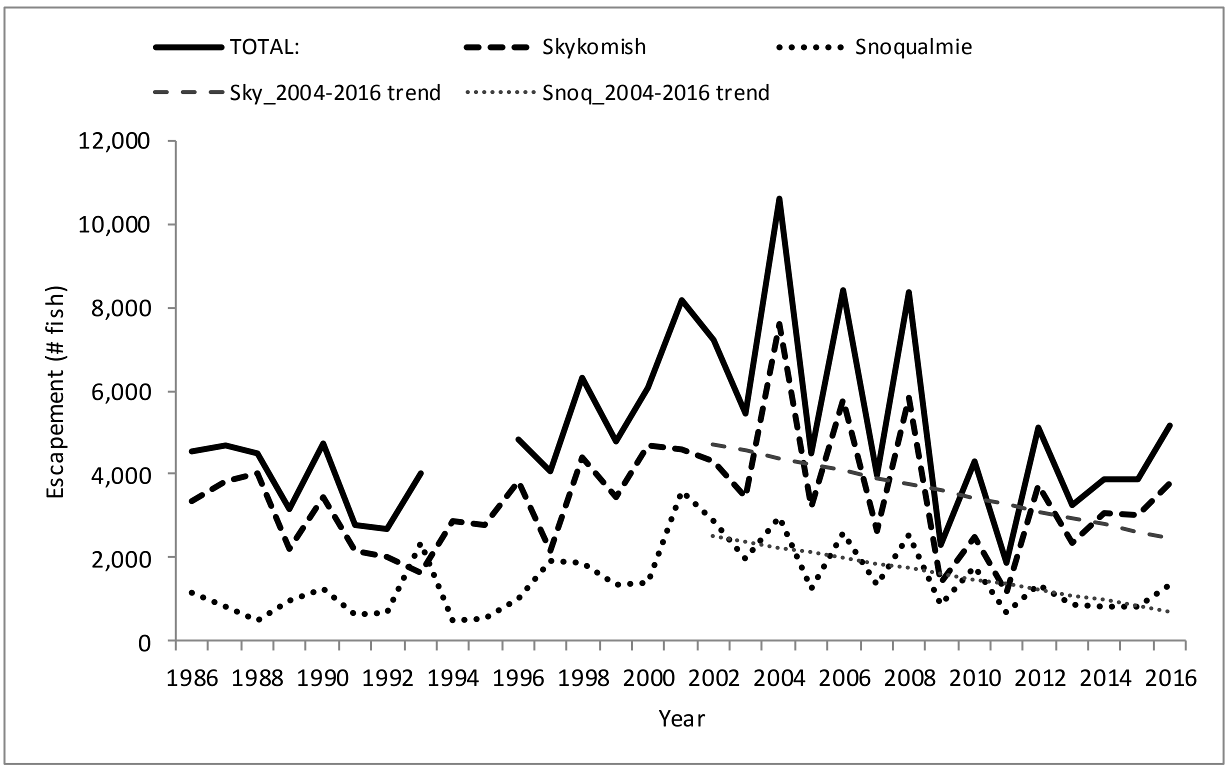
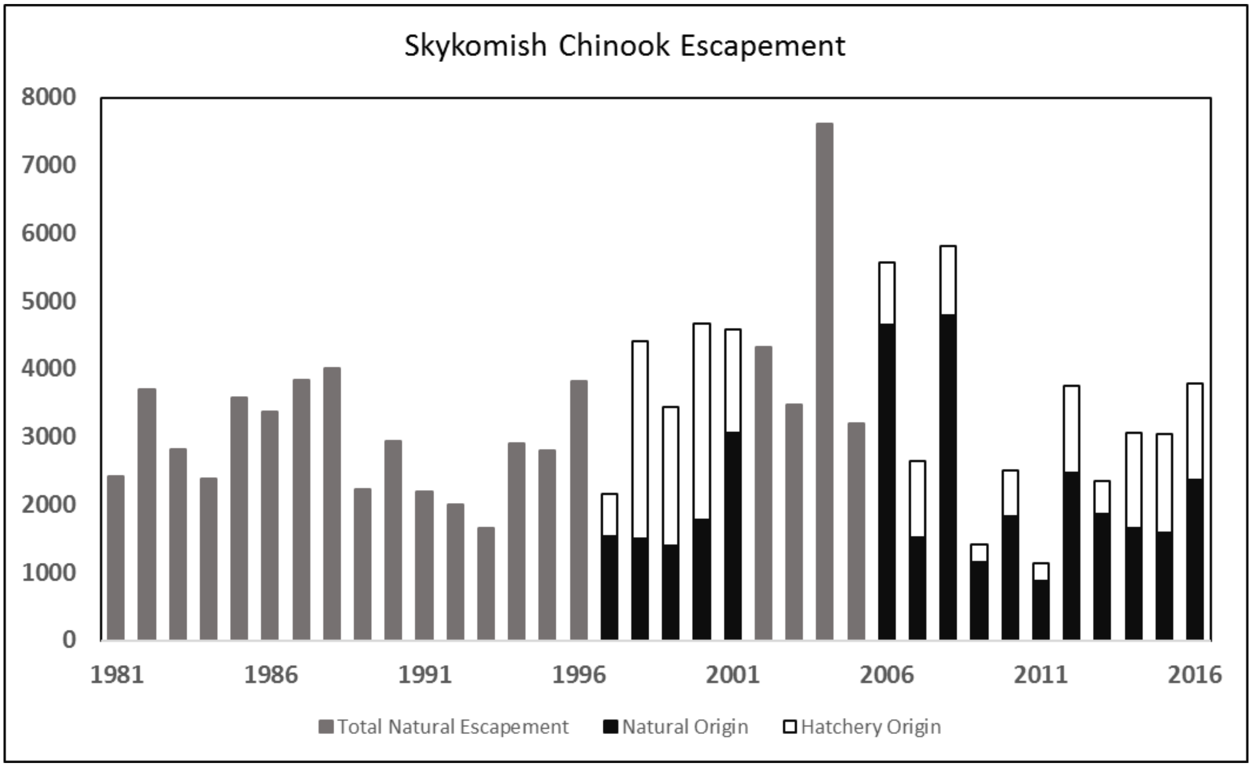


Figure 1. Total (HOR and NOR) Snohomish Chinook salmon escapements for the two listed populations and the basin total (1986-2016). No estimates are available for the Snoqualmie population in 1994 and 1995.

Naturally-produced Chinook comprise a majority of natural spawners, averaging 73.8% for the basin in recent years (2005-2016, 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 (30.5%) is still lower than during 1997-2001 (49.9%), it has increased in recent years (2014-16) to an average of 43.8%. The hatchery-origin fraction of the naturally spawning Snoqualmie Chinook population during 2005-2016 has averaged 20.5%, which is slightly higher than the 1997-2001 average of 15.6% (Table 1).



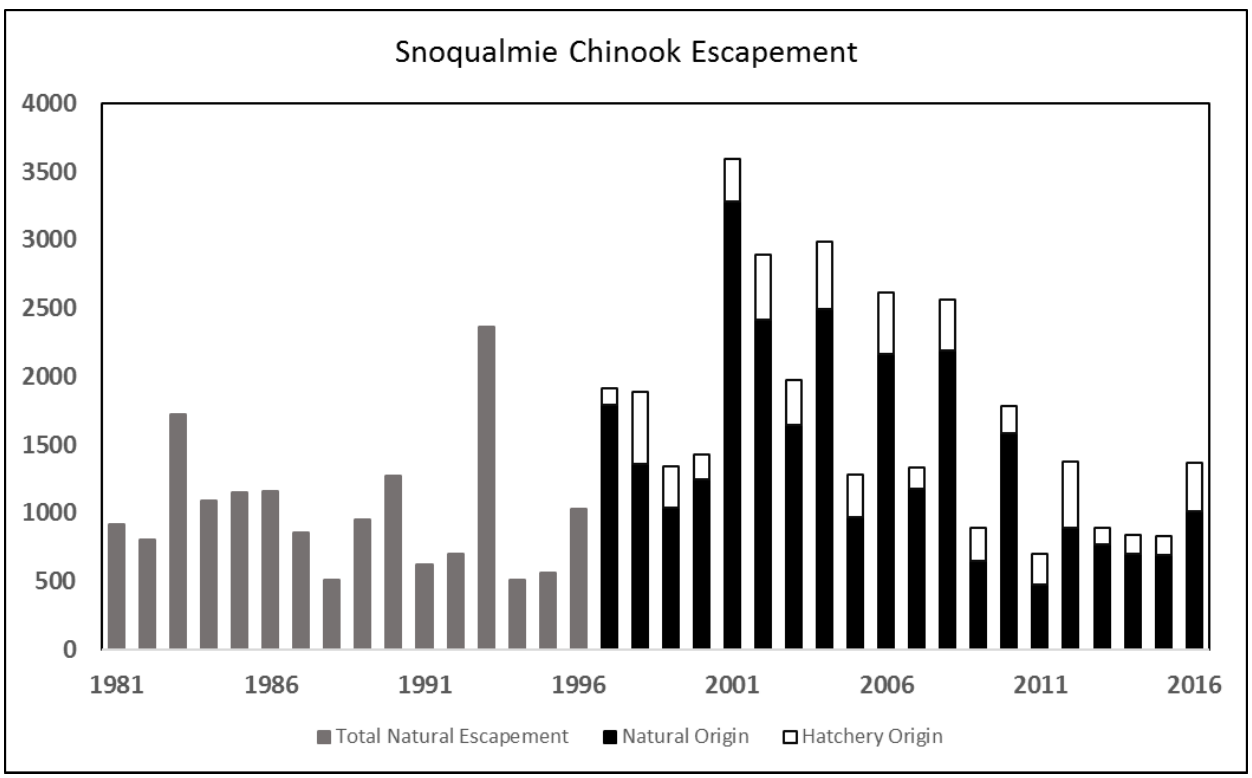


Figure 2. Skykomish (top) and Snoqualmie (bottom) Chinook natural escapements (1981-2016). Since 1997, natural and hatchery origin fractions have been estimated, except during the period 2002-2005 in the Skykomish.

Table 1. Chinook salmon escapement to the Snohomish basin, 2003-2016. 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	Sky NOR	HOR+NOR	Snoq 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	898
2013	2,355	1,860	889	770
2014	3063	1,654	839	698
2015	3034	1,585	829	694
2016	3785	2,363	1,368	1,013

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 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. The production goal is 2.4 million subyearling Chinook smolts released annually, which are also double index-tagged but with 100,000 AD + CWT and 100,000 CWT only. Since this program switched to summer Chinook broodstock in brood year 2004, straying rates[13] declined substantially, as well as the contribution rate[14] of Tulalip Hatchery Chinook to the spawning grounds. In the earlier portion of that

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

period, the reduction in the contribution rate was also partially due to smaller Tulalip Chinook run sizes, although in the last two years, when Tulalip Hatchery-origin Chinook returns have 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.

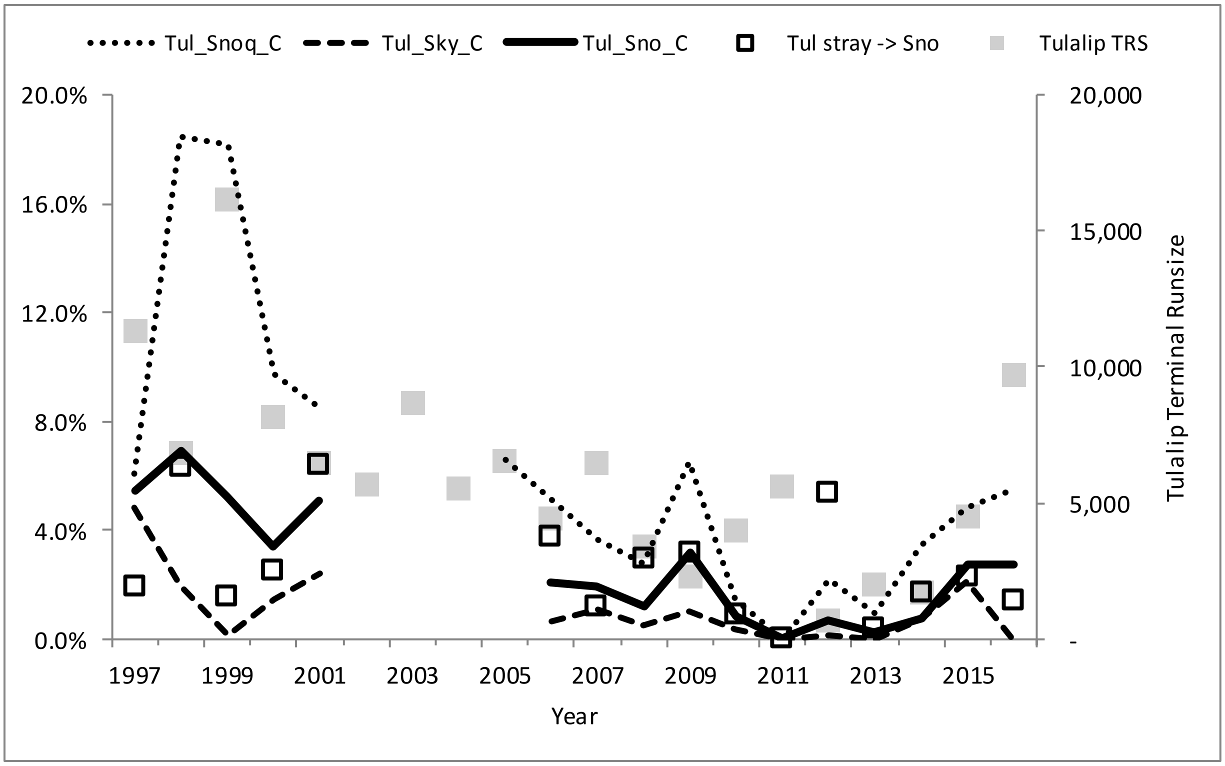


Figure 3. Tulalip Hatchery Chinook (Tul) contributions (C) to escapement in the Snohomish system (Sno), Skykomish (Sky) and Snoqualmie (Snoq) basins, straying rates to the Snohomish (hollow squares), and terminal run size (filled squares).

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 46.9% and 45.1% of the total fishing mortality respectively, while preterminal SUS troll and net fisheries (mostly in Puget Sound) account for only 4.2% and 2.1% respectively (Table 2).

Table 2. Recent (2009 – 2015) distribution of Exploitation Rate from recovery of Wallace River Hatchery coded-wire tags (PSC CTC 2017).

AK	B.C.	SUS troll	SUS net	SUS sport
0.6%	15.7%	1.4%	0.7%	15.1%

Post-season FRAM (validation) estimates of the total ER for Snohomish Chinook were lower than pre-season estimates in all years but 2014, but since 2011 pre- vs post-season estimates have been much closer. In this period, projected SUS fisheries have been underestimated 3 out of 4 years by an average of 3.4% ER (33% under the post-season SUS ER).

From 2004 to 2014, the total exploitation rate on Snohomish Chinook ranged from 11% to 23%, averaging 17.6%. Exploitation rates associated with SUS fisheries ranged from 10% to 20%. From 2004 to 2014, 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 3. Exploitation rates for Snohomish Chinook estimated by pre-season and post-season FRAM models.

	Total ER			SUS ER		
Year	Pre-season	Post-season	Pre-post	Pre-season	Post-season	Pre-post
2004	28.72%	17.05%	11.67%	12.74%	7.82%	4.93%
2005	32.67%	22.59%	10.09%	15.69%	10.99%	4.71%
2006	33.10%	12.72%	20.38%	16.38%	6.40%	9.98%
2007	35.32%	22.13%	13.19%	12.44%	11.44%	1.00%
2008	25.43%	10.87%	14.56%	12.63%	3.82%	8.81%
2009	26.43%	16.95%	9.49%	13.74%	6.69%	7.06%
2010	20.31%	12.66%	7.65%	10.74%	5.89%	4.85%
2011	22.29%	21.48%	0.81%	10.32%	13.39%	**-3.07%**
2012	16.44%	13.88%	2.55%	8.76%	5.86%	2.91%
2013	23.06%	20.23%	2.83%	11.23%	14.37%	**-3.14%**
2014	20.35%	22.95%	**-2.60%**	9.33%	13.27%	**-3.93%**

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).

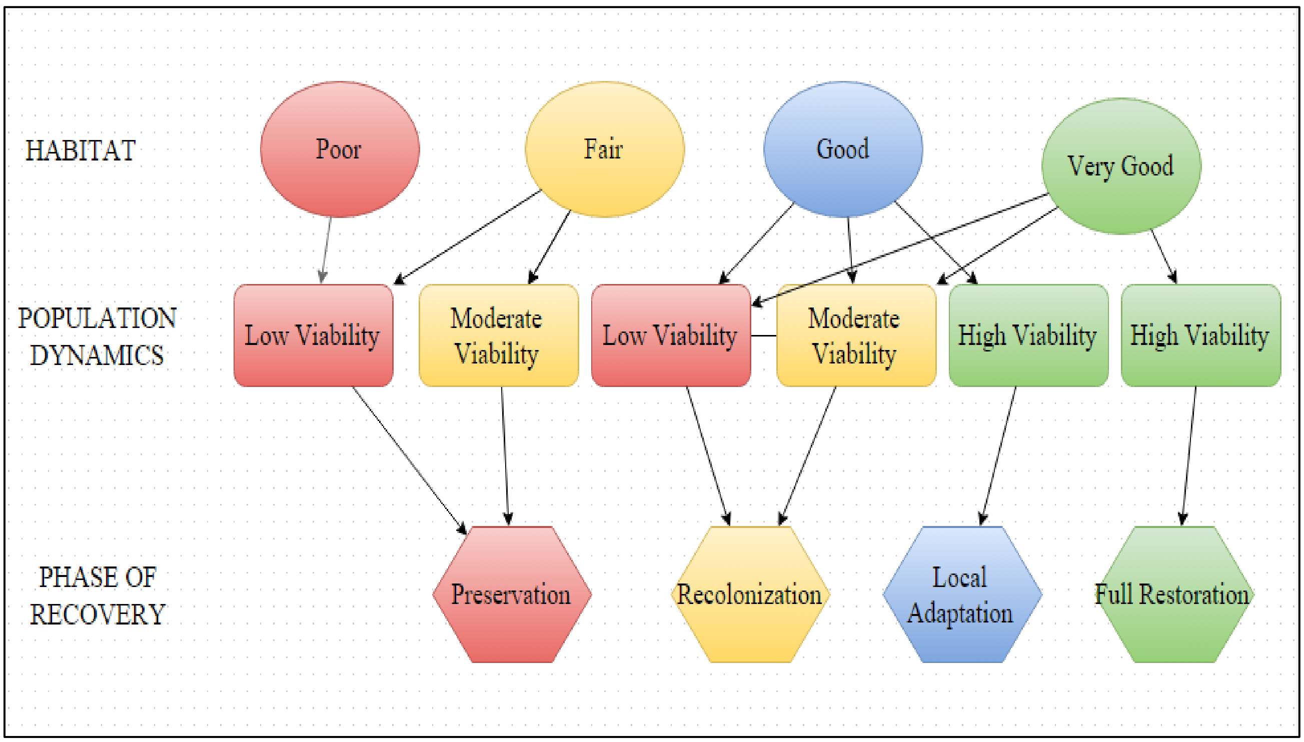


Figure 4. Phase of Recovery depends on both population viability and habitat status

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:

- **<u>High Viability</u>** = VSP, as defined in PS recovery planning, i.e. a probability of 95% or greater of persisting for more than 100 years,
- **<u>Moderate Viability</u>** = 40 year persistence probability of 95% or higher, and
- **<u>Low Viability</u>** = 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):

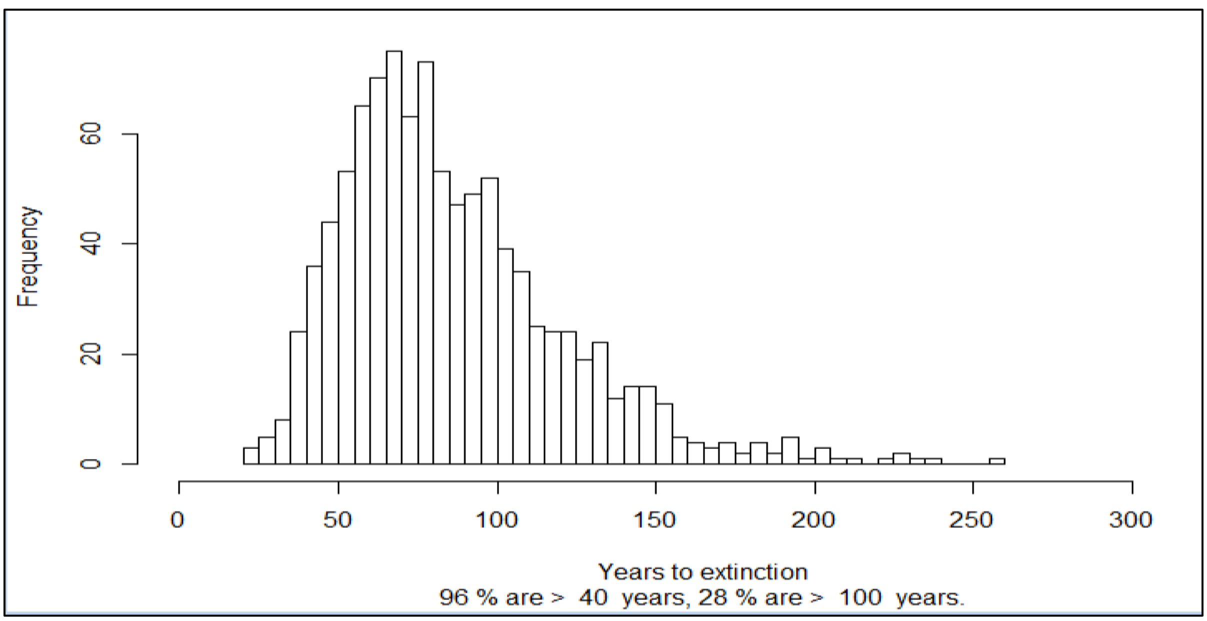


Figure 5. Frequency distribution of the number of years to quasi-extinction in 1,000 simulations for the Skykomish Chinook population.

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).

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.

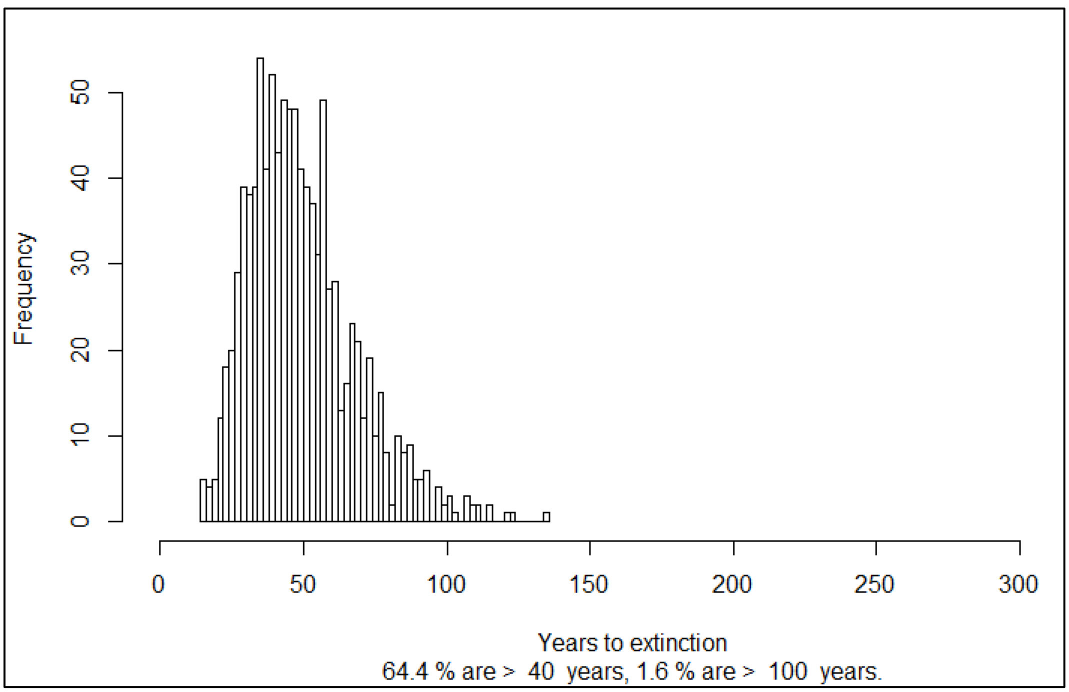


Figure 6. Frequency distribution of the number of years to quasi-extinction in 1,000 simulations for the Snoqualmie Chinook population.

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; Appendix 3) 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 in the 2017 Harvest Plan are modified for the duration of this Plan and are only applicable to natural-origin fish. They consist of:

Reference Point	Skykomish	Snoqualmie	Management Unit
Lower Bound Threshold	1,745	700	
Lower Abundance Threshold	2,092	1,066	3,375
Upper Management Threshold	3,600	1,300	4,900
Rebuilding Exploitation Rate (not to be exceeded)	21%		
Critical Exploitation Rate Ceiling	15%		

Management objectives for Snohomish summer/fall Chinook salmon include an upper limit on total exploitation rate, to insure that harvest 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. Fisheries will be managed to achieve a total adult equivalent exploitation rate (as estimated in FRAM) associated with all salmon fisheries, not to exceed 21 percent[15]. 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 2011 only 881 Chinook returned to the Skykomish, and only 479 to the Snoqualmie. Very low abundance levels have persisted for up to three consecutive years (2013-2015) in the Skykomish and to some degree in the Snoqualmie as well.

The lower bound value proposed for the Skykomish (1745) is 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).These impacts include all mortalities related to fisheries, including direct take, incidental take, release mortality, and drop-off mortality.

Should the projected escapement fall below the lower bound of 1745 for the Skykomish and 700 for the Snoqualmie, then additional SUS harvest measures will be taken to attempt to prevent further declines in abundance. The comanagers will discuss and implement a contingency set of actions that will contribute to increasing abundance back to levels above the LAT. As potential actions are examined, the comanagers will consider for 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.

[15] When previous RER analysis in 2003 were performed (also using CTC brood year ER in the VRAP modelling), a 24% ER was estimated for the Skykomish. Co-managers agreed to use the 21% RER for preseason FRAM modelling of fisheries during North of Falcon, and was also adopted in the 2010 and 2014 Management Plans. This value was the highest preseason ER in supplemental models during the planning of the fisheries in the period 2000-2003. Now in 2017, using the same VRAP methodology (if any, more sophisticated and with updated time series for escapement and origin, exploitation rates, and recruitment), we have estimated the RER for Skykomish at 22%, two points less the 24% calculated previously, reflecting possibly, a reduction in the productivity of the Skykomish population, and potentially in the Snoqualmie population as well.

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).

The Puget Sound Salmon Management Plan mandates that fisheries will be managed to achieve maximum sustainable harvest (MSH) for all primary natural management units. The recovery exploitation rate is likely to be lower than the rate associated with MSH under current conditions of productivity, as in the case where recovery involves increasing the current level of productivity. The conservatism implied by the recovery exploitation rate imbues caution against the potential size and age selectivity of fisheries, and the effects of that selectivity on reproductive potential, and potential uncertainty and error in management.

Abundance Threshold for Management

A low abundance threshold of 3,375 spawners (natural origin, naturally spawning fish) for the Snohomish management unit is established as a reference for pre-season harvest planning. If escapement is projected to fall below this threshold under a proposed fishing regime, extraordinary measures 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 Escapement Thresholds (CTE) 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 escapement thresholds are levels that we do not want to go below under any circumstances. For each population, the critical escapement threshold was determined and then expanded to an adjusted level for management use according to the following formula, and summarized in Table 5:

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

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

$E_{crit,\mathbf{p}}$ is the critical threshold 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 Threshold Escapement	881 (2011)	400
$(R/S)_{low,p}$	0.54 (1996, 2006, 2008)	0.48 (2006, 2008, 2010)
Rebuilding Exploitation Rate	0.22	0.22
$Low_{threshold}$	2092	1066
NOR_{stock}/NOR_{tot}	0.62	0.38
Lowthreshold (NORstock/NORtot)	3375	2807

Maximum Exploitation Rate Guideline

Introduction

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 conditions, in other words, assuming that hatchery and habitat management remain as they are now and that survival from environmental effects remain as they are now.

We choose the RER such that the population is unlikely to fall below a Critical Escapement Threshold (CTE) and likely to grow to or above a rebuilding escapement threshold (RET). The CTE is chosen as the smallest previously-observed escapement from which there was a greater than 1:1 return per spawner. For the Skykomish population, this escapement level (881) was observed in 2011. For the Snoqualmie, we kept the 400 level used in the previous plan (also used in 2017 NOAA’s analysis).

The RET is chosen as the smallest escapement level such that the addition of one additional spawner would be expected to produce less than one additional future recruit under current conditions of productivity. This level is also known as the maximum sustainable harvest (MSH) escapement. It is extremely important to recognize, though, that under this plan the RET is not an escapement goal but rather a level that is expected to be exceeded most of the time. It is also the case that, when the productivity conditions for the population improve due to recovery actions, the RET will usually increase, and the probability of exceeding the RET using the RER computed for current conditions will also increase over the probability computed under current conditions. Thus the RET serves as a proxy for the true goal of the plan, which can only be evaluated once we have information on likely future conditions of habitat that will result from recovery actions, and hatchery as well as harvest management.

It also follows from the above, given that the likely chance of achieving the RET is greater than 50%, that the actual harvest from the population under this plan will be less than the maximum sustainable harvest, the amount less being dependent on the likelihood (%) of achieving the RET. All sources of fishing-related mortality are included in the assessment of harvest, and nearly 100% of the fishing-related mortality will be due to non-retention or incidental mortality; only a very small fraction is due to directed fishing on Snohomish populations.

WDFW and Tulalip Tribes recently 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. In the next pages, we present an abbreviated version of this 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 1.64 (Ricker) and 2.07 (Beverton-Holt) for the Skykomish summer/fall Chinook population, and 2.14 (Ricker) and 2.54 (Beverton-Holt) for the Snoqualmie summer/fall Chinook population (Table 6). Equilibrium population size was 3,597 (Ricker) and 3,330 (Beverton-Holt) for the Skykomish fall Chinook population, and 2,170 (Ricker) and 2,100 (Beverton-Holt) for the Snoqualmie fall Chinook population.

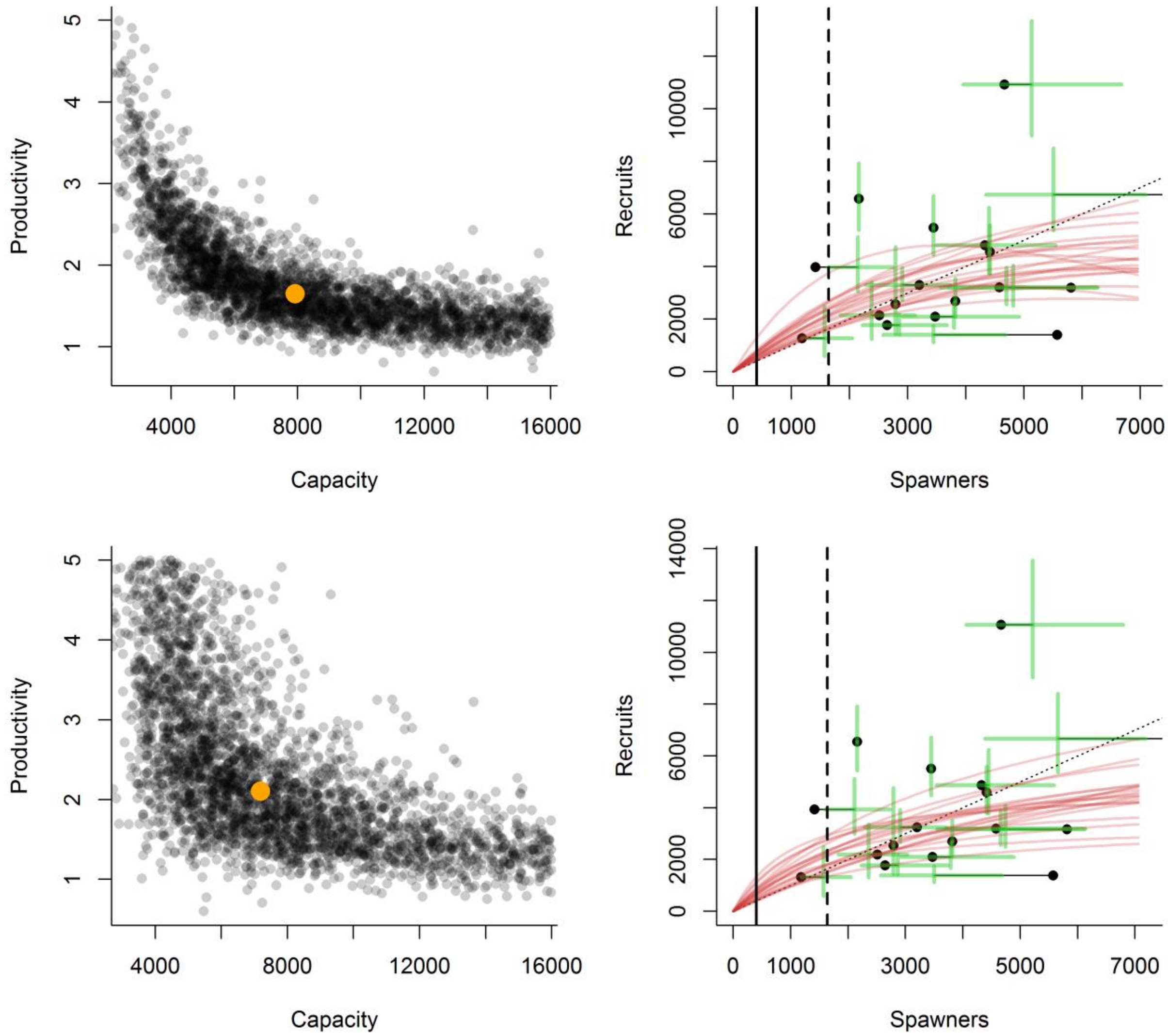


Figure 7. Posteriors of the Ricker and Beverton-Holt spawner-recruit parameters and fits to the spawner-recruit data for the Skykomish summer/fall Chinook population. The upper panels describe the Ricker fits and the lower panels describe the Beverton-Holt fits. The left panels represent the joint posterior 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.

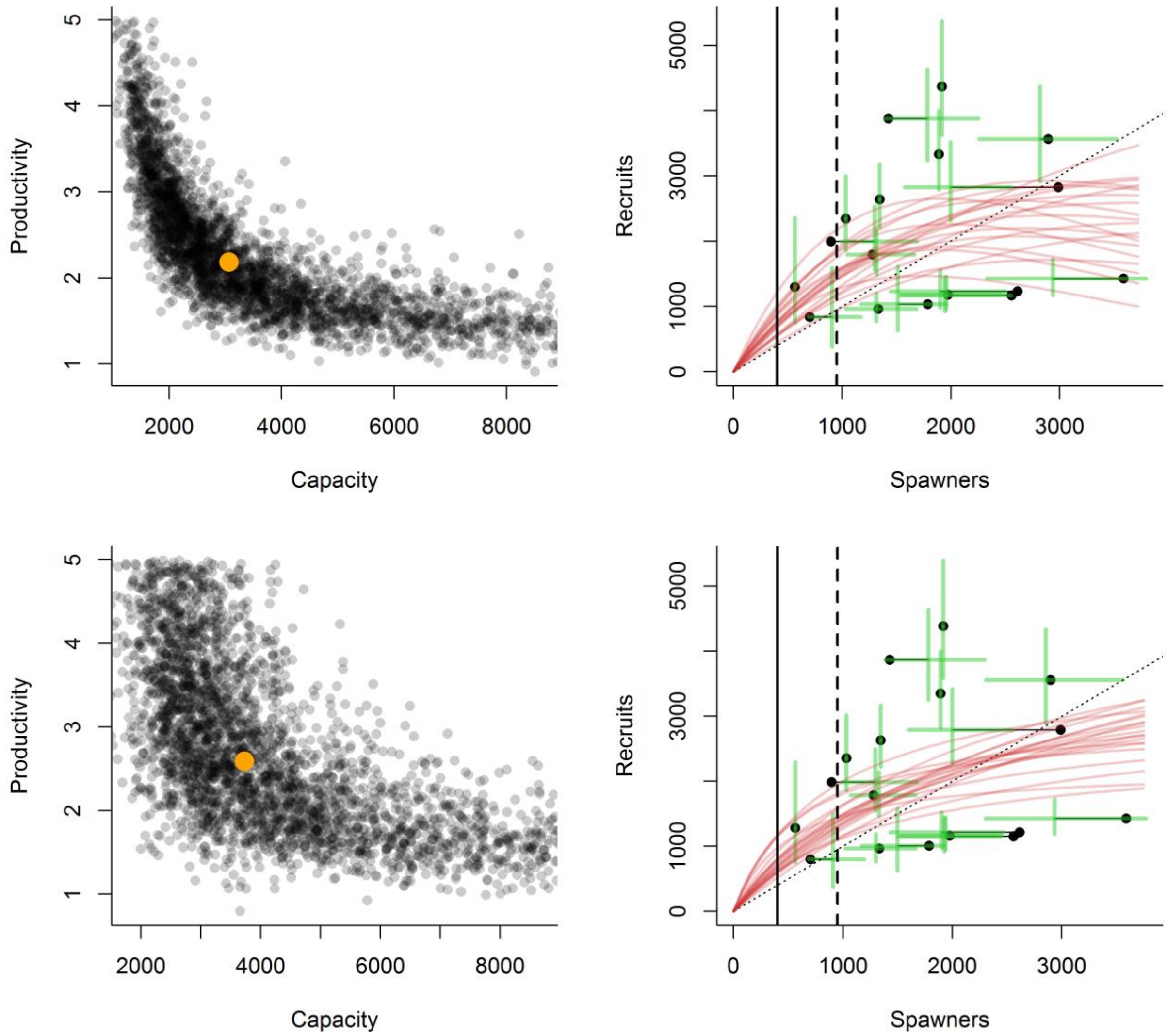


Figure 8. Posteriors of the Ricker and Beverton-Holt spawner-recruit parameters and fits to the spawner-recruit data for the Snoqualmie summer/fall Chinook population. See Figure 7 for details on the elements of the figure.

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.

	Productivity	Productivity - last 10yrs	Productivity at CET	Capacity	Spawners at MSY	Equilibrium
Skykomish - Ricker	**1.64** *(1.22, 2.57)*	**1.5** *(1.17, 2.37)*	**1.56** *(1.17, 2.35)*	**7,660** *(3,963, 13,543)*	**1,642** *(985, 2,419)*	**3,597** *(2,056, 5,265)*
Skykomish – Beverton-Holt	**2.07** *(1.31, 3.84)*	**1.89** *(1.26, 3.57)*	**1.84** *(1.24, 2.9)*	**6,827** *(4,197, 12,500)*	**1,299** *(857, 1,991)*	**3,330** *(2,034, 4,937)*
Snoqualmie - Ricker	**2.14** *(1.48, 3.42)*	**1.82** *(1.27, 3.03)*	**1.87** *(1.36, 2.7)*	**2,898** *(1,657, 6,384)*	**957** *(716, 1,399)*	**2,170** *(1,593, 3,064)*
Snoqualmie – Beverton-Holt	**2.54** (1.59, 4.21)	**2.2** (1.38, 3.68)	**1.96** (1.41, 2.62)	**3588** (2387, 6713)	**794** (551, 1,230)	**2,100** (1,469, 3,082)

Patterns in the recruitment residuals and recruits per spawner

There is some indication of a negative trend in recruitment residuals (Figures 10 and 11), particularly for the Snoqualmie River population. The average productivity in the last ten years for the Snoqualmie is 1.82 (based on the Ricker) compared to the time series average of 2.14.

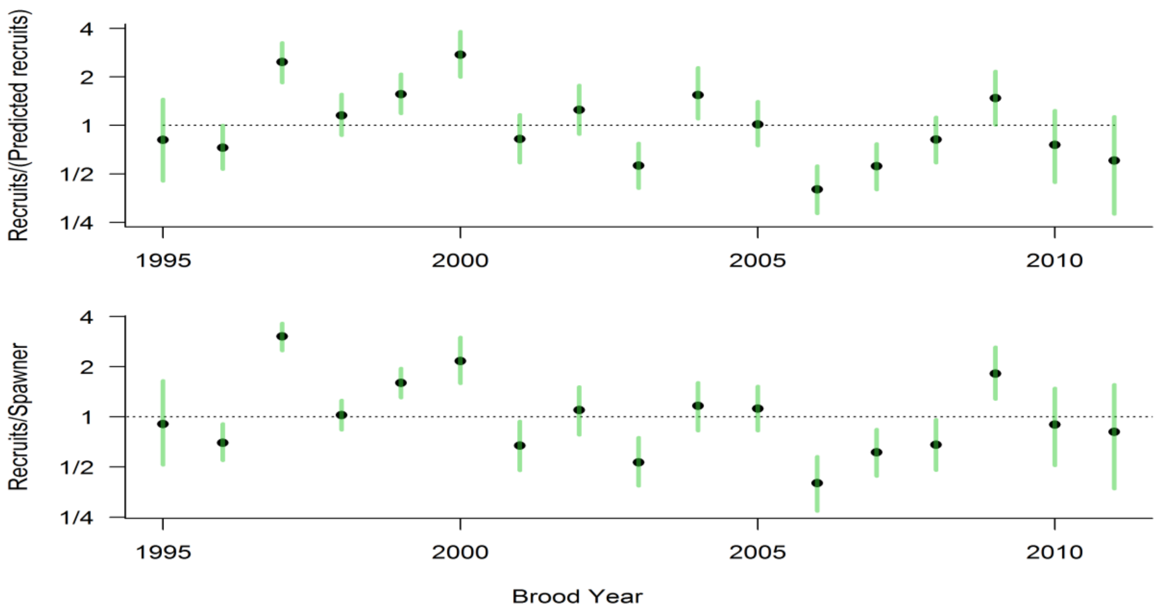


Figure 9. Patterns in recruitment by year for the Ricker fit for the Skykomish River summer/fall Chinook population. The upper panel represents the recruitment residuals, which are log recruits minus log predicted recruits. The green lines represent 80% credible intervals for the standard residuals.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

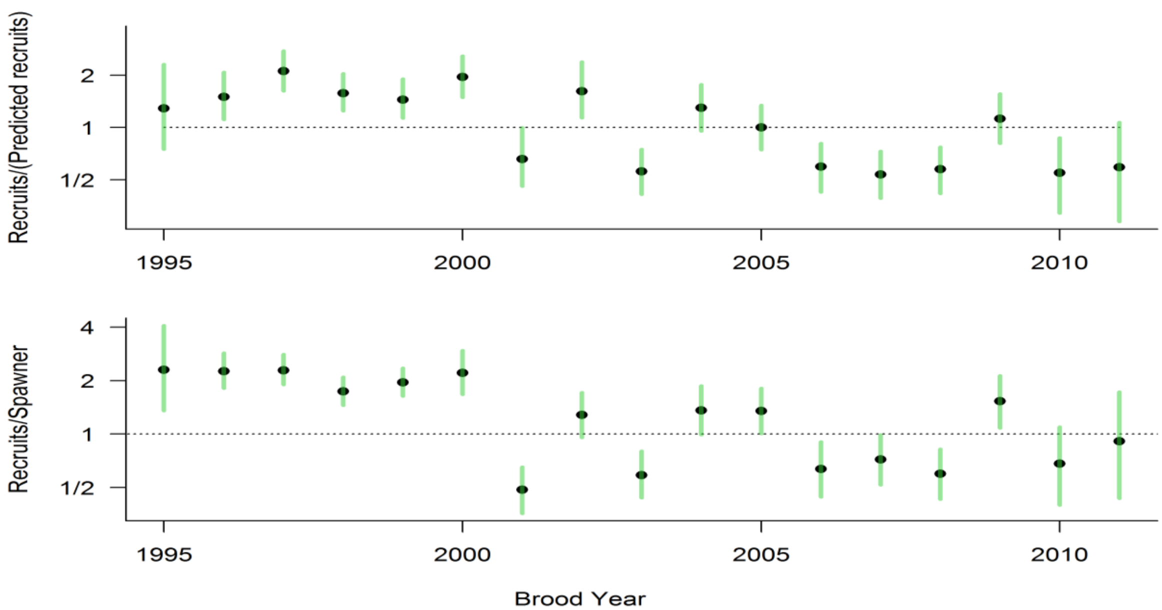


Figure 10. Patterns in recruitment by year for the Ricker fit for the Snoqualmie River summer/fall Chinook population. The upper panel represents the recruitment residuals, which are log recruits minus log predicted recruits. The green lines represent 80% credible intervals for the standard residuals. 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 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 1,640 (Skykomish) and 950 (Snoqualmie). For the Beverton-Holt they were 1,300 (Skykomish) and 790 (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: 1,500 (Skykomish), 900 (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 = 1.032, stdev = 0.227: NOAA Fisheries, draft manuscript, Appendix B). 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.

RER results

Recovery Exploitation Rates 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 = 18%, Skykomish-BH = 28%, Snoqualmie-Ricker = 31%, Snoqualmie-BH = 31%, 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). Therefore, if half of the area in the histogram (sum of the bar areas) falls to the right of a value, then there is a 50% probability that the RER is greater than that value. This is of course all conditional on the data and all of the model assumptions (including the priors). One approach to summarizing the uncertainty is to use credible intervals (the Bayesian analogue to the confidence intervals). For example, with a 50% credible interval, 50% of values from the histogram fall within the interval and 50% are outside (we use symmetric intervals, 25% to the left and 25% to the right). The 50% credible intervals for the constraining RERs excluded 0 in all cases (Skykomish-Ricker = 0.12-0.23, Skykomish-Beverton-Holt = 0.21-0.33, Snoqualmie-Ricker = 0.25-0.36, Snoqualmie-Beverton-Holt = 0.27-0.36). If the two spawner-recruit functions are assumed to be equally plausible the RER posterior distributions can be combined to get a single posterior distribution. This results in median RERs and 50% credible intervals of 22%, (15% - 30%), for the Skykomish and 31%, (26% - 36%), for the Snoqualmie.

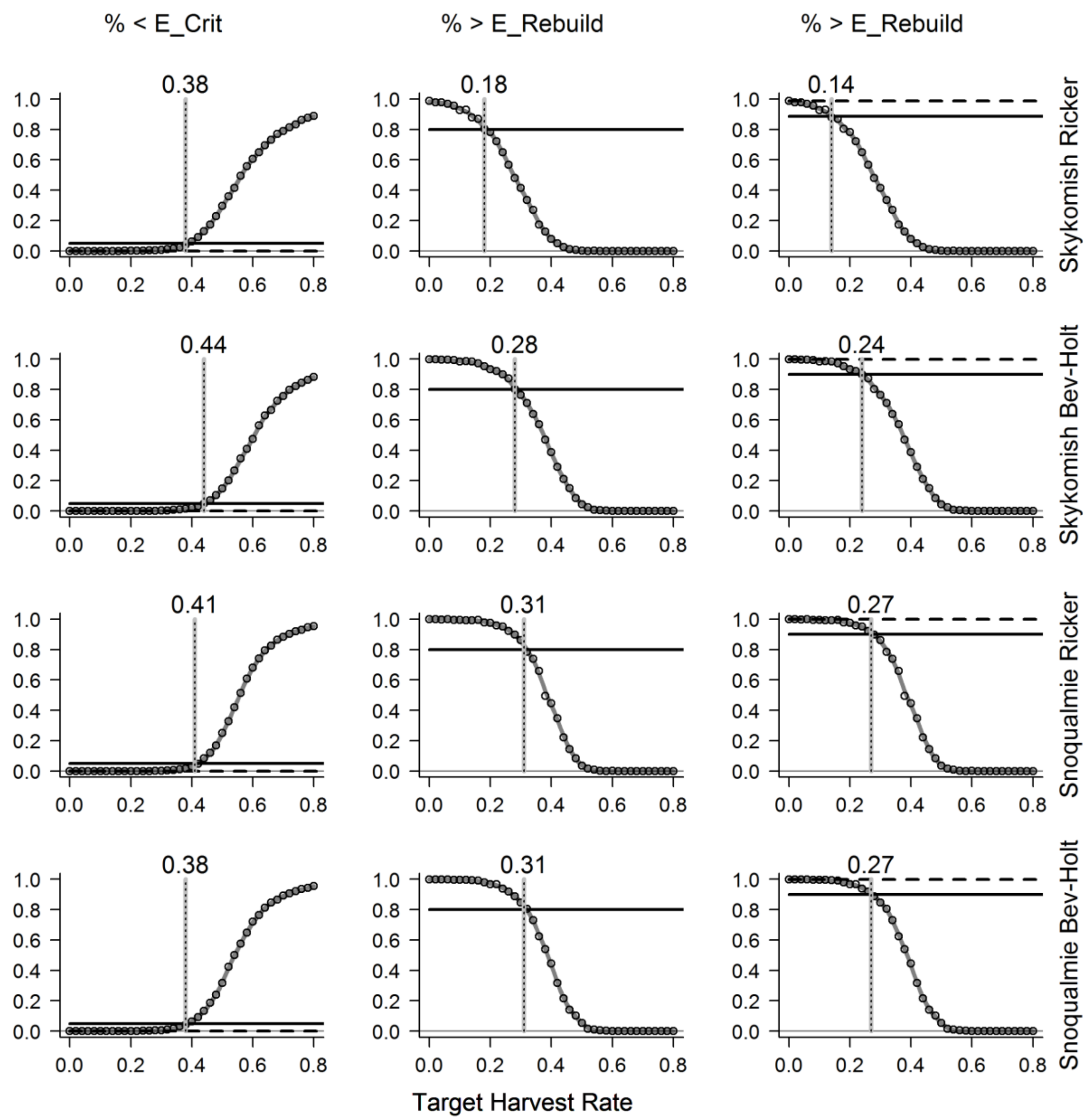


Figure 11. The proportion of times each of the three criteria was met for the two runs based on the median results. The dashed horizontal lines represent the % of values above or below at zero harvest rate for Skykomish and Snoqualmie summer/fall Chinook populations. The solid horizontal lines represent the relative thresholds for the first and third columns and the absolute threshold for the second column.

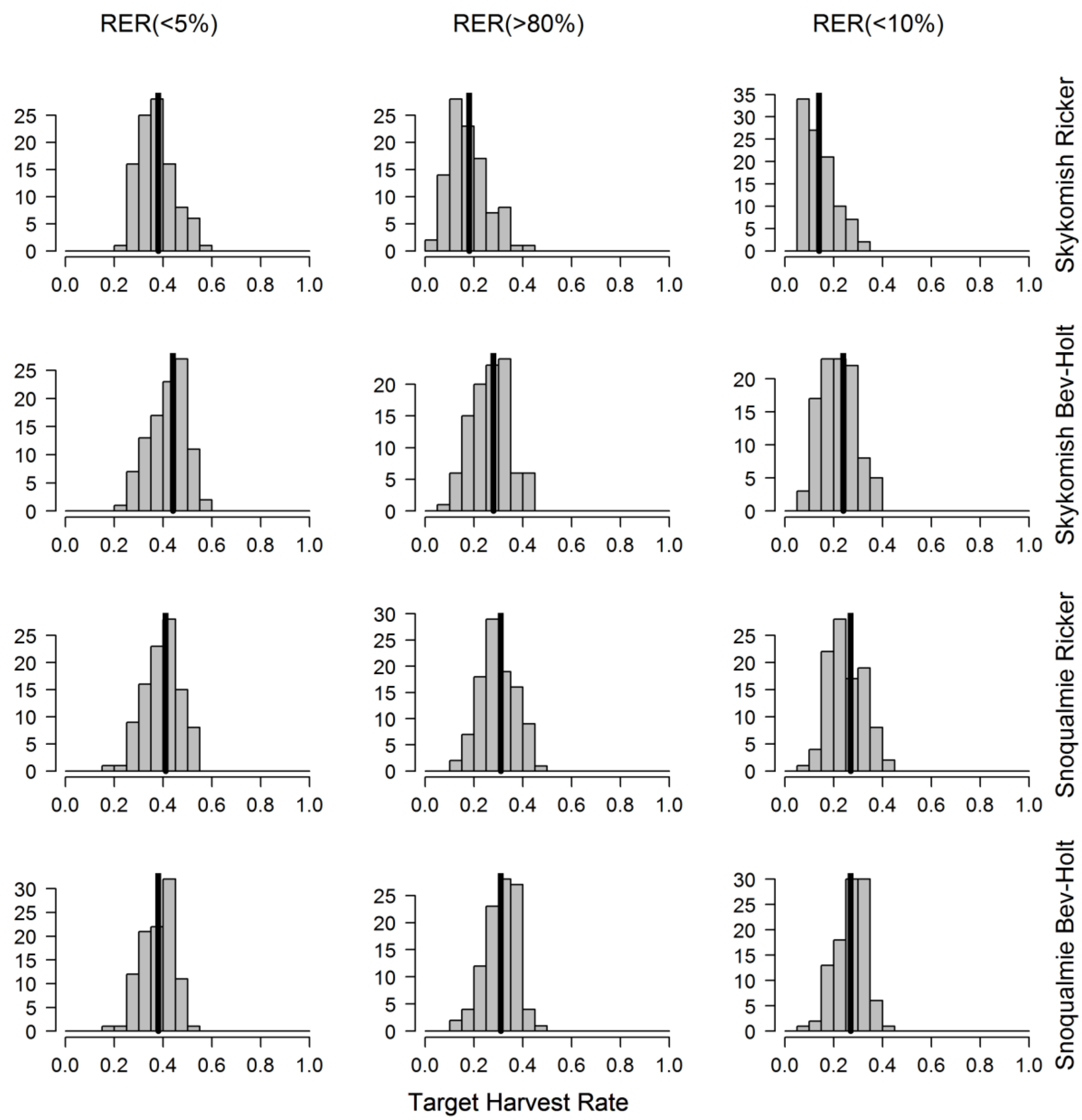
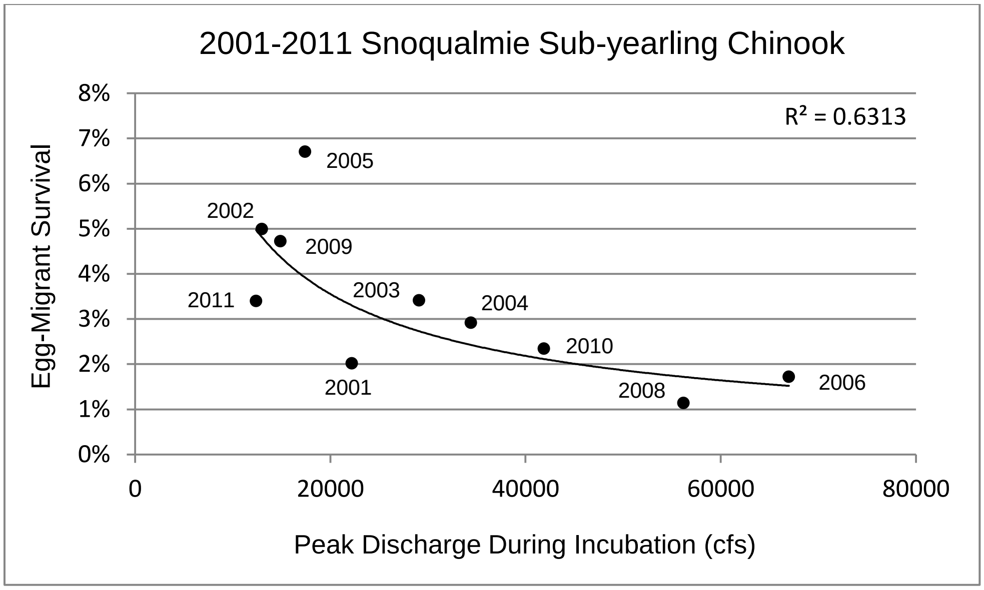


Figure 12. Histograms representing the posterior distributions of the Skykomish and Snoqualmie summer/fall Chinook RERs for the three criteria (columns) and different runs (rows). The vertical black lines represent the median RERs. The histograms represent 101 draws from the posterior distribution.

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)



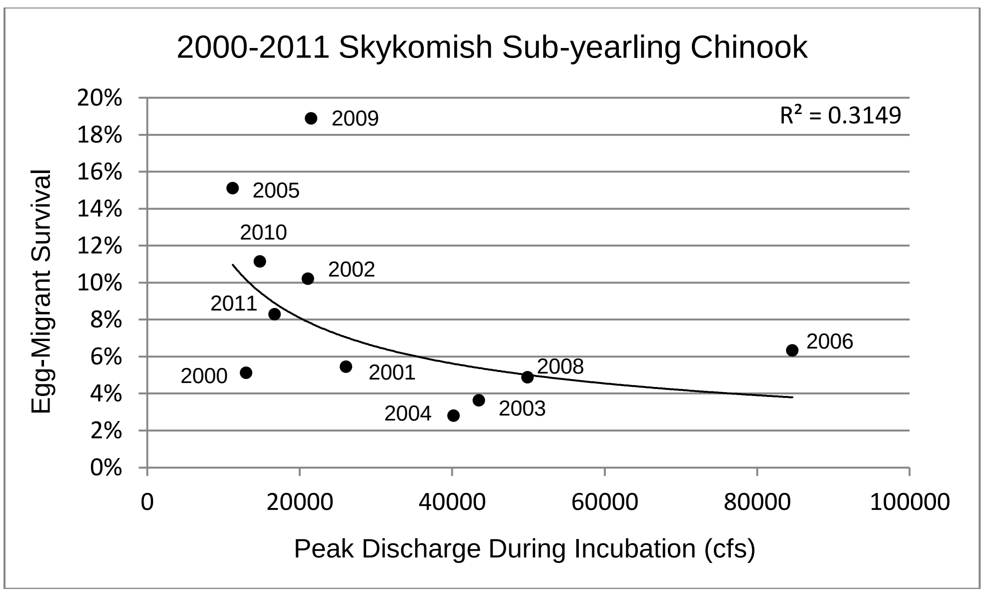


Figure 13. Egg-to migrant survival plotted against peak discharge during incubation for sub-yearling Chinook in the Snoqualmie and Skykomish Rivers from brood year 2001-2011 (Tulalip unpublished data 2015). The incubation period was estimated using a three-month period, which started 15 days before peak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

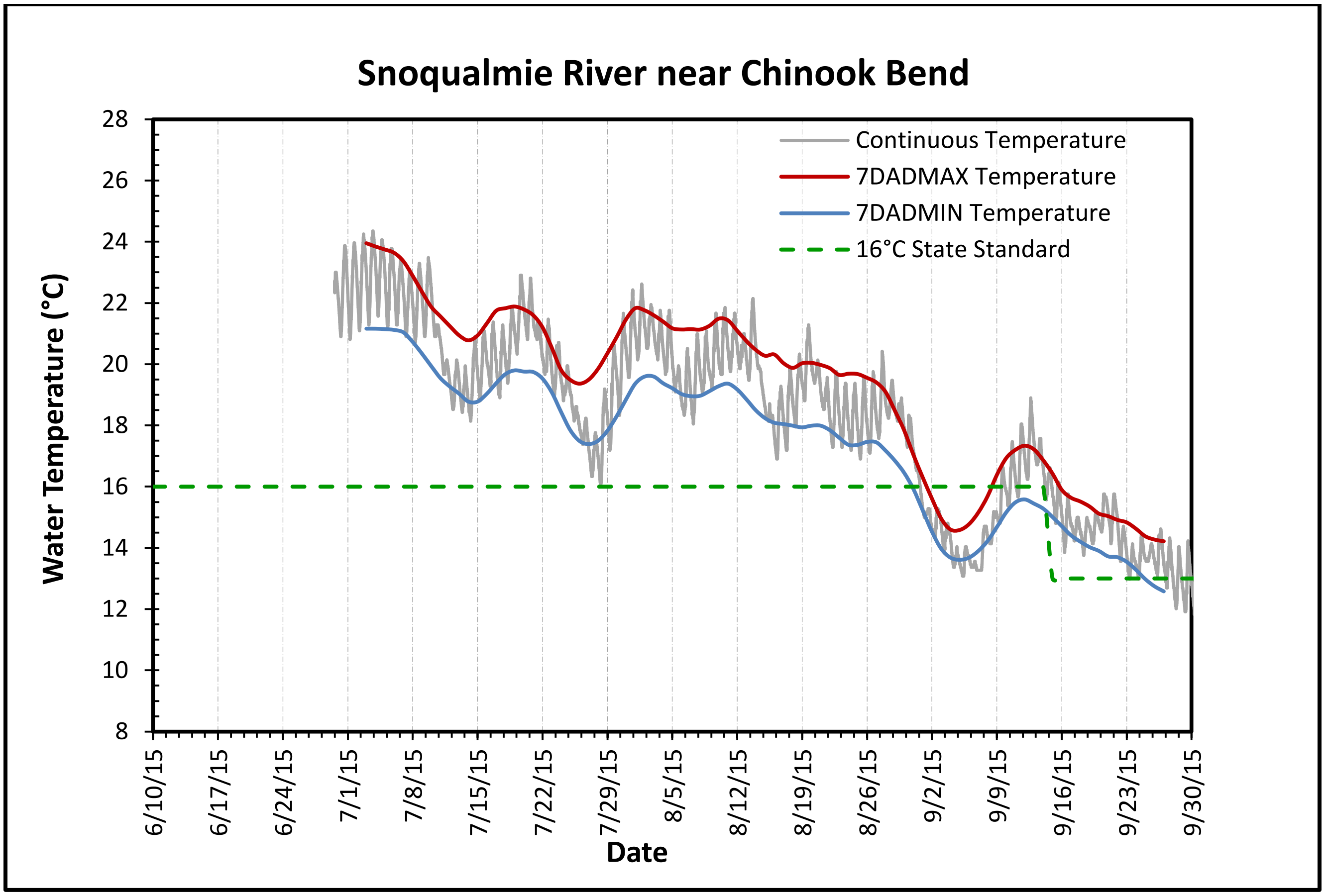


Figure 14. Record high temperatures in the Snoqualmie River basin in 2015 exceeded state standards for salmon in all life stages. Figure provided by Joshua Kubo, King County, and the Snoqualmie River Watershed 2015 Water Temperature Study.

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).

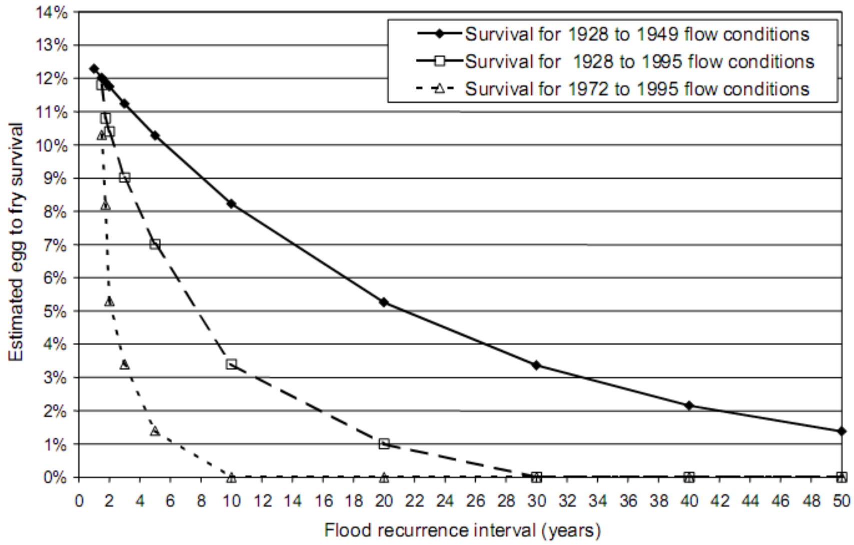


Figure 15. Reduction in egg-to-fry survival related to peak flow recurrence interval. Source: Beamer and Pess (1999).

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[16]

Geographic Distribution

The Lake Washington basin 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.

Cedar River

Fish passage facilities were completed at Landsburg Dam in 2003, and Chinook may now access suitable spawning areas upstream to Cedar Falls. The majority of spawning still occurs in the mainstem Cedar River upstream of RM 5 to Landsburg Dam. Chinook also spawn in two Cedar River tributaries, Rock Creek and Taylor Creek.

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. Approximately 10.0 of the 12.4 miles of Bear Creek are accessible to Chinook, most spawning occurs between RM 4.3 and 8.8. Spawning 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. 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.

[16] TRT defined population. Co-managers believe that recent data indicates that this is not a viable population.

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.

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 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.

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 records 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 both principally derived from Green River hatchery stock. Since 1994, the Issaquah hatchery has exclusively used local broodstock from Issaquah Creek.

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. Issaquah Creek Hatchery production averaged 1.7 million sub-yearling smolts for brood year 2011-2015, while the current production objective is 3.0 million sub-yearling smolts. 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 1A) and from 182 to 2,303 in the Sammamish River (Figure 1B) basin from 1988-2016 (Figure 1). Total spawners on the Cedar and Sammamish River declined throughout the 1990s but began a rapid increase to levels seen today. Total spawners in both systems have been higher and more variable since the early 2000s. 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 1C). 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 1D).

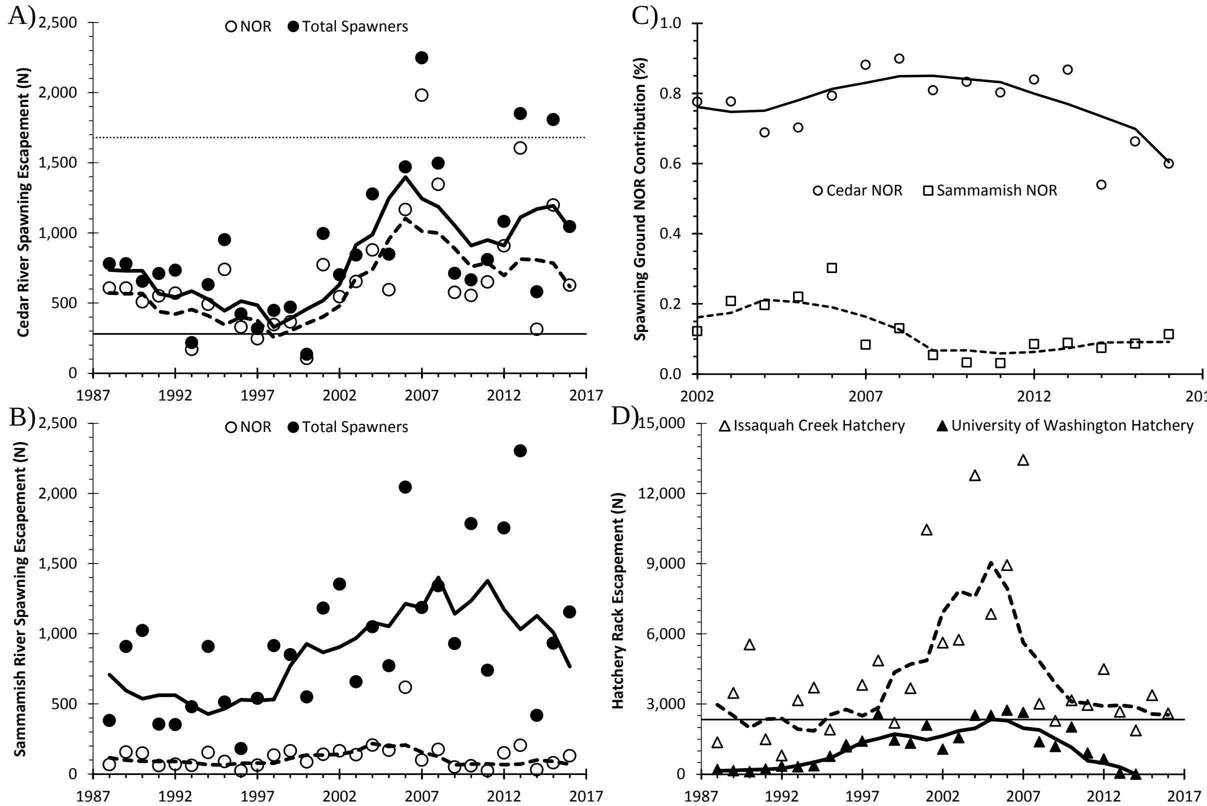


Figure 1. Observed NOR (open circle) and total (filled circle) escapement on the Cedar River (panel A) and Sammamish River (panel B) from 1988-2016. A 5-year running geometric mean for total escapement (solid line) and NOR escapement (dashed line) is fit to each data series. The Cedar River interim escapement goal of 1,680 spawners (lite dashed line) is contrasted with the MSY escapement goal of 280 (108-389 95%CI) 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 (panel C) to the Cedar River (open circle) and Sammamish River (open square) spawning grounds from 2002-2016 with a 5-year running geometric mean. Observed hatchery rack escapement (panel D) at Issaquah Creek Hatchery (open triangle) from 1988-2014 and University of Washington Hatchery (closed triangle) from 1988-2014 is shown with a 5-year running geometric mean. The hatchery escapement goal of 2,337 adult Chinook needed to make current program goals at Issaquah Creek Hatchery is shown (lite solid line).

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 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 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 1989-2009 (Figure 2). For this model, a=0.1121 and b=0.0007943 which resulted in a spawning stock size at equilibrium of 1,118 and a theoretical maximum recruitment of 1,259. The spawning stock size MSY is 280 (108-389 95%CI) which is expected to result in 837 (762-924 95%CI) recruits. Due to uncertainty in stock dynamics at population sizes this small and the potential for negative genetic impacts, an escapement goal of 500 spawning adults will be the management goal.

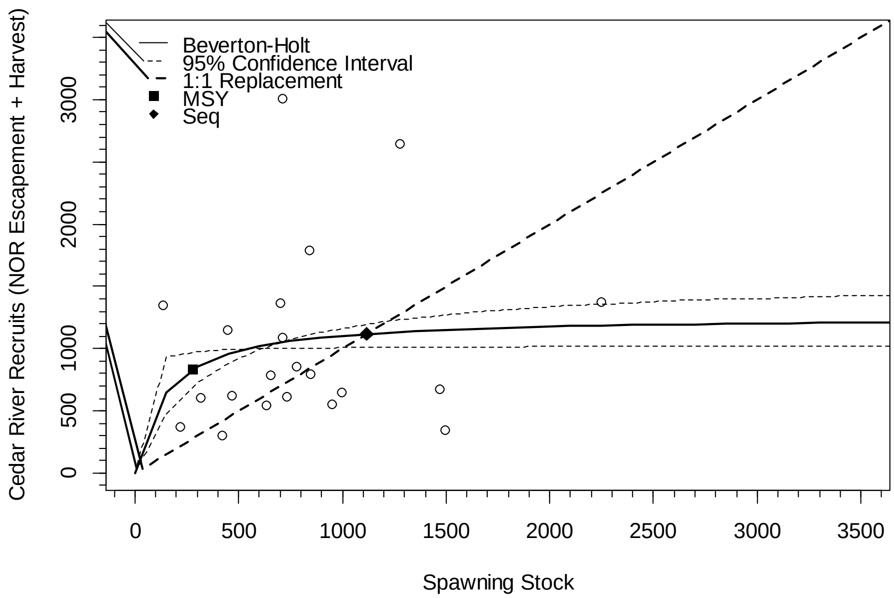


Figure 2. Beverton-Holt stock-recruit curve for Cedar River Chinook based on brood years 1989-2009. The spawning stock size at MSY is 280 (108-389 95%CI) which results in 837 (762-924 95%CI) recruits. The spawning stock size at equilibrium is 1,118 (1,008-1,219 95%CI) Chinook.

Uncertainty exists about the historical presence of a Chinook population in the Sammamish River sub-basin. The TRT 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 escapement goal has been 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 1989-2009 (Figure 3). For this model, a=2.5786 and b=0.001439 which did not result in an equilibrium stock size or spawning stock size at MSY. Recruits to the Sammamish River population never reached replacement. 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.

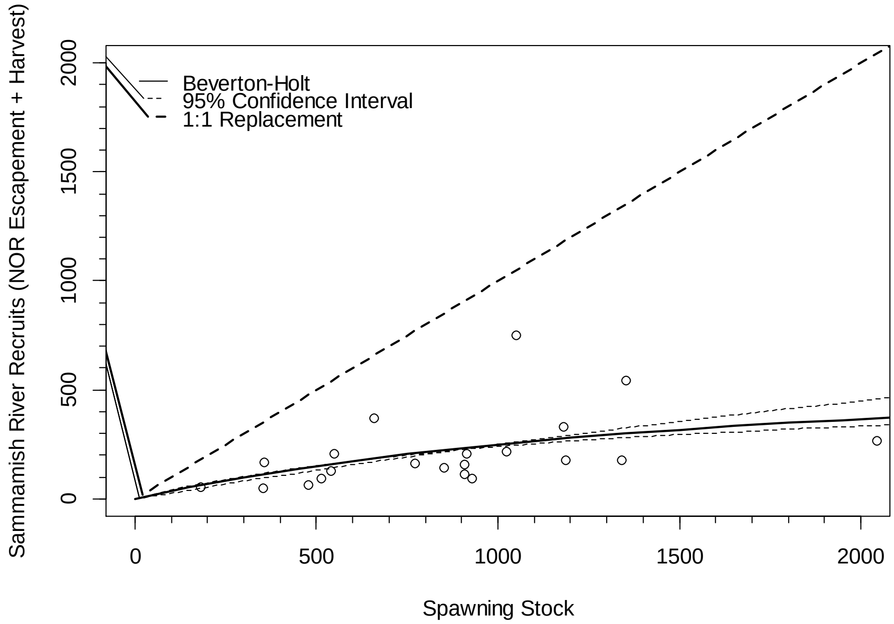


Figure 3. Beverton-Holt stock-recruit curve for Sammamish River Chinook based on brood years 1989-2009. There is no MSY for this population because recruits never reach replacement under current habitat conditions.

Recruits per spawner have been highly variable in the Cedar River population while the Sammamish River population has been consistent and poor (Figure 4). The 2000 brood year was the most productive brood with 10.0 recruits per spawner produced in the Cedar River. No brood year was greater than 0.7 recruits per spawner in the Sammamish River. The 2005-2008 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 1,515, which is well the 812 average in the Cedar River across the available years. Following the streak of poor recruitment years, recruits per spawner was 4.2 for the 2009 brood year and was produced by a stock size of 712. There is a weak correlation between Cedar River and Green River (r = 0.39) Chinook productivity. Within the Lake Washington basin, Cedar River and Sammamish River Chinook productivity is poorly correlated (r = 0.25). The average productivity for Cedar River Chinook across all brood years is 1.8 recruits per spawner whereas 3.0 recruits per spawner is the current productivity at MSY.

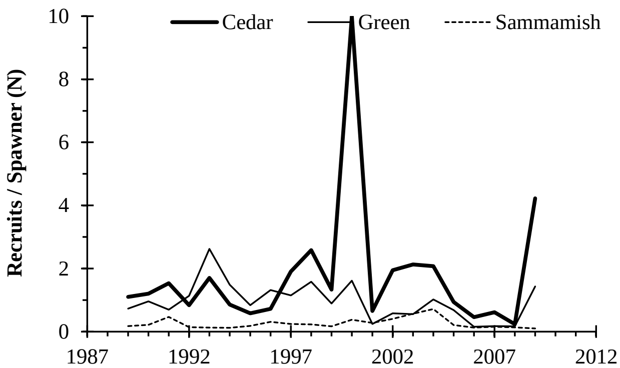


Figure 4. Trend in recruits per spawner for Cedar River (bold line), Green River (solid line), and Sammamish River (dashed line) management unit natural origin recruits from completed brood years (1989-2009).

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 5A). 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.

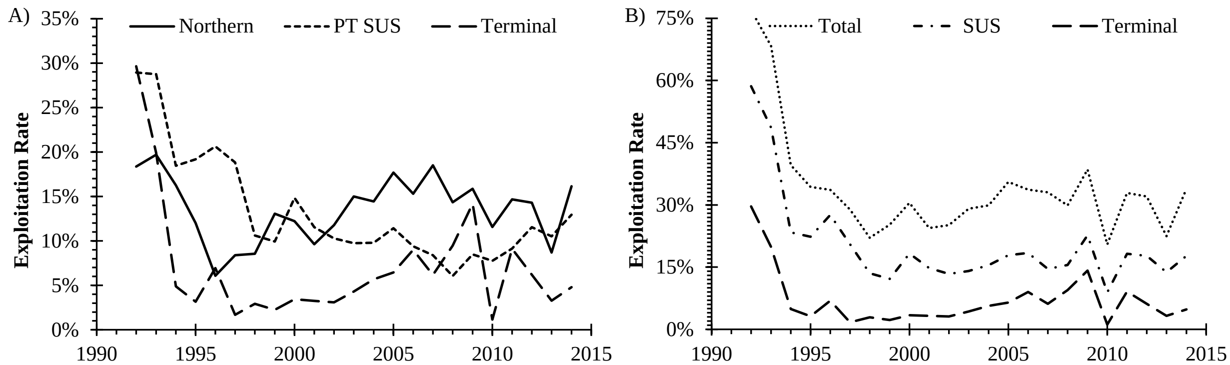


Figure 5. Trend in the A) northern (solid line), pre-terminal southern US (short dashed line), and terminal (long dashed line) exploitation rates and B) Total (dotted line), Southern US (dashed and dotted line), and terminal (long dashed line) exploitation rates on Cedar River natural origin Chinook from 1992-2014, based on the new FRAM base period (version 8/16/17).

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 that aims to prevent demographic instability. 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.

MSY associated with current habitat condition is 280 (108-389 95%CI) naturally spawning adult Chinook, less than 25% of the 1,680 that were managed for under previous plans. The new UMT for Cedar River spawning escapement is 500 adults. This trigger will allow a pre-terminal exploitation rate of up to 12%. 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 13% pre-terminal ER, then all Mid-Puget Sound aggregate MUs will be managed for a 13% pre-terminal SUS ER (Table 1).

Hatchery escapement will be managed for an approximate 2,337 adult escapement goal (Figure 1D); 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

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

goals are met. The LAT, based on a calculation of 40% of MSY is 112 adult Chinook on the spawning grounds, however, the co-managers agree that an LAT of 200 adults to maintain genetic health is appropriate (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 12% (13% if criteria in the Green River and Puyallup River MU are met; Table 1) 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.

Table 1. Management thresholds and corresponding exploitation rate ceilings for stock components of the Mid-South Puget Sound FRAM stock aggregate. The MMT is triggered when natural spawning escapement is forecasted between the LAT and the UMT. In pre-terminal fisheries the aggregate is managed for its weakest component MU.

Management Unit	MSY	LAT (SUS)	MMT (SUS)	UMT – trigger 1 (PT SUS)	UMT – trigger 2 (PT SUS)
Lake Washington[1]	280	200 (12%)	18%	500 (12%)	500 (13%)
Green River	2,013	805 (12%)	18%	3,800 (12%)	6,000 (13%)
Puyallup River	797	319 (15%)	30%	1,300 (12%)	1,300 (13%)

[1] The Cedar River is the natural managed component of the Lake Washington MU

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. 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 MMT or LAT will only have incidental impacts to Chinook as fisheries will be directed at other salmonids. Due to the use of in-season monitoring and management in the terminal area, abundance may be observed that is sufficiently greater than UMT such that a limited directed terminal fishery could be prosecuted which would result in higher exploitation rates in the terminal area than modeled in the pre-season but would result in meeting both natural spawning and hatchery escapement goals. 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 pre-season process, Puget Sound (sport and terminal) fisheries will be planned to meet the broodstock needs at Isssaquah 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 goals as additional information becomes available.

There is some uncertainty in annual ERs from northern fisheries (British Columbia and Alaska) on Lake Washington Chinook, but impact of those fisheries is unlikely to decrease significantly relative to recent years (Figure 5A). 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 Cedar River Chinook, while allowing limited fisheries to continue in years when natural spawning abundance falls below the management objectives.

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 MSY and hatchery escapement goals will be met. It is understood that this will increase the total SUS ER over pre-season expectations. 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 Cedar River Chinook and Issaquah Creek Hatchery escapement objectives, 500 and approximately 2,337 respectively. 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.

Data Gaps and Information Needs

Table 2. 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	Independent assessment of Chinook abundance and migration through large lock chamber
Temperature impacts on adult Chinook and eggs	Quantify pre-spawning mortality and sub-lethal effects. These include the viability and maturation rate of eggs exposed to high temperatures in vivo.
Outmigration survival by stock	Estimate mortality associated with juvenile passage at the Chittenden Locks, piscine and avian predation in the lake and canal, and other mortality factors.
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.
Refinements to terminal in-season runsize update model.	Develop methodology to estimate Cedar River NOR and Issaquah Hatchery Chinook in the Lake Washington terminal run.
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 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 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 Green River basin has been dramatically altered by hydro modification. The White River was permanently diverted into the Puyallup River Basin in 1906. The Cedar River was diverted into Lake Washington basin in 1916 with the completion of the Ship Canal and Hiram M. Chittenden Locks. These two actions reduced the watershed to approximately 30% of its historic size. The lower Duwamish River basin and estuary (Elliott Bay) have been extensively modified by urbanization and industrial uses. The lower 5.5 river miles are routinely dredged for commercial shipping. Access to the upper Green River watershed was limited by construction of the Tacoma Diversion Dam in 1911 and Howard Hanson Dam in 1961.

Fall Chinook spawning occurs in the mainstem Green River and in two major tributaries, Soos Creek and Newaukum Creek. Spawning in the mainstem Green River occurs from RM 25.4 to RM 61. An adult trap and haul facility was constructed in 2005 at the Tacoma Diversion Dam (RM 61), however, spawning access is currently restricted to downstream areas because no juvenile fish passage facilities exist at Howard Hanson Dam (RM 64). 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.

Life History Traits

Fall Chinook begin entering the Duwamish River in July, and spawn from mid-September through early November. 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 2000-2014, fry emigration averaged 59% of the sub-yearling component but was as low as 10% and as high as 92%. 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.

Hatchery Production

Shortly after 1900, the first hatchery in the basin was constructed on Soos Creek. Current hatchery production involves three programs: production of 3.2 million sub-yearlings released on-station from the Soos Creek Hatchery, 1.0 million sub-yearlings which are acclimated and released from Palmer Ponds, and 0.3 million yearlings released from the Icy Creek Hatchery. The Palmer Pond release program began in 2011 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.
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 to harvest opportunity and to maintaining abundances of naturally-spawning Chinook, particularly in highly urbanized watersheds like the Green and Duwamish rivers.

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. There is significant genetic interchange between natural- and hatchery-origin Chinook on the spawning grounds (WDFW et al. 2002).

Status

The Green River Chinook population is managed for total natural spawners on the spawning grounds, which has varied from 688 to 10,263 since 1988 (Figure 1A). Through the early 2000s, spawning escapement was relatively steady with a 5-year geometric mean that remained close to the escapement goal of 5,800. However, from 2009-2015 total spawning escapements were consistently below the historic escapement goal. NOR spawners have declined across the time series of available data. From 1988-2016, the average NOR contribution to the spawning grounds is 44% but the most recent 5-year average has fallen to less than 30% (Figure 1B). 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 1C).

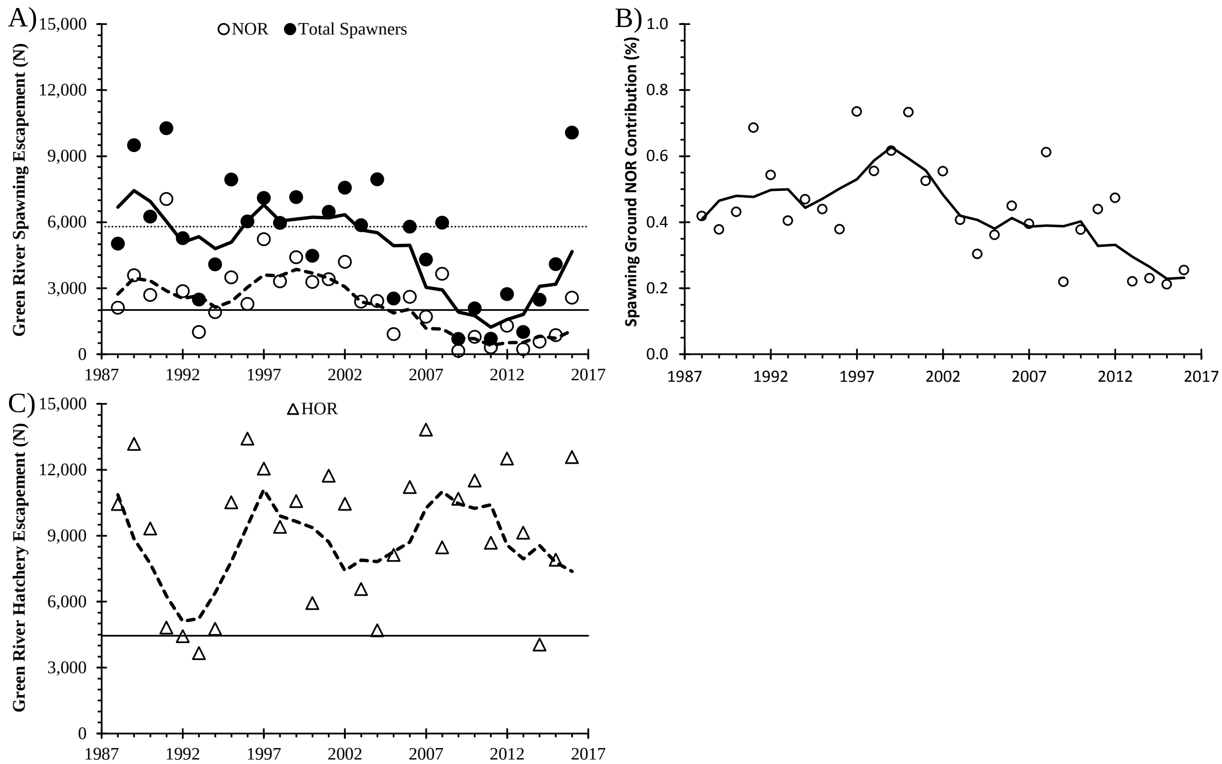


Figure 1. Observed NOR (open circle) and total (filled circle) escapement on the Green River Chinook spawning grounds (panel A) from 1988-2016. A 5-year running geometric mean for total escapement (solid line) and NOR escapement (dashed line) is fit to each data series. The historic escapement goal of 5,800 natural spawners (lite dashed line) and MSY escapement goal of 2,013 (1,401-2,178 95%CI) natural spawners (lite solid line) based on current habitat conditions are shown. Observed NOR Chinook contribution to the Green River spawning grounds (panel B) from 1988-2016 (open circles) with a 5-year running geometric mean (solid line). Observed hatchery rack escapement (open triangle) at Soos Creek Hatchery (panel C) from 1988-2016 is shown with a 5-year running geometric mean. The hatchery rack escapement goal of 4,452 adult Chinook needed to make current program goals is shown (lite solid line).

The historic escapement goal (i.e. Upper Management Threshold) was established in 1977 (WDF Tech Report 29, 1977) as the average of estimated natural spawning escapements from 1965-1974. This goal does not reflect the lower productivity associated with the current condition of habitat. 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 1989-2009 (Figure 2). For this model, a=0.5766 and b=0.0000908 which resulted in a spawning stock size at equilibrium of 4,663 and a theoretical maximum recruitment of 11,014. The spawning stock size MSY is 2,013 which is expected to result in 2,650 recruits.

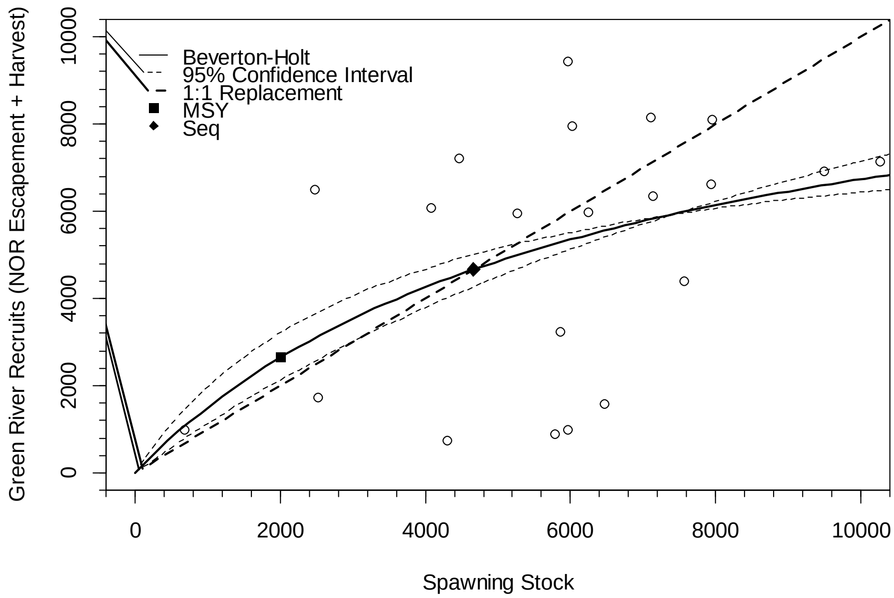


Figure 2. Beverton-Holt stock-recruit curve for Green River Chinook based on brood years 1989-2009. The spawning stock size at MSY is 2,013 (1,401-2,178 95%CI) which results in 2,650 (1,553-3,227 95%CI) recruits. The spawning stock size at equilibrium is 4,663 (3,038-5,246 95%CI) Chinook.

An independent assessment of optimal spawning escapement based on smolt production was recently completed (Anderson and Topping, in prep). 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. This is consistent with the conclusion from the spawner recruit analysis that the productivity of the watershed has declined and the equivalent optimal escapement is much less than 5,800 spawners used as a goal in the past.

An analysis of the Rebuilding Exploitation Rates (RER) was recently completed (NWFSC 2017). The RER analysis used data from the abundance and productivity tables that NOAA maintains and 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 are 20% and 31% for the Ricker and Beverton-Holt models, respectively. Assuming the two spawner-recruit functions were equally plausible, the results were combined 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 as well as an independent assessment of escapement based on smolt production.

Recruits per spawner have been moderately variable in the Green River population (Figure 3). The 1993 brood year was the most productive brood with 2.6 recruits per spawner produced. The least productive brood years were 2006-2008 which produced fewer than 0.2 recruits per spawner. Escapement during these years averaged 5,354, which is about average in the Green River basin. Recruits per spawner was 1.4 for the 2009 brood year, the largest observed since the 2000 brood year which occurred at the end of a stable period where recruits per spawner was consistently greater than 1.0. There is a weak correlation between Green River and Puyallup River (r = 0.41) or Cedar River (r = 0.39) Chinook productivity. The average productivity across all brood years is 1.0 recruits per spawner whereas 1.3 recruits per spawner is the current productivity at MSY.

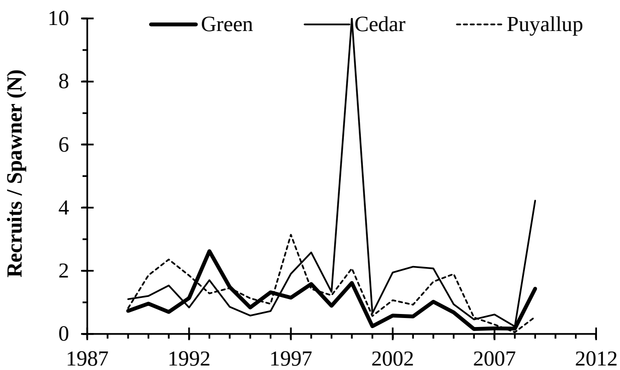


Figure 3. Trend in recruits per spawner for Green River (bold line) and adjacent management unit natural origin recruits from completed brood years (1989-2009).

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 4A). Beginning in the early 2000s northern exploitation rates began to increase to levels near where they were in the early 1990s. Terminal exploitation rates are highly variable and dependent upon whether there is a directed terminal fishery.

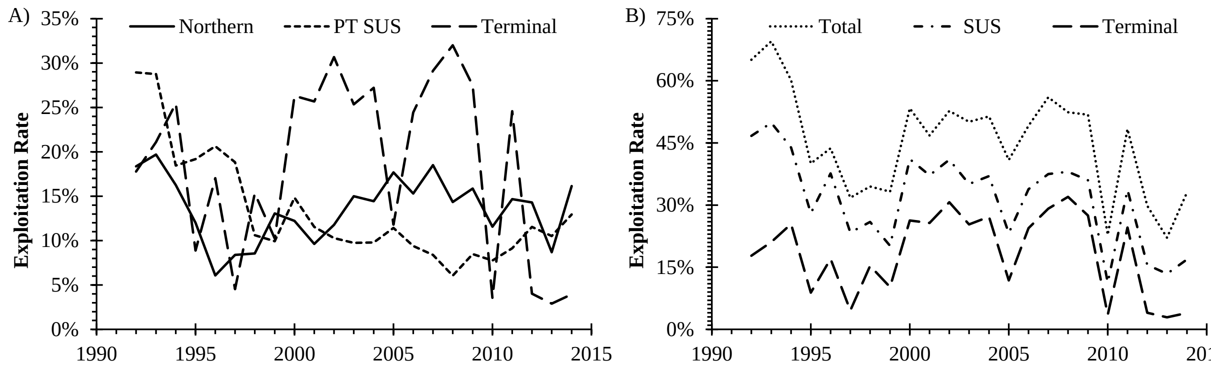


Figure 4. Trend in the A) northern (solid line), pre-terminal southern US (short dashed line), and terminal (long dashed line) exploitation rates and B) Total (dotted line), Southern US (dashed and dotted line), and terminal (long dashed line) exploitation rates on Green River natural origin Chinook from 1992-2014, based on the new FRAM base period (version 8/16/17).

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 needed to achieve program goals[17]. Green River escapement goals will be consistent with escapement according to MSY under current habitat conditions. The Upper Management Threshold (UMT) will be set at MSY escapement 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. The Low Abundance Threshold (LAT) will be set at 40% of the escapement goal.

MSY associated with current habitat conditions is 2,013 (1,401-2,178 95%CI) naturally spawning adult Chinook, less than half of the 5,800 that were managed for under previous plans. The first UMT trigger will allow a pre-terminal exploitation rate of up to 12% and will be triggered when 3,800 adult Chinook in the terminal area are destined for the spawning grounds. This represents the MSY escapement goal of 2,013, plus a buffer that 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 13% and will be triggered when 6,000 adult Chinook in

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

the terminal area are destined for the spawning grounds. Similar to the first trigger, the second trigger represents the MSY escapement goal of 2,013, plus a buffer that accounts for forecast uncertainty and a limited 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 (Table 1).

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 1C). Hatchery escapement will be managed for approximately 4,452 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. The LAT will be 805 adult Chinook on the spawning grounds. The lowest observed natural spawning escapement on the Green River was 688 in 2009, which produced 984 recruits from this cohort.

Consistent with the goals of achieving the natural spawning and hatchery escapement goals and ensuring that terminal directed fisheries will occur, at abundances above the UMT triggers of 3,800 and 6,000 adults in the terminal area destined for the spawning grounds, PT SUS fisheries will be planned not to exceed a 12% or 13% exploitation rate, depending on which trigger has been met. In the terminal area (Area 10A /Inner Elliott Bay and 80B), directed Chinook fisheries will be designed to achieve spawning and hatchery escapement at or above management objectives. 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.

If 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. If 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 MMT or LAT will only have incidental impacts to Chinook as fisheries will be directed at other salmonids. 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 which would result in higher exploitation rates in the terminal area than modeled in the pre-season but would result in meeting both natural spawning and hatchery escapement goals. The lowest SUS ER observed was 11.3% in 2010 and is the only time since 1992 the SUS ER has been below 12% according to post-season validation runs.

Table 1. Management thresholds and corresponding exploitation rate ceilings for stock components of the Mid-South Puget Sound FRAM stock aggregate. The MMT is triggered when natural spawning escapement is forecasted between the LAT and the UMT. In pre-terminal fisheries the stock aggregate is managed for its weakest component MU.

Management Unit	MSY	LAT (SUS)	MMT (SUS)	UMT – trigger 1 (PT SUS)	UMT – trigger 2 (PT SUS)
Lake Washington[1]	280	200 (12%)	18%	500 (12%)	500 (13%)
Green River	2,013	805 (12%)	18%	3,800 (12%)	6,000 (13%)
Puyallup River	797	319 (15%)	30%	1,300 (12%)	1,300 (13%)

[1] The Cedar River is the natural managed component of the Lake Washington MU

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.

There is some uncertainty in rates of impact of northern fisheries (British Columbia and Alaska) on Green River Chinook, but impact of those fisheries is unlikely to decrease significantly relative to recent years (Figure 4A). 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 State, 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.

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 update (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 three nights, once per week during management weeks 29-31. If the ISU model projects a harvestable surplus above management objectives, the planned terminal fisheries 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, 2,013 and approximately 4,452 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.
Temperature impacts on adult Chinook and eggs	Quantify pre-spawning mortality and sub-lethal effects. These include the viability and maturation rate of eggs exposed to high temperatures in vivo. Estimate thermal history of Chinook migrating from Puget Sound to the spawning grounds with a combination of radio tags and temperature thermistors.
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.
Estimate mortality of Chinook during years with high and low numbers of pink salmon	Encounter rate study, freshwater hooking mortality study, compliance study, tagging 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 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

Geographic distribution

The White River is glacially influenced and was diverted into the Puyallup River in 1906 after a large flood and log jam redirected the majority of the flow into the Stuck River. This diversion was made permanent in 1915 with the construction of a concrete structure. A diversion dam was constructed on the White River at RM 23.4 for hydropower generation in 1911 along with a canal and flume system to Lake Tapps before returning flow to the White River 20 miles downstream. Hydropower production ceased in 2004 and the associated facilities and water rights were later sold to the Cascade Water Alliance for a future municipal water supply. The U.S. Army Corps of Engineers (USACE) constructed the Mud Mountain Dam at RM 29.6 in 1948 for flood control, permanently blocking anadromous access to the upper White River watershed. Chinook and other anadromous species are trapped at the diversion dam in the USACE Buckley Trap and hauled above Mud Mountain Dam. The poor condition of the diversion dam and fish trap facilities have resulted in injury, migration delay, and prespawning mortality of Chinook and other species. Within the next five years, the USACE plans to replace and upgrade both its trap and haul facilities and the diversion dam as required by a 2014 Biological Opinion.

Spring Chinook spawning above Mud Mountain Dam occurs in the mainstem White River and several tributaries including the West Fork White River, Clearwater River, Greenwater River, and Huckleberry Creek. Spring Chinook spawn below the diversion dam in the White River mainstem, Boise Creek and Salmon Creek. Spawning ground surveys are conducted in the Clearwater River, Greenwater River, Huckleberry Creek, the White River mainstem, Boise Creek, and Salmon Creek. Glacial turbidity in the mainstem impairs surveys in most years.

Life History Traits

Spring Chinook enter the Puyallup River from May through mid-September, and spawn from mid-September through October. In contrast to other spring stocks in Puget Sound, White River Chinook smolts emigrate primarily as subyearlings. Based on scale samples taken at the Buckley Trap, 92% of Chinook sampled migrated as sub-yearlings. Further, smolt trapping data during 2016 and 2017 has indicated >99% sub-yearlings (Puyallup Tribe unpublished data). The average age composition of adult natural origin returns between 2005 and 2016 was 54% age 3, 44% age 4 and 2% age 5.

Hatchery Production

An emergency egg bank was begun out of basin in 1977 at the Minter Creek/ Hupp Springs Hatchery Complex. Variable numbers of yearlings and subyearlings were released into the White

River basin from this program. The Muckleshoot Indian Tribe began operating the White River Hatchery in 1989 at RM 23.4. Beginning in 1992, additional Chinook were planted in the upper watershed at acclimation ponds in an effort to more fully seed available spawning habitat above Mud Mountain Dam. Releases for the acclimation pond program (APP) have been those fish surplus to the core Minter/Hupp and White River on-station programs. The APP Chinook are managed as if they are NOR Chinook and count toward the interim escapement goal.
These Chinook are reared at Clarks Creek/Puyallup Trout Hatchery and the White River Hatchery prior to transfer to the acclimation ponds. White River Hatchery has production goals of 340,000 sub-yearling smolt on-station releases, 55,000 yearling smolt on-station releases, with surplus production up to 1.3 million for the acclimation ponds. The core White River Hatchery program requires 1,100 adults to meet the juvenile release goals. Hupp-Minter has a production goal of 400,000 on-station releases with any surplus going towards the acclimation pond program. The Clarks Creek and Puyallup Trout Hatcheries take up to a million surplus eggs from White River Hatchery and rear the resulting fry until they can be taken to the acclimation ponds. Transfers from the Minter/Hupp program to the White River are being discontinued and the yearling on-station release program at White River Hatchery is being halted for up to 4 years beginning with brood year 2017 to address disease concerns.

Genetic Information

Genetic analyses have shown significant differences between White River Spring Chinook and Puyallup River Fall Chinook (Ruckelshaus et al. 2006). Within the White, the early run hatchery and wild genetic samples are indistinguishable, reflecting the effects of the broodstock program that began in the 1970s. The late-returning Chinook population in the White River is genetically indistinguishable from Green River-origin Chinook which were widely introduced into the Puyallup River.

Status

The White River Spring Chinook population is the only extant early timed population remaining in the South Puget Sound geographic region. As such, this population is categorized as a tier 1 population, meaning it is essential for preservation, restoration, and recovery of the ESU. White River Spring Chinook declined from escapements of more than 5,000 in the early 1940s to less than 100 by the early 1970s. The initial supplementation program stabilized this trend until the construction of the White River Hatchery. From the years immediately preceding the initiation of the hatchery program up through 1996, the natural origin (NOR) Chinook stock saw slight increases in population size (Figure 1). Two of the three subsequent brood years were among the lowest returns of NOR Chinook in the time series. However, the 2000 return exceeded the interim escapement goal of 1,000 Chinook (NOR + APP) passed at Buckley Trap for the first time with the majority of the recruits coming from the NORs. This begins a 17 year period of widely fluctuating returns. Over these 17 years, only 4 years failed to meet the 1,000 Chinook interim passage goal with 8 of these years being met with NOR recruits. Up through 2004, the APP saw only modest returns. Beginning in 2005, APP returns began making up a much larger fraction of the total passage at Buckley Trap. In addition, 2005 marked the beginning of consistently exceeding about 1,500 total Chinook passed at Buckley Trap. By 2009 the NOR stock saw its first major decline since the late 1990s and has persisted at an average of about 700 at the Buckley trap. Conversely, APP recruits have exhibited periodic explosions in abundance reaching approximately 3,000 individuals at the Buckley Trap.

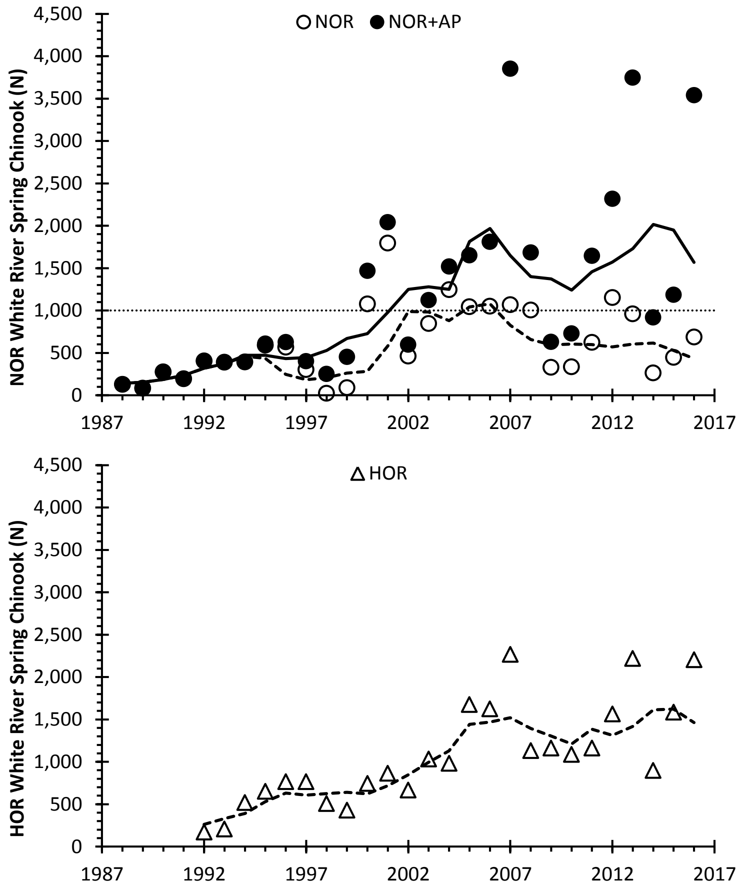


Figure 1. Observed NOR (open circle) and total (filled circle) escapement at Buckley Trap (top panel) with 5-year running geometric mean for total escapement (solid line) and NOR escapement (dashed line). The interim escapement goal of 1,000 is shown as a lite dashed line. Observed hatchery fingerling recruits (HOR) trapped at the White River Hatchery and Buckley Trap (bottom panel) with a 5-year running geometric mean.

An interim escapement goal of 1,000 spring Chinook (NOR + APP) spawners passed above the Mud Mountain dam, which does not include mainstem spawners downstream of the dam, has been the management goal under recent plans. A Ricker stock recruit function was fit to White River Spring Chinook spawning escapements and their subsequent brood from the 1989-2009 brood years (Figure 2). This resulted in a stock size of 380 spawners 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 355-415 spawners at MSY. This implies that 615-821 (715 at MSY) recruits would be produced from this range of spawning escapement. The exploitation rate (ER) at MSY would be 46.9% (range 44.7-48.3%). The expected maximum number of recruits in this population will be 954 (944-993 95% CI) under current habitat conditions. This number is expected to increase with planned upgrades at the trap and haul facility.

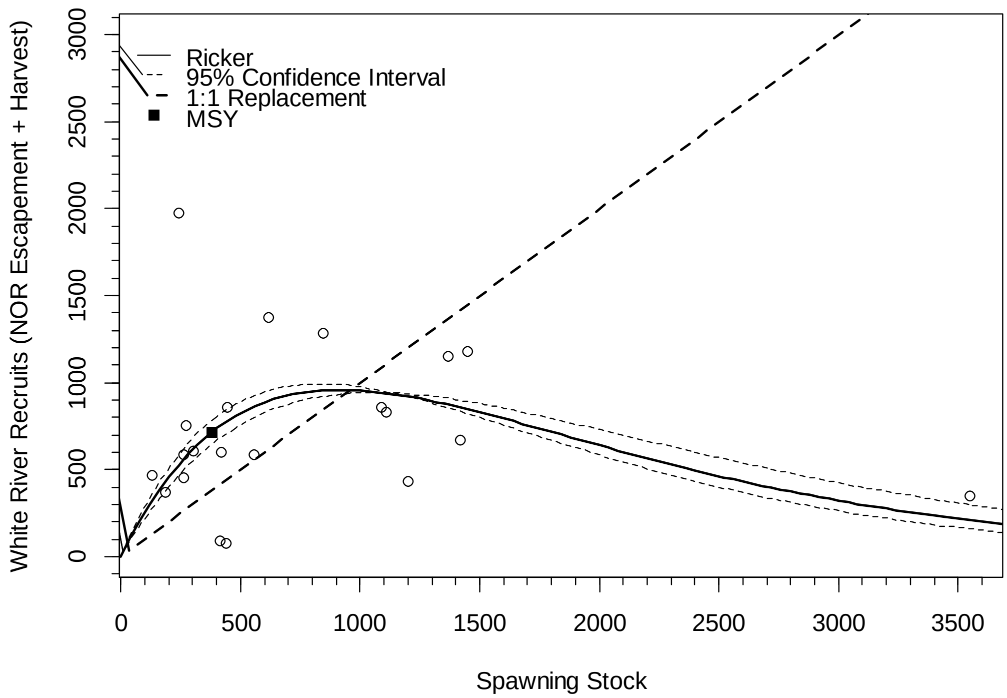


Figure 2. Ricker stock-recruit curve for White River Spring Chinook based on brood years 1989-2009. MSY is calculated from Scheuerell (2016) and results in an optimal stock size of 380 (355-415 95% CI) Chinook. The maximum number of recruits is 954 (944-993 95% CI).

Recruits per spawner have been highly variable in the White River population (Figure 3). The 1997 brood year was the most productive brood at more than 8 recruits per spawner. The least productive brood was 2006 which produced 0.1 recruits per spawner. The 2006 brood was the largest spawning escapement observed at 3,550 total spawners. There is no correlation between productivity with Green River and White River Chinook productivity (r = 0.17). However, Puyallup River and White River Chinook productivity was moderately correlated (r = 0.60). The average productivity across all brood years is 1.6 recruits per spawner whereas 1.9 recruits per spawner is the current productivity at MSY.

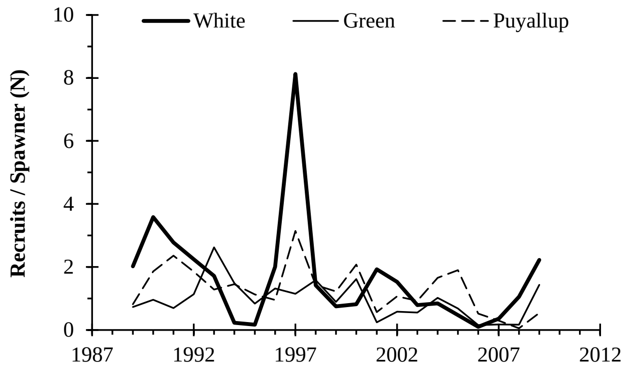


Figure 3. Trend in recruits per spawner for White River (bold line) and adjacent management unit natural origin recruits from completed brood years (1989-2009).

Harvest Distribution and Exploitation Rate Trends

White River Chinook exploitation rates are calculated based on marked fingerling release groups at the White River Hatchery from 1991-1996, which is modeled through terminal fisheries within the Terminal Area Management Module (TAMM). These set of years are out of base with most other stocks in FRAM because current production is not marked. Yearling release groups are not managed but exploitation rates can be calculated from a different set of indicator years.
As estimated by FRAM/TAMM for White River Chinook, fisheries in British Columbia and Alaska (Northern) had a combined 6% average exploitation rate, the pre-terminal southern US (PT SUS) exploitation rate averaged 6% and the terminal exploitation rate averaged 9% from 2010-2014. Pre-terminal exploitation rates declined across the series from the very high rates seen in the mid-1990s to more moderate levels seen today (Figure 4). Beginning in the late 1990s northern exploitation rates rapidly increased to near 15% but have gradually declined since. Terminal exploitation rates have increased across the series as ceremonial and subsistence fisheries were implemented by both the Muckleshoot and Puyallup tribes.

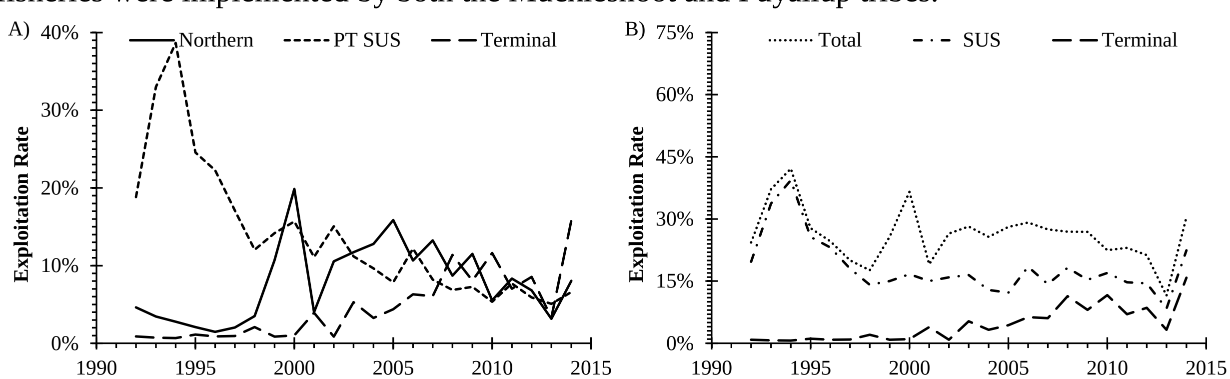


Figure 4. Trend in the A) northern (solid line), pre-terminal southern US (short dashed line), and terminal (long dashed line) exploitation rates and B) Total (dotted line), Southern US (dashed and dotted line), and terminal (long dashed line) exploitation rates on Puyallup River natural origin Chinook from 1992-2014, based on the new FRAM base period (version 8/16/17).

Management Objectives

The White River will continue to be managed for an interim Upper Management Threshold of 1,000 adult spring Chinook (NOR + APP) above Mud Mountain Dam. After upgrades to the USACE Buckley trap and haul facility which includes sorting capacity, additional fish (depending on the return) could be released upstream so those increases in productivity can be measured. Increased confidence in sorting will allow managers to select the sex ratio of Chinook on the spawning grounds. Placing up to 50% females on the spawning grounds will optimize production and allow for increased certainty in productivity estimates. Based upon the Ricker stock-recruit modeling, more than 1,500 spring Chinook should not be placed on the upper White River spawning grounds. The Low Abundance Threshold (LAT) will be set at 40% of the escapement goal.

MSY associated with current habitat conditions is 380 (355-415 95% CI), less than half of the interim escapement goal and not different than the current LAT of 400 adult Chinook. The pre-season exploitation rate management ceiling will be for a 22% Southern US ER with an assumed northern ER of 6.3% (recent 5-year average) or 9.0% (recent 10-year average) (Figure 4).

Terminal fisheries will begin to implement in-season management in the White River with in-season update models that project escapement to the White River Hatchery and Buckley Trap. This management regime will be designed to maintain at least 1,000 adult spring Chinook on the upper White River spawning grounds and ensure escapement to White River Hatchery meets program objectives. After program objectives are met, the terminal exploitation rate will not be constrained to pre-season ceilings. If escapement is forecasted to fall below the LAT, a critical exploitation rate ceiling of 15% will be implemented for the total Southern US exploitation rate and terminal fisheries directed at other species will be further shaped to reduce their impacts on Chinook.

Data Gaps/ Information Needs

Table 1. 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 in the White River	The current Buckley trap and haul facility is scheduled to be replaced within five years. This facility is severely constrained during large runs of pink and coho salmon. A modern facility would allow more accurate counting of all species trapped and hauled above Mud Mountain Dam.
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 trap and haul facility resulting in the transportation of an unknown number of fall Chinook above Mud Mountain Dam. Increased genetic sampling on the lower White River spawning grounds is necessary to identify the numbers of spring Chinook present and their contribution.
Estimation of natural smolt production	Quantify total and tributary specific smolt production above Mud Mountain Dam.
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 spawning abundance.
Estimate the pre-spawning mortality of Chinook based on fish condition when trucked upstream	Sampling has documented large numbers of wounded Chinook in the Buckley Trap. Understanding the viability of injured Chinook on the spawning grounds is necessary to resolve differences between spawning ground estimates with the number of Chinook hauled above Mud Mountain Dam.
Uncertainty in factors governing the distribution of Chinook spawning in the White River	Comprehensive spawning ground surveys are needed to identify any interactions between Chinook salmon and other salmonids with respect to the low productivity of the natural stock.

The data gaps described above assume that the annual monitoring that is routinely done 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

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 river systems that flow through 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.

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.

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 2005 and 2016 was 14% age-3, 75% age-4 fish, and 11% age-5.

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, is 1.0 million sub-yearlings released on-station, 0.2 million acclimated and released (Rushingwater Creek, Cowskull Creek, and Mowich River) from 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.

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 (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 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. 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 1A). The mainstem Puyallup River and Carbon Rivers are not consistently surveyable due to glacial turbidity and/or high flows, so the escapement estimation method relies on the ratio of current-year escapement to 1999, when the mainstem and Carbon were surveyed. The marked increase in pink salmon escapement to the Puyallup basin after 2000 further confounded Chinook escapement estimates. Large numbers of pink salmon concurrently spawning in South Prairie Creek lead to increased uncertainty with Chinook escapement estimates.

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 has been negative across the available data. Since the series low in 2012, spawning escapement has increased to over 2,500 in 2016. Spawning abundance has never fallen below the LAT, however, spawning abundance has fallen below the UMT four of the last seven years. NOR spawners have followed a similar pattern as total spawners. Since mass marking of hatchery Chinook has been implemented and confidence in contribution has increased, NOR contribution to the spawning grounds have decreased from near 60% to less than 40% (Figure 1B). 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 1C).

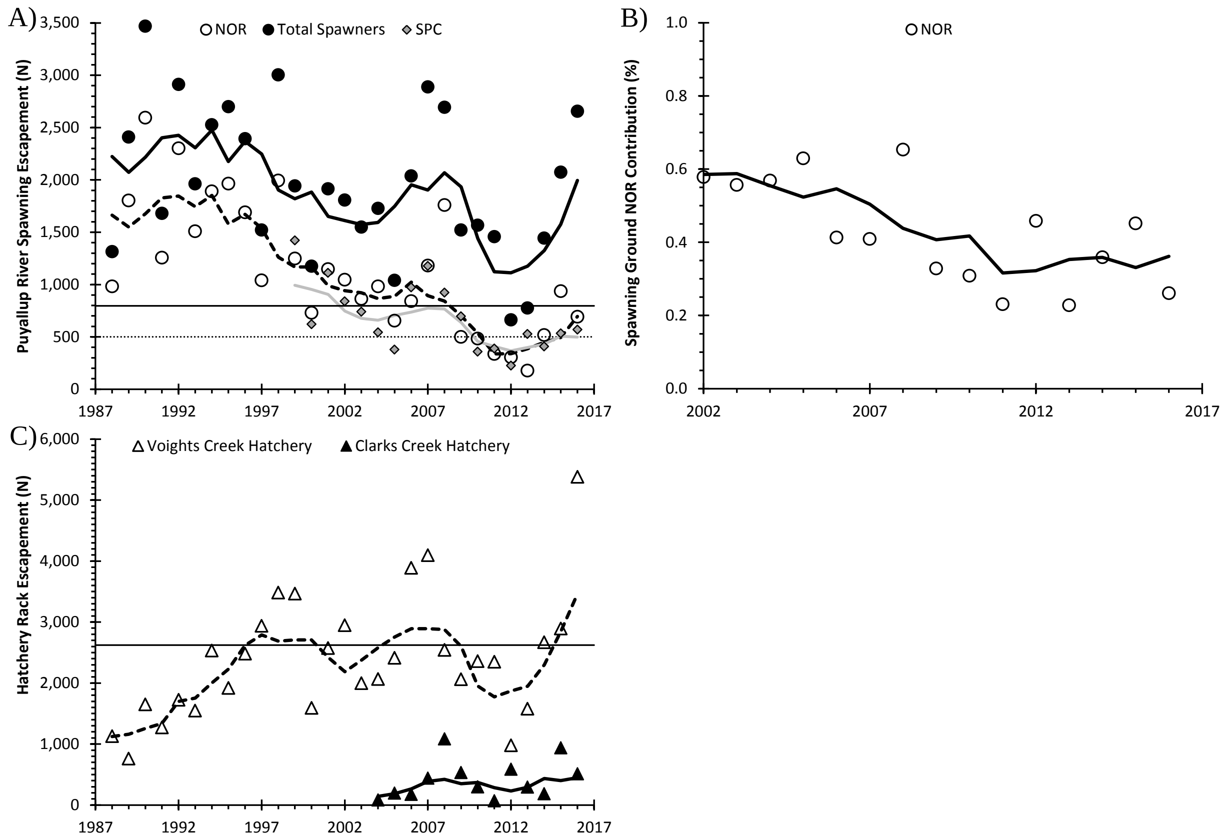


Figure 1. Observed NOR (open circle), total (filled circle), and South Prairie Creek (filled diamond) escapement on the Puyallup River Chinook spawning grounds (panel A) from 1988-2016. A 5-year running geometric mean for total (solid line), NOR (dashed line), and South Prairie Creek (gray line) escapement is fit to each data series. The historic escapement goal of 500 natural spawners in South Prairie Creek (lite dashed line) and MSY escapement goal of 797 (503-1,207 95%CI) total 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 (panel B) from 2002-2016 (open circles) with a 5-year running geometric mean (solid line). Observed hatchery rack escapement (panel C) at Voights Creek Hatchery (open triangle) from 1988-2016 and Clarks Creek Hatchery (closed triangle) from 2004-2016 are shown with a 5-year running geometric mean. The combined hatchery rack escapement goal of 2,622 (the current goal is not necessarily reflective of historic goals) adult Chinook needed to make current 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 curve (Beverton and Holt 1957) to brood years 1989-2009 (Figure 2). For this model, a=0.1946 and b=0.0003095 which resulted in a spawning stock size at equilibrium of 2,602 and a theoretical maximum recruitment of 3,231. The spawning stock size MSY is 797 which is expected to result in 1,806 recruits.

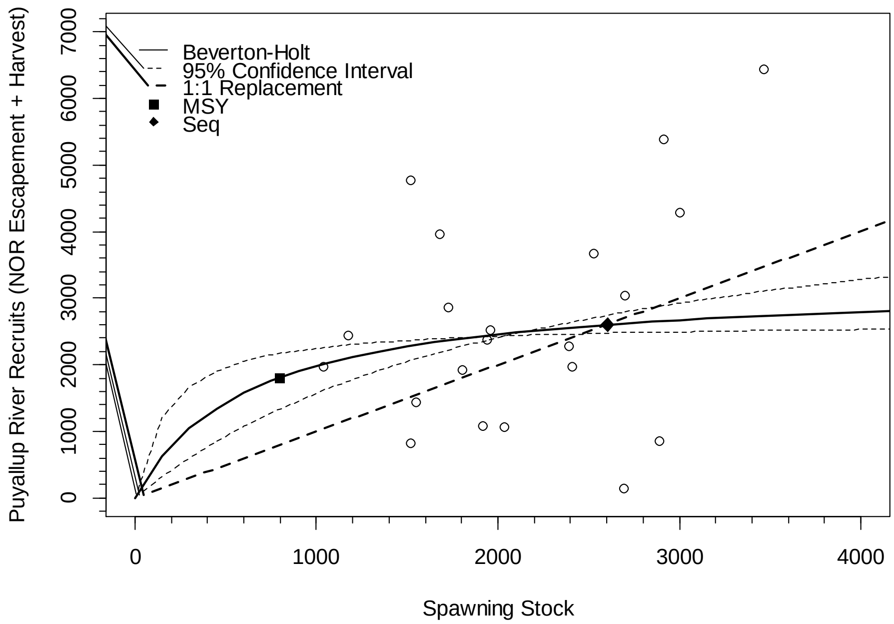


Figure 2. Beverton-Holt stock-recruit curve for Puyallup River Chinook based on brood years 1989-2009. The spawning stock size at MSY is 797 (503-1,207 95%CI) which results in 1,806 (1,610-1,980 95%CI) recruits. The spawning stock size at equilibrium is 2,602 (2,467-2,870 95%CI) Chinook.

Recruits per spawner have been moderately variable in the Puyallup River population (Figure 3). The 1997 brood year was the most productive brood with 3.1 recruits per spawner produced. The least productive brood years were 2006-2008 which produced fewer than 0.5 recruits per spawner. Escapement during these years averaged 2,865, which is larger than average recruitment in the Puyallup basin. There is a weak correlation between Green River and Puyallup River Chinook productivity (r = 0.41). Within the Puyallup basin, Puyallup River fall and White River Chinook productivity is moderately correlated (r = 0.60). The average productivity across all brood years is 1.3 recruits per spawner whereas 2.3 recruits per spawner is the current productivity at MSY.

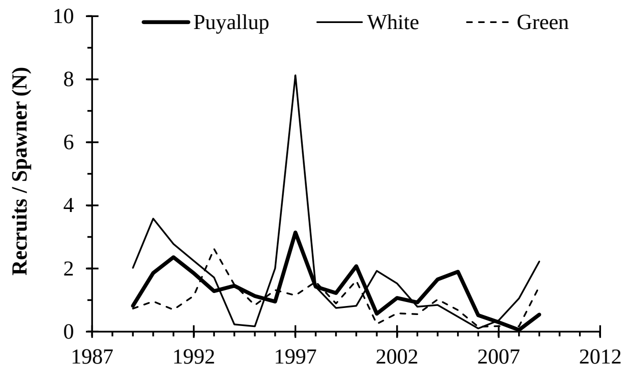


Figure 3. Trend in recruits per spawner for Puyallup River (bold line) and adjacent management unit natural origin recruits from completed brood years (1989-2009).

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, 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% from 2010-2014. Pre-terminal exploitation rates generally declined through the 1990s (Figure 4). 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 been consistent across the time series at about 30% with only a few years falling below 20%.

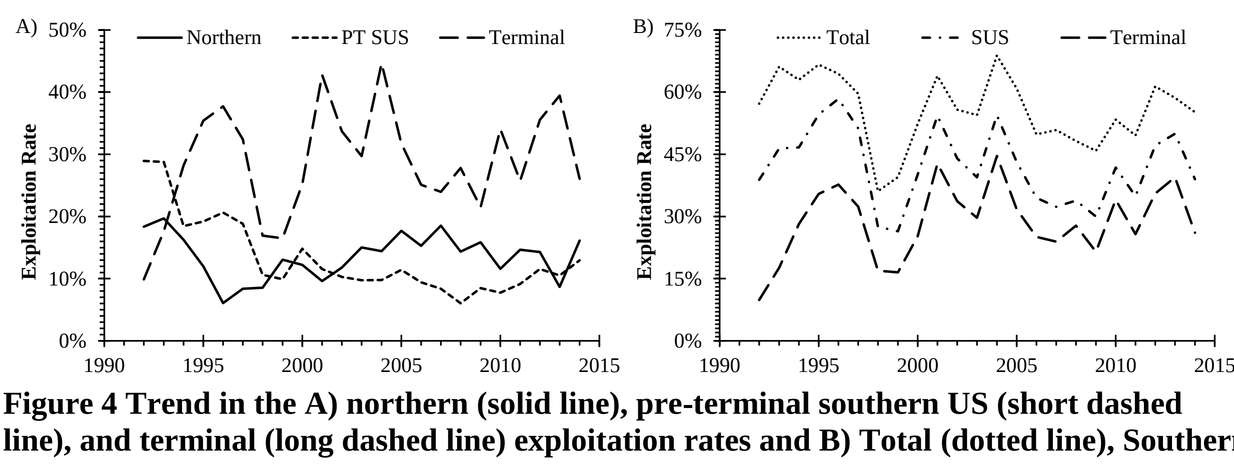


Figure 4 Trend in the A) northern (solid line), pre-terminal southern US (short dashed line), and terminal (long dashed line) exploitation rates and B) Total (dotted line), Southern US (dashed and dotted line), and terminal (long dashed line) exploitation rates on Puyallup River natural origin Chinook from 1992-2014, based on the new FRAM base period (version 8/16/17).

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[1]. Puyallup River escapement goals will be consistent with escapement according to MSY under current habitat conditions. 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 be reasonably assumed to meet the natural spawning and hatchery escapement objectives. The Low Abundance Threshold (LAT) will be set at 40% of the escapement goal.

MSY associated with current habitat conditions is 797 (503-1,207 95%CI) naturally spawning adult Chinook, which is similar to the 500 Chinook on South Prairie Creek that were managed for under previous plans. The new UMT for Puyallup River is 1,300 adults in the terminal area destined for the spawning grounds. This trigger will allow a pre-terminal exploitation rate of up to 12%, unless the Lake Washington MU has met its UMT and the Green River MU meets its upper trigger for a 13% pre-terminal ER, then all Mid-Puget Sound aggregate MUs will be managed for a 13% pre-terminal SUS ER (Table 1). The LAT will be 319 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 1,039 in 2005, which produced 1,975 recruits. The five most recent complete cohorts have produced an average of only 961 recruits.

Table 1. Management thresholds and corresponding exploitation rate ceilings for stock components of the Mid-South Puget Sound FRAM stock aggregate. The MMT is triggered when natural spawning escapement is forecasted between the LAT and the UMT. In pre-terminal fisheries the stock aggregate is managed for its weakest component MU.

Management Unit	MSY	LAT (SUS)	MMT (SUS)	UMT – trigger 1 (PT SUS)	UMT – trigger 2 (PT SUS)
Lake Washington[1]	280	200 (12%)	18%	500 (12%)	500 (13%)
Green River	2,013	805 (12%)	18%	3,800 (12%)	6,000 (13%)
Puyallup River	797	319 (15%)	30%	1,300 (12%)	1,300 (13%)

[1] The Cedar River is the natural managed component of the Lake Washington MU.

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

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 of 1,300 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 12% (13% if criteria in the Lake Washington and Green River MU are met; Table 1) exploitation rate. In the terminal area (81B), directed Chinook fisheries will be designed to achieve spawning and hatchery escapement at or above management objectives. 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.

If 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 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 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 and predicts a terminal run-size above the UMT that is sufficient for limited terminal Chinook directed fisheries.

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 will guide actions that 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, but impact of those fisheries is unlikely to decrease significantly relative to recent years (Figure 4A). 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.

Unlike the Lake Washington or Green River MUs, there is no current in-season update methodology in place to guide terminal fisheries. Historic test fishery data is available that the co-managers reasonably believe could be used to develop an ISU model or guide data collection that will result in an ISU during the life of this plan.

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 hoking 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.
In-season run size update	Historic test data are available but do not show a relationship with run sizes. Establish a test fishery that can measure run sizes in-season.
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

Component Populations

Nisqually River fall-run Chinook

Geographic Description

Adult Chinook ascend the mainstem of the Nisqually River to river mile 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.

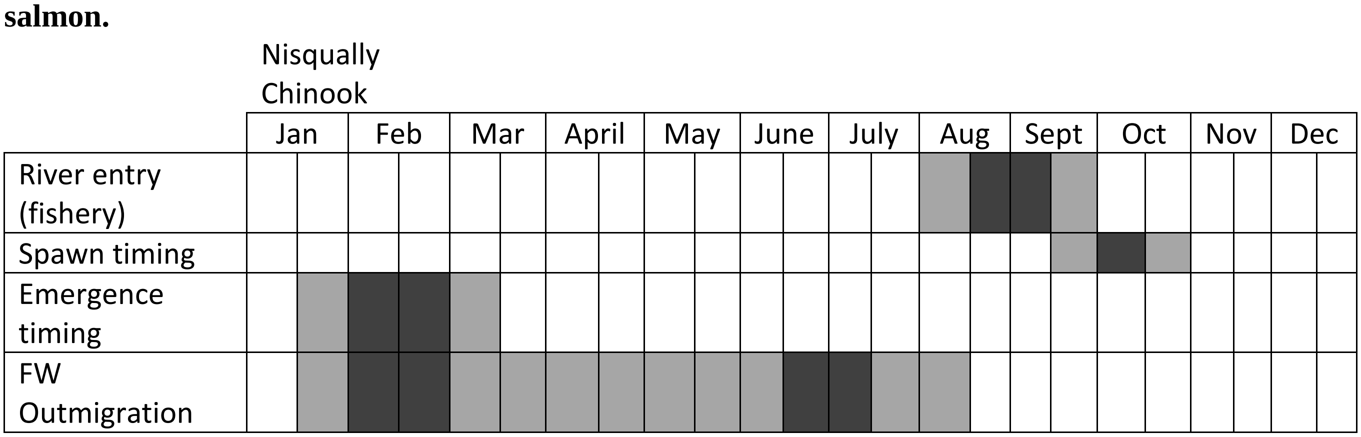


Table 2. Nisqually Chinook Age Composition.

Marked	Age 2	Age 3	Age 4	Age 5	Unmarked	Age 2	Age 3	Age 4	Age 5
2004	25.2%	23.9%	47.4%	3.5%	2004	22.4%	15.2%	60.2%	2.2%
2005	16.4%	56.4%	23.5%	3.7%	2005	12.5%	52.9%	24.9%	9.7%
2006	27.3%	47.6%	24.9%	0.2%	2006	31.7%	37.7%	30.6%	0.0%
2007	17.6%	63.0%	18.6%	0.8%	2007	12.5%	66.3%	20.4%	0.8%
2008	22.8%	31.1%	45.6%	0.5%	2008	12.1%	28.6%	59.0%	0.3%
2009	35.8%	31.0%	33.1%	0.0%	2009	30.0%	25.1%	44.5%	0.4%
2010	5.9%	76.2%	17.8%	0.1%	2010	5.4%	75.0%	19.6%	0.0%
2011	26.2%	16.3%	56.8%	0.7%	2011	18.6%	19.3%	61.6%	0.5%
2012	11.2%	65.4%	22.4%	1.1%	2012	6.3%	54.8%	37.2%	1.7%
2013	11.1%	40.6%	47.7%	0.6%	2013	10.7%	33.8%	55.5%	0.0%
2014	11.6%	41.1%	44.4%	2.8%	2014	8.4%	49.1%	38.6%	3.9%
average	19.2%	44.8%	34.7%	1.3%	average	15.5%	41.6%	41.1%	1.8%

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 less than 1,000 Chinook in recent years, following two strong returns in 2007 and 2008 (Figure 1). Natural-origin natural spawning escapement has been relatively stable despite declining natural-origin adult runs to the river (Figure 1). 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.

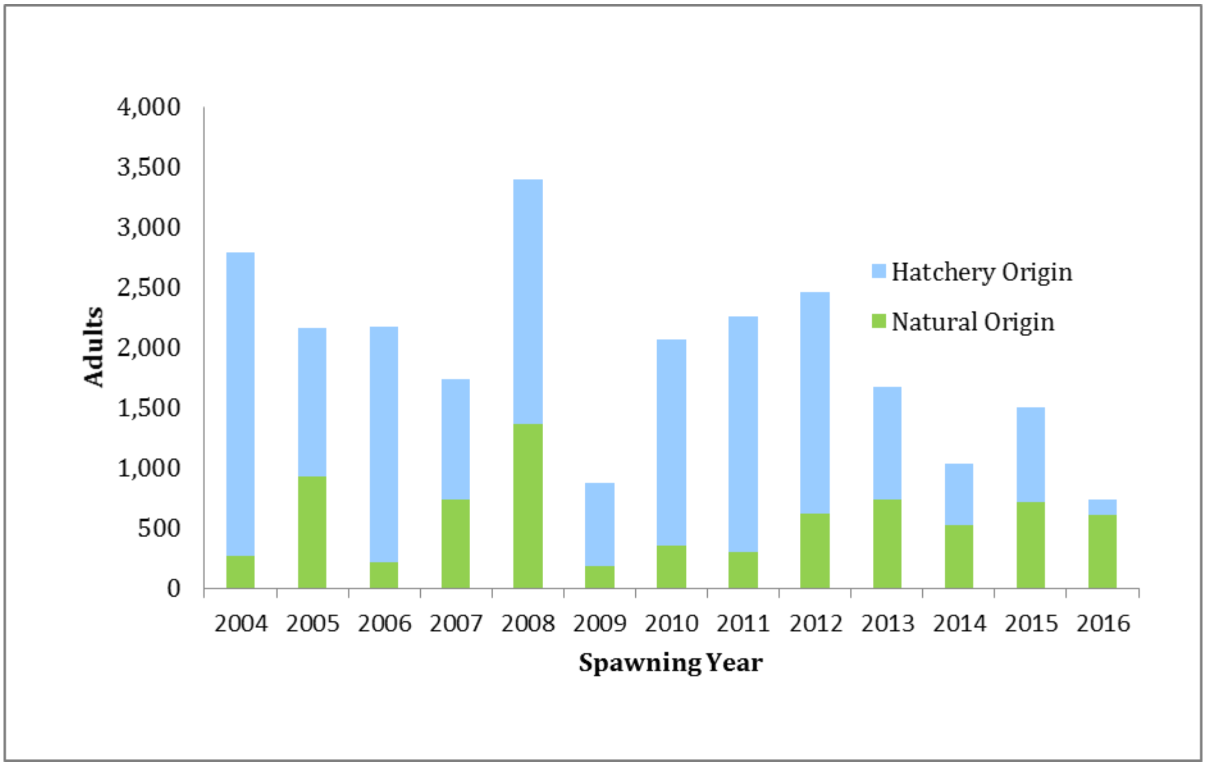


Figure 1. Natural Spawning Escapement of Natural-Origin and Hatchery-Origin Chinook. Source: Nisqually Chinook run reconstruction ISIT file (January 2017).

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 2). 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 3).

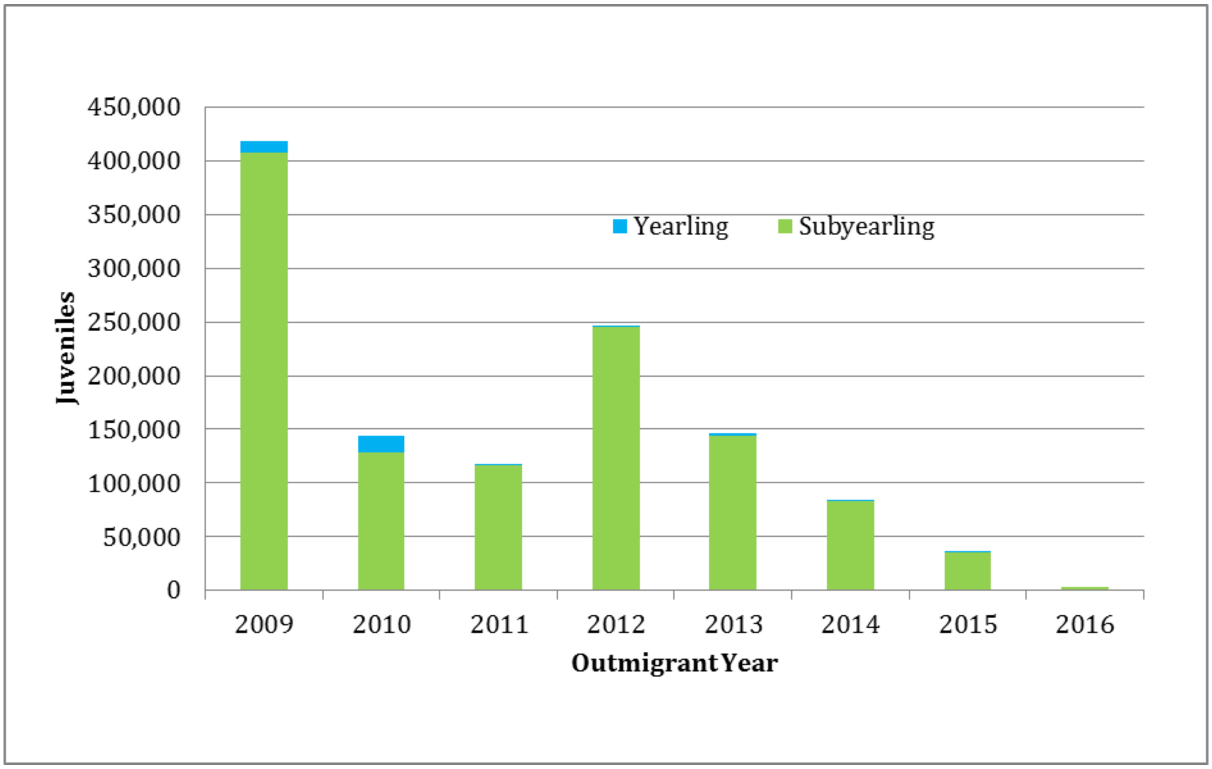


Figure 2. Estimated Annual Juvenile (Subyearling and Yearling) Chinook Abundance at RM 12.8. Source: Klungle et al. in prep

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 2.0 recruits per spawner from the 2015 brood year to 150 recruits per spawner from the 2009 brood year (Figure 3). Compared to the Skagit River, a watershed with an abundant Chinook population and long-time series, where the range of out-migrants per female spawners varied from 270 to 1,230 out-migrants 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 4.0 to 300, with a geometric mean freshwater productivity of 93. 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.

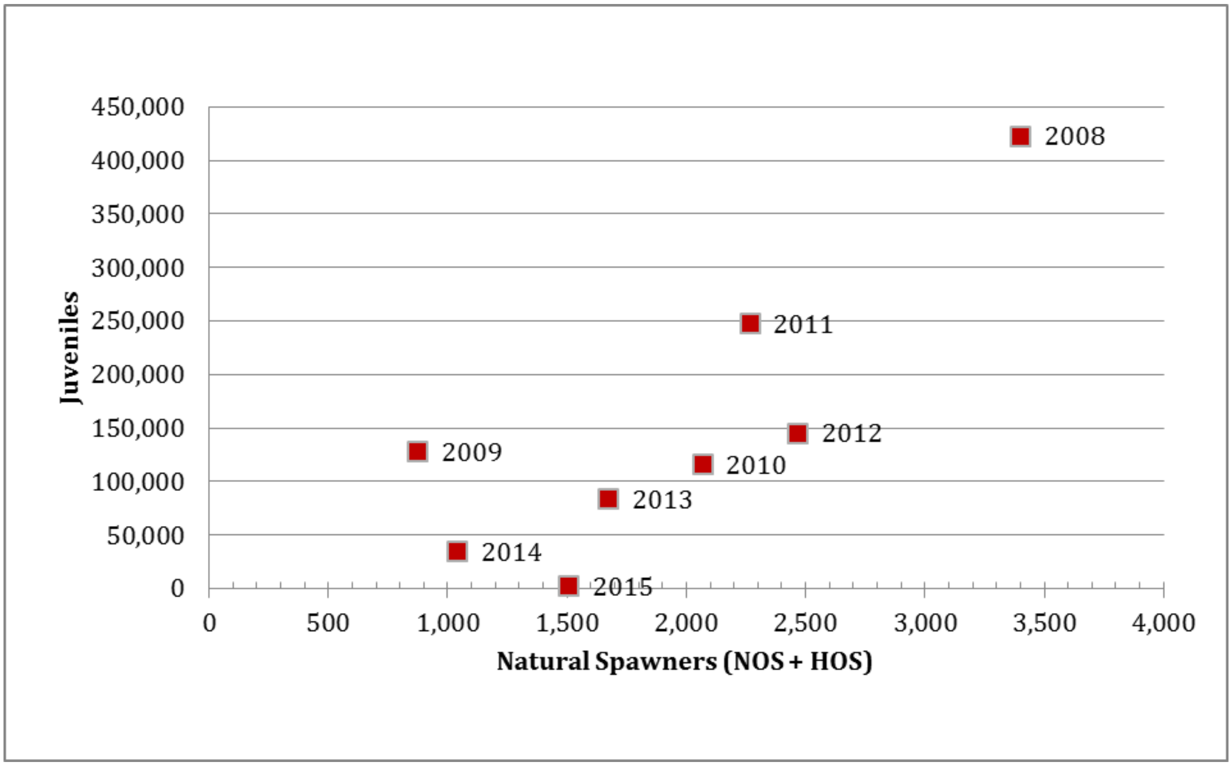


Figure 3. Juvenile Recruits per Spawner (brood years shown). Source: NIT and WDFW year pending.

Adult recruits per natural spawner has varied from 0.2 to 1.5 from 2004 to 2011. Adult recruitment exceeded replacement (recruits per spawner greater than 1.0) in just two brood years (2004 and 2009) over the eight-year period (Figure 4). 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.

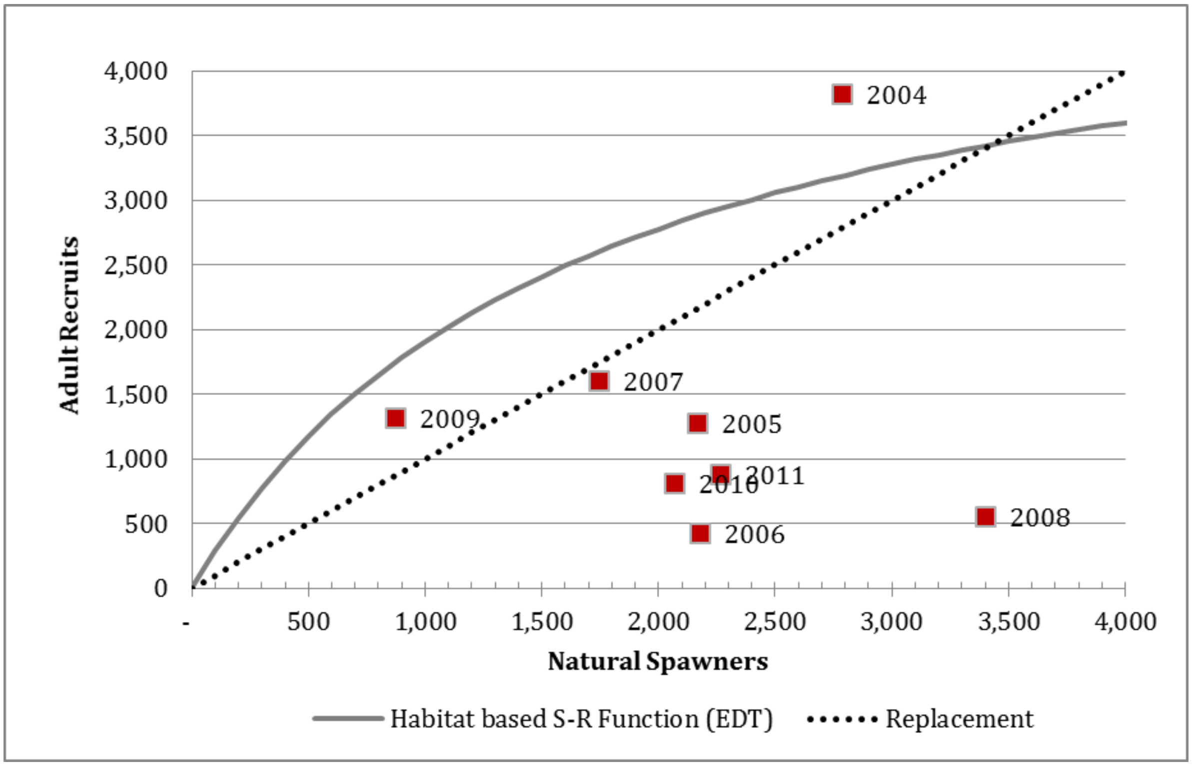


Figure 4. Natural-Origin Adult Recruits per Spawner (brood years shown). Source: Pending.

Taking these various aspects of VSP parameters into consideration, the Nisqually technical work group agreed that, based on the HSRG recovery phase framework, the population status is in the Colonization phase and management priorities should focus on substantially increasing natural-origin fish (NIT and WDFW, in draft).

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 1990 at Clear Creek Hatchery with the sole purpose of supporting harvest. The 2017 Nisqually Stock Recovery Plan identifies hatchery program objectives for the current population status (NSIT 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 (NSIT 2017). Changes to the hatchery program are envisioned, dependent on evaluation of population status (NSIT 2017).

Habitat Limiting Factors

Since the implementation of the original Nisqually Chinook Recovery Plan (Nisqually Chinook Recovery Team 2001), major habitat restoration initiatives have been accomplished in core areas while efforts have continued to protect existing habitat and 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* (Nisqually Chinook Recovery Team 2001) contained an action plan that outlined specific restoration and protection priorities. The action plan, which was guided by Ecosystem Diagnostic and Treatment (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 and now consider South Sound Nearshore habitat protection and restoration to be 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, USGS, and others of the restoration of 900 acres of the Nisqually Delta identified altered physical processes (river flow control, reduced sediment inputs) and the 100-year history of subsidence since initial diking threaten to undermine the recovery trajectory of the Nisqually Delta (Curran et al. 2016). When viewed in light climate change and sea level this threat is even greater. In order to alleviate the sediment deficit, the routing of sediment needs to be improved through I-5 and more sediment needs to make it through Alder and LaGrande Reservoirs. These projects will 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* (Nisqually Chinook Recovery Team 2001) and the *Draft Nisqually Winter Steelhead Recovery Plan* (Nisqually Steelhead Recovery Team 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 manage them for long-term ecosystem services recovery and sustainable local economies. This initiative will cost nearly $200 million and 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 5). However, even larger jumps in Nisqually Chinook population performance can be expected from successful implementation of large-scale habitat initiatives, including 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.

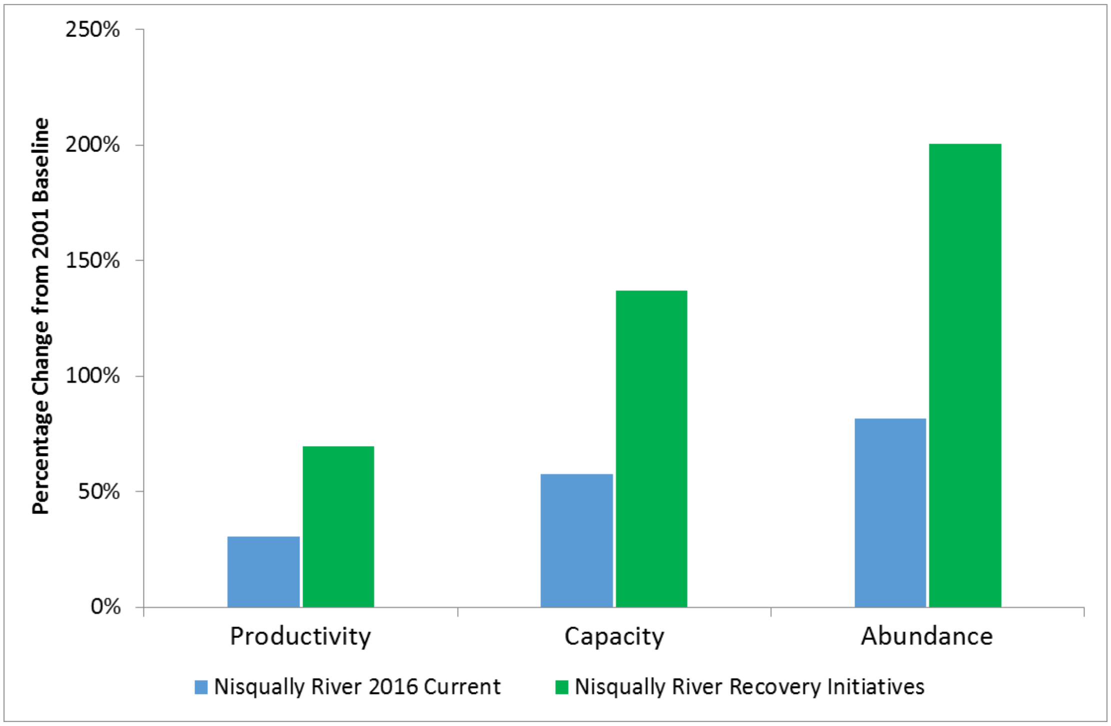


Figure 5. Modeled Improvements in Nisqually Chinook Population Performance. Source: Pending

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-based reporting of total exploitation rates shows a decrease from approximately 70% in 2008 and 2009 to 50% or less in recent years (Figure 6). This decrease has been primarily from reductions in the terminal treaty fishery; recent year (2012–2014) terminal rates averaged 27% compared to an average rate of 49% from 2008 to 2010 (Figure 7). SUS pre-terminal impact has seen a positive trend since 2011 (Figure 8). From 2011 to 2015, the average terminal harvest rate among treaty and non-treaty sportfishers was 35.2% (±.12.2 S.D.).

Pre-terminal (fisheries operating outside of the Nisqually River) exploitation rates have tended be stable over the period, averaging 21% (Figure 6).

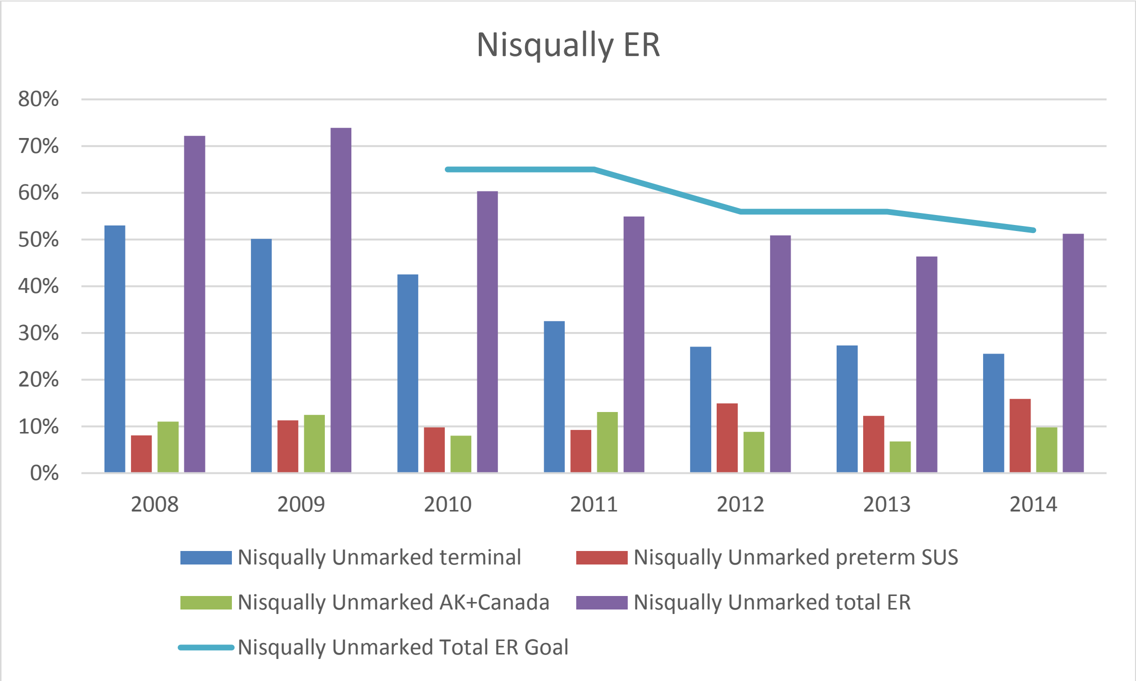


Figure 6. Exploitation Rates on Unmarked Nisqually Chinook. Source: FRAM Validation August 2017

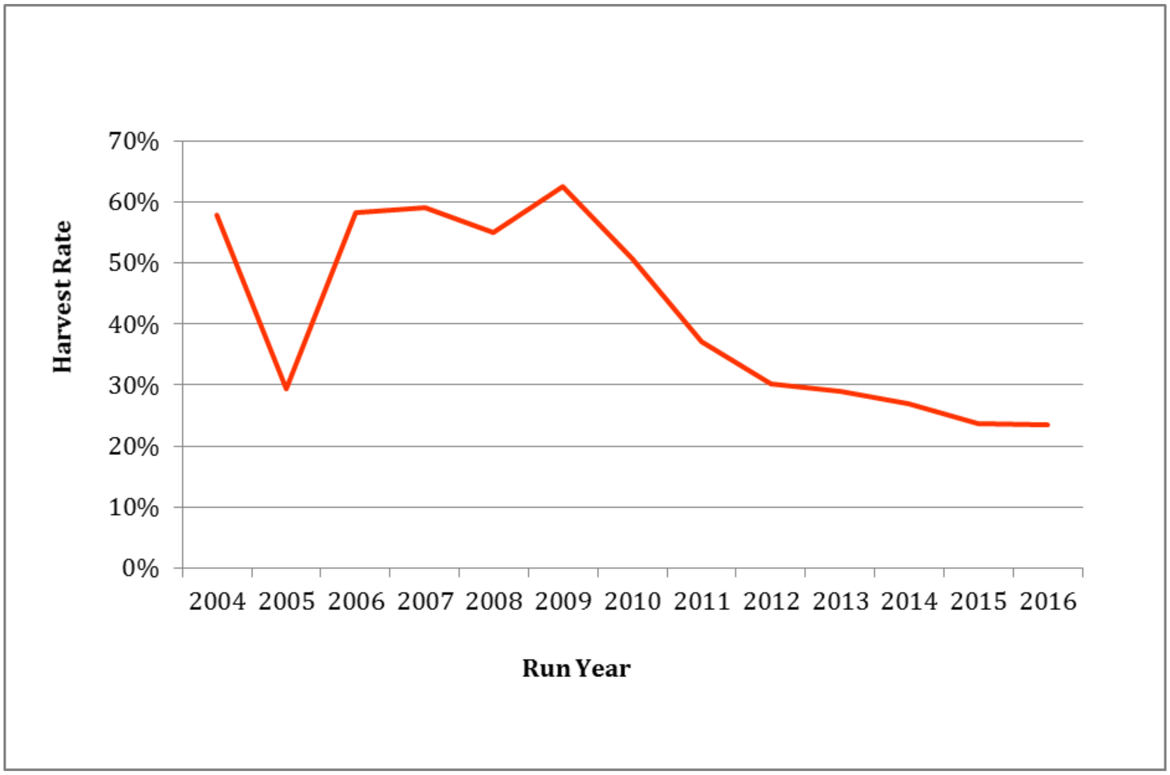


Figure 7. Nisqually Treaty Net Harvest Rates on Unmarked Chinook. Source: Nisqually Chinook run reconstruction ISIT file (January 2017).

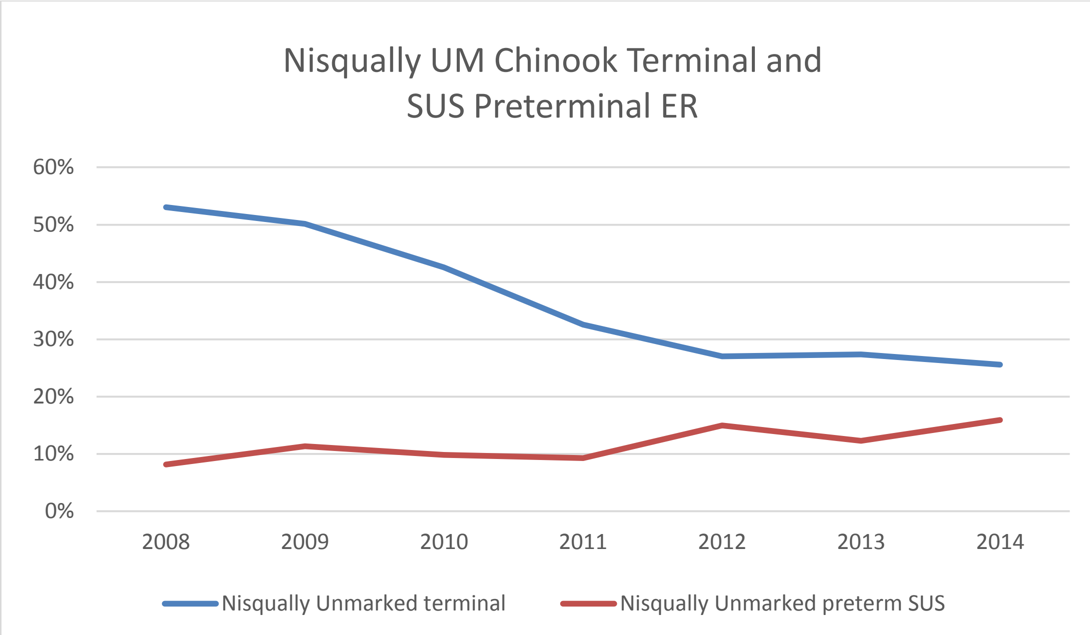


Figure 8. Increasing trend in SUS Pre-terminal fisheries.

Management Objectives

During colonization, the goal is to achieve escapement of at least 3,500 natural spawning adults, which is likely to include a substantial component of trucked fish from the hatchery. As a result, the LAT will consist of a total basin escapement goal (to the hatcheries and spawning grounds) of at least 7,000 adult chinook including a minimum of 2,800 for broodstock needs. The 7,000 LAT also includes a buffer for anticipated pond mortalities and to assure trucked adults will be representative of the complete run-timing. When pre-season escapement estimates are projected to exceed the LAT, an ER ceiling of 47% will be implemented for Nisqually unmarked Chinook, with the Nisqually Tribe maintaining a minimum 20% harvest rate in river. The LAT of 7,000 has been obtained in the past 13 years, during much higher ER ceilings, (Figure 9.)

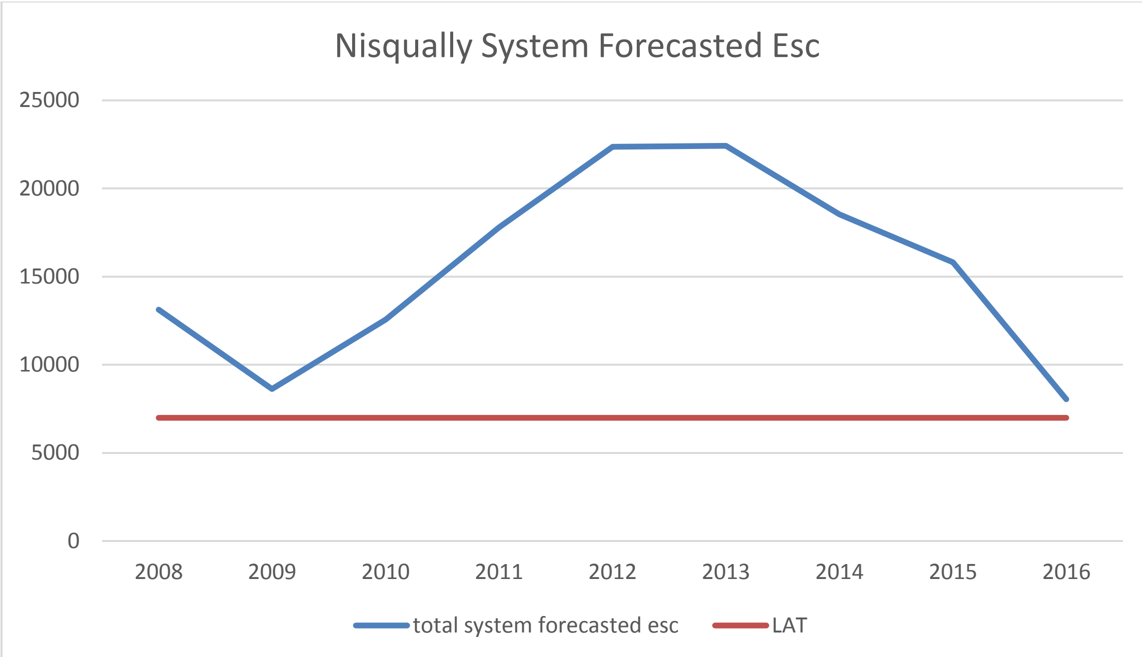


Figure 9. Nisqually LAT if applied to historical data set.

In order to fulfill a core objective in the 2017 Nisqually Stock Management plan, the Nisqually Indian Tribe will be investigating selective fishing techniques to consider using in its traditional in-river commercial and C&S fisheries. In order to provide the incentive to meet this objective, we will utilize up to 2% additional ER to support this effort. The Nisqually Indian Tribe, with the full agreement of the WDFW, will be conducting an investigation into gear types and opportunities to selectively harvest hatchery origin chinook in the Tribe's traditional commercial fisheries during the colonization phase. The Tribe will undertake this investigation utilizing up to an additional 2% ER through a combination of staff and fisher implemented actions consistent with the recovery objectives for the colonization phase. We will monitor the instantaneous mortality associated with each gear type, the relative success of the gear types, and the response of the fishers to the gear. The Tribe will report the results of the annual investigation of selective gear types during our annual adaptive management review.

The investigation will occur utilizing up to an additional 2% ER during a non-pink year in 2018 and a pink year in 2019. We will not experiment in 2020. We will then select our preferred gear types for additional testing utilizing up to an additional 2% ER in 2021 and 2022. Unless agreed to by the co-managers and NOAAF, the experimental phase of this effort will sunset after the 2022 season. Based on the results of our previous work and with input from WDFW and NOAFF, the Tribe will determine which gear type(s) to integrate into our commercial fishery within the 47% ER in 2023 consistent with the recovery objectives for that season. Our desire is to identify and implement selective opportunities acceptable to the tribal community with an agreed to understanding of the release mortality by the time we reach the local adaptation phase and an increased need to manage for escapement composition.

It is unlikely that the LAT cannot be met during the colonization phase. However if pre-season escapement does not exceed the LAT escapement, the Critical Exploitation Rate (CERC) will be triggered. For the Nisqually River MU, the CERC will be up to a maximum 50% reduction in SUS ER impacts (including elimination of the freshwater gear evaluation fishery) after accounting for Alaskan and Canadian fisheries to a FRAM estimated total escapement of 7,000 fish, thereby providing greater certainty of achieving escapement needs of the Stock Recovery Plan Objectives for the colonization phase. The SUS ER reduction will be made equal and commensurate to both marked and unmarked Nisqually Chinook. No further SUS fishery reductions will occur, if after a maximum reduction of 50% US fishery impacts on marked and unmarked Nisqually Chinook does not result in a total FRAM escapement estimate of 7,000 fish.

The co-managers have also agreed to move 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.

Data gaps

The following monitoring activities and directed studies would provide additional information to evaluate program assumptions and population performance. These activities are dependent on funding that has not yet been identified and are not part of the core monitoring program that will be implemented under the 2017 Nisqually Stock Management Plan (NSIT 2017).

Adult Catch and Escapement Monitoring

Nisqually River Catch in Treaty and Sport Fisheries

- Creel surveys could be conducted to improve estimates of landed and incidental mortality of natural-origin Chinook from the sport fishery catch.
- Mark-selective treaty fishery study: test an array of potential commercial selective fishing gear for catch efficiency, incidental mortality, and fishery compatibility.
- Mark-selective sport fishery study: test for differential sport release mortality between estuary and river caught Chinook.
- Study of net dropout rate in treaty commercial fishery to improve fishery mortality estimates.

Nisqually Watershed-Wide Adult Escapement and Composition

- A genetic-based mark-recapture study to estimate spawning escapement based on tissue samples[18] from adult spawners and the following spring's outmigrants (Pearse et al. 2001; Rawding et al. 2014). These escapement estimates would be compared to those from the change-in-ratio method, described under the core monitoring programs to improve estimates of juveniles to adult.
- Genetic-based estimates of effective breeders to juvenile production by origin based on tissue samples from adult spawners by origin and the juveniles outmigrating the following spring to assess differential reproductive success between spawners of natural origin, hatchery-origin strays, and hatchery-origin trucked Chinook.
- Historical escapement could be estimated from live and dead counts and expansion formula (Tweit 1986) and calculated to better understand bias in the historical abundance estimates.
- Carcass recovery surveys of the Mashel River above Highway 7 and along the Nisqually mainstem from the mouth of the Mashel to Powell Creek would further expand understanding of composition.
- Radio tagging and tracking of adults (hatchery- and natural-origin) captured would improve evaluation of migration and spawning behavior above and below the Centralia Diversion Dam.

Juvenile Nisqually River Delta Monitoring

- Lampara net sampling (May to September) in the shallow open delta mudflats areas (including eelgrass bed adjacent areas), and lampara or tow-net sampling in the offshore areas adjacent to the delta would improve life-history and delta productivity estimates.
- Biweekly fyke net sampling (April to September) of sloughs in the emergent marsh zone, areas not reachable by beach seine, would improve delta capacity estimates. As with the beach seine sampling, index fyke trap sites would be chosen from the five sites with data for multiple years, along with a limited number of randomly selected new sites. Index and new sites would be chosen to represent different levels of connectivity to the mainstem Nisqually and to represent the geography of the area, including the Red Salmon Slough and McAllister Creek sides of the delta. Catch and density records would be adjusted for trap efficiency as measured with mark-recapture sampling at each trap on one sampling day.
- Benthic core samples, invertebrate fallout trap samples, and neuston tow samples could be collected monthly from April to July to quantify prey from the substrate, the terrestrial environment, and the water column, respectively.

[18] Genetic-based estimate of spawner abundance for 2012 through 2014 will be completed by the Northwest Indian Fisheries Commission in 2018.

- PIT tags to mark and recapture individual fish also be used to study fish movements within the delta and timing patterns between tagging (at the outmigrant trap, hatchery, or hatchery off-station release site), entry into the delta, and capture or presence at an antenna in the delta. PIT tag recapture rates in the delta and differences between recaptures at well-connected mainstem sites and less well-connected sites could be compared to outmigrant trap annual estimates to look for evidence of differences in habitat use and dispersal with differences in abundance of juvenile Chinook entering the delta.
- Otoliths collected from returning adults to determine the delta residence patterns of adults that survived to return could be paired with juvenile otolith sampling to characterize residence time and growth of juveniles and to compare life-history types between juveniles and successfully returning adults.

Stock Recruitment Analysis

Natural-Origin Adult Abundance to River

- Creel surveys to improve estimates related to the sport fishery catch would also improve estimates of natural-origin adult abundance to river.
- Genetic mark-recapture study described under *Nisqually Watershed-Wide Adult Escapement and Composition* would also improve estimates of natural-origin adult abundance to river.

Survival Rates (Juvenile Outmigrants to Adult Recruits to River)

- Otolith microchemistry for growth, residence time, and life-history types surviving to adult return would improve estimates of survival rates.

Recruitment Rates (Spawners to Adults by Brood Year)

- Genetic-based study of contribution by origin to adult recruitment would improve estimates of recruitment rates.

Habitat Monitoring

- A habitat status and trends program, as recommended in *Methods and Quality of Salmonid Habitat Monitoring of ESA Listed Puget Sound Salmon and Steelhead with Identified Critical Gaps* (Crawford 2013) would link Chinook population response to habitat recovery actions.

Skokomish River Management Unit Status Profile

Component Populations

Spring Chinook Salmon
Summer-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 (Figure 2.1) (Elmendorf and Kroeber 1992; Smoker et al. 1952; Deschamps 1954; WDF 1957a). The spatial separation between the spring and fall populations was generally regarded to be in the vicinity of Little or Big Falls[19] 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 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. Both indigenous racial groups are now extinct in the river basin (Ruckelshaus et al. 2006; SIT and WDFW 2017). This fact presents particular challenges for recovery since well-adapted genetic stock sources do not currently exist in the river system.

Chinook 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 are located in the lower South Fork—a

[19] / The two falls are also often referred to as Upper Falls (Big Falls) or Lower Falls (Little Falls), as discussed in James (1980).

number that has shrunk because of the difficulties that adult Chinook salmon have had in accessing the lower South Fork in recent years due to aggradation and dewatering of the channel. 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[20]. 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.

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 1980's reached record lows in the 1990's and have increased from the early 2000's ranging from about 6,000 to 24,000 fish from 2008-2016 (Table 1). There is significant uncertainty in estimates of natural escapement for some years in this time series. Also, estimates of the proportions of hatchery-origin and natural-origin fish among natural spawners are probably biased in years prior to 2008 due to low mark and sampling rates, few recoveries of coded-wire tagged 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 56% (range of 21% to 95%) from 1999-2007 but averaged approximately 81% (range of 71% to 86%) from 2008-2016 (Table 1).

[20] / 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)

Table 1. Chinook salmon spawning escapement-Skokomish River watershed (SIT and WDFW 2017).

Escapement						Hatchery Origin Return		
Return Year	GA Hatchery Total	Skokomish River				**Total**	**Return rate**	**Stray rate**
		HOR	NOR	Total	pHOS			
1999	8,235	1,310	382	1,692	77%	9,545	86%	14%
2000	4,031	742	220	962	77%	4,773	85%	16%
2001	8,816	1,808	105	1,913	95%	10,624	83%	17%
2002	9,394	109	1,370	1,479	7%	9,503	99%	1%
2003	1,022	266	860	1,126	24%	1,288	79%	21%
2004	12,275	1,650	748	2,398	69%	13,925	88%	12%
2005	16,026	1,599	433	2,032	79%	17,625	91%	9%
2006	12,358	717	492	1,209	59%	13,075	95%	6%
2007	13,270	112	419	531	21%	13,382	99%	1%
2008	13,695	842	292	1,134	74%	14,537	94%	6%
2009	13,220	873	193	1,066	82%	14,093	94%	6%
2010	12,891	902	312	1,214	74%	13,793	94%	7%
2011	14,385	1,147	174	1,321	87%	15,532	93%	7%
2012	22,874	1,323	210	1,533	86%	24,197	95%	6%
2013	21,444	1,469	253	1,722	85%	22,913	94%	6%
2014	6,227	643	206	849	76%	6,870	91%	9%
2015	6,032	310	122	432	72%	6,342	95%	5%
2016	22,076	1,110	232	1,342	83%	23,186	95%	5%
Average	12,126			1,331	80%	13,067	93%	6%
Weighted average					81%			8%

Harvest distribution and exploitation rate trends

The harvest distribution of Skokomish River Chinook salmon is described by coded-wire tag recoveries of fingerlings released from George Adams Hatchery. Since harvest estimates presented in 2010 PSCHMP and Skokomish MUP 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 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 and24% in Canadian (BC) fisheries, with less than 1% occurring in Alaskan (AK) fisheries (Table 2).

Table 2. Harvest distribution of George Adams Hatchery fingerling Chinook salmon, from analysis of CWT recoveries (TCCHINOOK 17-1). 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%

The total annual (i.e., management year) exploitation rate as computed by post-season FRAM runs has exceeded 50%. This exceedance 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.). Pre-terminal SUS ERs ranged from 7% to 10%, and terminal ERs ranged from 19% to 35%.

Table 3. Total fishery-related adult equivalent exploitation rates of Skokomish River natural fall Chinook salmon for management years 2001- 2014, projected by post-season FRAM validation runs using the new Base-Period.

Year	North	PT SUS	Term	Total
2001	8%	15%	32%	56%
2002	13%	14%	26%	52%
2003	13%	14%	30%	58%
2004	14%	18%	24%	56%
2005	11%	15%	30%	57%
2006	12%	13%	39%	64%
2007	16%	14%	39%	69%
2008	14%	11%	40%	65%
2009	14%	9%	40%	62%
2010	11%	10%	34%	55%
2011	15%	10%	29%	55%
2012	12%	14%	35%	61%
2013	9%	11%	29%	49%
2014	11%	15%	32%	59%

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, PST 2010 Chinook Annex).

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 (both plans are currently being updated as per Federal Court Order), 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 for Skokomish River Chinook salmon reflect a new strategy for recovering Chinook salmon suited to environmental conditions in the Skokomish River watershed restored to normative conditions.[21] 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. 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.

To meet this challenging Chinook salmon recovery issue, the Skokomish Tribe 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 Skokomish Indian Tribe (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 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 (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

[21] / 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.

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 or adversely affect the potential for recovering a late-timed (fall) population component. Further, fisheries will be managed to maintain future options for recovery of late-timed Chinook salmon should that need develop. As the plan goes forward, the potential for expanding recovery efforts to include the late-timed racial group is to 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).

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 Chinook salmon, with emphasis on the latest timed 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 mortality in all fisheries.

Harvest Management Objectives and 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 early and summer/fall Chinook salmon, and fisheries for sockeye, coho, and fall chum that involve indirect impacts on either Chinook salmon stock.

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. 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 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.

In order to maximize spawning escapement in the early stages of this process, 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 opportunities will be evaluated and implemented as determined to be consistent with management objectives. Additional commercial fishing opportunities will occur once the population is recovered (SIT and WDFW 2017).

During the re-introduction recovery phase, limited C&S fisheries will occur in the lower Skokomish River 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 1). 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, (as follows), and returns exceed broodstock requirements of the North Fork hatchery program.

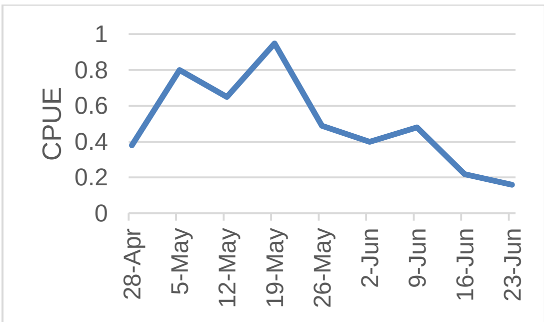


Figure 1. River entry timing for Skagit spring Chinook salmon (SIT and WDFW 2017).

Pre-terminal fisheries will involve incidental mortality of spring Chinook salmon returning to the Skokomish River. Sport Chinook salmon blackmouth fisheries in 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 spring Skokomish River Chinook salmon.

The re-introduction of spring Chinook salmon to the Skokomish River Basin began with release of BY 2014 smolts in the spring of 2015 (WDFW Hatchery Database (FishBooks, 2017), from which the first Age-3 adults were expected to return in 2017. We cannot predict the level or distribution of fishing mortality these Chinook salmon experienced and The Recovery Plan for Skokomish River Chinook salmon will specify the elements of the monitoring program necessary to estimate catch distribution and fishing mortality, and develop harvest objectives and conservation measures.

When sufficient information has been collected to characterize fisheries mortality and distribution, the Skokomish River 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 terminal abundance – 600 adults returning to the Skokomish River mouth - has been set to mark the transition from the Re-introduction phase to the Colonization phase of recovery. 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-early 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 include:

- 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 late component 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 expect that natural escapement will exceed 1,200 in most years.

Summer/Fall George Adams Hatchery Chinook Salmon (2018-----)

Consistent with the objectives of the 2017 Skokomish Chinook Recovery Plan of 1) Reintroduction of spring Chinook salmon, 2) Stabilization of the extant George Adams summer/fall population, and 2) Experimental effort to develop 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 2). The George Adams stock appears poorly adapted to conditions in the Skokomish River, likely due to hatchery influences and impaired habitat and has demonstrated a long-term failure to achieve spawner to spawner productivity values approaching replacement (Table 4).

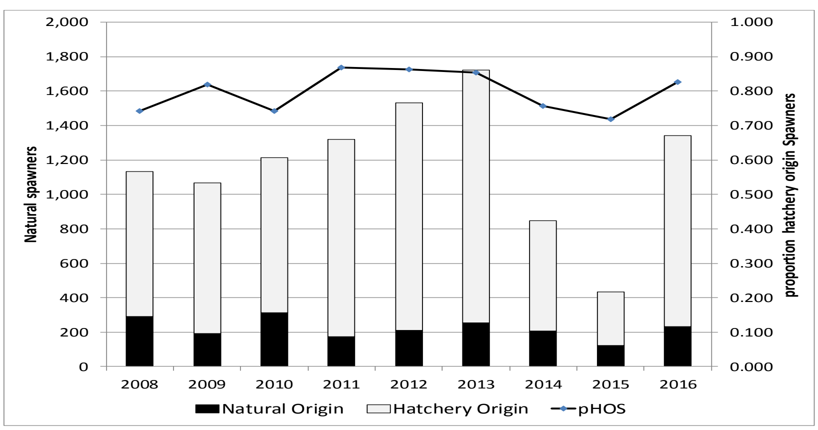


Figure 2. Skokomish River Chinook salmon natural escapement origin (2017 Chinook Recovery Plan update).

Table 4. Spawner to spawner productivity (λ) of Skokomish River fall Chinook salmon salmon. Analysis does not account for harvest and assumed age structure of natural-origin fish is the same as hatchery origin fish due to lack of natural origin scale samples. For spawning years 1999 – 2007, NOR estimates based on expanded CWT recoveries (small sample size with high variability). For spawning years 2008 – 2011, NOR estimates based on proportion of adipose marked broods (increased sample size, lower variability than 1999 – 2007). For spawning years 2008 – 2016, NOR estimates based on approximately 100% marked broods (greatest sample size, lowest variability).

	Spawning Escapement			Returning adults					
Return Year	NOR	HOR	Total	Age-2	Age-3	Age-4	Age-5	Total	Productivity (λ)
1999	382	1,310	1,692	1	450	622	13	1,087	0.643
2000	220	742	962	19	226	499	23	767	0.798
2001	105	1,808	1,913	0	223	195	12	429	0.225
2002	1,370	109	1,479	13	211	328	0	552	0.373
2003	860	266	1,126	4	85	236	0	325	0.288
2004	748	1,650	2,398	67	111	70	0	249	0.104
2005	433	1,599	2,032	72	211	164	4	451	0.222
2006	492	717	1,209	10	29	104	0	143	0.119
2007	419	112	531	0	191	104	1	297	0.560
2008	292	842	1,134	12	25	27	1	66	0.058
2009	193	873	1,066	44	160	114	4	323	0.303
2010	312	902	1,214	21	121	112	4	258	0.213
2011	174	1,147	1,321	17	77	88	3	184	0.139
2012	210	1,323	1,533	13	50	43			
2013	253	1,469	1,722	8	119				
2014	206	643	849	73					
2015	122	310	432						
2016	232	1,110	1,342						

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 more and more advanced 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 will 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 earlier component of 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, and in Purdy Creek (as per the SCSCI). Skokomish River fisheries will commence the first week of July, with regulations for use of hook & line, dip-net, gillnet, and beach seine gear (as per the SCSCI).

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 in Area 12C will be closed during the month of September, with the Skokomish River closed for the month of September thru the first week of October in order to provide escapement for the “late-timed” Chinook salmon population. Coho directed fisheries will begin October 1 in Area 12C and by the second week of October in the Skokomish River.

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 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 than 50%.

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. Coded wire tag recoveries will be used to estimate terminal area harvest rates. However, since these fish are ummarked, 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.

The higher fishing pressure during July, to assist the shift in run timing, and continuing through August, will increase the terminal harvest rate, and the total exploitation rate on this early component of the summer-fall management unit, which is expected to be 60% or more.

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 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. 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.

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 2). 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.

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.

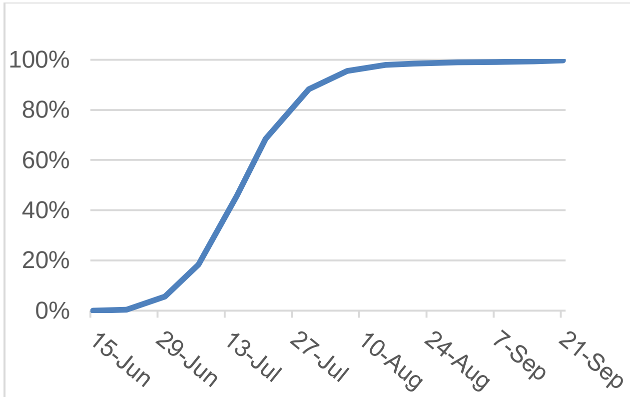


Figure 3. The timing of arrival of sockeye salmon at the Baker River trap (SIT and WDFW 2017).

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 (Fig 3) since the listing (Lestelle et al. draft 2017). The threshold for determining low risk of extinction for the Hood Canal summer chum population is being exceeded by a substantial margin. Summer chum have also rebounded substantially in the Skokomish River and this subpopulation is now considered to be robust (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.

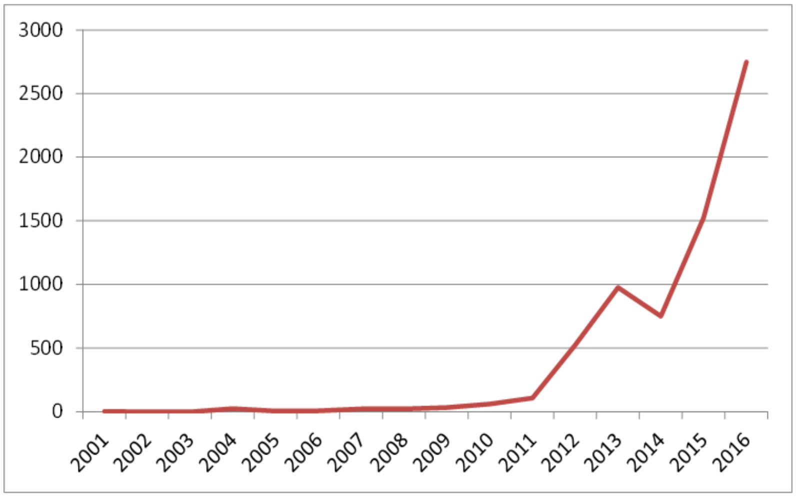


Figure 4. Live counts of summer chum in the Skokomish River, 2000 - 2015. (WDFW SaSI 2017; L Lestelle and Mark Downen pers comm June 6, 2017).

Coho

Fisheries directed at coho salmon in Puget Sound have been managed in accordance with the Comprehensive Coho Plan developed by the co-managers in the 1990s (though this plan was not formally agreed by all parties). Harvest of wild coho 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. 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 (Skokomish Tribe-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 re-evaluate the current methodology used to estimate natural spawning escapement(i.e. current survey reaches, survey frequency, assumptions about redd life and sex ratios)
- Monitor the effects of normative flows, and resulting channel changes in the North Fork on spawning distribution.
- Continue sampling terminal catch and spawning grounds to determine age composition and hatchery / natural origin.
- Continue to operate the smolt trap in the North Fork to estimate production (especially after early-stock reintroduction).
- Monitor and re-evaluate success of the “Late-Timed” Chinook salmon Program
- Re-evaluate terminal cohort reconstruction in order to monitor recruitment and productivity.

Mid-Hood Canal Management Unit Status Profile

Component Sub-populations

Hamma Hamma River summer/fall
Dosewallips River summer/fall
Duckabush River summer/fall

Geographic description

Chinook spawn in the Hamma Hamma River mainstem up to river mile 2.5, where a barrier falls prevents higher access. Spawning can occur also in its tributary, John Creek, when flow permits access. A series of falls and cascades, which may be passable in some years, block access to the upper Duckabush River at river mile 7 and to the upper Dosewallips River at river mile 14. Spawning may also occur in Rocky Brook Creek, a tributary to the Dosewallips. Most tributaries to these three rivers are inaccessible high gradient streams, so the mainstems of the rivers provide nearly all the production potential.

Population structure

In delineating historical population structure, the Puget Sound Technical Recovery Team (TRT) concluded the three Mid-Hood Canal rivers may have supported a single independent Chinook population (Ruckelshaus et al. 2006). The proximity of the Mid-Hood Canal rivers to the Skokomish River suggests there could have been genetic exchange between fish originating from those separate watershed regions. The TRT also considered alternative population structures for Chinook Salmon in Hood Canal, including the possibility that one or more self-sustaining populations of Chinook (e.g., fall and/or spring) occurred in the Skokomish River, with the Mid-Hood Canal rivers (Dosewallips, Duckabush, and Hamma Hamma) having been largely supported by strays from a Skokomish River “source” population.

If there was an indigenous self-sustaining population of Chinook in the Mid-Hood Canal rivers, it likely died out some time in the past due to a combination of factors, including habitat degradation, historic use of splash dams, hatchery influence, and historic harvest practices. A genetic analysis comparing adult Chinook returning to the Hamma Hamma River in 1999 to other Hood Canal and Puget Sound Chinook populations, suggests that returns to the Hamma Hamma River are not genetically distinct from Skokomish River Chinook or from recent George Adams and Hoodsport hatchery broodstock (A. Marshall, WDFW unpublished data). This may be due to the use of George Adams Hatchery origin Chinook by the Hamma Hamma River hatchery supplementation program and to Chinook from other origins (Skokomish River, George Adams Hatchery, and Hoodsport Hatchery) straying into the Mid-Hood Canal watersheds.

Status

The time series of escapement estimates since 1990 shows the population in chronic critical status (Table 1). Escapement estimates for the years prior to 1986 are not accurate, because they were extrapolated from estimates for the Skokomish River population, and were not based on local surveys. Escapement survey areas and survey effort have increased since 2007, so the time series shown in Table-1 may not consistently represent total escapement in the index reaches of these rivers. Surveys in the lower reaches may include some "dip-ins" that ultimately spawned elsewhere in Hood Canal.

Table 1. Natural spawning escapement of Mid-Hood Canal fall Chinook Salmon, 1990-2016.

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	n/a	24
1997		no estimates		
1998	172	57	58	287
1999	557	151	165	873
2000	381	28	29	438
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	16	1	13	30
2007	60	4	9	73
2008	255	0	18	273
2009	98	9	23	130
2010	69	0	15	84
2011	273	5	11	289
2012	416	6	7	429
2013	661	7	4	672
2014	117	13	11	141

2015	236	20	3	259
2016	268	15	8	291

A preliminary analysis of CWT and otolith marks from carcasses collected from the Hamma Hamma River from 2009 through 2016 estimated that hatchery-origin Chinook, including hatchery supplementation origin recruits (SOR), make up 85% of natural spawners, with a range of 71% to 99% (Table 2). Although recoveries of hatchery Chinook have occurred in the Dosewallips and Duckabush rivers, the proportion of hatchery-origin adults spawning in these rivers is uncertain, because few carcasses are available to sample and southern Hood Canal hatchery releases have only been mass-marked since brood year 2007.

Table 2. Proportions of natural, hatchery, and supplementation origin Chinook, based on carcass recoveries from 2009 through 2016.

Origin	2009	2010	2011	2012	2013	2014	2015	2016	Average
NOR	0.24	0.21	0.15	0.01	0.06	0.29	0.04	0.21	0.15
HOR	0.11	0.00	0.02	0.00	0.06	0.00	0.04	0.00	0.03
SOR	0.64	0.79	0.84	0.99	0.88	0.71	0.93	0.79	0.82
Hatchery (HOR & SOR)	*75%*	*79%*	*85%*	*99%*	*94%*	*71%*	*96%*	*79%*	*85%*
Natural Origin (NOR)	*24%*	*21%*	*15%*	*1%*	*6%*	*29%*	*4%*	*21%*	*15%*

HOR are determined by adclips of CWT's w/o otolith marks

2011 and 2016 determined with cwt data only

The hatchery supplementation program for Mid-Hood Canal Chinook began in the Hamma Hamma River in 1995. The program ended in 2015 primarily because it was not successful at achieving its goal of restoring a self-sustaining Chinook population to the Hamma Hamma River, and more broadly a Chinook population to the Mid-Hood Canal Rivers (LLK Memorandum, 2014). A secondary consideration for ending the program was limited staff and funding. In 2005, following a primary recommendation of the Hatchery Scientific Review Group, the supplementation program attempted to collect 100% of broodstock from the Hamma Hamma River to promote local adaptation. However, the program was unable to collect enough brood from the Hamma Hamma River, and continued to rely on cross basin transfers from the George Adams Hatchery to supply a large proportion of its annual broodstock needs. The supplementation program's progress toward establishing a locally adapted self-sustaining Chinook population was likely inhibited by the small size of the program, limited quality habitat, poor population fitness, and the likely possibility that the current stock's life history does not match the habitat and flow regimes of the Mid-Hood Canal rivers. Fishery related mortality may also have contributed to the lack of success, however total fishery related mortality has been relatively low with an average of less than 25% total exploitation rate (stdev 2.4%) from 1999 through 2014.

Current habitat conditions, available spawning area, and flow regimes of the Mid-Hood Canal rivers may not be suitable to sustain natural fall Chinook production. Although spawner abundance estimates showed a dramatic increase between 1998 and 2001, that increase was followed by a decrease of similar magnitude since 2002. There is evidence to suggest that these changes in abundance were in part related to concurrent changes in marine net pen yearling Chinook hatchery production in the area, and therefore may not be indicative of changes in the status or productivity of the population (WDFW memorandum to Co-Managers, February, 2010). Natural productivity of the present Mid-Hood Canal Chinook stock is very low, with natural origin fish representing only a small proportion of total escapement (Figure 1).

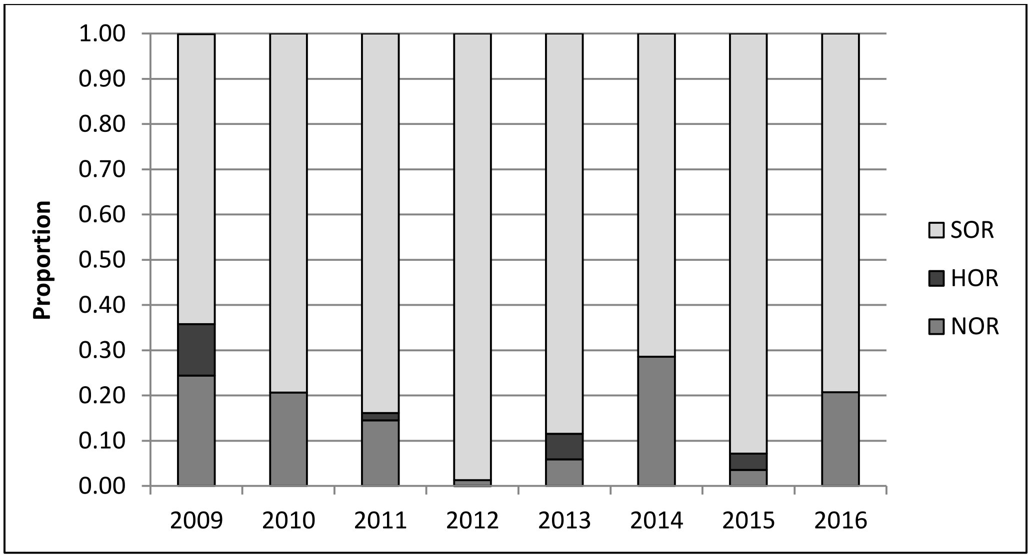


Figure 1: Proportions of natural, hatchery, and supplementation origin Chinook, based on carcass recoveries from 2009 through 2016.

Although habitat has been identified as a limiting factor, it alone does not explain the very low natural Chinook productivity of the Mid-Hood Canal rivers. This has led to doubt as to whether the George Adams (Green River origin) fall Chinook stock is a suitable stock for recolonizing Mid-Hood Canal. Furthermore, there are potential inconsistencies between the current stock's life history and the flow regime of the mid-Hood Canal rivers. The peak flows, in both the Dosewallips and Duckabush rivers, occurs from April through early July, with the Duckabush River having a second peak from Late October through December. The lowest flows for both rivers occur August through mid-October at the time when adult Chinook currently return to the Mid-Hood Canal rivers.

Alternatively, the chronically low natural production in Mid-Hood Canal rivers and the lack of success of the hatchery supplementation program could support increased consideration of the hypothesis that historically the Mid-Hood Canal rivers may have only supported an intermittent and not self-sustaining population. The Mid-Hood Canal watersheds may have been dependent on a healthy returning Skokomish River population to contribute straying spawners to support the Chinook production in those systems.

Considering the current stock's poor natural productivity and the discontinuation of the hatchery supplementation program, the co-managers anticipate that Mid-Hood Canal Chinook escapement will be extremely low for the duration of this plan, and likely below a point of population stability. However, within the timeframe of this plan, it is possible that an alternative program to restore a self-sustaining, locally adapted Chinook population could be implemented, in conjunction with continued habitat improvement and restoration.

Harvest distribution and exploitation rate trends

The FRAM model is used to create both preseason and postseason estimates of AEQ exploitation rates for Mid-Hood Canal Chinook. The FRAM model does not directly estimate the harvest distribution and fishery exploitation rates of Mid-Hood Canal Chinook, because of insufficient numbers of mid-Hood Canal Chinook CWT recoveries from fisheries. Instead, FRAM relies on coded wire tag recoveries of George Adams Hatchery, Hoodsport Hatchery, and Rick's Pond fall fingerling Chinook as a surrogate for Mid-Hood Canal Chinook, because it is reasonable to assume that given their similar genetic make-up and life history, the tagged fingerling Chinook released from the George Adams Hatchery on the Skokomish River should follow a similar migratory pathway and experience mortality in a similar set of pre-terminal fisheries in British Columbia and Washington.

The FRAM model was recently updated with a new base period, which better reflects the distribution and structure of modern salmon fisheries that impact Puget Sound Chinook. The co-managers completed a series of postseason FRAM validation runs with the new base period for the years 1992 through 2014. These postseason FRAM validation runs with new base period were used to re-evaluate past fishery impacts on Mid-Hood Canal Chinook (Table 3). FRAM with the new base period was first used for preseason planning in 2017.

Table 3. Average AEQ ER on Mid-HC Chinook by fishery region for the periods (1999-2014), (2004-2009), and (2010-2014) as estimated by FRAM validation runs with new base period.

PERIOD	AK/CAN	P-T SUS	TERM	TOTAL
1999-2014	12.4%	11.6%	0.2%	24.2%
2004-2009	13.9%	10.9%	0.1%	25.0%
2010-2014	11.8%	11.3%	0.2%	23.4%

The postseason FRAM estimates of total annual exploitation rates for Mid-Hood Canal Chinook show a large decreasing trend in total exploitation rate from 1992 through 1995, from a high of 51.6% down to 24.7%. Then for the period 1995 through 2013, the annual total exploitation rate has been relatively steady with an average of 24.5%, standard deviation 2.4% (Figure 2). The southern U.S. exploitation rate showed a decreasing trend during the period 1992 to 1999, before becoming relatively stable from 1999 through 2014 (Figure 3), with an average of 11.8% (stdev 2.2%) during the stable period. In contrast, the exploitation rate trend in northern fisheries (Alaska and Canada) has shown a contrary pattern of substantially higher exploitation rates from 2002 through 2014 (Figure 4). Terminal area exploitation rates have remained very low since 1992, averaging less than 1%. FRAM estimates of fishing impacts on Mid-Hood Canal Chinook utilize recoveries of George Adams Hatchery, Hoodsport Hatchery, and Rick's Pond tags in the updated FRAM model base period. The co-managers are currently re-examining those assumptions for Mid-Hood Canal Chinook in Hood Canal and other Puget Sound fisheries.

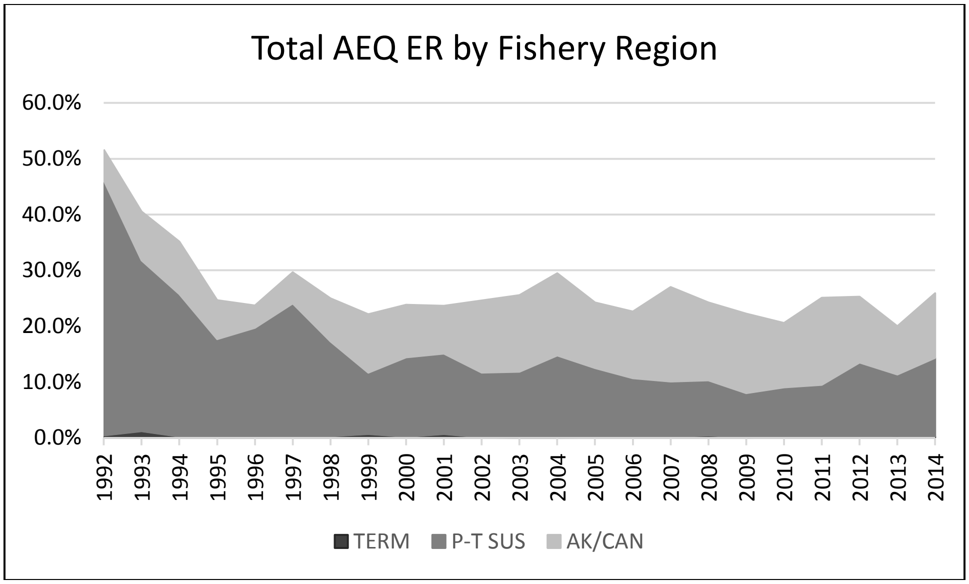


Figure 2. Total annual adult equivalent fisheries exploitation rate of Mid-Hood Canal Chinook from 1992 – 2014, as estimated by FRAM validation runs using new base period.

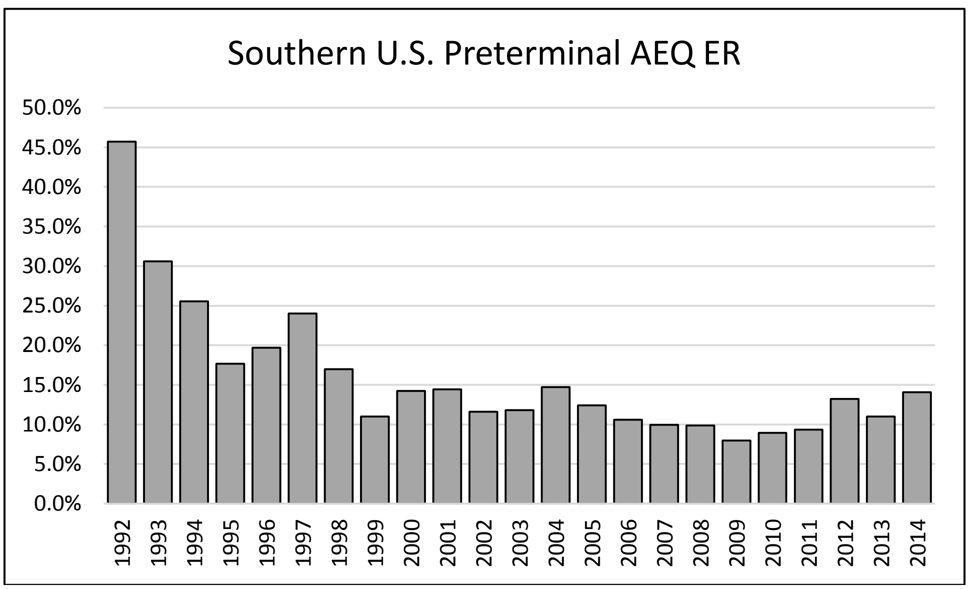


Figure 3. Southern U.S. annual adult equivalent fisheries exploitation rate of Mid-Hood Canal Chinook from 1992 – 2014, as estimated by FRAM validation runs using new base period.

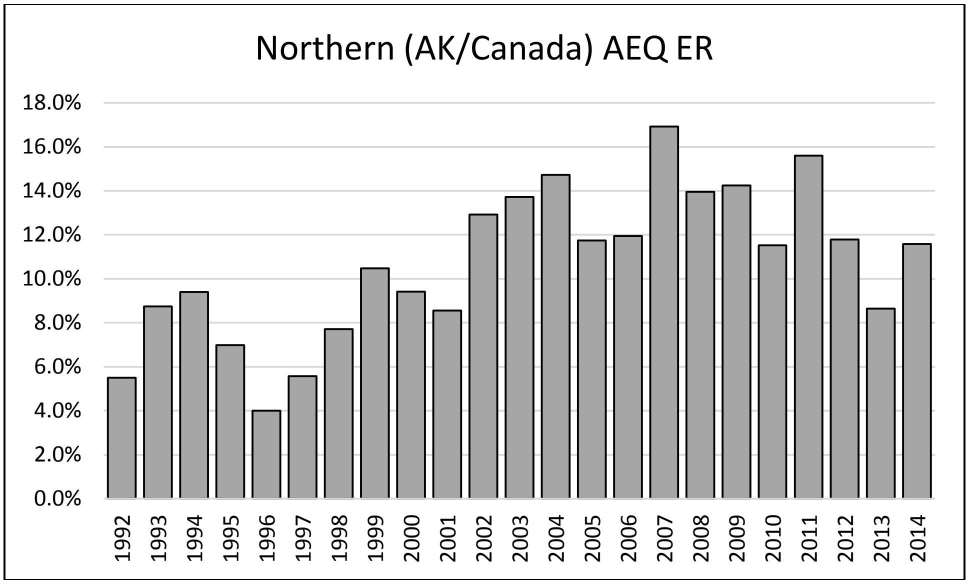


Figure 4. Northern fisheries (Alaska and Canada) adult equivalent fisheries exploitation rate of Mid-Hood Canal Chinook from 1992 – 2014, as estimated by FRAM validation runs using new base period.

Management Objectives

The recovery objective for the Mid-Hood Canal MU is to restore and maintain a sustainable, locally adapted, natural-origin Chinook sub-population. The harvest management objective is to avoid impeding the recovery objective for a Mid-Hood Canal Chinook population.

The UMT is set at 750, which is the best available estimate of MSH escapement for the Mid Hood Canal population. If escapement is projected to be less than 750, Southern U.S. pre-terminal fisheries will be managed to not exceed an exploitation rate of 15%, as estimated by the FRAM model. In this case preterminal fisheries include coastal troll and recreational fisheries managed under the Pacific Fisheries Management Council, marine commercial fisheries outside of Hood Canal, and marine recreational fisheries in Puget Sound. The extreme terminal areas for this management unit, the Hamma Hamma, Dosewallips, and Duckabush rivers, will be closed if escapement is not projected to exceed 750.

Terminal-area fisheries at the far southern end of Hood Canal, near the mouth of or in the Skokomish River, are assumed to have no impact on the Mid-Hood Canal population. Coded-wire tag recovery data representing Mid-Hood Canal Chinook, including recoveries of Hamma Hamma hatchery Chinook, are under review to evaluate the validity of this assumption.

A low abundance threshold of 400 Chinook spawners has been established for the Mid-Hood Canal MU. This value is approximately 50% of the current MSY goal for the Mid-Hood Canal sub- populations. If escapement is projected to fall below this threshold, conservation measures will be implemented in pre-terminal SUS fisheries to further reduce mortality, such that that the projected pre-terminal Southern U.S. (PTSUS) exploitation rate does not exceed 12.0%.

Even with a hatchery supplementation program operating on the Hamma Hamma River from 1996 to 2015, spawning escapements of Mid-Hood Canal Chinook has been nearly consistently below the low abundance threshold since 1990, with the only exceptions being years 2000 and 2013, with 873 and 672 spawners respectively (Figure 5). The Mid-Hood Canal management unit is expected to remain in critical status for the duration of this Plan. The co-managers recognize the need to provide across-the-board conservation measures in this circumstance and to avoid an undue burden of conservation falling on the terminal fisheries.

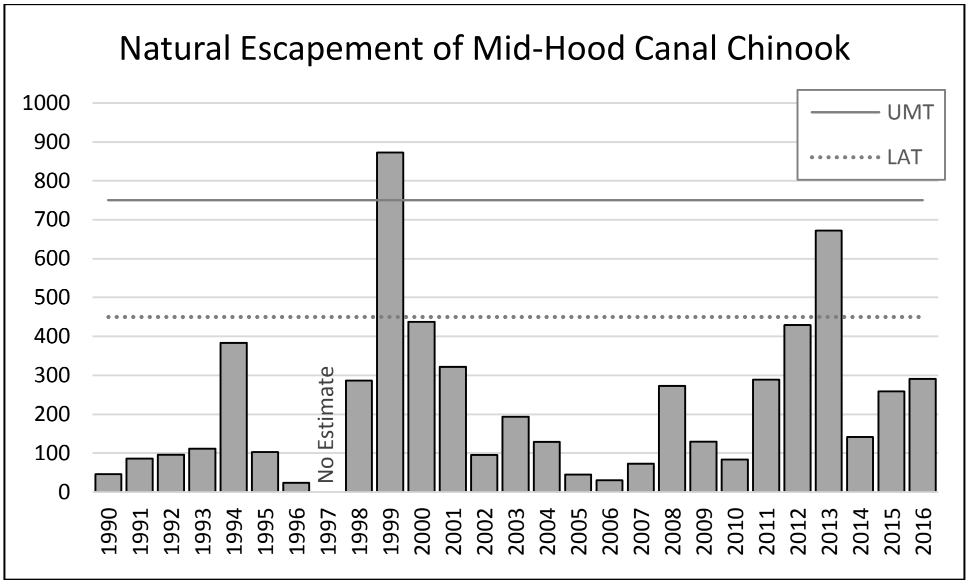


Figure 5. Natural spawning escapement of Mid-Hood Canal fall Chinook Salmon 1990-2016 in relation to the Low Abundance Threshold and Upper Management Threshold.

Terminal-area fisheries in northern Hood Canal have averaged 0.2% exploitation rate on Mid Hood Canal Chinook since Puget Sound Chinook were ESA listed in 1999, as estimated by postseason FRAM using the new base period. Southern U.S. preterminal fisheries have averaged less than 12% exploitation rate during that same time period. Southern U.S. impacts on Mid-Hood Canal Chinook are expected to remain at this level (or below) for the term of the Co-managers' Plan.

Tribal net fisheries in Areas 12 and 12B have been closed during the Chinook management period; coho fisheries, which have been delayed until late September in Area 12 and until October in Area 12B, may include very low incidental mortality on Mid-Hood Canal Chinook; Tribal beach seine fisheries in Area 12, 12A, and 12B are required to release Chinook until September 30th. Recreational fisheries in northern Area 12 have been closed, or when open are required to release Chinook through October 15th. Similar regulatory measures are anticipated to continue for the duration of this Plan.

Data gaps

- Continue to improve escapement estimates
- Evaluate performance of the preseason forecasts and make appropriate refinements
- Continue to monitor and evaluate historic and recent coded-wire tag recoveries, including recoveries of tags from the Hamma Hamma supplementation program, in fisheries and escapement to review current assumptions about effects of fisheries within Hood Canal and other Puget Sound marine areas upon Mid-Hood Canal Chinook
- Use additional adult escapement, spawner composition, and juvenile outmigrant data as they become available, to improve understanding of the productivity and capacity of the MU
- Continue to identify and improve the understanding of factors limiting the productivity of Chinook Salmon in Mid-Hood Canal
- Continue to evaluate habitat and flow regimes to help determine if there is a more suitable stock with life history traits that would more closely match the current environmental conditions of Mid-Hood Canal rivers, and in consideration of potential effects of climate change

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). Elwha Chinook river entry timing has been documented as early as May 20 and ended near September 10 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-three 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.

Table 1. Historic comparison of Redd distribution, 1998 – 2016.

Historic Comparison of Redd Distribution, 1998 through 2016									
Stream and section	Reach	SURVEY REACHES (miles)			Minimum	Maximum	Average		Average
Lower Dungeness River (RM 0.5-RM 10.8)	Number	Lower RM	Upper RM	Total length	Redd count	Redd count	Redd count	Proportion	redds/mile
Mouth to Woodcock Bridge	1	0.50	3.30	2.80	2	127	30.2	0.174	10.79
Woodcock Bridge to Hwy 101	2	3.30	6.40	3.10	1	128	37.5	0.216	12.09
Hwy 101 to Taylor Cut-Off - May	3	6.40	9.20	2.80	5	88	33.0	0.190	11.79
Taylor Cut-Off - May to Canyon Ck.	4	9.20	10.80	1.60	4	75	25.3	0.145	15.79
Total				**10.30**				**0.725**	
Upper Dungeness River (RM 10.8-RM 18.7)									
Canyon Creek to Clink Bridge	5	10.80	13.80	3.00	0	79	18.8	0.108	6.26
Clink Bridge to Forks Campground	6	13.80	15.80	2.00	0	59	11.0	0.063	5.50
Forks Campground to East Crossing	7	15.80	17.50	1.70	0	42	7.2	0.042	4.24
East Crossing to Gold Creek	8	17.50	18.70	1.20	0	13	1.5	0.009	1.27
Total				**7.90**				**0.222**	
Gray Wolf River (RM 0.0-RM 6.1)									
Mouth to RM 1.0 Bridge	9	0.00	1.00	1.00	0	26	4.6	0.026	4.58
RM 1.0 Bridge to Above 2 Mile Camp	10	1.00	2.50	1.50	0	38	4.1	0.023	2.70
Above 2 Mile Camp to Cliff Camp	11	2.50	4.00	1.50	0	5	0.5	0.003	0.32
Cliff Camp to Slab Camp -Suppl. Surveys	12	4.00	5.10	1.10	0	3	0.3	0.002	0.24
Slab Camp and upstream 1 mile -Suppl. Surveys	13	5.10	6.10	1.00	0	0	0.0	0.000	0.00
Total				**6.10**				**0.0540**	

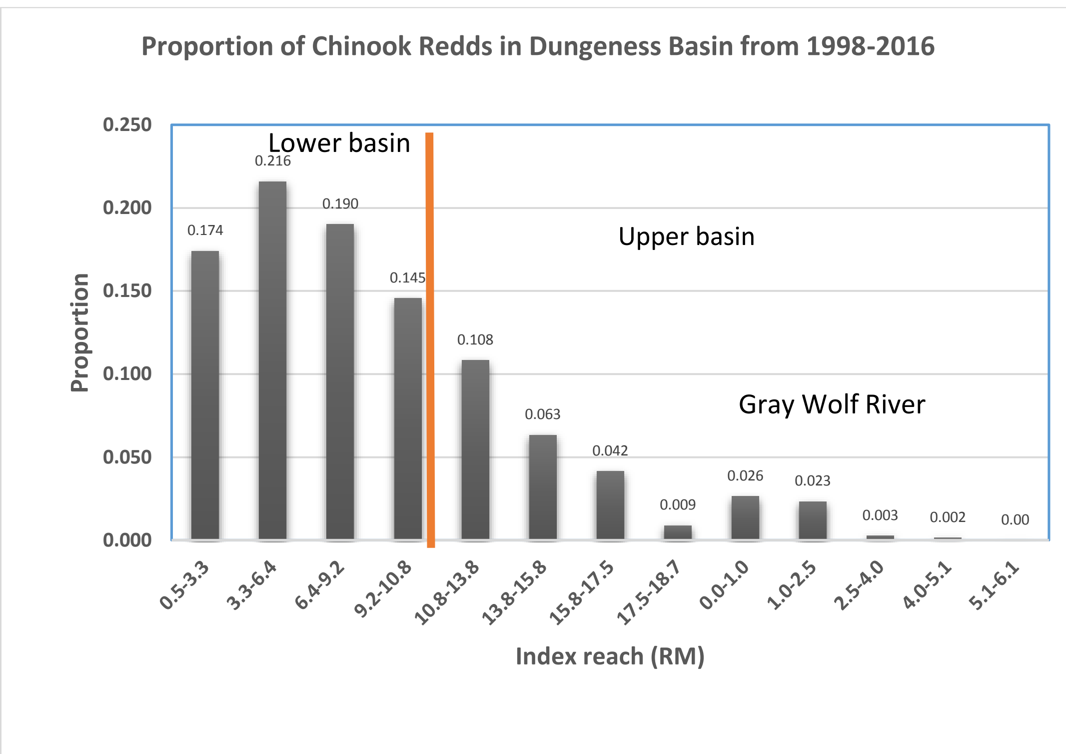


Figure 1. Proportion of Chinook redd in Dungeness Basin from 1998-2016

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 18% and 22%, 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 1986-2016

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 phases which may increase capacity. Upon completion of these projects production capacity may be assessed again. From 1986 through 2000, the average total escapement was only 153. Escapements increased from 2000 through 2006, averaging 893. However, this increase is largely attributable to the captive brood supplementation program. Estimates of natural-origin fish have remained low, averaging only 179 from 2001-2006. 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.

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 for Return Years 1988-2016.

Return year	Age 3	Age 4	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	199	600	278	1,077
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	88	93	23	204
2015	101	279	27	407
2016	121	303	90	514
Mean	71	237	87	395
Stand. dev	80	226	124	347
95% CI	38	108	59	165
Sample size	29	29	29	29
SQRT (n)	5.39	5.39	5.39	5.39
Lower CI	33	129	28	230
Upper CI	109	345	146	560
Proportion	0.1795	0.6003	0.2202	1.0000

For return years 2007-2016, the NOR portion of the Chinook returns ranged from 43 to 250 and the number of HOR returns ranged from 90 to 561. The ten-year average proportions of NORs and HORs are 0.3428 and 0.6572, respectively (Table 3).

Table 3. Total number of NOR and HOR natural spawners and broodstock in the Dungeness River for return years 2007-2016.

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	Proportion NOR Spawners + Broodstock	Natural Spawners + Broodstock HOR	Proportion HOR Spawners + Broodstock	Total returns NOR+HOR
2007	146	159	305	47	51	98	193	0.4789	210	0.5211	403
2008	86	54	140	53	36	89	139	0.6070	90	0.3930	229
2009	71	57	128	42	50	92	113	0.5136	107	0.4864	220
2010	76	269	345	18	94	112	94	0.2057	363	0.7943	457
2011	83	452	535	21	109	130	104	0.1564	561	0.8436	665
2012	212	296	508	38	68	106	250	0.4072	364	0.5928	614
2013	46	122	168	31	79	110	77	0.2770	201	0.7230	278
2014	21	87	108	22	74	96	43	0.2108	161	0.7892	204
2015	65	200	265	37	105	142	102	0.2506	305	0.7494	407
2016	135	273	408	30	77	115	165	0.3204	350	0.6796	515 4/
Mean	94.1	196.9	291.0	33.9	74.3	109.0	128.0	0.3428	271.2	0.6572	400.0

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 2005-2016

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 54,507 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 Juvenile Salmonid Production 2005-2016.

Catch and estimated production of juvenile salmonids migrating from the Dungeness River (2005-2016)

Begin	End	Subyearling Chinook Natural Prod.	Subyearling Chinook Hatchery Prod.	Natural 0+ Coho Prod.	Natural 0+ Pink Prod.	Natural 0+ Chum Prod.	Natural 1+ Steelhead Prod.
3/8/2005	8/5/2005	81,865		57,095			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		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		155,645	5,972
2/3/2016	7/25/2016	5,556	73,279	20,493	89,802	23,927	4,354
Average production all years		54,507	65,902	32,182		275,337	10,093

Data source DRAFT: Pete Topping, WDFW

1/ Natural origin Chinook production estimates are extrapolated to and starting date of 1/15 and an ending date of 8/31

2/ 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.

3/ 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 (Pete Topping, WDFW).

Estimated egg to smolt survival has averaged 5.03% 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. The last two years (2015 and 2016) have seen some of the highest flows, as well as the highest number of days at high flow. Consequently, the last 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-smolt survival related to peak flow (CFS) 2005-2016.

Natural origin subyearling Chinook production and estimated egg to migrant survival related to peak flow (CFS) during inter-gravel period, Dungeness River trapping years 2005-2016.								
	Max Flow (CFS) Oct 1 thru Feb 1				Estimated			
Trap			# Day's flows	Number	Deposition	Subyearling	Egg to migrant	Migrants
Year	CFS	Date	> 2000CFS	Redds	at 5,300 eggs	production	Survival	Per Redd
2005	2130	10-Dec	2	381	2,019,300	81,865	4.05%	215
2006	2440	25-Dec	1	382	2,024,600	136,724	6.75%	358
2007	1820	15-Dec	0	562	2,978,600	110,021	3.69%	196
2008	3180	4-Dec	2	122	646,600	11,612	1.80%	95
2009	1640	8-Jan	0	56	296,800	20,443	6.89%	365
2010	3100	12-Jan	5	51	270,300	10,604	3.92%	208
2011	3890	12-Dec	2	138	731,400	10,250	1.40%	74
2012	1500	23-Nov	0	214	1,134,200	71,810	6.33%	336
2013	1450	1-Dec	0	203	1,075,900	164,815	15.32%	812
2014	817	11-Jan	0	67	355,100	26,513	7.47%	396
2015	3680	10-Dec	6	43	227,900	3,870	1.70%	90
2016	3420	9-Jan	6	106	561,800	5,556	0.99%	52

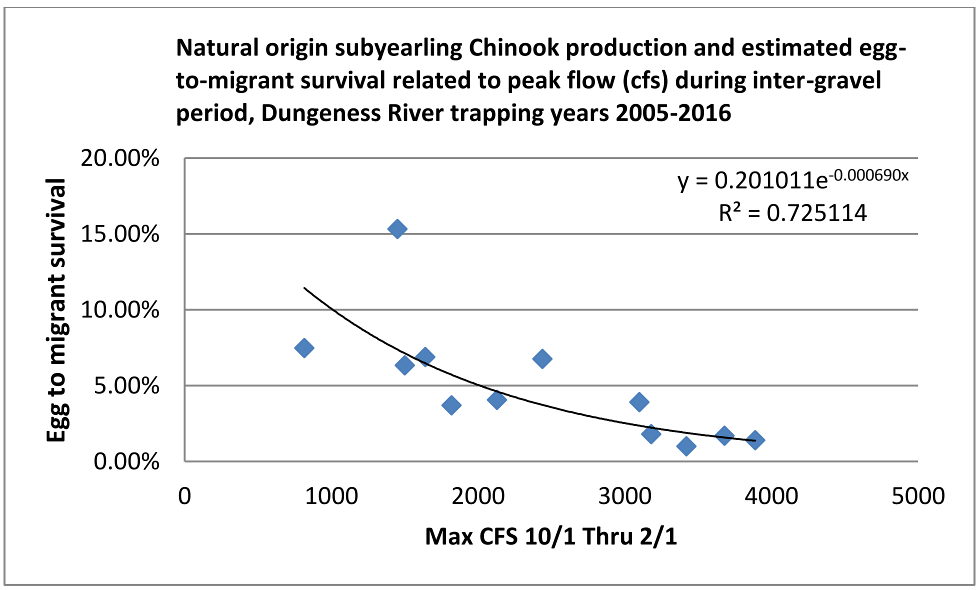


Figure 2. NOR sub-yearling Chinook production vs Peak Flow (CFS).

Another concern for co-managers is the low in-river survival rate associated with hatchery Chinook. Since 2007, the average survival rate for hatchery Chinook from release site to the trap site was 50.3% and has gone as low as 12% in 2009 (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 involved trucking one CWT release group 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.

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.

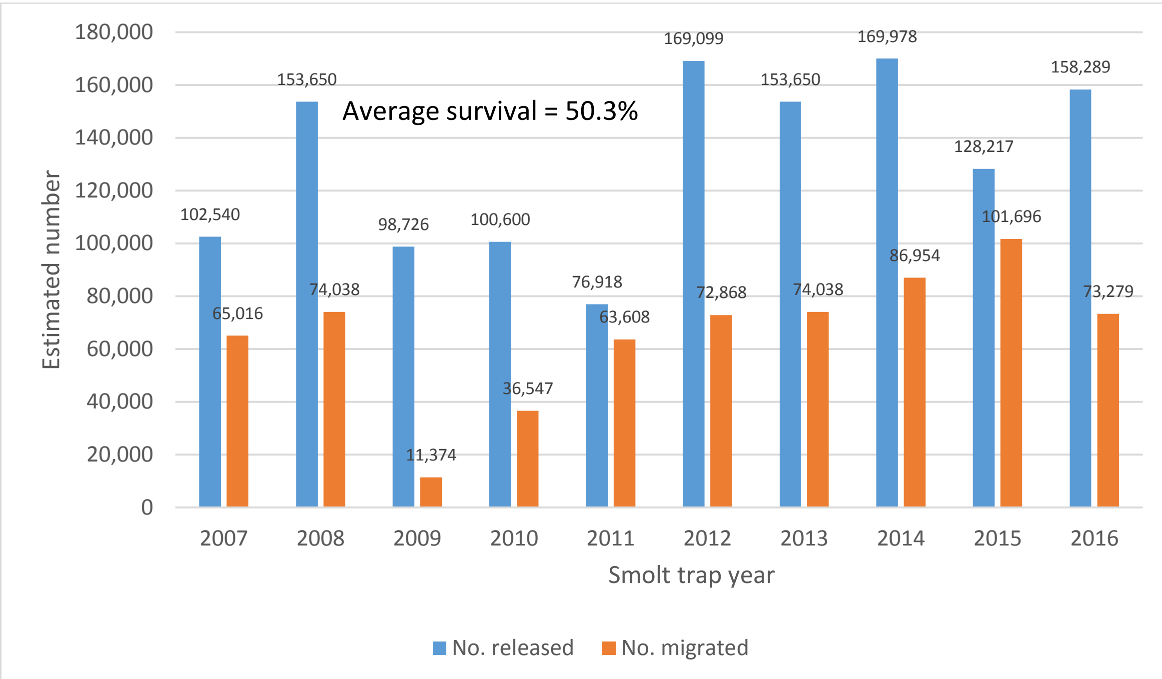


Figure 3. Number of hatchery Dungeness Chinook sub-yearlings released in the Dungeness basin and the estimated number Chinook sub-yearlings migrating past trap located at RM 0.5 by trap year.

Dungeness Marine Survival and Productivity

The Smolt-to-Adult Rate (SAR) survival for Dungeness Chinook is relatively low, with an average of 0.0049 from 2004 through 2011. NOR smolt-to-adult return rates were estimated by dividing the number of NOR adults produced from natural spawners by the number of natural origin smolts. NOR return rates, based on age 2 to age 5 returns, ranged from 0.0008 to 0.0116 (Table 6). Recruits per Spawner (R/S) or Adult (HOR+NOR natural spawners) to Adult (NOR) production were measured for brood years 2004 to 2011 and ranged from 0.0598 to 1.6286 and averaging 0.4499 for the 8- year period.

Table 6. NOR smolt- to- adult return rates and recruits per spawner (R/S) or adult (NOR+HOR) -to-NOR adult return rates for Dungeness River Chinook for brood years (spawn years) 2004-2011.

Spawn year	Total natural spawners	Smolt trap year	Juvenile Chinook abundance	Age 2 NOR	Age 3 NOR	Age 4 NOR	Age 5 NOR	Age 6 NOR	Total NOR	NOR Smolt- to-Adult Rates (SAR)	R/S Adult-to-Adult Rate
2004	953	2005	81,865	0	75	98	17	0	190	0.0023	0.1994
2005	955	2006	136,724	0	38	96	12	0	146	0.0011	0.1529
2006	1,405	2007	110,021	0	4	57	23	0	84	0.0008	0.0598
2007	305	2008	11,621	0	25	44	19	0	88	0.0076	0.2885
2008	140	2009	20,443	0	37	175	16	0	228	0.0112	1.6286
2009	128	2010	10,604	0	56	57	10	0	123	0.0116	0.9609
2010	345	2011	10,250	0	2	21	11	0	34	0.0033	0.0986
2011	535	2012	71,810	0	13	74	26	TBD	113	0.0016	0.2112
2012	508	2013	164,815	0	14	120	TBD	TBD	134	TBD	
2013	168	2014	26,513	0	16	TBD	TBD	TBD	TBD	TBD	
2014	108	2015	3,870	4	TBD	TBD	TBD	TBD	TBD	TBD	
2015	265	2016	5,556	TBD	TBD	TBD	TBD	TBD	TBD	TBD	

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% (Figure 4.)

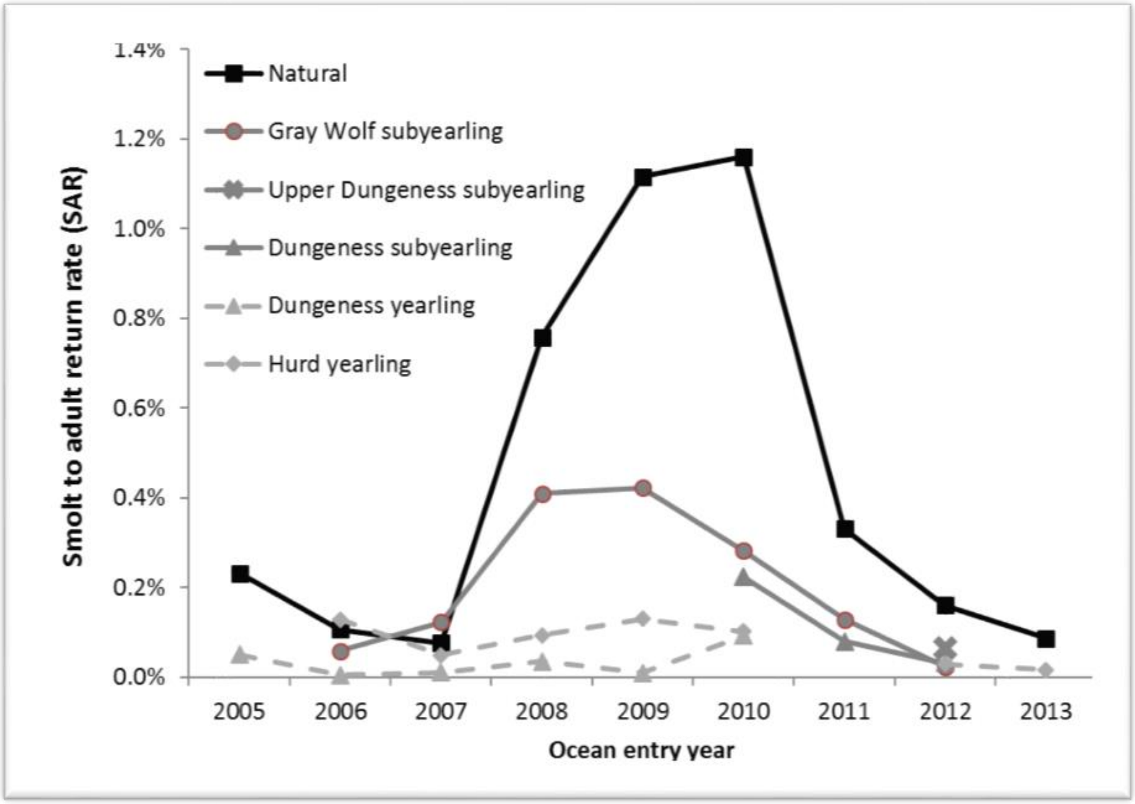


Figure 4. Smolt to adult return rate of natural origin (black) and hatchery produced (gray) Chinook salmon in the Dungeness River. Natural survivals are from the river mouth (smolt trap location) to adult return, whereas hatchery survivals are from release to adult return. In comparison to the natural survival, hatchery estimates therefore include the additional mortality suffered in the river prior to ocean entry. Estimates are total return to the river, and do not account for fishing mortality. DRAFT January 10 2017: Randy Cooper, Pete Topping, and Joe Anderson WDFW.

Hatchery and Habitat Practices/Projects

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 out-performed the yearling releases. Consequently, the release strategy has been adjusted to include 200,000 accelerated zero aged Chinook as well as an additional 50,000 yearling 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.

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 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 over conserved 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 2018.

Management Objectives

The management objectives for Dungeness Chinook are to stabilize escapement and recruitment, with the ultimate objective of restoring the natural-origin recruit population through adaptive hatchery supplementation, habitat improvements, and fishery restrictions.

The Upper Management Threshold (UMT) for the Dungeness MU is a TRS of 925 adult returns, corresponding to the calculated escapement goal described above. The Low Abundance Threshold (LAT) is a TRS of 500 adult returns (HOR + NOR), which is approximately 50% of the escapement goal. The status of this population under the 2010 plan has been above the critical level in 3 of the last 10 years. At the recent year average NOR proportion of 32.04% (Table 3) the 500 LAT corresponds to about 160 NOR's. The NOR range over the last 10 years has been between 43 and 250. A return of 500 or less would yield few NOR returns and require additional management actions to be implemented.

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 due to the fact that 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 five of the QAQC process, August 2017), the pre-terminal SUS ER has averaged 3% over the last 10 years and the terminal ER has averaged 0.7% over the same time period. In contrast, harvest in Canadian and Alaska fisheries have averaged 12% ER over the last 10 years with 2 years reaching as high as 20%. In years 2011 and 2012, when the forecast exceed 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 7). 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 while providing opportunities for other Chinook stocks that may be available for harvest in mixed stock areas.

Table 7. New Base Period post season FRAM exploitation rates for Dungeness Chinook 2005-2014.

Year	Northeren ER	PT SUS ER	Terminal SUS ER	Total ER
2005	7%	1%	0%	8%
2006	5%	1%	0%	6%
2007	14%	3%	0%	18%
2008	20%	4%	2%	26%
2009	8%	3%	5%	16%
2010	14%	6%	0%	20%
2011	20%	5%	0%	25%
2012	13%	4%	0%	17%
2013	7%	4%	0%	10%
2014	11%	4%	0%	15%
10 yr Avg	**12%**	**3%**	**1%**	**16%**

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 very close to the point of instability, and will be treated as such. As mentioned above, a LAT of 500 relates to about 160 NOR Chinook. Looking back at table 6, the average NOR R/S ratio was 0.45 between 2004 and 2011 and was only greater than one in one year of the data set. Given an average NOR R/S ratio of less than a half a fish per spawner, a NOR return of 160 may compromise the population. 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). These actions are likely to continue in the future, and other actions 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. Specifically, when sufficient years of CWT and adipose clipped Elwha Chinook releases have accrued, an out-of-base FRAM calibration procedure using those tag groups will be explored.

Contribution to Fisheries

No harvest is presently directed on listed Chinook produced in the Dungeness River. Tribal and non-Tribal fisheries directed at species other than Chinook will be 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 hand held 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 impacts to Dungeness Chinook. Harvest opportunity is the long-range objective, both direct and indirect, when recovery goals are attained.

Table 8 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 total mortalities annually from 2008 through 2014, while fisheries to the North (particularly Canada) have averaged 77 total mortalities annually during the same time period. Most SUS impacts to Dungeness Chinook occur in the winter/spring time period due to the fact that the Chinook and 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 9 and 10 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 8. Impacts on Dungeness Chinook by fishery expressed as adult equivalent (AEQ) mortalities.

Impacts on Dungeness Chinook By Fishery Expressed as adult equivalent (AEQ) Mortalities										
Fishery	**2017**	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**
Canada	58	77	N/A	24	21	102	177	76	18	61
Alaska	10	11	N/A	3	3	13	20	13	2	6
South of Falcon	0	0	N/A	0	0	0	0	0	0	0
NoF Ocean (Non-Treaty)	2	1	N/A	0	0	2	2	1	0	0
NoF Ocean (Treaty)	4	5	N/A	2	2	9	4	3	0	2
PS Treaty Troll	5	7	N/A	1	2	1	4	7	1	0
Area 5 Sport	4	3	N/A	1	1	3	13	7	1	1
Area 6 Sport	5	9	N/A	4	3	4	16	6	3	1
Area 7 Sport	2	2	N/A	1	1	3	3	1	0	1
Area 8-13 Sport	4	4	N/A	1	1	4	4	3	1	1
Puget Sound Net (Non-Treaty)	1	1	N/A	0	0	0	0	0	0	0
Puget Sound Net (Treaty)	1	2	N/A	2	1	3	2	2	9	10
FW Sport	0	0	N/A	0	0	0	0	0	2	0
FW Net	0	0	N/A	0	0	0	0	0	0	0
Escapement	364	347	N/A	198	271	614	649	435	189	222

1/2016 and 2017 data come from pre-season estimates.
2/2014 and earlier data come from post-season data.
3/2015 data are not yet available (managers have a new base period for Chinook, so no preseason run is available for 2015; the most recent post-season run was for 2014).

Table 9. Dungeness River Hatchery Spring Chinook Fishery Contributions.

Brood Years: 2000-2011			
Fishery Years: 2004-2015			
Average SAR% [a]		**0.09**	**0.19**
Agency	***Non-WA Fishery***	***% of total Survival***	
		Sub-yearlings	***Yearlings***
CDFO	All	*5.81*	*11.15*
NMFS	All	*3.93*	*0.06*
Agency	***WA Fishery***	***Sub-yearlings***	***Yearlings***
WDFW	10- Ocean Troll	---	*0.32*
WDFW	15- Treaty Troll	---	*1.35*
MAKA	15- Treaty Troll	*3.35*	---
QDNR	22- Coastal Gillnet (Strays) [b]	---	*0.15*
SUQ	23- PS Net	---	*0.23*
WDFW	23- PS Net	---	*0.42*
WDFW	23- PS Net (Strays) [c]	---	*0.31*
WDFW	41- Ocean Sport- Charter	---	*0.09*
WDFW	42- Ocean Sport- Private	---	*0.74*
WDFW	45- PS Sport - May to September	---	*2.89*
WDFW	45- PS Sport - Winter Blackmouth (Oct - April)		*2.43*
WDFW	50- Hatchery Escapement (Strays) [d]	*0.66*	*0.42*
SUQ	54- Spawning Grounds [f]	---	*0.09*
WDFW	54- Spawning Grounds [h]	*85.22*	*78.84*
WDFW	54- Spawning Grounds [i]	*1.03*	*0.48*
	Total :	*100*	*100*

RMIS 2017
a Average SAR% = (tags recovered/tags released).
b Strays to WRIA 21
c Strays to WRIA 11 and 16.
d Strays to Elwha, Marblemount and Minter Creek hatcheries
f Strays to WRIA 15
h Spawning Ground recoveries in the Dungeness and Gray Wolf Rivers
i Strays to the Elwha River

Table 10. Gray Wolf River Hatchery Spring Chinook Fishery Contributions.

Brood Years: 2000-2011		
Fishery Years: 2004-2015		
Average SAR% [a]		**0.26**
Agency	***Non-WA Fishery***	***% of total Survival Sub-yearlings***
CDFO	All	*3.67*
NMFS	All	*12.84*
Agency	***WA Fishery***	***Sub-yearlings***
WDFW	10- Ocean Troll	*0.43*
MAKA	15- Treaty Troll	*0.2*
WDFW	15- Treaty Troll	*0.38*
QDNR	22- Coastal Gillnet (Strays)[b]	*0.17*
WDFW	23- PS Net	*0.08*
WDFW	41- Ocean Sport- Charter	*0.06*
WDFW	42- Ocean Sport- Private	*0.09*
WDFW	50- Hatchery Escapement (Strays)[c]	*0.19*
WDFW	54- Spawning Grounds[d]	*81.19*
WDFW	54- Spawning Grounds (Strays)[e]	*0.7*
	Total :	*100*

RMIS 2017
a Average SAR% = (tags recovered/tags released).
b Strays to WRIA 21
c Strays to Elwha Hatchery
d Spawning Ground recoveries in the Dungeness and Gray Wolf Rivers
e Strays to the Elwha River

Data Gaps

- 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

Component Populations

Elwha River Chinook

Geographic Distribution and Life History Characteristics

In terms of sheer magnitude, the Elwha River is the site of the most significant fish passage barrier removal in United States history. For over a century prior to removal of the Elwha and Glines Canyon Dams, utilization by Chinook salmon was confined to the lower 4.9 miles of the river below the Elwha Dam. However, 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 dam at RM 3.4. The Elwha River Ecosystem and Fisheries Restoration Act of 1992 authorized 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. As the largest dam decommissioning to date in the United States, removal of these dams restored approximately 71.5 miles of Chinook spawning and rearing habitat, allowing Chinook and the other species of Pacific salmon, as well as steelhead 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 was expected to eventually release 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 deleterious effects on downstream salmonid spawning habitats (Peters *et al.* 2017).

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 of these species on the Elwha River. The Guidelines for Monitoring and Adaptively Managing Restoration of Chinook Salmon (*Oncorhynchus tshawytscha*) and Steelhead (*O. mykiss*) on the Elwha River (Peters et al. 2014) 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.

Status

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 Elwha River Monitoring and Adaptive Management Plan (see Table 6) (Peters et al. 2014). 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.

Natural abundance: SONAR enumeration

Prior to dam removal, adult enumeration was conducted using foot and boat surveys to estimate the returning numbers of Chinook salmon. Dam removal was projected to make visual techniques even more limiting as sediment levels increased during and immediately following project implementation. Facing the prospect of not being able to accurately enumerate any species of salmon following dam removal, NOAA made a grant award 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).

Table 1: Annual SONAR estimates of returning adult Chinook to the Elwha River.

Year	Chinook
2010	1,270
2011	1,864
2012	2,187
2013	5,510
2014	4,343
2015	4,112
2016	In Preparation

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 method was further 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 river kilometer (RKM) 1. The SONAR equipment cannot monitor during periods of high flow and turbidity events and so passage during these periods is estimated by averaging passage from four days before and after each data gap. Estimated passage of adult Chinook based on SONAR monitoring for 2010 through 2016 is summarized in Table 1 (Lower Elwha Klallam Tribe 2016).

Escapement of non-jack Chinook in 2016 was estimated to be 2,628 fish above the SONAR sites (Figure 1). The downturn in 2016 escapement was expected due to the extraordinary rate of sediment transport in the Elwha River while dam removal was taking place when this cohort out-migrated as juveniles in 2012 (Weinheimer *et al.* 2017).

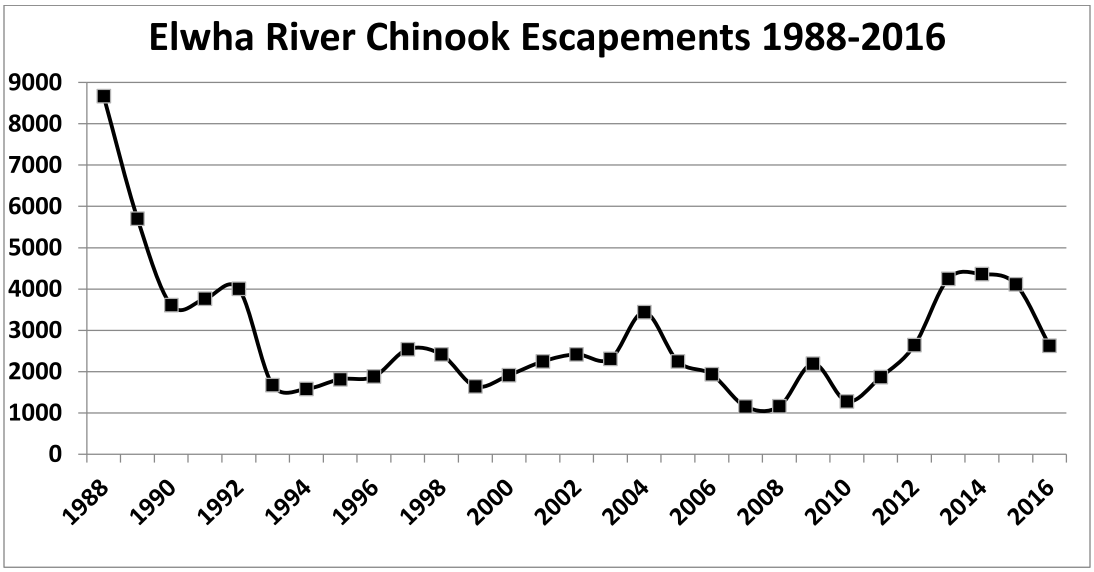


Figure 1: Trend in Elwha River Chinook escapement 1988-2016.

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 in late 2015 found that, overall, the proportion of hatchery-origin Chinook salmon returning to spawn was 96% (Figure 2) (Weinheimer et al. 2017).

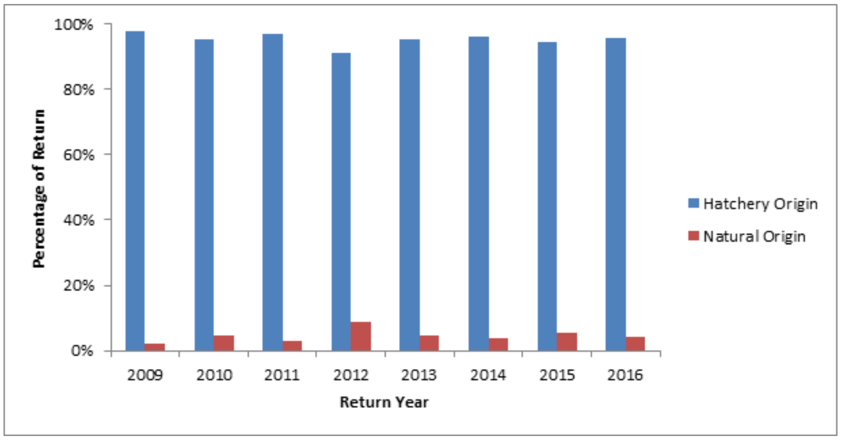


Figure 2: Percent composition of hatchery- vs. natural-origin spawning Chinook detected in the Elwha River between 2009 and 2016 (Weinheimer 2017, p.21).

Productivity

Hatchery marks (CWT, adipose, and otolith marks) in combination with SONAR counts and age data from scale collections provided the cohort analysis needed to evaluate spawner-to-spawner productivity for natural-origin spawners (Table 2) and all hatchery- and natural-origin spawners (Table 3) (Weinheimer et al. 2017). (Note that in their analysis, the authors defined "natural spawners" as fish that spawn naturally in the Elwha River and tributaries, regardless whether they themselves were produced in a hatchery.)

Table 2: Spawner-to-spawner ratio for all spawners (natural origin) Chinook in the Elwha River, brood years 2004-2015 (Weinheimer et al. 2017).

Brood Year	Natural Spawners	Returning adults						Spawners per spawner
		Age-2	Age-3	Age-4	Age-5	Age-6	Total	
2004	2,075	NA	16.4	47.4	0.5	0	64.2	0.03
2005	835	2.0	10.5	41.3	22.7	0	76.6	0.09
2006	693	0	2.3	10.1	0.1	0	12.6	0.02
2007	380	0.0	15.8	17.3	5.9	0	39.1	0.10
2008	470	8.6	29.2	66.3	5.9	0	110.0	0.23
2009	678	6.0	147.4	144.8	32.4	1.6	330.6	0.49
2010	569	11.8	47.0	95.1	32.6	0.2	186.4	0.33
2011	852	4.4	38.4	150.6	25.1		218.5	0.26
2012	1,480	1.2	46.0	68.1			115.4 A	0.08A
2013	2,313	1.9	10.3					
2014	2,513	6.6						
2015	2,548							

Table 3: Spawner per spawner ratio for all spawners (natural + hatchery origin) Chinook in the Elwha River, brood years 2004-2015 (Weinheimer et al. 2017).

Brood Year	Hatchery + Natural Spawners	Returning adults						Spawners per spawner
		Age-2	Age-3	Age-4	Age-5	Age-6	Total	
2004	3,439	NA	143	279	23	0	445	0.13
2005	2,231	29	784	2,053	507	0	3,372	1.51
2006	1,920	0	116	226	5	0	347	0.18
2007	1,140	0	354	613	67	0	1,034	0.91
2008	1,137	191	1,034	756	123	0	2,105	1.85
2009	2,192	210	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		4,351	2.34
2012	2,638	31	813	1,618			2,462[A]	0.93[A]
2013	4,243	34	245					
2014	4,360	158						
2015	4,112							

[A] Incomplete cohort, age-5 offspring will return in 2017.

Hatchery and natural spawners had a combined average of 1.6 returning adults per spawner for complete brood years 2004-2011, and the last four complete brood cycles (2008 - 2011) have each exceeded the replacement value of 1.0 (Table 3). However, natural spawner productivity averaged 0.19, or one returning adult for every five natural spawners (Table 2), well below the replacement value of 1.0 required for Elwha Chinook salmon recovery (Peters 2014).

By combining the carcass samples with the SONAR data, it was estimated that 108 (4%) of the non-jack adults returning in 2016 were natural-origin (Table 4). The 2016 return was dominated by age-4 hatchery-origin Chinook salmon that were released in 2012 as sub-yearlings (Table 4). This 2012 cohort was the first out-migration to occur during the dam removal process, and the low four-year return of spawners from this cohort is due in part to mortality suffered shortly after release in spring 2013 due to the extraordinary rate of sediment transport in the Elwha River during out-migration (Schwartz 2013).

Table 4: Estimated age composition of returning adults to the Elwha River 2016, based on age data from scales and SONAR abundance estimates (Denton et al. 2016).

Origin	Juvenile life-history	Age 2	Age 3	Age 4	Age 5	Age 6	SUBTOTALS
Natural	Sub Yearling	NA	13	63	32	0	108
	Yearling	NA	0	0	0	0	-
Hatchery	Sub Yearling	NA	190	1,387	538	6	2,121
	Yearling	NA	57	266	76	0	399
						TOTAL	**2,628**

Diversity: juvenile life histories of fish returning to the Elwha River watershed

A key diversity metric for Chinook salmon is the proportion of naturally spawned salmon that adopt stream-type vs. ocean-type life histories. Stream-type Chinook have a longer freshwater residency time than ocean-type Chinook, spending an entire year in freshwater prior to seaward migration. Ocean-type Chinook migrate within their first year of life, either as small fry soon after emergence or as larger parr that have spent 1-6 months rearing and growing in fresh water. Compared to the Chinook salmon native population that historically inhabited the Elwha River prior to dam construction, the current population exhibits a truncated life history diversity, notably the absence of the early-timed adult returns (Ruckelshaus et al. 2006).

Elwha Basin Chinook salmon historically included spring and summer/fall races characterized by a unique, large-body phenotype. The current population is comprised of a composite hatchery and wild stock with less diversity in adult return timing relative to the historic populations. However, because the hatchery population was developed from native Elwha Chinook stock and considering the ability of salmon to adapt, use of the extant population for restoration is believed to provide the best opportunity for successful recolonization (ERFRP 2008).

Within Puget Sound, dam construction has selectively restricted access to the majority of snowmelt dominated headwater streams that are typically associated with the stream-type life history (Beechie et al. 2006). Currently, the vast majority of natural-origin Elwha Chinook exhibits the ocean-type life history strategy (McHenry et al. 2015). It is hypothesized that access to the upper watershed might allow for this stream-type life history trait to re-emerge (Pess *et al.* 2008, McHenry et al. 2016).

Spatial distribution

In 2015, a total of 937 Chinook salmon redds and 753 adults (366 live/387 dead) were observed and 77% of those redds were located above the former Elwha Dam site (Figure 3). Over 95% of those Chinook salmon redds were observed in mainstem Middle Elwha River habitats rather than the tributaries. A high number (100) of Chinook salmon redds were observed immediately downstream of the former Glines Canyon Dam. Neither adult Chinook salmon nor Chinook salmon redds were observed immediately upstream of Glines Canyon Dam in 2015. Large boulders originating from Glines Canyon fell into the channel shortly after dam removal was completed in 2014. These boulders created a vertical drop of 12-15 feet through the canyon reach and were blasted in October, 2015, in an effort to improve fish passage. The blasting was too late, however, to affect passage conditions during the Chinook migration period. The distribution of Chinook salmon redds in the Middle Elwha suggested that mainstem spawning habitat in the Elwha River, and to a lesser extent tributary habitat, was being colonized by Chinook salmon (McHenry *et al.* 2016).

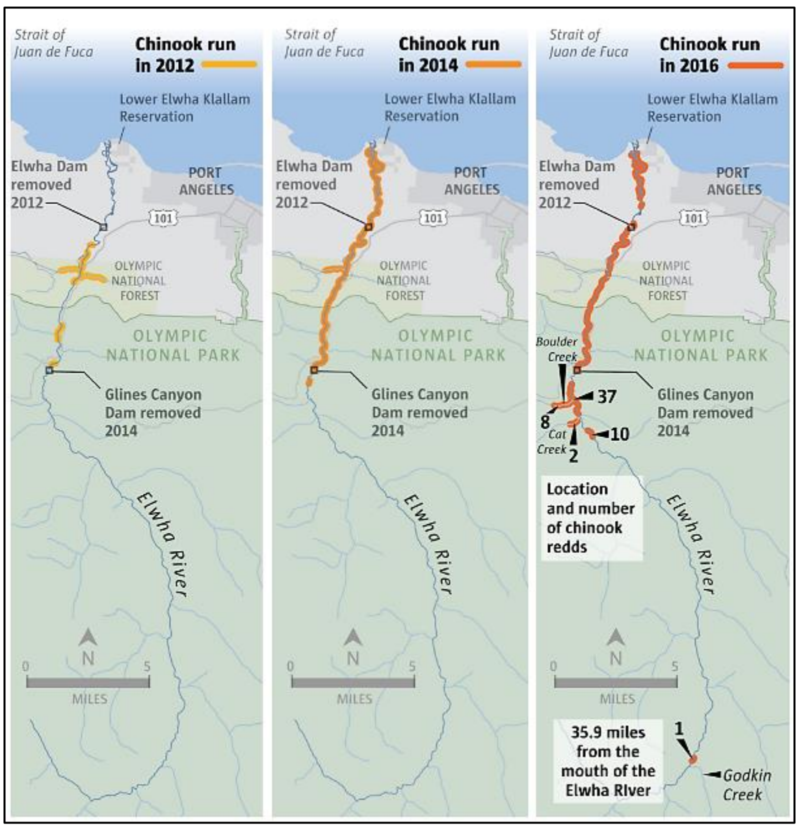


Figure 3: Distribution of Chinook salmon redds in the Elwha River between 2012 and 2016 based on data in McHenry *et al.* 2016 (Nowlin and Martinez 2017).

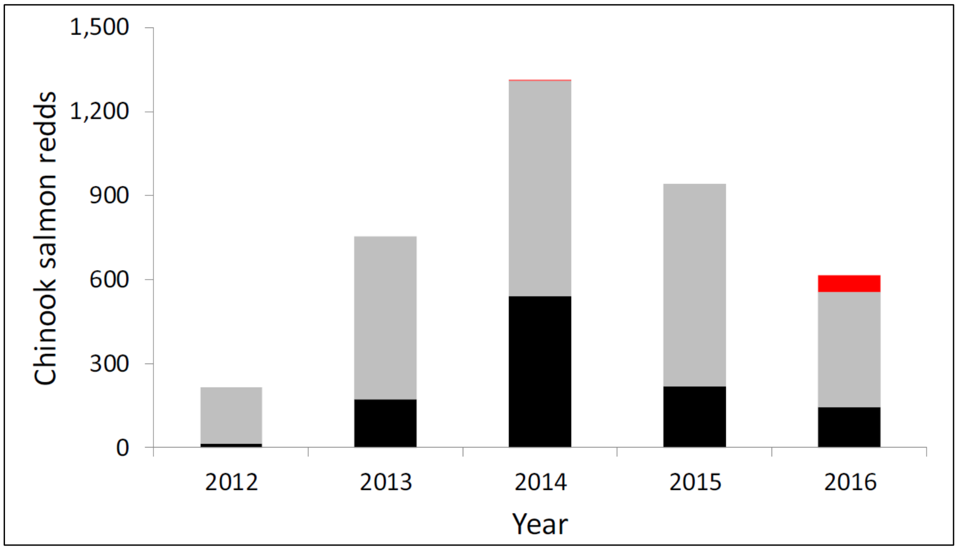


Figure 4: Utilization of the Elwha River by Chinook salmon since dam removal. Black bars indicate the number of Chinook redds below former Elwha dam. Grey bars indicate the number of Chinook redds between former Elwha dam and former Glines Canyon dam, and red bars indicate the number of redds above former Glines Canyon dam (McHenry *et al.* 2017).

Harvest Distribution and Exploitation Rate Trends

FRAM (the Fisheries Regulation Assessment Model) is used by the co-managers during pre-season fisheries planning and post-season exploitation rate evaluation to estimate pre-terminal rates of exploitation. The original base period for FRAM in the late 1970s to early 1980s used catches, size limits, encounters, growth functions, and abundances to calculate CWT-based exploitation rates by stock, age, fishery, and time period. The new base period, which began in 2007, does the same as above using contemporary CWT, fishery data, and stock data with additional modification to account for mark selective fisheries.

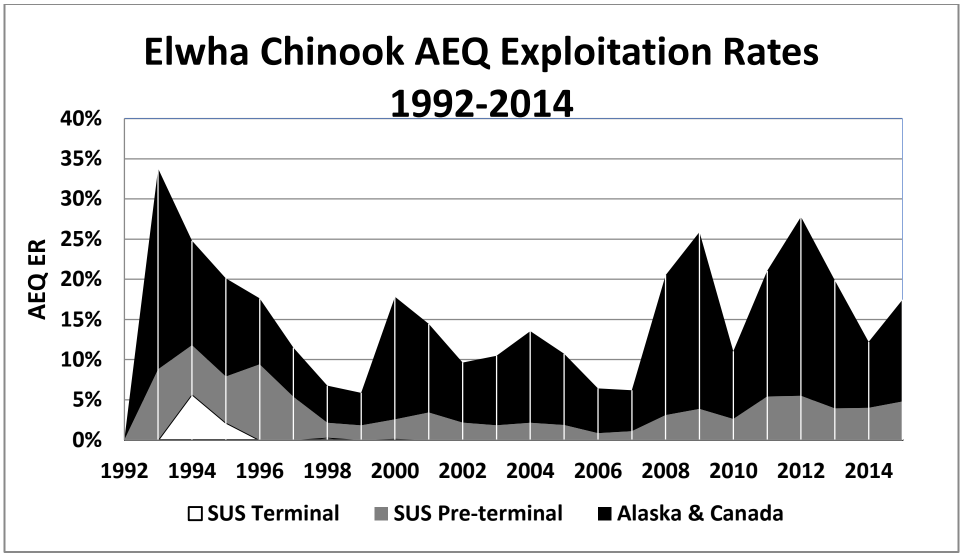


Figure 5: Adult equivalent exploitation rates (AEQ ERs) for Elwha Chinook in each Pacific Salmon Treaty area (Alaska/BC, pre-terminal Southern United States, and terminal fisheries) from 1992-2014, estimated by post-season FRAM analysis.

Table 5: Total Adult-Equivalency Exploitation Rates (AEQ ERs) of Elwha River Chinook of the Pacific Salmon Treaty Regions.

Elwha River Chinook (Natural + Hatchery) Exploitation Rates				
Return Year	Alaska & Canada	Southern US		Totals
		Pre-terminal	Terminal	
1992	25%	9%	0%	34%
1993	13%	6%	6%	25%
1994	12%	6%	2%	20%
1995	8%	9%	0%	18%
1996	6%	5%	0%	11%
1997	5%	2%	0%	7%
1998	4%	2%	0%	6%
1999	15%	2%	0%	18%
2000	11%	3%	0%	14%
2001	7%	2%	0%	10%
2002	9%	2%	0%	10%
2003	11%	2%	0%	14%
2004	9%	2%	0%	11%
2005	6%	1%	0%	6%
2006	5%	1%	0%	6%
2007	17%	3%	0%	21%
2008	22%	4%	0%	26%
2009	8%	3%	0%	11%
2010	16%	5%	0%	21%
2011	22%	6%	0%	28%
2012	16%	4%	0%	20%
2013	8%	4%	0%	12%
2014	13%	5%	0%	17%
Averages				
All Years	12%	4%	0%	16%
1992-1998	10%	6%	1%	17%
1999-2008	11%	2%	0%	14%
2009-2014	14%	4%	0%	18%

An adipose fin clip is essential for CWT detection in many FRAM fisheries. However, in order to minimize exposure to mark-selective fisheries, Elwha Chinook CWT release groups were not adipose fin clipped during the updated base period years used to calibrate FRAM. 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, 2015). 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, 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. Specifically, when sufficient years of CWT and adipose-clipped Elwha Chinook releases have accrued, an out-of-base FRAM calibration procedure using those tag groups will be explored.

Management Objectives

Recovery of Elwha Chinook salmon populations will require significant management actions in all three areas of habitat, harvest, and hatchery management, 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 cannot be evaluated without knowing the status of actions in the other areas. Harvest management plans typically acknowledge that productivity is dependent on the state of habitat 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 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 lost and degraded, 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

Harvest Management

The harvest strategy for Elwha Chinook salmon is to maintain overall fishery-related mortality at a level that will allow the Elwha Chinook population to increase, assuming that the spawner-recruit productivity relationship does not decline from its current level. It is expected that once natural escapement in the Elwha population can be sustained at 4,000 Chinook, productivity reaches two recruits per spawner, and Chinook salmon are spawning throughout their historic range, then substantial reductions in hatchery production may be appropriate (Ward *et al.* 2008).

Fishing regulations affecting Chinook salmon in the area from Southeast Alaska to south of the Columbia River are negotiated 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 and manageable. Planned fisheries that affect ESA-listed Elwha Chinook salmon have been developed according to the co-managers' harvest management plan (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2010), then evaluated and approved annually by NMFS.

The Lower Elwha Klallam Tribe and Washington Department of Fish and Wildlife have concurred in adjusting escapement goals for Elwha Chinook in order to better align escapement goals with the first tier of VSP restoration triggers needed to transition the Elwha restoration process from the Preservation Phase to the Recolonization Phase (see Table 6). At a time of stock rebuilding, the current Low Abundance Threshold (LAT) of 1,000 Chinook salmon (critical escapement threshold, the lowest spawner level that results in positive recruitment over the FRAM model's extended time series) is outdated given that access to 70 miles of spawning habitat upstream of the two hydroelectric projects has been restored following dam removal activities in 2011-2013. Given a minimum hatchery brood requirement of 500 spawners and a minimum of 1,000 natural spawners, a new LAT of 1,500 spawners (hatchery and natural spawners combined), established in concurrence with WDFW will serve as the minimum escapement below which a 6% exploitation rate will be set for the Elwha component of this population.. The Upper Management Threshold (UMT) will remain at 2,900 Chinook escapement, the minimum escapement below which a 10% exploitation rate will be set for the Elwha component of this population, which was defined in the 2010 Puget Sound Chinook Harvest Management Plan (Puget Sound Indian Tribes and Washington Department of Fish and Wildlife 2010).

Hatchery Management

The Elwha River Fish Restoration Plan (Ward *et al.* 2008) identifies two main restoration approaches for Chinook stock restoration in the Elwha River: natural recolonization and artificial supplementation. Hatchery operations are a necessary component of the preservation and restoration strategies outlined in the fish restoration plan. The use of hatcheries to preserve stocks is supported by the management responsibilities mandated by the ESA and by the trust responsibilities of the federal government to exercise its authorities to promote the harvestable surplus of anadromous fish in accordance with treaties between the United States and the tribes.

By co-manager agreement, the Elwha Chinook population will be categorized in critical status if the forecasted escapement is fewer than 1,500 fish (1,000 natural spawners and 500 hatchery fish) at which point southern U.S. fisheries will be restricted to a 6% harvest exploitation rate. As long as the Elwha population is forecasted to produce an escapement of 1,500 or more spawners, southern U.S. fisheries can sustain a harvest exploitation rate ceiling of 10% for Elwha Chinook salmon.

However, escapement abundance must significantly exceed 1,500 fish – up to as many as 4,340 Chinook spawners (Peters 2014, p. 20) – in order to drive the other threshold VSP parameters of spatial distribution, percent hatchery-origin fish, productivity, and diversity necessary to achieve Recolonization Phase recovery goals (*ibid.*, 19). The various phases of restoration described in the Elwha Fish Restoration Plan rely heavily on natural spawning abundance, while hatchery spawning abundance and harvest rate serve as exogenous variables of abundance (*ibid*, 21). To sustainably and adaptively manage for changing conditions, Ward *et al.* (2008) stipulates that restoration management of Elwha Chinook must maintain a proportion of natural influence (PNI) greater than 67% for the natural population to meet essential recovery or viability criteria as defined and designated under the ESA for a given ESU of Pacific salmon. However, Peters *et al.* (2014) establish goals for reducing hatchery influence that far exceed the 67% PNI for essential population recovery by assigning the transition from the Local Adaptation Phase at a percent hatchery-origin fish (pHOS) rate equal to zero (i.e., full elimination of the hatchery). At this time, though, approximately 95% of Chinook spawning in the Elwha River is attributable to hatchery-origin fish (Figure 4). This shift from a hatchery-dominated spawning population goal to one that emphasizes natural spawning is described in the EMAMG (Peters et al. 2014) accompanying other VSP criteria. To meet these additional targets, the role of natural recolonization in the recovery strategy is critical.

Importance of Hatchery-Harvest Integration

Recovery of natural Elwha Chinook, while providing for some modest harvest opportunities, relies on hatchery supplementation. However, despite the critical role that hatchery supplementation has provided as a lifeboat for sustaining the localized genetics of the Elwha Chinook population during and immediately following the dam removal phase, WDFW and the Lower Elwha Klallam Tribe remain concerned about the increased risk of under-escapement for depressed Puget Sound Chinook salmon under current levels of Canadian and Alaskan harvest impacts and the additional constraints on Washington fisheries required to protect Chinook salmon (ERFRP, 166). It is expected that once natural escapement in the Elwha population can be sustained at 4,340 natural-origin Chinook, productivity is greater than 1.56 recruits per spawner, and Chinook salmon are spawning above the former Elwha Dam, then substantial reductions in hatchery production may be appropriate (Peters *et al.* 2014). Until then, hatchery supplementation will continue to play a major role in stock rebuilding. Increasing the Chinook escapement goal reflects the continued needs of brood stock for the hatchery program as well as the numbers of fish expected to populate the newly accessible habitat in the Elwha River.

Status Quo vs. Recovery Escapement

Over the last few years, Elwha Chinook salmon have maintained escapements well above the 1,000 spawners needed to avoid being placed in critical status. However, this escapement rate was calibrated to maintain the status quo of equilibrium conditions that existed under pre-dam removal conditions rather than responding to the recovery process now underway by accommodating increased levels of production under current watershed conditions. The new low abundance threshold (LAT) of 1,500 Chinook salmon agreed to by co-manager concurrence is a more accurate reflection of habitat capacity in the Elwha River that minimizes the risk of chronic listing of Elwha River Chinook as a driver for weak stock management in the annual PFMC/North of Falcon planning process. To further prevent the risk of placing Elwha Chinook in critical status, a lower bound (LB) management threshold set at the 2010 Harvest Plan LAT escapement goal of 1,000 fish will be established below which co-managers will discuss what, if any, incidental and ceremonial and subsistence fishery regime will take place.

Habitat Management

Habitat Assessment

A number of tools and methods have been developed to assess changes in habitat quantity and quality after dam removal by measuring available spawning habitat (quantity and quality), rearing habitat (quantity and quality), and water quality.

Ecosystem Response

In addition to directly monitoring the size, diversity, and viability of salmonid populations, it is also important to study the responses of the ecosystems upon which salmon depend. Because of the large changes expected in the areas downstream of the dams, as well as the changes that the salmon themselves will have on the ecosystem (e.g., from marine derived nutrients, bioturbation of spawning gravels, interactions with predators and scavenger communities), estimating the response of the aquatic ecosystem is vital. In particular, an important component to be studied is the direct and indirect effects of high sediment levels on biological food webs and the role that ecosystem changes may play in the recovery of Elwha fish populations. Since dam removal, potential 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 ESA-listed Chinook, although it may negatively impact floodplain habitat quality for coho, chum, pink, and steelhead spawning. 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

Once 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 restore habitat-forming processes and was necessary to stabilize accumulated sediment that was stored on hillslopes and terraces during dam removal. The overall revegetation effort for Elwha restoration is guided by the Elwha Revegetation Plan (Chenoweth et al. 2011). The revegetation plan's goals, broadly stated, are to establish native vegetation communities and to accelerate natural succession toward older vegetation communities.

Implementation of revegetation activities is 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 initially focused on control of exotic vegetation adjacent to project areas, collection of native seed to be used in Elwha revegetation, construction of a greenhouse/nursery facility to propagate native plants used in revegetation and seed amplification with the Natural Resources Conservation Service (NRCS) facility in Corvallis, Oregon. Revegetation efforts began in the fall of 2011 with reservoir drawdowns and dam removal. In the winter of 2012, the first plantings of native trees and shrubs occurred on the former Mills Reservoir. These efforts accelerated over the next five years, culminating in the eventual planting of 400,000 native trees and shrubs and over 5,000 pounds of native grass seed. With the exception of some additional planting planned for 2018, the vast majority of planned planting of native vegetation has been completed. Control of exotic vegetation continues to be carried out during the summer and fall seasons. As funding for the tribal revegetation effort ends in September of 2018 and ONP revegetation efforts also diminish, this phase of Elwha River restoration is planned to conclude by the end of 2018 (McHenry 2017, *personal communication*). Monitoring plans have been developed to modify and refine planting actions (Peters et al. 2014).

Habitat Restoration

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 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 will be implemented in 2018-19.

Additional restoration efforts focusing on the Elwha River estuary and 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 filling, appears to lack large wood and may be an excellent candidate for engineered logjams (Peters et al. 2014).

Two new logjams are planned for installation in 2017 to address habitat connectivity issues with the surface water diversion structure that provides water to the City of Port Angeles. Additional engineered logjam structures designed for installation in the lower river channel await funding for pending construction. In addition, a major restoration project in the lower portion of Indian Creek has been identified. An agreement between LEKT and the US Bureau of Reclamation to do a partial design of that project beginning fall 2017 is currently underway. Once completed, full engineering design and funding for construction will begin (McHenry 2017, *personal communication*).

Suspended Sediment

Suspended and bedload sediment transport are being monitored in real time by the Bureau of Reclamation (BOR), the National Park Service (NPS), and the US Geological Survey (USGS) as part of the sediment monitoring and adaptive management activities of the Elwha dam removal project (Randle et al. 2012). Additionally, changes in reservoir and riverbed elevation as well as water surface elevation are monitored through time, as is 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)

Integrating Harvest, Hatchery, and Habitat Management

Hatchery, harvest, and habitat management interact with one another to create the conditions for Elwha Chinook population recovery by targeting VSP (Viable Salmon Population) parameters as performance indicators for moving through four distinct phases of recovery (Table 6). Based on Guidelines for Monitoring and Adaptively Managing Restoration of Chinook Salmon (*Oncorhynchus tshawytscha*) and Steelhead (*O. mykiss*) on the Elwha River (Peters et al. 2014), the biologically based goals and objectives of Elwha Chinook monitoring and adaptive management are designed to progress through the following four restoration phases:

Table 6: VSP performance indicators defining each successive phase of Elwha Chinook salmon recovery (Peters et al. 2014)

VSP Indicators		Preservation	Recolonization	Local adaptation	Viable Natural Population
Abundance	**Natural spawners**	950	>950 or <4,340	>4,340 or <10,000	>10,000
	Spawner escapement duration	4 years	4 years	4 years	4 years
Managing for pHOS	**pNOS (natural-origin spawner)**	*	0.95	1.0	1.0
	pHOS (proportion hatchery-origin spawner	*	0.05	0	0
Productivity	**#juvenile migrants/female**	200	200	200	200
	#pre-fishing recruits/spawner (h+n)	>1.56	*	*	*
	#spawners/spawner (h+n)	>1.0	*	*	*
	#pre-fishing recruits/spawner (n)	*	>1.56	>1.56	>1.85
	#spawner/spawner (n)	*	>1.0	>1,0	~1.0
	Productivity trend	4 years	4 years	4 years	4 years
Spatial distribution	**Extent**	A portion of fish accessing above Elwha Dam	Above Elwha Dam; 43% of Intrinsic Potential	Above Glines Canyon Dam; 86% of Intrinsic Potential	100% of Intrinsic Potential
	Barriers	No migration barriers exist below Elwha Dam	No ‘artificial’ migration barriers exist in Aldwell reach	No ‘artificial’ migration barriers exist in Mills reach	No ‘artificial; barriers exist within Intrinsic Potential
Diversity	**Stream-type proportion**	*	*	Positive trend	Stable, > Preservation Phase
	Entry timing variance	*	*	Positive trend	Stable, > Preservation Phase

Preservation – the period during and shortly after dam removal when elevated suspended sediment concentrations are expected, at times, to be lethal to all fish in the river, resulting in a high risk for complete loss of native fish populations and their associated genetic and life history diversity if no protective measures are taken. Having begun with the start of dam removal in 2011, this phase is currently in progress. The goal of the Preservation Phase is to protect the existing genetic and life history diversity of native salmonid populations until fish passage is restored and water turbidity is determined to be non-lethal to fish in the river.

Recolonization – the period after the dams are removed, passage is restored, and fish have access to refugia from lethal suspended sediment concentrations, or suspended sediment concentrations no longer reach lethal levels expected to negatively impact fish populations. The goal of the Recolonization Phase is to ensure that salmonids are continually accessing habitats above the former dam sites with some fish spawning successfully and producing smolts.

Local Adaptation – the period during which: (1) sufficient numbers of spawning adults (e.g., meeting or exceeding minimum VSP criteria) are accessing and using newly accessible habitats above the former dam sites, and; (2) fish are successfully spawning at a rate that allows for population growth. The goal of the Local Adaptation Phase is to maintain or increase life-history diversity of natural spawning populations through local adaptation to the Elwha River ecosystem until minimum levels of spawner abundance, productivity, and distribution are met.

Viable Natural Population – the period when all aspects of the previous stages are met, and viable natural populations exist that can withstand exploitation by fisheries without hatchery augmentation. The goal of the Viable Natural Population Phase is to ensure that viable natural and exploitable population levels continue once desired values for all VSP and habitat parameters have been met and hatchery programs are no longer needed to provide for protection, recovery, or exploitation.

Data Gaps

- Calculation of HOR/NOR ratio
- Enumerating adult salmon
- Productivity estimates
- Spatial distribution of up-river type spawners, especially evidence of a stream-type Chinook sub-population displaying the overwintering stream-type life history trait.
- Estimates of total and natural smolt production in the upper Elwha basin with smolt trapping
- Spawner to spawner calculations to analyze hatchery vs. natural-origin Chinook salmon productivity
- Measuring changes in bed aggradation (scour) in the Elwha River floodplain channel

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 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 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 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 River Chinook is considered when setting quotas in the northern fisheries, it can provide additional protection for other Puget Sound stocks.

Geographic Description

The Hoko River is the largest watershed in the western end of 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 and a half 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. Harvest of timber in the watershed began in the 1880's. At this point in time, 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 all, 1995).

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 subyearlings (Williams *et al*., cited in Myer *et al.*, 1998). The Hoko Falls Hatchery releases its Chinook as subyearlings, usually in June of the year of hatching.

Based on scales collected from natural spawners and broodstock from return years 1989 through 2015, returning Hoko River adults are predominately age 4 (46%) and age 5 (29%), with the other age groups comprising smaller proportions of the recruits.

Table 1. Average age composition of Hoko Chinook recruits from return years 1989-2015.

	Age 2	Age 3	Age 4	Age 5	Age 6	Total
Percent of Recruits	4%	18%	45%	31%	2%	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 1,800 ocean recruits (return years 1988-2015) and has ranged from as low as 611 to a high of 4,547 (Figure 1). Since the 1980's, just under half (46 percent) of these recruits have been of natural origin (Figure 2). In recent years, however, the natural-origin proportion of the total run size has increased.

The stock's productivity in recent decades presents a problem for recovery. Recruits per spawner have averaged 1.89 for complete brood years (1989 through 2011). That average, however, is heavily influenced by five productive brood years, and masks the problem of most brood years producing fewer ocean recruits than the number of spawners that produced them. Cohort-reconstruction estimates of recruit abundance shows that for most completed brood years (14 out of 23) since the mid-1980's, the number of natural-origin recruits has been lower than the number of spawners that produced them.

This problem 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 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.

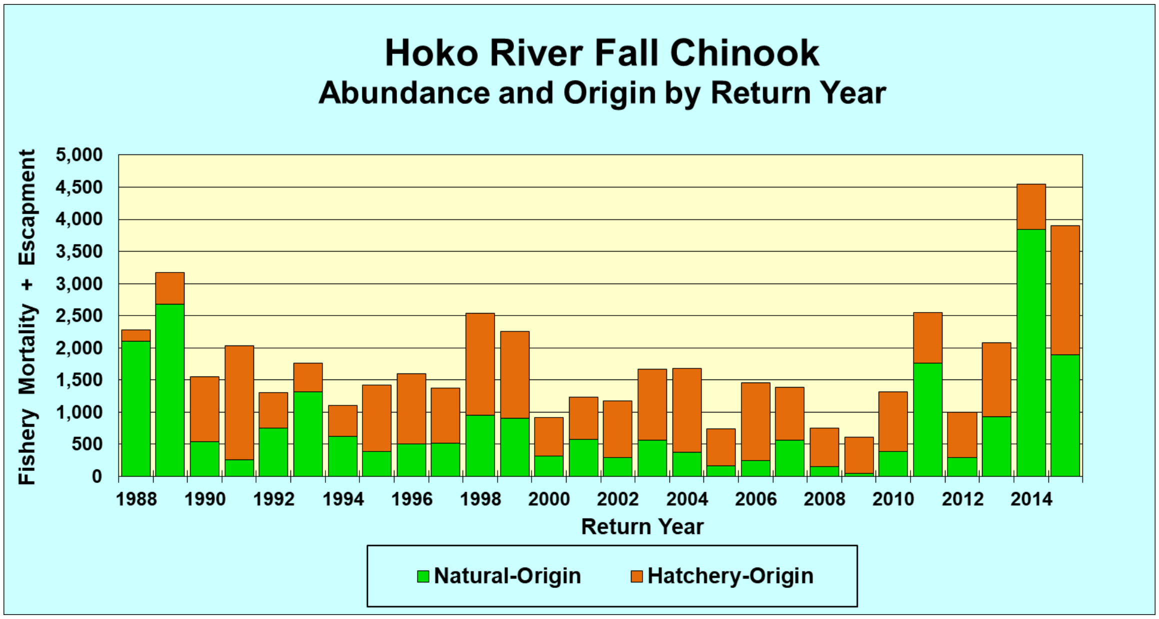


Figure 1. Figure 1. Hoko River Chinook, Abundance and Origin by Return Year. Over the long-term, slightly over half (58%) of the recruits have been of hatchery origin.

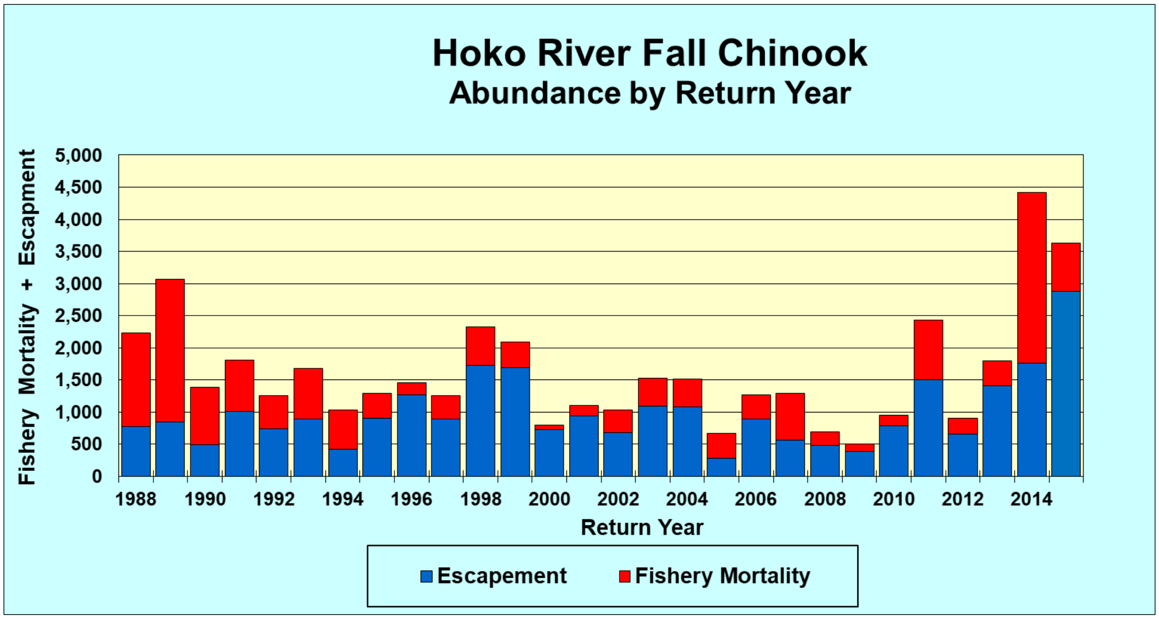


Figure 2. Hoko River Chinook, Abundance by Return Year, showing breakouts of escapement and fishery mortality. Total exploitation rates on Hoko River Chinook, as estimated by CWT data, have declined from an average of nearly 30% in the 1990's, to an average of 23% in the years since the 2009 Pacific Salmon Treaty Chinook agreement.

Table 2. Hoko Chinook escapement by return year.

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	53	162	128	38	4	0	385
2010	33	632	102	25	1	0	793
2011	4	105	1,326	68	0	0	1,504
2012	40	58	151	414	1	0	663
2013	431	408	405	143	19	0	1,406
2014	152	1,053	472	83	0	0	1,760
2015	160	437	2,145	135	0	0	2,877
2016	129	419	552	224	0	0	1,324
Averages (1988-2016)	**46**	**186**	**440**	**315**	**25**	**0**	**1,012**
Averages (2011-2016)	**152**	**413**	**842**	**178**	**3**	**0**	**1,589**

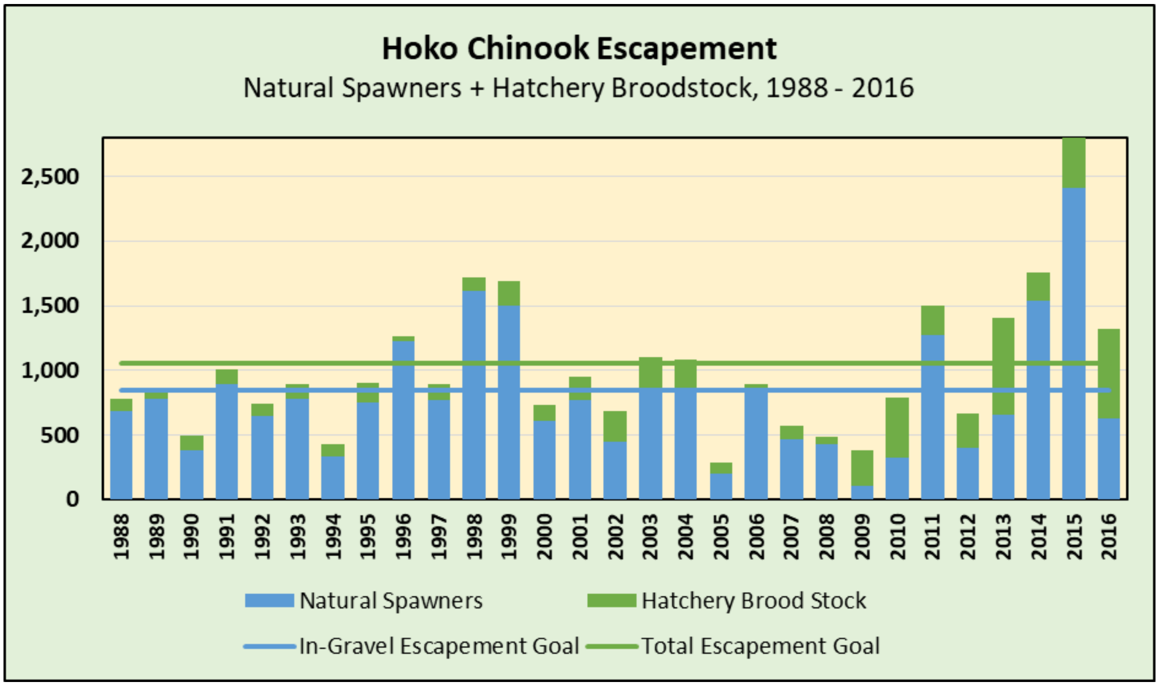


Figure 3. Hoko Chinook Escapement by Return Year, showing breakout of natural spawners and hatchery broodstock. Hoko Chinook escapement has achieved the goal of 1,050 total spawners in less than half of the years (13 of 29 years) since 1988.

The established escapement goal for Hoko River Chinook is 850 natural spawners (*i.e.*, spawners spawning in the gravel, regardless of their origin). This goal, first presented in 1977 in WDF *Technical Report 29*, is based on early estimates of freshwater habitat capacity. The total escapement goal is 1,050, which includes 200 broodstock for the supplementation and reintroduction program. For the Hoko Chinook stock as a whole, the combined spawning escapement (natural plus hatchery) averaged 1,475 spawners from 2010 through 2016.

Although the escapement goals set in Technical Report 29 have been commonly accepted, it is not certain that the spawner level of 850 is the optimum Chinook escapement level for the Hoko River. Further analysis of habitat suitability and usage should be conducted to determine whether spawning or rearing habitat limits Chinook production in the Hoko.

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 hatchery has operated its program treating the Chinook as an integrated population, often taking unmarked spawners from the river as broodstock, and taking care to not breed a separate stock of hatchery fish.

The Hoko Hatchery is a small facility operated by the Makah Tribe, producing Chinook since 1985. In addition to Chinook, the hatchery also raises steelhead, and as part of the Lake Ozette sockeye recovery program, it incubates Lake Ozette Sockeye at remote sites. Additionally, plans are underway to start a coho program at the Hoko Hatchery.

The fall Chinook program is an integrated program, meaning that natural-origin and hatchery-origin recruits are intended to be a single stock.

The Hoko Hatchery has varying releases for fall Chinook based on availability of broodstock, but they average about 250,000 sub-yearling releases with a high of 514,000 and a low of 68,000. Of those releases, an average of 77% are coded-wire tagged, with a similar proportion, 80%, being adipose fin-clipped. In 2011, the Hoko Hatchery began using a salt-enhanced feed for Chinook raised in the hatchery. This change in feed appears to be related to higher returns to the Hoko River, but further analysis of return rates is needed for more complete brood years.

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 the recent-year average of 774 spawners. Since 2007, about one-third of the Hoko River natural spawners can be attributed to the supplementation program. The goal of 850 natural spawners has been achieved in only six of the last 29 years (1988 to 2016; Figure 3).

Harvest Distribution and Exploitation Rate Trends

Total exploitation rates on Hoko River Chinook, as estimated by CWT data, have declined from an average of nearly 30% in the 1990’s, to an average of 23% in the years since the 2009 Pacific Salmon Treaty Chinook agreement (Makah Tribe, unpublished cohort reconstruction data).

The migration pathway and harvest distribution of Hoko River Chinook have been described from recoveries of coded-wire tagged fish released from the Hoko Falls Hatchery. The tag data used in cohort reconstruction indicate that 94 percent of the fishery mortality on Hoko Chinook is in fisheries in Southeast Alaska and British Columbia.

Prior to 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 greatly different from that of the other two Strait stocks, with Hoko Chinook showing later timing, entering the river in October and spawning well into November. For this reason, since 2006, Hoko has been modeled separately from the other Strait stocks. FRAM-based post-season estimates of exploitation rates specific to Hoko are available for 2006 – 2014

(Table 3). Like the annual CWT data, FRAM validation estimates suggest that Hoko River Chinook are harvested primarily in northern fisheries, with a similar proportion: FRAM estimates using the 2007-2013 base period show 91 percent of fishing mortality taken in the northern fisheries; cohort reconstruction for return years 1989 through 2015 show 94 percent.

One area in which Hoko Chinook are not harvested is the Hoko River itself. Because of the low abundance of naturally spawning Hoko River Chinook, the Makah Tribe has not had a Chinook-directed terminal fishery in the Hoko River since 1981. Non-treaty 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 even incidental impacts to Hoko Chinook. In addition, both treaty and non-treaty fisheries in the Strait of Juan de Fuca are closed in Hoko Bay, outside the river.

Table 3. Distribution of exploitation rates on Hoko River Chinook from FRAM validation runs using new base period.

Year	Alaska	Canada	SUS-Pre	Terminal	Totals
2006	10%	14%	2%	0%	27%
2007	17%	15%	1%	0%	33%
2008	11%	9%	1%	0%	21%
2009	9%	12%	3%	0%	23%
2010	4%	9%	2%	0%	15%
2011	10%	11%	2%	0%	23%
2012	10%	10%	2%	0%	23%
2013	5%	8%	2%	0%	15%
2014	6%	9%	2%	0%	17%
Averages	**9%**	**11%**	**2%**	**0%**	**22%**
Data Source: post-season FRAM, 2017 validation, 5th round					

Management Objectives

Since the early 1980's, the Makah Tribe has pursued the goal of rebuilding Hoko River Chinook, which had been at a low level of abundance. That goal was the reason for the tribe to build and operate the Hoko Falls Hatchery, which has been supplementing this run since 1985. All broodstock for this hatchery has been local 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.

Management objectives for the western Strait of Juan de Fuca management unit include an escapement goal, abundance thresholds for two abundance tiers, and exploitation rate ceilings, as shown in Table 4, below.

Table 4. Management objectives for Hoko River Chinook.

Upper Management Tier		Low Abundance Threshold	
Abundance	**Expl. Rate Ceiling**	**Abundance**	**Expl. Rate Ceiling**
1,050 Natural spawners	10% SUS	500 Natural Spawners	6% SUS

The escapement goal used in this plan is for 850 Chinook spawning in the gravel. Other methods to estimate 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 from the escapement goal of 850 that the co-managers have used since 1977.

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 second 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 might not be the best approach to recovery of the stock.

The Parken habitat-based model, on the other hand, produced an estimate of MSY escapement that was about 200 spawners higher than the current escapement goal; however the Parken model is based on habitat from a range of 12 watersheds producing ocean-type Chinook from Alaska to Oregon. The average watershed area used in developing this model is over 2,000 square 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 it does in the other watersheds in the Parken data set.

In addition to the 850 in-river spawners, the Hoko Falls Hatchery requires a broodstock of 200 spawners per year, bringing the total escapement need to 1,050 spawners.

The exploitation rate ceiling is 10% in southern U.S. 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 Pacific Salmon Treaty Chinook agreement, the total exploitation rate has averaged 19%, as estimated by post-season FRAM modeling.

The Low Abundance Threshold for Hoko River is 500 natural spawners. When natural spawning escapement for this stock is projected to be below this level, the harvest management plan will call for southern U.S. fisheries to be limited to a 6% exploitation rate ceiling.

As described 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 (Ames and Phinney, 1977). 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 which are not currently in the budget for the hatchery.

- **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.

12. 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:

- Sockeye, pink, and chum fisheries managed according to PST Annexes.
- Net fisheries closed from mid-November through mid-June.
- 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).